ICDRM 2019

INTERNATIONAL CONFERENCE ON DISASTER RISK MANAGEMENT

PROCEEDINGS ON INTERNATIONAL CONFERENCE ON DISASTER RISK MANAGEMENT 2019

Organizing Partners

URBAN RESILIENCE PROJECT

BUET IDPUS

ARCH | URP | IWFM

Published by: BUET-Japan Institute of Disaster Prevention and Urban Safety (BUET-JIDPUS)
Dhaka, Bangladesh

January 2019

ISBN: 978-984-34-5794-3

PREFACE

It is our great privilege to inform that BUET-JIDPUS has organized the second international conference since the inception of this institute. International Conference on Disaster Risk Mitigation, 2017 (ICDRM 2017) was organized solely by BUET-JIDPUS whereas this year, International Conference on Disaster Risk Management, 2019 (ICDRM 2019) has jointly been organized by the Department of Architecture, Department of Urban and Regional Planning, Institute of Water and Flood Management of BUET, Urban Resilience Project: RAJUK Part and Bangladesh Fire Service and Civil Defence along with BUET-JIDPUS with a much broader scope than the previous ICDRM 2017. ICDRM 2019 is expected to provide a forum for fruitful interaction and exchange of ideas between the participants coming from around the world.

We express our gratitude and thankfulness to the Vice Chancellor of BUET, Prof. Dr. Saiful Islam and the university administration for providing full support in organizing the conference. BUET-JIDPUS was established with cooperation from The Embassy of Japan. It is a matter of great pleasure that in this occasion the ambassador of Japan to Bangladesh His Excellency Hiroyasu Izumi has graced the inauguration ceremony as the Chief Guest and Chief representative of JICA, Mr. Hitoshi Hirata has attended the ceremony as a Special Guest. Dr Jamilur Reza Choudhury, National Professor and Vice Chancellor of University of Asia Pacific, who has recently won the Japanese national award titled “The Order of the Rising Sun, Gold Rays with Neck Ribbon” has been present as the Guest of Honor. The keynote and invited speakers of the conference are from Japan, France, Netherlands and Nepal and researchers from Nepal, India, Pakistan, Sri Lanka, Tajikistan, Philippines and Italy have presented their respective papers.

A total of 238 abstracts were received from different parts of the world for the conference out of which approximately 128 papers of different fields have been presented in different sessions of the conference.

Since disaster management can play a pivotal part in implementing the Sustainable Development Goals (SDG) and Delta Plan of Bangladesh, we expect that this conference has presented an excellent opportunity to discuss the pros and cons of these issues in detail. Through this conference we hope to build a network among academics, professionals, government and non-government organizations working on disaster resilience in Bangladesh.

Prof. Dr. Raquib Ahsan
Convener, Organizing Committee, ICDRM 2019
Director, BUET-JIDPUS

Prof. Dr. Md. Munsur Rahman, BUET
Prof. Dr. Md. Rezaur Rahman, BUET
Mr. Md. Rafiuz Zaman, BUET
Prof. Dr. Mehedi Ahmed Ansary, BUET
Prof. Dr. Mohammad Anisul Haque, BUET
Prof. Dr. Mohammad Shariful Islam, BUET
Prof. Dr. Muhammad Ashraf Ali, BUET
Prof. Dr. Nasreen Akter, BUET
Prof. Dr. Nasreen Hossain, BUET
Dr. Nayma Khan, BUET
Prof. Dr. Raquib Ahsan, BUET
Prof. Dr. Saiful Amin, BUET
Dr. Sara Nowreen, BUET
Prof. Dr. Sarwar Jahan Md. Yasin, BUET
Prof. Dr. Shakil Akhter, BUET
Prof. Dr. Shamim Mahabubul Haque, KU
Prof. Dr. Sheikh Serajul Hakim, KU
Prof. Dr. Tahmeed M. Al-Hussaini, BUET
Prof. Dr. Tahsin Reza Hossain, BUET
Dr. Tanvir Ahmed, BUET
Prof. Dr. Tanvir Manzur, BUET
Prof. Dr. Zebun Nasreen Ahmed, BUET

ORGANIZING COMMITTEE

Director, BUET-JIDPUS (Convener)
Head, Department of Architecture
Head, Department of Urban and Regional Planning
Director, IWFM
Project Director, Urban Resilience Project- RAJUK Part
Director General, Fire Service and Civil Defence (BFSCD)
Dr. Apurba Kumar Podder, BUET
Mr. Ishfaq Aziz, BUET
Prof. Dr. Ishrat Islam, BUET
Mr. Maruf Billah, BUET
Mr. Md. Aminul Islam, BUET
Prof. Dr. Mehedi Ahmed Ansary, BUET
Prof. Dr. Mohammad Shariful Islam, BUET
Prof. Dr. Nasreen Hossain, BUET
Dr. Nayma Khan, BUET
Dr. Sara Nowreen, BUET
Ms. Shamontee Aziz, BUET
Major (Engr.) Shamsuddin Ahmed Chowdhury, RAJUK
Ms. Tasnim Tarannum Isaba, BUET
Ms. Uttama Barua, BUET
Mr. Atif Ibne Zoha Sreezon, Graduate, URP, BUET
Ms. Saraf Anjum Disha, Graduate, URP, BUET

PROCEEDINGS PUBLICATION TEAM

Anurima Jahangir
Dilruba Afroze
Fairooz Tasnim
Fajle Rabbi Ashik
Joya Rani Mallick
Kashfia Tabassum
Lazim Munim Esti
Mamata Jafrin Mouli
Maria Mehrin
Md. Enayet Chowdhury
Md. Hamidur Rahman
Nafisa Tabassum
Rabbi Sikder
Rashada Sultana
Rehnoma Tarannom
Sabah Tajin Tarique Aesha
Samia Zakir Sarothi
Shakib Sharker
Srishti Roy Chowdhury
Tahsin Afroz Hoque Nishat
Tahsin Tabassum

Table of Contents

Proceedings on International Conference on Disaster Risk Management, Dhaka, Bangladesh, January 12-14, 2019

GEOTECHNICAL/ GEOLOGICAL PROBLEMS HIGHLIGHTED IN THE RECENT DESTRUCTIVE EARTHQUAKES IN JAPAN

K. Konagai[1]

ABSTRACT

Remote sensing imagery with "very high" spatial resolution is becoming routinely available. Because soils are hysteresis materials exactly like a magnetic storage device recording the past, high-resolution remote sensing images often capture not only the real devastations but also marks of past disasters, suggesting that similar events may have happened over and over at the same location. Actual examples in recent earthquakes such as the 2011 Great East Japan Earthquake, the 2016 Kumamoto Earthquake and the 2018 Hokkaido Eastern Iburi Earthquake are given herein. These examples include liquefactions, landslides, etc. As long as clear evidence of past large soil deformations is there, we can bring potential hazard to light and take necessary actions. However, these pieces of evidence can often be draped with surface soil deposits particularly when we have volcanoes nearby. Moreover, porous nature of these volcanic matters can cause never-seen-before phenomena of large soil deformation, which phenomena are to be thoroughly studied and passed down to posterity.

Introduction

Earthquake hazard maps have been prepared by many municipalities in Japan as a mean to help people know earthquake-hazard-susceptible locations. The Japanese Ministry of Land, Infrastructure, Transport and Tourism made a web portal "Wagamachi" available in 2007 (MLIT, 2007) to bring hazard-map information from diverse municipalities. "Wagamachi" literally means "My town". However, when we look up liquefaction hazard maps on this web portal, we realize that there yet remain many municipalities left completely blank, which include those affected by liquefactions in recent devastating earthquakes. The Japanese Ministry of Internal Affairs and Communications made its study result public in 2015 (MIC, 2015). The result says that 33% of municipalities in Japan never had regular full-time officers for disaster management. This percentage has been improved as compared with 45% in 2009. However, it still remains as a difficult task for many municipalities to prepare liquefaction hazard maps, which task requires a lot of time, efforts, costs and knowledge to not only read many borehole logs but also develop scenario earthquakes.

However, soils are hysteresis materials exactly like a magnetic storage device recording the past. Thus, high-resolution remote sensing images often capture not only the real devastations but also marks of past disasters, suggesting that similar events may have happened over and over at the same location. Actual examples in recent earthquakes such as the 2011 Great East Japan Earthquake, the 2016 Kumamoto Earthquake and the 2018 Hokkaido Eastern Iburi Earthquake are given herein. These examples can offer another perspective on what will likely happen in the future.

Liquefactions

Once soil liquefies in an earthquake, liquefied soil grains are going to re-establish slowly their fabric due to the effect of gravitational force, which process is very similar to the process that they were originally deposited in water. Thus, the liquefaction hardly improves the soil's characteristics, and the granular fabric can remain as weak as before. Yokoyama et al. (2012) conducted a series of Swedish weight sounding (SWS) tests in Urayasu, Chiba, Japan, which liquefied in the Moment Magnitude (M_w) 9.0 Off the Pacific Coast of Tohoku Earthquake of March 11th, 2011, also known as the Great East Japan Earthquake. The team had conducted the tests at the same location over and over since before the earthquake, and they could see the chronological change of the liquefied soil in terms of its strength (equivalent N value) as shown in Figure 1. It is noted in this figure that it took about a month or two for the liquefied soil to regain its strength, and the regained soil strength was slightly above or below its original strength (broken line), indicating that it has again become vulnerable to liquefaction.

[1]*Professor Emeritus, University of Tokyo, Tokyo, Japan*

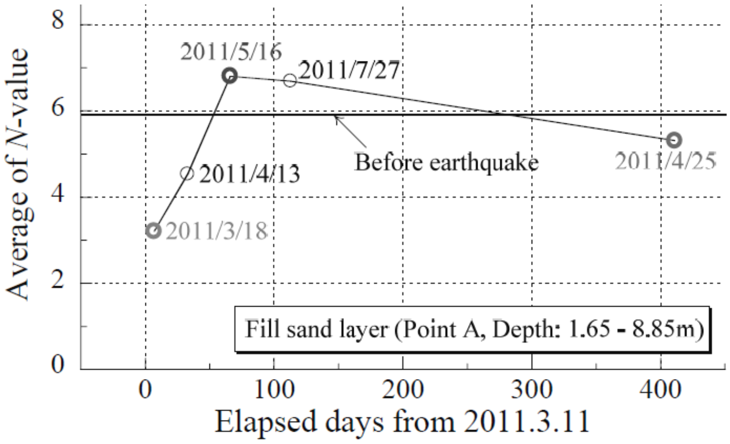


Figure 1. Chronological change in equivalent N value averaged over the depth from 1.65 to 8.85 m at Benten, Urayasu, Japan (Yokoyama et al., 2012).

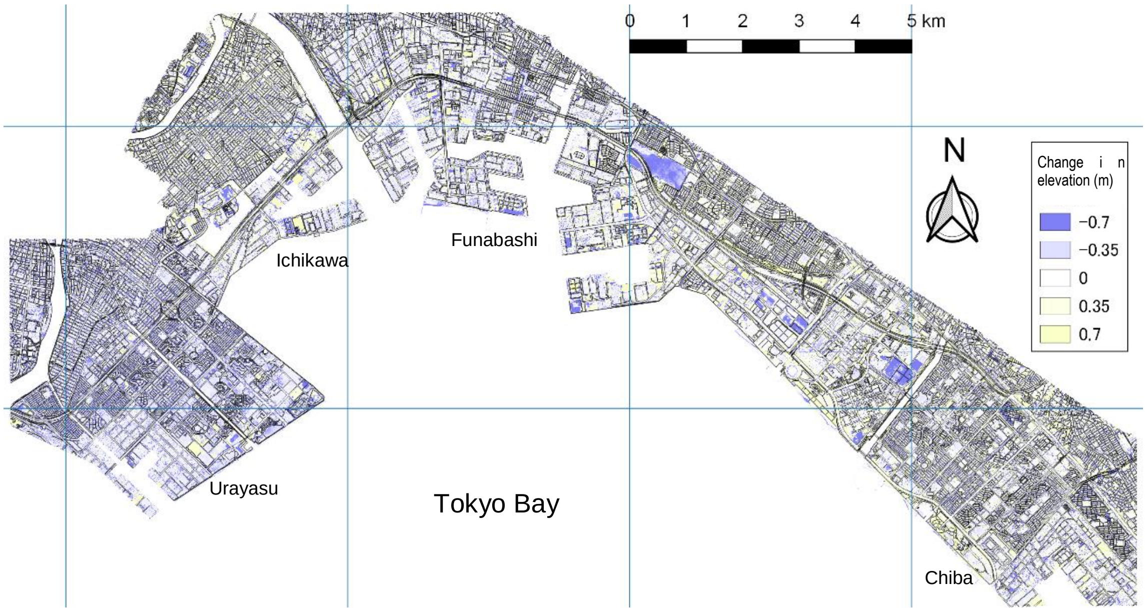


Figure 2. Ground subsidence map for the northeastern half of the Tokyo Bayshore Area (Konagai et al., 2013)

The March 11th, 2011 Great East Japan Earthquake has shown that a long stretch of landfills along shorelines of the Tokyo Bay has very high susceptibility to liquefaction, causing concerns about re-liquefactions of the area in the scenario earthquake expected in the capital's metropolitan area. An attempt was made by the author and his colleagues to detect liquefaction-induced soil subsidence from raster images converted from airborne LiDAR (Light Detection and Ranging) data before and after the earthquake (Konagai et al, 2013). To eliminate deep-seated tectonic displacements and systematic errors of LiDAR surveys, the template matching technique was used for clusters of pile-supported buildings and bridge piers chosen as templates in source images of the target areas. The obtained subsidence maps describe the spatial distribution of soil subsidence in great detail (Figure 2 for the northeastern half of the Tokyo Bayshore Area). Figure 2 shows changes in elevation measured after almost all sand ejecta were cleared up from streets. As the color shifts from yellow to blue, the ground subsidence becomes larger (see the legend). Taking the slow strength-recovery process of liquefied soil into account, the amount of ground elevation loss was considered not due to the soil densification but largely due to the removal of sand ejecta. Therefore, it is expected that there yet remain liquefaction-susceptible weak soils just beneath blue-colored sunken areas. Some recent studies including the one by Kiyota et al. (2017) are now paving the way to assess liquefaction potential in a quantitative manner with easy-to-reach information of in-situ shear wave velocities. These methods together with the ground-subsidence maps will help examine the liquefaction susceptibility over a wide area in a rational and practical way.

Landslides

Starting with a $M_w 6.5$ foreshock on April 14, 2016, a series of major earthquakes including the $M_w 7.3$ main shock on April 16 hit the central Kumamoto area of Kyushu, Japan, causing deaths, injuries and widespread damage to various facilities. The observed features of the damage again showed that not only intense shakes but also ground deformations such as landslides, etc., which were found within a swath along Futagawa fault that moved in this earthquake, can be equally or more often responsible for devastations. According to Japan Railway Kyushu (2017), 73% of about 750 compiled damage reports were of landslides, rock falls and debris flows, 20% were due to rail track deformations, and the remaining 7% were about damage to buildings. The "Ground zero" in terms of extensive damage to transportation systems was in and near a narrow valley cutting deep across the world largest caldera of Mt. Aso. This opening has formed as a consequence of an accumulation of continual extensional movements of the SW-NE trending Futagawa fault that diagonally crosses the caldera wall. Major landslides occurred along this narrow valley and along the wall of the caldera. These landslides included the largest one that has hit an important location for traffic, transmission lines and a waterway leading to a penstock (see Figure 3). LiDAR, Laser based altimetry, can penetrate through tree canopy, revealing detailed feature of bare earth left behind by past natural hazards, and the LiDAR image in Figure 3 shows evidence of past landslides as well as the most recent one. Moreover, cracks are seen along the exposed scar indicating potential future risk.

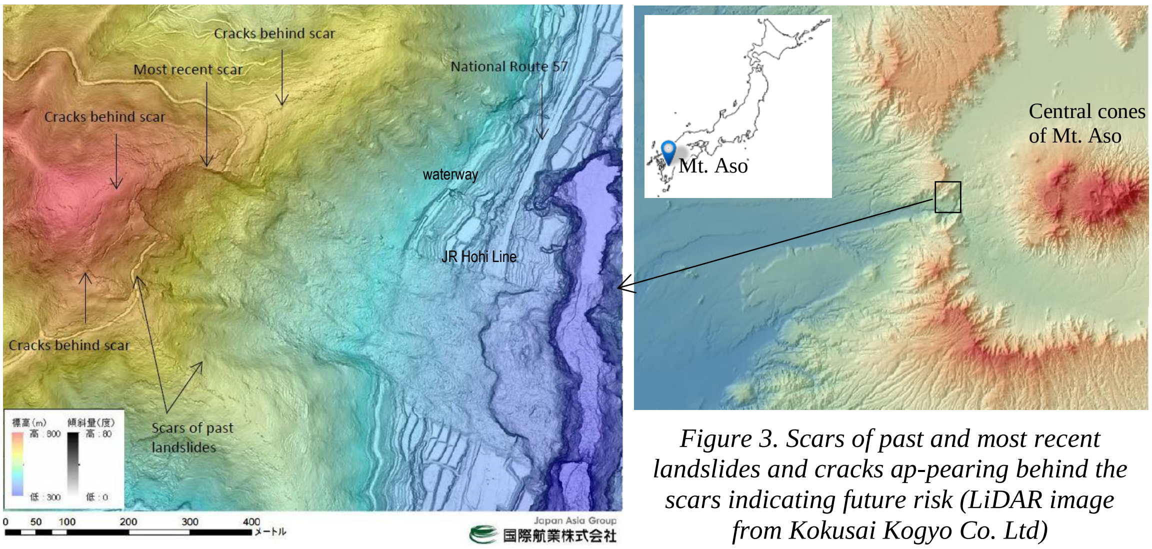


Figure 3. Scars of past and most recent landslides and cracks ap-pearing behind the scars indicating future risk (LiDAR image from Kokusai Kogyo Co. Ltd)

Soils are hysteresis materials exactly like a magnetic storage device recording the past. As long as clear evidence for past large soil deformation is there in LiDAR images, landslides/active fault maps etc., we can bring potential hazard to light and take necessary actions. However, these pieces of evidence can often be draped with surface soil deposits particularly when we have volcanoes nearby. Moreover, these volcanic matters are extremely porous and thus have crushable nature. Once these volcanic matters are completely water saturated, grain crushing, which can occur in an intense earthquake, can cause a sudden increase in excessive pore water pressure, and trigger landslides even on extremely gentle slopes. One of these large-scale runout slope failures, known as the Takanodai landslide on a 12 degrees gentle slope, destroyed at least 7 houses and killed 5 people (Chiaro et al., 2018).

The $M_w 6.7$ September 6, 2018 Hokkaido Eastern Iburi Earthquake produced the largest area of multiple landslides, $A_{exposed} \cong 13.4\ \mathrm{km}^2$, in the past 100 years or more. The multiple landslides can largely be attributed to the geological features of the region. As shown in many reports of geological surveys, the region is draped thick with volcanic ash and crushable pumice from nearby volcano eruptions of Shikotsu (about 40,000 years ago), Eniwa (about 20,000 years ago) and Tarumae (about 9,000 years ago). Many of these landslides slid even on very gentle slopes. To examine the mobilized frictional coefficient, the movement of a single planar and coherent landslide mass that has slid along Line C_3-C_4 in Figure. 4 was discussed by Konagai et al. (2018). This planar landslide mass, after sliding on the very gentle slope with the average inclination of about 0.2 (Figure 4), hit the opposite wall of a shallow valley and stopped forming a transverse

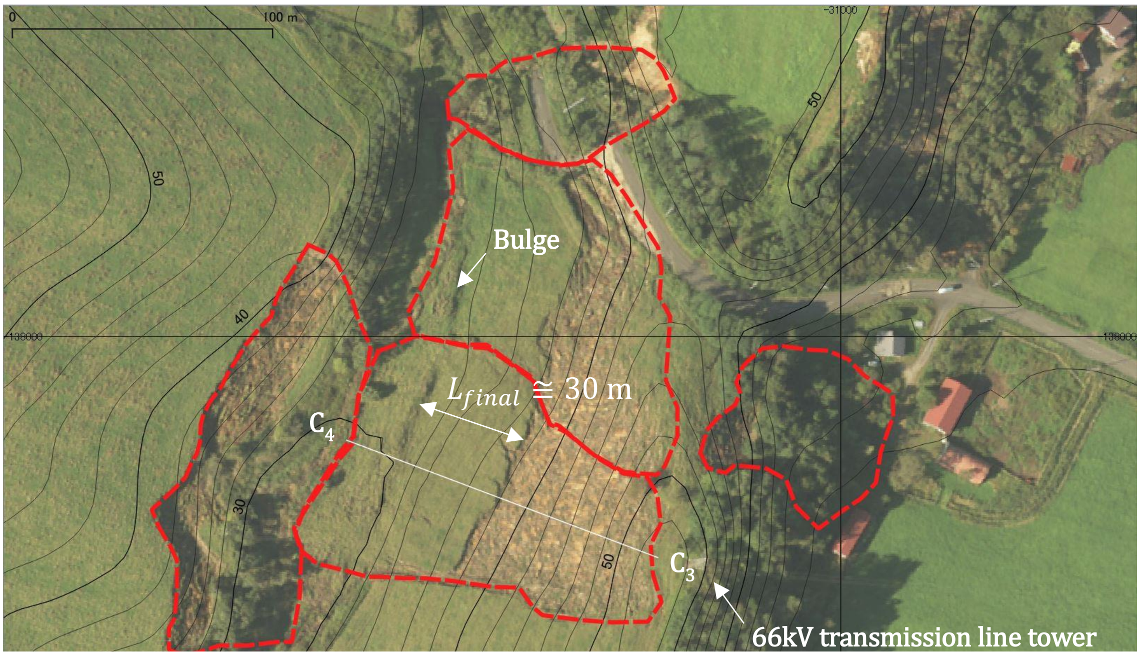


Figure 4. Coherent landslide mass compressed against the other side wall of valley (Konagai et al., 2018)

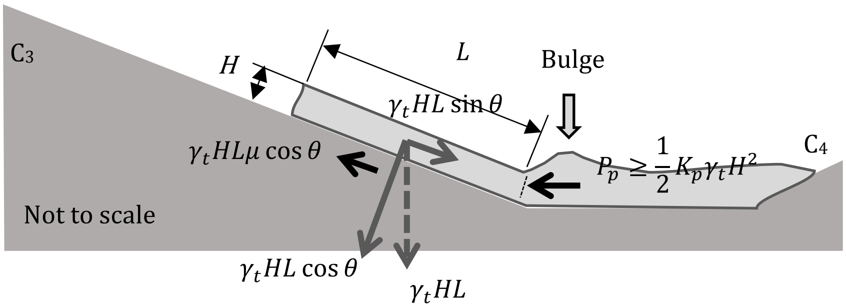


Figure 5. Cross-section of landslide mass that has stopped moving being compressed against the other side wall of valley (Konagai et al., 2018)

bulge as illustrated in Figure 5. This bulge is assumed to have developed where two-dimensional wedges of passive soil failure formed one after another at the boundary between the toe part pressed against the opposite valley wall and the slowing tail part with the uniform thickness *H* as illustrated in Figure 5. This tail part was gradually shortening until its final length of *L* was reached. Equation (1) shows the final equilibrium condition immediately before the final length *L* of the tail part is reached:

$$(\gamma_t HL \sin\theta - \gamma_t HL\mu \cos\theta)\cos\theta \geq \frac{1}{2} K_p \gamma_t H^2 \qquad (1)$$

where, an inequal sign is necessary because the bulge worked as a surcharge, γ_t = unit weight of the wet landslide mass, and K_p = coefficient of passive earth pressure, which is given by:

$$K_p = \tan^2\left(\frac{\pi}{4} + \frac{\phi}{2}\right) \qquad (2)$$

with ϕ = internal friction angle of the landslide mass, which ranges in the epicentral area from 42 to 48° under low effective confining pressures (Kitago et al., 1973). Assuming that $\phi \cong 45°$, $H \cong 1.5$ m and $L \cong 30$ m for the Line C_3-C_4, $\cos\theta \cong 1$ and $\sin\theta \cong \theta$ given that $\theta \cong 0.2$, one obtains;

$$\mu \leq \theta - \frac{1}{2} K_p \frac{H}{L} = 0.2 - \frac{5.83 \times 1.5}{2 \times 30} \cong 0.054 \qquad (3)$$

There are still much to examine to be sure, but this value suggests that the sliding surface beneath the landslide mass must have been very slippery like a banana peel.

Never-seen-before Phenomena

The 2016 Kumamoto Earthquake was followed by torrential rain of June 20 and 21, 2016, and a low-lying

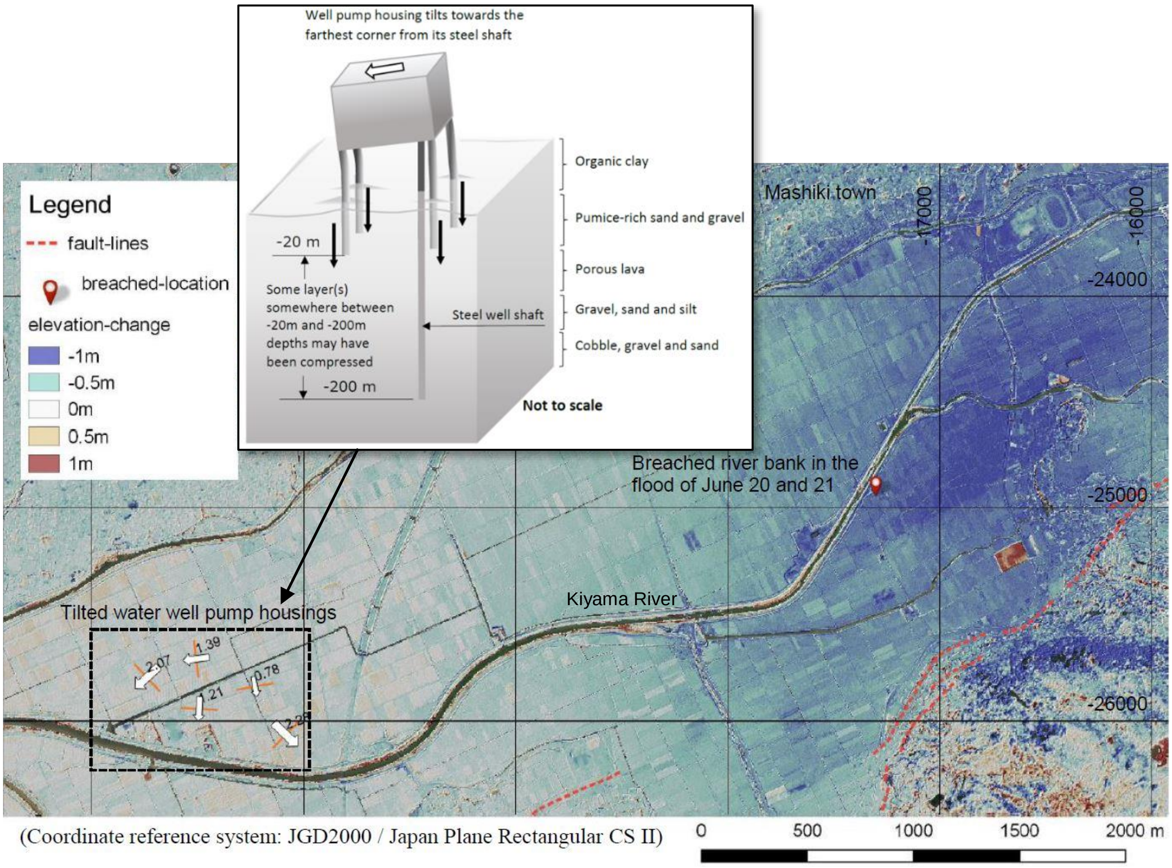


Figure 6. Elevation change caused by the earthquake and tilted RC housings for pumps of clean water wells. Arrows and their labels show directions and angles of tilt for five pump housings. Red place mark shows the location of river bank breached in the torrential rain of June 20 and 21. (Konagai et al., 2017)

valley south of Mashiki town cutting shallow into the outer foothill of Aso Caldera was flooded (Konagai et al., 2017). When digital terrain models of this area before and after the earthquake are compared, this area is found sunken by more than a meter (Figure 6). The swelling water of Kiyama River that flows through the low-lying area overtopped the left river bank at the location of the red place mark shown in Figure 6.

This ground subsidence is considered to be largely due to tectonic deformation. However, a never-seen-before phenomenon observed in the west part of the inundated area was that many RC housings for pumping facilities for water wells were found tilting as illustrated in Figure 6. Kumamoto city depend 100% on groundwater from nearly 100 water wells, and the main shock was the most damaging, resulting in nearly 460,000 customers' outages. One of the primary reasons for the outages was rather artificial due to regulatory requirements for clean water quality. Kumamoto city has set a standard on the allowable turbidity in drinking water. When the turbidity 5 on the Japanese Turbidity Standards (JIS K0101) is reached in any well, its pump stops automatically. If all pumps in the tilting housings have stopped due to the increase of turbidity, it may suggest that the soil grain crushing may have occurred in their common aquifer underneath the flood plain due to large strain build-up.

Angles and directions of tilt of these well-pump housings were measured using a total station (Figure 6). Tilt angles ranged from 1 to 2 degrees, and there was no clear directional regularity observed for these housings. However, it is noted that the steel shaft of each well embedded about 170 to 200 m deep in the thick deposit of volcanic matters goes straight up to its housing and is clamped to the floor off its exact center such that the steel shaft is much closer to one of four corner columns of the housing. Meanwhile four corner columns of the housing are supported by PC piles, 2 piles for each column, and thus total 8 piles, which are all about 20 m long embedded in the uppermost organic clay layer. Now that each housing is found tilting towards the farthest corner from its steel shaft, it is considered that the uppermost organic soil layer has sunken as a whole in the earthquake dragging down all PC piles, while the steel shaft of each well worked as a strut. Though negative skin frictional forces could have been exerted equally upon all PC piles, the largest distance from the strutting steel shaft made the moment from the farthest pile be the largest, and thus caused the housing to tilt in that particular direction.

The tilts of housings thus suggest that some layer(s) somewhere between -20m and -200m depths may have been sheared and compressed. This phenomenon and its cause are to be thoroughly studied because any deformation of the ground surrounding underground facilities can be responsible for damage to them.

Conclusions

Not only intense shakes but also large ground deformations in an earthquake can be equally or more often responsible for serious devastations. These ground deformations can occur over and over at the same locations. Even soils that liquefied in an earthquake, which often leave marks of serious ground depression, can remain as weak as before. That is why advanced remote sensing technology helps estimate susceptibility of ground deformations. Sometimes, these marks of large ground deformation can be draped with newly deposited soils such as pumice and volcanic ash. These porous volcanic matters can exhibit extremely slippery nature when they are wet and crumbled and cause multiple landslides even on gentle slopes.

A never-seen-before phenomenon, which may be attributed to the crushable nature of volcanic matters, was observed in the 2016 Kumamoto Earthquake. Many RC water-well pump housings were found tilting near the western foothill of Aso volcano. Each housing has four legs on 20 m long pile foundations, while its steel shaft, embedded about 170 to 200 m deep in the thick deposit of volcanic matters, goes straight up to the housing and is clamped to the floor off its exact center. Since every housing was found tilting towards the farthest corner from its steel shaft, the shaft seems to have worked as a strut suggesting that some layer(s) above -200m depth may have been compressed in the earthquake. Even after the wound from a big earthquake heals, ground depressions remain forever causing long lasting problems such as flooding. For better post-quake rehabilitations and to be prepared for the next big event, landform changes are to be recorded in a quantitative manner, and their causes are to be thoroughly studied.

References

Chiaro, G., Chew, K.S.Y. and Kim, J.S. (2018) "Numerical analyses of the earthquake-induced Takanodai landslide, Kumamoto, Japan", *International Conference on GIS and Geoinformation Zoning for Disaster Mitigation*, At Auckland, New Zealand.

Japan Railway Kyushu (2017) "Damage to railway facilities", *JSCE Symposium in commemoration of the 2016 Kumamoto Earthquake*, http://committees.jsce.or.jp/eec2/node/96.

Kitago, S., Takaiwa, M., and Kamiya, M. (1973) "Geotechnical features of pumice covering the central part of Hokkaido", *Bulletin of the Faculty of Engineering, Hokkaido University*, 68(2): 223-241.

Kiyota, T. and Wu, C. (2017) "A method for evaluating liquefaction resistance based on in situ and laboratory measured shear wave velocities", *Japanese Geotechnical Journal*, 12 (4), 375-383.

Konagai, K., Kiyota, T., Suyama, S., Asakura, T., Shibuya, K. and Eto, C. (2013) "Maps of soil subsidence for Tokyo bay shore areas liquefied in the March 11th, 2011 off the Pacific Coast of Tohoku Earthquake", *Soil Dynamics and Earthquake Engineering*, 53, 240-253, https://doi.org/10.1016/j.soildyn.2013.06.012.

Konagai, K., Shiga, M., Kiyota, T. and Ikeda, T. (2017) "Ground deformation built up along seismic fault activated in the 2016 Kumamoto Earthquake", *Journal of Japan Society of Civil Engineers*, Ser. A1 (Structural Engineering and Earthquake Engineering), 73(4), I-208 – I-215. https://www.jstage.jst.go.jp/article/jscejseee/73/4/73_I_208/_article/-char/en.

Konagai, K., Nishiyama, S., Ohishi, K., Kodama, D. and Nanno, Y. (2018) "Large ground deformations caused by the 2018 Hokkaido Eastern Iburi Earthquake", *JSCE Journal of Disaster Fact Sheets*, FS2018-E-0003, 1-8, http://committees.jsce.or.jp/disaster/FS2018-E-0003.

Ministry of Internal Affairs and Communications, MIC (2015) "*Study on authorized number of officers for autonomous bodies*" http://www.soumu.go.jp/menu_news/s-news/100402.html.

Ministry of Land, Infrastructure, Transport and Tourism, MLIT (2007) "*Wagamachi – Hazard maps of my town*", https://disaportal.gsi.go.jp/hazardmap/.

Yokoyama, Y., Kyokawa, H., Kondo, Y. and Kiyota, T. (2012) "Liquefaction-induced damage on the reclaimed area in Urayasu city and the result of SWS test", *SEISAN-KENKYU* (*Monthly journal of the Institute of Industrial Science*), University of Tokyo, 64(6), 27-31.

BUILDING DISASTER RESILIENT COMMUNITY BY ICT AND YOUTH EMPOWERMENT IN INDONESIA FROM THE SURVEY OF THE MT. MERAPI – INTRODUCE NEW IDEA OF WIDE VIEW DISASTER INFORMATION PREDICT SYSTEM

Stefano Toshiya Tsukamoto[1]

ABSTRACT

Osaka University and Universitas Gadjah Mada (UGM) have been corroborated to set up the Satellite office in UGM, Institute of International Studies (IIS). We have developed the application for the multi-cultural and multilingual situation to get the Disaster information system. This is The Multilingual- Wide view Disaster Information Predict System (We call it "CARED"). We are planning to have a test of this system for Indonesian Consulate in Osaka as a Disaster Information System for Indonesian people who live in Japan, also. This idea made by my experiences in Sri Lanka Conflict 2009 that my methodology of how to reorganize the peace zone in the field. I call it Zone of Peace index (ZPI). It methodology show use the scale of the people's mind about the happiness and peace.

In 2014, Osaka University –UGM Satellite office supported three group of student community services (KKN) taking location in three villages in Yogyakarta. All three villages have different characters to each other in correlation to its hazards. Also as requested from the residents of the villages, more varieties of programs were conducted in addition to the infrastructure programs such as evacuation map for the life-stock, food management and security during disaster, alternative food-stock and cleanliness in shelter. We have analyzed the to use ZPI methodology. This report will summarize the research and how did I have developed the CARED App for the disaster victims. In the end 2014 term, the office is successfully sign a MoU with Badan Penanggulangan Bencana Daerah (BPBD) Yogyakarta. This legal and formal cooperation will open the more chances for Cared to be institutionalized in government agency for disaster management. We need to consider and trust that improvement in social risk management consciousness will be raised from improvement and empowerment in college students' consciousness in the future.

Keywords: Zone of Peace Index (ZPI), multicultural Disaster Management, wide view disaster information system, Disaster Resilient Community, human centered disaster management.

Problems found in research on disaster countermeasures

The Yogyakarta Special Region (with a population of approximately 4 million) has lost many residents to natural disasters including the Java Earthquake in 2006 and the eruption of Mount Merapi volcano in 2010. This March we started research on the status of the disaster countermeasures in place there to identify the particular problems that they face. In July and August, we dispatched 29 undergraduate students of Universitas Gadjah Mada (UGM) to two Sub-Districts, where they spoke with the residents of local villages and helped them draw hazard maps, draft disaster countermeasures, organize evacuation drills and create websites for the villages. Although the region's local government has encouraged villages to draw hazard maps since 2009, most of the villages have not yet prepared any.

The results of the research above revealed that there were problems in their method of collecting information at the time of disaster. The national government and the Red Cross understand that the system for collecting information at the time of disaster is not sufficient and they are therefore exploring an effective information collection system in the case of disasters, though no appropriate system has been developed yet.

In disaster prevention, local municipalities are mostly in charge of implementing appropriate measures. In an actual disaster, information gathering is performed at the discretion of local municipalities. In Japan, under the country's vertically divided administrative structure, it is no exaggeration to say that disaster prevention and disaster relief measures are entirely placed in the hands of the nearly 1,800 local municipalities nationwide. A similar situation was observed in Indonesia in the research conducted by the RESPECT Satellite Office in the first half of this year. All actions are taken in a vertically divided structure, in which almost none of the municipalities have a system linked to neighboring municipalities to cooperate in response to a disaster. It is necessary to establish a horizontal network among local municipalities, and also to integrate the disaster prevention measures at the municipal and provincial (regional) levels. Our research found that Indonesia has the same problems as Japan.

---

[1]*Osaka University*

In recent years in Japan, we have seen many large-scale disasters, such as torrential rain, tornados occurring in unexpected areas, and typhoons causing extraordinary damage. Earthquakes have also caused damage to broad areas, which often exceeds the handling capacity of local municipalities. This is why many volunteers played a crucial role in the aftermath of the Great Kanto Earthquake, the Great Hanshin-Awaji Earthquake and the Great East Japan Earthquake. As public awareness of such volunteers has improved, we see many people willing to make some kind of a contribution at the time of a disaster. Thus, besides physical volunteer activities, we examined the possibility of obtaining support from many residents for information gathering in addition to efforts by local municipalities.

Yogyakarta is located in the central part of Java, where most residents speak both Indonesian and Javanese. For such a multicultural region, it is necessary to analyze the differences between various cultures before determining earthquake countermeasures.

In Japan, municipal actions are mostly taken using the Japanese language and support for foreign residents from various areas is not sufficient, Bringing immeasurable anxiety and stress to those who experience a disaster in a place where they do not understand the language. Some municipalities prepare disaster prevention manuals in several languages, but it is doubtful that foreigners are able to fully understand Japanese disaster prevention measures by reading such translated manuals. It is probably necessary to prepare manuals based on sufficient understanding of the cultures and customs of each foreign country.

We examined the situations for various types of disasters, and found that residents have a poor understanding of countermeasures for not only earthquakes and other natural disasters but also infectious diseases. If a new influenza (H5N1), for example, develops into a pandemic, the basic response in Japan is to stay home. Data from some 5,000 medical centers all over the country is not available. I therefore believe that, instead of waiting for data from the central government, each municipality should have a certain ability to collect and analyze data of infectious diseases.

Since the situation is found to be almost the same in the Yogyakarta Special Region, a system to gather and analyze as much local information as possible is necessary to plan their disaster relief measures.

Need for broad-area disaster relief measures

As represented by the recent Great East Japan Earthquake and the Sumatra earthquake ten years ago, most earthquakes did not occur within the small area of a single municipality but caused damage to a broad area of over 500 km. If the currently anticipated series of earthquakes occur from the Nankai Trough to the Tonankai and Tokai areas, linked to the Tokyo metropolitan area, local municipalities, in taking countermeasures, must have a broad-area network between at least the prefectural government and the municipalities. It is questionable, however, whether appropriate actions can be taken in the present vertically divided administrative structure in Japan.

As mentioned above, other projected disasters, such as a pandemic of new influenza and an eruption of Mt. Fuji, may cause damage to a broad area of the entire Kanto region and Tokai area, depending on the wind direction. Moreover, the pandemic is highly likely to spread throughout Japan, then to Asia and even all over the world. Earthquakes, tsunami, volcanic eruptions, and infectious viruses are not confined to national boundaries nor municipal barriers.

From this perspective, similarly in Indonesia, for future disaster relief activities, it seems necessary to establish a system that enables the gathering information from a broad area and finding ways to make effective use of the collected information for the benefit of residents of the disaster-affected area.

Zone of Peace

Background

Mt. Merapi (Indonesian: Gunung Merapi) is a volcano located in Central Java, Indonesia. The Volcano has been very active since May 2006. On May 13 of that year an official evacuation alert was issued and on the 15th an extensive pyroclastic flow occurred. In 2006 earthquakes occurred in Java, and the region of Yogyakarta was visited by a variety of disasters in the form of quakes, tsunamis, and volcanic eruptions.

A a result of massive volcanic eruptions in October and November of 2010, more than 350 people died and over 300,000 were forced to evacuate their homes. The nearby Borobudur temple complex ruins, a World Heritage site, was covered in ash, leading to a sharp drop in tourist visitors, which usually number about 2 million annually.

For approximately two years after these volcanic eruptions of 2010, together with university students from Japan and from the University of Gadjah Mada (in Yogyakarta), I visited villages in the Yellow Zone and Red Zone to conduct a survey of disaster prevention awareness.

Survey areas

Our first visit was to the village of Pangukreejo in the Red Zone. Its population was 676 and 195 of its houses were destroyed by the volcanic eruption. It is located 10 km from the mouth of Mt. Merapi. According to local government officials, many of the village's residents lost their homes as a result of the pyroclastic flow, but many in the village remained in the locality. They did not wish to move away because they are taking up work opportunities such as selling souvenirs and photos of Mt. Merapi to the tourists who came from all over Indonesia to see the state of the mountain, and arranging tours of the affected local areas by car.] Since staying within this Red Zone was not permitted, relief supplies were not distributed here. However, it seemed that a good number of people worked energetically at re-establishing a livelihood by setting up shops or catering to the tourist trade.

Next, we visited the village of Pentingsatri in the Yellow Zone. Its population was 398. Almost none of the houses in the village suffered damage. The village is located 12.5 km from the mouth of Merapi. Before the eruption many of the village residents earned their livelihoods through eco tours and the like, and they continued to do this. In addition, relief supplies from the government and other organizations were distributed in the village.

Survey method

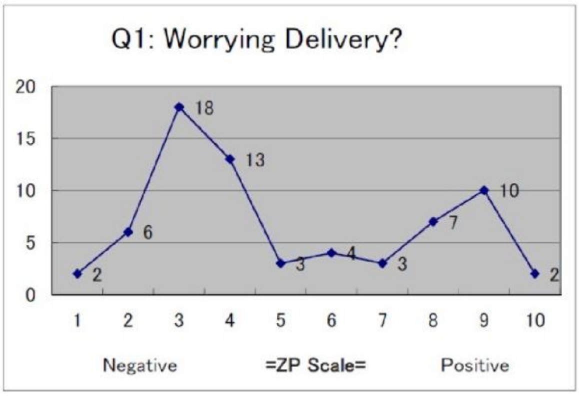
The survey was conducted by pairs of Japanese and Indonesian students posing a set of 16 questions randomly to villagers in each of the locations. The survey results were then used to compute a Zone of Peace Index (ZPI) based on qualitative questions relating to disaster prevention, to quantitatively assess the safety situation of residents. (Tsukamoto Method)

In what ways can people achieve peaceful living conditions? The absence of war alone does not result in peace. For example, Japan has enjoyed more than 60 continuous years without a war, yet the lack of social security that has accompanied economic development has led to social chaos.

Certainly it cannot be said that the mere absence of war has brought peace. Genuine peace enhances the peace of mind or sense of security of citizens because it enables the security of communities, by facilitating a stable livelihood, education, and health care, and ensuring public law and order. It has been a challenge to quantify this kind of qualitative data. However by simply assigning scores out of 10 to each of a series of qualitative questions, it is possible to draw out useful analytical findings—something that is not possible with two-choice questions.

The graph below was constructed by applying the ZPI method to a survey of the attitudes to childbirth of pregnant women in an IDP (internally displaced person) camp after the conclusion of a conflict.

Sample of survey in Sri Lanka at 2007



Graph 1: Attitude survey of pregnant women on childbirth (Sri Lanka)

If the question posed in the IDP camp were "Are you worried about given birth?" "Yes" or "no," the results would reveal that many worried people, but with the ZPI method, as shown in the graph above, there is substantial variation in the feelings of these people. And we can imagine from this graph that this sense of anxiety moves over time like a wave, according to conditions, as people's feelings change. Given their situation, people in the camp were questioned to find out if they were worried about giving birth?" If they were asked only for a "yes" or "no" answer, the results would reveal a high number of responses indicating that they were worried. However, with the ZPI method (see graph above), we can infer that the feelings of the worried people are temporary. We could also infer that that this sense of anxiety, as mapped on the graph, would move like a wave according to situation and conditions.

Graph 2: Image of the data of 3 month before (Sri Lanka)

Graph 3 Are you still worried about the next eruption?

The survey was taken in the third month after the people moved to the IDP camp. We could assume that three months earlier, having found themselves in miserable circumstances, many of the IDPs would have felt anxiety about how they would be able to deliver a child. If the same question were asked at that time, we would most likely see a much larger peak on the left side of the graph.

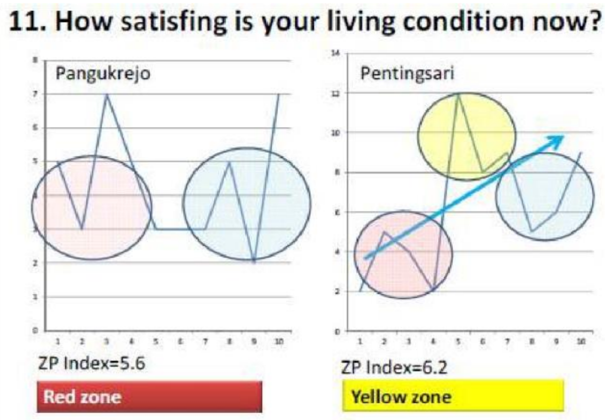
Then over the following three months, as government health agencies and NGOs distributed dietary supplements and dispatched health workers, midwives, and doctors, the IDPs would have come to learn that there was a sufficient system in place to support the delivery of a child. As a result the peak of "anxiety" would have subsided and a new "no anxiety" peak would have appeared on the graph. In addition, this ZPI method analysis indicates that there is a need to examine ways to develop a system to make the "no anxiety" peak larger by providing further, continuous support.

The ZPI value here is 5, representing an intermediate value for the sense of security felt in the IDP camp.

An Attitude Survey of Evacuation Zones after Eruption of Mt. Merapi in Yogyakarta, Indonesia

The responses of the people in the Yellow Zone and Red Zone to this question tended to be similar.

That is, in broad terms there seemed to be two basic kinds of people. One group of people was worried; the other group was unworried. It's only natural that the people in the worried group were sincerely worried, since many people had died as a result of the pyroclastic flows and many were forced to evacuate—not to mention that there were people still living in the Red Zone despite the fact that the government had prohibited this. Yet, many people remained "unworried," while a few others were undecided.. Many Indonesians are devoted Muslims and tend to leave their fate to God, so there were many people who were "unworried" for this reason.



Graph 3: sample of the ZPI data about "the satisfying the living condition?"(Merapi)

This question assesses the feelings of villagers about their present living conditions. The graphs for the residents of the Red Zone and Yellow Zone show completely opposite patterns. The people of the Red Zone are divided into two main groups—those satisfied with conditions and those dissatisfied. Only a small number of people are in the intermediate class. Not surprisingly, there are quite a few factors that give rise to dissatisfaction, due to the fact that the Red Zone receives no external support. In contrast, there are also many positive villagers who are satisfied because they are able to work catering to tourists in areas they are very familiar with.

On other hand, the people of the Yellow Zone can be broadly divided into three groups—a dissatisfied group, an intermediate group, and a satisfied group. Although the Yellow Zone receives support, the local farm production has been impacted by ash and other effects, making it difficult for some villagers to sustain a livelihood. Some villagers were earning a livelihood by conducting eco tours even before the disaster. So we can conclude from this graph that providing technical support to the intermediate group would shift them into the satisfied group. The ZIP value, which is now 6.2, could perhaps be increased to over 7.0 by implementing greater direct support to the dissatisfied villagers and technical support to the intermediate group, thereby leading to a greater numbers of satisfied villagers.

Features of the Wide View Disaster Information System from ZPI survey

According my experiences of the field researches by ZPI, I realized that how can I show the result of the Disaster condition and the people's feeling at the disaster time.

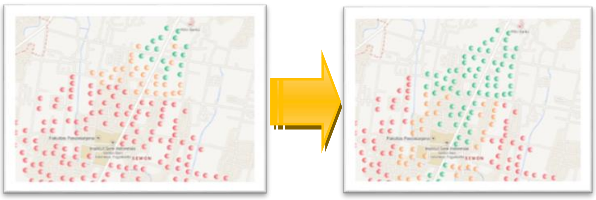
Unlike the municipal government-controlled systems being developed by municipal governments, this Wide View Disaster Information System is an information system operated under the initiative of residents. In this system, residents are requested to answer by cellphones some simple questions prepared in advance regarding the situation after various disasters, based on which the status of the disaster-hit area is described in maps colored in red, yellow or green, depending on the degree of damage and the progress of support. These maps are provided to local municipalities, the Red Cross, NGOs, etc. as useful information for implementing disaster countermeasures. This system was developed based on the concept proposed by Osaka University, through several discussions with the provincial government's disaster management agency, Red Cross, etc. This system includes the following features:

1. The degree of damage is visually presented on Google Maps, enabling easy identification of the areas that need emergency relief. An overall picture of the damage can be grasped from the wide-view data while local information on each municipality can be analyzed by enlarging the map. For collaborating municipalities, the system allows access to the guarded private information of the disaster-hit area. For the general public, it offers wide-area maps of the damage status.

Map1: Sample of wide view Disaster Result

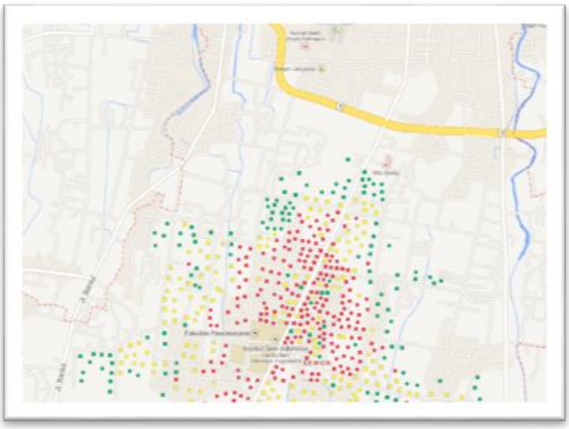
Graph4: Automatically Statistic data analysis

2. After the disaster, it collects information every week and shows the progress of relief activities by changing color.



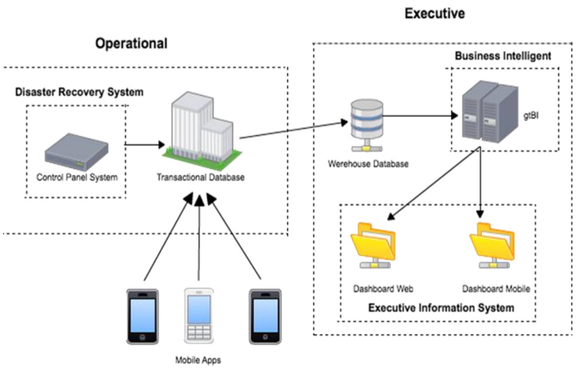
Map2: Sample of the progress of Food distribution.

3. By enlarging the distribution map on Google Maps, the detailed status of the damage of each area can be viewed.



Map3: Image of the spot map of Disaster

4. Information from a wide area can be collected, statistically analyzed, and plotted on graphs for the wide area or each municipality.
5. So far, it has been difficult to statistically collect qualitative information regarding relief activities such as complaints from the victims, which are often heard at disaster sites during relief activities. On the other hand, there are many victims who are physically or mentally unable to express themselves. This system enables residents to communicate their conditions or feelings via cellphone. It helps make the silent voices in a disaster-hit area heard

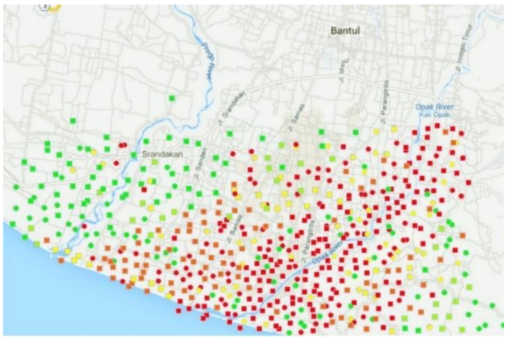


6. This system allows each local municipality to release trends in the population infected by highly virulent new influenza. If the new flu is highly virulent, people are basically required to stay home while the telephone lines for public health centers etc. are likely to be in a highly confused state. In the case of an infectious disease, volunteers are not able to freely move around like in the case of an earthquake. Under such a situation, there is no doubt that a disaster information system using cellphones will work effectively. Moreover, by identifying the infected areas, users are able to decide the locations to distribute Tamiflu or relief supplies. As shown by the graph below, highly virulent flu requires a long-term support system, though at present, Japanese municipalities have no way to grasp the infection status. The Wide View Disaster

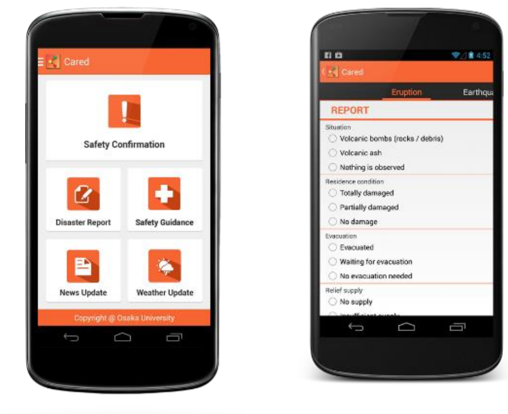
Information System will enable each municipality to analyze the situation and plan relief activities

What is CARED?

CARED is a mobile app for a Multilingual Wide View Disaster Information Prediction System.



Map 3: Sample of Wide view Disaster Information Based on affected people's response to simple questions in an app on their cell phones, disaster damage is visually displayed on a map. The damage levels are plotted according to severity as red (most), yellow, or green (least) dots on a map. To predict



damage and assist in emergency aid planning, the information can also be organized into data sorted by municipality. CARED was developed by Osaka University led by Professor Tsukamoto and piloted in the Yogyakarta Special Region in partnership with the Department of International Relations, Universitas Gadjah Mada. The system is currently available 8 languages like in Indonesian, Javanese, and English. Japanese, Spanish, Portuguese, Korean, and Chinese versions 2015. We wish to use this system more than 20 languages in the near future.

Basic features of CARED

(1) Visualization of disaster analysis: Information is displayed in map or data form based on responses from affected people's smart phones.

(2) Collection of disaster information from a wide area: Data is collected from multiple municipalities, allowing wide-range disaster management and support measures to be designed.

(3) Assessment of the progress of support activities: Weekly follow-ups analyze the changes in affected people's situations.

(4) Nationality-based analysis: As part of their disaster management measures for foreign residents in Japan, embassies and consulates can help identify foreigners affected by a disaster.

(5) Disaster guidelines for foreign tourists in Japan: General guidelines for each type of disaster are currently available in nine languages (Indonesian, Javanese, English, Japanese, Korean, Chinese, French, German, and Thai). Additional languages (Spanish, Portuguese, Italian, Russian, Tagalog, Vietnamese, Burmese, Hindi, and Nepalese) are currently under consideration. This information can be used as part of the disaster readiness measures for foreigners during the 2020 Tokyo Olympic Games.

(6) Prediction and Tracking of Communicable Diseases: Disease outbreaks (e.g., influenza) are followed by municipality, allowing each municipality to take appropriate measures according to its own estimated contamination peaks.

(7) Monitoring of other types of disasters: This tool is applicable to other types of crises such as outbreaks of livestock diseases (e.g., hoot-and-mouth disease) and weather-related issues (e.g., snowfall).

(8) Incorporation of a personal safety confirmation tool: In addition to visualizing the overall picture by color (red ○ for unsafe, green ○ for safe) on a map, individual data can be sent to up three designated emails or SMS numbers.

(9) Mapping of domestic and foreign trekkers: In case of an emergency, the location and movements of trekkers on Mt. Fuji and other volcanic mountains can be visually identified.

(10) Tracking of impending disasters: Residents living in 1 of the 52 high-risk landslide areas nationwide can report signs of an imminent threat (e.g., spring water running or rumbling noises coming out of a mountain).

Potential applications of CARED (future development)

(1) A safety confirmation tool for schools, organizations, and companies: Just like the basic system, this application retrieves information on the safety and conditions of students and school staff during a disaster and displays it using a color-coded map. This along with basic regional information should help identify the number of students and staff in heavily damaged areas and aid in planning appropriate actions. Conversely, schools, organizations, and companies can protect and manage personal data on their own, enabling communication with individual members at their actual locations if Skype or SNS contacts are registered with their emergency contacts. Additionally, this system can be used as a safety confirmation tool for international students by partnering with supporting companies.

(2) A safety confirmation tool for Japanese citizens abroad: This system can be introduced as a Japanese technology that can be used globally to estimate the damage from a disaster in different parts of the world. Using the system in the same manner as described above allows safety information of Japanese nationals and tourists in foreign countries in a disaster area anywhere in the world to be analyzed.

(3) A disaster information system for foreign residents or tourists in Japan: Similar to above, this system can be utilized to estimate the impact on foreign residents or tourists when a disaster occurs in Japan.

(4) A tool to monitor outbreaks of highly virulent illnesses: In principle, patients who have contracted highly virulent new strains of influenza like H5N1 or other highly communicable diseases are expected to self-quarantine at home. During influenza season or during an outbreak of another disease if necessary, the system maps patients with temperatures over 38 °C in red, around 37 in yellow, and 36 or below in green.

The rates are analyzed by municipalities every week to estimate the disease rates, allowing municipalities or public health centers to comprehend the fever situation via information from a network of registered residents. If the system is combined with information from the National Institute of Infectious Diseases, which analyzes the incidence of diseases and provides the information to municipalities, municipalities could be informed of subtle developments in patients' conditions by themselves, which should improve communications with residents and monitor the sequence of an infectious outbreak.

* Although patients with highly virulent new strains of influenza are basically expected to self-quarantine, information can still be collected via the app in the same manner as the basic system.

Currently this system is being piloted in Yogyakarta, Indonesia, but it should be introduced to the rest of the country soon. The system itself can be used anywhere in the world. We are hoping to implement it in Japan after the successful pilot in Indonesia and eventually to the rest of the world beginning with ASEAN (Association of the Southeast Asian Nations) countries. Japan is always on alert for potential massive earthquakes. Currently, one weakness in disaster response is its lack of wide-area disaster management. Hence, establishing a multilingual disaster information system for local citizens, foreign residents, and tourists in Japan is imperative. We are trying to develop such a system under an industry–academia partnership and are seeking partnership and support with companies, embassies, and consulates.

Conclusion

From my investigation of a disaster, I have developed the system which can acquire disaster information also to people of many languages and multiple cultures.

However, we have not given still sufficient disaster information for people to many foreigners involved in a disaster on the spot. In the future, we think that we should have to simplify disaster information more. Moreover, we might to think the thing like the mark which cannot express disaster information with a text but can appeal against it visually is required. For example, I think that it is one with required offering information like the triage at the time of a health professional's accident and a disaster classified by color. Then, foreign people can understand and notice that the disaster information on that situation is the "Warning level" or the "Advisory level".

I think that we should make the visual mark which we understand by people of a country in the world.

[i] About CARED:
http://www.respect.osaka-u.ac.jp/satellite-gadja hmada-en/program/cared/

A COMPARATIVE STUDY ON SEISMIC LOAD ANALYSIS BY BNBC-1993 AND BNBC-2017

Md. Mohiuddin Ahmed[1], Subrata Roy[2], Maqsuda Haque[3]

ABSTRACT

Significant changes have been introduced in BNBC 2017 with regard to analysis for seismic loads. To identify the changes in design and analysis of various structures a comparative study is necessary between existing code and the previous one. This study aims at the comparison of provisions of earthquake analysis only given in BNBC 1993 and BNBC 2017. It is found that seismic base shear of the building calculated by BNBC 2017 varies significantly from seismic base shear calculated by BNBC 1993. Finally, structural analysis and design of a typical eight-story hospital building situated in Sylhet (most severe zone) city are conducted to demonstrate the changes regarding seismic load in BNBC 2017 with respect to BNBC 1993. The basic differences in seismic base shear and maximum lateral displacement with the same number of stories using two codes are presented. The comparison in inter-story drift is also made using two codes. The analysis is made to compare the maximum reinforcement requirement for corner column and interior column design to provide a guideline to the engineer for the most economic design. Design of reinforced concrete buildings for seismic load in BNBC-2017 is relatively economic than BNBC-1993 the since the amount of reinforcement required is less in BNBC-2017.

Keywords: BNBC-1993, BNBC-2017, inter-story drift, maximum lateral displacement, seismic base shear, overturning moment.

Introduction

Earthquake is a disastrous event that needs to be addressed in a more coordinated way. Although Bangladesh is extremely vulnerable to seismic activity, the nature and the level of this activity is yet to be defined. In Bangladesh, complete earthquake monitoring facilities are not available. The dynamic effects earthquake loads are usually analyzed as an equivalent static load in most small and moderate-sized buildings. A comparative study has been made to see the basic difference between BNBC (Bangladesh National Building Code) 1993 and BNBC 2017 regarding earthquake load only. The developed countries in North America, Europe, India regularly update their codes. Bangladesh National Building Code (BNBC-2017) has significant changes comparing to BNBC-1993.
A detailed comparison between BNBC 1993 and BNBC 2017 is presented in tabular form for the seismic load analysis only. The effects of gravity load in combination with lateral loads are out of the scope of this study. For earthquake load analysis equivalent static method is implemented. The case study on a typical hospital building is performed for Sylhet city only. The results may vary for other cities of Bangladesh. However, a detailed comparison of lateral loads along with the impact on design analysis for low to medium rise buildings for Bangladesh is required. In this work, corresponding parameters of Earthquake loads found using the BNBC 1993 and BNBC 2017 codes are compared. A typical hospital building situated in Sylhet is selected for the case study to identify the changes in analysis and design with BNBC 2017 as compared to BNBC 1993. The analyses are conducted for base shear, maximum lateral displacement. For earthquake load base shear, maximum lateral displacement and inter-story drift are higher in BNBC 2017 than BNBC 1993.

Design of reinforced concrete buildings for lateral load in BNBC-2017 is relatively economic than BNBC-1993 as the amount of reinforcement requirement is less in BNBC-2017. The main objectives of this study are: Determination of the base shear, base moment, story shear and inter-story drift according to BNBC 1993 and BNBC 2017. Comparison of base shear, story shear, base moment and inter-story drifts by preparing an identical model to understand the comparison between the two codes. Analysis and design of a corner column

---

[1]Lecturer, Dept. of Civil Engineering, University of Information Technology & Sciences, Dhaka-1212, Bangladesh.
[2]Lecturer, Dept. of Civil Engineering, University of Information Technology & Sciences, Dhaka-1212, Bangladesh.
[3]Lecturer, Dept. of Civil Engineering, University of Information Technology & Sciences, Dhaka-1212, Bangladesh.
Email of Corresponding Author – mohiahmed22@gmail.com

and an interior column for both BNBC 1993 and BNBC 2017. Comparing the column axial forces, column dimensions and reinforcement requirement.

Methodology of the Present Study

A typical eight storied hospital building (22.5m X 22.5m) situated in Sylhet city is selected for the comparison of BNBC 2017 and BNBC 1993. The buildings are assumed to be fixed at the base and the floors act as rigid diaphragms with a 3-meters height for each story, regular in plan is modeled. Finally, the buildings have been modeled by using ETABS software nonlinear v 9.7

Analysis Results and Findings from BNBC 1993 and BNBC 2017

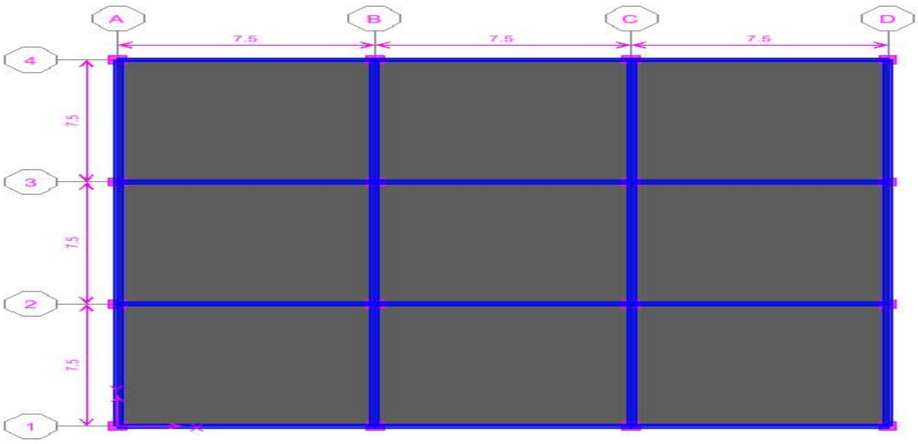


Figure 1. Plan of a typical story.

To ease to understand how much story shears are varying for two different codes the shear forces are represented together as diagrams below:

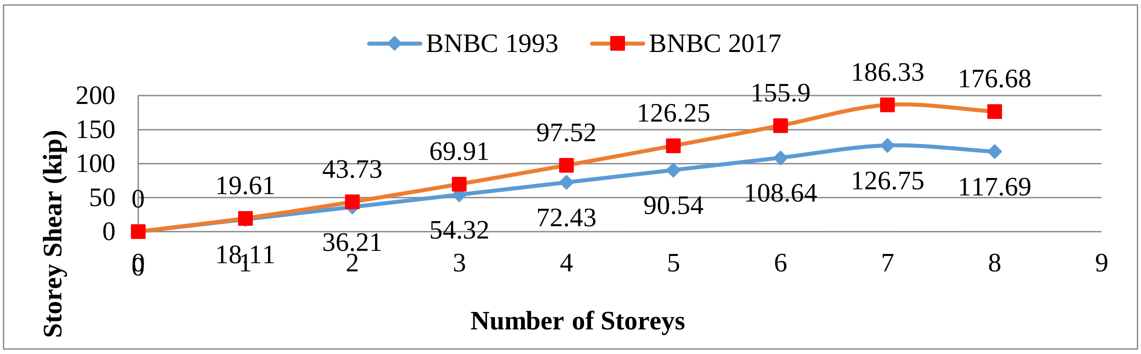


Figure 2. Storey shears comparison between BNBC 1993 and BNBC 2017.

To understand how much base shears are varying for two different codes the base shears are represented together as bar charts below:

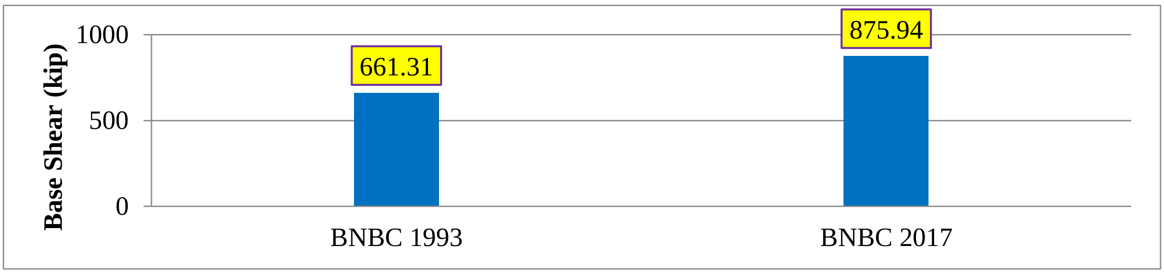


Figure 3. Base shears comparison between BNBC 1993 and BNBC 2017.

Story displacement and drift analysis

The drift analysis is done for every floor to see the gradual displacement of the floors. To make it easier to understand how much inter-story drifts and story displacements are varying for both codes some figures are given below:

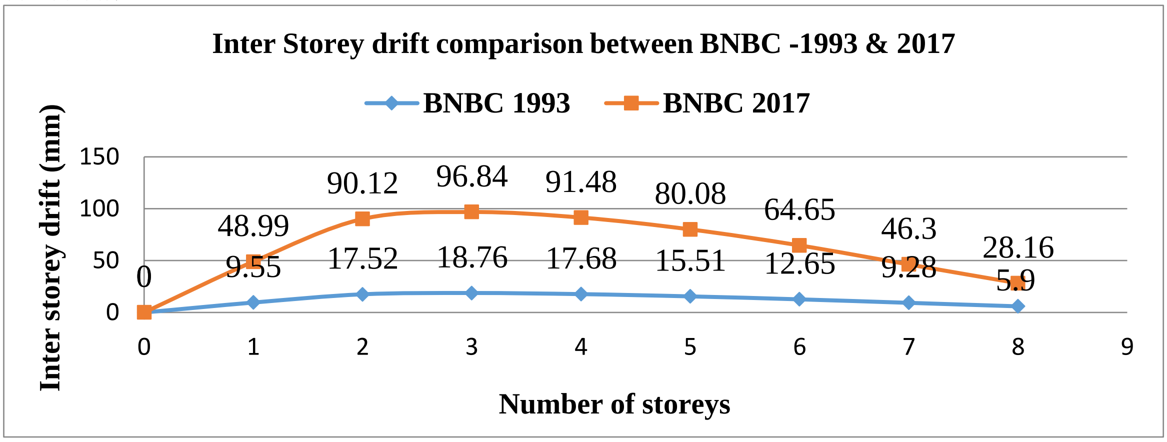


Figure 4. Comparison of inter-story drifts (mm) according to BNBC-1993 and BNBC-2017.

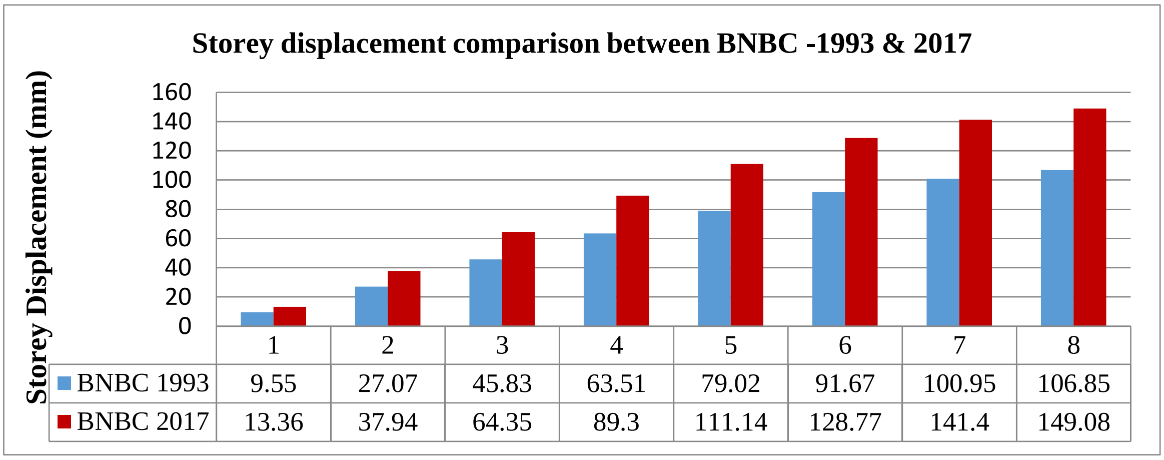


Figure. 5. Comparison of story displacement (mm) according to BNBC-1993 and BNBC-2017.

A corner and an interior column analysis and design

For analyzing and design purpose a corner column and an interior column have been selected for both BNBC-1993 and 2017 so that we can make a clear comparison of column dimensions and number of bar requirements as well as bar diameters. Here are the tables showing differences of findings of columns forces and steel area (in^2).

Table 1. Column forces in kip according to BNBC-1993 and BNBC-2017

BNBC - 1993		BNBC - 2017	
Corner column force (kip)	Interior column force (kip)	Corner column force (kip)	Interior column force (kip)
557.30	1641.70	382.97	1322.52

Table 2. Column dimensions (in x in) according to BNBC-1993 and BNBC-2017

BNBC - 1993		BNBC - 2017	
Corner column size (in x in)	Interior column size (in x in)	Corner column size (in x in)	Interior column size (in x in)
18x18	30x30	15x15	30x24

Steel area required (in^2)			
3.24	9.0	2.25	7.2

Table 3. Required bar diameter (mm) for columns according to BNBC-1993 and BNBC-2017

BNBC - 1993		BNBC - 2017	
Corner column	Interior column	Corner column	Interior column
8-20mmΦ	16-22mmΦ	6-20mmΦ	12-22mmΦ

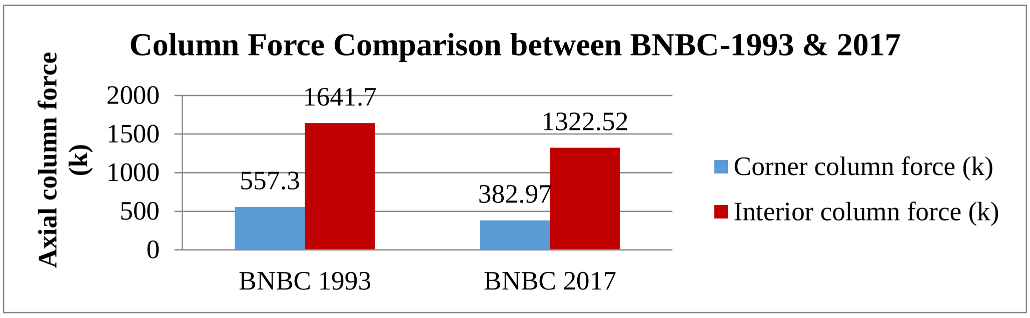


Figure 6. Comparison of column forces (kip) according to BNBC-1993 and BNBC-2017

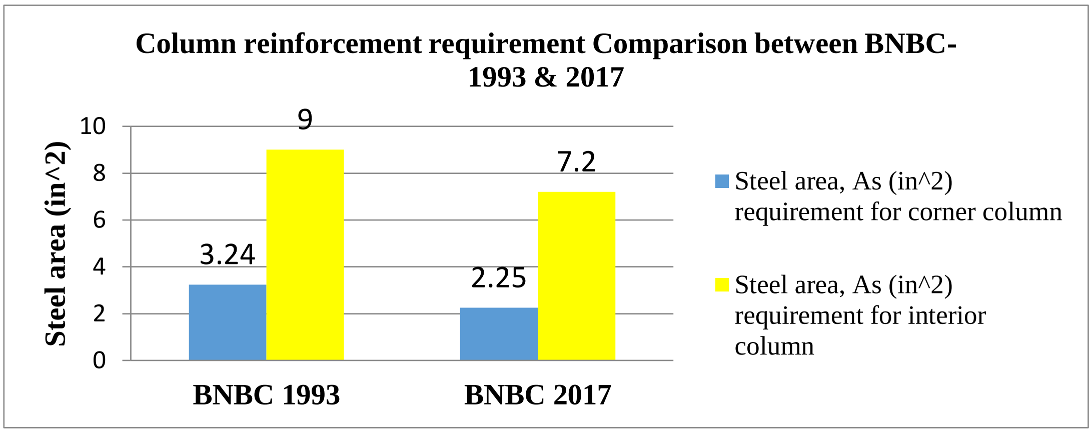
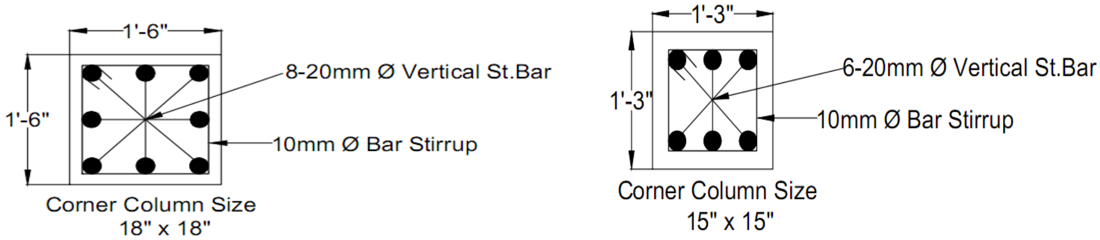


Figure 7. Comparison of steel area (in^2) requirement for a corner and an interior column according to BNBC-1993 and BNBC-2017



BNBC 1993 BNBC 2017

Figure 8. Comparison of column area (in^2) and bar diameter (mm) for corner columns according to BNBC-1993 and BNBC-201

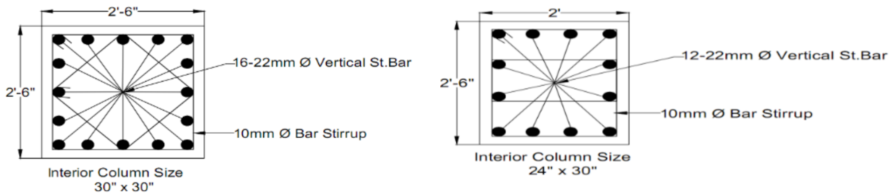


Figure 9. Comparison of column area (in^2) and bar diameter (mm) for interior columns according to BNBC-1993 (Left) and BNBC-2017 (Right)

Conclusion

Base shear is increased in BNBC-2017 than BNBC-1993 due to increase in zone coefficient (z), structural system factor(R) and self-weight (W). In BNBC-1993 design basis earthquake is not clearly defined. In BNBC-2017 design basis earthquake is two third of the maximum credible earthquake. In BNBC-1993 load factor, 1.4(0.75*1.7*1.1) is used with earthquake load which means the earthquake load is increased by 40% because of the uncertainty of load. However, this factor is quite unnecessary since the maximum credible earthquake is considered for design. BNBC-2017 gives a wide variety of choices to calculate seismic force with clear guidelines as compared to BNBC-1993. From Base shear versus no of story graph and story shear versus no of story graph it is seen that base shear and story shear are much higher for BNBC-2017 than BNBC-1993. Maximum lateral displacement is also found to be higher for BNBC-2017 than BNBC-1993. In both code maximum inter drift occurs almost at the mid-height of the building. Design of reinforced concrete buildings for seismic load in BNBC-2017 is relatively economic than BNBC-1993 as the amount of reinforcement required is less in BNBC-2017 which is applicable for Sylhet city only.

Recommendations

The following recommendations can be made for future research work

- The case study conducted in this research is for Sylhet city only. However, the seismic zone coefficient varies for different parts of Bangladesh. A similar study can be performed for other parts of Bangladesh, especially for seismic active zones.
- In BNBC-1993 load factor, 1.4(0.75*1.7*1.1) is used with earthquake load which means the earthquake load is increased by 40% because of the uncertainty of load. That's why the column forces are more in BNBC 1993 compared to BNBC 2017. However, this factor is quite unnecessary since the maximum credible earthquake is considered for design in BNBC-2017.
- In this study, only column axial forces were considered during analysis so it is recommended to consider column moments too for future research work.
- Comparison of seismic load in BNBC 2017 can be made with other codes such as Euro code, Indian code, IBC, UBC, ACI, Italian code etc.
- Similar study can be performed for other types of buildings such as steel frames, ordinary moment resisting frames and masonry structures etc, located in different places with different site conditions.
- To find the impact on design only the reinforcement requirement in columns were considered. This study can be extended on a large scale of analysis including foundations, beams, and slabs etc.

References

BNBC 2017, —*Bangladesh National Building Code (BNBC),* Bangladesh House Building Research Institute, Dhaka.

BNBC 1993, —*Bangladesh National Building Code (BNBC),* Bangladesh House Building Research Institute, Dhaka.

Manual for Seismic Design of Reinforced Concrete Building- PWD, Bangladesh.

Eqball, M. S., 2011, —"A comparison of Proposed BNBC-2012 with Other Building Codes Regarding Seismic Provisions", B. Sc. Engr. Thesis, Dept. of Civil Engr. BUET, Dhaka.

Hasan, M. R. and Hoque, M. T., 2007, —" Comparative Studies of Different Building Codes In Context of Bangladesh National Building Code.

PERFORMANCE EVALUATION OF RC BUILDINGS BY TIME HISTORY ANALYSIS

A. Ghosh[1], S. Ahammed[2], K. I. M. Iqbal[3] and T. R. Hossain[4]

ABSTRACT

Different dynamic analysis methods are performed in order to evaluate the performance of a structure which is subjected to earthquake load. Among all the dynamic analysis methods, Non-linear Time History seismic analysis method is more accurate. Because it generates a real earthquake load on a structure and analyzes the response of the structure. In this study, the structural behavior of RC building is observed subjected to an earthquake motion by Nonlinear Time History analysis method. Different parametric studies have been performed to investigate its responses during an earthquake. These studies include variation in story level and changes in the earthquake zones. Using BNBC-2015, a residential building is designed using ETABS v2015 and then analyzed it using the same software. ACI 318-08 is used in this analysis. A ground motion El Centro (1940) is applied at the base of the structure and the seismic capacities at structural and element levels are evaluated according to the guideline of ATC 40 (1996). Formation of plastic hinges is used as the basis of local performance evaluation and story drift is used as the basis for evaluating global performance. It is found that the designed building satisfies the acceptable performance criteria as per code ATC 40 (1996). It has been observed that both for varying story level and different earthquake zones, the structure meets the performance objective in serviceability earthquake and design basis earthquake and passed all the criteria.

Introduction

Structures are vulnerable to earthquake ground motion and damage the structures. In order to take precaution for the damage of structures due to the ground motion, it is important to know the characteristics of the ground motion. The most important dynamic characteristics of an earthquake are peak ground acceleration (PGA), frequency content, and duration. These characteristics play predominant rule in studying the behavior of structures under the earthquake ground motion.

The objective of the seismic design is to constrain the damage in a structure to a worthy sum. The structures designed in such a way that should have the capacity to resist minor levels of an earthquake without damage, withstand moderate levels of an earthquake without structural damage, yet the probability of some nonstructural damage, and withstand significant levels of ground motion without breakdown, yet with some structural and in addition nonstructural damage.

In present work, Six-story regular reinforced concrete (RC) buildings which are modeled as two-dimension and analyzed for three earthquake design cases varying the PGA, are subjected to the corresponding models and non-linear time-history analysis is performed using structural analysis and design software.

Methodology

These models are first designed as Intermediate moment resisting frames (IMRF) and then as special moment resisting frame (SMRF) and they are performed by nonlinear time history analysis using the El Centro earthquake data using ETABS. Each model is subjected to the data with three different PGA which corresponds to the three earthquake design considerations. The responses of the structures are then compared with the ATC- 40 document.

A strong-motion seismograph at El Centro recorded the earthquake and provided the first example of such a recording made very close to a fault rupture in a major earthquake. This gave a detailed record of different types of shaking associated with the earthquake. It is often used in the design of earthquake-proof structures today, particularly for the time history analysis method.

[1,2,3] Lecturer, Dept. of Civil Engineering, Daffodil International University, Dhaka-1207, Bangladesh.
[4]Professor, Dept. of Civil Engineering, Bangladesh University of Engineering & Technology, Dhaka-1207, Bangladesh.
Email of Corresponding Author – iqbal.buet11@gmail.com

Modeling of the Structure and Basic Design Data

The basic dimensions of the panels are kept as 20 feet in the x-direction, 20 feet in the y-direction and 10 feet of floor height. The material properties are kept non-linear, as the analysis of the structures would be performed by non-linear Time history analysis later on. The load cases are defined properly according to the code specified. The structures are designed as IMRF. The plan view of the structure is shown in the Figure. 1

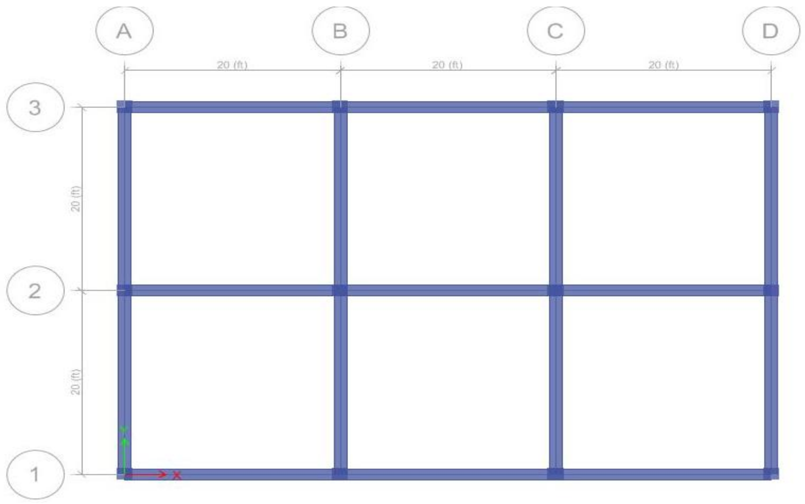


Figure 1. Plan View of 6 storied RC Building

The panel size along the x-axis is 20 feet and the panel size along the y-axis is kept 20 feet. So the total model becomes a 60'X40' building.
The basic design data is shown in Table 1.

Table 1. Basic Design Data

Properties	Values
fc′	4 ksi
fy	60 ksi
Design area	Dhaka
Basic Wind Speed	130.48 mph
Super-imposed DL	3.4 k/ft
LL	0.8 k/ft
Soil Classification	SC
Beam section	18 in * 16 in
Column section	20 in * 18 in

Non- Linear Time History Analysis

Nonlinear Time-History analysis, also known as Nonlinear Dynamic analysis, is a powerful method to identify the response of the structure to ground motion acceleration.
Defining time history load case, using the defined time series function with load type U_x of acceleration with a scale factor of (32.2*0.2/0.3128) to convert the g units and to incorporate the zone co-efficient of Dhaka.
The number of output time steps and time step size shall be specified, the more output time will simply provide more details on output. We used 1600 steps per 0.02 second for duration of (1600*0.02) = 32.2 seconds.
For this analysis, three types of earthquake case are defined.

Serviceability Earthquake (SE) case

It is the ground motion with a 50% chance of being exceeded in a 50 year period.

Maximum Credible Earthquake (MCE) case

It is the ground motion with a 10% chance of being exceeded in a 50 year period.

Design Basis Earthquake (DBE) case

It is the maximum level of ground motion expected within the known geologic framework, ground motion with a 2% chance of being exceeded in a 50-year period.

Performance Evaluation of the Structure

The structure is evaluated on the basis of two performance criteria. Global performance and local performance. Global performance is evaluated with respect to lateral drift of the structure. The values obtained from the software is compared with the deformation limit of provided in ATC40. Each element is checked to determine whether its individual components satisfy acceptability requirements under performance point forces and deformation.
Displacement time history at the topmost edge joint is plotted.

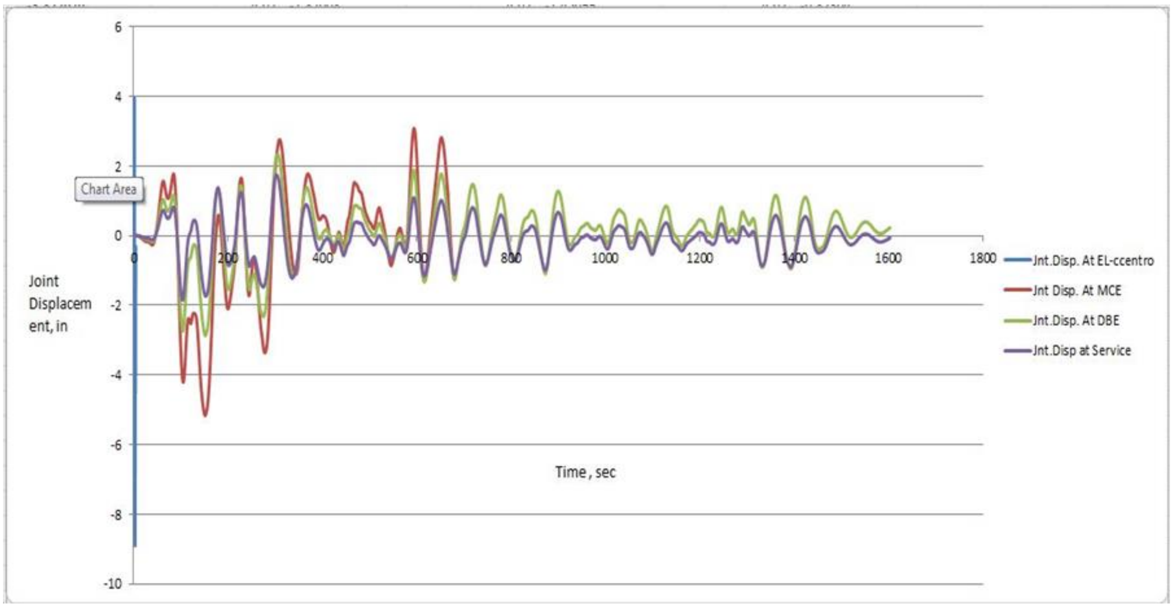


Figure 2. Displacement of joints at different earthquake levels.

From Figure. 2 it can be seen that at MCE level the displacement crosses 2 inches and according to ATC 40 it goes to the full inelastic non-linear stage. At DBE level the displacement just crosses the limit (2 inches) and about to go non-linear stage. The service level earthquake is in the elastic stage and able to withstand the ground motion.
From Figure. 3 it can be seen that the lateral drift of the structure satisfies during serviceability earthquake. The curve shows that during serviceability earthquake it does not cross the 0.01 line which is Immediate Occupancy criteria set by ATC 40 (1996). During design base earthquake the story drift gradually goes beyond the 0.01 line but it does not cross the 0.02 line which is maximum acceptable drift for Life Safety level. At maximum Credible Earthquake, almost all the points go beyond Immediate Occupancy. None of them crosses the Life Safety level. It is clearly understood from the outcome that the designed building can withstand the earthquake. Freeman (1978) states that "As the response of the buildings depends on the severity of the ground motion, the performance level including lateral drift will be checked for different ground motion." As a result, lateral drift was calculated for 3 levels of the earthquake as well as ground

motions.

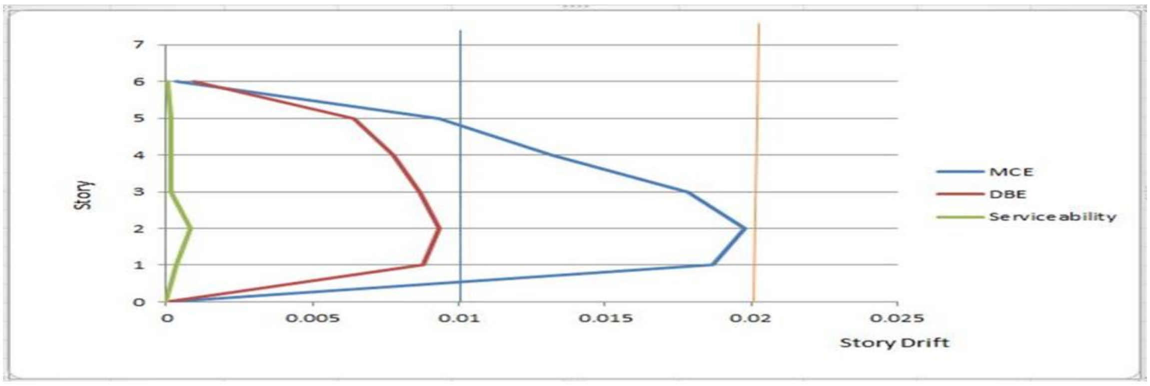


Figure 3. Storey Drift at different Earthquake Level

From the performance analysis, it is found that no hinges are formed during the serviceable earthquake. From Figure. 5 it can be seen that the structure forms plastic hinges in DBE which crosses the IO (Immediate Occupancy) level but restrain from forming LS (Life Safety) level hinges. During MCE numerous life safety hinges are formed which can be seen from Figure. 4. No hinges are formed which goes beyond collapse prevention range. So it concludes that the structure can withstand a moderate earthquake.

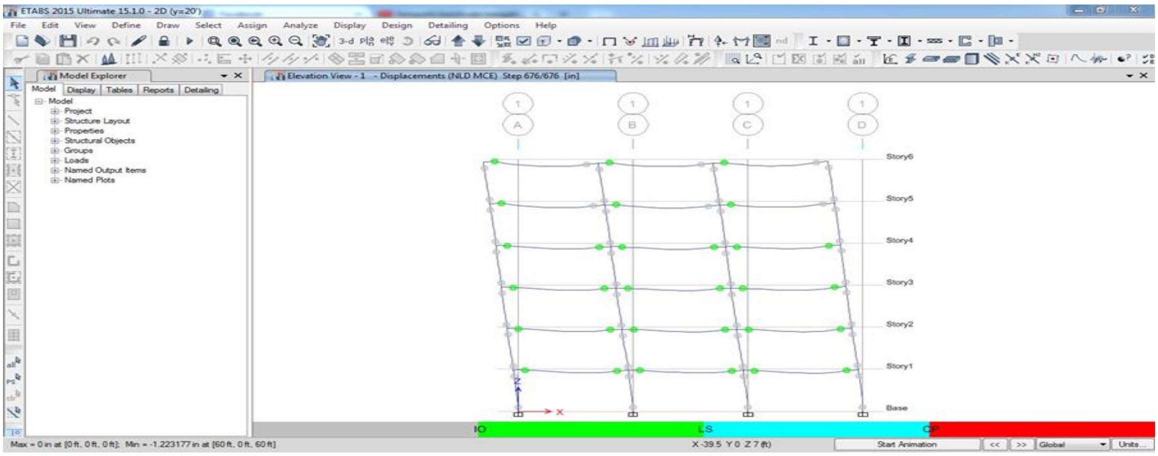


Figure 4. Hinge formation at MCE level

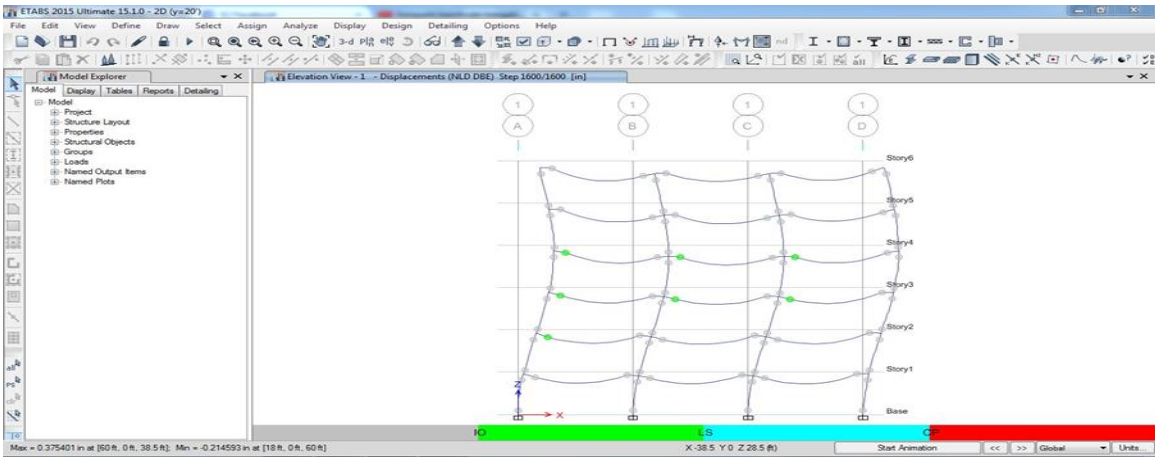


Figure 5. Hinge formation at DBE level

Conclusions

In this study, a regular structure designed following BNBC (2015) was analyzed using non- linear time history analysis. The structure meets the performance objective in serviceability earthquake and design basis earthquake. But the structure does not retain its stability during a maximum earthquake. This finding can be used for understanding the BNBC (2015) guideline better.

There are some limitations to this study. The study was performed on a 2-dimensional frame, not an actual 3-dimensional building. The structure considered only contains frame elements e.g.-beams and columns. No shear wall was considered in this study. The study can be performed in a 3-D frame with the shear wall. It will be an improvement of this study.

References

ACI Publication 318-08 (2008). "*Building Code Requirement for Structural Concrete"*, American Concrete Institute, Detroit, USA.

ATC (1996). "*Seismic Evaluation and Retrofit of Concrete Building*", *Report (ATC-40)*, Applied Technology Council, California, Vol. 1, USA.

BNBC (2015). "*Bangladesh National Building Code"*, Housing and Building Research Institute, Mirpur, Dhaka, Bangladesh.

Computer and Structures Inc. "*ETABS Nonlinear Version 15.0"*, California, USA.

Freeman, S. A. (1978). "*Prediction of response of concrete buildings to severe earthquake motion*". Publication SP-55, 589-605. Detroit, Mich.: American Concrete Inst.

COMPARISON OF PROPERTIES OF VARIOUS TYPES OF MORTARS EXPOSED TO FIRE

M. T. Islam[1], M. A. Rahman[2] and I. Ahmed[3]

ABSTRACT

Fire is the rapid exothermic oxidation process causing combustion of materials and forming various reaction products. Cement mortar is the largest amount of material that envelops the major parts of any structures and when a fire breaks out, it acts as a thermal barrier. Usually, mortars have good fire resisting properties. But some changes in physical and chemical properties of mortar might occur when exposed to fire. This paper focuses on investigating the effects of fire on various types of mortars made with locally available slag fine aggregate, river sand, brick fine aggregate and coarse sand. After burning, the effects of air cooling and water cooling are also compared. The study covers four types of mortars each with three different water-cement ratios. The mortar samples were burned in open fire for two hours. An equal number of samples were cooled in air and water after burning. Compressive Strengths according to ASTM C109 and Flexural Strengths according to ASTM C348 were evaluated for comparing the loss of strength due to fire exposure. Moreover, the changes in their properties due to the variation of the cooling process were also investigated.

Introduction

One of the most important factors that influence the durability of any structure is its resistance to fire on higher temperature (Shoaib, 2001). When a fire breaks out, the first construction material that comes in contact with fire is cement mortar. By choosing cement mortar made of appropriate material, it is possible to minimize the adverse effects of fire (Aydin, 2008). Both in concrete and cement mortar the aggregate expands on heating while the cement paste shrinks beyond the point of maximum expansion and these two opposing actions weaken the material causing cracks in concrete or cement mortar (Lea, 1998). The behavior of concrete or mortar on heating depends mainly on the types of aggregate used in it (Poon, 2001). Siliceous aggregate containing quartz such as quartz sand expands steadily up-to 573^0 C. At this temperature, α-quartz transforms into β-quartz and undergoes sudden expansion and causes disruptive action in concrete (Taylo, 1990). On the other hand, sandstone shrinks on heating and counteracts with the expansion of the other grains resulting in higher loss of strength (Ghosh, 1983). No crystalline basic material like limestone, basic igneous rocks, and lightweight aggregates like crushed bricks and induction furnace slag expands steadily and have low thermal conductivity. Therefore, performs as a good fire-resistant aggregate (Mehta, 1997). Hydrated Portland cement contains a higher amount of $Ca(OH)_2$ which loses its water above $400\text{-}500^0$ C leaving CaO. If this CaO (quick lime) becomes wetted, again it hydrates back to $Ca(OH)_2$ accompanied by an expansion in volume (Ramachandran, 1969).

Methodology

Comparison of compressive and flexural strength of four different types of mortar with each of them having three different water-cement ratios under normal condition (unburnt condition) and under fire exposure condition was made. Four different types of mortars were made using locally available induction furnace slag fine aggregate (Slag fine aggregate), river sand, fine aggregate from burnt clay brick and coarse sand. Water-cement ratios of 0.4, 0.5 and 0.6 were used for all of them. Compressive strength tests were conducted on 50 mm cube specimens following ASTM C109 and flexural strength tests were conducted on 4 cm x 4 cm x 16 cm prism specimens following ASTM C348 after 28 days of curing. The mortar samples were burned in open fire for two hours. 72 number of samples were cooled with water after burning and 72 number of samples were kept in normal atmospheric condition for cooling after burning. The test was conducted under control temperature. The temperature was continuously measured with the help of Infrared Thermometer and the temperature was controlled through a continuous supply of wood and kerosene as fuel. The process of burning

[1]Postgraduate Student, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, Bangladesh
[2]Graduate Research Assistant, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, Bangladesh
[3] Professor, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, Bangladesh
Email of Corresponding Author – tariqulaunto.1993@gmail.com

the mortar samples is illustrated in Figure 1.

Figure 1. Burning of cement mortar samples under controlled temperature.

The temperature development with time is shown in Figure 2.

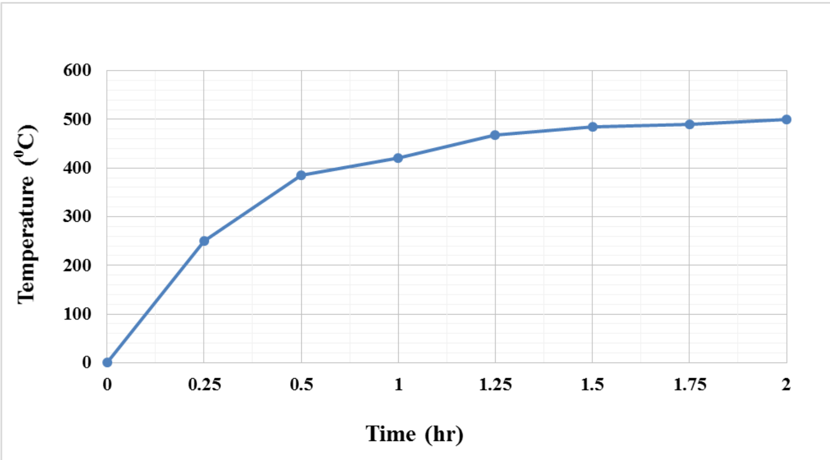


Figure 2. Temperature development with time

Compressive Strength Test on Mortar

Compressive strength test was determined using standard procedure ASTM C109 and was represented to nearest 0.1 MPa.

Flexural Strength Test on Mortar

The test was conducted according to ASTM C348. The test procedure is demonstrated in Figure 3.

(a) (b)

Figure 3. The test procedure for determining the flexural strength of cement mortars. (a) Test setup, (b) Samples after testing

Flexural strength was determined following ASTM C348 and by using Eq. 2 and was represented to nearest 0.1 MPa.

$S_f = 0.0028P$ (1)

Where, S_f = Flexural strength (in MPa)

P = Total maximum calibrated load (in N)

Properties of Fine Aggregates Used in Various Mortars

Various engineering properties of four different kinds of fine aggregates used in four different types of cement mortars are presented in Table 1.

Table 1. Summary of the engineering properties.

Test parameters	Standard Test Method	Obtained Values			
		Slag Fine	Brick Fine	Course Sand	River Sand
Unit Weight (Bulk Density)	ASTM C29	1630 Kg/m^3	1310 Kg/m^3	1540 Kg/m^3	1450 Kg/m^3
Voids in Aggregates (Compacted by Rodding)	ASTM C29	40%	34%	40%	38%
Bulk Specific Gravity (OD)	ASTM C128	2.74	1.95	2.59	2.50
Water Absorption Capacity	ASTM C128	3.90%	16.50%	1.00%	0.60%
Gradation of Aggregates (FM)	ASTM C136	3.64	3.44	3.07	1.20

All the fine aggregates were passing on number 4 standard sieve size (4.75 mm) and retained on number 200 standard sieve size (0.075 mm).

Results and Discussions

The summary of test results is presented in Table 2.

Table 2. Summary of the test results

Aggregate Type	W/C	Compressive Strength (MPa)			Flexural Strength (MPa)		
		Normal Sample (unburnt)	After burning		Normal Sample (unburnt)	After burning	
			Water Cooled Sample	Air Cooled Sample		Water Cooled Sample	Air Cooled Sample
Coarse Sand	0.4	42.6	33.1	11.2	6.6	4.9	0.5
	0.5	40.8	27.7	6.6	6.0	3.2	0.2
	0.6	36.9	18.6	5.4	5.3	2.4	0.1
River Sand	0.4	24.6	22.1	10.2	5.5	4.7	1.6
	0.5	22.8	18.6	7.6	5.4	4.0	1.0
	0.6	21.9	11.6	5.8	5.1	3.1	0.2
Brick Fine	0.4	35.8	32.8	20.4	6.5	3.9	1.8
	0.5	25.3	24.5	10.7	5.4	3.4	0.8
	0.6	23.8	15.6	7.3	5.3	2.8	0.5
Slag Fine	0.4	44.5	31.4	24.0	8.6	4.3	1.4
	0.5	36.4	24.7	18.1	8.0	3.8	0.6
	0.6	34.6	18.9	13.5	5.4	3.2	0.2

The results show that significant strength (50%-80% compressive and 70%-95% flexural strength) was lost for all four types of mortar when they were exposed to fire up to a temperature of 510^0C for 2 hours. However, the strength (30%-40% compressive and 50%-60% flexural strength) was regained to a large extent when the mortars were cooled using water. This is illustrated in Figure 4 and Figure 5.

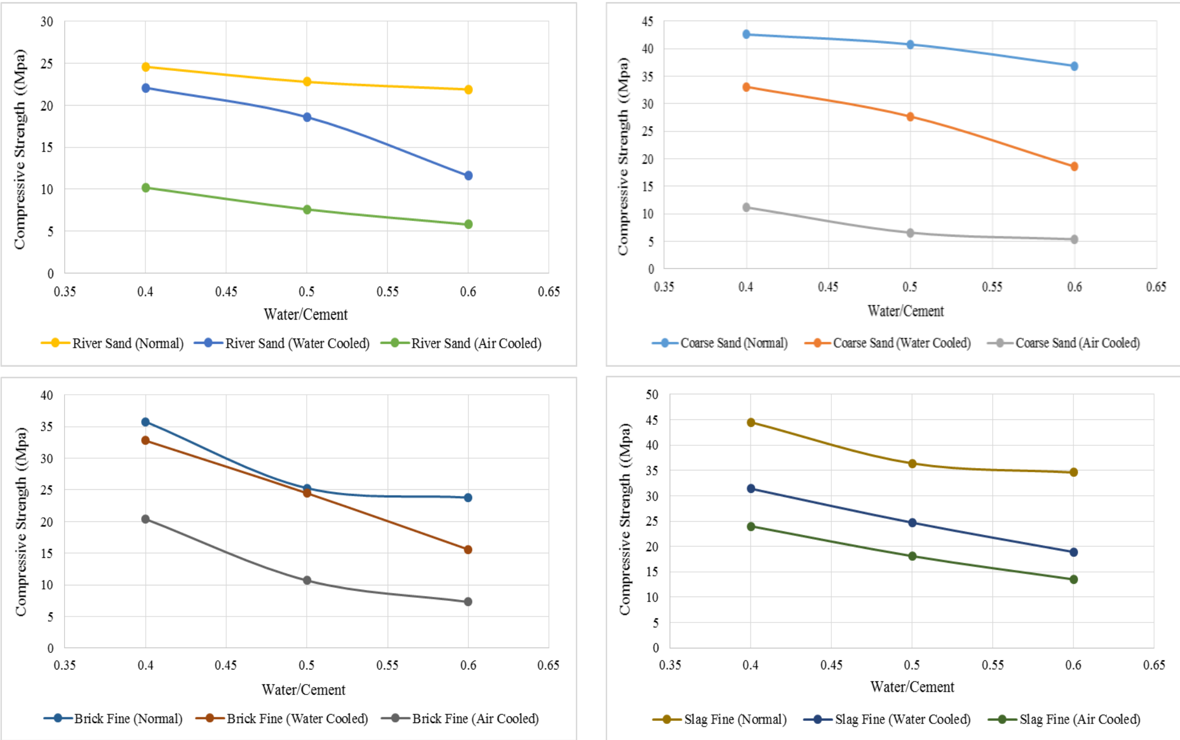


Figure 4. Variation of compressive strength with water-cement ratio for different types of mortars under different conditions.

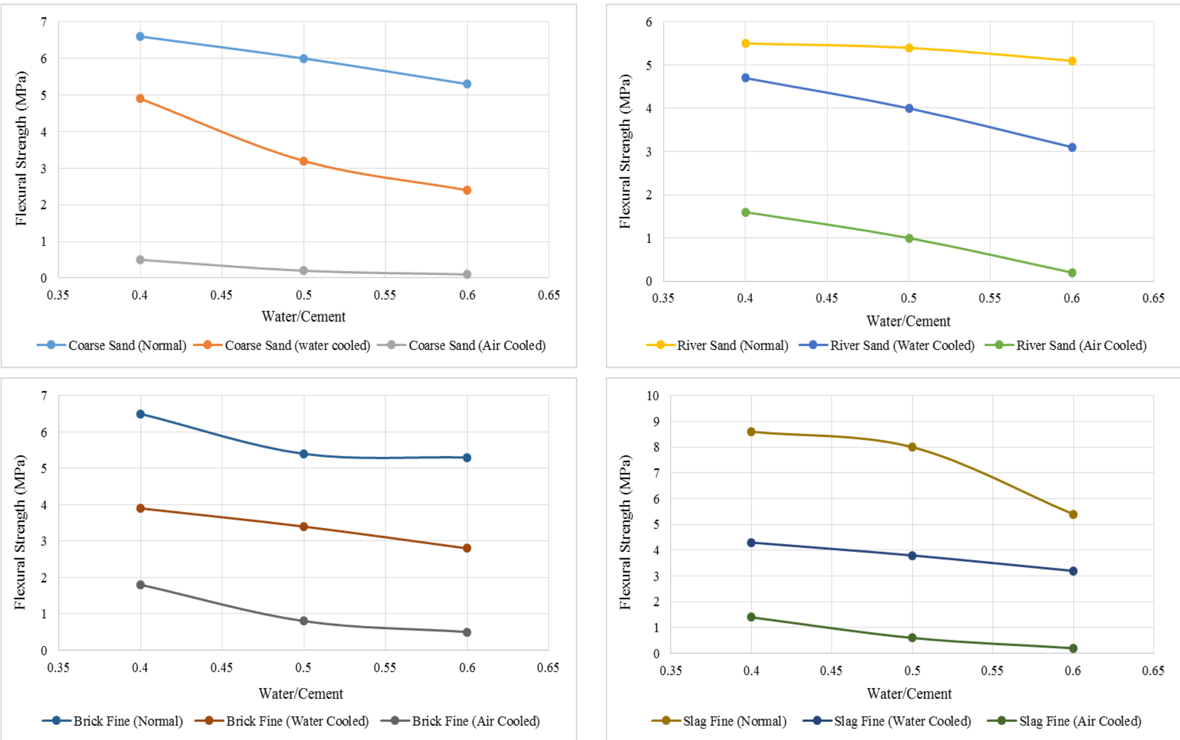


Figure 5. Variation of flexural strength with the water-cement ratio for different types of mortars under different conditions.

From the above figures, it can be seen that mortars made of coarse sand and river sand showed a remarkable reduction of strength (70%-80% compressive and 85%-95% flexural strength) when exposed to fire than mortars made of slag fine and brick fine aggregate (50%-55% compressive and 70%-80% flexural strength). Besides, the regaining of strengths (35%-40% compressive and 55%-60% flexural strength) in contact with water was also remarkable for mortars made of coarse sand and river sand. Whereas, the difference of strength under various conditions was less remarkable for mortars made of slag fine and brick fine aggregate. The performance of different types of cement mortars as a thermal barrier during a fire incident largely depends on its thermal conductivity. Mortars made of slag fine and brick fine had a lower thermal conductivity (0.38 to 0.48 W m^{-1} K^{-1}) compare to mortars made of river sand and coarse sand (0.60 to 0.65 W m^{-1} K^{-1}) and that's why mortar made of slag fine and brick fine showed better performance.

Conclusions

This paper investigated the behavior of four different kinds of mortar exposed to fire up-to 510^0 C for 2 hours and the effects of two different kinds of cooling process on their structural properties. The study also found that all the four types of mortars lost a significant level of strength (50%-80% compressive and 80%-95% flexural strength) when the samples were kept in normal atmospheric condition for cooling after burning. On the other hand, if the samples were cooled with water after burning it lost less strength. But it was still lower (20%-30%) than its normal strength. However, mortars made of slag fine aggregate and brick fine aggregate showed better performance than two other types of mortars (river sand and coarse sand) in case of exposure to fire. On the contrary, mortar made of river sand and coarse sand showed the worst performance in case of exposure to fire. Cement mortars are normally used as plaster and its contribution as a thermal barrier is usually neglected. As mortars made of slag fine and brick fine showed better performance after 2 hours burning in open fire with less reduction of strength, it can be concluded that using mortars made of slag fine and brick fine aggregate can ensure additional 2 hours fire rating to the RC structure. Under fire condition, cement mortar acts as a thermal barrier. Cement mortars don't add any strength to structural members but in order to act as an efficient thermal barrier, its own strength is necessary and that's why if a fire breaks out, it must be cooled with water for better strength gain of mortar. Choosing the right type of cement mortar can ensure improving the fire ratings of the structural members and better safety against fire.

Acknowledgment

The authors pay their profound thanks to the concrete laboratory, structural mechanics laboratory, department of civil engineering, BUET for their kind assistance in this research work.

References

ASTM Standard C29 (2017) "Standard test method for bulk density ("unit weight") and voids in aggregate", *ASTM International,* West Conshohocken, PA, USA.

ASTM Standard C128 (2015) "Standard test method for relative density (specific gravity) and absorption of fine aggregate", ASTM International, West Conshohocken, PA, USA.

ASTM Standard C109 (2016) "Standard test method for compressive strength of hydraulic cement mortars", ASTM International, West Conshohocken, PA, USA.

ASTM Standard C136 (2014) "Standard test method for sieve analysis of fine and coarse aggregates", ASTM International, West Conshohocken, PA, USA.

ASTM Standard C348 (2014) "Standard test method for flexural strength of hydraulic cement mortars", *ASTM International,* West Conshohocken, PA, USA.

Aydin, S. (2008) "Development of a high temperature-resistant mortar by using slag and pumice", *Fire Safety Journal,* 43, 610-617.

Ghosh, S. N. (1983) "Advance in cement technology; critical reviews and case studies on manufacturing, quality central, optimization and use", Pergamon Press, London, United Kingdom.

Lea, F. M. (1998) "*The chemistry of cement and concrete"*, Arnold Publishing Group, London, United Kingdom.

Mehta, P. K. and Monterio, P. J. M. (1997) "Concrete-microstructure, properties and materials", *Indian Concrete Institute,* Chennai, India.

Poon, C. S., Azhar, S., Anson, M. and Wong, Y. L. (2001) "Compression of the strength and durability performance of normal and high strength pozzolanic concretes at elevated temperatures", *Cement Concrete Research,* 31(q), 1291-1300.

Ramachandran, V. C. (1969) "*Application of differential thermal analysis in cement chemistry",* Chemical publishing, New York, USA.

Shoaib, M. M., Ahmed, S. A. and Balah, M. M. (2001) "Effect of fire and cooling mode on the properties of slag mortars", *Cement and Concrete Research*, 31, 1533-1538.

Taylo, H. F. W. (1990) "*Cement Chemistry",* Academic Press, New York, USA.

TENTATIVE DESIGN LIFE OF REINFORCED CONCRETE STRUCTURES: BANGLADESH PERSPECTIVE

T. Torsha[1], F. A. Khan[2], M. J. Hasan[3], R. Mutsuddy[4] and T. Manzur[5]

ABSTRACT

Prediction of design life of any structure, particularly under adverse conditions, is of immense importance for ensuring required durability standard. Reinforced concrete (RC) structures near coastal regions are always susceptible to chloride-induced corrosion and often, if not properly proportioned, suffer from reduced design life. Similar degradation of RC structure is also common in the southern belt of Bangladesh. However, there is no definite guideline available in local codes to address the service life issues of RC structures subjected to the harsh environment. In this article, an attempt has been made to discuss the procedure of evaluating tentative design service life of RC structure of the country following relevant international standards. However, the available international standards are based on site-specific construction practice and quality of concrete constituents. It is, therefore, extremely important to understand the cautious utilization of various parameters of such codes. The quality of the concrete mix is found to the most influencing factor affecting the service life for a particular location since environmental parameters are more or less identical if the temporal variation is not considered. Hence, the service life of RC structures has also been predicted based on the quality of some common concrete mixes of the country following the discussed procedure.

Keywords: RC Structure; Service Life; Prediction; Corrosion; Chloride.

Introduction

Forecasting design life of the concrete structure is of immense importance to ensure required durability. Corrosion is one of the prime concerns regarding the durability of reinforced concrete (RC) structures particularly in aggressive conditions like-coastal areas (Manzur et al., 2017; Angst, 2011). Under such environment, RC structures are always susceptive to chloride-induced corrosion. The high permeability of concrete structures and resulting high amount of chlorine ingress lead to corrosion of embedded reinforcement (Lai et al., 2013). The ingress of chloride reduces the corrosion initiation time and as a consequence, RC structures may face premature failure causing reduced design life than expected (Page, 1996). The RC structures in the southern belt of Bangladesh often experience similar distressed condition (Manzur at al., 2018; Baten et al., 2016). However, the demand for building durable structures is constantly increasing and the focus is shifting towards extending the service life of concrete infrastructure especially in marine regions. The extension of service life is also important considering the high cost of maintenance and repair of distressed structures (Clifton, 1993) and the indirect costs associated with traffic delays and lost productivity in case of highway bridges. Such delays on highways have been estimated to cost as high as 10 times the direct costs associated with corrosion-related structural damages from life cycle analysis (Yunovich et al. 2002). It is, therefore, obvious that service life extension with proper proportioning of materials should be given utmost priority as compared to any repair and rehabilitation technique. However, there is no particular approach available in local guidelines to address service life issues of RC structures due to chloride-induced corrosion. Hence, globally accepted international codes need to be followed to predict the service life of different types of RC structures of the country. In this study, an attempt has been made to determine the probable service life of some common concrete mixes of the country following the fib code (fib Bulletin 34, 2006). The procedure is discussed in rational details and various parameters affecting the service life are explained. It has been found that the chloride permeability of the concrete mix and aging factor of the concrete are the two most important factors significantly influencing the corrosion initiation of embedded rebar (fib Bulletin 76, 2015; Hasan, 2018). On the other hand, concrete cover has a major influence on crack initiation and propagation time (Wang et al., 2010). The study also provides a general understanding of the effect of different parameters of some common concrete mixes of the country on the service life of a structure. The PCC cement based concrete has been found to be exhibited significantly higher service life than that of OPC

[1,2]Undergraduate Research Assistant, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh
[3]Grraduate Research Assistant, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh
[4] Assistant Professor, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh
[5]Professor, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh
Email of Corresponding Author –tmanzur.buet@gmail.com

concrete in extreme conditions. In several cases, the OPC concrete failed to exhibit expected medium to long design life of RC structure. This study is important due to the paucity of such corrosion related serviceability data of concrete mixes of the country. The findings are expected to motivate practicing engineers to become cautious in selecting proper concrete mixes, particularly in extreme surroundings. However, only a limited number of concrete mixes are considered in this article. More researches are necessary in this field in order to have a holistic idea. It should be understood that necessary focus must be given on durability-based design for ensuring long term sustainability of RC structure that is subjected to harsh conditions like the marine environment.

Experimental Program

The following sections summarize the experimental program, carried out during this research task.

Mix Design Details

A total number of 10 concrete mixes were considered for this study, following a typical volumetric ratio of 1:1.5:3 and with moderate cement content (419 kg/m3). However, water-cement (w/c) ratio was kept variant within the range of 0.42~0.55 in order to observe their impact on concrete permeability and therefore, in the service life of a particular mix. Two types of locally available cement-Ordinary Portland Cement (OPC) and Portland Composite Cement (PCC) were used. As for coarse and fine aggregate, ¾ inch downgraded stone aggregate (unit weight of 1470 kg/m3) and Sylhet sand (unit weight of 1490 kg/m3) were used, respectively. Cylindrical specimens were cast for both compressive strength measurement (ASTM C39, 2014) and migration test (NT BUILD 492, 1999). All the concrete cylinders were of diameter 100mm and height 200mm and cured by submerging them in a pond of lime water solution.

Compressive Strength Measurement

Concrete cylinders of diameter 100 mm and height 200 mm were tested for compressive strength as prescribed in the standard ASTM C39 (2014). The samples were tested using a universal testing machine after 28 days of curing.

Rapid Migration Test

During this study, the concrete resistance to chloride ingress was determined in terms of diffusion or migration coefficients from a rapid migration test as specified in NT BUILD 492 (1999). The principle involves forcing chloride ions from an outside source into the specimen by applying external electrical potential. First, a 100mm x 200mm cylinder was cut into 50mm thick slices as stated in NT Build 492 (1999). Then, the specimen was surface dried and colored along the side to prevent any kind of permeation through sides.

(a)

(b)

Figure 1: a) Desiccator, b) Migration Test Setup

This specimen, upon drying of the applied color, was placed inside a desiccator (Figure 1.a) for vacuum treatment up to 18~20 hrs. During this vacuum process, two end surfaces of the specimen were kept exposed. After the 18~20 hrs elapsed, the specimen was placed inside the setup (shown in Figure 1.b) and tested for rapid chloride migration as per the procedure and for the duration described in NT Build 492 (1999). After completion of the test, the chloride penetration depth and ultimately, the diffusion coefficient was measured following the methodology and equations specified in the aforementioned code.

Service Life Evaluation

When a concrete structure is exposed to a marine environment like the southern belt of Bangladesh, it's service life primarily depends on the time required to initiate the corrosion of rebar and the time to occur severe damage due to the initiated corrosion process. For this study, service life for different types of concrete was predicted in terms of corrosion initiation time, crack initiation time and crack propagation time. The relevant equations and affecting parameters with their corresponding values are given below. In order to consider environmental impact, the exposure was considered to be similar to that of XS2 type as described in fib 76 (2015). The XS2 exposure includes marine structures near tidal or splash zone and subjected to cyclic wet and dry condition.

Corrosion Initiation Time

In case of chloride-induced corrosion, the time required for the accumulation of the chloride ions inside the concrete to the critical level is defined as the corrosion initiation time (Wang et al., 2010; fib Bulletin 34, 2006). Corrosion initiation time (t) was calculated based on the model developed by Duracrete (1998) and available in fib Bulletin 34(2006):

$$Ccrit = Co + (Cs, \Delta x - Co)\left[1 - \text{erf}\left(\frac{x - \Delta x}{2.\sqrt{Ke.Kt.(\frac{to}{t})^{a}.Drcm(to).t}}\right)\right] \quad (1)$$

Here,

Diffusion Coefficient at time t_o, D_{rcm} (m^2/s) from diffusion coefficient tests as per NT BUILD 492 (1999).
Time to initiate corrosion at a distance x from concrete surface, t (years)
Concrete cover, x (mm)
Environmental Variable, $K_e = exp[b_e\left(\frac{1}{T_{ref}} - \frac{1}{T_{real}}\right)]$ (2)
Depth of Convection Zone, Δx (mm) = 10 mm (for XS2)
Regression Variable, b_e (ºK) = 4800
Temperature of the Ambient, T_{real} = 303 ºK
Standard Test Temperature, T_{ref} = 303 ºK
Aging Exponent, α or a = 0.6 (PCC) and 0.3 (OPC)
Chloride Concentration, C_{crit}or $C_{Dc,t}$(% by weight of cement) = 0.6
Initial Chloride Concentration, C_o (% by weight of cement) = 0.1
Chloride Concentration at Δx, $C_{\Delta x,S}$(% by weight of cment) = 2
Reference (RMT test) Time, t_o = 45 days

Crack Initiation Time

Time to crack initiation is usually considered to be the time from corrosion initiation by depassivation of protective layer to the initiation of first crack (Wang et al., 2010). For this study, crack initiation time (t_{1st}) was calculated based on the model suggested by El Maaddawy and Soudki (2007).

$$t_{1st} = \left[\frac{7117.5\,(D+2\delta_0)(1+\nu+\Psi)}{365.i_{corr}.E_{ef}}\right]\left[\frac{2CF_t}{D} + \frac{2\delta_0.E_{ef}}{(D+2\delta_0)(1+\nu+\Psi)}\right] \quad (3)$$

$$\text{Constant } \Psi = [\frac{(D+2\delta_0)^2}{2C(C+D+2\delta_0)})] \quad (4)$$

Here,

Diameter of Reinforcing Bar, D (mm)
Concrete cover, C (mm)
Concrete tensile strength, F_t (MPa)

Effective Elastic Modulus, E_{ef}
Thickness of the Porous Zone around the Rebar, δ_0 = 0.015mm
Poisson's Ratio of Concrete, ν = 0.2
Corrosion Current Density @ Temperature 20^0C, $i_{corr-20}$ = 6.035μA/cm²

Crack Propagation Time

The time required for the crack propagation spans from the time since corrosion initiation to the time to reach a limit crack width (in this case 1 mm) (Wang et al., 2010; Mullard and Stewart, 2009). Here, the time from corrosion cracking initiation to the time required to reach a certain crack width for constant corrosion rate (icorr-20) is evaluated based on the model suggested by Mullard and Stewart (2009).

$$T_{sev} = Kr.\left[\frac{w-0.05}{Kc.ME.r(crack)}\right][(\frac{0.0114}{i_{corr,20}})] \quad (5)$$

Cover Cracking Parameter, $\Psi = [\frac{C}{D.F_t}]$ (6)

Cracking rate, r (crack) (mm/hr)= $0.0008.e^{-1.7\psi}$ (7)

$$Kr = .95[\exp\{\frac{(-0.3 i_{corr}.exp)}{(i_{corr-20})}\} - \{\frac{i_{corr,exp}}{(2500.i_{corr,20})}\} + 0.3] \quad (8)$$

Here
Crack Propagation time, T_{sev}(years)
Concrete cover, C (mm); Bar Diameter, D (mm)
Concrete tensile strength, F_t (MPa)
Crack width, w = 0.1 mm
Confinement Factor, k_c = 1.4
Model Error for rate of Crack Propagation, ME.r(crack) = 1.04
Accelerated Corrosion Rate, icorr-exp = 100 μA/cm²
Corrosion Current Density @ Temperature 20^0C, $i_{corr-20}$ = 6.035 μA/cm²

Results and Discussion

The primary objective of this study was to evaluate service life of some common concrete mixes based on their mix quality and resistance to chloride ion ingress. Hence, the diffusion coefficient values of these mixes were determined through rapid migration test and later, coefficient values were utilized in calculating the time required to initiate corrosion. This initiation time constitutes the majority of the total service life of a RC structure, exposed to a harsh marine environment. Thereafter, crack initiation and propagation up to a code specified failure limit follow. This study involves service life evaluation of stone aggregate concretes, prepared using OPC and PCC for varying w/c ratios. Due to later age hydration and better pore refinement capability, concrete mixes with PCC can be presumed to perform better in resisting any kind of adverse impact of chloride permeation, as compared to their OPC counterparts. Figure 2 shows the effect of OPC and PCC usage on the ultimate service life of stone aggregate RC element with 75mm cover (code specified for extreme conditions) and extreme exposure (XS2) for varying w/c ratios. Based on this graphical representation it can be presumed that the usage of PCC increases the ultimate service life of stone aggregate concrete (with a concrete cover of 75 mm and extreme exposure) about 40~41 times, on average, with respect to that of OPC. In all cases, PCC concrete exhibited significantly higher life expectancy (values greater than 200 years) whereas, all OPC concrete mixes failed to attain, even, a medium life expectancy of 50 years. These observations, eventually, confirm the aforementioned presumption regarding the better performance of PCC concrete. The factors that contribute to such discrepancies are considerably lower diffusion coefficient and higher aging exponent values of PCC concrete. PCC contains supplementary cementitious materials like fly ash which hydrate at a later age due to the presence of pozzolanic silica and eventually, refine the micropores and improve the packing capacity. As a result, concrete mixes with PCC were observed to be better at resisting chloride ion ingress and yielded lower diffusion coefficient values. As for aging exponent values (α) in case of extreme marine exposure, fib 34 (2006) specified the value to be 0.6 for composite cement containing fly ash whereas, in case of OPC, it is 0.3. The higher value signifies ongoing hydration even at later ages resulting in a concrete with a smaller number of interconnected pores and thus, with increased resistance to corrosion initiation when subjected to a harsh marine environment (fib 76, 2015). The study also revealed the considerable impact of concrete cover on the serviceability of a RC element. As demonstrated in Figure 3, increase in concrete cover values from 50mm to 75mm results in about 10.5~11 times better service life, in the case of PCC concrete. In the case of OPC mixes the improvement was observed to be about 2.5~3 times which is, considerably, less prominent than their PCC counterparts.

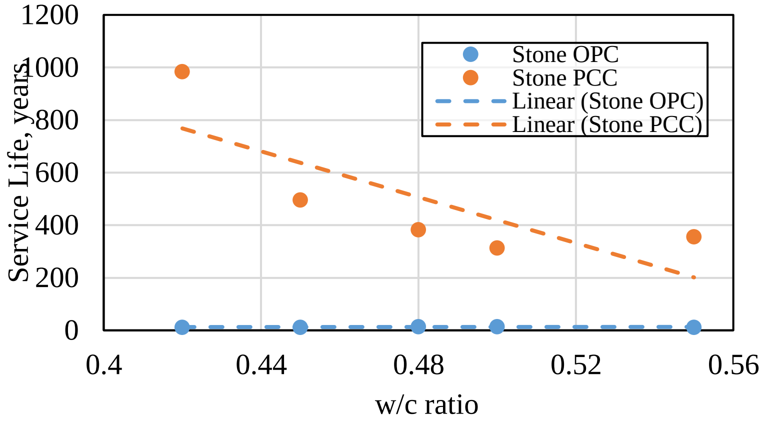
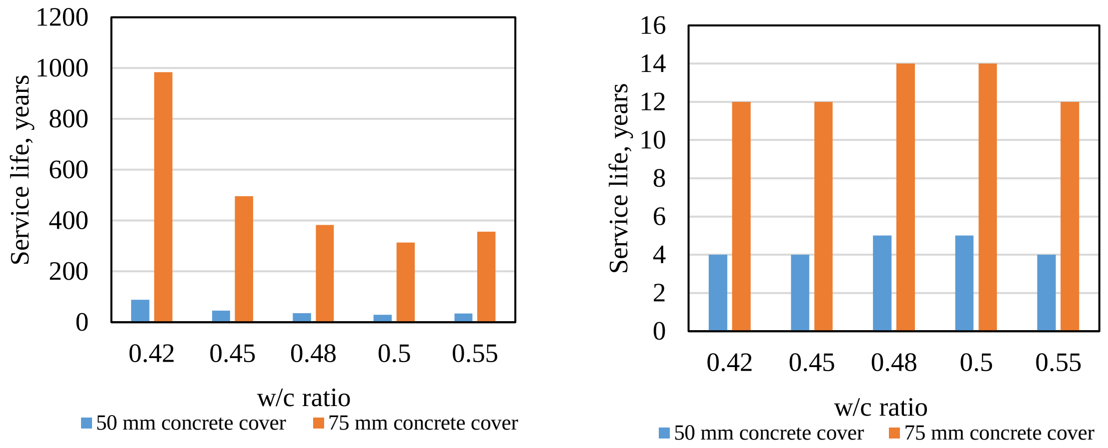


Figure 2: Service life of RC element with stone aggregate and 75 mm concrete cover for OPC and PCC



(a) (b)

Figure 3: Effect of varying concrete cover on the service life of RC element-a) with PCC and stone aggregate and b) with OPC and stone aggregate

Conclusions

The essence of this study is to introduce the concept of serviceability evaluation of a RC structure or element when subjected to a harsh marine environment. The evaluation was based upon a quality assessment of some locally used concrete mixes, in terms of corrosion resistance using code specified values. The study revealed the prominent impact of migration or diffusion coefficient and aging exponent values, both of which greatly depend upon the types of binding material, on the service life of RC element under extreme saline exposure. PCC mixes, owing to its lower diffusion coefficients and higher aging exponent values, demonstrated significantly better resistance to corrosion initiation and thus, higher service life. In addition to diffusion coefficient and aging exponent, the concrete cover also affects a structure’s service life significantly. However, in the case of mixes containing PCC, the impact can be perceived to be more noticeable than that of OPC. This paper provides a comparative analysis of some locally used mixes in terms of serviceability that might motivate a field engineer in choosing durable material and concrete mixes for extreme surroundings. Nevertheless, further research, involving a probabilistic approach with higher sample size, is essential to obtain a complete understanding of the serviceability concept.

References

Angst, U. (2011) "Chloride induced reinforcement corrosion in concrete: Concept of critical chloride content – methods and mechanisms", *Ph.D. thesis,* Department of Structural Engineering, Norwegian University of Science and Technology.

ASTM C39 – 14a, (2014) "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens", ASTM International, West Conshohocken, PA.

Baten, B., Hasan, M.J., Bose, B., and Manzur, T. (2016) "Corrosion Potential of Stone and Brick Aggregate Concrete in the Context of Bangladesh", BUET-ANWAR ISPAT 1st Bangladesh Civil Engineering Summit, BUET, Dhaka.

Clifton, J. (1993) "Predicting the service life of concrete", *ACI Materials Journal*, 90(6), 611–617.

DuraCrete (1998) "Modelling of Degradation, DuraCrete - Probabilistic Performance based Durability Design of Concrete Structures", EU - BriteEuRam III, Contract BRPR-CT95-0132, Project BE95-1347/R4-5, 174 p.

El Maaddawy, T., and Soudki, K.A. (2007) "A Model for Prediction of Time from Corrosion Initiation to Corrosion Cracking", *Cement & Concrete Composites,* 29(3): 168-175.

Fib Bulletin 34 (2006) "*Model Code for Service Life Design"*, Lausanne.

Fib Bulletin 76 (20015) "Benchmarking of deemed to satisfy provisions in standards: durability of reinforced concrete structures exposed to chlorides", Lausanne.

Hasan, M. J. (2018) "Service life prediction for different types of concrete using chloride diffusion coefficients", *M.Sc. Thesis*, Bangladesh University of Engineering and Technology, Dhaka.

Lai, W., Kind, T., Stoppel, M., and Wiggenhauser, H. (2013) "Measurement of Accelerated Steel Corrosion in Concrete Using Ground-Penetrating Radar and a Modified Half-Cell Potential Method", *Journal of Infrastructure Systems,* 19(2): 205-220.

Manzur, T., Baten, B., Hasan, M.J., and Bose, B. (2017) "Application of Corrosion Potential as a Tool to Assess Sustainability of Indigenous Concrete Mixes in Bangladesh", International Conference on Sustainable Infrastructure, ASCE.

Manzur, T., Baten, B., Hasan, M.J., Akter, H., Tahsin, A., and Hossain, K. M. A. (2018) "Corrosion Behaviour of Concrete Mixes With Masonry Chips", *Construction and Building Material,* 185: 20-19.

Mullard, J.A., and Stewart, M.G. (2009) "Corrosion-Induced Cover Cracking of RC Structures: New Experimental Data and Predictive Models", *Research Report No. 275.01.2009*, Centre for Infrastructure Performance and Reliability, The University of Newcastle, NSW, Australia.

NT BUILD 492 (1999) "Concrete, Mortar and Cement Based Repair Materials: Chloride Migration Coefficient from Non-Steady State Migration Experiments", Finland.

Page, CL. (1996). *"Corrosion of reinforcement in concrete construction."* The Royal Society of Chemistry, Cambridge, 55.

Wang, X., Nguyen, M., Stewart, M.G., Syme, M., and Leitch, A. (2010) "Analysis of Climate Change Impacts on the Deterioration of Concrete Infrastructure – Part 1: Mechanisms, Practices, Modelling and Simulations – A review", *CSIRO*, Canberra.

Yunovich, M., Thompson, N. G., Balvanyos, T., and Lave, L. (2002) "Highway Bridges, Appendix D, Corrosion Cost and Preventive Strategies in the United States," *FHWA-RD-01-156*, McLean, VA.

DURABILITY OF NYLON FIBER REINFORCEMENT CONCRETE

S. Samrose[1] and R. Mutsuddy[2]

ABSTRACT

Cement concrete reinforced with steel reinforcement is widely used construction materials. However, these types of reinforced concrete structures are experiencing deterioration when exposed to deleterious environment. These sorts of deterioration often reduce the service life of structure. Many studies were done in order to the ways to develop the durability of reinforced concrete structures. Use of supplementary cementitious material is one of the techniques for the improvement of durability. At present, most of cement manufacturing companies in Bangladesh are producing Portland Composite Cement (PCC) which contains different supplementary cementitious material (fly ash, slag etc.). On the other hand, several researches have shown improved durability in concrete when reinforced with small fiber (i.e. steel, polypropylene, jute etc.). Nylon is a readily available non-reactive material which may be used in cement concrete as fiber reinforcement. This study shows a comparison on the effect of OPC and PCC as well as the use of nylon fiber on the improved durable condition which ultimately transpired in the service life of structure. Having supplementary cementitious materials, PCC reinforced with nylon exhibits better performance. Moreover, electrical induction from Rapid Chloride Penetration Test (RCPT) and chloride migration coefficient from Rapid Migration Test (RMT) is determined to obtain the optimum nylon fiber content.

Keywords: Durability, Supplementary cementitious material, Nylon fiber, Service Life.

Introduction

Concrete is an indispensable element for any country's infrastructure. Among all the properties of concrete, compressive strength is considered most foremost to assess the quality. But for long term performance, this parameter must be changed into durability. Durability of concrete symbolizes its ability to persist for a substantial amount of time without any significant damage. To ensure a prolonged durable structure, Fiber Reinforced Concrete (FRC) is one of the best methods and using all over the world. Concrete specimens with silica fume and fly ash have a reduction in permeability when reinforced with polypropylene fibers (Zhang & Li, 2013). Also, experimented with steel FRC, with increase in curing age, permeability increases (Singh, A. P., &Singhal, D, 2011).

Though many different kinds of fiber reinforcement are using all over the world, in the perspective of Bangladesh, Nylon is a readily available non-reactive material provides high abrasion resistance and resistance to chemical attack. For its versatile properties, many studies have already done to investigate the properties when it is mixed with concrete. Improved mechanical properties of concrete are found with increase of nylon content (Martínez-Barrera, 2005). Also, small amount of longer length of nylon fiber can be used to have better performance of concrete (Spadea, Farina, Carrafiello, & Fraternali, 2015). As concrete cannot obtain tension and cracks occur in tensile area, nylon can be used as fiber reinforcement to provide a bridge within the cracks formed in that zone. In this study, for a particular water cement ratio containing different nylon fiber content, the variation of chloride ion permeability and total charge passed through specimen is measured. Also, this result is compared with chloride migration co-efficient. Form this study, optimum nylon fiber content is established for sound and resilient structure. The lower amount of chloride penetrability means concrete having higher property and more durable structure. Generally, PCC exhibits more durable property due to its composition with supplementary cementitious materials and tendency to form C-S-H gel. To enhance the structural integrity and build a sustainable structure, minimizing cracks and a long-term superior, durable condition must be ensured.

Methodology and Experimental Setup

Two types of cement, OPC and PCC, both were used for this study as a binder material. About 1.5" to 2" fiber content of 0%, 0.25% and 0.5% nylon were chosen to compare the effect of fiber reinforcement in concrete. A fixed water-cement ratio of 0.45 was used for all 100mm × 200mm cylindrical mortar specimens which

[1] *Undergraduate Student, Dept. of Civil Engineering, BUET Dhaka-1000, Bangladesh.*
[2] *Assistant Professor, Dept. of Civil Engineering, BUET Dhaka-1000, Bangladesh*
Email of Corresponding Author – samina.samrose@gmail.com

were prepared as per ASTM C192 (2002). In order to calculate the permeability by electric charge movement, RCPT test was conducted in accordance with ASTM C1202-12(2012). Test specimens were cured in limewater for 56 days. For this experiment, 50mm thick specimen was cut out parallel to the top from the cylinder and core sample was selected.

The cylindrical specimens were allowed to dry for an hour and then the sides of the surface were painted with epoxy coating. This coating is provided for resisting current passing from the round surface but must be passed through the two faces. Specimens were placed in vacuum desiccator after the paint was dry and no longer sticky. Pressure was decreased to 50mm Hg for 3hours. With the water pump still running, sufficient water was drained to cover the specimen for additional one hour. After that, specimens were soaked in water for 18 ± 2hr. blotting off the excess water, specimens were placed in the RCPT test cell. The top surface of the specimen was filled with 3% NaCl solution and the other side with 0.3N NaOH solution. Concrete specimens were subjected to a constant voltage of 60 ± 0.1V and current reading was recorded every 30minutes interval for 6hours.

Rapid migration test was performed as per NT BUILD 492 (1999-11) covers determination of chloride penetration resistance of concrete. Before starting, specimens were put in vacuum container for preconditioning. Maintaining 3hr vacuum desiccation, container must fill with saturated Ca $(OH)_2$ solution for 1hr. After desiccation, the specimens were placed in rubber sleeve and solution of 0.3N NaOH and 10% NaCl were placed above the specimen and in plastic reservoir respectively. A potential of 60V was set and was carried out for 18hr. Both current and temperature of before and after experiment was recorded. Removing from the sleeves, specimens were split into two pieces and 0.1M silver nitrate was sprayed adequately. After 15mins, white silver chloride precipitation was found and depth of penetration was measured.

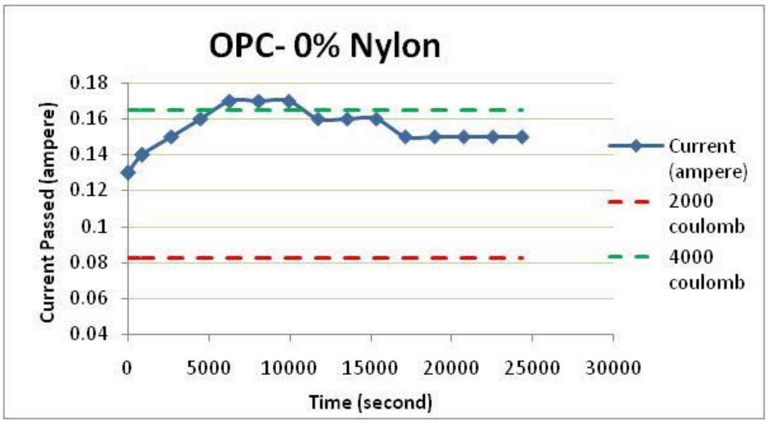
Results and Discussion

RCPT Test Result

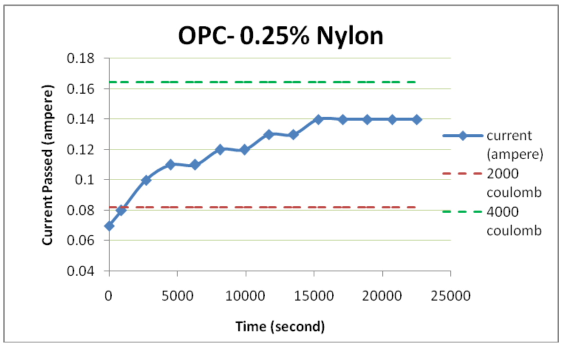
In RCPT test, total amount of current passed through the concrete is calculated and this current indicates the permeability of the concrete specimen. Qualitative indication of chloride ion penetrability is given in Table 1 as per ASTM C1202-12(2012). Categorized based on penetrability, more preferable cement with nylon fiber is indentified. For each type of specimen, current versus time graph is plotted and the area under the curve signifies the total amount of charge passed in coulombs in 6hr duration. Decreased amount of chloride ion penetrability indicates better durable condition.

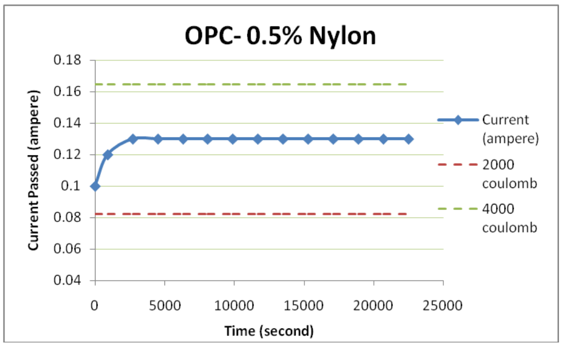
Table 1: Chloride Ion Penetrability Based on Charge Passed (per ASTM C 1202-12)

Charge Passed (coulombs)	Chloride Ion Penetrability
>4,000	High
2,000-4,000	Moderate
1,000-2,000	Low
100-1,000	Very Low
<100	Negligible



(a) For 0% Nylon Fiber Content

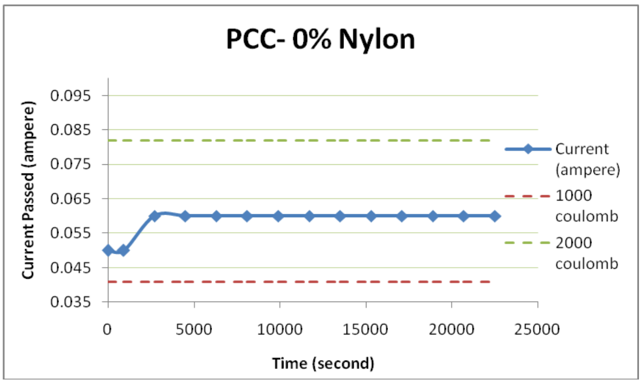




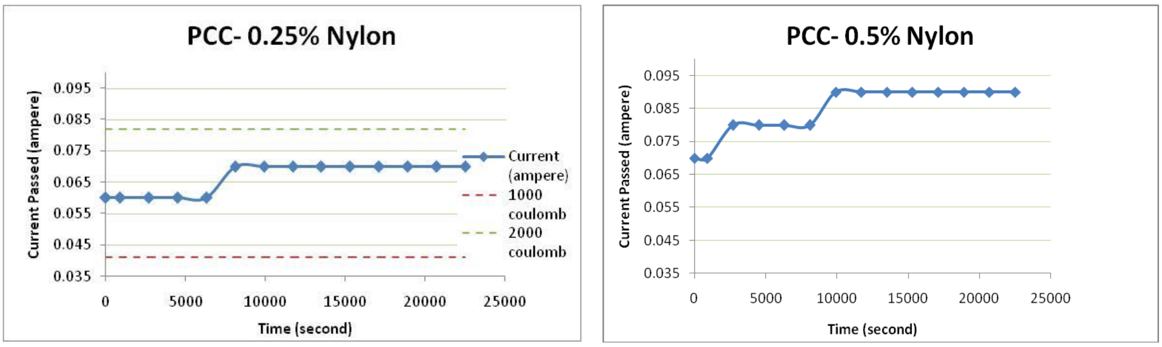
(b) For 0.25% Nylon Fiber Content *(c) For 0.50% Nylon Fiber Content*

Figure 1. Amount of charge passed through OPC reinforced with nylon fiber content.

For OPC cement type containing 0% nylon, anomalous behavior is derived from the current versus time graph. Although the curve exceeds 4000 coulombs for a certain time, maximum area lies between 2000 coulomb and 4000 coulombs. Total number of charges passed is 3532.5 coulomb which indicates moderate penetrability. In OPC containing both 0.25% and 0.5% nylon content, curves also lie between 2000 coulomb and 4000 coulomb demonstrating moderate permeability but for 0.25% nylon, the initial portion is below 2000 coulomb line. Total amount of current passed through 0.25% and 0.5% nylon are 2649.5 coulomb and 2898 coulomb respectively. This indicates increase of chloride penetrability of concrete combined with increased amount of nylon fiber content although lower amount of nylon fiber can cause lower chloride ion penetration.



(a) For 0% Nylon Fiber Content



(b) For 0.25% Nylon Fiber Content *(c) For 0.50% Nylon Fiber Content*

Figure 2. Quantity of charge passed through PCC reinforced with various nylon fiber content.

Figure 2 shows chloride ion penetrability in terms of current passed through specimens for PCC type of cement. For 0%, 0.25%, 0.5% nylon fiber content, total amount of current passed is 1332 coulomb, 1503 coulomb and 1917 coulomb respectively. It can be seen that for all condition of nylon fiber ratio, chloride ion penetration lies in 1000-2000 coulomb range which indicates moderate penetrability. Increasing amount of total current is derived which designates lower durability. But only PCC can reduce chloride ion penetrability 43.92% than mortar containing 0.5% nylon.

RMT Test Result

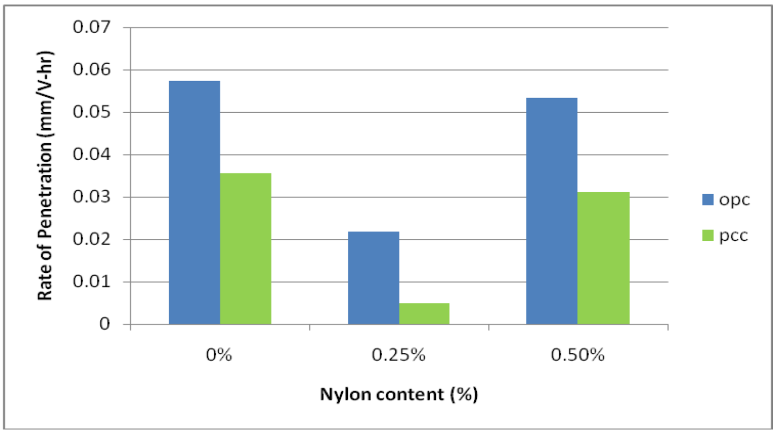


Figure 3. Permeability of nylon fiber reinforced concrete.

Depth of chloride penetration was measured with 10mm intervals for RMT test. Figure 3 shows the rate of penetration of fiber reinforced concrete having various nylon ratio and cement type. Chloride penetration decreases using nylon fiber reinforcement. Moreover, OPC has about 38% higher chloride penetration rate than PCC in every case. It is evident that chloride penetration is lower within a range of nylon content after which penetration value increases. This content is optimum content that is 0.25% nylon fiber content. Lest 0.00486 mm/V-hr chloride penetration rate is observed in PCC cement containing 0.25% nylon fiber reinforcement.

Analyzing both condition of OPC and PCC for various nylon fiber content, PCC using 0.25% nylon fiber reinforcement shows a better performance than all other combinaions. A previous study also shows better durable condition of PCC than OPC cement (R Rumman, 2015). This is beacuse fly ash reacts with calcium hydroxide to form more C-S-H gel with time and eventually refines the pores. Also, with increase in time, durability increases and the service life of a structure also increases. In contrast with using nylon fiber reinforcement, lower amount of nylon provides greater durable structure. Use of little amount of nylon fiber reinforcement illustrates better durable condition and more service life. Also, better strenuous condition has found using nylon as a fiber reinforcement.

This result can be found due to the factors affecting chloride ion penetration. Decrease in durability may occur due to water-cement ratio. Crossing the optimum water cement ratio may cause misleading results. Variation of durability with varied water-cement ratio is to be studied. Also type and properties of the quantity of supplementary cementitious materials, presence of polymeric admixtures can make different results while reinforcing with nylon fiber reinforcement. Moreover, more nylon fiber causes higher porosity in mortar which diminishes the strength.

Conclusion

This research studied the performance of six types of cement mortars mixed with various proportions of nylon fiber content. As can be seen from work presented above, PCC can be used for making durable and long-lasting structure. A durable condition arises with increment of nylon fiber content within the optimum limit. For 0.45% water-cement ratio, PCC reinforced with 0.25% nylon fiber content is the optimum limit and makes structure more durable. Moreover, using 0.25% nylon fiber, structure can withstand any hazardous situation as well as increases its service life. Also, OPC reveals less durability than PCC due to its chemical formation. The outcome of the study, therefore, necessitates the importance of further research to identify the properties of durability with change in water-cement ratio. Moreover, conclusions cannot be drawn based on durability results only.

Acknowledgments

The authors would like to acknowledge the assistance of lab instructor from Concrete Laboratory from Department of Civil Engineering, BUET for their help and support.

References

ASTM C 192/ C 192M-02(2002). Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory, West Conshohocken, PA

ASTM C 1202-12 (2012). Standard Test Method for Electrical Induction of Concrete's Ability to Resist Chloride Ion Penetration, West Conshohocken, PA

Martínez-Barrera, G., Vigueras-Santiago, E., Hernández-López, S., Martínez-Barrera, G., Brostow, W., & Menchaca-Campos, C. (2005). Mechanical improvement of concrete by irradiated polypropylene fibers. *Polymer Engineering & Science*, *45*(10), 1426–1431.

Spadea, S., Farina, I., Carrafiello, A., & Fraternali, F. (2015). Recycled nylon fibers as cement mortar reinforcement. *Construction and Building Materials*, *80*, 200–209.

Zhang, P., & Li, Q. (2013). Effect of polypropylene fiber on durability of concrete composite containing fly ash and silica fume. *Composites Part B: Engineering*, *45*(1), 1587–1594.

OPTIMUM GEOMETRIC CONFIGURATION OF FUSE FOR SEISMIC FORCE RESISTING ROCKING FRAME

Radin Md Mahirul Hoque[1], Khan Mahmud Amanat[2], Devabrata Dutta[3]

ABSTRACT

Self-centering rocking frame is a seismic lateral-force resisting system to prevent the structural damage due to seismic forces and minimize the residual drift. This system mainly consists of braced steel frame, post tensioning strands and energy dissipating fuses. The system rocks upon its foundation on the application of lateral seismic forces. The post tensioning strands provide the overturning resistance as well as the self-centering property against the lateral force and the structural fuses dissipate the energy. The frame and the post tensioning strands are designed to remain elastic during major seismic events. In this study, the frame behavior has been evaluated in terms of drift and column uplift. For this purpose, a finite element model has been established. The numerical model has been verified using previous experimental studies. With the verified FE model, in depth studies have been carried out to find the optimum and economical geometric configuration of structural fuse for minimizing the drift and uplift of rocking frame. The optimum geometry found in this study has a lower drift and uplift and also have good agreement with the design fuse with 1.04% variation in the calculated fuse force. Also, the changing pattern of drift and uplift ratios for different geometric properties of fuse are found in this research. The uplift and drift of frame as well as the structure reduces with higher b/t ratio of fuse geometry, at the same time they increase with higher L/t ratio. Balancing these two diverging conditions an optimum fuse geometry has been suggested.

Introduction

Conventional seismic design of structures mainly focuses on prevention of structural failure. The provisions for serviceability and damage control are not addressed in the existing codes. Structural members go inelastic deformations and have permanent residual drift in the event of earthquakes. Also, the large story drifts cause unrepairable architectural and structural damages. As a result, the buildings do not collapse aftershock but suffer severe damages which lead to great economical losses.

Self-centering rocking frame system is low-damage seismic force resisting system. Controlled rocking behavior of the system has been studied in this research, focusing on eliminating residual drifts of structures and minimizing the plastic deformations.

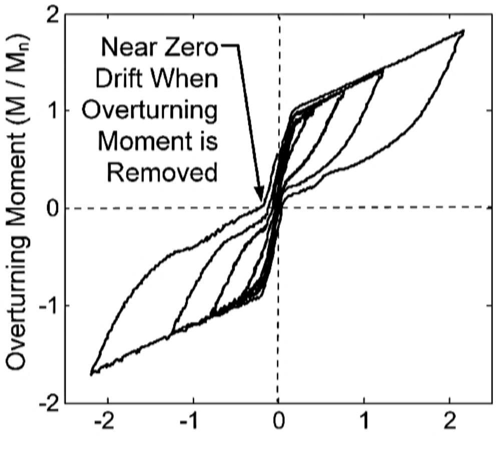


Figure 1: Experimental load deformation behavior

[1] Lecturer, Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka 1000, Bangladesh. E-mail: mahir@ce.buet.ac.bd
[2] Professor, Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka 1000, Bangladesh. E-mail: amanat@ce.buet.ac.bd
[3] Undergraduate Student, Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka 1000, Bangladesh. E-mail: devabrata.ce.buet@gmail.com

The system minimizes damage through a controlled rocking mechanism during earthquakes. The energy dissipating structural fuses dissipates the seismic force and the pre-stressed tendons makes the frame come back to its original position through rocking by providing self-centering force. The performance of the rocking frame in a seismic event can be explained with a flag-shaped hysteresis as shown in Figure 1. From the figure it is evident that residual drift of the system after an earthquake is zero, due to the self-centering property of the frame.

The behavior of rocking system has been studied extensively in the recent years by many researchers. (Roke et al. 2010, Eatherton and Hajjar 2010, Ma et al. 2011, Wiebe and Christopoulos 2014, Steele and Wiebe 2016). However, this paper investigates the performance of the rocking system in terms of roof drift and frame uplift while considering the b/t ratio and L/t ratio of structural fuse. Here, b, L and t are different geometric parameters of butterfly fuse, shown in Figure 2.

In this research, the numerical model of the frame is subjected to ground acceleration (Northridge Canoga park, 1994) to find the optimum b/t ratio and L/t ratio of the energy dissipating fuse for finding the minimum roof drift and column uplift. The optimum b/t and L/t ratios from numerical study suggest a better geometric configuration of fuse for lowering the drift and uplift.

The numerical studies conducted in this paper have been performed, following the experimental program described in Ma et al. (2010). In the experimental research the behavior of butterfly fuse is studied, but the geometric configuration is not considered. So, this study suggests an optimum fuse geometry.

In the numerical study, to simulate the fuse model the strength and stiffness of the fuse are calculated as follows from equation described in Ma et al. (2011).

$$F_{fuseP} = \frac{4}{9}\,\frac{n_L b^2 t \delta_y}{L} = 1340.98\text{ kN} \qquad (1)$$

According to this equation the design force for the fuse has been found as 1340 kN.

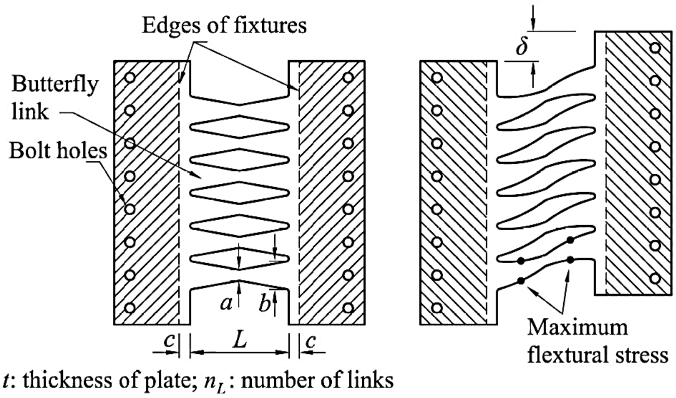


Figure 2: Geometry and deformation of butterfly fuse

RDR and ULR are the two terms frequently used in this paper. These two terms are used to refer the vertical displacement of the column base and horizontal displacement of roof of the frame respectively. So, this two terms quantifies the roof drift and column uplift. They are characterized by equations 2 and 3.

$$RDR = \frac{\Delta_{roof}}{H} \qquad (2)$$

$$ULR = \frac{\Delta_{up}}{A} \qquad (3)$$

Where, *RDR*: roof drift ratio
ULR: uplift ratio
Δroof: horizontal displacement at roof of the frame
Δup: vertical displacement of column base

H: frame height
A: frame bay width

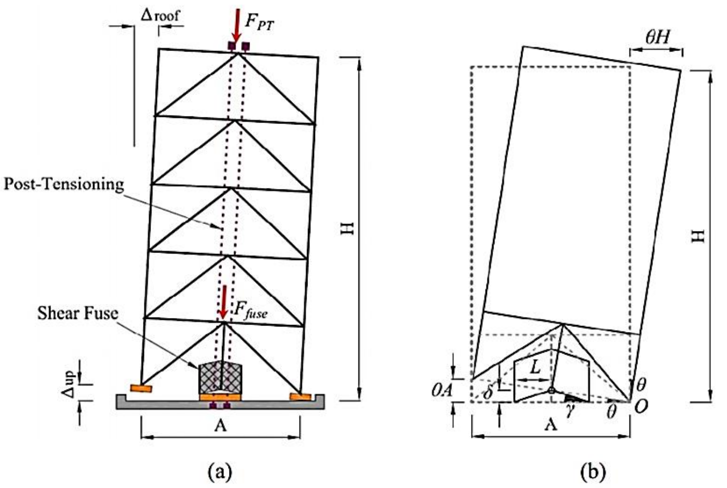


Figure 3: Controlled rocking system concept: (a) scheme of single rocking frame; (b) rigid body behavior

Numerical Modelling of Rocking Frame

In order to predict the dynamic responses of a controlled rocking system numerical model has been developed. The model is two dimensional, with both material and geometric nonlinearities involved. The investigation model of the shaking table experiment specimen consists of the braced frame, testbed mass device, post-tensioning (PT) strands and fuse assembly.

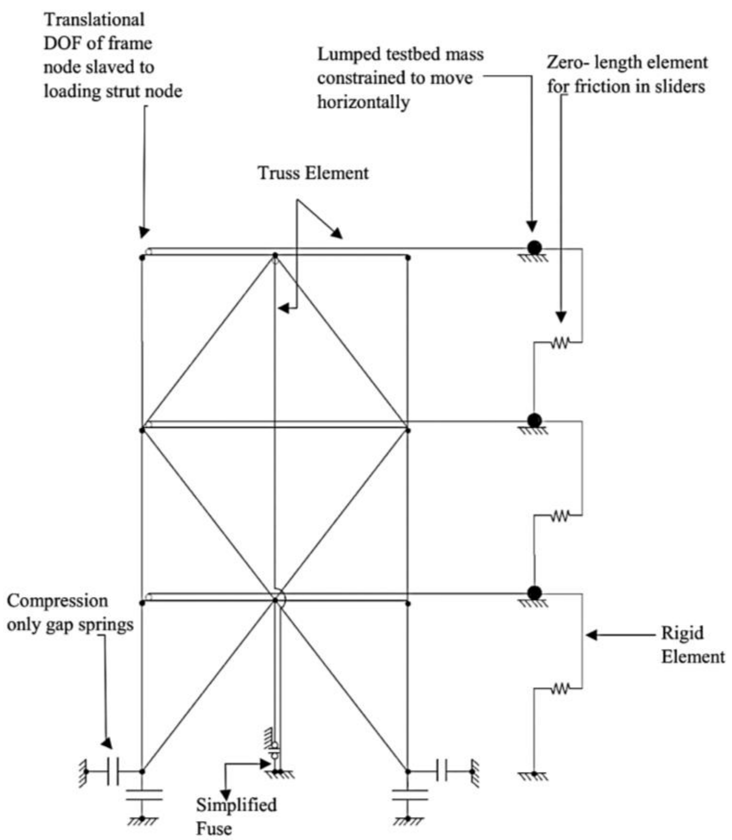


Figure 4: Rocking frame model for simulation of experiment of (Ma et al. 2011)

In developing modelling of rocking system different types of elements are selected from elements library of

ANSYS according to their application.

In order to define the linearity of different materials, input of modulus of elasticity and the major Poisson's ratio are quite enough for a certain material type. In the proposed model frame members and the post-tensioning strand remain always elastic and so material linearity is considered for these cases. The elastic frame members are modeled using beam element from material library and the post tensioning strand is modeled using link type truss element. Cross-sectional characteristics are employed according to the computed values of the sections that are abbreviated in (Ma et al. 2011). To simulate the rocking behavior of the frame according to the shake table experiment, spring elements are inserted at the column bases. Spring elements are chosen from element library for this purpose.

To attach the load from the different story and the self-weight of the frame are simulated as lumped mass. Half of the mass of each story of the frame is applied to the right column nodes and mass of half of the frame plus the connection block is applied to the left column nodes. Mass element without rotary inertia is chosen for modeling the lumped masses.

A single truss element with calibrated force-deformation (material) relationship to characterize the entire fuse is used for modeling simplified fuse model. Parameters of the model can be determined based on fuse strength F_{fuseP} (Ma et al. 2011). All the elements, considered for the frame modelling has shown in the figure 4.

The dynamic analyses of the rocking frames are conducted with data collected from (Ma et al. 2011). Also, the numerical model is validated using this data. The system hysteresis has been compared for both experimental program and numerical study using 65% Kobe Earthquake at MCE (Maximum Considered Earthquake) level. The simulation has shown good agreement with the experimental result. The comparison is shown in figure 5.

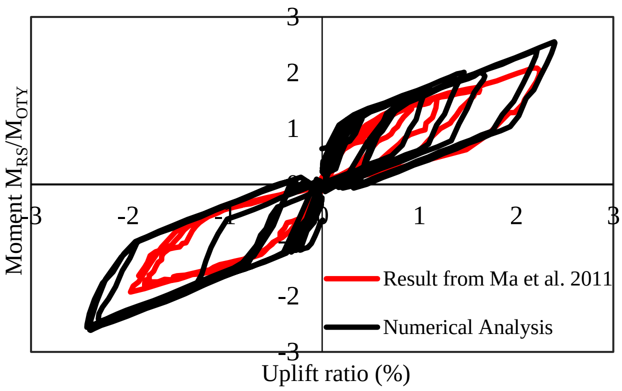


Figure 5: System hysteresis comparison: fuse (65% Kobe) Parametric Study

A time history analysis has been done using Northridge Canoga Park (1994) acceleration. The acceleration has been employed as MCE level earthquake to calculate the RDR and ULR.

In this study concentration has been given on the geometric configuration of the butterfly fuse. The parametric study has been done for different b/t and L/t ratio of fuse configuration mean while the pre-tensioning properties has been kept constant. The performance of the fuse is observed with the simulated simplified fuse model according to the experimental program based on Ma et al. (2010) for varying geometric configuration. The different geometries used in this study are summarized in the test matrices. In the test matrix 1 the L/t ratios have been kept fixed for evaluating fuse performance at different b/t ratio. In the test matrix 2 the fuse performance has been observed in the same way considering different L/t ratio, while the b/t ratio was fixed. The change in ULR and RDR is very close for the selected b/t and L/t ratio (Figure 6). Actually according to the theory, due to the rigid body behavior of the frame the numerical values of RDR and ULR should be the same. But, in the time history analysis of the frame, there induces some flexibilities in the frame members, which brings slight variations in the values of drift and uplift ratio. However, both RDR and ULR are increasing with the increase of L/t ratio and decreasing with the increase of b/t ratio. But, the change in the RDR and ULR are not regular in the study region of b/t and L/t ratios.

Table 1: Test matrix 1

b/t	L/t	L (mm)	t (mm)	b (mm)	a (mm)	c (mm)	nL	FfuseP (kN)
2.2	9.4	300	32.00	70.00	26.80	18.70	13.00	1041.85
2.3	9.4	300	32.00	75.00	26.80	18.70	13.00	1196.00
2.5	9.4	300	32.00	80.00	26.80	18.70	13.00	1360.78
2.7	9.4	300	32.00	85.00	26.80	18.70	13.00	1536.20
2.8	9.4	300	32.00	90.00	26.80	18.70	13.00	1722.24
3.0	9.4	300	32.00	95.00	26.80	18.70	13.00	1918.92

Table 2: Test matrix 2

b/t	L/t	L (mm)	t (mm)	b (mm)	a (mm)	c (mm)	nL	FfuseP (kN)
2.5	7.8	250	32.00	80.00	26.80	18.70	13.00	1632.94
2.5	8.6	275	32.00	80.00	26.80	18.70	13.00	1484.49
2.5	9.2	295	32.00	80.00	26.80	18.70	13.00	1383.85
2.5	10.2	325	32.00	80.00	26.80	18.70	13.00	1256.11
2.5	10.9	350	32.00	80.00	26.80	18.70	13.00	1166.38
2.5	11.7	375	32.00	80.00	26.80	18.70	13.00	1088.63

The analysis results shows that both the drift and uplift ratios are decreasing with the increase of b/t ratio. But, the ratios are increasing with the increase of L/t ratio. As, the whole rocking system is designed to minimize the drift of structures, so it is desirable to minimize the ratios. In this study the fuse thickness has been kept fixed. Hence L should be decreased to lower the L/t ratio and b should be increased to rise the b/t ratio.

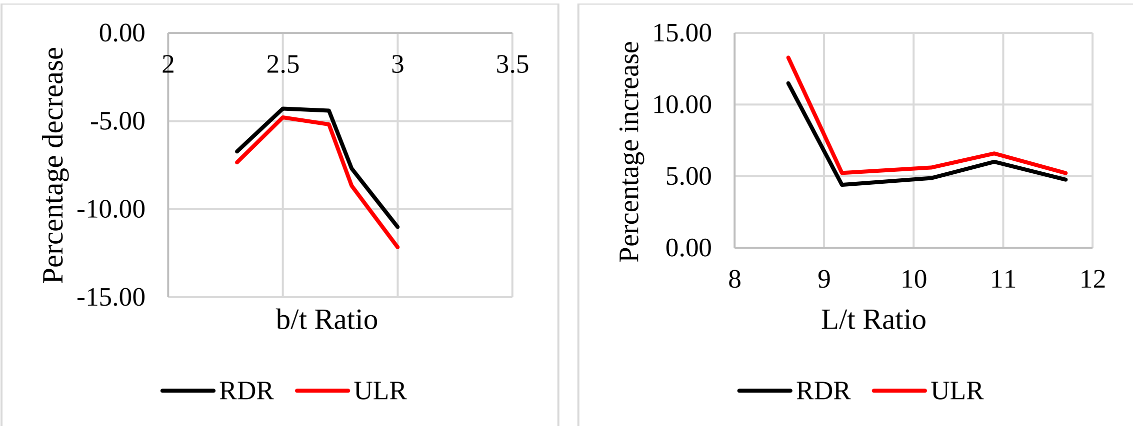
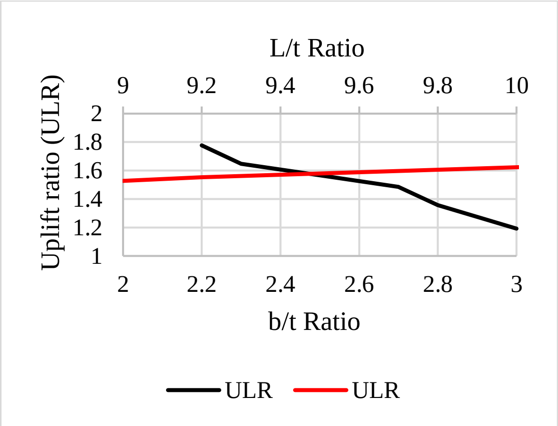
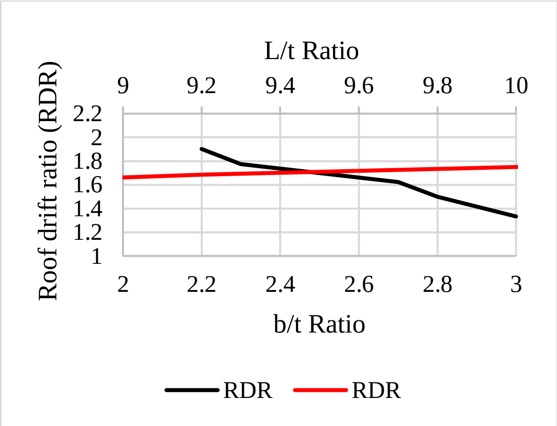


Figure 6: Percentage change in RDR and ULR with b/t and L/t ratios

To balance this two opposite conditions and minimize RDR and ULR, both curves are superimposed and intersected at a common point (Figure 7). This intersecting point suggests optimum b/t and L/t ratio which balances two diverging conditions. To find this optimum ratio, the plot of RDR and ULR with changing b/t and L/t were adjusted several times and the best intersecting point has been chosen. The optimum b/t and L/t ratio found on this study are 2.48 and 9.48 respectively.

With the optimum L/t and b/t ratio, the fuse force has been found as 1326kN, using the design concept of Ma et al. (2011). The value is very close to the design fuse force (1340kN) with 1.04% variation only.





(a) (b)

Figure 7: (a) ULR vs. b/t and L/t ratio; (b) RDR vs. b/t and L/t ratio

Conclusion

The numerical study has been carried out considering geometry of structural fuse as there is no previous study on fuse geometry. It is evident from the research that, the performance of the rocking frame in controlling the drift and uplift, fuse geometries have significant impacts. From the study, the change in ULR and RDR of the system with the geometric properties of the fuse have been found. The RDR and ULR increase with the decrease of b/t ratio. At the same time drift and uplift goes up with the increase of L/t ratio. So, in this research an optimum as well as economical fuse geometry is suggested balancing two opposite conditions. The optimum b/t and L/t ratio found in this study are 2.48 and 9.48 respectively. However, in this research only b/t and L/t ratios are considered. Further studies can be carried out considering other fuse parameters and ratios and using more fuse specimens. The optimum fuse geometry found from this study have 1.04% variation with the design fuse force. So, the result have a very good agreement with the previous studies. This results would have been more accurate if the optimum configuration was obtained by deriving an equation. A further extensive study can be carried out to define the equation for the optimum fuse geometry.

References

FEMA (2009) "Quantification of building seismic performance factors", Washington, D.C.

Ma, X., Borchers, E., Peña, A., Krawinkler, H., and Deierlein, G. (2010) "Design and behavior of steel shear plates with openings as energy-dissipating fuses", *Report No. 173*, John A. Blume Earthquake Engineering Center, Stanford University, Stanford CA.

Ma, X., Deierlein, G., Eatherton, M., Krawinkler, H., Hajjar, J., Takeuchi, T., Kasai, K., Midorikawa, M., and Hikino, T. (2010) "Large-scale shaking table test of steel braced frame with controlled rocking and energy dissipating fuses", *Proceedings of the 9th US and 10th Canadian Conference on Earthquake Engineering*, Toronto.

Ma, X., Krawinkler, H., and Deierlein, G. G. (2011) "Seismic Design and Behavior of Self-Centering Braced Frame with Controlled Rocking and Energy Dissipating Fuses", *Report No. 174*, John A. Blume Earthquake Engineering Center, Stanford University, Stanford CA.

Proceedings on International Conference on Disaster Risk Management, Dhaka, Bangladesh, January 12-14, 2019

NON-LINEAR FINITE ELEMENT INVESTIGATION OF THE LATERAL LOAD CAPACITY OF STIFFENED SPSW FOR VARIOUS ASPECT RATIOS

Mumtahina Akter[1], Khan Mahmud Amanat[2]

ABSTRACT

Steel plate shear wall (SPSW) has been identified as an effective option for lateral load resisting system in both retrofit and new constructions. The current study has focused on the use of diagonal stiffener to incorporate advantages of the stiffening approach into the seismic behavior of an unstiffened thin steel plate shear wall. A finite element analysis has been done to study the behavior of steel plate shear wall with diagonal stiffener. Verification of this finite element model has been performed with reference to the experiment done by other researchers in the past. It has shown good agreement, exists between present analysis and the experimental results. This establishes the acceptability and validity of the present finite element model to carry out further study. Parametric studies were done on the effect of the ratio of width to height of infill plate (aspect ratio). Comparison of the capacity of diagonally stiffened SPSW with respect to unstiffened ones shows important relationships. It has been observed that with increase in aspect ratio of the infill plate, the strength of the unstiffened as well as diagonally stiffened SPSW increases. For same volume of material consumption, the diagonally stiffened SPSW can carry more lateral load than an unstiffened system. It has also been observed that two-side stiffened system has more capacity than the one-side stiffened system for same volume of material. Findings of the study shall enable us to design efficient diagonally stiffened SPSW.

Keywords: Steel plate shear wall (SPSW); Aspect ratio; Infill plate; Lateral loading.

Introduction

Steel plate shear wall (SPSW) is an innovative lateral load-resisting system capable of effectively bracing a building against both wind and earthquake forces. In general, steel plate shear wall system consists of a steel plate wall, boundary columns and horizontal floor beams. Together, the steel plate wall and boundary columns act as a vertical plate girder. The columns act as flanges of the vertical plate girder and the steel plate wall acts as its web. The horizontal floor beams act, more-or-less, as transverse stiffeners in a plate girder. During the last three decades, many research programs have been performed on steel plate shear walls (SPSWs).
The first approach is founded on the use of heavy horizontal and vertical stiffeners to ensure that the infill steel plate reaches its full plastic strength prior to the elastic out-of-plane buckling. Takahashi et al. (1973) studied cyclic behaviors of stiffened SPSWs with light and heavy stiffeners. Despite the good performance of the stiffened system, construction of many horizontal and vertical stiffeners is often time-consuming and may impose high-fabrication cost on a project.
The second approach is based on the post buckling strength of an unstiffened thin steel plate because of the development of tension field action in the infill plate after the elastic out-of-plane buckling of the plate. The demands and reactions on the boundary elements increase because of the development of tension field action inside of the panel. Cases of failures of the boundary elements or their connections have been reported in the tests conducted on unstiffened steel shear walls by Elgaaly et al. (1993), Driver et al. (1998), and Astaneh Asl (2001).

Previously mentioned areas of concern regarding the two approaches have provided opportunities for investigating a modified system or finding reasonable solutions for the problems. In this respect, much research has been recently conducted on SPSWs; for instance, Li et al. (2010) used horizontal restrainers on the web plate of a narrow steel shear wall to decrease the forces in the members by limiting the magnitude of the out-of-plane buckling of the web plate. Other methods with different concepts have been also studied and proposed for improvement of the seismic behavior of steel shear walls, such as utilizing slits in the panel webs (Hitaka and Matsui 2003), using composite shear walls (Zhao and Astaneh-Asl 2004), and perforating

[1] *Lecturer, Dept. of Civil Engineering, Military Institute of Science and Technology, Dhaka-1216, Bangladesh.*
[2] *Professor, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1205, Bangladesh.*
mumtahinatomalika@gmail.com

the infill plate with special holes (Vian et al. 2009).

The experimental study by Alavi and Nateghi (2013) has focused on the use of diagonal stiffeners to incorporate advantages of the stiffening approach into the seismic behavior of an unstiffened thin steel shear wall by means of a minimum number of stiffeners.

This paper focused on developing a three dimensional finite element model using ANSYS 16.2 to investigate the behavior of diagonally stiffened steel plate shear wall considering both the geometric and material nonlinearities. The proposed finite element model is then used to simulate the experimental results from Alavi and Nateghi (2013). The proposed model is then used to examine the effects of diagonal stiffener and the aspect ratios of infill plate.

Methodology for Finite Element Analysis

This section describes a finite element model to predict the responses of unstiffened as well as stiffened steel plate shear wall. The model accounts for both material and geometric nonlinearities. The stress-strain curves of steel used at different conditions with different material properties are assumed to follow elastic-plastic model behavior. In case of performing the modeling in a generalized way, the origin is taken at the center of the infill plate where the eccentricity is applied to ensure the geometric nonlinearity. To perform the test HEB160 section is used for the boundary elements; beam and column.

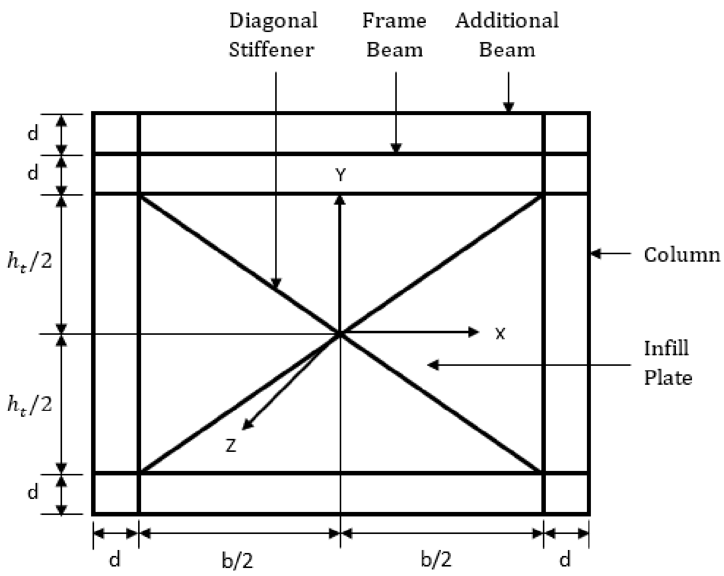
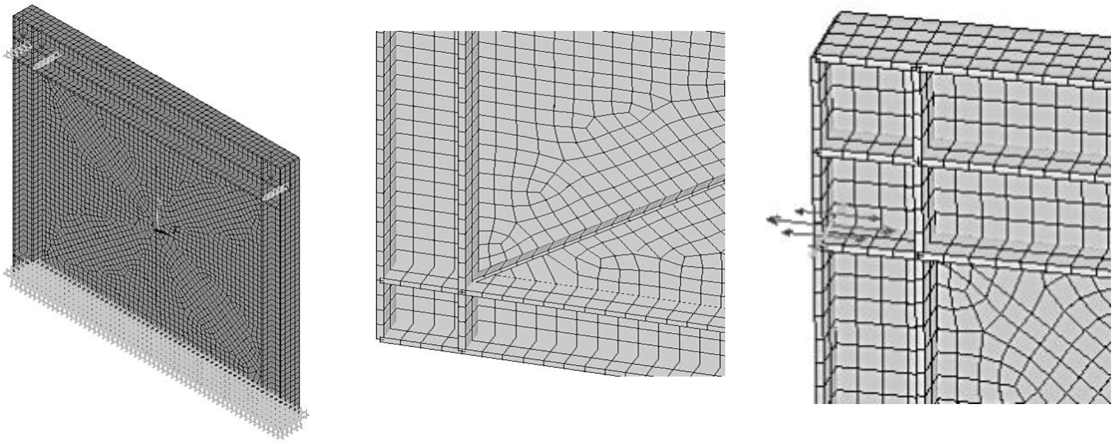


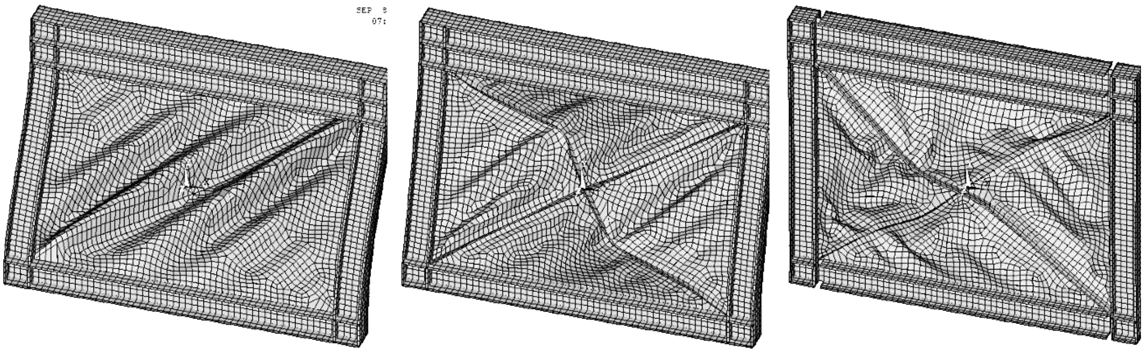
Figure 1. Schematic 2-D sketch of the two-side stiffened SPSW

In Figure 1 the geometry of two-side stiffened SPSW considered in finite element modeling along with the considered x, y, z direction is shown. Since this study is concerned with thin structural sections, shell element is the best option to get resemblance with the practical one. Restraints are provided in the model considering the test setup (Alavi and Nateghi, 2013). Lateral supports were designed and installed at the top level of specimens along the intersection of the inner flanges of the columns, bottom flange of the top frame beam are kept restrained for z only to prevent lateral movement of the boundary elements. Bottom flange of the bottom beam is kept restrained for translation in all the x, y and z direction. Some sketches of finite element mesh, details of boundary conditions and loading are shown in Figure 2. For the infill plate, boundary element and the stiffener non-linear behavior has been incorporated in the model. For obtaining the load deflection diagram, nonlinear analysis has been performed by considering Newton-Raphson method. The typical deformed shapes for the proposed model have been obtained like following Figure 3.



(a) (b) (c)

Figure 2. (a) Finite element mesh of SPSW (Unstiffened) along with boundary conditions and loading. (b) Close view of meshing of stiffened SPSW. (c) Close view of applying deformation in modeling.



(a) (b) (c)

Figure 3. 3D view of typical deformed shape for (a) Unstiffened SPSW, (b) One-side stiffened SPSW, (c) Two-side stiffened SPSW.

Simulation of Experiments

The finite element model needed to be verified against previously done experiments for its reliability and acceptability. For this purpose, experimental study performed by Alavi and Nateghi (2013) has been taken into consideration. A comparison between experimental and numerical analysis is shown in Figure 4.
However, considering the overall base shear vs drift responses, it can be said that a reasonably good agreement exists between test results and finite element analysis from the observation of Figure 4. Thus, the proposed finite element modeling scheme can be reliably used as a replacement procedure for costly lab experiments.

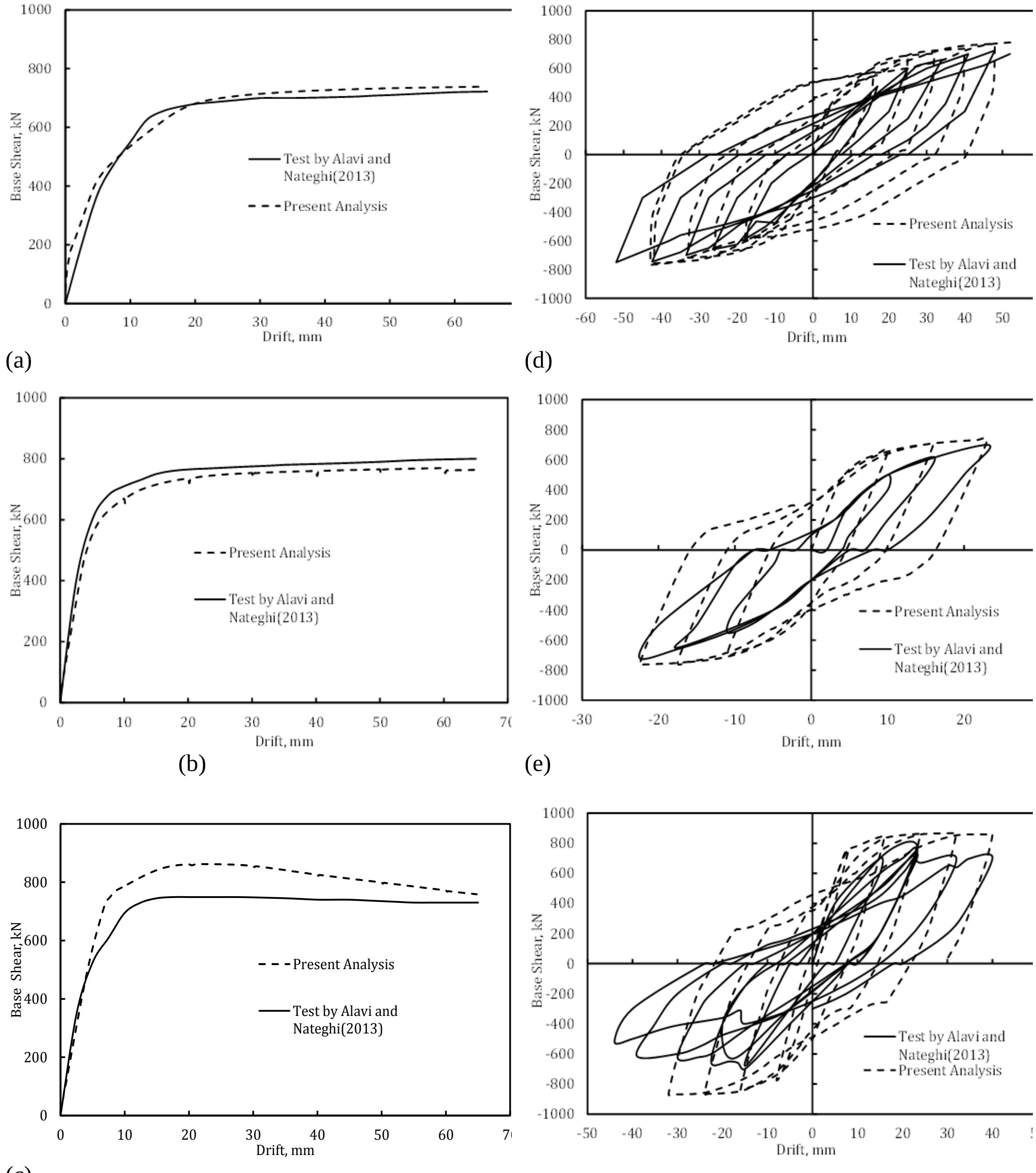


Figure 4. Base shear vs. drift behavior in case of pushover analysis for (a) unstiffened, (b) one-side stiffened, (c) two-side stiffened SPSW. Base shear vs. drift behavior in case of cyclic loading for (d) unstiffened, (e) one-side stiffened, (f) two-side stiffened SPSW.

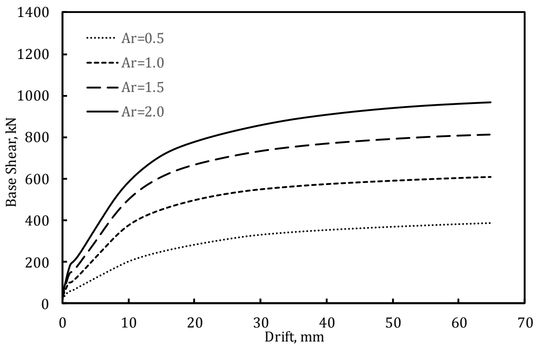
Table 1. Material properties used for infill plate, stiffener and boundary elements

Material Properties Used for	Elastic modulus (MPa)	Static yield (MPa)	Static ultimate (MPa)	Yield strain (%)	Hardening strain (%)	Ultimate strain (%)	Rupture strain (%)
Infill Plate and Stiffener	204000	280	500	0.14	0.3	21.6	27.0
Boundary Elements	207000	400	450	0.19	2.7	13.2	15.1

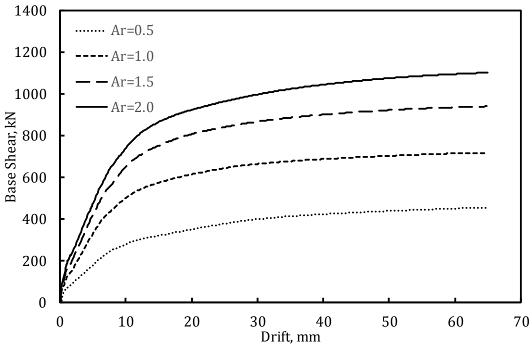
Parametric Study and Discussion

Some parametric studies on unstiffened as well as stiffened steel plate shear wall have been carried out using the proposed finite element model. Here, all the analysis for the parametric studies are done by applying monotonic displacement i.e. by pushover analysis. For this purpose, all the beam-column connections are assumed as moment connection. The considered material properties of infill plate, stiffener and the boundary elements throughout the studies are shown in Table 1.

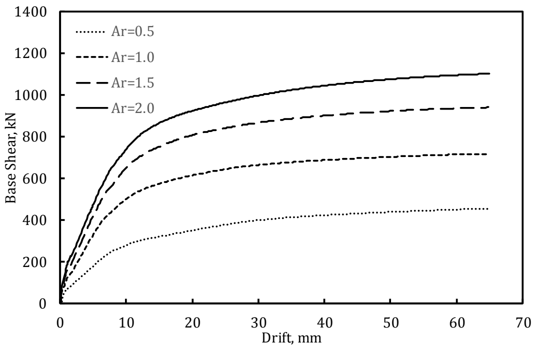
Effect of Aspect Ratio of Infill Plate



(a) Unstiffened



(b) One side stiffened



(c) Both side stiffened

Figure 5. Base Shear vs. Drift behavior with different aspect ratios of steel plate shear wall.

The aspect ratio of an infill plate is its width to height ratio. In this study the effect of aspect ratio of infill plate is studied for unstiffened SPSW (SPSW2), one-side stiffened SPSW (SPSW(S3)), two-side stiffened SPSW (SPSW(S2)). Here for each individual system the height is kept constant. And then only the width of the infill plate is changed gradually to get different aspect ratios. The effect of aspect ratio of the infill plate is shown with graphical representation and in Figure 5.

From the graphical representation it is seen that the strength of SPSW proportionally increases with the increased aspect ratio of infill plate. With constant height, when the aspect ratio is increased the total area as well as the volume of infill plate is increased. So for the same shear deformation, with higher aspect ratios require more strength.

Effect of Diagonal Stiffener

To check the effect of diagonal stiffener on strength of steel plate shear wall, the three specimens (unstiffened, one-side stiffened, two-side stiffened) are compared by varying the thicknesses of the infill plates. To get the same strength from stiffened and unstiffened SPSWs, the unstiffened SPSWs require relatively larger thickness of infill plate than the stiffened system. And two-side stiffened SPSWs require smaller thickness of infill plate than the one-side stiffened SPSWs. Figure 6 shows the effect of diagonal stiffener.

In case of one-side stiffened SPSW the volume consumption is reduced by 11.11% with respect to the unstiffened SPSW. For the two-side stiffened SPSW this volume consumption is reduced by 22.22% to get the same strength. The causes of decreasing material consumption with increasing the number of stiffening is given below.

Stiffener reduces the lateral buckling of the infill plate, increases the shear capacity and thus increases the load carrying capacity of the system. Diagonal stiffener can also carry tension. The total number of stiffener increases, the confinement of the infill plate increases. So in case of two-side stiffened SPSW, the material consumption is lower than the one-side stiffened SPSW.

Conclusions

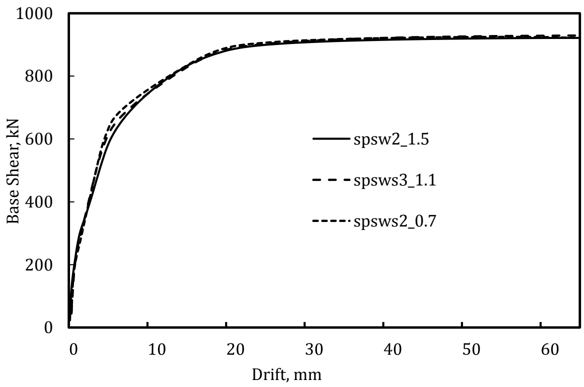


Figure 6. Base Shear vs. Drift behavior showing the effect of diagonal stiffener.

In this study, a three dimensional finite element model of diagonally stiffened steel plate shear wall has been developed. Verification of this finite element model has been demonstrated with reference to the experiment of Alavi and Nateghi (2013) and good agreement has been found. This authenticates the validity and acceptability of performing further study using this numerical model instead of conducting comparatively expensive experimental study. For this reason, the proposed model is then used for performing the parametric studies. Based on the parametric studies the following conclusions are drawn.

(1) Increase in aspect ratio of the infill plate increases ductility as well as increases the strength of the unstiffened and diagonally stiffened SPSWs.

(2) The capacity of SPSW of resisting lateral load increases with increase in thickness of the infill plate. To gain the same strength diagonally stiffened SPSW can be used which can reduce the thickness of the infill plate and thus the total volume of material consumption gets reduced. Diagonally stiffened SPSWs ensure economy with strength.

References

AISC Steel Design Guide 20

Alavi, E., and Nateghi, F. (2010). "Nonlinear behavior of diagonally stiffened steel plate shear walls." Proceedings, 9th US National and 10th Canadian Conference on Earthquake Engineering, Earthquake Engineering Research Institute (EERI), Oakland, CA, 1–10.

Astaneh–Asl, A. (2001). "Seismic behaviour and design of steel shear walls." Steel TIPS Rep., Structural Steel Educational Council, Moraga, CA.

Driver, R.G., Kulak, G.L., Elwi, A.E. & Kennedy, D.J.L. (1998), "FE and simplified models of steel plate shear wall", Journal of Structural Engineering ASCE, 124(2), 121– 130.

Elgaaly, M., Caccese, V., and Du, C. (1993). "Post buckling behavior of steel-plate shear walls under cyclic loads." Journal of Structural Engineering, 119(2), 588–605.

Hitaka, T., and Matsui, C. (2003). "Experimental study on steel shear wall with slits." Journal of Structural Engineering, 129(5), 586–595.

Li, C.-H., Tsai, K.-C., Lin, C.-H., and Chen, P.-C. (2010). "Cyclic tests of four two-story narrow steel plate shear walls. Part 2: Experimental results and design implications." Earthquake Engineering and Structural Dynamics, 39(7), 801–826.

Nateghi, F., and Alavi, E. (2009). "Non-linear behavior and shear strength of diagonally stiffened steel plate shear walls." International Journal of Engineering Transactions B, 22(4), 343–356.

Takahashi, Y., Takemoto, T., and Tagaki, M. (1973). "Experimental study on thin steel shear walls and particular bracing under alternative horizontal load." Preliminary Rep. IABSE Symp. on Resistance and Ultimate Deformability of Structures Acted on by Well-Defined Repeated Loads, International Association for Bridge and Structural Engineering
(IABSE), Zurich, Switzerland, 185–191.

Vian, D., Bruneau, M., Tsai, K. C., and Lin, Y. C. (2009). "Special perforated steel plate shear walls with reduced beam section anchor beams. I: Experimental investigation." Journal of Structural Engineering, 135(3), 211–220.

Zhao, Q., and Astaneh-Asl, A. (2004). "Cyclic behaviour of traditional and innovative composite shear walls." Journal of Structural Engineering, 130(2), 271–284.

MOST EFFICIENT STEEL BRACING PATTERN OF A SEISMICALLY VULNERABLE RC BUILDING BASED ON NONLINEAR STATIC PUSHOVER ANALYSIS

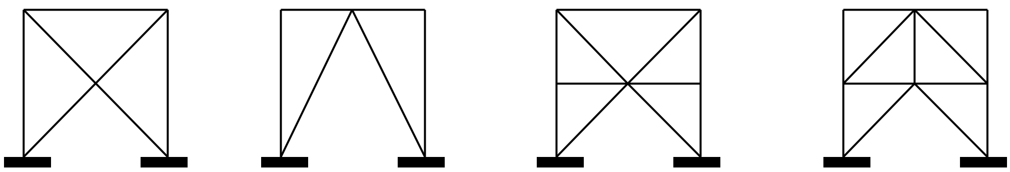
Dr. Shohel Rana[1], Md. Hisamuzzaman[2]

ABSTRACT

In recent years, many Reinforced Concrete (RC) buildings in Bangladesh are being retrofitted using different types of steel bracing system. However, there is a lacking of guideline or design philosophy to obtain the most efficient steel bracing retrofitting system. This study compares the performance of different bracing pattern systems of a seismically vulnerable RC building. The most efficient steel bracing pattern is thus determined. Nonlinear static pushover analysis is carried out to assess the structural performance of different bracing pattern systems. Different steel bracing patterns such as inverted V-bracing, X-bracing, ZX-bracing and Zipper-bracing are used. The effects of some parameters influencing the performance i.e. bracing element type and lateral load patterns are also investigated.

Introduction

Bangladesh has experienced eight small magnitudes on Richter scale earthquakes in last one year (https://earthquaketrack.com/p/bangladesh/biggest). An earthquake of even medium magnitude on Richter scale can produce a mass damage without any previous notice in major cities of the country, particularly in Dhaka (Sarraz, et. al., 2015). A great number of existing buildings in Bangladesh, especially in Dhaka city are designed without seismic design criteria and detailing rules (Sadat et. al., 2010). To overcome the risk caused by seismic disaster, the structures are required to be retrofitted. Among the retrofitting techniques, steel bracing is one of the most efficient solutions (Navya and Agarwal, 2016). The better performance of steel braced RC frames depends on appropriate bracing patterns (Yu, X., Ji, T. and Zheng, T., 2015). Badoux & Jirsa (1990) investigated analytically and conceptually steel braced RC frames and concluded that steel bracing is very suitable for exterior retrofitting scheme. Abou-Elfath & Ghobarah (2000) performed analysis for a three-storied building and concluded special arrangement for X bracing pattern only. Safarizki et al. (2013) performed pushover analysis to evaluate 5- storied building's global capacity using X bracing pattern only. Kadid & Yahiaoui (2011) investigated the performance of RC frames strengthened with different types of steel bracing. In recent years, many RC buildings in Bangladesh are being retrofitted using different types of bracing. However, there is a lacking of guideline or design philosophy to obtain the most efficient steel bracing system. In this study, an attempt is made to assess the performance of different braced systems within a specific building. The performance of different bracing systems under application of different invariant lateral load patterns using nonlinear static pushover analysis are assessed. Four structural configurations: X-braced, inverted V braced, ZX braced, and Zipper braced are used as shown in Figure 1.



(a) X bracing (b) Inverted V bracing (c) ZX bracing (d) Zipper bracing

Figure 1. Structural configuration of different bracing systems.

Finite Element Modelling of a RC Building

Finite element modelling of a RC building is performed as shown in Fig. 2. The building has 3x3 bay of 6.93m x 5.91m spacing as shown in plan of building in Fig. 2. The elevation of the building is shown in Fig. 3. The building is seismically vulnerable and retrofitting of the building is proposed by X-bracing, Inverted V, ZX and Zipper bracing system as shown in Fig. 4. The frame selected for analysis is shown in Fig. 2.

[1] *Associate Professor, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.*

[2] *Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.*

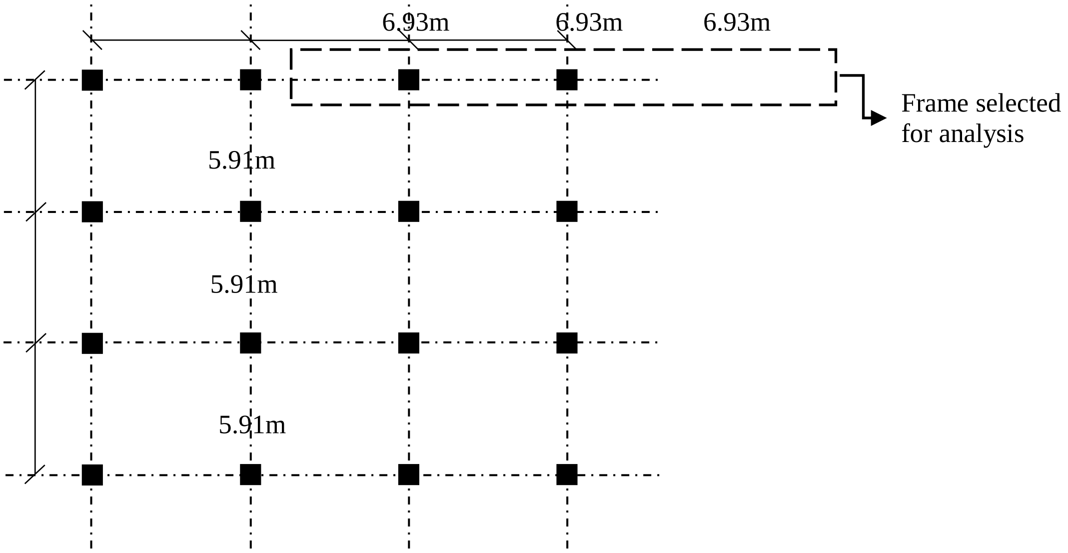


Figure 2. Typical Plan of the Example RC building

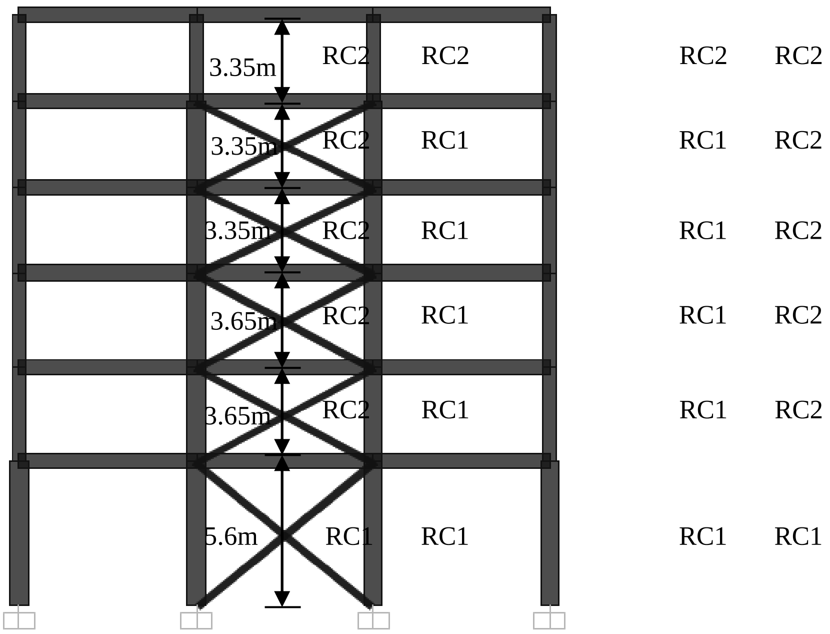
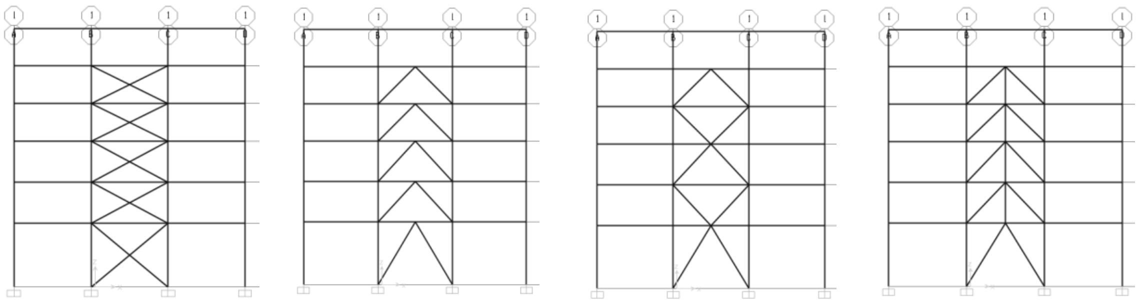


Figure 3. Elevation and column notation of selected Frame

After retrofitting, all the frames are checked against earthquake considering Dhaka zone (Z= 0.15). Structural importance is taken as special occupancy structure (I=1). Soil profile is taken as 21 meter or more in depth and containing more than 6m of soft to medium stiff clay but not more than 12 meter of soft clay (S = 1.5) and response modification factor is taken as Intermediate moment resisting frame (R=8). Table 1-6 describe the details of material properties, static load cases, beam section, column sections and bracing elements. The bracing elements size are first determined based on equivalent static earthquake load method.



(a) X- bracing (b) Inverted V bracing (c) ZX bracing (d) Zipper bracing

Figure 4. Different types of Bracing models

Table 1. Material Properties

fc’	27.57 MPa
fy	413.68 MPa
All structural steel sections	275.7 MPa
All connection plates	A36 Grade

Table 2. Loading on the building

Load Name	Load Type	Details	Value
Dead	Dead Load	Slab self wt	3.59 KN/m^2
		Floor Finish	1.43 KN/m^2
		Partition Wall	1.43 KN/m^2
		Wall	8.026 KN/m
Live	Live Load	On floor	3.00 KN/m^2

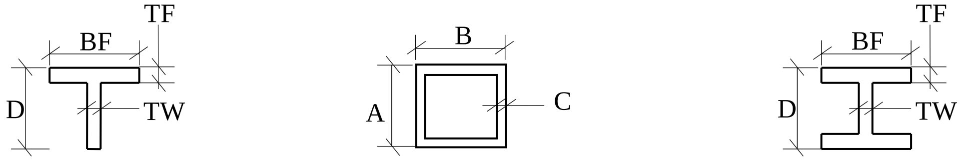
Table 3. Beam Section

Story	Beam				DL (KN/m)	LL (KN/m)
	Dimension (mm)		Reinforcement (sq mm)			
	Depth	Width	Top	Bottom		
1-5	609.6	304.8	1200	1200	35.60	12.84
6	609.6	304.8	1200	1200	29.77	12.84

Table 4. Column Section

Story	Column	Dimension (mm)		Number of Bars		Bar Area (sq mm)
		X-dir	Y-dir	X-dir	Y-dir	
1-5	RC1	812.8	609.6	10	7	200
6	RC2	508	304.8	10	7	284

Fig. 5 describes the section details of bracing elements. For performance assessment between the different bracing system, braces are added to bracing system in such a way that the total steel required is same for all the braces except for Zipper braced. The same brace sizes of X-braced (WTS-2) pattern are used in addition to zipper struts. To assess the influence of section type, T-shape, Tube and I-shape steel section are considered. The cross-sectional area of the different sections is considered same for comparison.



(a) T -Section (b) Tube Section (c) I –Section

Figure 5. Section of Bracing Element

Table 5. Bracing element for X pattern

T- Section				
Name	D(mm)	TW(mm)	BF(mm)	TF(mm)
WTS-1	300	20	350	20
WTS-2	300	12	300	12
I-Section				
Name	D(mm)	TW (mm)	BF (mm)	TF (mm)
WTS-1	240	20	215	20
WTS-2	184	12	214	12
Tube Section				
Name	A(mm)	B(mm)	C(mm)	
WTS-1	177.5	177.5	20	
WTS-2	186.4	186.4	10	

Table 6. Bracing element for inverted V, ZX and Zipper pattern

T- Section				
Name	D(mm)	TW (mm)	BF (mm)	TF (mm)
WTS-1	325	25	381.31	25
WTS-2	270	20	255.79	20
I-Section				
Name	D(mm)	TW (mm)	BF (mm)	TF (mm)
WTS-1	250	25	240.665	25
WTS-2	200	20	172.897	20
Tube Section				
Name	A(mm)	B(mm)	C(mm)	
WTS-1	195.327	195.327	25	
WTS-2	146.449	146.449	20	

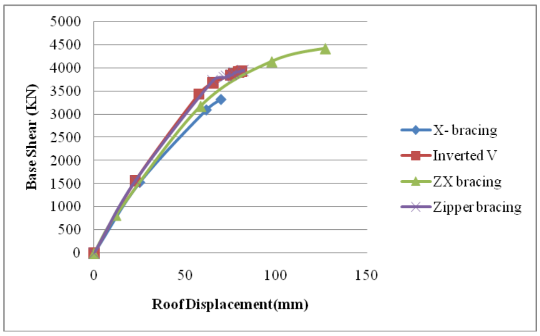
Nonlinear static pushover analysis

Nonlinear static pushover analysis is performed on 2-D RC Frame using different lateral load patterns to determine the effects of the lateral load on the global structural behavior through load–displacement curve. In the pushover analysis method, force and displacement demands are estimated by FEMA-356 criteria. Hinges are assigned at both the ends of each column, beam element and at mid-span of braces according to FEMA-356. For column, coupled (PMM) hinges, which yields based on the interaction of axial force and bi-axial bending moments at the hinge location, are used. P (axial) hinges are assigned for steel braces in tension/compression and Moment-rotation hinges are assigned for the beam elements. In this study, displacement-controlled pushover analysis for all the example frames are carried out. The target displacement used for each frame is 4% of the total height of the frame (ATC-40). Default-hinge properties are available in some programs based on the FEMA-356 and ATC-40 guidelines. In standard Finite Element software such as SAP2000v15 uncoupled moment (M2 and M3), axial force (P) and shear force (V2 and V3) displacement relation can be defined according to FEMA-356.

FEMA 356 suggests to use at least two load pattern / lateral load distribution to have upper limit capacity and lower limit capacity for a specific structure. Uniform load pattern provides the maximum capacity curves (Oguz, 2005). Where BNBC 2015 suggests to use elastic first mode load pattern / lateral load distribution which provides the lower limit capacity curve. The different lateral load patterns used in this study are (a) Uniform lateral load pattern and (b) Elastic first mode lateral load pattern. In uniform lateral load pattern, the lateral force at a storey is proportional to the mass of the storey. The elastic first mode load pattern is related to the first displacement mode shape (Φ) of vibration. The lateral force of a storey is proportional to the product of the amplitude of the elastic first mode and mass at the storey. P-Delta effect is not considered for each load combination used in this study.

Result and Discussion

The capacity curves obtained from pushover analysis of the frames with different bracing patterns (Fig. 4) are shown in Figure 6-7. The curves reveal that the shape of capacity curve directly depends on lateral load patterns. Figure 6 also shows that, for this particular building when uniform load pattern is used, inverted V, ZX and Zipper bracing system exhibit 15.6%, 25.01%, 24.49% greater capacity respectively as compared to X bracing system. In the case of Elastic first mode, inverted V, ZX and Zipper bracing system are showing respectively 16.28%, 17.05% and 16.90% greater capacity respectively as compared to X bracing system. Table 7 describes the maximum capacity for two lateral load patterns. The differences in maximum base shear for different lateral load cases are depicted in Figure 8. ZX bracing has the maximum base shear for both the load pattern for this specific structure.



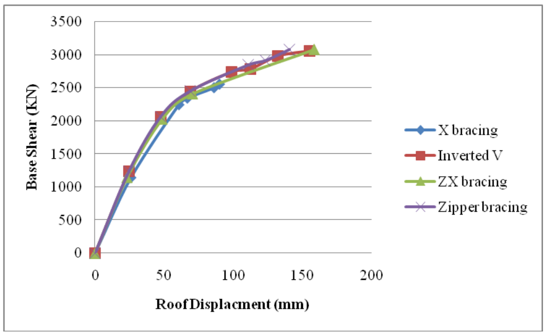
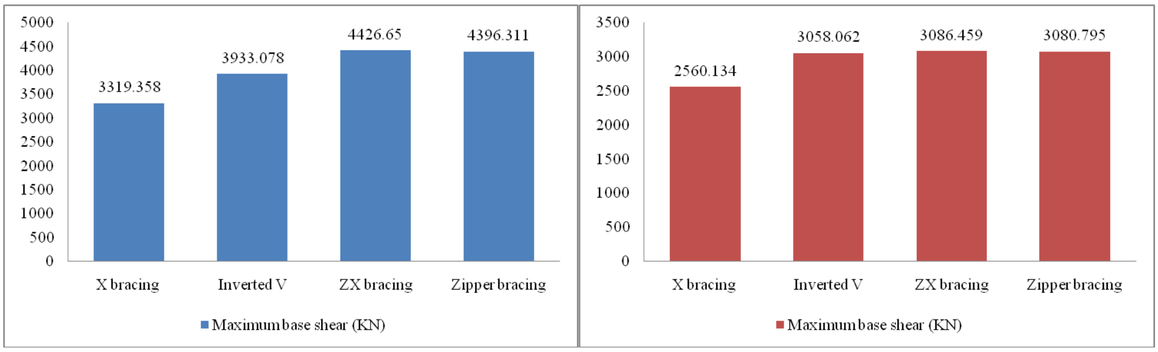


Figure 6. Capacity Curves using Unifrom load pattern *Figure 7. Capacity Curves using Elastic first mode*

Table 7. Maximum Base Shear for Different bracing

Pattern	Load case	Maximum Base Shear (KN)
X	Unifrom	3319.358
	Elastic first mode	2560.134
Inverted V	Unifrom	3933.078
	Elastic first mode	3058.062
ZX	Unifrom	4426.65
	Elastic first mode	3086.459
Zipper	Unifrom	4396.311
	Elastic first mode	3080.795



Uniform lateral load pattern *(b) Elastic first mode lateral load pattern*

Figure 8. Bar diagram for Maximum base shear considering different bracing system.

Figure 9 represents the maximum average base shear considering three type of steel sections (see Fig. 5) for X bracing pattern. Tube section has 6.04% and 4.64% greater capacity as compared to T-section and I-section. Therefore, for X bracing pattern, Tube section is the most efficient section observed in this study. Figure 10 represents the maximum average base shear of those steel sections for inverted V bracing pattern. T-section and Tube section are of nearly same capacity and has around 24.08% greater capacity as compared I-section.

Figure 11 represents the maximum average base shear for ZX bracing system. Tube section has 3.21% and 16.85% greater capacity as compared to T-section and I-section respectively. Therefore, for ZX bracing pattern, Tube section is the most efficient. Figure 12 represents the maximum average base shear for zipper bracing system. T-section has 3.81% and 20.83% greater capacity compared to Tube-section and I-section. Therefore for Zipper bracing pattern, T-section is the most efficient section.

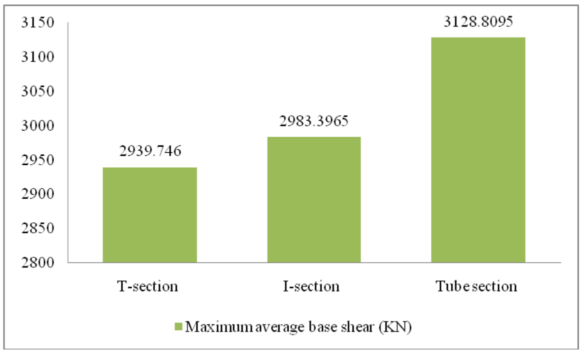


Figure 9. Maximum average base shear considering three section types for X bracing.

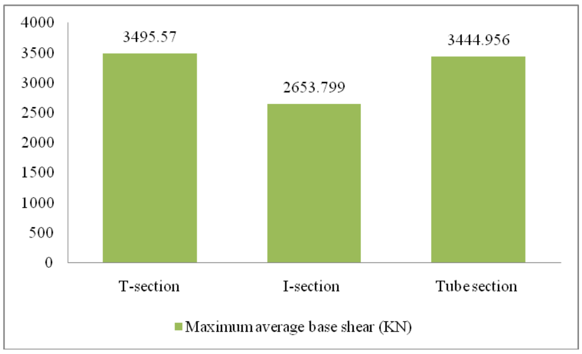


Figure10. Maximum average base shear considering three section types for Inverted V bracing.

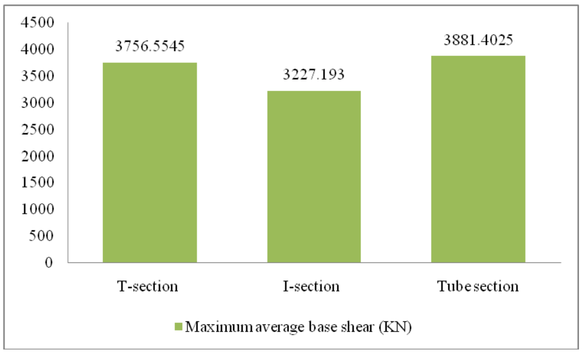


Figure 11. Maximum average base shear considering three section types for ZX bracing.

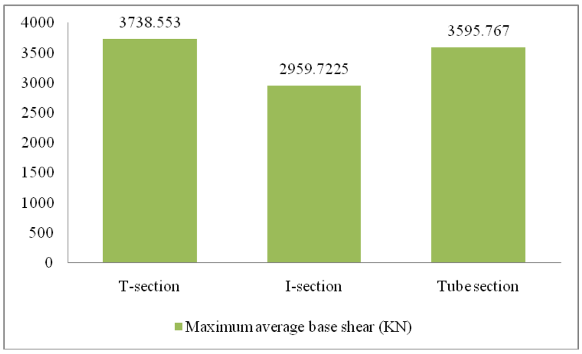


Figure 12. Maximum average base shear considering three section types for zipper bracing.

Conclusions

In this paper, a numerical study is conducted to a seismically vulnerable RC building which is retrofitted with different types of steel bracing system such as X bracing, Inverted V, ZX bracing and Zipper bracing system. Performance of different bracing system and section type to this building is assessed using pushover analysis according to FEMA-356, ATC-40 and BNBC-2015 guidelines. The performances are compared based on the capacity curve. The results obtained indicate that ZX bracing system with tube section or Zipper bracing systems with T-section are found to be the most efficient system for the case considered in this study.

References

Abou-Elfath, H. and Ghobarah, A., (2000). Behaviour of reinforced concrete frames rehabilitated with concentric steel bracing. NRC. *Canadian Journal of Civil Engineering*. vol. 27, pp. 433-444.

BNBC 2015, Bangladesh National Building Code (BNBC), Bangladesh House Building Research Institute, Dhaka, 2015, volume: II, part 6

Badoux, M. and Jirsa, J.O., (1990). Steel bracing of RC frames for seismic retrofitting. ASCE, *Journal of Structural Engineering*. vol.116, pp. 55-74.

Federal Emergency Management Agency (FEMA) (2000). NEHRP Guidelines for the Seismic Rehabilitation of Buildings.

Kadid, A. and Yahiaoui, D., (2011). Seismic Assessment of Braced RC Frames. Procedia Engineering, vol.14, pp.2899–2905.

Navya, G. and Agarwal, P. (2016). Seismic Retrofitting of Structures by Steel Bracings.12th International Conference on Vibration Problems, vol. 144, pp. 1364-1372.

Oguz, S. (2005). Evaluation of pushover analysis procedures for frame structures, *M. Sc. Engg. Thesis*, Graduate School of Natural and Applied Sciences, Middle East Technical University.

Sadat, M. R., Huq, M. S. and Ansary, M. A., (2010). Seismic vulnerability assessment of buildings of Dhaka city. IEB, *Journal of Civil Engineering*, vol. 38 (2), pp. 159-172.

Safarizki, A. H., Kristiawan, S. A. and Basuki, A., (2013). Evaluation of the Use of Steel Bracing to Improve Seismic Performance of Reinforced Concrete Building. Procedia Engineering, vol. 54, pp. 447– 456.

Sarraz, A., Khorshed, A. M. And Chandra, D. D., (2015). Seismic Vulnerability Assessment of Existing Building Stocks at Chandgaon in Chittagong city, Bangladesh. *American Journal of Civil Engineering*, vol. 3(1), pp. 1-8.

Yu, X., Ji, T. and Zheng, T. (2015). Relationships between internal forces, bracing patterns and lateral stiffnesses of a simple frame. *Engineering Structure*, vol. 89, pp. 147-161,

FINITE ELEMENT INVESTIGATION OF COLUMN BASE PLATE THICKNESS TO AVOID PRYING ACTION WHEN SUBJECT TO MOMENT

Mantaka Mahjabin Momo[1] and Khan Mahmud Amanat[2]

ABSTRACT

Design method proposed by AISC *Steel Design Guide* for column base connection has some limitations as pointed out in previous studies. Reasonably predicting the performance of column base connection is difficult. Though many experiments have been conducted for characterizing the response of base plate with W-sections, a few tests have been performed using HSS sections. So detailed study is needed regarding the performance of this type of connection. The objective of this study is to observe the behavior of column base connection for HSS section under moment. A three-dimensional finite element model featuring HSS column base connection was developed using ANSYS. Material nonlinearity was considered for this model. The anchor rods and the contact between base plate and concrete footing were simulated using contact elements. Analysis was conducted for moment loading only. The effect of base plate thickness and the number of anchor bolts on the load resisting capacity of the base plate connection was studied to determine the optimum thickness. It had been found out that, to avoid prying action, reducing the stiffness of anchor rods is more efficient than increasing base plate thickness. The study also showed that for eight anchor rods layout patterns linear relationship can be established between the tensile forces resisted by outer and inner row of anchor rods for a particular base plate thickness. The findings of the study will help engineers towards better understanding the behavior of column base plate supporting HSS columns and its design.

Keywords: Base plate connection, Prying action, HSS section, Finite element model, Plate thickness.

Introduction

Column base connection connects the column with the underlying foundation. Among the component of this connection base plate and anchor rods play an important role in transferring the loads from column and distribute it properly throughout the concrete foundation. It needs to have proper moment resisting capacity to sustain lateral loading.

Numerous analytical studies were carried out by researchers in Greece, including the development of a design procedure for the derivation of base connection moment-rotation curves (Ermopoulos and Stamatopoulos, 1996). Additional studies include (1) a closed form analytical model for the determination of the response of exposed column bases under cyclic loading (Ermopoulos and Stamatopoulos, 1996b), (2) an analytical model that describes the non-linear bearing stress distribution under the base plate (Ermopoulos and Michaltsos, 1998) and (3) a simulation of the dynamic behavior of column base connections (Michaltsos and Ermopoulos, 2001). Another analytical evaluation of the bearing stress distribution under the base plate, acted upon by axial forces and flexure, is presented by Sophianopoulos et al. (2005). In addition, Stamatopoulos & Ermopoulos (1997) developed moment-axial interaction curves for the ultimate behavior of column base connections.

The poor performance of steel frame base plate connections was revealed after Northridge (1994) and Hyogo-ken Nanbu (1995) earthquakes. Midorikawa (1997) carried out the statistical analysis of the structural damage for Hyogo- ke Nanbu (1995) earthquake. In this earthquake, column base plate connection damage occurred more commonly than other structural elements. Many studies have been conducted to improve the seismic performance of the base plate connection (Astaneh et al. 1992, Fahmy et al. 1999, Gomez et al. 2010).

However, since these elements are not replaceable, any damage or permanent deformation here can result in building demolition. So, there is a need to develop the base connections that sustain almost no damage during a major earthquake.

Most of the work to develop a low damage steel structure is focused on the moment resisting beam to column joint (Clifton 2005, MacRae et al. 2010) and the brace (Chanchí Golondrino et al. 2012). However, even with

[1]*Lecturer, Dept. of Civil Engineering, Ahsanullah University of Science and Technology, Dhaka-1208, Bangladesh*
[2] *Professor, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1205, Bangladesh.*
mantakamomo@gmail.com

these features, a building with damaged column bases may not be a low damage building. Previously although many experiments have been conducted to investigate the response of Wsection subjected to major axis bending attached to base plate, a very few tests have been performed using HSS sections. There also exists no design method for characterizing the base plate with more than four anchor rods. Kavinde et al (2014) investigated the seismic response of exposed hollow steel section columns to base plate connections through a series of eight experiments and proposed a new design method that explicitly incorporates the third row of rods in case of base connection with eight anchor rod layout.

As conducting experimental studies is both costly and time consuming the present study is emphasized on the numerical simulation of column base connection with square hollow structural section (HSS) column for better understanding their behavior under seismic loading. For verification purposes this model is used to simulate the experimental study done by Kavinde et al (2014).

Methodology of the Study

By using ANSYS 16.2 a numerical model of column base connection is developed considering material nonlinearity. Qualitative sketch of the model is shown in Figure 1. Column and base plate are modeled with SHELL181 element while COMBIN39 is used to model the anchor rods and to simulate the contact between base plate and concrete footing. To reduce the computation time, in the column finer meshing is done only near the base plate as shown in Figure 2. Figure 4 shows the properties assigned to simulate the anchor rods and the contact between column base plate and concrete footing.

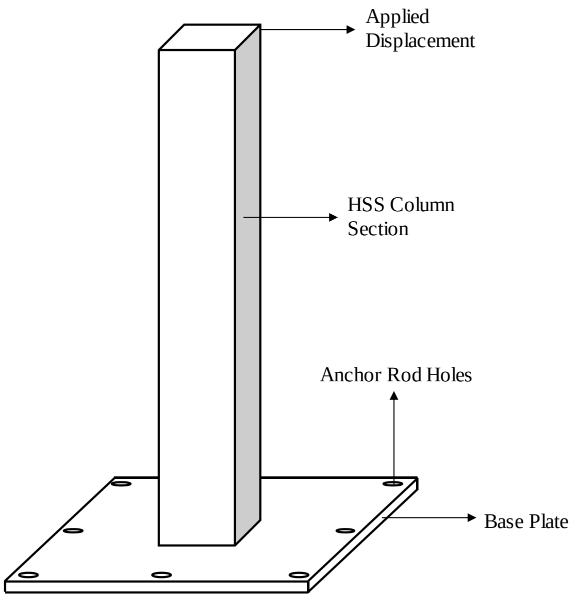


Figure 1. Base connection for HSS Column (8 anchor rods layout)

The peripheral nodes of the circular holes are coupled with the center node. This is done to directly deduce the total force from the central node. The ends of contact elements are kept fixed. The four corner points of the base plate is laterally restrained in both X and Y direction. Displacement is applied at the top of the column and the resulting deformation can be shown in Figure 3.

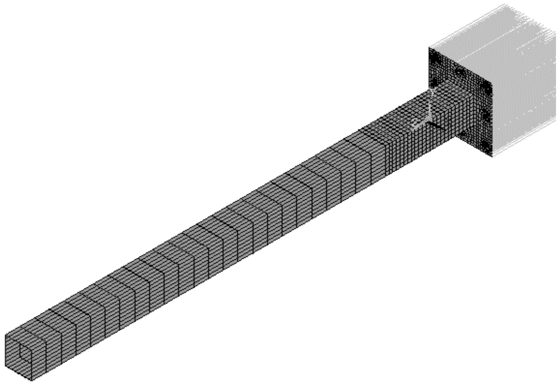


Figure 2. Meshing of Column

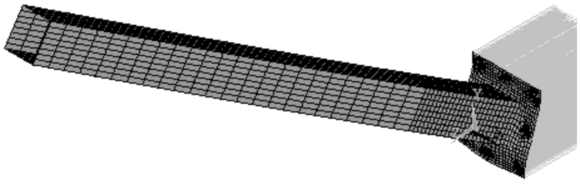
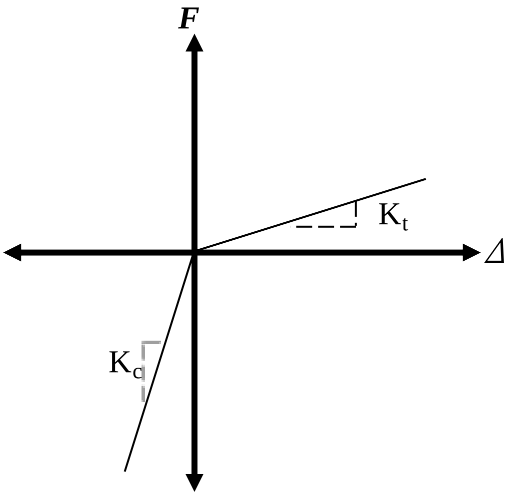
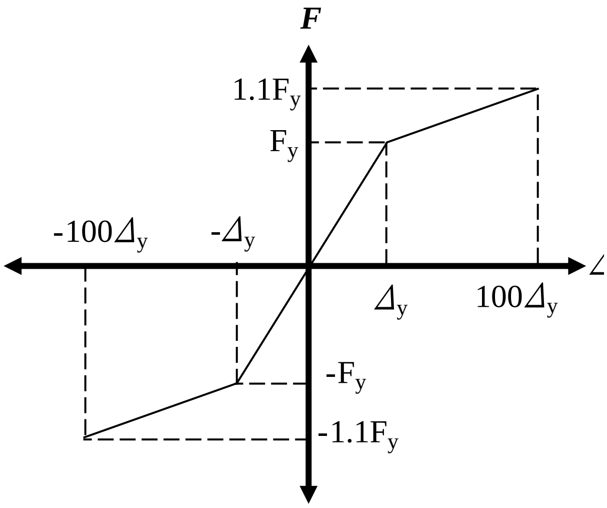


Figure 3. Deformed Shape



(a)



(b)

Figure 4. Real Constant (a) Contact Spring (b) Anchor Rod

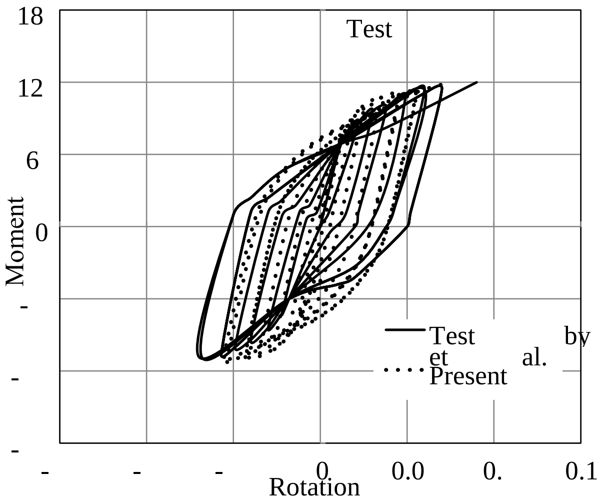


Figure 5. Verification of the model

The model is verified with the experimental data presented by Kavinde et al. (2014) as shown in Figure 5. Material and section properties for the parametric study are given below in Table 1.

Table 1. Material and Section Properties

Column Size (mm)	HSS203X203X9.5
	HSS229X229X9.5
Yield strength of Column material(Mpa)	414
Base Plate Size (mm)	457X457
Yield strength of Plate material(Mpa)	337
Youngs Modulus(Mpa)	200000
Poisson's Ratio	0.3

Result and Discussion

This study mainly focuses on the contribution of anchor rods in resisting tension caused by the bending moment at the base plate. For this study, P=0.

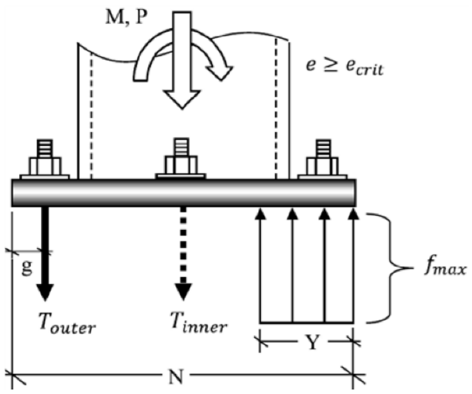


Figure 6. Stress distributions for base connection (Kavinde et al (2014))

The ratio of tension resisted by inner row of rods and that of outer row is determined for column sections HSS203X203X9.5 and HSS229X229X9.5. This ratio is defined *k* as shown in Eqn 1 as proposed by Kavinde et al.(2014).

$$T_{inner} = k \times T_{outer} \tag{1}$$

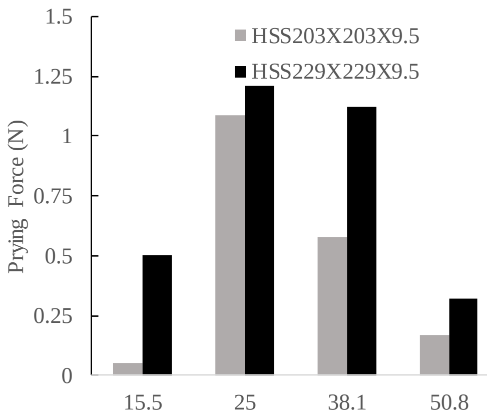


Figure 7. Prying force at baseplate corner for applied plastic bending.

Plastic bending moment is applied to both the columns and the value of *k* is studied for different baseplate thicknesses. The prying force is obtained for the analysis and shown in Figure 7. The minimum baseplate thickness to avoid the prying action is found 15.5 mm. Figure 8 and 9 show the variation of *k* with base plate thickness. From these graphs it can be concluded that as the displacement increases the base plate yields a linear relationship between the inner and outer row of rods in terms of resisting tension.

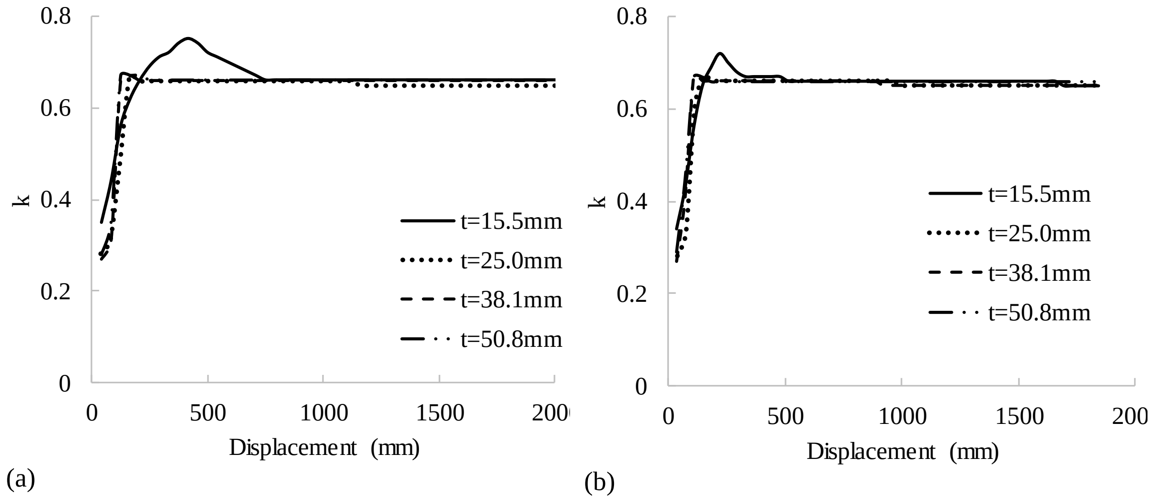


Figure 8. Variation of k with base plate thickness t for column sections (a) HSS203X203X9.5 and (b) HSS229X229X9.5

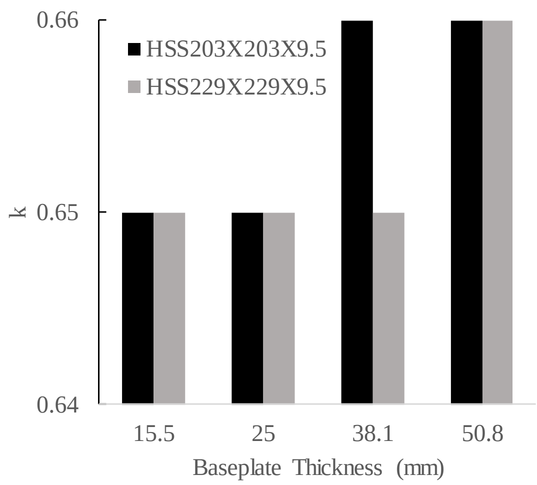


Figure 9. Comparison of k value for different base plate thickness

As shown in Figure 6 there are three unknowns (T_{outer}, T_{inner}, Y) with two equilibrium equations namely force equilibrium and moment equilibrium equation. By introducing the linear relationship as shown in Eq. 1 this indeterminate problem can be made determinate and analysis for the connection becomes simple. From Figure 8 the value of *k* can be taken as 0.65~0.66.

Conclusion

The aim of this study is to observe the behavior of column base connection with eight anchor rods layout under lateral loading. When the displacement is small the major portion of the load is carried by the outer row of anchor rods. But at higher displacement both the inner and outer row of anchor rods contribute to resist tension and the relation between them become linear in terms of tensile resisting capacity.

Notations

P	=	Axial load
M	=	Bending moment
E	=	Load eccentricity
e_{crit}	=	Critical eccentricity
T_{outer}	=	Tension forces in outer row of rods

T_{inner} = Tension forces in inner row of rods
Y = Bearing width
f_{max} = Maximum Bearing Stress

References

Astaneh, A., Bergsma, G., and Shen J.H. (1992), "Behavior and Design of Base Plates for Gravity, Wind and Seismic Loads," Proceedings of the National Steel Construction Conference, Las Vegas, Nevada, AISC, Chicago, Illinois.

Chanchí Golondrino, J., MacRae, G.A., Chase, J Geoffrey, Rodgers, G.W., Mora Muñoz, A., and Clifton, C.G., (2012). "Design considerations for braced frames with asymmetrical friction connections - AFC." STESSA, Santiago de Chile.

Clifton, C.G. (2005). "Semi-Rigid Joints for Moments Resisting Steel Framed Seismic Resisting Systems." *PhD Thesis*, University of Auckland.

Fahmy, M., Stojadinovic, B., and Goel, S. C. (1999). "Analytical and experimental studies on the seismic response of steel column bases." Proceedings of 8th Canadian Conference on Earthquake Engineering, Canadian Association for Earthquake Engineering.

Gomez, Ivan Ricardo, Kanvinde, A., & Deierlein, G. G. (2010). "Exposed column base connections subjected to axial compression and flexure". American Institute of Steel Construction.

Midorikawa, M. (1997*).* "Damage Investigation of Steel Buildings in Specific Areas Observed from the 1995 Hyogoken-Nanbu Earthquake". Japan-US Workshop on Brittle Fracture of Steel Buildings Subjected to Earthquakes, San Francisco.

Kanvinde, P. Higgins, R. J. Cooke, J. Perez and J. Higgins. (2014). "Column Base Connections for Hollow Steel Sections: Seismic Performance and Strength Models" *Journal of Structural Engineering.*

Ermopoulos, J., and Stamatopoulos, G. (1996a), "Mathematical Modeling of Column Base Plate Connections," *Journal of Constructional Steel Research*, 36 (2), 79-100.

Ermopoulos, J., and Stamatopoulos, G. (1996b), "Analytical Modeling of Column Base Plates under Cyclic Loading," *Journal of Constructional Steel Research*, 40 (3), 225- 238.

Ermopoulos, J., and Michaltsos, G.T. (1998), "Analytical Modeling of Stress Distribution under Column Base Plates," *Journal of Constructional Steel Research*, 46 (1-3), Paper No. 136.

PERFORMANCE OF UNREINFORCED MASONRY WALLS IN SHAKING TABLE TEST

M.A. Islam[1], R. Ahsan[2]

ABSTRACT

Masonry is one of the oldest materials used and even now-a-days it is being used for the construction purpose in many countries. But performance of masonry structures in earthquake are very poor. Being a non-homogeneous material, the performance of masonry is very difficult to predict. Moreover, no dynamic loading test is done yet using Bangladeshi materials. Therefore, the objective of this research is to understand the dynamic behavior of unreinforced masonry (URM) walls made by indigenous materials. For this purpose, a half scale masonry room was constructed having dimension 1.83m x 1.52m (6'x5') (length x width), height 1.52m (5') and wall thickness 63mm (2.5"). Then the model was tested on an earthquake simulator. Dynamic testing was done using Imperial Valley Earthquake time history. The test shows that most of the cracks generated at the corner of the specimen. The model underwent an acceleration of 1.05g with severe cracks in the bed joints and head joints. The lateral force is compared with the prescribed shear force (capacity) as per Bangladesh National Building Code (BNBC 1993). The sample failed after reaching the capacity. Therefore, the code is conservative in terms of lateral load resisting capacity.

Introduction

Since Bangladesh situated in the high seismic zone, those buildings including the historical heritages are in very high risk. For simulation of structural behavior of such buildings, performance of embedded joints (head joints and bed joints) is important from the point of view of seismic design. Mostly vertical loading is considered during the design of masonry. While, the structural elements such as walls in URM buildings which were designed for vertical loads only, have to carry lateral load as well during an earthquake. As a result, those structures are vulnerable to earthquake because there is no ductility provision, which is necessary to withstand a certain level of earthquake. The heavy damage inflicted on masonry structures by some historic earthquake such as earthquake in 1987 in Srimangal, Bangladesh; 1997 in Umbria-Marche, Italy; 2005 in Kashmir, Pakistan; 2008 in Wenchuan, China; 2010 in Darfield, New Zealand; 2015 in Gorkha, Nepal all especially emphasized the high seismic vulnerability of unreinforced masonry structures. Therefore, complicated and intensive research on the seismic behavior of masonry structures is essential. Both experimentally and theoretically have gained much attention since the 1990s in different countries. A number of experimental researches e.g. In-plane tests (Fam et. al., 2002; Capozucca, 2011; Elgwady et. al., 2002), out of plane tests (Derakhshan and Ingham, 2008; Simsir et. al., 2004) and shake table tests (Elgwady et. al., 2002; Simsir et. al., 2004; Hanazato et. al., 2008; Ersubasi and Korkmaz, 2010) were conducted in different countries using their indigenous materials and testing equipment. But in Bangladesh, there are very few experimental evidence/results of lateral load resistance capacity of URM wall/buildings and no actual dynamic loading test have been conducted yet now.

In Bangladesh, there are very few (Das, 2016; Asif et. al., 2017) experimental evidence of lateral load resistance capacity of URM wall and no actual dynamic loading test have been conducted. The exact crack pattern will, of course, depend on the wall boundary conditions and the aspect ratio of the URM elements. Seismic actions are bidirectional and the URM can perform in both in-plane and out-of-plane direction. Therefore, the objective of this research is to understand the overall dynamic behavior, in-plane and out of plane behavior of walls as well as the failure pattern of masonry structures with retrofit (using wire mesh) and without retrofit under shaking table tests in context of Bangladesh.

Experimental Program

Primary focus of this research program is to focus the dynamic behavior of half scale unreinforced masonry

[1]*Lecturer, BUET-Japan Institution of Disaster Prevention and Urban Safety, Dhaka-1000, Bangladesh*
[2]*Director, BUET-Japan Institution of Disaster Prevention and Urban Safety, Dhaka-1000, Bangladesh*
Email of Corresponding Author- ai.buet08@gmail.com
(URM) walls. For this purpose, a half scale URM room was constructed. This section describes the materials used for the specimen construction, construction, and testing procedure.

Description of Model Material Properties

The bricks used in the test structure were sized to be 1/2 of Bangladeshi bricks. The dimensions of the scaled bricks are 127mm x 57mm x 38mm (5" x 2.25" x 1.5") (L x W x H). The average compressive strength of the scaled bricks was 2114 psi. Local sand was used for the construction of wall (brick joining) and Sylhet sand was used for base and slab construction. Type-M2 mortar with cement: sand in 1:4 proportions were used in the construction of the model. This type of mortar is used in the local construction practice in Bangladesh. Compressive strength of mortar was 10 MPa (21 days).

Foundation pad casting and curing

The foundation pad was design to serve as an interface between the earthquake simulator platform and the structures. It also provides a lifting element for transportation of the structures via the overhead crane. The pad formed the shape of a rectangular ring and had dimensions of 7' x 6' with 8" thickness. The rectangular ring was 16" wide. To serve the interface requirements, the pad had 24 holes for bolting to the simulator platform (shaking table) and was roughed on its top surface along the footprint of the structures to increase the bond with the base mortar joint. Amount of reinforcement was more than required to prevent the premature failure of the foundation pad before the failure of structure. Figure 1 shows the reinforcement used in the foundation pad. Total weight of the foundation pad is 1.24 ton.

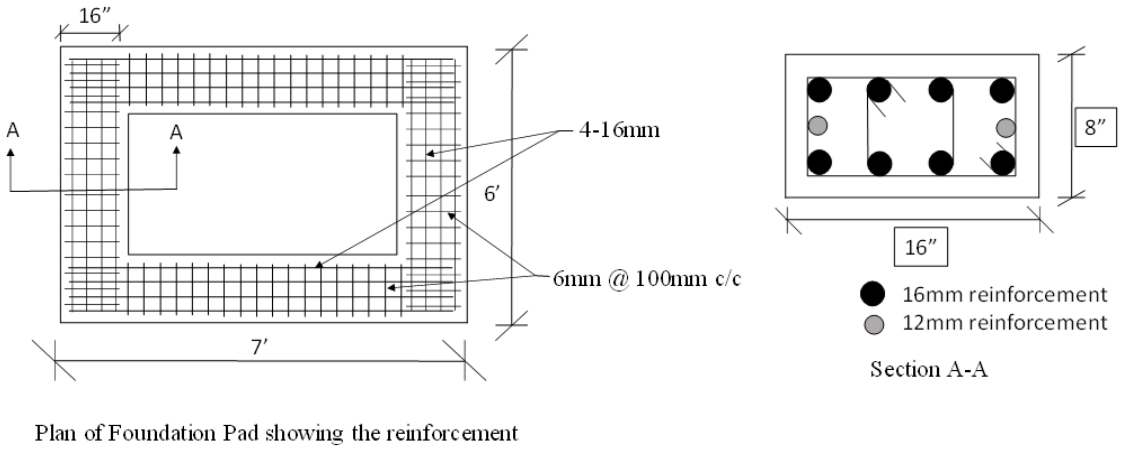


Figure 1. Detailing of foundation pad and cross section

Masonry room construction

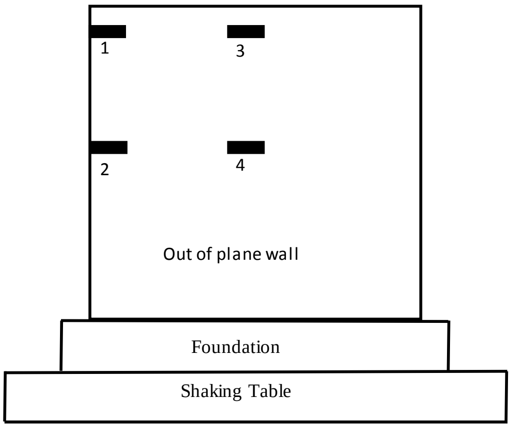
Masonry room was constructed on the foundation pad after placing the foundation pad on the shake table. The experimental model was built using a 1:2 reduced scale, taking in account Cauchy’s law of similitude. The material properties of the experimental model should be equal to the prototype, the model represents the typical room size of the Bangladeshi masonry structure. The prototype was 12' x 10' (length x width) with 10' height. Typical wall thickness of a masonry building in Bangladesh is 5". Keeping this dimension in mind, the size of model was kept 6' x 5' (length x width) with 5' height and 2.5" wall thickness. Walls were constructed in stretcher bond. The thickness of mortar used in the construction is 10mm. No openings were kept because opening in one or two side may create torsion and stiffness degradation. Total weight of the masonry model is 1.24 ton. The slab was design considering the loads comes from upper storey. The model was tested considering two storey building and 220 lb/ft comes from the upper storey.

Axial load estimation

Considering two storey building, axial load on the bottom storey’s wall was calculated and scaled down according to the rules of the scaling. One hundred and four weights were used which were rectangular in shape and nominally weighed 45 pounds (20 kg) each. Of the One hundred and four weights used, eighty-four weights (84 nos*20 kg=1680 kg) were kept along the periphery of the room to simulate the axial compression of the wall and remain twenty weights (20 nos*20 kg = 400 kg) were kept at the central area of the building to simulate the live load on the slab. Hence total surcharge weight acting on the slab is 2080 kg that is equal to 2.08 ton.

Instrumentation

Two piezo-resistive accelerometers (Capacity: 500mV/g) were used during the dynamic testing of masonry building. One accelerometer mounted to the earthquake simulator while the other was attached to the slab of the masonry room. Two Laser Displacement Sensors (LDSs) were positioned to the in-plane wall to record displacement of the wall in the direction of testing while two additional LDSs were added to measure out of plane displacements of the wall. Figure 2 shows location of LDSs and complete instrumentation.



a) Location of LDSs

b) Complete Experimental Setup

Figure 2. Instrumentation and complete setup for test

Dynamic Testing

Time history of Imperial Valley Earthquake was used for dynamic testing. Figure 3 shows the time history of Imperial Valley Earthquake used in this research. Test was conducted with incremental acceleration.

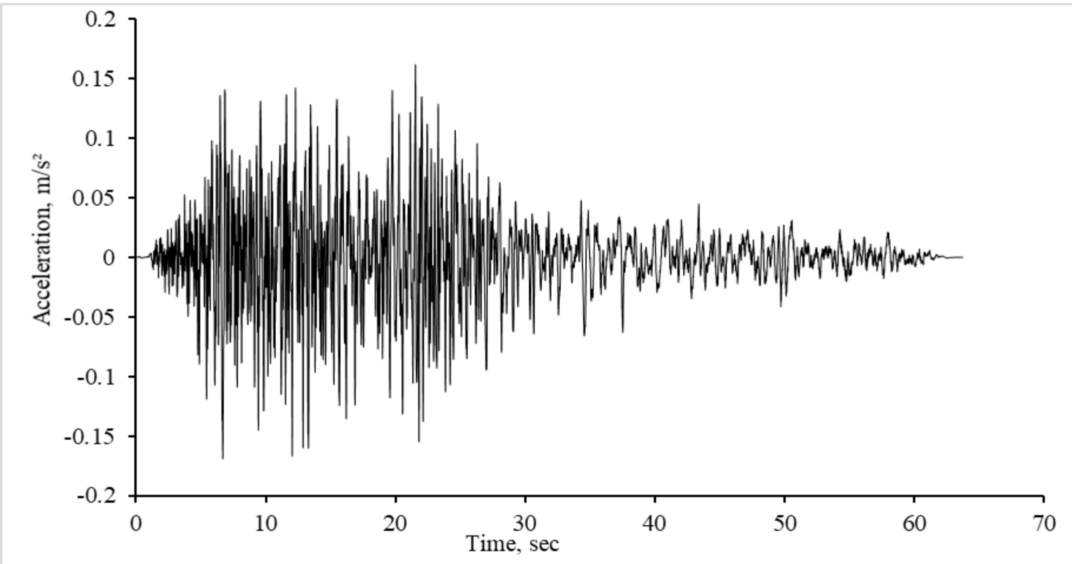


Figure 3. Time history of Imperial Valley Earthquake

Between each earthquake simulation, visible damage was noted and recorded. Prior to their testing, model structure was painted white to facilitate crack identification and marking. Cracks were marked with colored pens, with a different color used for each run that induced new cracks. The test was conducted in the Earthquake Engineering Lab of BUET-JIDPUS in a unidirectional shaking table.

Results and Discussion

The cracks generation or damage pattern and displacement characteristics of unreinforced masonry walls are in the following sections. The results presented here for the model structure. To predict for prototype Cauchy's law of similitude (Islam, 2018) need to be applied.

Damage Pattern

Total nine seismic motion were run and the visible cracks were summarizing in Table 1. No crack was observed in the first seven run in which acceleration range was from 0.27g to 0.76g. First horizontal crack was observed at 0.83g in east wall which is the out of plane wall. For the next runs (at 0.92g and 1.05g acceleration), the cracks generated in bed and head joints of in-plane and out-of-plane walls.

Table 1. Crack distribution in different acceleration

Run	Table Acceleration (g) of Reference Model	Crack Distribution
1	0.27	no crack
2	0.36	no crack
3	0.41	no crack
4	0.59	no crack
5	0.66	no crack
6	0.76	no crack
7	0.83	visible crack in out of plane wall (east) in bed joint
8	0.92	visible crack in out of plane wall (east), In-Plane wall (north, south) in head and bed joint
9	1.05	visible crack in out of plane wall (east), In-Plane wall (north, south) in head and bed joint. Previous cracks were extended

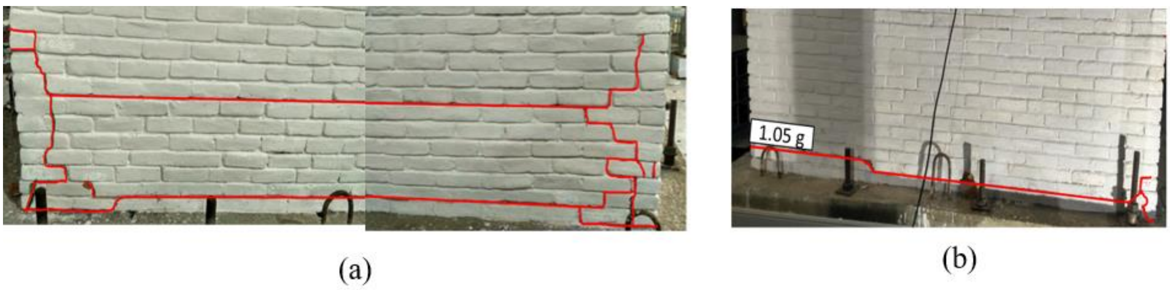
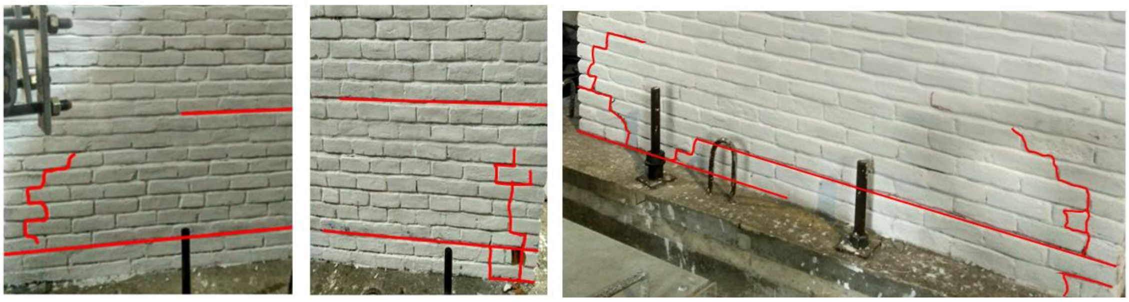


Figure 4. Cracks in the in-plane walls [a) north wall b) south wall]

It should be stressed that almost all cracks developed along the unit-mortar interface, even if some brick units were also affected with minor cracks. Horizontal cracks appear to be the result of lack of in-plane flexural resisting mechanism associated with low values of vertical pre-compression. All stair-stepped cracks are localized in the corner of the walls. At this stage, the cracks developed in the in-plane (north and south side) and out-of-plane walls (east and west side) walls covering the whole lower one third length of the walls. Figure 4 and 5 depicts the cracks in-plane and out-of-plane walls.

Displacement Characteristics

For each test run, displacements at four points of the structure were measured by the laser sensors; two at mid height of the walls (In-plane and Out-of-plane) and two at the top of the walls. The displacements for the in-plane wall was plotted by joining the displacement readings at top and middle height at the instantaneous time when absolute top displacement was maximum. Joining these points eventually lead to a deflected shape of the wall. The same thing was done for the Out-of-plane wall. Through this process the approximate deflected shapes of both the in-plane and out of plane wall during the time of peak displacement at top can be depicted for different test runs. The results are shown in Figure 6 and 7 for in-plane wall and out-of-plane wall respectively.



(a) (b)

Figure 5. Cracks in the out-of-plane walls [a) east wall b) west wall]

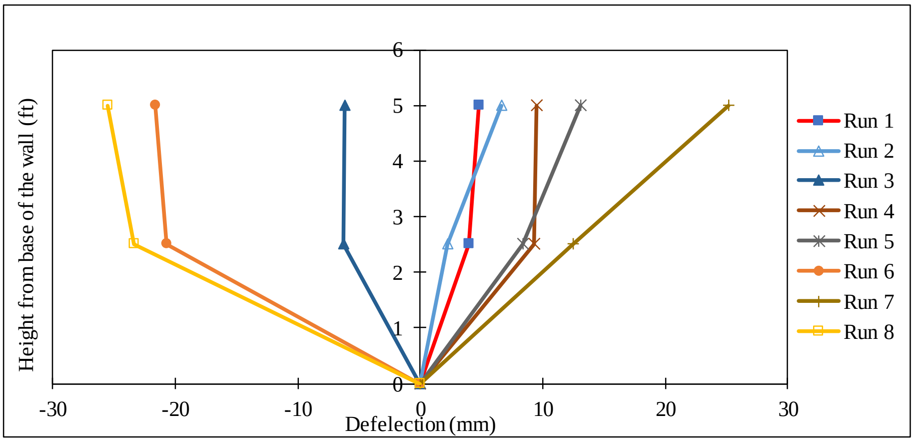


Figure 6. Approximate deflected shape of In-Plane wall for maximum top deflection

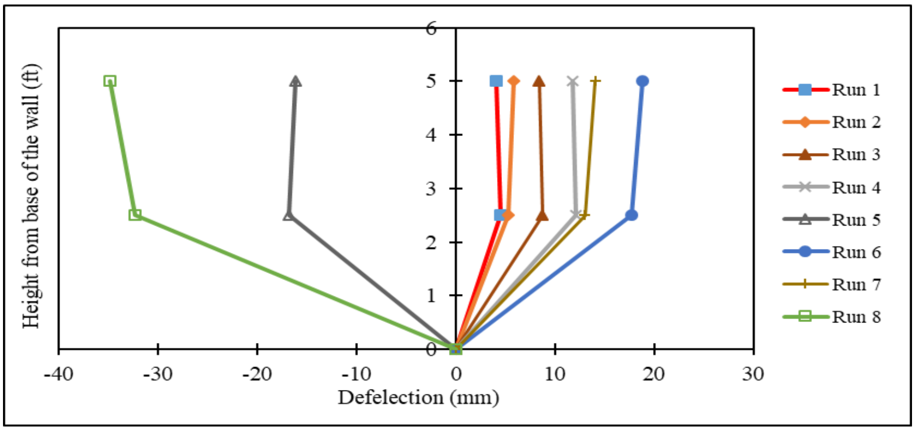


Figure 7. Approximate deflected shape of In-Plane wall for maximum top deflection

It is seen that displacement increase as the acceleration of the excitation increases. Out of place wall experienced more displacement, which is 34.7 mm for the excitation of 0.92g (Run 8). At the same excitation, in-plane wall also experienced maximum displacement, which is 25.5mm.

Conclusions

Based on the results obtained from this experiment are summarized here as a conclusion. The following observations are drawn from this experiment:

I. The cracks are mostly localized in the corner of the walls and within the lower one-third of the walls. Therefore, corners of the walls are more vulnerable.
II. First crack was observed in the out-of-plane wall. Moreover, out-of-plane wall experienced more displacement than in-plane wall. So, special care must be taken in the design of out of plane walls because those will be more vulnerable than in-plane walls.
III. Cracks are also observed in the base-wall intersection. Therefore, proper precautionary measures should be taken in the base wall connection.

Limitations

There was no opening in the walls. Therefore, the results will be different for the walls having opening. The additional weights on the slab could not properly simulate inertia force rather those weights provide some damping force.

Acknowledgments

Authors are very much grateful to Dr. M.A. Ansary, Professor, Department of Civil Engineering, BUET for his support. Authors are also grateful to technical personnel and faculty member of BUET-JIDPUS for their assistance in this research work.

References

Asif, M. M., Alam, M. Z. and Ahsan, R., "Cyclic Load Test on Ferrocement Retrofitted Masonry Wall Units," Proceedings, International Conference on Disaster Risk Mitigation, Dhaka, Bangladesh, September 23 - 24, 2017.

Capozucca, R. "Experimental Analysis of Historic Masonry Walls Reinforced by CFRP Under In-Plane Cyclic Loading," Composite Structures, Vol. 94, pp-277-289, 2011.

Das, T., "Behaviour of Masonry Wall Retrofitted With Ferrocement Under Lateral Cyclic Loading," M. Sc Engg. Thesis, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, 2016.

Derakhshan, H., and Ingham, J. M., "Out-of-plane testing of an unreinforced masonry wall subjected to one-way bending". In Australian Earthquake Engineering Conference, AEES 2008. Ballarat, Victoria, Australia.

Elgwady, M.A., Lestuzzi, P., Badoux, M., "Dynamic In-Plane Behavior of URM Wall Upgraded With Composites," 3rd ICCI'02, San Francisco, USA, 2002, Paper No. 009.

Fam, A., Musiker, D., Kowalsky, M., and Rizkalla, S., "In-Plane Testing of Damaged Masonry Wall Repaired With FRP," Advanced Composite Letter, Vol. 11, No. 6, 2002.

Hanazato, T., Minowa, C., Narafu, T., Imai, H., Qaisar Ali, Kobayashi, K., Ishiyama, Y. and Nakagawa, T., "Shaking Table Test of Model House of Brick Masonry For Seismic Construction," The 14th World Conference on Earthquake Engineering, Beijing, China, 12-17 October 2008.

Simsir, Can. C., Aschheim, M.A., Abrams, D.P., "Out of Plane Dynamic Response of Unreinforced Masonry Bearing Walls Attached to Flexible Diaphragms," 13th World Conference on Earthquake Engineering, Vancover, B.C., Canada, Paper No. 2045, 1-6 August 2004.

Islam, M.A., "Dynamic Behaviour of Unreinforced Masonry Building," M. Sc Engg. Thesis, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, 2018.

STRUCTURAL VULNERABILITY AND SOCIAL READINESS IN MYMENSINGH, BANGLADESH

M.A. Islam[1], U. Barua[2], T. Akter[3], R. Ahsan[4], M.S. Akther[5], I. Islam[5], M.A. Ansary[6]

ABSTRACT

Vulnerable structures are prone to damage or collapse in an earthquake and can cause loss of life and property. To increase resilience, it is important to know the condition of the existing structures. The objective of this paper is to present the structural vulnerability of buildings and social readiness of ward 14, Mymensingh Municipality, Bangladesh. For this purpose, total 707 buildings were assessed according to the methodology of Rapid Visual Screening (RVS) prescribed by FEMA P-154. To know the social readiness, household questionnaire survey of 700 sample households in the study area were carried out. The results reveal that 36% buildings are below RVS cut-off score which are vulnerable to earthquake. On the other hand, only 44% respondents are aware that their area is vulnerable to earthquake. In addition, only 26% know that their buildings are vulnerable and among 430 owners, 242 are willing to invest money for building strengthening.

Keywords: Earthquake vulnerability, RVS, natural disaster, building strengthening.

Introduction

Bangladesh is one of the disaster prone countries. It is among the most at risk countries in the world with its high population density and rapid urbanization. Mymensingh town lies in an active earthquake prone area of Bangladesh (Sarker et. al., 2010). In Great Indian Earthquake of 12 June 1897, this city was completely demolished due to a surface wave magnitude of 8.1 (Sarker et. al., 2010). The Indian Plate is moving northeast at a rate of 5 cm/year (Molnar and Tapponier, 1975) slowly colliding with the Eurasian Plate forming the Himalayan Mountains. This collision formed the diverse form of land and giving rise to the severest earthquake. Enormous Dauki fault located in the northern border of Bangladesh. Movement along this fault formed the large Shillong Plateau. There is a high possibility of large earthquake around the Himalayan region because of differential energy accumulation in this region (Bilham et. al., 2001). Moreover, many historical earthquakes hit Mymensingh during the period of 1762 to 2009. Table 1 shows historical earthquake affected Mymensingh.

Table 1. Some historical earthquakes that affected Mymensingh

Name of Earthquakes	**Fault Name**	**Magnitude**
1885 Bengal Earthquake	Modhupur	7.0
1897 Great Indian Earthquake	Assam	8.1
1918 Srimangal Earthquake	Sub-Dauki	7.6
1923 West Durgapur Earthquake	-	7.1
1930 Dhubri Earthquake	Dhubri	7.1
2008 Modhupur Earthquake	Modhupur	4.2
2008 Haluaghat Earthquake	Haluaghat	4.8
2008 Mirzapur Earthquake	Modhupur	4.6
2015 Gafargaon Earthquake	Kishorganj	4.0

Building vulnerability assessment provides an understanding about the vulnerability of a certain building and

[1] *Lecturer, BUET-Japan Institution of Disaster Prevention and Urban Safety, Dhaka-1000, Bangladesh.*
[2] *Lecturer, Department of Urban and Regional Planning, BUET, Dhaka-1000, Bangladesh.*
[3] *Graduate Student, Department of Urban and Regional Planning, BUET, Dhaka-1000, Bangladesh.*
[4] *Director, BUET-Japan Institution of Disaster Prevention and Urban Safety, Dhaka-1000, Bangladesh.*
[5] *Professor, Department of Urban and Regional Planning, BUET, Dhaka-1000, Bangladesh.*
[6] *Professor, Department of Civil Engineering, BUET, Dhaka-1000, Bangladesh.*
Email of Corresponding Author- ai.buet08@gmail.com

its susceptibility to suffer damage, and how this vulnerability is affected by the various structural and non-structural components. As a whole, these assessments reveal general characteristics of buildings in an area collectively. These outcomes may be used to develop prevention and mitigation measures (e.g. strengthening and retrofitting), as well as revision of building code provisions and guidelines (NORSAR, 2018). Socio-economic vulnerability assessment will help to provide community's characteristics leading to their earthquake vulnerability. It also provides the potential impact of earthquake on their social and economic life (Lal et. al., 2011). This assessment is necessary to ensure community-based risk reduction considering socio-economic context of local people, their risk perception and opinion for contingency planning.

Therefore, the objectives of this paper is to present the structural vulnerability of ward 14, Mymensingh Municipality. This paper also includes the level of awareness of the people. This is the outcomes of a project run by BUET-Japan Institute of Disaster Prevention and Urban Safety (BUET-JIDPUS) on April to November 2017.

Methodology

For the purpose of data collection, ward 14 of Mymensingh Municipality is divided into seven clusters. Buildings and socio-economic data were collected from the study area using appropriate tools. For building vulnerability, Rapid Visual Screening (RVS) Method prescribed by Federal Emergency Management Agency (FEMA), USA was used. Total 707 buildings were screened for the building vulnerability assessment. The screening process was conducted by an engineer who filled up a data collection form. Building identification information, including its use and size, a photograph of the building, sketches, and documentation of pertinent data related to seismic performance were the content of the survey form.

Socio-economic data were collected by questionnaire survey method. The questionnaire survey was conducted through a face to face interview of 700 households. The socio-economic includes the perception of the community regarding earthquake. Both socio-economic and building vulnerability assessment were conducted in the same building.

Data Analysis

According to the methodology of RVS method, the surveyed buildings are classified into two categories: a) buildings those are risk to life and b) those seismically hazardous buildings that should be investigated extensively by a design professional experienced in seismic design. Pertinent data related to seismic performance were focused in the results e.g. vertical and plan irregularity, seismic force resisting system, structural type, clear distances from surrounding structures, overhang, non-structural hazards, number of storey etc. To understand the socio-economic context of the area, statistical analysis of the collected data from socio-economic survey was performed.

Results and Discussion

The results of the study for Ward 14, Mymensingh Municipality is presented in the following sections. Vulnerability of the buildings is presented based on RVS score. The awareness level of the people is presented based on the statistical analysis of the socio-economic survey.

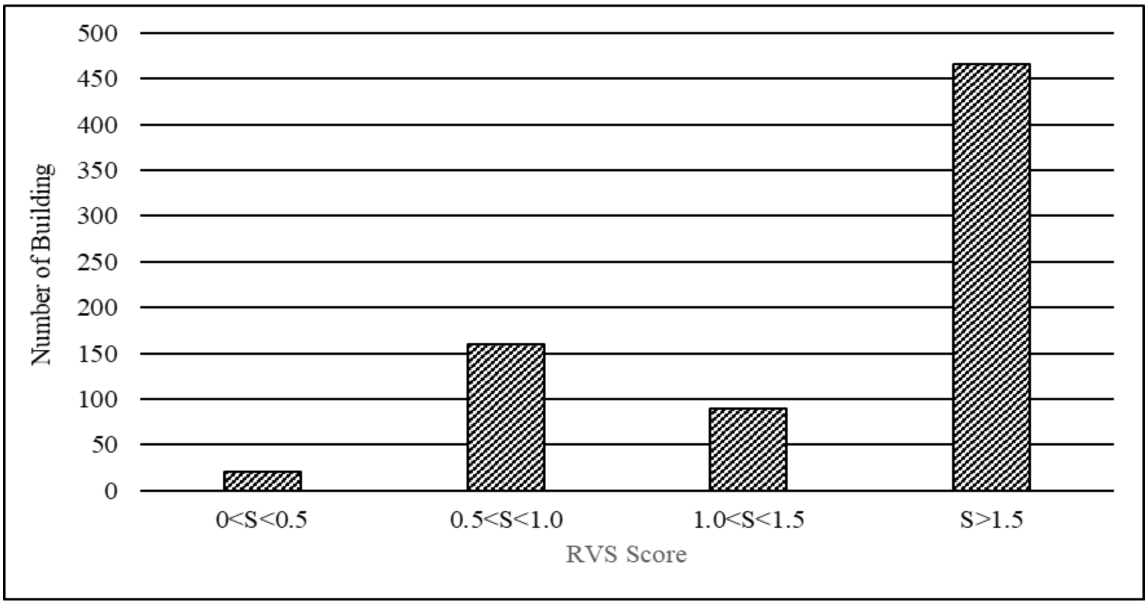
Vulnerability of Buildings Based on RVS score

A basic score was applied to the building considering the structural system. Then, the basic score was modified by adding or subtracting scores based on special features of the building and hence final score is obtained. The cut off score for the buildings has been set as 1.5 for this study considering the seismicity of the regions and probability of building collapse. Building having higher scores will perform better than those having lower score. RVS score of the surveyed buildings are presented in Figure 1. According to this method, about 64% buildings having a score greater than cut-off score. But, about 36% buildings having score less than cut-off score are dangerous and need to take effective measures for those to minimize damage and losses of life and resources.

Survey area has more RCC structure than URM. But, about 30% buildings are unreinforced masonry (URM), which are much more vulnerable to Earthquake. 87% of the surveyed buildings had a regular type of plot shape and about 13% buildings having irregular shape. Buildings with irregular plan tend to be more vulnerable to earthquake.

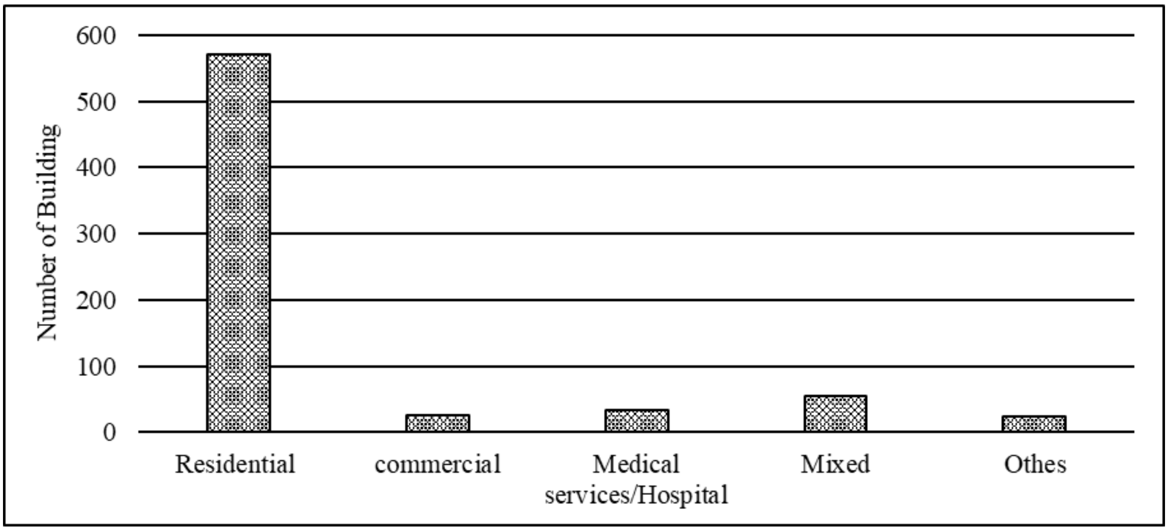
In the surveyed area residential building is much more and it is about 83%. Health complex is about 7% and mixed used buildings are about 5%. Commercial buildings are about 3.5%. Figure 2 depicts the number of buildings according to their usage.

One storied building is predominant in the surveyed area and it is about 42%. The second dominant buildings are 2 and 3 storey and they are 17% and 16.7% respectively. 4 storey and 5 storey buildings are only 14% and 5% respectively. High rise buildings are not much more. It is about 4% in total (including 6 to 10 storey buildings). It has been found that buildings having an average floor area of 500-1500 sq. ft. are dominant in the area surveyed.



(Source: Field survey, 2017)

Figure 1. Relations between Number of Buildings & Building Score (RVS)



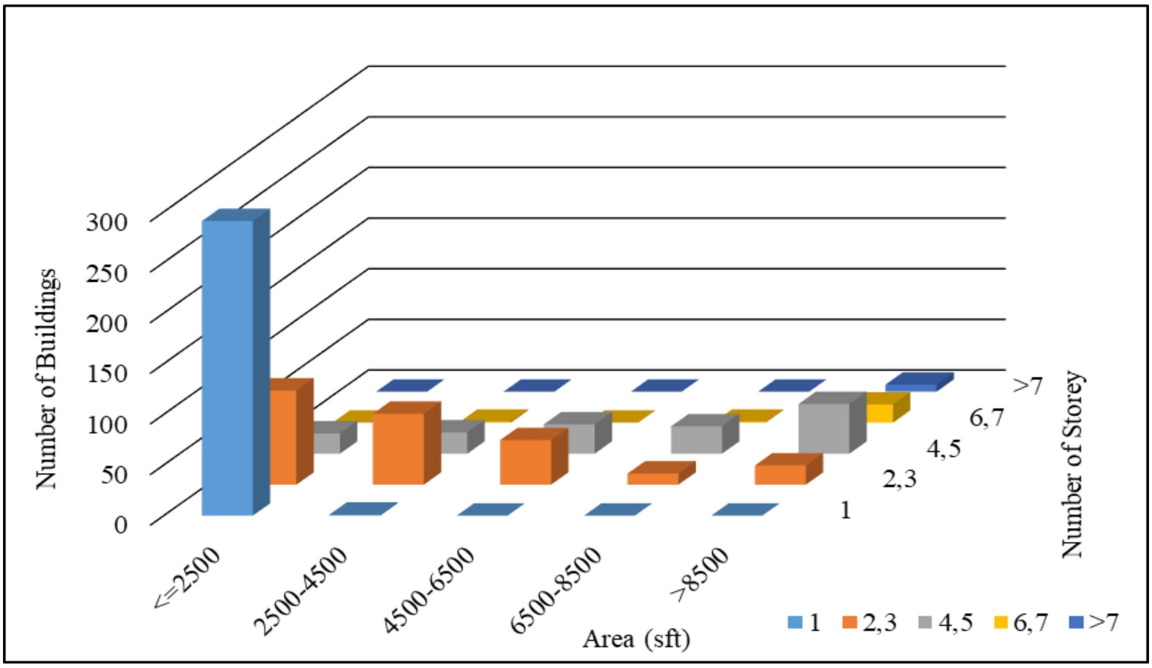
(Source: Field survey, 2017)

Figure 2. Relations between numbers of Buildings with building usage

Among the RCC structure (491 nos) surveyed, percentage of soft storey is about 4%, but those are much more vulnerable in Earthquake. To prevent the building collapse of those soft storeys building in earthquake, effective measure should be taken. It has been found that buildings having setback is only 18% but they are vulnerable in earthquake.

Only 4% buildings tend to have overhung (3ft-5ft) (mostly verandah). But, Heavy overhang makes a structure risky for earthquake.

14% buildings tend to have pounding effect. Buildings with pounding effect tend to be more vulnerable during earthquake. Figure 3 shows the distribution of number of buildings with number of storey and floor area.



(Source: Field survey, 2017)

Figure 2. Relations between Number of Buildings, Number of Storey and Area (sft)

Awareness of the People

To understand the actual level of awareness about earthquake of the local people, their awareness status has been analyzed with respect to their social context.

Though the area is vulnerable to earthquake, only 44% have the awareness about this. This is actually alarming, as these 56% (392 out of 700) respondents do not have any idea about the earthquake vulnerability of the area. So they don't know the actual reasons and are not aware of the precautions that should be taken. So they can be the worst victims of earthquake. Table 2 shows the response of the people about the vulnerability of the area along with their duration of stay in the area.

Table 2. Distribution of respondents according to their perception regarding earthquake vulnerability of the area and duration of stay (Source: Field survey, 2017)

Perception / Duration of stay in the area	Area vulnerable to earthquake	Area not vulnerable to earthquake	Total
Less than 1 year	3%	4%	7%
1 year to 5 years	8%	11%	19%
5 years to 10 years	4%	5%	9%
10 years to 15 years	4%	6%	10%
15 years to 20 years	5%	5%	10%
Greater than 20 years	20%	25%	45%
Total	**44%**	**56%**	**100%**

On the other hand, when respondents were asked whether they know about the earthquake vulnerability of their building, only 26% (Table 3) respondents said that they know about earthquake vulnerability of their building. From building vulnerability assessment it has been found that a number of buildings in the study area are vulnerable to earthquake. To ensure safety of the residents, these buildings should be subjected to emergency retrofit.

Owners' knowledge about building vulnerability and willingness for financial investment will be required to strengthen buildings. From Table 4 it can be seen that among 430 owners, 60 of them who have knowledge about their buildings being vulnerable and are willing to invest money for building strengthening. On the other hand 182 owners who don't have any knowledge about building vulnerability but they are willing to invest money. It is notable that 38 owners know that their buildings are vulnerable but they are not willing to invest money to strengthen their buildings. It can also be seen that 150 owners who are not aware of their building vulnerability are also not willing to invest money.

Table 3. Distribution of respondents according to their perception about earthquake vulnerability of their building and ownership status (Source: Field survey, 2017)

Perception / **Building ownership status**	**Building vulnerable to earthquake**	**Building not vulnerable to earthquake**	**Total**
Owner	14%	47%	61%
Tenant	10.6%	24.4%	35%
Government service holder	1.4%	2.6%	4%
Total	**26%**	**74%**	**100%**

Table 4. Willingness of the owners to invest for strengthening building with respect to their perception about the building being earthquake vulnerable (Source: Field survey, 2017)

Willingness / **Perception**	**Willing to invest money for building strengthening**	**Not willing to invest money for building strengthening**	**Total**
Building vulnerable to earthquake	60	38	98
Building not vulnerable to earthquake	182	150	332
Total	**242**	**188**	**430**

Conclusions and Recommendations

This study focused on the structural vulnerability and social readiness of Ward 14 of Mymensingh Municipality. Based on the results obtained from the study following conclusions and recommendations can be drawn.

I. According to the building vulnerability survey, around 36% buildings are in vulnerable condition. To avoid casualties and fatalities in an earthquake, appropriate steps need to be taken for to strengthen of those buildings.
II. Among 430 owners, 242 of them have agreed to retrofit their buildings to reduce vulnerability of earthquake. Further initiatives can be undertaken to encourage, motivate and assist owners to strengthen buildings because only 26% respondents know about their building vulnerability which can create a worst condition in an earthquake.
III. Only 44% respondents know that their area is vulnerable to earthquake. Pourashava should take immediate steps for the awareness building of local people.
IV. Detailed Engineering Assessment (DEA) can be done for those buildings possessing a RVS score below cut off score by an expert in seismic design.

Acknowledgments

Authors are grateful to United Nations Development Programme (UNDP) for providing financial support for this study. Authors are also thankful to Mymensingh Municipality for their assistance in conducting the study.

References

Bilham R, Gaur V.K.and Molnar P. (2001) "Himalayan seismic hazard", *Science*, 293:1442-1444.

Lal, P., Alavalapati, J. R., & Mercer, E. D. (2011) "Socio-economic impacts of climate change on rural United States", *Mitigation and Adaptation Strategies for Global Change*, 16(7), 819.

Molnar P., Tapponier P. (1975) "Cenozoic tectonic of Asia, effects of a continental collision", *Science*, 189(8):419-426

NORSAR (Norwegian Seismic Array). (2018). "Structural Vulnerability Assessment", Retrieved 28 May, 2017, from https://www.norsar.no/r-d/safe-society/earthquake-hazard-risk/structural-vulnerability-assessment/

Sarker JK, Ansary MA, Rahman MS, Safullah AMM (2010) "Seismic hazard assessment for Mymensingh, Bangladesh", *Environmental Earth Science*, 60:643.

GOOD PRACTICES IN THE HANDLING OF FUSION BONDED EPOXY COATED BARS FOR REAPING MAXIMUM PROTECTION AGAINST CORROSION

M. T. Islam[1], M. A. Rahman[2] and I. Ahmed[3]

ABSTRACT

Corrosion of the reinforcing bars embedded in concrete can be caused by intrusion of chlorides, sulphates, sulphides and carbon dioxide which might cause premature deterioration of concrete structures. Structures located in highly saline environment, structures subjected to intermittent wetting and drying (Bridge Piers) and structures exposed to dampness (Roof Slab, Concrete Pavements) are highly susceptible to corrosion damage. Such kinds of corrosion causes serious durability problems and shortens the service life of structures. Epoxy coated bars can be a solution to afore mentioned problems. Corrosion led deterioration becomes a major maintenance issue for bridges, jetties, buildings in offshore and coastal area. A huge amount of public funds are drained in maintenance of those structures. For improved durability and reducing life cycle costs, the use of epoxy coated bars in lieu of conventional black bars can be a judicious choice. In the recent time, the use of epoxy bars has increased and its demand is on the rise. However, it needs special care in handling in order to reap maximum benefit out of this bar. This paper describes the various field handling techniques of epoxy bars during transporting, fabricating and concreting which can be useful for engineers and construction contractors.

Introduction

Corrosion is the chemical or electrochemical reaction between material and its surrounding environment that causes deterioration of the material (ASTM G15). Corrosion in embedded reinforcing steel in concrete is a prime cause of concrete durability related problems. Corrosion of rebar embedded in concrete can occur from chloride diffusion from saline environment due to carbonation process or by any other surrounding acidic environment. Structures at coastal regions, dams, bridge piers, abutments lie in immense risk of corrosion. The structures which are exposed to dampness and intermittent drying and wetting like top floor slabs also possess high risk of corrosion. Epoxy coating on the fusion bonded epoxy coated bars acts as a barrier from corrosion reactions and the rate of corrosion of epoxy bars are 40-50 times less than the uncoated bars (Efaz et al., 2016). As a result, the use of epoxy bar has increased in recent times. However, use of epoxy coated bar needs special care. ASTM A775, ASTM A934 and ASTM D3963 describes the basic requirements of epoxy coated bar.

Fusion Bonded Epoxy Coated Bars

Fusion bonded epoxy coated bars (FBECB) are reinforcing bars coated with thermosetting epoxy resins and other additives which are applied in the powder form on the surface of the reinforcing bars and fused to create a continuous coating (ASTM A775). The powder form additives are applied at a typical temperature of 225^0 C to 245^0 C through spraying it using suitable spray guns on to the hot blast cleaned rebars after it being fluidized (Efaz et al., 2016).

Basic Requirements for Epoxy Coated Bars

In order to reap the maximum benefit out of the epoxy coated bars must fulfill some basic requirements. The basic requirements according to ASTM A775 and ASTM A934 are:

i. Coating thickness
ii. Coating continuity
iii. Coating flexibility

[1]*Postgraduate Student, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, Bangladesh*
[2]*Graduate Research Assistant, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, Bangladesh*
[3] *Professor, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, Bangladesh*
Email of Corresponding Author – tariqulaunto.1993@gmail.com

iv. Coating adhesion

Quality Control Issues of FBECB

Over the time ASTM requirements for fusion coated epoxy coated bars have become more and more stringent in order to ensure proper quality control. The chronology of changes made to ASTM A775 is shown in Table 1.

Table 1. Chronology of Changes Made to ASTM A775

Year	Changed Status	Provision of Prior Version
1981	First version approved	-
1989	Permissible damage reduced to 1%	2%
1989	Introduction of anchor profile of 1.5-4 mil	-
1990	Repair of all damage	Repair of damage > 0.1 in^2
1993	Coating thickness 7-12 mil	90 percent between 5 and 12 mil
1994	Increase bend test to 180^o	120^o
1995	Reduce allowable holidays to less than 1 per foot	2 per foot
1995	No coating deficiency allowed	0.5 percent
1995	Coat within 3-hours	8 hours
1997	Coating adhesion CD test	-
1997	Cover bars stored outside if longer than 2 months	-
2004	Coating thickness increased for larger diameter bars. 7-16 mil (Nos. 6-18)	7-12 for all bar sizes
2004	Clarified individual thickness measurements no single measurement <80% of minimum or >120% of maximum	-
2006	Clarification on thickness measurements added	-
2007	Added patching material requirements	-

Challenges for Fusion Bonded Epoxy Coated Bars

Fusion bonded epoxy coated bars (Epoxy coated bars) are used for its dielectric properties which protects rebar from corrosion and helps to increase the service life and durability of the structure. However, there are some critical issues in implementing this bar in construction industry. These are:

i. One of the main problems of epoxy bars are its bonding problem. In order to get better bonding more development length is to be provided (Xing et al., 2015). As a consequence, more amount of reinforcing bars are needed and this causes increase in the total cost.

ii. With the increase of the thickness of the coating on the bars the bond performance decreases (Anda et al., 2006). Increased thickness of the coating might be useful for better durability but it reduces the bonding among the materials. For this reason the coating thickness must be within the range of 7 to 16 mil (ASTM A775).

iii. Special care is a must to ensure protection against coating damage especially in transportation, field handling, storage, fabrication and casting (ASTM D3963).

Recommended Work Practices for Fusion Bonded Epoxy Coated Bar

The following precautions are necessary for reaping maximum protection against corrosion:

During Transportation, Handling and Stacking

- Coated bars should never be dragged
- Coated bars should be lifted in a way so that minimum sagging occurs.
- Unloading of the coated bars must be near the casting site in order to minimize handling.
- Bundles of coated bars should not be stored on the ground.

- If the coated bars are stored in outdoors, then it is necessary to cover it with opaque material. Because long exposure to sunlight (ultra violet rays) would damage the coating and effectiveness of corrosion protection.
- Coated and uncoated bars should not be stored in a same place

Storing process is further illustrated in Figure 1.

Figure 1. Precautions taken during storage of coated bar

During Cutting, Banding and Welding

- Coated bars should be placed where no corrosive metallic substance are present.
- Coated tie wires should be used for the purpose of tie.
- Coated bars should not be flame cut rather than it should be cut using power shears and chop saws.
- Cut ends, damaged spots, welded areas should be repaired with special epoxy which is compatible with the coating material. If mechanical splices are used if should also be epoxy coated.
- Mandrel should be nylon/Teflon collared while bending

Precaution process during fabrication is demonstrated in Figure 2.

(a) (b) (c)

Figure 2. Precautions taken during fabrication. a) Cut ends being repaired with epoxy, b) Coated tie wires and c) Nylon collared mandrel.

During Concreting

- Extra care is necessary during concrete placing.
- Compaction should be done by using plastic headed vibrators instead of metallic nozzle.
- Free fall of concrete during placing should be avoided.
- If partial concreting is made then special measures should be taken for ensuring protection against UV rays for the uncovered parts.

The necessary precaution during concreting is illustrated in Figure 3.

Figure 3. Precautions taken during concreting.

Conclusions

Corrosion of the embedded rebar is one of the main obstacles for ensuring durability of concrete structures. Fusion bonded epoxy coated bars not only reduces the corrosion probability but also improves the durability of structures and hence it prolongs the service life of a structure. The effective corrosion protection with the use of epoxy coated bar would require stringent field handling and compliance to be met. Without special care for transporting and handling of epoxy coated bars, protection from corrosion initiated problems cannot be reaped. Poor performance of epoxy coated bars has been attributed to improve field handling practices in project like Florida Keys (Bridge).Both field engineers and field workers must be made aware of the standard requirements (ASTM A775, ASTM A934 and ASTM D3963) during manufacturing, transportation, fabrication and concreting. Moreover, the necessary work practices must be included in the country's codes and standards.

References

Anda, L. D., Courtier, C. and Moehle, J. P. (2006) "Bond strength of prefabricated epoxy-coated reinforcement", *ACI Structural Journal,* 103(2), 226-234.

ASTM Standard A775/A775M (2004) "Standard specification for epoxy-coated steel reinforcing bars", *ASTM International,* West Conshohocken, PA, USA.

ASTM Standard A934/A934M (2004) "Standard specification for epoxy-coated prefabricated steel reinforcing bars", *ASTM International,* West Conshohocken, PA, USA.

ASTM Standard D3963/D3963M (2000) "Standard specification for fabrication and jobsite handling of epoxy-coated steel reinforcing bars", *ASTM International,* West Conshohocken, PA, USA.

ASTM Standard G15 (2008) "Standard terminology relating to corrosion and corrosion testing", *ASTM International*, West Conshohocken, PA, USA.

Efaz, I. H., Mahmood, T., Manzur, T. and Ahmed, I. (2016) "Scope and application of fusion bonded epoxy coated rebars" as a viable solution for corrosion problems in Bangladesh: a review", *BUET-ANWAR ISPAT 1st Bangladesh Civil Engineering SUMMIT.*

Xing, G., Zhou, C., Wu, T. and Liv, B. (2015) "Experimental study on bond behavior between plain reinforcing bars and concrete", *Advances in Materials Science and Engineering.*

COMPARATIVE ANALYSIS OF RC FRAME STRUCTURES FOLLOWING BNBC 1993 AND 2017 VERSIONS OF CODE FOR HIGH SEISMIC AND HIGH WIND ZONE

S. Z. Sarothi[1], M. S. Sakib[2], M. A. Hasan[3], A. Akhter[4], T. Rabbi[5] and D. K. M. Amanat[6]

ABSTRACT

The general requirement for the structural design and provisions for design parameters in Bangladesh are specified and regulated by the Bangladesh National Building Code (BNBC). The advent of new civil engineering techniques, knowledge and material in the last two decades has caused design parameters and techniques to be modified. So, keeping in line with the change, BNBC 2017 was drafted. To better understand the changes in design and analysis, a systematic parametric structural analysis of RC frame structures was carried out using both codes via FEA for high seismic and high wind zone-Chattogram. Analysis results dictate, the newer code provisions generally results in a relatively less economic design with higher safety margin when compared to the design based on the old code.

Keywords: *BNBC, Comparison, Wind Load, Seismic Load, RC Frame, 2017, Chattogram*

Introduction

The primary differences between BNBC 1993 and 2017 are in the analysis of wind and seismic loads which are relatively more complex than static dead load. For wind load analysis modified gust response factor, external and internal pressure coefficient, recording of wind speed, topographic factors, terrain exposure levels have been introduced in the new code. For seismic loads, seismic zoning and design spectral acceleration have been restructured; response modification factor of the structural system has been diversified. The sole purpose of this study was to investigate and quantify these changes from a structural and economic point of view.

Literature Review

The proposed changes to BNBC 1993 was first brought up by the research team of Tahmeed M. Al-Hussaini, Tahsin R. Hossain and M. Nayeem Al-Noman. They conducted a thorough study on PGA, spectral acceleration, soil classification system, site-dependent response spectrum and worked extensively in defining seismic design category. In their paper "Proposed Changes to the Geotechnical Earthquake Engineering Provisions of the Bangladesh National Building Code" (Al-Hussaini et al, 2012) showed that BNBC 1993 needs a major update in term of provision for design and structural analysis. "A Comparative Study on Seismic Analysis of Bangladesh National Building Code (BNBC) with Other Building Codes" (Bari and Das, 2014) -had been one of the most comprehensive studies on the subject, which showed an analytical evaluation of BNBC in comparison with other building codes.

Modeling and Analysis

Typical multistoried commercial building situated in high seismic and high wind zone of Bangladesh (Chattogram) was selected for the case. The soil on which the building is to be constructed is soft to a medium stiff clay. The analysis is conducted for both low rise & high rise building (8, 16 stories). The floor-to-floor height was set to 3.60m. A 3-span by 3-bay floor (16.5 m x 24 m plan area) was considered for all buildings. The structural analysis and design are carried out using finite element analysis.
Structures are analyzed and designed for gravity loads (e.g. dead loads and live loads). Dead loads include self-weight of building frame and shell elements, floor finish, partition wall and other superimposed loads. Live loads include all temporary loads applied after the construction of building superimposed dead and live loads that were used for the analysis, are as followed-
Live load= 3 KN/m²

[1-5]B.Sc in Civil Engineering,Bangladesh University of Engineering and Technology,Dhaka-1000,Bangladesh
[6]Dr. Khan Mahmud Amanat,Professor, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000,Bangladesh
Email of Corresponding Author- saadmansakib01@gmail.com

Floor Finish= 1.5 KN/m²
Partition wall= 2.5 KN/m²
Live load due to lift machine= 4.79 KN/m²
Live load due to water tank= 17.24 KN/m²

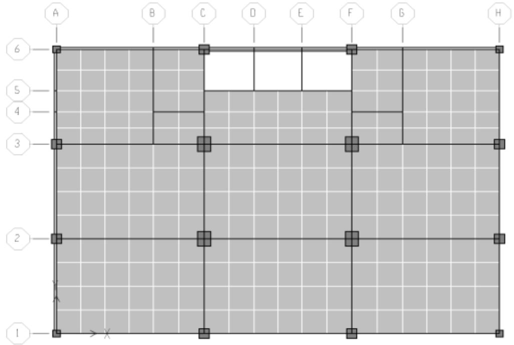


Figure 1. Plan layout

Table 1. Design parameter - wind load analysis

Wind load design parameter BNBC 1993	Wind load design parameter BNBC 2017
▪ Analysis Method: Surface Area Method ▪ Basic Wind Speed: 260 km/hr. (Fastest mile speed) ▪ Standard Occupancy Structure, IF– 1.00 ▪ Exposure Category – A (Urban – Suburban area) ▪ Max Deflection Limit - $\frac{h}{500}$ for 100% Wind effect ▪ ETABS Analysis Algorithm - UBC 94	▪ Analysis Method: Analytical Procedure ▪ Basic Wind Speed: 288 km/hr. (3 sec Gust wind) ▪ Standard Occupancy Structure IF – 1.00 ▪ Exposure Category – A (Urban – Suburban area) ▪ Max Deflection Limit - $\frac{h}{500}$ for 70% Wind effect ▪ Topographical Factor K_{zt} – 1.00 ▪ Directionality Factor K_d - 0.85 ▪ ETABS Analysis Algorithm – ASCE 7-05

Table 2. Design parameter – Seismic load analysis

Seismic load design parameter BNBC 1993	Seismic load design parameter BNBC 2017
• Seismic Zone Coefficient Z = 0.15 • Site Classification: S3 • Site Coefficient S = 1.5 • Importance Factor = 1.0 • Time Period: $T = C_t h_n^m$; C_t = 0.03 • Frame System – IMRF • Structure Reduction Factor – 8 (IMRF) • ETABS Analysis Algorithm – UBC 94	• Seismic Zone Coefficient Z = 0.28 • Site Classification: SD • Site Coefficient = 1.5 • Importance Factor = 1.0 • Time Period: $T = C_t h_n^m$ • Seismic Design Category: D (High Severity) • Frame System & Reduction coefficient: • -8F: SMRF (R=8) • -16F: SMRF with Shear wall (R=7) • ETABS Analysis Algorithm - User Coefficient

Cross-sectional dimension for beam and column were kept identical for both sets of codes. These dimensions were determined by an iterative process, maintaining deflection limit for maximum lateral sway and serviceability criteria-

1. Column width in X direction was kept to a maximum of 700mm, to maintain a minimum clear distance of 7300mm for 2 parallel set of car parking.
2. Clear height between floor and false ceiling are generally kept at 2600mm. For air-conditioning ducts between the false ceiling and beam bottom, depth of 150mm to 200mm is required. Keeping these in consideration, beam depth was kept below 750mm for the floor to floor height of 3600mm.

Table 3. Cross-sectional dimension for frame elements and shear wall

Beam	16 Story (mm x mm)	8 Story (mm x mm)	Column	16 Story (mm x mm)	8 Story (mm x mm)
External Long Span	600x400	600x300	Corner	500x450	450x450
External Short Span	500x300	650x300	External Long Span	N/A	600x550
Internal Long Span	700x300	600x300	External Short Span	600x650	600x600
Internal Short Span	750x600	600x350	Internal	600x1200	600x800
Lift-core & Stairs	400x300	400x300	Water tank & Roof	250x250	250x250
			Shear Wall	400	N/A

Result and Discussion

This section mainly focuses on differentiating between various analysis results of BNBC 1993 and BNBC 2017. Particularly, change in wind load and seismic base shear with the varying story no is presented. Wind load governs for both cases due to higher base shear values.

Effect on Seismic Base Shear

Fig 2 indicates higher seismic base shear values in BNBC 17. This happens primarily for two reasons-

1. In BNBC 93, seismic zone coefficient had a lower value of Z = 0.15, but in BNBC 17 seismic zoning map was updated and an increased seismic zone coefficient of Z=0.28 was allotted to Chattogram.
2. The main difference in base shear is encountered as the structural system used in both code is different (IMRF in BNBC 1993, SMRF in BNBC 2017) which cause a change in R-value. Also, the introduction of Cs (normalized acceleration response spectrum) in BNBC has contributed to increasing base shear. Table 4 shows variation in base shear due to this change in the parameter. The lower value of R in BNBC 17 generated a higher spectral acceleration (S_a), which in turn increased the seismic base shear.

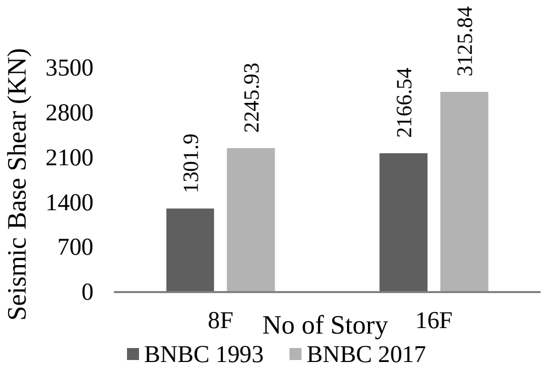


Figure 2. Seismic base shear vs no of story

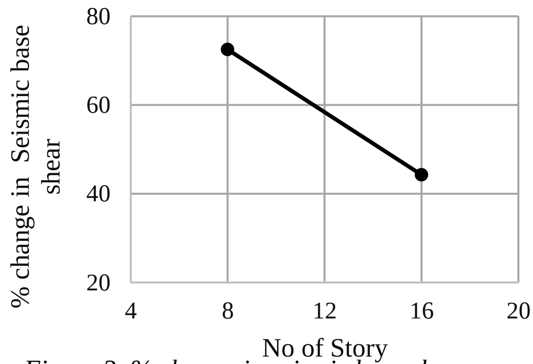


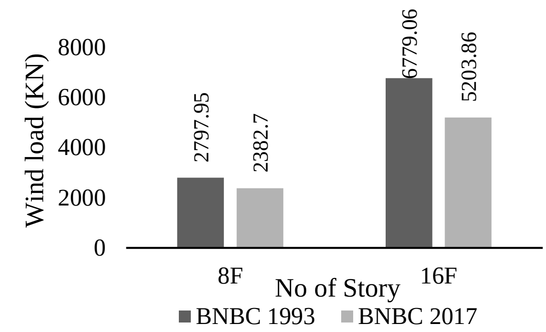
Figure 3. % change in seismic base shear w.r.t BNBC 93

Table 4. C/R (BNBC 1993) vs Cs/R (BNBC 2017)

	BNBC 1993				BNBC 2017				Comment On Cs/R
No of story	Base Shear Equation	C	R	C/R	Base Shear Equation	Cs	R	Cs/R	
8F	$V = \frac{ZIC}{R}W$	1.789	8	0.224	$V = \frac{2}{3}\frac{ZIC_s}{R}W$	2.3	6	0.383	71% increase
16F		1.298	8	0.162		1.24	7	0.177	9.5% increase

For 8F and 16F respectively Cs/R value increases 71% and 9.5% w.r.t to 93's code. Even though the total seismic base shear is decreased by 1/3, the net base shear increases due to consideration of addition on 25% of live load and increase of Cs/R-value by a significant margin.

Effect on Wind Load



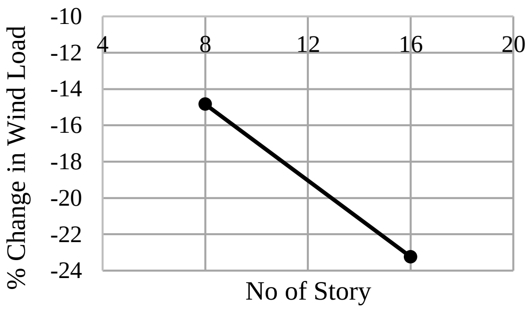
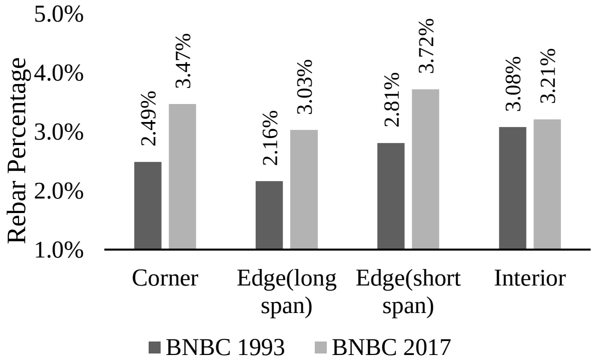


Figure 4. Wind load vs No of story *Figure 5. % change in Wind load w.r.t BNBC 93*

As shown in Figure 4, structures designed in accordance with BNBC 17 is subjected to lower wind base shear than its predecessor. Figure 5 indicates a reduction of 'base shear percentage' increases with floor height in BNBC 17. This is mainly due to the difference in analytical procedure between both sets of codes (Table 1) and the difference in wind velocity, where BNBC 17 design is subjected to higher values of wind speed.

Design Outcome

Design outcome shows how max rebar percentage inflect when designed using both BNBC codes. Moreover, which load combination controls the design is also discussed below.



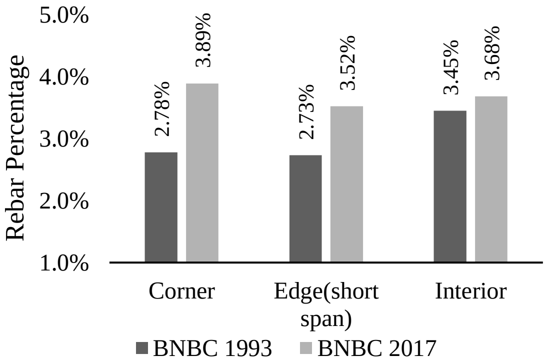


Figure 6. Rebar % in a column of 8 story building *Figure 7. Rebar % in a column of 16 story building*

Both Fig 6 and 7 shows that column rebar percentage is higher for BNBC 2017 than BNBC 1993. Table 6 and 7 indicates for high seismic & high wind zone, in column design wind load governs for both BNBC 2017 and 1993. As per the analysis, wind load is higher for BNBC 1993 than 2017. It means rebar % should be higher for BNBC 1993, but the result is quite the contrary. The main reason for this issue is that in BNBC 2017, a high factor of safety is implemented by increasing the load factors. Moreover, table 6 and 7indicates that for both BNBC 2017 and 1993 in most of the case wind load dictates column design.

Table 6. Governing load combination and percent change in load factor multiplier for 8 story building

Column Designation	Governing load combination				
	BNBC 1993	BNBC 2017	DL w.r.t 93	LL w.r.t 93	Wind w.r.t 93
Corner	1.05DL+1.275LL+1.275WY	1.2DL+LL+1.6WY	↑ 14%	↑ 21%	↑ 25%

Edge (long span)	1.05DL+1.275LL-1.275WY	1.2DL+LL-1.6WY	↑ 14%	↓ 21%	↑ 25%
Edge (short span)	1.05DL+1.275LL-1.275WY	1.2DL+LL-1.6WY	↑ 14%	↓ 21%	↑ 25%
Interior	1.4DL+1.7LL	1.2DL+LL+1.6WY	↓ 14%	↓ 41%	WY 1.6 times

Table 7. Governing load combination and percent change in load factor multiplier for 16 story building

Column Designation	Governing load combination				
	BNBC 1993	BNBC 2017	DL w.r.t 93	LL w.r.t 93	W/EQ w.r.t 93
Corner	1.05DL+1.275LL-1.275WX	1.2DL+LL+1.6WX	↑ 14%	↓21%	↑ 25%
Edge (long span)	Shear Wall				
Edge (short span)	1.4DL+1.7LL	1.326DL+LL-EX-0.3EY	↓ 5%	↓ 41%	Seismic Loading EQ_x EQ_y
Interior	1.4DL+1.7LL	1.2DL+LL-1.6WY	↓ 14%	↓ 41%	WY 1.6 times

Here, percent changes are expressed w.r.t to load factor multiplier of BNBC. ↑ indicates increase and ↓ indicates a decrease in load factor multiplier values.

Conclusions

Seismic Base shear is increased in BNBC 2017 w.r.t BNBC 1993 due to change in zone coefficient (Z) , structural system factor (R), and the introduction of Cs (normalized acceleration response spectrum) in BNBC 2017. On the other hand, BNBC 1993 shows high wind load compared to that in BNBC 2017. Column reinforcement is higher as per design code of BNBC 17. The design outcome dictates in spite of having lower wind base shear in BNBC 17, reinforcement requirement in columns are higher in BNBC 17 than 93,s code due to higher values of load factor multipliers. This analysis and design consequence can provide a guideline to the engineer for the most economic design.

This case study is conducted for Chattrogram city only. A similar study can be conducted for other cities of Bangladesh with varying wind and earthquake intensities. The only change in column reinforcement between two codes is covered in this paper. This study can be extended by the design of beam, foundation, shear wall to get a precise perception of which code gives the more economic result.

Acknowledgments

We highly acknowledge Dr. Khan Mahmud Amanat, Professor, Department of Civil Engineering, BUET for his kind supervision and guidance throughout the research.

References

Al-hussaini, T.M., Hossain, T.R., and Al-Noman, M.N. (2012) "Proposed changes to the geotechnical earthquake engineering provisions of the Bangladesh National Building Code", *Geotechnical Engineering Journal of the SEAGS & AGSSEA*, 43(2), ISSN 0046-5828.

Bangladesh House Building Research Institute (1993) *"Bangladesh National Building Code, BNBC"*, Dhaka.

Bangladesh House Building Research Institute (2017) *"Bangladesh National Building Code, BNBC (Draft)"*, Dhaka.

Bari, Md. S., and Das, T. (2014) "A Comparative Study on Seismic Analysis of Bangladesh National Building Code (BNBC) with Other Building Codes", *Journal of the Institution of Engineers (India)*, 94(3), 131–137.

Hasan, Md.A. (2018) "Comparative Analysis of BNBC 1993 and BNBC 2017 provisions for the design of RCC and steel buildings on high seismic and high wind zone of Bangladesh" *B.Sc.Engg. Thesis*, Bangladesh University of Engineering and Technology, Dhaka.

STRUCTURAL RESPONSE OF COASTAL WOODEN INFRASTRUCTURE TO CYCLONIC WIND AND SURGE INDUCED THRUST FORCE

M. W. Zaman[1], M. M. Ali[2], K. S. Mita[1], A. A. Azad[1], M. Akter[1], R. Ahsan[3], A. Haque[4] and M. Rahman[4]

ABSTRACT

Cyclones, not only pose threat to human lives and ecosystem but also cause severe damage to the livelihood means of people and their houses. There is an immense physical, economic and financial loss to the coastal community due to houses and other infrastructures that are vulnerable to cyclonic events. After every cyclone, many households are damaged, either fully or partially, causing temporary or in extreme case permanent migration. Coastal communities do not explicitly consider thrust force that is coming from storm surge as potential impact loading. The effects of this loading on structures located in cyclone-prone areas have recently gained significant interest from researchers, engineers, government and non-governmental agencies. These include the effects of the initial surge, the impact of floating debris, the drag caused by the velocity of the flow, and the uplift caused by rapidly rising water levels. This study focuses on the performance assessment of structural members of a representative household under different wind speeds and surge induced thrust force. Kutcha houses (wood) have been modeled and analyzed. Based on the analysis, it is found that in case of wind velocity, purlin, a roof truss member, fails first. It is also observed that surge load is much greater comparing to wind load and surge load of 1 ft. surge height is almost three times larger than the wind load at a wind speed of maximum 250 km/hr.

Keywords: Coastal structure, Storm surge, Wind load, Debris load.

Introduction

Most of the countries in the tropical area of the world are threatened by storm surge generated by cyclonic wind. Storm surges are generated by cyclonic winds and the atmospheric pressure drop associated with a cyclone. The major contribution comes from the winds that exert stress on water surface which is proportional to the square of wind velocity. They are additional to normal tides and when added to high tides they can cause extreme water levels and flooding: flooding would be most severe when a surge coincided with spring tides. In addition to human lives, storm surges cause severe damages to the coastal infrastructure due to the tremendous force exerted by the surge wave on these structures. Tropical cyclones create storm surges that can strike densely populated coastal regions with devastating force (Dasgupta et al., 2009). The 1970 Bhola Cyclone generated a 9.1m storm surge in Bangladesh that killed approximately 300,000 people (Frank and Husain, 1971; Dube et al., 1997). In 2005, Hurricane Katrina inflicted $149 billion in losses (adjusted to 2013 Consumer Price Index), making it the costliest natural disaster in U.S. history (National Climate Data Center, 2014) and three times costlier than any non-storm surge disaster in the U.S. The destruction due to the storm surge flooding is a serious concern along the coastal regions of the countries, for example along the coasts of Bangladesh, India, and Myanmar. Bangladesh is on the receiving end of about 40% of the impact of total storm surges in the world (Murty et al., 1992). In Bangladesh cyclone and storm surge is a regular phenomenon. The coastal regions of Bangladesh almost been hit by cyclones in pre-monsoon (April-May) or in post-monsoon (October-November) (Haque, 1991; Khan, 1995; Debsharma, 2009; Dasgupta, 2011). Most of the worst affected areas are either off-shore islands or coastal areas (Paul and Rahman, 2006). Most inhabitants in these areas live in houses made of bamboo, thatch, locally available materials and a few affluent members live in houses made of brick and concrete (Bern et al., 1993). In the cyclone of 1991, a huge number of houses were damaged causing the death of 138,882 people (Hossain et al. 2008). Sidr (2007) destroyed more than 150,000 houses and killed 3,500 people (Sarker and Azam, 2012). Since houses are highly vulnerable to these dreadful disasters, analysis of the strength of these houses has become essential. The objective of the present study is to analyze the performance of different components of the kutcha house under cyclonic wind and surge induced thrust force at coastal areas of Bangladesh.

The present study focuses on the assessment of direct physical damage to buildings caused by flood actions

[1]*Research Assistant, Institute of Water and Flood Management, BUET, Dhaka, Bangladesh*
[2]*Postgraduate student, Dept. of Civil Engineering, BUET, Dhaka, Bangladesh*
[3]*Professor, Dept. of Civil Engineering, BUET, Dhaka, Bangladesh*
[4]*Professor, Institute of Water and Flood Management, BUET, Dhaka, Bangladesh*

during storm surge with associated high-speed winds. Buildings located in coastal areas, in particular, are frequently affected by high winds, in addition to the flood actions. In these situations, both flood and wind actions can adversely affect structures and it can be difficult to differentiate the damage caused by hydraulic loading from that caused by wind. However, wind-building interactions and the corresponding damage potential are outside the scope of the present study.

Methodology

In this study, to collect detail information about the existing houses a survey has been conducted at different locations in the coastal zone of Satkhira, Barguna, Bhola, Noakhali, Chittagong and Cox's Bazar in Bangladesh. Following steps were taken in the present study:
a) Information on the coastal area was collected.
b) Detail information on a sample of houses was collected.
c) Numerical modeling of the kutcha house was done.
d) Numerical simulations for different wind speeds and surge velocity were conducted.
e) The results were prepared from the numerical simulations.

Field Survey

Total 100 houses were surveyed in Satkhira, Barguna, Bhola, Noakhali, Chittagong and Cox's Bazar. The people were asked some basic questions about their houses including the house's performance and damage type during past cyclones. In this survey housing materials were also investigated. Most of the houses were made of locally available materials such as wood, bamboo, tin, CGI sheet, clay tile, and low-grade RCC. Houses observed in coastal area were divided into four categories such as pacca, semi-pucca, kutcha and jhupri based on the building materials and people's perception about their houses but in the present study, analysis for the only kutcha house is presented.

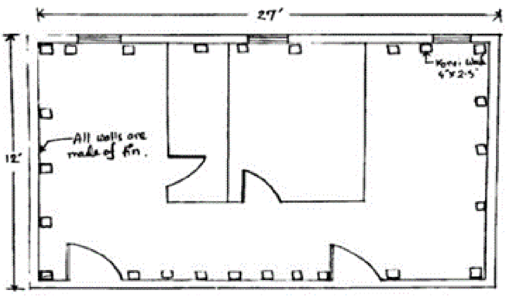


Figure 1(a). Plan view of the kutcha house.

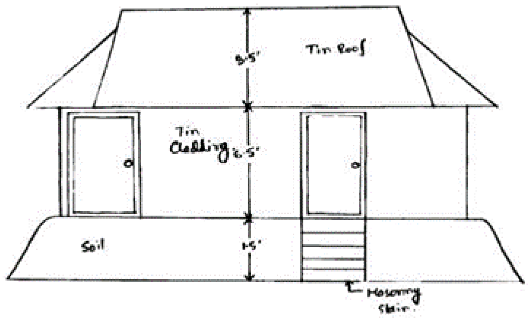


Figure 1(b). Front Elevation of the kutcha house.

Numerical Modeling

After the completion of field survey, structural modeling of these houses was done in the structural analysis software. The maximum bending moment is checked for different structural components.

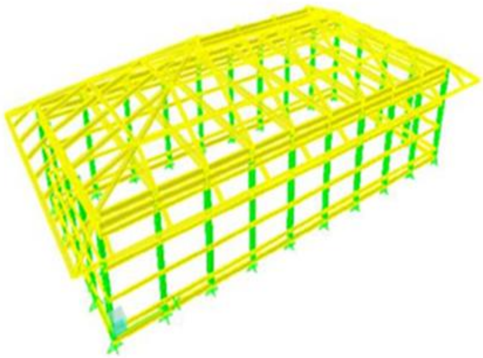


Figure 2(a). Structural modeling of the kutcha house.

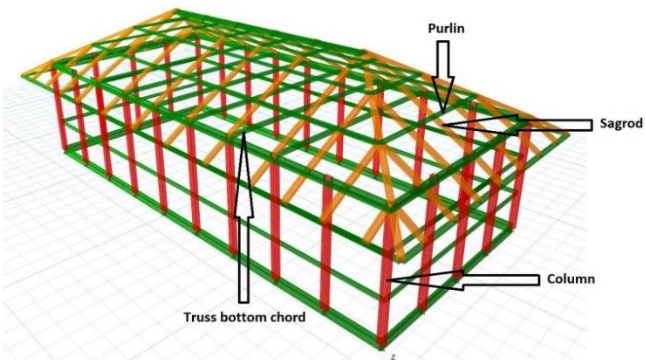


Figure 2(b). Structural members in a kutcha house.

Wind Load Calculation

Associated wind load from wind speed was calculated by the guideline of BNBC 2006. The Numerical models of the houses were analyzed against wind speeds ranging from 50 km/h to 250 km/h.

Surge Velocity Calculation

The Numerical models of the houses were analyzed against surge depths ranging from 0.305m (1 ft) to 2.745m (9 ft). For South-western coastal zone of Bangladesh, associated surge velocity from a particular surge depth was calculated by an empirical equation that was made from the correlation of surge depth and surge velocity. The equation is given below:

$$y = \frac{5.07\times10^{-20}n - 6.86\times10^{-22}p + 1.6\times10^{-18}m}{1.73\times10^{-19}}x^3 - \frac{4.09\times10^{-19}n + 3\times10^{-20}p + 1.24\times10^{-17}m}{1.7\times10^{-19}}x^2 + \frac{9.102\times10^{-19}n + 1.5\times10^{-19}p + 2.5\times10^{-17}m}{1.7\times10^{-19}}x + \frac{8.33\times10^{-21}n + 1.7\times10^{-20}p + 8.2\times10^{-20}m}{1.7\times10^{-19}}$$

Where, x = surge depth,
y = surge velocity

Values of n, p, m for the Western zone:

$$5.07\times10^{-20}n - 6.86\times10^{-22}p + 1.6\times10^{-18}m = 7.71\times10^{-21}$$
$$4.09\times10^{-19}n + 3\times10^{-20}p + 1.24\times10^{-17}m = 6.34\times10^{-20}$$
$$9.102\times10^{-19}n + 1.5\times10^{-19}p + 2.5\times10^{-17}m = 1.35\times10^{-19}$$

Surge Load Calculation

Total surge load is calculated according to BNBC 2015 (ASCE 7-2010). To consider breaking wave loads on vertical walls, maximum combined dynamic and static wave pressures (P_{max}) and net breaking wave force per unit length of structure (F_t) were calculated. According to ASCE 7-2010, impact loads are those that result from debris, ice, and any object transported by floodwaters striking against buildings and structures or parts thereof. Impact loads shall be determined using a rational approach as concentrated loads acting horizontally at the most critical location at or below surges depth velocity of the debris (m/s) is assumed equal to the velocity of water (surge velocity).

Comparison of Surge and Wind Load

Calculated load for the model structure is listed in the table below (Table 1)**.** Wind load has been calculated for a wind speed of 50 kph to 250 kph with 25 kph increment. Surge load, on the other hand, has been calculated from 0.305m (1 ft) to 2.745m (9 ft) with 1 ft increment. From the results, it is observed that the surge load of 1 ft. surge height is almost three times higher than the wind load at a maximum wind speed of 250 km/h (Fig.3)

Table 1. Calculated surge and wind load in the column.

Surge Load	
Depth (m)	Total surge load (kN) as Point Load in column
0.305	5.4
0.610	20
0.915	43.8
1.220	76.7
1.525	119
1.830	170.4
2.135	231.2
2.440	301.3
2.745	380.8

Wind Load	
Wind Speed (km/h)	Wind Load (kN) as Point Load in Column
50	0.0787
75	0.1771
100	0.3148
125	0.492
150	0.7084
175	0.964
200	1.2594
225	1.594
250	1.9678

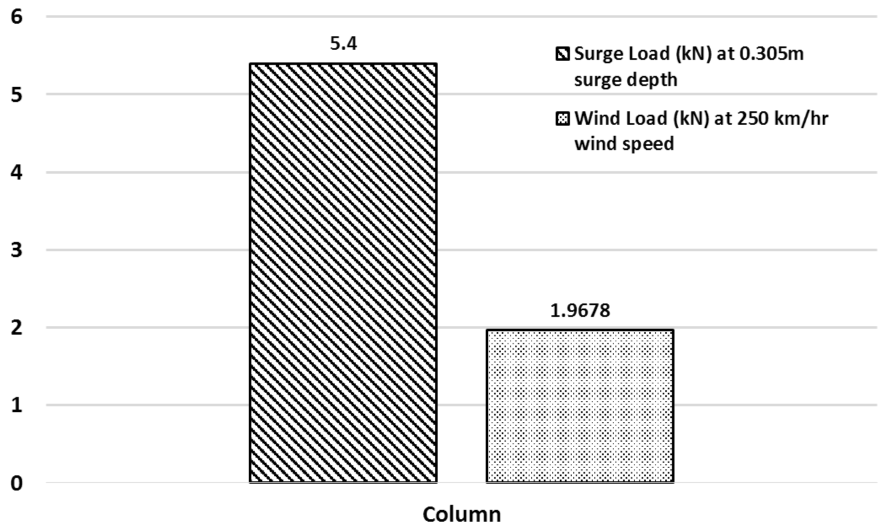


Figure 3. Comparison of surge load and wind load in the column.

Results

The structure has been analyzed under three scenarios (i) wind load only, (ii) surge load only and (iii) combination of wind and surge load. Allowable stress of the used material (wood in this case) is found to be 7.3 N/mm^2. The analysis has been done following this hypothesis: when stress on any structural member exceeds the allowable limit, the member will fail. Additionally, when a column member fails, it depicts the failure of the whole structure.

(i) Wind load only

The analysis has been done imposing wind load on the structure. Later, the calculation of each member stress is done manually. Figure 4 represents maximum stress on each type of structural member for corresponding wind speed. From the analysis, it has been found that all the structural members (Column, Purlin, Sagrod and

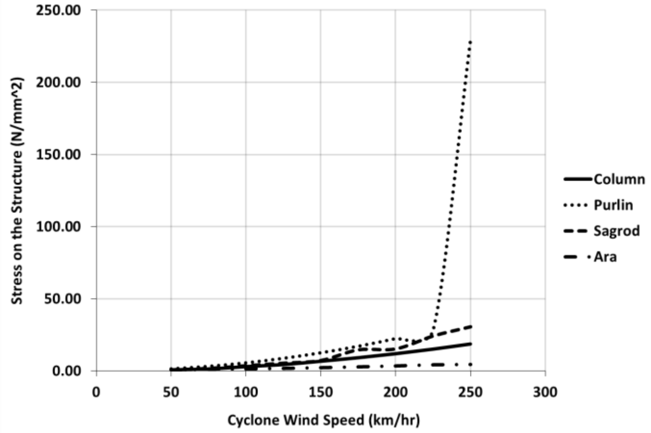


Figure 4. Stress on structural members due to cyclonic wind only.

truss bottom chord) can withstand stress exerted on them till 100 kph wind speed. However, Purlin (a roof truss member) fails first at the wind speed of 125 kph which can be termed as partial damage. With a gradual increment of wind speed, column and agreed fail at a minimum wind speed of 175 km/h. So, it can be said that, starting from wind speed of 175 kph, the kutcha structure is prone to destroy completely because of the load exerted by the wind.

(ii) For surge load only

Similar to wind load, surge load is also calculated according to the procedure described in methodology.

Calculated surge load is imposed on the structure as point load on the column. As illustrated in Figure 5. Surge load in far more vulnerable for a kutcha structure than wind load only. Even for surge depth of as low as 0.305m (1 ft.) structure can be destroyed completely.

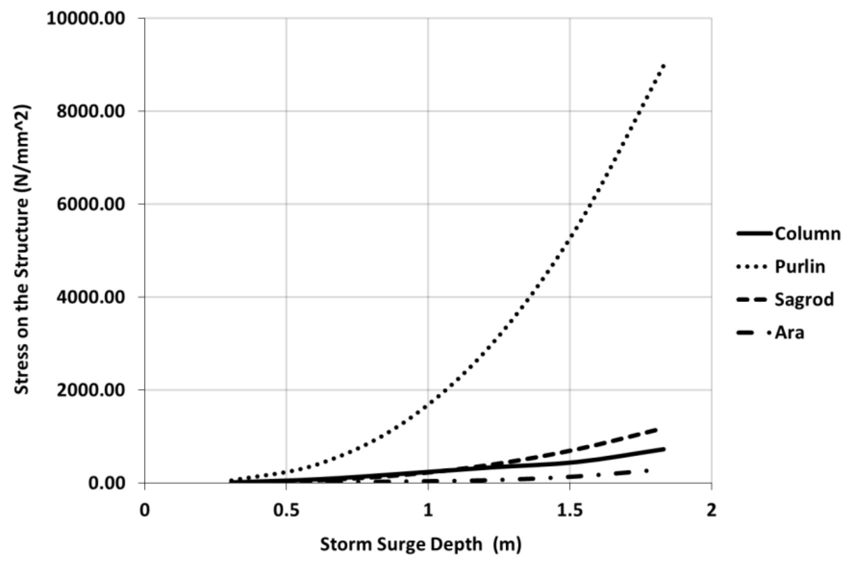


Figure 5. Stress on structural members due to surge load only.

(iii) Combination of wind and surge load

Since surge load only poses a destructive threat to the kutcha structure. It is only natural that the combined wind and surge load will cause more damage. Figure 5 depicts the same phenomenon. For combined loading, stresses occurred in the structural members, is very high at the initial condition. Combined load from a 0.305m (1 ft.) surge height and 50 km/h wind can severely damage the structural members of a kutcha house. It is seen at most of the cases that only truss bottom chord sustains under this load combination. But as the column fails at this combination, it is counted that the whole structure will be collapsed eventually.

Conclusions

From the field survey, it is seen that most of the structures in the coastal region are made of wood (kutcha house). Without the presence of intruded water, these structures are safe for up to 100 kph cyclonic wind. Wind speed greater than that is capable of damaging the structure severely and for 175 kph wind and onwards, the structure fails completely. Analysis with only surge load shows that the presence of water is more threatening to the kutcha structure. Only 1 ft. of water can exert load that is capable of damaging column which means in the other word fully damage to the structure. Similarly, when superposition of both loads is considered alike phenomenon prevails. It can be concluded from this analysis, during the cyclone, kutcha houses adjacent to ocean or river where inundation is likely to occur are more prone to full damage even in low strength cyclone. Houses that don’t get inundated, on the other hand, can sustain wind speed up to 100 kph remaining unharmed.

Acknowledgments

The research is funded by the SATREPS project (funded by JST-JICA) on ‘Research on Disaster Mitigation against Storm surges and Floods in Bangladesh’. The support provided by the SATREPS project is gratefully acknowledged.

References

Dasgupta, S., Laplante, B. Murray, S. Wheeler, D., 2009. Climate Change and the Future Impacts of Storm-Surge Disasters in Developing Countries. Policy research working paper, World Bank.

Dasgupta, S., Laplante, B. Murray, S. Wheeler, D., 2009. Sea-Level Rise and Storm Surges: A Comparative Analysis of Impacts in Developing Countries‖. Policy research working paper, World Bank.

Nicholls, R.J., Hanson, S., Herweijer, N. Patmore, S., Hallegatte, J., Corfee-Morlot, J., Chateau, R. and vulnerability to Climate Extremes. OECD Environment Directorate, Environment Working Papers

No. 1.

Dube, S.K., Rao, A.D., Sinha, T.S., Murty, T.S. and Bahualyan, N., 1997. Storm surges in the Bay of Bengal and Arabian Sea: The problem and its prediction. Mausam 48(2):283304.

Murty, T.S. and El-Sabh, M.I., 1992. Mitigating the effects of storm surges generated by tropical cyclones: A proposal, Natural Hazards 6(3), pp.251-273.

Haque, C.E., 1997. Atmospheric Hazards Preparedness in Bangladesh: A Study of Warning, Adjustments and Recovery from the April 1991 Cyclone, Natural Hazards, vol. 16, pp.181-202.

Khan, S.R., 1995. Geomorphic Characterization of cyclone hazards along the coast of Bangladesh, ITC-MSc study.

Debsharma, S.K., 2009. Simulations of Storm Surges in the Bay of Bengal. Marine Geodesy Journal, 32(2):178-198.

Dasgupta, S. Muray S. Laplante B. and Wheeler, D. 2011. Exposure of Developing Countries to sea level rise and Storm Surges. Forthcoming in Climate Change.

Oumeraci H., Kortenhaus A., Allsop N.W.H., De Groot M.B., Crouch R.S., Vrijling J.K. &Voortman H.G. (2001) "Probabilistic Design Tools for Vertical Breakwaters." 392 pp, ISBN 90 580 248 8, public. Balkema, Rotterdam.

Akter, M. (2016) "Analytical Solution of the Distributive Thrust Forces due to Storm Surges in Coastal Area", Master's thesis, Department of Mathematics Bangladesh University of Engineering and Technology (BUET).

Bern, C., Sniezek, J., Mathbor, G. M., Siddiqi, M. S., Ronsmans, C., Chowdhury, A. M., Choudhury, A. E., Islam, K., Bennish, M., and Noji, E. (1993) "Risk factors for mortality in the Bangladesh cyclone of 1991", Bulletin of the World Health Organization, 71(1),73-78.

BNBC (2006) "Bangladesh National Building Code", Housing and Building Research Institute, Bangladesh.

Kabir, R., Khan, H. T. A., Ball, E. and Caldwell, k. (2016) "Climate Change Impact: The Experience of the Coastal Areas of Bangladesh Affected by Cyclones Sidr and Aila", Journal of Environmental and Public Health.

Paul, A. and Rahman, M. (2006) "Cyclone Mitigation Perspectives in the Islands of Bangladesh: A Case of Sandwip and Hatia Islands", Coastal Management, 34(2), 199-215.

Ali M. M, Alam M.Z, Asif M. M, Purkayastha S, and Ahsan R. (2017) "Damage Assessment of Rural Infrastructure due to Cyclone in Bangladesh", Proceedings, International Conference on Disaster Risk Mitigation, Dhaka, Bangladesh, September 23 - 24, 2017.

Mita K.S, Azad A.A, Zaman M.W, Sakib M, Amin G.M.R, Asik T. Z, Haque A, Rahman M. M, (2018) "Effectiveness of Adaptive Measures Against Storm Surge Hazard Based on Field Experience from A Real-Time Cyclone in Bangladesh Coast", Proceedings of 2nd International Conference on Sustainable Development, Dhaka, Bangladesh, February 16-18, 2018. ISBN 978-984-34-4755-5.

Al Azad, A.S.M.A.; Mita, K.S.; Zaman, M.W.; Akter, M.; Asik, T.Z.; Haque, A.; Hussain, M.A.; Rahman, M.M. (2018) Impact of Tidal Phase on Inundation and Thrust Force Due to Storm Surge. *J. Mar. Sci. Eng.*, Vol. *6*, Issue 4, 110.

ASCE, 2010: Wind loads. Minimum Design Loads for Buildings and Other Structures, ASCE Standard Series, Vol. ASCE/SEI 7-10, ASCE, 241–258.

American Society of Civil Engineers (ASCE). Minimum design loads for buildings and other structures (ASCE/SEI 7-10). Reston, VA: ASCE; 2010.

CYCLIC LOAD TEST ON BEAM-COLUMN BEHAVIOR OF PORTAL FRAME STRENGTHENING BY MICRO-CONCRETE

M. S. Hosain[1], Y. A. Khan[2] and M. R. Ahsan[3]

ABSTRACT

Strengthening of concrete structures is very common for damage caused due to an earthquake or any natural disasters. Studies show that reinforced concrete columns can experience a significant increase in the ultimate capacity and ductility when strengthened by a micro concrete. This study investigates the effectiveness of strengthening of half-scaled RC columns by Micro concrete jacketing. Among three physical models, one simulates the existing structural condition and others simulate retrofitted behaviors. All specimens were modeled to examine the seismic effect by cyclic loading. The concept of the weak beam-strong column was also applied for the test. Micro-concrete was produced with the locally available materials. To investigate the performance of retrofitted RC frames, the columns of two models were jacketed with micro-concrete by 50 mm widening and cyclic loading was applied with sustained gravity load. This test was a displacement control test. Retrofitted specimens with 6.3 ksi micro concrete and 8.3 ksi showed higher stiffness and ductility than the un-retrofitted specimen. The higher strength of jacketing material doesn't affect the stiffness and the lateral load carrying capacity significantly due to the anchorage failure of columns. All specimens were tested by a hydraulic testing machine. Raw data were collected manually from displacement dial gauge and from a computer database of video extension meter.

Keywords: Cyclic loading, Portal frame, Micro concrete, Jacketing, Strengthening, Stiffness, Horizontal displacement, etc.

Introduction

The rapid growth of urban population in both developing and industrialized countries, reinforced concrete has become a material of choice for construction because it's cheaper compared to other materials. In the construction of the reinforced concrete structure, it is very important to consider the earthquake provision. Generally, most of the reinforced concrete structure has been constructed without seismic provision. To facilitate such provision for the constructed structure it has been essential to strengthen the existing structure. The stronger structure can be made by new technology but strengthening the existing structure needs retrofitting of the structure by appropriate materials. For retrofitting RC structures micro concrete is now being used. The various components of the existing structure are retrofitted. In this study, the column will be retrofitted by micro concrete. The column of the existing structure will be widened by 50mm all around. The aim of the present study is to investigate the strength improvement and performance of retrofitted RC portal frame under incremental cyclic horizontal load with sustained vertical load. Most of the previous researches were performed on behavior and response of structure by retrofitted with different material. Now it will be studied with micro concrete.

Objectives of the Research

The main objective of this paper is to conduct experiments on two frames with retrofitted by micro-concrete and one frame without retrofit to interpret the experimental findings. The terminal objectives of the investigation are as follows: To investigate the ultimate lateral load carrying capacity and the maximum lateral displacement of square RC columns strengthened using MC jacket

1. To study the effectiveness of the applied jacketing style in terms of ultimate lateral load carrying capacity, failure patterns and to compare the obtained results with that of the columns of Control specimen (CS)
2. To study the effect of jacket thickness on both the ultimate load carrying capacity and the lateral displacement and to compare the obtained results with that of the columns of the CS
3. To observe the response of the specimens under the strength variation with different grain size

[1] *Post Graduate Student, Department of Civil Engineering, BUET, Dhaka-1000, Bangladesh*
[2] *Graduate from Department of Civil Engineering, BUET, Dhaka-1000, Bangladesh*
[3] [3]*Professor, Department of Civil Engineering, BUET, Dhaka-1000, Bangladesh*

4. To increase the factor of safety against lateral load carrying capacity by means of retrofitting.

Methodology

To investigate the behavior of reinforced concrete frame with varying retrofitted parameters, cyclic static incremental horizontal load were provided to test the frames with sustained vertical load. Half scale RC model frames were prepared, integral with a heavily reinforced concrete base. Frames were of 1.5 m height and 2.6 m span. Then the following parameters were considered for the study: A total of three frames were constructed for the study:

1. All three frames were constructed with the same base beam cross section (300mm x 250mm)
2. All three frames were constructed with the same top beam cross section (125mm x 125mm)
3. All of three frames were constructed with column section by (125mm x 125mm) at first stage
4. After retrofitting the column section of two frames were (225mm x 225mm)

Finally, the load-deflection curves were compared for the considered different frames with retrofit and without retrofit.

Material and Mix Proportions

Cement

Ordinary Portland cement (OPC) was used. Specification and composition of cement by the manufacturer: 28th days cube strength 42.5 N by ASTM C595, Clinker: 65-79%, Slag, Fly ash & Limestone: 21 - 35% Gypsum: 0-5%, specific gravity 3.15 and unit weight 197 pcf.

Sand

Sylhet sand FM is 2.5. Sand was free from clay.

Reinforcement

Table 1: Material Properties Tested By Laboratory

Material	***Diameter***	***Yield Strength MPa (Min)***	***Ultimate Strength (MPa)***	***Elongation %***
420 W	*10 mm*	*426*	*523*	*14*
420 W	*12 mm*	*440*	*685*	*14*
420 W	*16 mm*	*429*	*658*	*15*

Concrete Mix Proportions

Highest compressive strength 7820 psi was achieved by a ratio of 1:1:1.5 (cement: fine aggregate: coarse aggregate) with water cement ratio of 0.3 (Hassan and Ahmed, 2016). Two retrofitted specimen were prepared by different strength to demonstrate the effect of strength on the retrofitting behavior. To make a variation of strength, another mix ratio of 1:1.25:1.7 was used (6830 psi by Hassan and Ahmed, 2016).

Table 2. *Volumetric Mix ratio for concrete for control and retrofitted specimen*

Item	Cement	Sand: FM	CA (mm)	w/c	Ratio Cement: Sand: CA	Slump (mm)
CS	OPC	2.5	12.5 downgrade	0.46	1:1.5:3*	70
RS-1	OPC	2.5	6.0 downgrade	0.23	1:1:1.5**	250
RS-2	OPC	2.5	8.0 downgrade	0.28	1:1. 25:1.7 **	200

* Conventional volumetric mix ratio which exhibits existing concrete ratio.

**Volumetric mix ratio for high strength concrete was suggested by Hassan and Ahmed, 2016.

Concrete Cylinder Strength

Item	Cylinder size	7th day f'c (psi)	14th day f'c(psi)	28th day f'c(psi)
Control specimen	100mmx200mm	1620	2150	2680
Retrofitted specimen 1	100mmx200mm	5800	N/A	8160
Retrofitted specimen 2	100mmx200mm	4610	N/A	6300

Admixtures

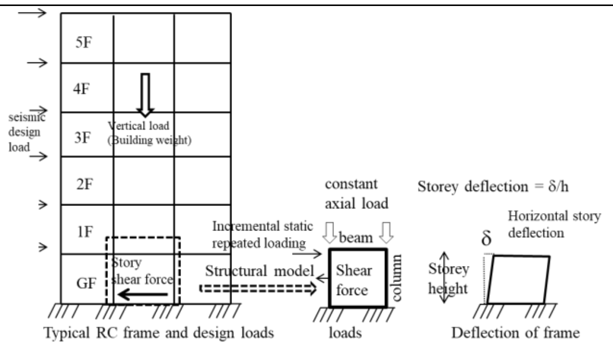
Water reducing admixture was used for reducing the water-cement ratio of dozes 9.0 ml/kg of cement.

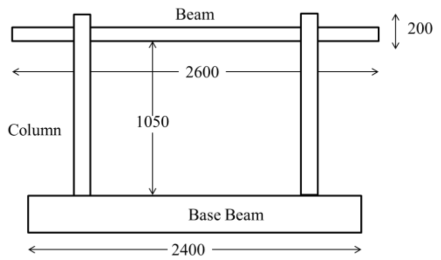
Chemical Binder (Epoxy)

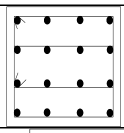
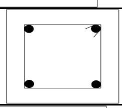
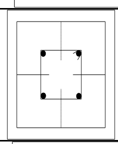
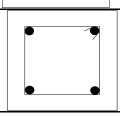
Chemical binder was used for proper binding between concrete and the steel reinforcement.

Methodology

To identify the effect of seismic loading on the retrofitted column, a one bay frame of the bottom story of a six-storied building structure was selected. The model was designed in half scale of the original structure.





Frame Part	Cross Section	Reinforcement Detail
Base Beam		Base Beam: B x D = 300mm x 250 mm Main bar: 16-R16 ,Stirrup: R12 @100 with 135 degree hook, Clear cover = 20 mm
Column of CS		Column: B x D = 125 mm x 125 mm Main bar: 4-R12, Hoop: R8 @150 with 90 degree hook, L = 6d ,Clear cover = 20 mm
Column of RSs		Column: B x D = 225 mm x 225 mm Main bar: 4-R12, Hoop: R10 @150 with 90 degree hook, L = 6d, Clear cover = 20 mm
Beam		Beam: B x D = 125 mm x 125 mm Main bar: 4R10, Stirrup: R10 @150 mm with 90 degree hook, L = 6d, Clear cover = 20 mm

Specimen Preparation

First Stage

Three Frame specimens were prepared by casting horizontally (Figure 1). For time constraint it was chosen to casting horizontally. But to reflect the existing condition of concrete it should be casted vertically.

Figure 1: Horizontal Concrete Casting

Figure 2: Application of Epoxy Chemical

Second Stage

In the second stage of the construction process, the two specimens were retrofitted by micro concrete of different strength. One specimen was retrofitted by micro concrete of lower strength [6300 psi] and another was retrofitted by higher strength micro concrete [8160 psi] to observe the response for the cyclic load. The two specimens were extended by 50 mm on each side of the column only (Figure 3).

Figure 3. Formwork for a widening of column

Figure 4. Micro-concrete placement

No surface epoxy was applied for bonding between existing and fresh concrete to reflect the worse effect of retrofitting (Figure 4). Epoxy grouting agent was used for the insertion of new rebar into the control specimen (Figure 2).

Figure 5. Control Specimen (CS)

Figure 6. Retrofitted Specimen (RS-1)

Figure 7. Retrofitted Specimen (RS-2)

Test Set-Up, Instrumentation

The entire test was carried out in the hydraulic testing machine. The vertical hydraulic jacks were first loaded to a combined force of 20 ton, 10 ton on each column top (Figure 10) (Fancy, 2014). The horizontal hydraulic jacks were responsible for imposing the cyclic displacements to the specimen through complete cycles. The test was displacement control.

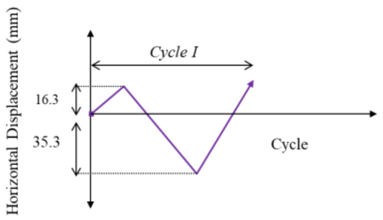


Figure 8. Loading History for Control

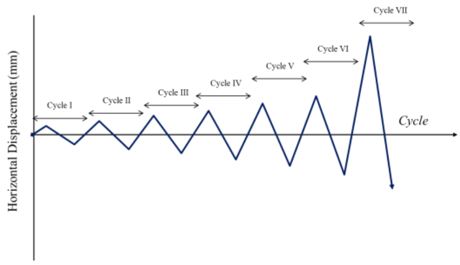


Figure 9. Loading History for Retrofitted Specimens

Age of Testing Specimens

Specimen	*Age of Specimen at Testing day (Days)*
CS	*67*
RS-1	*60 (after retrofitting)*
RS-2	*64 (after retrofitting)*

Test Result for retrofitted specimens

All specimens were tested under Hydraulic Testing Machine (HTM). The loading was incremental static cyclic loading with sustained gravity load. The load was applied at 0.5 ton interval to reach the desired displacement (Fancy, 2014).

Test Result of Control Specimen (CS)

First loading was applied at the beam-column joint of the left side. The cracks marked by red colour were during rightward loading (figure 11) and the cracks in black colour were for unloading (Figure.12). The test of CS was accompanied with its very first crack at positive first cycle loading at the right column with 1 ton load and corresponded to a displacement of 1.1 mm (Figure 11).

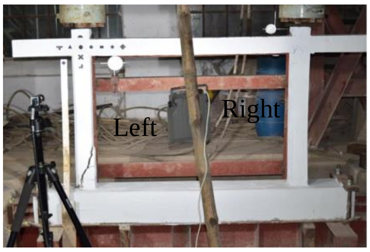
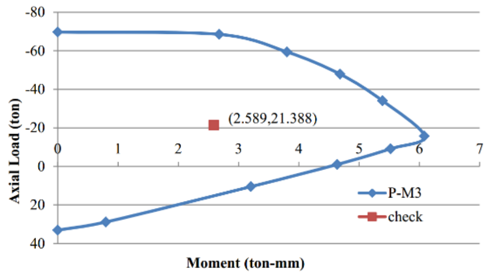


Figure 10. Final Crack Pattern of CS

Figure 11: Crack in Right Column after Failure

Figure 12*.Failure cracks in column- base beam joint at the left column*



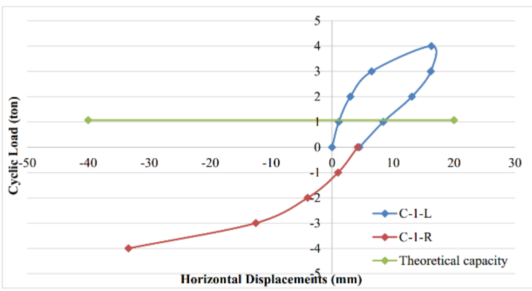


Figure 13 (a). P-M Interaction diagram

Figure 13 (b). Failure cycle of control speciment for *horizontal load*

Test Result of Retrofitted Specimen-1 (RS-1)

The cracks marked in black were those that surfaced during rightward loading and unloading. The red marked cracks represented the cracking that appeared during the leftward loading and unloading. The test of RS-1 was accompanied with its very first crack at positive first cycle loading at the left column and at base beam near right column with 4.5 ton load and corresponded to a displacement of 2.8 mm.

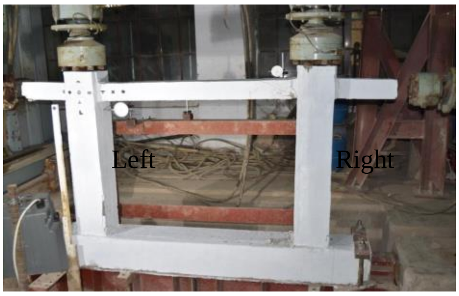


Figure 14. The final crack pattern of Retrofitted specimen-1

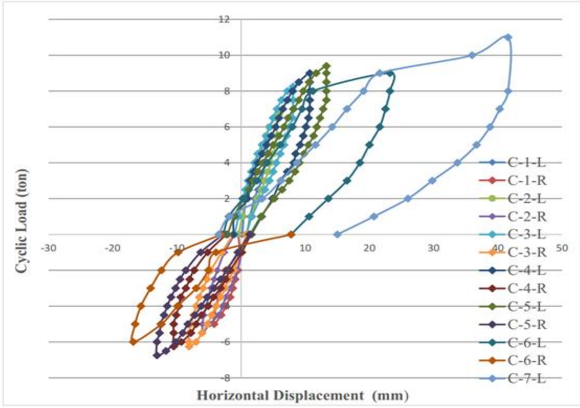


Figure 15. Load Vs. Displacement plot for all cycles

Figure 16. Crack Pattern at Beam-Column Joint

Figure 17. Crack Pattern at Beam-Column Joint

Figure 18. Crack Pattern at Column-Base beam Joint

Figure 19. Crack Pattern at Column-Base beam Joint

Test Result of Retrofitted Specimen-2 (RS-2)

The cracks marked in black were those that surfaced during rightward loading and unloading. The red marked cracks represented the cracks that appeared during the leftward loading and unloading. During the test of RS-2, its very first crack was found at positive first cycle loading at the joint of the base beam and left column with 6 ton load and corresponded to a displacement of 4 mm.

Figure 20. Retrofitted specimen-2 under Hydraulic testing Machine

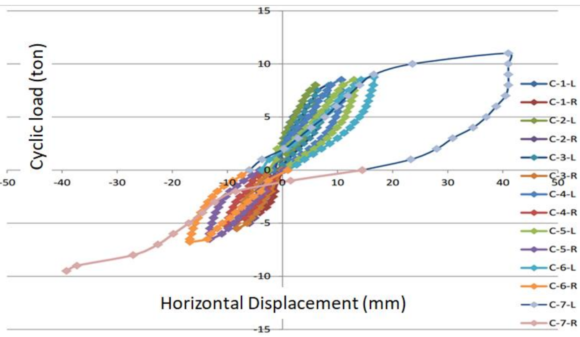


Figure 21. Load Vs. Displacement plot for all cycles

Figure 22. Crack Pattern at Beam-Column Joint

Figure 23. Crack Pattern at Beam-Column Joint

Figure 24. Crack Pattern at Column-Base beam Joint

Figure 25. Crack Pattern at Column-Base beam Joint

Conclusions

This research investigated the ultimate load carrying capacity and the maximum lateral displacement of RC columns strengthened by micro-concrete. All fabricated frame specimens were subjected to successive cyclic loading. Following conclusions are drawn based on the experiment and analysis of the results:

- Ultimate lateral load carrying capacity of RS-1 and RS-2 was found to be 175% greater than that of CS
- Before the formation of the first crack, the RS-1 experienced 350% more lateral load than the corresponding CS whereas RS-2 experienced 300% more lateral load than CS.
- Test results show that the CS suffered shear failure at the base of the column and significant degradation of strength at relatively low lateral displacement.
- Although RS-2 [8160 psi] was stronger than RS-1 [6300 psi], it didn’t increase the load carrying capacity and the stiffness of the RSs significantly.
- The failure mode of both RS-1 and RS-2 was anchorage failure. It indicates inadequate penetration of longitudinal rebars during retrofitting.
- No hooks were provided in the longitudinal rebars during retrofitting of the columns. This resulted cracking in the top of the column during the test.
- The results of this investigation indicated that the strengthening of a square reinforced concrete column with micro concrete may be considered as successful.

References

Fancy, S. F., (2014) “Experimental Investigation on Performance of Beam-Column Frames with Column kickers”.

Hassan, M. R., Ahmed, S., (2016) “Production of Micro-concrete Using Indigenous Materials”.

AXIAL COMPRESSIVE BUCKLING, BENDING AND SPLITTING TENSILE BEHAVIOR OF FIBER REINFORCED MORTAR

S. Sarwar[1], R. Hassan[2] and A. Chakraborty[3]

ABSTRACT

This research aims to introduce the advantages of FRM masonry structures over plain masonry members. The masonry walls durability is at stake during the earthquake more than any other structural components. In this experiment for enhancing the tensile and compressive strength, ductility, toughness of mortar locally available and economical fibers is used.

In this paper, the investigation is evaluated based on three different effects, effects of the volume ratio of fiber, types of fibers (Steel, Nylon and natural fibers), and length of fibers. Also, the tensile stress-strain behavior of FRM is found by MATLAB analysis.

The tensile capacity of hooked steel FRM having volume ratio 1.5% is increased by 2.1 times and for mild steel wire having 3% volume ratio capacity is increased by 1.44 times with respect to control specimen. This research can propose FRM with steel fiber and nylon fiber can merge to the masonry constructions to increase ductility, stability along with crack resistance at the time of natural calamities especially during the earthquake when masonry structures are subjected to seismic loading.

Introduction

Mortar is brittle material which is stronger in terms of compression, while weaker in terms of flexure and tension. When subjected to tension, these unreinforced brittle matrices initially deform elastically. The elastic response is followed by micro-cracking, then localized micro-cracking, and finally fractures. (Erdogmus 2015) The fiber reinforcement into the structure of the mortars changes the failure mechanisms. This is due to the fact that fibers through their cohesion to the matrix are bridging the cracks formed and they absorb part of the transformation energy. A high percentage of fibrous materials are often found in renders to reduce the cracking tendency and to make them more resistant to extreme environmental conditions (Stefanidou et al. 2016).

Hence fiber-reinforced mortar (FRM) is introduced in masonry applications where different types of fibers are mixed with mortar for increasing compatibility, workability and bond strength of mortar joints. In a mortar, fiber is reinforced to increase the tensile strength, improvement in maximum tensile stress, also resist the microcracks due to shrinkage. In this study, the axial compression and splitting tensile behavior is observed under reinforced fiber.

Objective

The objectives of this study are to study the axial compressive behavior of FRM plate specimens due to different volume ratio of fibers, different types, and length of fibers and to observe the bending pattern of FRM plate specimens due to point load at the middle of the specimens. Also, from this experiment failure patterns of FRM specimens is examined and thus tensile stress-strain curves of FRM split cylinder specimens are constructed.

In this research work, the main purpose is to resist the earthquake effect on the partition wall which is also known as masonry wall. At the time of the earthquake, because of reinforcement, the collapse rate of beams and columns are comparatively lower than other structural or nonstructural members. The effect of the earthquake on masonry walls is relatively more and uncertain as there exists no direct connection between the structural components. The failure of the masonry walls is quick and no visible cracks are developed at the very beginning of the process. The factor of the safety of these walls is also very low during natural calamities. In this experiment for enhancing the tensile and compressive strength, ductility, toughness of mortar locally available and economical fibers is used. So that increment of tensile and compressive capacity along with economical structural components, FRM over plain mortar construction may encourage the construction industries of Bangladesh to adopt FRM as a construction material.

[1] *Graduation in Civil Engineering, Ahsanullah University of Science & Technology, Dhaka-1208.*
[2] *Civil Engineer in Dhaka Mass Rapid Transit Project, Sector-13, Uttara-1.*
[3] *Project Engineer in LPG Project at Mongla Port, Bagerhat, Khulna-9351.*

Experimental Program and Data Acquisition

The objective of this research study is to inspect the axial compression and splitting tensile behavior of fiber reinforced mortar prepared by using both steel fibers and natural fibers. For observing the tensile property of mortar specimen, it is shaped as cylinder whilst for the compression and bending characteristics, the specimen has been cast into a rectangular shape with different fibers. Both processed and naturally extracted fiber is used to get a variation in mortar strength behavior. All the fibers have been prepared in the laboratory at different shapes

Specimen Designation and Legends

All Specimens are separated by different legends throughout the experiment to keep up the balance in the identification of specific specimens. Legends and representations used in this study for different specimens are given in Figure 1

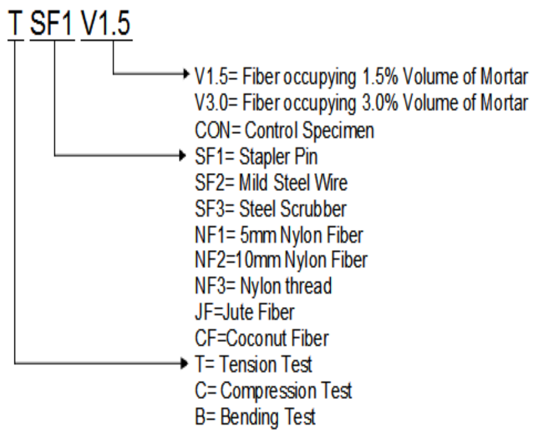


Figure 1: Typical Legends of Control and Fiber reinforced Specimen

Experimental Strategy

This research intends to investigate the axial compression buckling, bending and splitting tensile behavior of Fiber Reinforced Mortar (FRM). For this different type of manufactured and natural fibers varying the aspect ratio are prepared manually in the laboratory. To estimate the actual compression buckling, bending and tensile strength of mortar due to fiber mixed in the mortar matrix, the mortar is cast in a cylindrical shape for split tensile test and in plate shape for compression buckling and bending test. The molds shape and fiber length are maintained properly to ensure the volume ratio by varying the volume percentage tension, compression buckling, and bending behavior are checked throughout the experiment.

Mix Design

As with any other type of mortar, the mix proportions for fiber-reinforced mortar depend upon the requirements for a particular job, in terms of strength, workability, and so on. In this experiment that procedure for proportioning FRM mix is used, which emphasize the workability of the resulting mix. However, there are some considerations that are particular to FRM. The water-cement ratio was 0.5 to maintain the workability of the mixture. The ratio of cement and fine aggregate and all other properties are tabulated in Table 1.

Table 1: Mix design of plain mortar and FRM

Cement type	**PCC (Portland composite Cement)**
Fine Aggregate Size	4.75mm (No.4 sieve) passing & 0.75mm (No 200 Sieve) retained
C:FA	1:2
W/C	0.45
Fiber Volume	1.5% & 3%

Fiber type	Steel and natural fibers	
Fiber Tensile strength (Maximum)	160000 psi (1100 MPa)	
Fiber cross-section	SF1	Rectangular
	SF2	Rectangular
	SF3	Rectangular
	NF1	Circular
	NF2	Circular
	NF3	Circular
	CF	Circular
	JF	Circular
Mortar comp. strength	3163.27 psi (21.81 MPa)	

Testing and Data Acquirement

Gathering the Lateral and Vertical Load and Displacement Data

After 28 days all the specimens are prepared properly for testing the tensile and compressive strength of fiber reinforced mortar. The physical properties of cylinders and rectangular plates i.e. diameter, height, and weight are measured. A total of 17 splitting cylinders are tested at a constant rate of 3mm/min until the failure. For this test lateral displacement and lateral load were recorded from the load cell. Then 15 rectangular plates are tested at a constant rate of 10mm/min for compression test and 15 Rectangular plates are tested at a constant rate of 10 mm/min for bending test until failure occurs. Vertical displacement and axial load were recorded from the load cell. The lateral stress-axial strain curves for tension test are also plotted.

Data Analysis & Results

Effects on Splitting Tensile Strength

Compared to the plain mortar, tensile capacity of fiber reinforced mortar with Fiber having 1.5% and 3% volume is increased significantly. The tensile strength has increased for Coconut fiber 1.6 times and 1.4 times, Jute Fiber 1.1 times, hooked steel fiber 1.8 times and 2.1 times, Mild Steel Wire 1.34 times and 1.44 times, spiral steel fiber 1.3 times and 1.31 times, Nylon fiber (NF1)1.53 times and 1.51 times, Nylon Fiber type (NF2) 1.38 times and 1.375 times, Nylon thread 1.47 times (3%) for 1.5% and 3% volume ratio respectively. Beside this, the ductility also enhanced at the certain limit with an increment of volume ratio. So it can be easily said that steel fiber and nylon fiber is more effective to increase the tensile strength compared to compressive strength.

Effect of Fiber type on tensile strength

In this investigation, fiber type played a significant role in increasing the lateral tensile strength of FRM. Beginning of the test, all the physical properties of specimens have been taken. On basis of those data it can also be seen that in a change of fiber length, Aspect ratio also enhanced the strength in some cases, also decreased some of the mortars tensile stress. In Figure 3.1 and 3.2 variations of lateral stress among all types of fiber because of the volume ratio of 1.5% and 3% can be seen. In Figure 3.1 it can be noticed that though Nylon fiber length has been increased from 5mm to 10mm in two different types of specimens, it could not have any impact on the increment of tensile stress of FRM, in addition, the fiber length enhancement reduces the tensile strength capacity of the mortar. In between all fibers, Nylon thread has shown poor improvement in increasing in 1.5% volume, on the contrary, hooked steel fiber has enhanced the lateral tensile capacity of mortar to a remarkable limit. Also, from Figure 3.2 it is seen that hooked steel fiber again has increased the lateral stress whereas jute fiber has decreased the tensile capacity level for 3% volume.

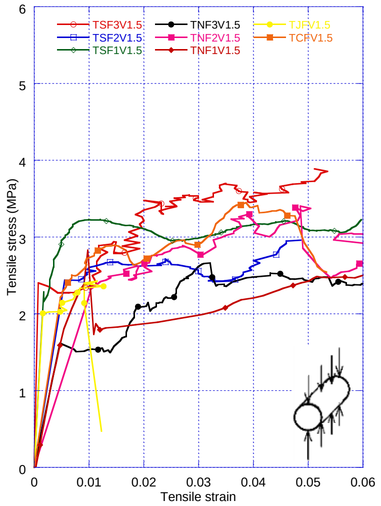


Figure 3.1: Evaluation of splitting tensile stress-strain behavior of FRM with All Fibers of volume ratio of 1.5%.

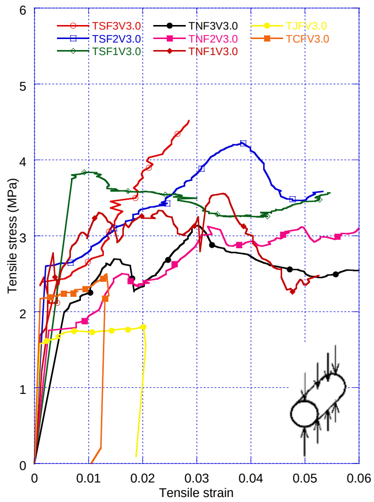


Figure 3.2: Evaluation of splitting tensile stress-strain behavior of FRM with All Fibers of volume ratio of 3%.

In Table 3.1 the maximum tensile stress and strain value of all type fiber-reinforced mortar is given.

Table 3.1: Summary of results of the tensile split test for cylindrical FRM specimens

Specimen ID	**First crack load (N)**	**Ultimate tensile load (N)**	**Ultimate tensile stress (MPa)**	**Tensile strain at peak tensile stress**	**Failure pattern**
TCON	31000	36811	1.835	0.005	Split tension
TSF1V1.5	53000	62047	3.226	0.0115	Split tension
TSF1V3.0	64000	73319	3.833	0.009	Split tension
TSF2V1.5	44000	54946	2.465	0.0058	Split tension
TSF2V3.0	52000	81984	2.65	0.0048	Split tension
TSF3V1.5	43000	76320	2.39	0.004	Split tension
TSF3V3.0	36000	56430	2.4	0.00083	Split tension
TNF1V1.5	34000	55059	2.75	0.0098	Split tension
TNF1V3.0	49000	66867	2.785	0.0035	Split tension
TNF2V1.5	43000	93240	2.536	0.0166	Split tension
TNF2V3.0	43000	60307	2.524	0.0155	Split tension
TNF3V1.5	51000	54895	1.61	0.0045	Split tension
TNF3V3.0	40000	62491	2.69	0.015	Split tension
TCFV1.5	42000	66916	2.89	0.0148	Split tension
TCFV3.0	53000	54654	2.488	0.013	Split tension
TJFV1.5	50000	52435	2.06	0.0048	Split tension
TJFV3.0	32000	36303	1.79	0.004	Split tension

Effect on Axial Compressive Buckling and Bending Capacity

Among all specimens, only three specimens compressive strength have increased than control specimen. Though steel wire and nylon fiber have increased the compressive capacity of mortar, from bending test it is seen that only hooked steel fiber has increased the load-bearing capacity of the FRM among all types of fibers.

Failure Pattern

For control specimen of lateral tensile strength test some spilling effect is observed while the whole cylinder is split during splitting cylinder test which shows the brittleness of the specimen and after using steel fiber of 1.5 % of total volume, the failure patterns are transformed from brittle failure to ductile failure. While circular plain mortar cylinders are completely split out, FRM cylinders are failed but not split out, the mortar materials are held by the fibers which are ductile behavior. If this property is developed in a structural member, during earthquake lateral members will not fail instantly and this will lessen the risk of injury and also allow movement of people to the safe location.

Discussion

This investigation is evaluated based on three different effects, effects of the volume ratio of fiber, effects of types of fibers, effects of length of fibers. From the experiment the comparison of tensile strength capacity with respect to control specimen, ultimate strain for peak point of static lateral stress condition. The tensile strength capacity is increased by adding steel fibers. The tensile capacity of hooked steel fiber reinforced mortar having 1.5% and 3% volume of fibers is increased by 2.1 and 1.76 times with respect to control specimen. By adding 1.5% and 3% volume ratio of mild steel wire, the capacity is increased by 1.34 and 1.44 times. But spiral steel fiber varying 1.5% and 3% volume ratio have the same increment of tensile capacity of FRM and increases the capacity by 1.3 times more than control specimen.

Also, nylon fiber (NF2) volume ratios 1.5% and 3% increase 1.4 times and 1.1.375 times than plain mortar respectively. Nylon thread volume 1.5% decrease the tensile strength of FRM whereas for volume ratio 3% tensile strength value increases 1.47 times than control specimens. As natural fibers like coconut fiber and jute fiber, the tensile strength increment ratio is lower than other fibers. Coconut fiber having 1.5% of total volume of mortar increases 1.57 times and Jute fiber for 1.5% volume ratio tensile capacity increases only 1.1 times than control specimen and for 3% volume ratio tensile strength decreases than the control specimen. In compression buckling and bending tests, the load-bearing capacity of FRM is decreased for increasing the volume ratio. Hooked steel fiber and mild steel wire take the maximum load to compare to the control specimen where other fibers decrease the load bearing capacity of FRM at both compressions buckling and bending experiments. For hooked steel fiber of 1.5% volume ratio takes 1.1 times more load than control specimen and load-bearing capacity of mild steel wire reinforced mortar due 1.5% volume of fiber is increased 1.2 times than plain mortar. In the bending test only, hooked steel fiber occupying 3% of total volume of mortar takes 1.4 times more load than control specimen.

Throughout the experiment brittleness of mortar is tried to be reduced by reinforcing different types of fibers with different types of volume ratio. This research can propose FRM with steel fiber and nylon fiber can merge to the masonry constructions to increase ductility, stability along with crack resistance at the time of natural calamities especially during the earthquake when masonry structures are subjected to seismic loading.

Conclusion

At the time of earthquake, the first cracking is visible on walls of an RCC structure, also most of the time walls are collapsed abruptly that decrease the factor of safety of structures. Because of reinforced beams and columns before breaking of these components, a certain limit of a factor of safety is maintained. To provide a definite limit to the masonry walls fiber-reinforced mortar (FRM) is introduced in this research to investigate the tensile, compressive buckling and bending behavioral variation of FRM over plain mortar. Based on the experimental investigation, it can be said that among all the parameters, the tensile strength of FRM has the most effective outcome. Most of the fibers increase the tensile strength of mortar. The tensile stress-strain behavior of cylinder specimens shows that for hooked steel fiber volume ratio 3% the tensile strength increases about 2.1 times with respect to control specimen. Also, nylon fiber (NF1) for volume 1.5% increases tensile strength about 1.5 times with respect to control mortar. These two fibers have the most successful effect on the FRM which is the main objective of this investigation.

The failure pattern of fiber reinforced mortar due to lateral load has shown improvement in terms of cracking compared to plain mortar and exhibit improvement due to improvement in bonding. There spilling has occurred to the plain mortar, among all the fibers hooked steel fiber and mild steel fiber resist this spilling failure to a certain limit with an increment of tensile strength.

Fiber reinforced mortar can be used for the construction of partition walls of RC structures, masonry structures, boundary walls and for architectural components which are subjected to seismic loading during an earthquake. In Future, there is the scope of carrying the study for cyclic loading and impacts loading as these effects are essential to know to resist the earthquake devastation. Also, evaluation of the enhancement of compressive buckling, bending and tensile behavior by varying aspect ratio differentiating the lengths of fiber can be done.

References

Erdogmus, E. (2015). 'Use of fiber-reinforced cement in masonry construction and structural rehabilitation' *Fibers*, Vol.3 (1), pp.41-63.

Stefanidou, M., Papachristoforou, M., & Kesikidou, F. (2016) 'Fiber-reinforced lime mortars' Pp.422-431.

NUMERICAL SIMULATION OF SEISMIC BEHAVIOR OF REPLACEABLE STEEL COUPLING BEAM

I. Aziz[1], K. M. Amanat[2]

ABSTRACT

In this study it was intended to investigate the cyclic behavior of replaceable steel coupling beam which is a part of coupled shear wall system. Nonlinear finite element analysis was carried out with a model which was developed with reference to a past experimental study. In the experimental study, a type of replaceable steel coupling beam was developed, which consisted of a central "fuse" shear link connecting to steel beam segments at its two ends for improving the seismic resilience of coupled shear wall systems. Three-dimensional finite element model of replaceable steel coupling beam was developed considering both geometric and material non-linearity. The shear-rotation behavior of the shear link and the beam for end plate connections was investigated by FEM. It was observed that adequate agreement existed between the results of numerical analysis and the experimental study. Further studies with the numerical model showed that the overstrength factor of the shear link decreases with the increase in length ratio of the link. Most importantly, it was observed that the strain energy density is concentrated in the shear link which indicates that maximum energy will be dissipated by the shear link and other parts can be made free from damage during an earthquake to a very large extent which will facilitate time saving and economic recovery in the post disaster period.

Keywords: Replaceable steel coupling beams, Shear link, Replaceability, Seismic behavior, Hysteretic response.

Introduction

In modern structures, wall openings are inevitably present due to windows, doors and service ducts. These features turn simple shear walls into coupled ones, which can be considered as two or more in-plane shear walls coupled together by a system of connecting beams. Coupled walls continue from the foundation to the top of the building but in between the walls, the connecting beams placed are at specific elevations keeping the rest space empty as openings between the walls. Coupled wall systems are often used in high rise buildings because of the superior strength and stiffness they provide. In such a system, coupling beams distributed along the building height, are designed to undergo inelastic deformation and dissipate seismic energy.

Recent large earthquake have demonstrated that modern buildings generally behave well in terms of life safety. However repair of these buildings was found to be costly in both money and time leading to long lasting loss of occupancy and slow recovery of the community. For minimum disruption in the life and business of urban society, prompt recovery of buildings is a clear need. One solution to achieve this is to use easily replaceable components or devices in the energy dissipation regions (i.e., plastic hinges) of the structure.

Ji et al. in 2017 developed a type of replaceable steel coupling beam for improving the seismic resiliency of coupled shear wall systems. The coupling beam consisted of a central "fuse" shear link connecting to steel beam segments at its two ends. Inelastic deformation was concentrated in the shear link during a severe earthquake, and the damaged links can be replaced easily as, specialized link-to-beam connections were adopted. Another experimental study was carried out by Ji et al. (2016) where a replaceable coupling beam was proposed comprising of steel hybrid shear links that are shorter than typical shear links in eccentrically braced frames (EBFs) and subjected to cyclic loading. Recently, various types of replaceable coupling beams were proposed and recognized as an alternative to traditional RC coupling beams (e.g.,Chung et al. 2009; Kumagai et al. 2009; Christopoulos and Montgomery 2013; Lu et al. 2013). Shahrooz et al. in 1993 studied the cyclic response of steel coupling beams embedded into reinforced concrete boundary elements.

In this paper non-linear finite element analyses on seismic behavior of "Replaceable steel coupling beams" have been presented. A three-dimensional finite element model of "Steel coupling beam with shear link" as a part of coupled shear wall system was developed in ANSYS 16.2. Verification of this finite element model has been achieved with reference to the experiment of Ji et al. (2017) and it has shown good agreement. Shear force versus rotation behavior of the beam and the link was verified.

[1]*Lecturer, BUET-Japan Institute of Disaster Prevention and Urban Safety, Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh. Email- ishfaqaziz94@gmail.com.*

[2]*Professor, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh. Email-kmamanat@gmail.com.*

Behavior of coupled shear wall system

Figure 1 shows the behavior of coupled shear wall under lateral load demonstrated by Tawil et al. (2010). When the walls deflect under the action of the lateral loads, the connecting beam ends are forced to rotate and displace vertically, so that the beams bend in double curvature and thus resist the free bending of the walls. The bending action induces shears in the connecting beams, which exert bending moments of opposite sense to applied external moments, on each wall. The shears also induce axial forces in the two walls, tensile in the windward wall and compressive in the leeward wall. The lateral load moment *M* at any level is then resisted by the sum of the bending moments, M_1 and M_2 in the two walls at that level, and the moment of the axial forces $N \times l$, where *N* is the axial force in each wall at that level and l is the distance between their centroidal axes.

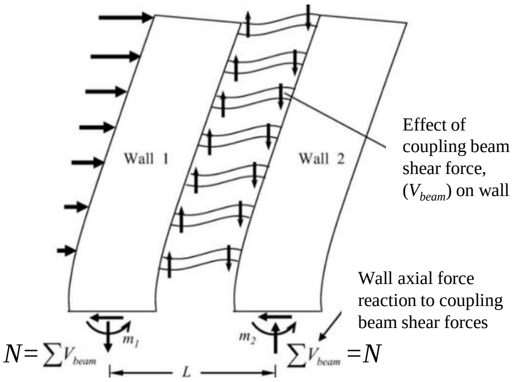


Figure 1. Behavior of laterally loaded coupled shear walls, Tawil et al. (2010)

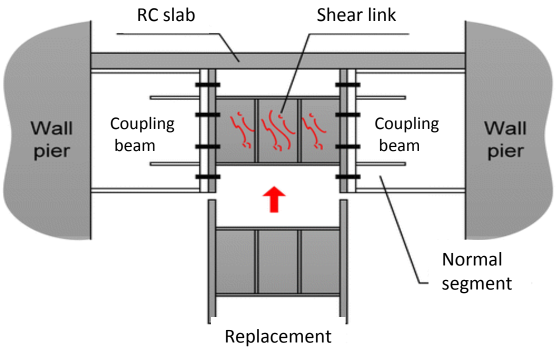


Figure 2. Coupling beam with shear link

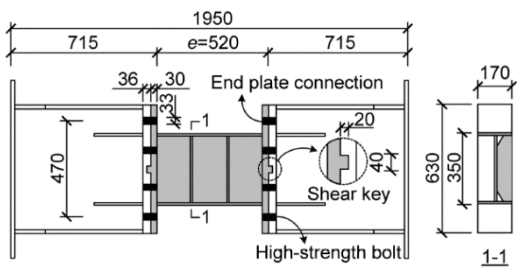


Figure 3. Test specimen of Ji et al. (2017) –End plate connection

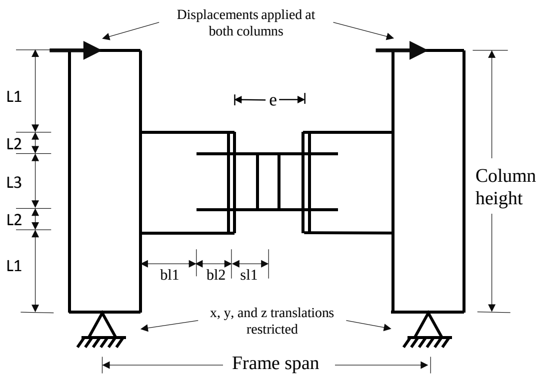


Figure 4. Sketch of the full structure in FEM

Replaceable coupling beam

Coupling beams are lateral structural members which connect two or more in-plane shear walls in a coupled shear wall system. In Figure 2, a coupling beam with a shear link is shown. Both the beam and the link are steel I sections.

Table 1. Material Properties used as given in experiment of Ji et al. (2017)

Member of shear link	**Yield strength**	**Ultimate strength**	**Elongation**
	F_y, (Mpa)	**F_u, (Mpa)**	**δ (mm)**
Web	228	330	54
Stiffener	273	432	44.4
Flange	396	557	44.4

Damages induced by cyclic loadings are made to concentrate in the link by specialized beam to link connection. Then the link can be replaced resulting economic and time saving recovery.

Computational modelling

Model generation

Figure 3 shows the specimen of Ji et al.'s (2017) experiment and Figure 4 shows the sketch of the model generated for verification.

The two columns at two ends are made sufficiently stiff to simulate the restraint induced by wall piers, and the elements in between the two columns are coupling beam and shear link. Since the structure is symmetric half of it was modelled and rest was mirrored. The element SHELL181 was used to model all the members. The material properties and parameters of the experimental study are provided in Table 2 and Table respectively. Material properties and parameters of the main model developed in ANSYS for verification are provided in Table 3 and Table 4 respectively.

Table 2. Parameters of shear link, Ji et al. (2017)

Specimen number	**Web steel**	**Length ratio** $e/(M_p/V_p)$	**Flange width-to-thickness ratio** $b_f / (2t_f)$	**Web width-to-thickness ratio** h_o/t_w	**Stiffener thicknes (mm)**	**Stiffener spacing (mm)**
CB1	LY225	0.70	7.1	32.6	10	180

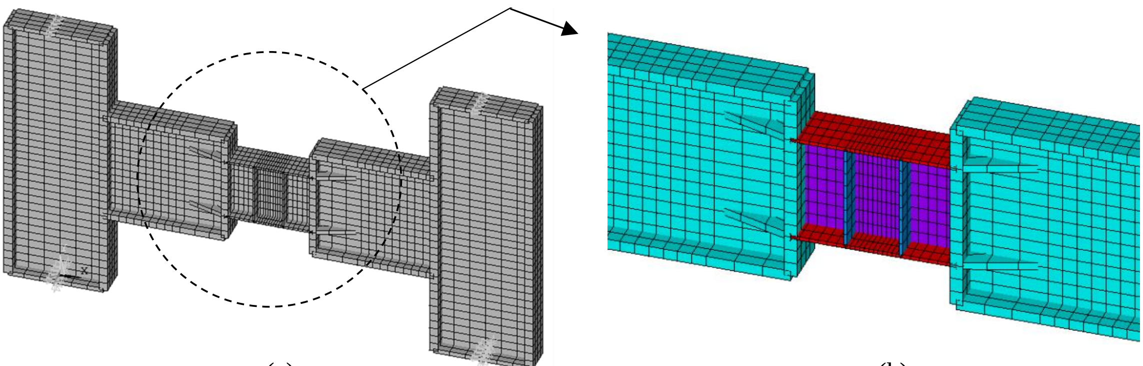
For beam column and stiffeners, yield strength of 385 MPa, utimate strength equal to 550 MPa and maximum elongation equal to 30 mm was used in FEM.

Meshing

All elements are meshed with the individual material property. Each column is divided into three major parts along its length. The mid part length was equal to the beam depth. The material properties of the web and flanges of the shear link are different. Divisions were done in such a way that the aspect ratio remains close to unit. Continuity between elements are ensured by matching boundaries of connected elements at connection. The full meshed structure is depicted in Figure 5.

Boundary conditions

At the bottom of both columns translations in x, y and z directions were restrained to simulate the support condition given by a foundation beam in the experimental study.



(a) (b)

*Figure 5. (a) Meshed structure with imposed boundary conditions; (**b)** Close view of shear link (Different colors indicate different materials of elements)*

The cyclic load which was applied in ANSYS was displacement controlled. Displacements were applied in positive and negative directions alternately. The first negative rotation of the beam was very small compared to the first positive rotation. So the first negative displacement was less than the first positive one. After the second step the displacements were gradually increased to generate cyclic loading effect in the structure.

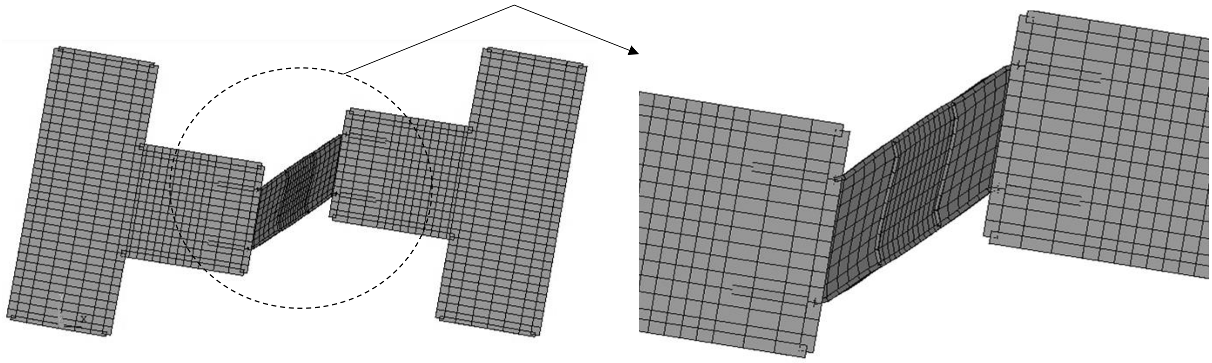


Figure 6. Deflected shape of the structure due to lateral load

Table 4. Parameters of the structure used in FEM

Parameters	Dimensions (mm)
Total height of the column, column height	1590
Support to support horizontal distance, frame span	2510
Vertical distance from support to bottom of the beam, *L1*	480
Vertical distance from bottom of beam to bottom of shear link, *L2*	140
Vertical distance from bottom of shear link to top of shear link, *L3*	350
Column flange width	170
Column flange thickness	50
Column web depth	560
Column web thickness	25
Length of beam from column to starting point of triangular stiffeners, *bl1*	452
Length of beam from starting to end of triangular stiffeners, *bl2*	263
Beam flange width	170
Beam flange thickness	35
Beam web thickness	20
Beam web depth	630
Length of shear link, *e*	520
Depth of shear link	350
Shear link web thickness	10
Shear link web thickness	10
Shear link flange width	170
Shear link flange thickness	12
Thickness of stiffeners in Shear link	10
Thickness of triangular stiffeners in beam	25
Thickness of plates at bottom and top of column	25
Beam- Link connecting plate thickness	40

Experimental model verification

Verification of the hysteretic behavior: Shear force versus Shear Link rotation and Beam rotation

The shear force in beam and link is equal to the vertical support reaction of a column. Shear forces in link has been found for different rotations of the link and it was used as a parameter for verification with the experimental study. Figure 7 shows a superimposed plot (shear force versus shear link rotation) of both the experimental study (Ji et. al, 2017) and numerical analysis performed in ANSYS 16.2. It can be seen from the figure that the peak and the shape of the curve found from the numerical analysis matches the experimental study to an appreciable extent. Again, Figure 9 shows that the peak shear forces in the link for different rotations are very close to the experimental values.

Similarly, the shear force versus beam rotation has also been found by numerical analysis and a superimposed plot of it with the experimental results of Ji et al. is depicted in Figure 8. Hysteresis plot of the beams does not match as much as that of the shear link. However, the peak shear forces of the numerical analysis has been found to be closer to the experimental study which can be observed from the plot of the ratio of the two values in Figure 10. It can be noted in this context that the shear key in beams that was used in the experimental study was not included in the numerical model which is a limitation of the developed model. Again, it was also shown in Figure 11 that, the peak shear forces of the experiment and the numerical analysis at maximum positive and negative rotations of each cycle were very close to each other.

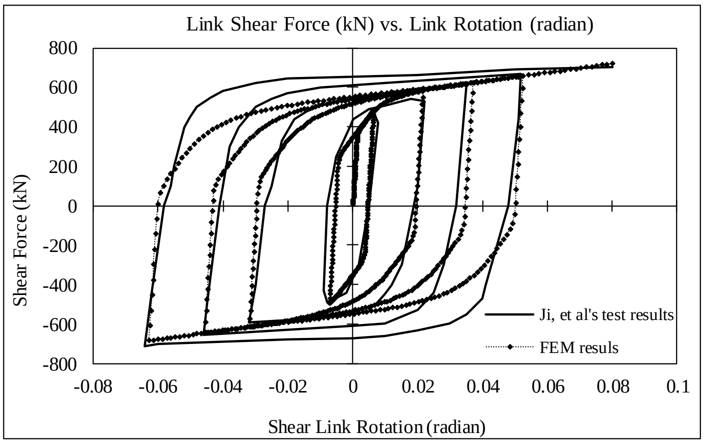


Figure 7. Hysteretic response curve of shear link; Experimental and FEM.

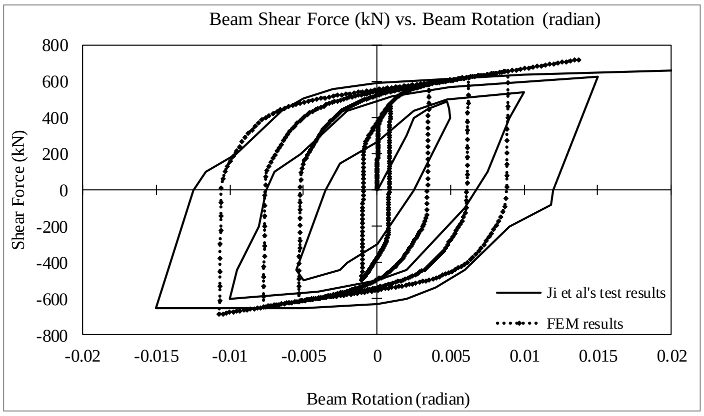


Figure 8. Hysteretic response curve of beams; Experimental and FEM.

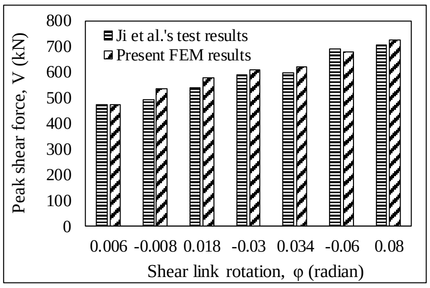


Figure 9. Peak shear force (kN) at different rotations of shear link.

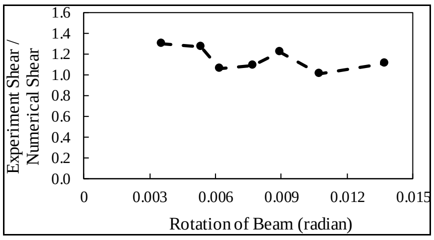


Figure 10. Ratio of Experimental shear force to numerical shear force at different rotations of beam

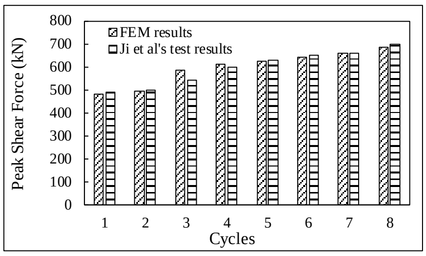


Figure 11. Peak shear forces at different cycles of loading

Parametric Studies

Overstrength factor and Plastic strain energy density

The overstrength factor of the structure was investigated for different length ratio of the shear link. The length ratio was calculated dividing the length of the link by the ratio of plastic moment strength to plastic shear strength of the link and the overstrength is defined as the ratio of the plastic shear strength of the link to the

maximum shear developed. It was found that overstrength factor increases with the decrease in the length ratio. Again with the increase in the number of stiffeners the overstrength factor increases.
The plastic strain energy density of the whole structure is shown in Figure 3. It can be observed that the energy density is maximum at the shear link and it has very small value in other parts of the structure. This indicates that most of the energy will be dissipated by the shear link and the damage in other parts of the structure will be negligible. So, after an earthquake, the damaged link can be replaced and can result in an efficient post disaster recovery.

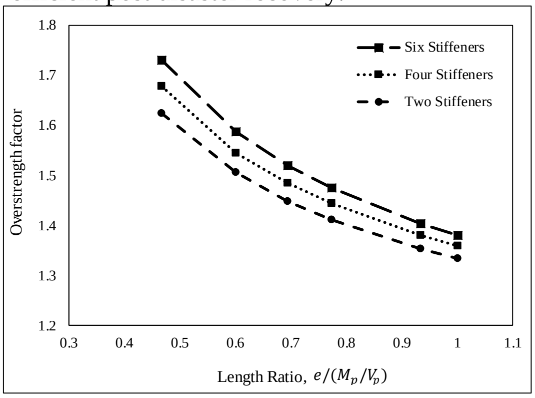


Figure 12: Plot of overstrength factor vs. length ratio for different number of stiffeners

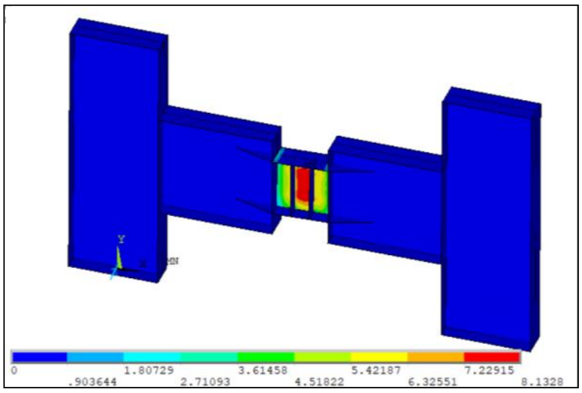


Figure 3: Plastic strain energy density

Conclusions

In this study, a numerical model of "Coupled shear wall system with replaceable steel coupling beam" is developed. Verification of the model was carried out with reference to the experimental study of Ji et al. (2017) and it has shown good agreement. Overstrength factor can be pivotal in seismic design of coupled shear wall systems the variation of which has been shown with the change in length ratio.
Replaceable components in significant structures can play vital role for minimizing the damages in the significant structural members and can assist in quick recovery of the system. However, these types of components demand more study regarding their resilience, replaceability and connection with other structural members. Since, adequate verification of the model is achieved, it will allow us to carry further investigations on behavior of replaceable steel coupling beam with this model.

References

Christopoulos, C., and Montgomery, M. S. (2013). "Viscoelastic coupling dampers (VCDs) for enhanced wind and seismic performance of high-rise buildings." Earthquake Eng. Struct. D, 42(15), 2217–2233.
Chung, H. S., Moon, B. W., Lee, S. K., Park, J. H., and Min, K. W. (2009). "Seismic performance of friction dampers using flexure of RC shear wall system." Struct. Des. Tall. Spec., 18(7), 807–822.
Ji, X., Wang, Y., Ma, Q., and Okazaki, T. (2017). "Cyclic Behavior of Replaceable Steel Coupling Beams." J. Struct. Eng., ASCE.
Ji, X., Wang, Y., Ma, Q., and Okazaki, T. (2016). "Cyclic behavior of very short steel shear links." J. Struct. Eng., 10.1061/(ASCE)ST.1943-541X.0001375, 04015114.
Kumagai, H., Shimazaki, K., and Hayashi, S. (2009). "Experimental study on coupling beams with steel dampers in mid-span." J. Struct. Constr. Eng., 74(638), 755–763 (in Japanese).
Lu, X., Chen, Y., and Jiang, H. (2013). "Research progress in new replaceable coupling beams." J. Earthquake Eng. Eng. Vib., 33(1), 8–15 (in Chinese).

Stafford Smith, B. and Coull, A. (1991). "*Tall building structures*. Analysis and design"
Subedi, N., K., (1991). "RC-Coupled Shear Wall Structures. I: Analysis of Coupling Beams". J. Structural Eng., ASCE.
Tawil, S., Harries, K. A., Fortney, P. J., Shahrooz, B. M. (2010). "Seismic design of hybrid coupled wall

NUMERICAL SIMULATION OF SEISMIC MOMENT CONNECTIONS WITH STEEL SLIT DAMPERS

M. I. Hossain[1] and K. M. Amanat[2]

ABSTRACT

To improve the seismic performance of steel frames after the Northridge (1994) and Kobe (1995) earthquakes, a slit steel damper system has been developed by researchers to prevent the damage formation on columns and beams by dissipating energy in the dampers at the beam-to-column connections of steel frames. In the present study, a three dimensional finite element model is developed for investigating the behavior of seismic moment connection system with a steel slit damper. The material nonlinearity as well as geometrical nonlinearity has been incorporated. The developed finite element model has been applied to simulate experimental studies done by past researchers and it has been found that fair agreement exists between present analysis and past experimental results, which establishes the acceptability and validity of the present finite element model to carry out further investigation. Study is then carried on different parameters of dampers such as damper thickness, strut width etc. which have significant effects on beam maximum yield strength. The results of the parametric studies have been compared with the results of past research and it is evident that damper strut width is more significant than other parameters and need to be considered cautiously in design as moment capacity of connection system changes greatly for slight variation of it. The proposed range of parameters need to be maintained to remain conservative.

Keywords: Seismic performance; Steel frame; Steel slit damper; Beam to column connection; Yield strength.

Introduction

An earthquake-resistant structure should have the necessary strength, rigidity, and ductility. Structural designers of earthquake-resistant reinforced concrete accept that reinforced concrete can behave similarly to steel from a ductility and strength perspective, but this behavior is very difficult to obtain, and requires special design and construction efforts. Due to this ductility and strength advantage, steel structures are accepted as superior and preferred systems over reinforced concrete in seismic regions. The general belief that steel structures will not be challenged and are the safest structures during an earthquake was thoroughly questioned during the 1994 Northridge California earthquake in the United States of America (Miller 1998). The damages that steel structures sustained in the 1995 Kobe earthquake motivated researchers to examine the causes of damage in steel frame structures, to explore the necessary measures to be taken, and to find new design approaches (Nakashima 1998).

Starting in the 1960s, engineers began to regard welded steel moment-frame buildings as being among the most ductile systems contained in the building code. Many engineers believed that welded steel moment-frame buildings were essentially invulnerable to earthquake-induced structural damage and thought that if any such damages occur, it would be limited to ductile yielding of members and connections. Earthquake-induced collapse was not believed possible. Partly as a result of this belief, many industrial, commercial and institutional structures employing welded steel moment-frame systems were constructed, particularly in the western United States. The Northridge earthquake of January 17, 1994 challenged this paradigm. Following that earthquake, a number of welded steel moment-frame buildings were found to have experienced brittle fractures of beam-to-column connections. The damaged buildings had heights ranging from one story to 26 stories, and a range of ages spanning from buildings as old as 30 years to structures being erected at the time of the earthquake.

After the Northridge and Kobe earthquakes experimental programs on beam-to-column connections were developed because of brittle fractures at welded beam-to- column connections. A number of studies are being carried out on a variety of materials and systems that dissipate the seismic loading effects in order to improve the seismic performance of steel frames.

In recent years to prevent damage to columns and beams by using seismic dampers in the beam-column

[1] *Lecturer, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh; email: irfancebuet@gmail.com.*
[2] *Professor, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh; email: kmamanat@gmail.com.*

connections of a steel frame under cyclic reversible loading configurations has become very popular throughout the world. It is anticipated that the damage would occur on the dampers that are placed in the beam-column connections and energy would be dissipated during an earthquake. The main purpose is to prevent damage to the beam or column by dissipating the loads in the dampers that are placed in beam-column connections when earthquake strength is provided by moment transferring frame systems. By this means, after a damage-inflicting earthquake, by simply replacing the dampers in the beam-column connections of a structure the structure can be made serviceable as there would be no damage to the beams or columns.

Moment Resisting Connections

Moment resisting connections are used in multi-storey un-braced buildings and in single-storey portal frame buildings. Connections in multi-storey frames are most likely to be bolted, full depth end plate connections or extended end plate connections. The most commonly used moment resisting connections are bolted end plate beam-to-column connections.

New Beam-To-Column Connections

To determine the optimum damage control design of the frame, it is desirable to construct structures that can be easily repairable, and to facilitate replacement after the earthquake by limiting the damage to the energy absorption devices. Accordingly, if the dampers on which the damage is concentrated are connected to a main frame by exchangeable high-strength bolts, the beams and columns are easier to repair than with welded connections. By designing dampers that are weaker than the beam and column, it is possible to limit damage to the dampers. The split-T connection is a typical example of the use of high-strength bolts on existing beam-to-column connections. While the advantages of this connection are the simple construction and superior stiffness of the connection, the compression force can cause local buckling on the beam flange. During an earthquake, it is preferable that the damage be limited to those energy absorption elements that have good hysteretic characteristics and not be transmitted to the main frame such as the beam and column.

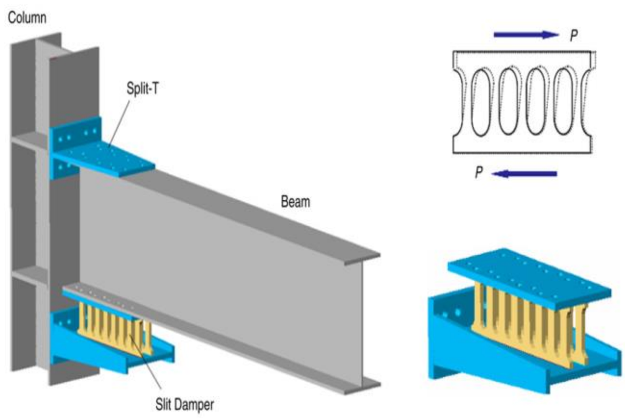


Figure 1. The proposed beam-to-column connection detail with slit damper (Oh. et al. 2009).

Figure 1 shows the new connection system with the energy absorption element proposed in this study. The slit damper on the bottom flange of the beam is actively plasticized before the main structural members. This system takes post-earthquake repairs into consideration as well as the presence of concrete slabs. High-strength bolts are used to connect all columns and beams. That is, the upper split-T is connected with high-strength bolts at the top of the beam to serve as the rotational center of the connection, while the lower split-T is connected with high-strength bolts to concentrate the deformation to the slit dampers of the bottom flange. (Oh. et al.2009)
As shown in Figure 2, since the rotation points on the left and right sides stay at the top flange, damage to the split-T on the top flange, which is difficult to exchange, is avoided. It is expected that deformation of a structure is concentrated on the slit dampers at the bottom flange, if the slit dampers show the same behaviors in positive bending (when the top flange is under compression) and negative bending (when the top flange is under tension). As a result, the dampers can freely deform at the bottom flange of the beam without causing significant damage to the concrete slab under large story drifts. This design permits the simple replacement of slit dampers as connection elements of the bottom flange, allowing the continued use of buildings after an earthquake. Since the major retrofit work after an earthquake is performed near the bottom flange, the slabs do not need to be removed.

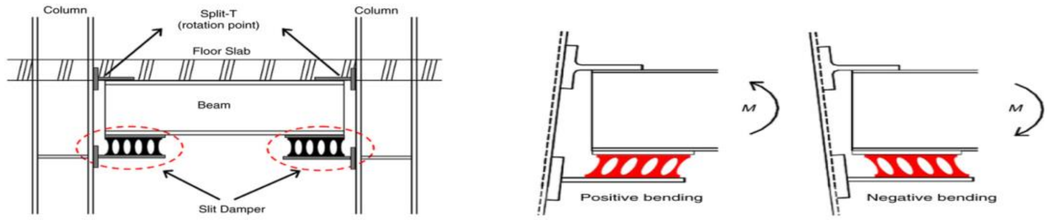


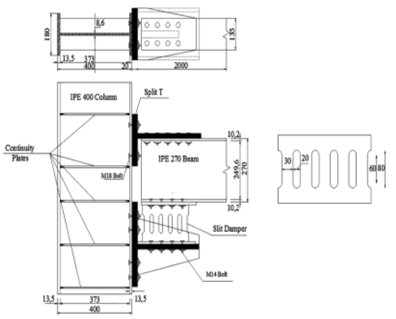
Figure 2. The proposed connection system and deformation (Oh. et al. 2009).

Steel Slit Damper

The Steel Slit Damper (SSD) is fabricated from a standard structural wide-flange section with a number of slits cut from the web, in a vierendeel truss arrangement. The device is a weld-free design, thereby eliminating the uncertainties and difficulties encountered in in-situ welding. The energy is dissipated through plastic deformation on the vertical struts of the slit dampers, as shown in Figure 2. It has been previously reported that the slit damper has an extremely good energy dissipative capacity as well as high stiffness and is considered appropriate to use as a connection element in the system proposed in this study. (Oh. et al. 2009) Performing experimental research related to the application of steel slit dampers on beam-to-column connections of steel frame structures is too much expensive for our country. For this, a numerical analysis by finite element method has been carried out in this study based on the experimental investigation of Koken and Koroglu (2013). If it is possible to show that numerical model can adequately simulate the experimental results than it would be really helpful in the design and construction of steel structure.

Modeling of Beam-Column Connection with Steel Slit Damper

This modeling procedure is developed based on the effort of reproducing the experiment conducted by Koken and Koroglu (2013). The model accounts for both material and geometric nonlinearities. Figure 3 illustrates the details of test specimens and figure 4 illustrates the I-beam section with steel slit damper used in modeling.



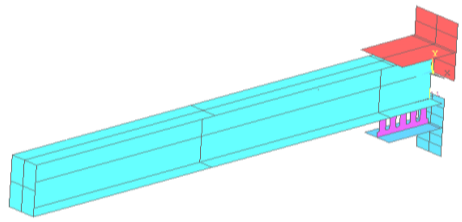


Figure 3. Details of the test specimens *Figure* ***4.*** *I-beam section with steel slit damper.*

(Koken & Koroglu, 2013)

Finite Element Modeling Parameters

To perform the modeling, IPE270 profile is used for beam. IPE270 beam, which has a 2,000-mm length measured from the face of the column to the application point of reversible cyclic loading, is used. The upper split-T that connects the upper flange of the beam to the column, is made of HEA600 profile and the gusset plate (lower split-T), which connects the beam to the column through the damper, is made of HEA800. Table 1 shows mechanical properties of the materials that were obtained from the tension tests.

Table 1. *Mechanical properties of steel materials (Koken & Koroglu, 2013).*

Test Specimen	Thickness (mm)	Steel Grade	σ_y (MPa)	σ_u (MPa)	Elongation (%)
Beam	Web, t=mm	St44	319.4	458.22	27.4
	Flange, t=mm	St44	298.75	444.3	29.3

Split T	Lower T, t=mm	St44	322.4	457.45	26.3
	Upper T, t=mm	St44	329.35	465.1	25.9
Damper	t=12mm	St37	314.1	402.2	31

Various parameters which are used in modeling are shown in Table 2.

Table 2. Parameters used in modeling.

Parameter	Input Value	Parameter	Input Value
Flange Width of Beam	135 mm	Upper T Height	300 mm
Flange Thickness of Beam	10.2 mm	Upper T Thickness	26 mm
Web Depth of Beam	270 mm	Lower T Length	250 mm
Web Thickness of Beam	6.6 mm	Lower T Width	135 mm
Damper Slit Width	20 mm	Lower T Height	300 mm
Damper Strut Width	30 mm	Lower T Thickness	28 mm
Damper Strut Thickness	12 mm	Young's Modulus	200000 N/mm^2
Damper Strut Height	60 mm	Poisson's Ratio	0.25
Net Damper Strut Height	80 mm	End Plate Thickness	50 mm
Beam Length	2000 mm	End Plate Width	135 mm
Upper T Length	250 mm	End Plate Height	270 mm
Upper T Width	230 mm		

Element Modeling
The element that is used for modeling different parts of the overall structural section are listed in Table 3.

Table 3. Elements used for modeling.

Material Type	Element Type
I-Beam, Damper, Upper T, Lower T, End Plate	SHELL181
Upper T, Lower T	COMBIN39

Deformed Shapes

Figure 5 shows the final deformed shape of the system. Here cyclic load is applied in both positive and negative direction by applying displacements on beam ends. It shows significant shear deformation in damper. The deformed shapes from the finite element analysis have resemblance with the actual deformed shapes of the system shown in Figure 6.

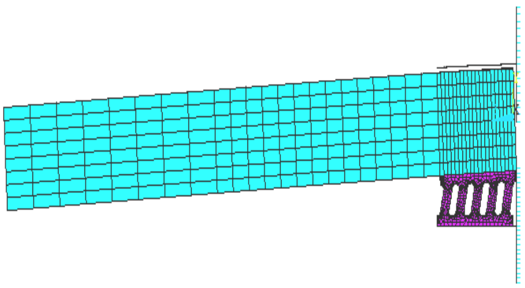


Figure 5. Deformed shape of the full system.

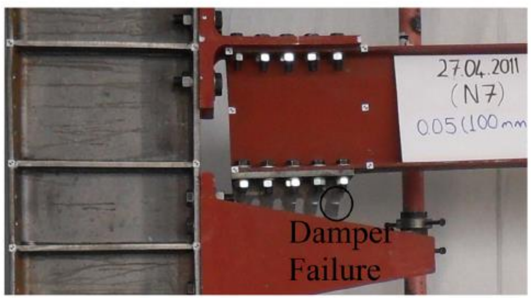


Figure 6. Damage photograph after the experiment (Koken & Koroglu, 2013).

Experimental Model Verification

Using the sectional geometric and material properties given by Koken and Koroglu (2013), the model is generated almost similar to the way only for N12 specimen. The developed model using SHELL181 and COMBIN39 elements is to be verified by comparing the load-deflection curves and moment-rotation curves obtained from the numerical analysis and the corresponding information obtained from the experimental results only for N12 specimen.

Verification of the Load vs. Displacement and Moment vs. Rotation Behavior

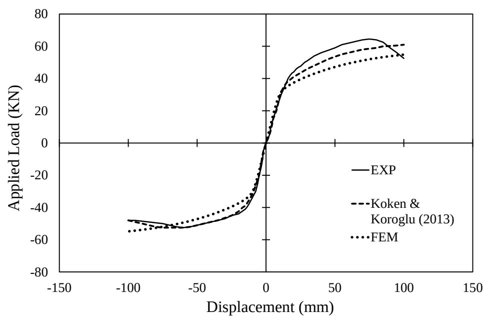


Figure 7. Load vs. displacement curves.

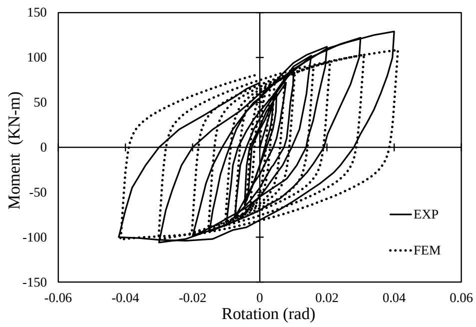


Figure 8. Moment vs. rotation curves.

Comparison between FE results and experimental results is shown in Figure 7 where FE result slightly vary with the test result because of not following the experimental setup exactly in the modeling.
Figure 8 shows that the FE results and experimental results are almost same for first few cycles and slightly vary in last few cycles. This is happened because experimental setup is not exactly followed in the modeling. As a summary of this study, it can be said that the developed finite element model is adequate enough to simulate the experimental test results done by Koken and Koroglu (2013). Therefore the same model can be used for further numerical study instead of performing experimental research works.

Effect of Damper Thickness and Damper Strut Width on Maximum Yield Strength of Beam

Figure 9 illustrates the effect of damper thickness on maximum yield strength of beam. Maximum yield strength of beam is found 138 kN-m from analytical formula. Here it can be seen that as the damper thickness increases, the maximum yield strength of beam also increases because the damper gets stiffer when thickness increases. The FEM value are less than the analytical value up to t=14 mm and slightly greater than the analytical value when t=16 mm. So the damper thickness should remain between 8 to 14 mm as when t=16 mm the FEM value is greater which means that the beam will reach its yield strength along with the damper and as a result the beam will yield which will cause damage to beam.

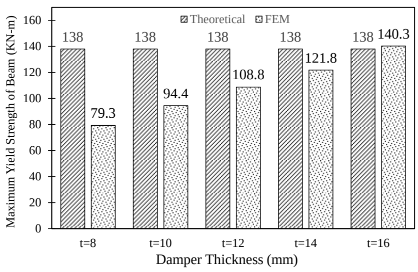


Figure 9. Effect of damper thickness on maximum yield strength of beam.

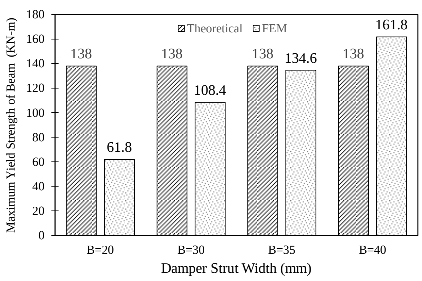


Figure 10. Effect of damper strut width on maximum yield strength of beam.

Figure 10 shows the effect of damper strut width on maximum yield strength of beam. Maximum yield strength of beam is found 138 kN-m from analytical formula. Here it can be seen that as the damper strut width increases, the maximum yield strength of beam also increases because the damper gets stiffer when strut width increases. The FEM value are less than the analytical value up to B=35 mm and slightly greater than the analytical value when B=40 mm. So the damper strut width should remain between 20 to 35 mm as when B=40 mm the FEM value is greater which means that the beam will reach its yield strength along with the damper which will cause damage to beam.

Considering the effects of damper thickness and damper strut width on maximum beam yield strength, it can be concluded that damper strut width is more significant than damper thickness as yield strength of beam changes rapidly for slight variation of it.

Conclusion

In this study, a numerical model for beam-column connection with steel slit damper has been developed using ANSYS 16.2 for the purpose of investigating the behavior of the connection under cyclic loading. Verification of this finite element model has been achieved with reference to the experiment of Koken and Koroglu (2013) and it has shown fair agreement. The proposed model is then used for performing the parametric study on the beam maximum yield strength by varying damper thickness, damper strut width etc. The parameters should be in the proposed range to improve the performance of the connection system.

References

Köken, A., and Köroğlu, M. A. (2013). "Experimental Study on Beam-to-Column Connections of Steel Frame Structures with Steel Slit Dampers." *Journal of Structural Engineering*, ASCE 2013.

Miller, D. K. (1998). "Lessons learned from the Northridge earthquake." *Eng. Struct*., 20 (4–6), 249–260.

Nakashima, M., Inoue, K., and Tada, M. (1998). "Classification of damage to steel buildings observed in the 1995 Hyogoken-Nanbu earthquake." *Eng. Struct.*, 20(4–6), 271–281.

Oh, S. H., Kim, Y.-J., and Ryu, H.-S. (2009). "Seismic performance of steel structures with slit dampers." *Eng. Struct.*, 31(9), 1997–2008.

SteelConstruction.info [online]. Available at: *http://www.steelconstruction.info.* [Accessed 5 Sept. 2017]

BEHAVIOR OF TYPICAL STEEL COLUMN SECTIONS UNDER STANDARD FIRE

M. K. Islam[1], M. J. Hasan[2] and T. Manzur[3]

ABSTRACT

Structural steel shows significant vulnerability to fire hazard because of its inherent lower resistance to elevated temperature. So, to lessen any catastrophic effect, the fire endurance time of a structural steel needs to be increased by providing adequate insulation such as concrete encasement against temperature rise. The recent growth in usage of steel as construction material obligates studying the actual behavior of steel members when exposed to fire. SAFIR, a SiF (Structure-in-Fire) modeling software can be used to analyze some typical steel column sections under fire to discuss and provide quantifications of their general traits. The study involved thermal analysis of the W and HSS type steel sections of varying weight to exposed area (W/D) ratio considering a standard ISO fire curve. In addition, the W sections were also analyzed with varying thickness of concrete encasement to observe and quantify possible enhancement in fire resistance. The obtained results show temperature rise up to certain failure limit within a very short period of time, in case of all steel sections without protection. However, the decreasing W/D ratio has adverse impact on the time required to reach the failure temperature. The study also provides insight on probable cover dimensions for a target fire rating of steel sections.

Keywords: Structural Steel; SAFIR; Fire Rating; Concrete Encasement; W/D Ratio; Failure Time.

Introduction

Fire has always been a very destructive natural phenomenon. There have been countless occasions throughout the history of mankind in which people lost valuable goods, estates, or even their lives because of fire accidents. Although, all construction materials lose strength under elevated temperature, steel members are found to be, comparatively, more sensitive to such a situation owing to its high thermal conductivity (Choe et al., 2011; Al-Jabri, 2007). The thermal expansion of the material contributes, significantly, towards its loss of strength and stiffness and ultimately, results in a catastrophic effect during a fire incident (Baetu et al., 2017). Therefore, it will be prudent to design steel structures in such a manner that it can withstand fire for the time, required to ensure safe evacuation of humans and valuable assets (Baetu et al., 2017; Franssen et al., 1998; EN 1993-1-2, 2005). Application of different fire insulating material such as paint, gypsum board, concrete etc. remain till date the most common techniques in ensuring fire resistance of a steel structure. Among those techniques, concrete encasement is usually, considered as most economic and easy to use when it comes to protect a steel column. The required thickness is determined considering that the protection will limit the temperature rise of steel member below 550^0C (Al-Jabri, 2007) for a specific period of time. ASCE design guideline-SFPE 29 (2005) has included the detailed procedure of such calculation using the value of fire resistance period and W/D ratio. W/D ratio can be defined as the ratio of weight per unit length of a steel member to its exposed perimeter (SFPE 29, 2005).

In recent years, Bangladesh has observed a significant increase in use of steel as a construction material, especially in the industries and commercial buildings. Still, the prevalent building design guideline hardly addresses the fire hazard related issues and related mitigation techniques for steel construction. Moreover, researches and studies evaluating and defining the actual trend of a structural steel under fire and the extent of possible improvement in fire resistance by concrete encasement, seem to be scarce. The principal aim of this study was to evaluate the thermal behavior of some typical steel column sections, both unprotected and protected using concrete encasement against standard ISO type fire exposure. The behavior of a steel structure when subjected to a fire incident, depends to a significant extent on the performance of the steel columns under elevated temperature (Varma et al., 2008). However, owing to high cost and long testing period, numerical simulation is mostly, preferred over an experimentation to assess the response of a structure, subjected to fire (Franssen 2005). This paper presents findings of the numerical simulation of typical W type and HSS type steel column sections under fire using a Structure-in-Fire modelling (SiF) software, SAFIR.

[1]*Graduate Student, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh*
[2]*Graduate Student, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh*
[3]*Professor, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh*
Email of Corresponding Author –tmanzur.buet@gmail.com

The study found poor performance of both types of steel column sections without any protection during a fire incident. W type sections, most widely used steel column sections, were studied more extensively, with W/D ratio varying within the range of 5~30 lb/ft/in. This was done to achieve a thorough understanding of the thermal response of W type column sections and to investigate the effect of varying W/D ratio on temperature rise. The results showed adverse impact of W/D ratio on the time required to reach the failure temperature. In addition to these, W type sections with concrete encasement of varying thickness (in this case 25 mm, 50 mm, 62.5 mm and 75 mm) were analyzed to observe possible improvement in resisting fire for certain time period. The primary objective of the study is to portray the extremely poor performance of unprotected steel under fire and consequently, raise awareness among concerned engineers regarding this issue. Such awareness is extremely important since despite such poor fire performance of steel, majority of steel construction in the country do not have proper protection or, in some cases, use no protection at all. Moreover, based on the findings, a table summarizing the probable thickness requirement of concrete encasement to ensure 3 hours of fire resistance, in case of W type sections with varying W/D ratio, is included in this paper. These findings will provide a field engineer with some idea on how to choose a proper W sections and required fire protection while designing a steel column member. However, it is recommended to calculate thickness of appropriate protection material for any steel member following standard codes.

Modelling and Simulation

Software for Modelling and Simulation

For this study, a SiF modelling software package, named SAFIR was used to perform the thermal analysis of the steel column sections. SAFIR was developed at University of Liege, Belgium, based on the hypotheses (Franssen, 2005) that:-

a) All materials are isotropic, not compressible and with no mechanical dissipation
b) No contact thermal resistance exists between adjacent materials.

This software is a combination of the following three-

a) GiD (Preprocessor)-used for model generation and creating input file for analysis
b) SAFIR (Processor)-used to process the simulation and generate an output file
c) Diamond (Postprocessor)-used to process and read the generated output of the analysis

Material and Sectional Properties

Two types of materials were considered for this study-steel column sections (in this case W type and Box or HSS type) and concrete (as a covering or protective material). Table 1 summarizes the material properties, considered during analysis:

Table 1. Summary of the material properties

Materials	Property type	Properties	Value
Steel	Mechanical Properties	Poisson's Ratio	0.3
		Yield Strength	3.55x 108 N/m^2
		Modulus Of Elasticity	29X106 psi
	Thermal Properties	Convection Coefficient (Hot)	25
		Convection Coefficient (Cold)	4
		Relative Emission	0.7
Concrete	Mechanical Properties	Poisson's Ratio	0.3
		Compressive Strength	4.35 ksi
		Tensile Strength	0.435 ksi
	Thermal Properties	Specific Mass	2400 kg/m3
		Moisture Content	0
		Convection Coefficient	25
		Parameter of Thermal Conductivity	0.5

Fire Condition

The thermal analysis, during this study, was performed based on the assumptions that the sections considered will face a fire incident or temperature rise, similar to that of ISO 834 curve (2014) as shown in Figure 1.

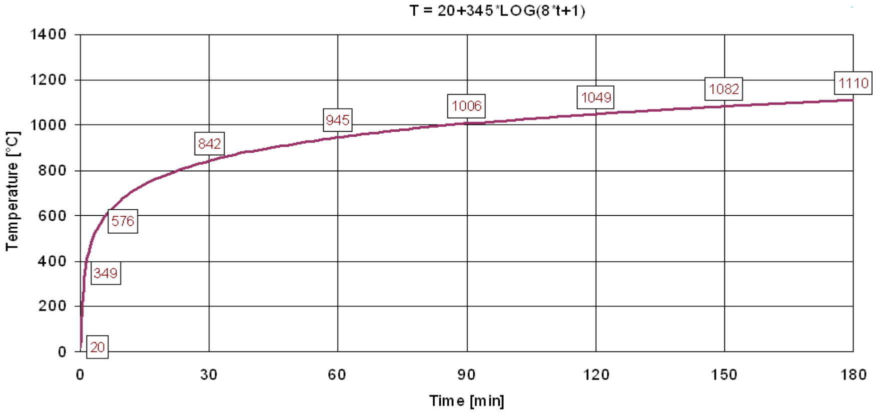


Figure 1. FISO time-temperature curve (ISO 834, 2014)

Model Generation, Simulation and Post-Processing

All the steel and composite sections were modelled within the GiD module of SAFIR. Initially, a project was created in 2-D for thermal analysis. Then, under the project name a model was created. This involved creating the section using built-in geometric tool, defining material properties and assigning boundary condition (fire curve). The FISO fire curve was assigned as a frontier constraint along the perimeter of the section to be analyzed. This is to simulate the fire exposure condition of column section with all of its longitudinal faces exposed to a fire incident. Thereafter, the generated model was analyzed for certain period of time to observe and predict its temperature rise with time. Post processing is done with DIAMOND software. It involves reading a XML document file (.xml) which can be found after the SAFIR simulation. DIAMOND allows to read the temperature of any node after a certain time of fire application in the form of a temperature vs time graph.

Results and Discussion

Fire Effect on Unprotected Steel Column

The main drawback of any kind of structural steel member is its high sensitivity towards elevated temperature which eventually, leads to the loss of strength and structural integrity. This study aims to provide with a quantitative evaluation of the thermal sensitivity of some common types of steel column sections. Figure 2 represents responses of HSS 16X12X5/8 and W12X72 with similar W/D ratio when subjected to an ISO type fire for 60 minutes.

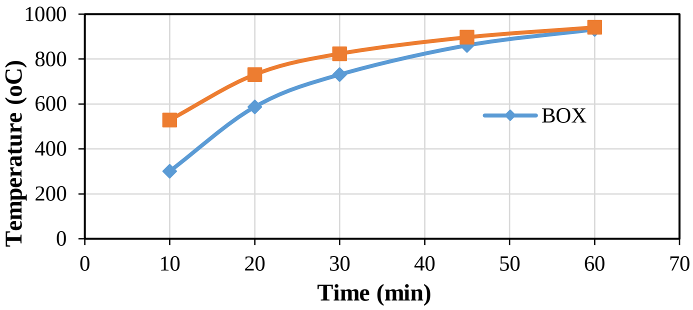
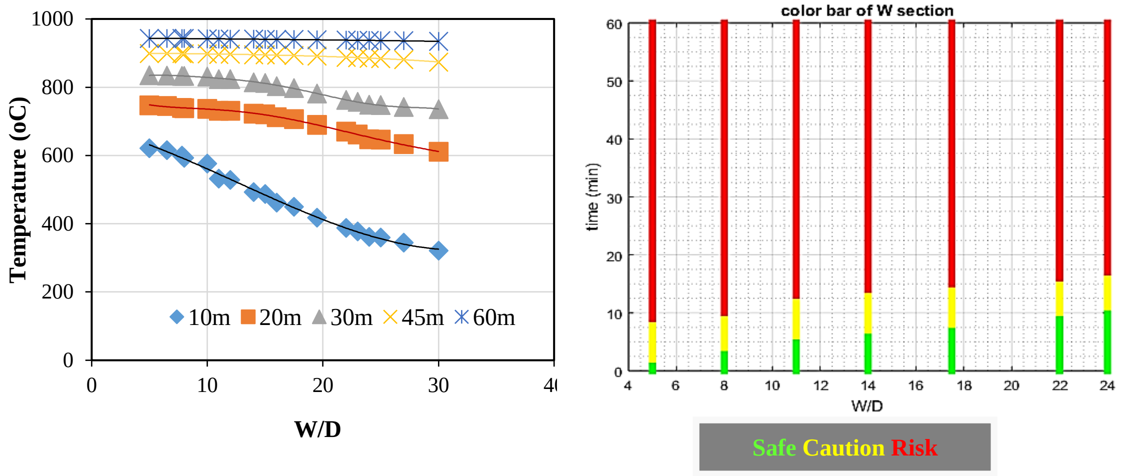


Figure 2. Effect of temperature with time on HSS 16X12X5/8 and W12X72 sections (similar W/D ratio)

The figure shows a rapid increase in temperature within initial 30~40 minutes of analysis, for both types of column sections. HSS or Box type sections showed a good initial performance compared to that of a W section. However, in both cases, the temperature rises above 900°C just after 45 minutes and after 1 hour it became constant with time.

British Design Code BS 5950: Part 8 (1990) has specified the limiting temperature for any fully stressed steel member to be 550ºC. It is evident from Figure 2 that a W type column section reaches this failure limit within 10 minutes of fire occurrence. On the other hand, in case of HSS or Box type section due to its relative better initial performance, it takes upto 17~18 minutes. Still, all unprotected steel sections will fail within 20 minutes or less which indicate a very unsatisfactory performance. Nevertheless, a W type column sections can be vindicated to be, comparatively, more prone to fire hazard. In order to understand the thermal behavior of W type sections more comprehensively and to observe effect of weight to exposed perimeter (W/D) ratio, different W type sections (from class W10 to class W18) with varying W/D ratios were analyzed for ISO type fire event using SAFIR. The outcomes are presented in Figure 3.

Figure 3.a shows the effect of W/D ratio on temperature rise, in case of W type sections, analyzed for 10~60 minutes using SAFIR. At the beginning of the fire application (up to about 30 minutes) on column sections temperature vs. W/D curve exhibits some irregular shape with a decreasing trend; especially at 10 minutes. If the fire continues even after 30 minutes (45 minutes or more), all sections were observed to face, somewhat, similar temperature rise, irrespective of the W/D ratios of the concerned sections. It implies that initially (upto about 30 minutes), W type sections with high W/D ratio show slower temperature rise as compared to those with low W/D ratios. It can further be validated from the phase diagram as shown in Figure 3.b. Here, the temperature up to 400ºC are considered as 'safe' because no reduction in steel's yield strength occurs (Baetu et al., 2017). However, after 400ºC the reduction in yield strength starts and reaches 50% of original value at a temperature near 550ºC-600ºC (Al-Jabri, 2007; Baetu et al., 2017). Therefore, this range of temperature is marked as a 'caution' range and any temperature greater than the limiting value is marked as a 'risk' zone. It can be deduced from the diagram that sections having W/D ratios less or equal to 8 lb/ft/in will reach the failure limit within 10 minutes of a fire incidents. Whereas, for sections with W/D ratio greater than 8 lb/ft/in, it could take 11~19 minutes. Nevertheless, all sections with W/D ratio less than 30 lb/ft/in will reach the limiting temperature of 550ºC in less than 20 minutes, in case of a fire occurrence.

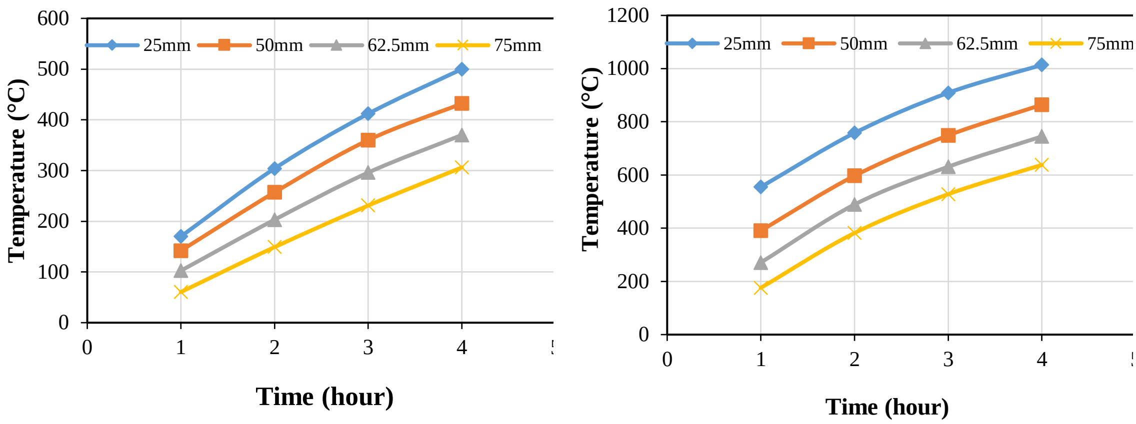


(a) (b)

Figure 3. Effect of W/D on temperature rise of W type steel sections-a) temperature vs W/D curve and b) Color Bar showing time vs W/D

Fire Effect on W Type Steel Column with Concrete Encasement

As discussed before, concrete encasement is one of the most common, economic and widely used technique to ensure steel structure's integrity during a fire event for a certain period of time (fire rating). For this study, all W type sections were analyzed with varying concrete cover of 25mm, 50mm, 62.5mm and 75 mm and the thermal behavior of such composite sections were observed. The analysis showed significant improvement in fire resistance period of all steel sections with concrete encasement owing to the low thermal conductivity of concrete. Figures 4.a and 4.b show the effect of concrete cover on temperature rise with time for two extreme W type sections considered in this study-W 18X211 (W/D=30) and W 10X33 (W/D=5).



(a) (b)

Figure 4. Effect of concrete cover on temperature rise of -a) W 18X211 and b) W 10X15

In case of W10X15 section, concrete cover of 25mm, 50mm, 62.5mm and 75mm can keep the temperature below the limiting value of 550°C upto, approximately 1 hour, 1.75 hours, 2.5 hours and 3 hours, respectively. In case of W 18X211 section, even a 4 hours of fire resistance is possible only with a concrete encasement of 25 mm. Table 2 summarizes the approximate thickness requirement of concrete cover to ensure fire resistance up to 3 hours for different W type sections, classified based on their W/D ratio values. It should be noted that Table 2 presents the findings from the SAFIR analysisof W type sections considered in this study. Table 2 only provides an idea on tentative thickness of concrete encasement required for 3 hours of fire rating of steel column sections with different W/D ratios. For actual fire protection design, code specified formula along with test data from certified laboratory should be used.

Table 2. *Variation in required thickness of concrete cover for 3hours of fire rating with respect to W/D ratios of W type steel sections (not suitable for real time fire protection design)*

W/D Ratio (lb/ft/in)	**Required Thickness of Concrete Cover, C (mm)**
<=5	>=75
5<W/D<10	62.5
10<W/D<16	50
W/D>16	25

Conclusion

This paper provides with an in-depth discussion on the thermal behavior of some typical W and HSS column sections. The study revealed that most steel sections reach the failure temperature limit within a very short (less than 20 minutes) period of time after a fire initiates. In case of W type sections, member with higher W/D ratio reaches the limiting value more slowly as compared to those with W/D ratios as low as 5~10 lb/ft/in. Nevertheless, even the slower rate is less than 20 minutes as mentioned above. For lower W/D ratios, the time required to rise to failure temperature could be as low as 10 minutes. This situation can be significantly improved by incorporating a concrete encasement around the steel section. In case of sections with W/D ratio greater than 16 lb/ft/in, concrete encasement of thickness 25 mm seems to ensure 3 hours of fire rating. As for sections with W/D ratio less than 16 lb/ft/in, concrete cover of 50mm or greater might be required. The essence of this study is to provide a quantitative comparison between the thermal behaviors of some commonly used W type sections. This paper also shows the probable thickness requirement of using concrete casing to ensure certain fire resistance period. However, the actual design must be based on code specified calculation method and standard fire testing. The authors believe that the findings of the study would aware practicing engineers about the severity of fire impact on unprotected steel members and importance of providing required protection.

References

Al-Jabri, K. S. (2007) “Behavior of Steel Framed Buildings in a Fire”, *Steel Structures,* 7(2007), 227-237.
Baetu, G., Galatanu, T., and Baetu, S-.A. (2017) “Behaviour of Steel Structures under Elevated Temperature”, *Procedia Engineering*, 181, 265-272.

Choe, L., Varma, A. H., and Surovek, A. (2011) "Behavior of Steel Columns under Fire Loading", Structures Congress by ASCE.

EN 1993-1-2, (2005) "*Eurocode 3: Design of Steel Structures*", European Standard, Brussels, Belgium.

Franssen, J. M. (2005) "SAFIR: A Thermal/Structural Program for Modelling Structures under Fire", *Engineering Journal,* Third quarter: 143-158.

Franssen, J. M., Talamona, D., Kruppa, J. and Cajot, L. G. (1998) "Stability of Steel Columns in Case of Fire: Experimental Evaluation", *Journal of Structural Engineering,* 124(2), 158–163.

ISO 834, (2014) "*Fire resistance tests-Elements of Building Construction*", International Organization of Standardization, Switzerland.

SFPE 29, (2005) *"Standard Calculation Methods for Structural Fire Protection",* SEI, ASCE, USA.Varma, A. H., Hong, S., Agarwal, A., and Prasad, K. (2008) "Behavior of Steel Building Structures Under Realistic Fire Loading." Proceedings of the 2008 Structures Congress – Vancouver, Canada, ASCE, 12 pp.

EFFECTIVENESS OF VARIOUS RETROFITTING OPTIONS OF FOOTING UNDER EXISTING BUILDING

Md. Jahangir Alam[1], Muhammad Saiful Islam [2] and Mahmudul Islam [3]

ABSTRACT

Recently Detail Engineering Assessment of Garments Factory Buildings has been carried out to ensure structural safety. In many situations, it is found that existing footings are not adequate in bearing capacity and punching shear. Sometimes, footings are adequate in long term bearing capacity using drained soil parameters, but inadequate in short term bearing capacity using un-drained soil parameters. Most effective retrofitting option is to enlarge and thicken the existing footing so that it would be adequate in bearing capacity and punching shear. In this paper one case study is presented where the footings are not adequate in bearing capacity and punching shear and it is difficult and challenging to enlarge and thicken the existing footing because of high water table and 4 m depth of foundation. Various options of retrofitting were tried using PLAXIS 3D FEM modeling where retrofitting works would be done at around ground level of the building. Effective innovative idea of this analysis was that 4 steel H-piles will be driven at outside of 4 corners of existing footing and a new footing will be constructed at 1 m depth. 4 hydraulic jacks will be installed between new footing and new driven piles. New footings will be pushed up by jacking which is supported on new piles. Then new piles and new footing will be connected and hydraulic jack will be removed.

Introduction

Retrofitting of individual footings of an existing building is a challenging task especially where water table is near to ground level or foundation level is so deep that it is difficult and risky to excavate up to such depth. Therefore, alternative retrofitting options need to be studied in such circumstances. Effective footing retrofitting options are footing replacement, strengthening of footing, and limiting forces transmitted to footings (Richard V. Nutt, 2005). A numerical study is presented in this paper where various options of retrofitting existing pad foundation are studied as shown in Figure 1.

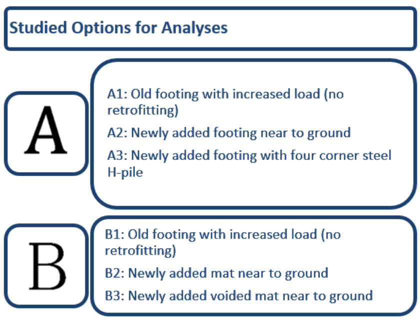


Figure 1: Studied options for analyses

Finite Element Modeling Details

PLAXIS 3D Finite Element software has been used in this study to capture three dimensional natures of various retrofitting options (as per Table 3 and Table 4) of existing footing. Detail properties of idealized sand layer and model elements are given in Table 1, and Table 2. To make sure that footing would not fail in bearing capacity in FE model, high value of cohesion 200 kPa is assigned to sand. Because, the objective of

[1]*Professor, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1205, Bangladesh*
[2]*Graduate Research Assistant, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1205, Bangladesh.*
[3]*Post Graduate Student, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1205, Bangladesh*
Email of Corresponding Author – saifulislamce@gmail.com

this study is to control stress increment and settlement of retrofitted footing under increased load. Here Mohr-Coulomb (MC) model is used which does not account for the effect of consolidation settlement and consequently, this paper focuses on the elastic settlement of sand. The standard boundary option in the program was selected, where movement in top surface is free and bottom boundary is fixed in all direction. And, x and y direction boundary was normally fixed. The generated mesh was selected very fine and it was refined in the zone of high stress and displacement automatically.

Table 1: Engineering Properties of subsoil.

Properties of Sand	Value	Unit
Type of Model	Mohr-Coulomb (MC)	
Unit Weight saturated, γ_{sat}	18	kN/m^3
Initial void ratio, e_o	0.8	
Modulus of Elasticity, E	12,000	kN/m^2
Poisson's ratio, υ	0.2	
Cohesion, c	200	kN/m^2
Drained Angle of Friction, ϕ	30	degree
Total Thickness of sand Layer	30	m

Table 2: Engineering Properties of Elements

Properties	Existing Footings	New Footings	H-pile	Mat	Voided Stiff Mat	Unit
Element Type	Plate	Plate	Embedded Beam	Plate	Plate	
Thickness, d	0.75	0.75	-	1	2	m
Total Length	-	-	20	-	-	m
Positioned below ground level	4	1	-	1	1	m
Size	3mx3m	4mx4m	0.3mx0.3m	29mx29m	29mx29m	
Modulus of Elasticity, E_1	$21.53X10^6$	$21.53X10^6$	$200X10^6$	$21.53X10^6$	$21.53X10^6$	kN/m^2
Unit Weight*	7	7	60	8	1.8	kN/m^3
Poisson's ratio, υ	0.15	0.15	0.3	0.15	0.15	
Axial skin resistance T_{skin}, start, max	-	-	3.770	-	-	kN/m
Axial skin resistance T_{skin}, end, max	-	-	9.040	-	-	kN/m
Base resistance, F_{max}	-	-	174.8	-	-	kN

*Soil weight is reduced from original element weight, in order to compensate overlap of element with soil.

Table 3: Salient features of different options of Case A

Option Name	Applied Point Load	Existing Footing	New Footings	H-pile	Hydraulic Jacking	Figure No
Initial Condition	3000 kN	Active	×	×	×	2-Initial
A1	4000 kN	Active	×	×	×	2-A1
A2	4000 kN	Active	Active	×	×	2-A2
A3	4000 kN	Active	Active	Active	Active	2-A3

Table 4: Salient features of different options of Case B

Option Name	Load on each Column	Matrix Pattern	Span Length	Existing footings	Mat	Voided Stiff Mat	Figure No
Initial Condition	3000 kN	5x5	6m	Active	×	×	2-Initial.
B1	4000 kN	5x5	6m	Active	×	×	2-B1
B2	4000 kN	5x5	6m	Active	Active	×	2-B2
B3	4000 kN	5x5	6m	Active	×	Active	2-B3

Construction Sequence of Option A3

Details step by step construction procedure for option A3 is given below.
1) Excavate 5mx5m area around the column up to 1.5m depth to construct new footing. 2) Construct 4mx4m size and 0.75m thick footing at 1m depth. 3) Utility bracket installation at the 4 corner of footing. Secure fit must be ensured by proper bolting with newly constructed footing. 4) Install steel H-pile around the four corners of newly constructed footing by using utility bucket and jacking. 5) Hydraulic pressure is applied in between newly added footing and H-pile to ensure a balanced lift. Here 250kN load is applied. Jacking forces are controlled by use of either powered or manually operated hydraulic pumps. When lifting is completed, newly added footing and H-pile are connected with proper connection.

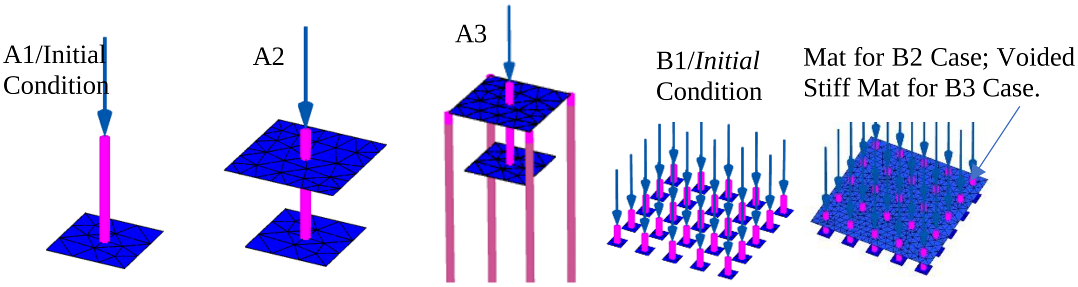


Figure 4: Different options of analyses for case A and case B

Effectiveness of Different Retrofitting Options

For options A1, A2 and A3 depth of pressure bulb of footings decreases subsequently beneath the old footing. Figure 5 shows the vertical settlement profile and vertical effective stress profile of option A3 and option B3.

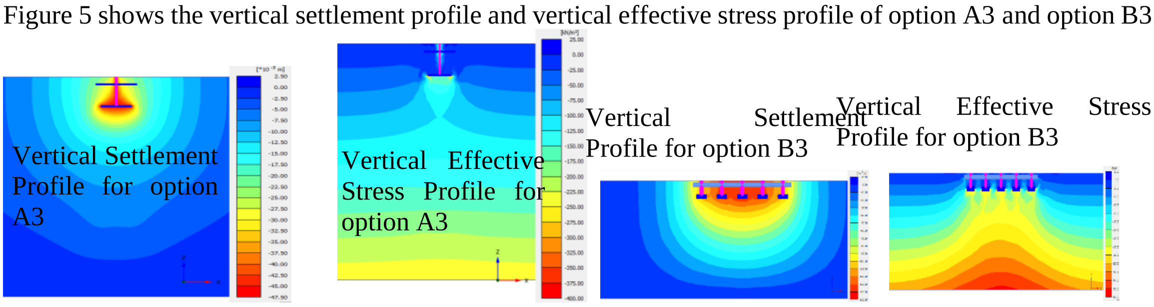
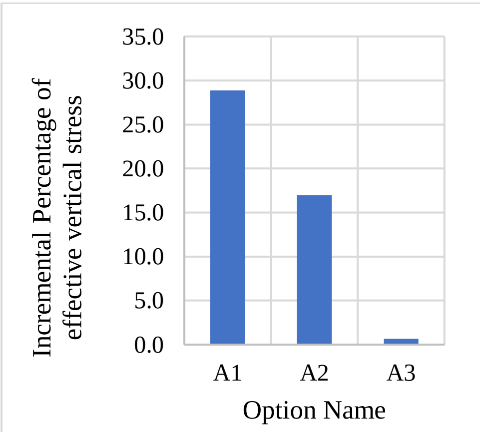
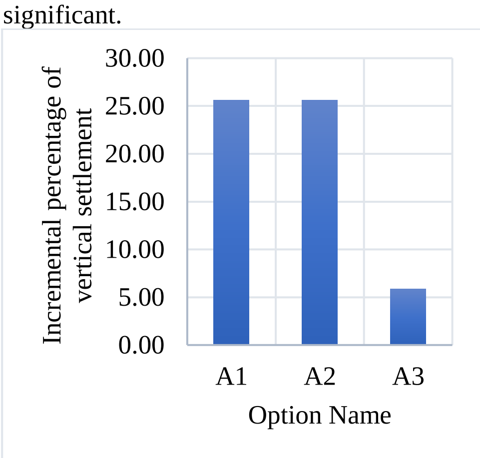
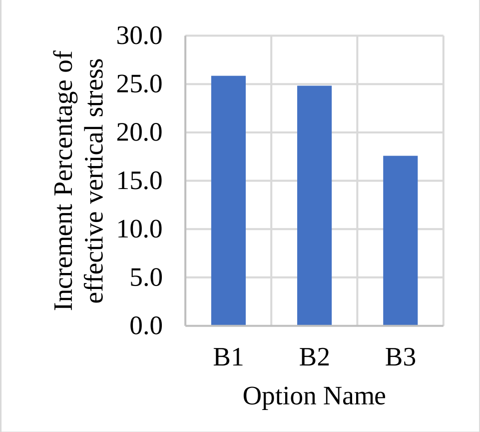


Figure 5: Vertical settlement and effective stress profile for option A3 and B3

Variation among the options for Case A and Case B are graphically represented in Figure 4. It is clearly observed that, vertical effective stress and vertical settlement increment for A3 option (beneath existing footing) is less than other options of case A. It indicates, newly added footing and H- pile are resisting load that's why less vertical effective stress beneath the existing pad footing. Also, vertical effective stress and vertical settlement increment for B3 option (Voided stiff mat) is less than those of mat (option B2), however settlement and vertical effective stress decrease is not significant.







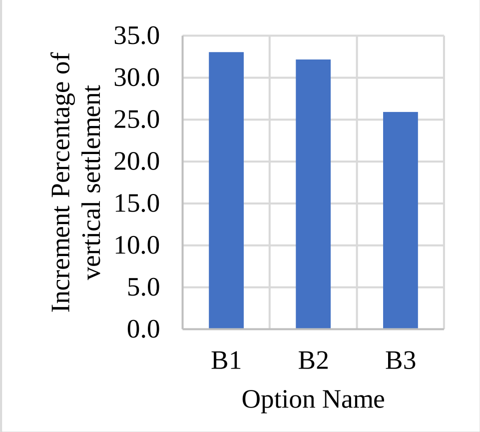


Figure 6: Incremental Percentage (with respect to initial condition) of Effective Vertical Stress and vertical settlement for different options of Case A and Case B

Conclusions

Based on the analyses, the following conclusions can be drawn.

1) Newly added footing without H- pile (option A2) is not effective. Newly added footing with four corner H-piles (Option A3) is effective to retrofit existing footing foundation. In this case with the increment of 1000 kN load, total settlement increase beneath the old existing footing, up to 5.84% whereas if 1000 kN incremented load directly impose upon the existing footing, total settlement increase up to 25.63%. And, with the increment of 1000 kN load, total Cartesian vertical effective stress increase beneath the old existing footing up to 0.1% whereas if 1000 kN incremented load directly impose upon the existing footing, total Cartesian vertical effective stress increase up to 28.9%.

2) Voided stiff mat (option B3) shows less settlement and vertical effective stress beneath the existing footing than those of mat (option B2), however settlement and vertical effective stress decrease is not significant.

References

Richard V. Nutt (2005) *"Seismic Retrofit of Highway Bridges"*, Portland State University, Portland, Oregon.

INTERPRETATION OF COMPRESSIBILITY CHARACTERISTICS FOR COASTAL SOIL OF BANGLADESH

Z. A. Urmi[1] and M. A. Ansary[2]

ABSTRACT

This study presents an approach to correlate compression index directly with CPT (q_c) and SPT (N_{60}) parameters and also with index properties (liquid limit, plasticity index, void ratio). For this study soil samples have been collected from 17 different locations of coastal embankments of Bangladesh. 17 pairs of CPT and SPT together with one dimensional consolidation and Atterberg limit tests have been done to establish these correlations. Liquid limit and Plasticity Index range from 30-43 and 6-25 respectively and most of the soil samples are low to medium plastic clay and silt. For a variation of N_{60} from 2-10 and q_c from 0-2.5 MPa coefficient of compressibility (Cc) ranges from 0.1-0.3 for studied soil type. This study presents a new insight on a possible exponential correlation of Cc with q_c/N_{60} and q_c.

Introduction

Compressibility characteristic of a soil is one of the basic requirements for foundation design. In most of the geotechnical investigation with limited budget, such important parameter is determined through empirical correlations without proper laboratory investigation. A number of large-scale construction projects have recently been carried out in the coastal areas of Bangladesh. Soft ground improvement has been raised as an important issue in the utilization of areas of soft ground. In particular, the compressibility characteristics of soft clay are carefully examined for large-scale construction projects, such as the Cox's Bazar Airport project and the projects under Chittagong Port Authority. There are other upcoming projects such as Matarbari Power Plant and proposed port at Maheshkhali, Payra Port and Power Plant at Payra etc.. It is well known that coastal clay is relatively more compressible compared to other soil deposits. Marine clay typically has a high-water content and an extremely low bearing capacity. Volume change or settlement of clay sediments is also dependent on the portion of silt and clay fractions, especially for highly colloidal clays with large equilibrium void ratios. The colloidal-size particles (<0.001 mm) with greater surface area per unit mass have the ability to attract large amounts of water. Since liquid limit is a measure of the water attracted to these clay particles, some correlation between liquid limit and soil compression index would be expected. Likewise, as bearing capacity, density, soil consistency (soft/hard) are some of the influencing factor for standard/cone penetration resistance value, it indicates a possibility that afore mentioned in-situ tests may also be influenced by void ratio or compressibility characteristics. Many approaches had been taken by a number of researchers (Skempton 1944; Terzaghi and Peck 1967; Lambe and Whitman 1969; Mayne 1980; Nakase et al. 1988; Yin 1999) in different parts of the world to establish empirical correlations for compressibility with easily obtainable index properties like natural moisture content, liquid limit, plasticity index and void ratio. There are also some useful studies for Bangladeshi marine soil which correlate compressibility index with void ratio (Siddique A. 1986; Ansary M.A.1999). But there is hardly any research to interpret compressibility characteristic directly from in-situ test results. This study will present a comparative analysis of the two approaches to determine compressibility index from the available correlations with index properties (liquid limit, plasticity index, void ratio) and from the CPT-SPT values.

Subsoil Investigation

General

As for subsoil investigation, both laboratory and field investigation has been done. 17 pairs of high quality Cone Penetration Test and Standard Penetration Test have been carried out in Satkhira, Barguna, Laxmipur, Bhola, Chottogram and Cox's Bazar district. Each pair of CPT and SPT was carried out as close as possible, maximum horizontal distance was not greater than 5m. Location and geology of the investigated regions are shown in Figure 1.

[1]*Graduate Research Assistant, Bangladesh Network Office for Urban Safety (BNUS), BUET, Dhaka-1000, Bangladesh*

[2]*Professor, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh*

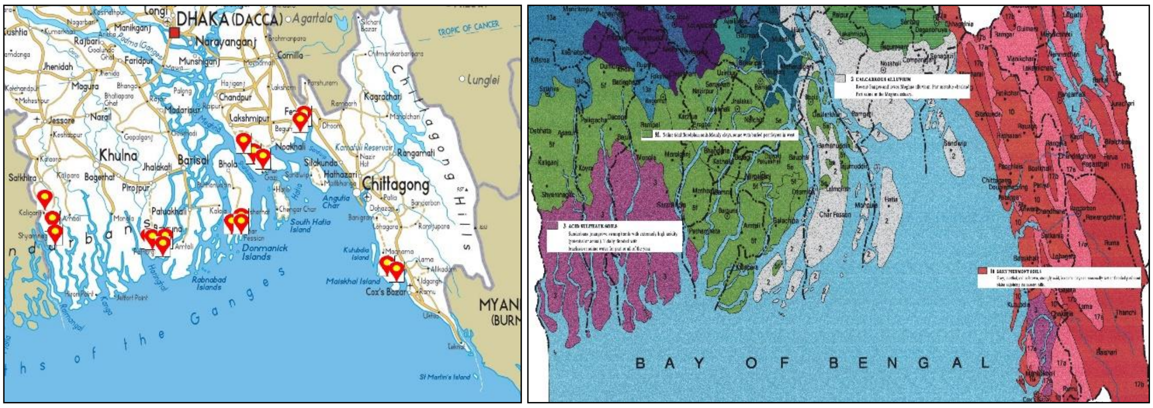


Figure 1. Location (left) and Geology (geology) of studied region

The investigated site includes acid sulphate Sunderbans saline soil in Shatkhira, saline tidal floodplain soil in Borguna and Bhola, calcareous saline alluvium in Laxmipur and grey/red brown piedmont soil in Chottogram and Cox's Bazar (European Soil Data Centre 1977).

Field Investigation

Standard Penetration Test

SPT were conducted per ASTM D1586. Boreholes for the SPT were advanced by wash boring. Shelby tubes were used to obtain undisturbed representative samples from 2-4m depth. Potential source of uncertainty which may affect SPT N-value has been carefully considered. Borehole drilling, soil sampling and SPT N-value recording procedures were observed by experienced geologist during the entire test program and this individual provided visual descriptions of the collected samples. The SPT N-value and disturbed samples were collected every 1.5 m intervals up to 30 m depth or to the depth of maximum resistance. Rope and cathead SPT hammer-release was used and the efficiency of hammer was 60%. Correction for overburden stress (Liao and Whitmann 1985) has been done to obtain normalized SPT ($N_{1,60}$) value.

Cone Penetration Test

CPT soundings were advanced using a Hogentogler type piezocone penetrometer with a cross sectional area of 10 cm^2 and which can measure the pore water pressure (u_2), as well as the cone tip resistance (q_c) and sleeve friction (f_s). To perform the test, the cone was pushed vertically into the ground at a constant rate of approximately 20mm/sec. During the advancement, measurements of dynamic pore water pressure, tip resistance and sleeve friction were recorded continuously at 10 mm depth increments. The typical penetration depth for this study was 30 m below from ground surface. Pore pressure correction has been done to obtain corrected CPT (q_{c1}) value.

For this research, only undisturbed samples have been used, so the in-situ properties of depth 2-4 m are of concern. Within this depth SPT blow count N_{60} varies from 4-8 and Cone Tip Resistance (q_c) varies from 0.2-2.4 MPa.

Laboratory Investigation

A pair of Liquid Limit and Plastic Limit Test was done for each borehole as per ASTM 4318. 4 out of 17 samples were silts and the rest were low plastic clays as shown in the plasticity chart in **Figure** . Consolidation test has been as per ASTM D 2435. e-logP curves have been produced for each sample to determine the coefficient of compressibility (C_c). All the index properties are summarized in

.

Table 1: Index Properties of Soil

Location	Borehole	Depth (m)	LL	PL	PI	$q_{c1\ (Mpa)}$	N_{60}	$N_{1,60}$	e_1	Cc
Satkhira	BH1	2.10-2.55	39	19	20	0.498	3	4.539	0.796	0.248
	BH2	3.60-4.05	39	27	12	1.776	8	11.168	0.750	0.200
	BH3	3.60-4.05	31	22	10	1.871	6	8.612	0.580	0.157
Tankibazar	BH2	3.60-4.05	33	20	13	2.257	4	5.934	0.605	0.170
Bhola	BH1	3.60-4.05	37	30	7	1.974	5	7.290	0.620	0.145
	BH 2	3.60-4.05	36	23	13	0.889	5	7.290	0.722	0.199
	BH3	3.60-4.05	37	27	10	1.044	4	5.934	0.703	0.206
Borguna	BH1	3.60-4.05	32	14	18	0.669	5	7.290	0.612	0.182
	BH4	3.60-4.05	39	20	19	1.016	6	8.612	0.760	0.217
Patharghata	BH1	3.60-4.05	32	21	11	0.669	6	8.612	0.756	0.193
	BH2	3.60-4.05	40	21	19	0.847	5	5.842	0.684	0.202
Ramgoti	BH1	2.10-2.55	33	21	12	1.488	4	5.934	0.674	0.186
	BH2	2.10-2.55	37	26	11	1.919	6	8.612	0.620	0.188
Anwara	BH1	2.10-2.55	43	18	25	0.913	8	15.987	0.770	0.259
	BH2	2.10-2.55	27	21	6	2.360	2	3.098	0.567	0.120
Maheshkhali	BH1	2.10-2.55	42	25	17	0.734	7	9.904	0.747	0.239
	BH2	2.10-2.55	32	18	14	0.263	4	5.934	0.678	0.188

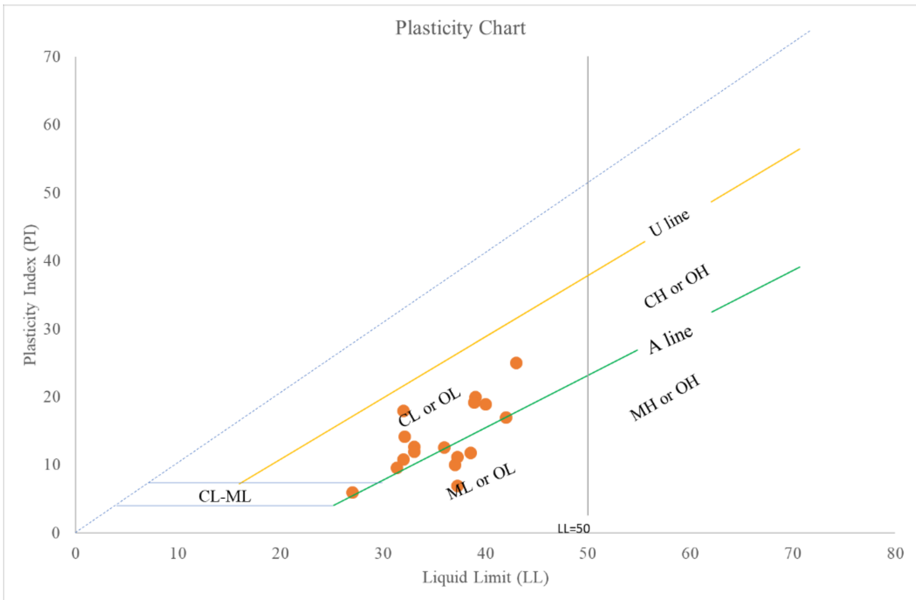


Figure 2 : Plasticity Chart for the studied samples

Analysis and Results

Interpretation of Cc from Index Properties:

Conventional regression equations generally relate compression index to one soil variable, namely liquid limit (LL), void ratio (e), or plasticity index (PI) are as summarized in Table 2. Most of these equations are linear in form. In this research, the relationships between compression index and soil parameters are investigated for the void ratio, liquid limit and plasticity index. The Laboratory obtained compressibility index have been plotted against liquid limit (LL), plastic limit (LL), initial void ratio e_0 and the void ratio e_1 (at a consolidation pressure of 1tsf) as illustrated in Figure 3. Study points formulate linear correlation similar to the previous ones but have different slopes (mostly flatter than the previous ones) and intercepts.

Table 2: Empirical Correlations for Compression Index with Soil Parameters

Equation	Reference	Applicability
For $Cc = f(\text{LL})$		
$Cc = 0.013(\text{LL} - 13.5)$	Yamagutshi 1959	All clays
$Cc = 0.017(\text{LL} - 20)$	Shouka 1964	All clays All clays
$Cc = (\text{LL} - 13)/109$	Mayne 1980	
For $Cc = f(e_o)$		
$Cc = 0.54(e_o - 0.35)$	Nishida 1956	All clays
$Cc = 0.43(e_o - 0.25)$	Cozzolino 1961	Brazilian clays
$Cc = 0.75(e_o - 0.50)$	Sowers 1970	Clays with low plasticity
For $Cc = f(e_1)$		
$Cc = 0.39(e_1 - 0.14)$	Siddique (1986)	Marine Bangladeshi Soil
$Cc = 0.384(e_1 - 0.06)$	Ansary (1999)	Marine Bangladeshi Soil
For $Cc = f(\text{PI})$		
$Cc = 0.02 + 0.014\text{PI}$	Nacci et al. 1975	North Atlantic clay
$Cc = 0.046 + 0.0104\text{PI}$	Nakase et al. 1988	Best for PI < 50%

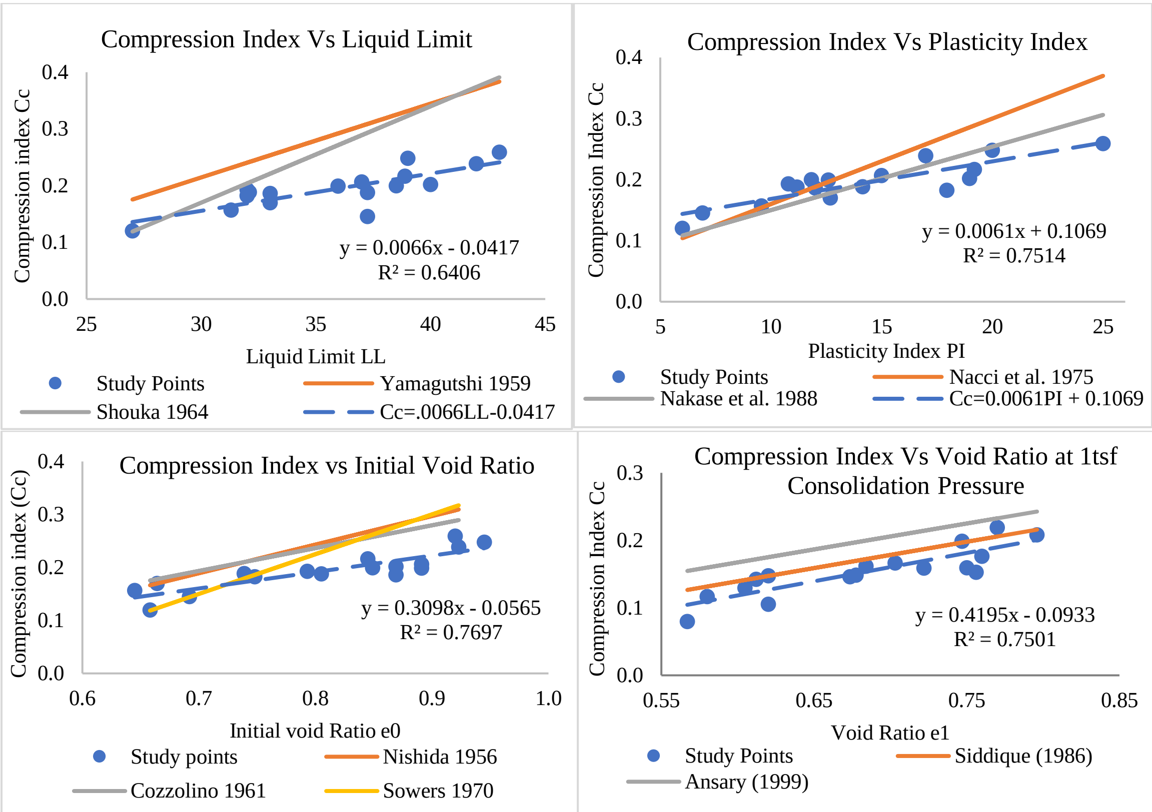


Figure 3: Correlations of Compression Index with Index Properties

Table 3: Observations from Figure 3

Correlation with	Proposed Equation	Squared Correlation Coefficient R^2
Liquid Limit , LL	Cc=0.0066LL-0.042	0.64
Plasticity Index, PI	Cc=0.006PI-0.1069	0.75
Initial Void Ratio e_0	$Cc=0.31e_0-0.0565$	0.77
Void Ratio at 1tsf	$Cc=.42e_1-.0933$	0.75

Interpretation of Cc from in situ tests:

Laboratory obtained compressibility index have been plotted against corrected SPT blow count ($N_{1,60}$), Cone tip resistance (q_{c1}) and $(q_{c1}/pa)/N_{1,60}$ as illustrated in Figure. The curves show that higher SPT values give higher Cc value whereas in case of CPT or CPT-SPT ratio an increase causes decrease in the compressibility index which is quite contrary to the linear proportional CPT-SPT correlation. Though the correlation between Cc and SPT appears to be linearly proportional like existing correlation with index properties, the R^2 value is much less than Cc vs CPT or $(q_{c1}/pa)/N_{1,60}$ curves. The observations have been summarized in Table 2**Error! Reference source not found.**. In the cases of CPT and CPT-SPT ratio-based correlations, exponential curves give slightly higher determinant values than that of the linear curves.

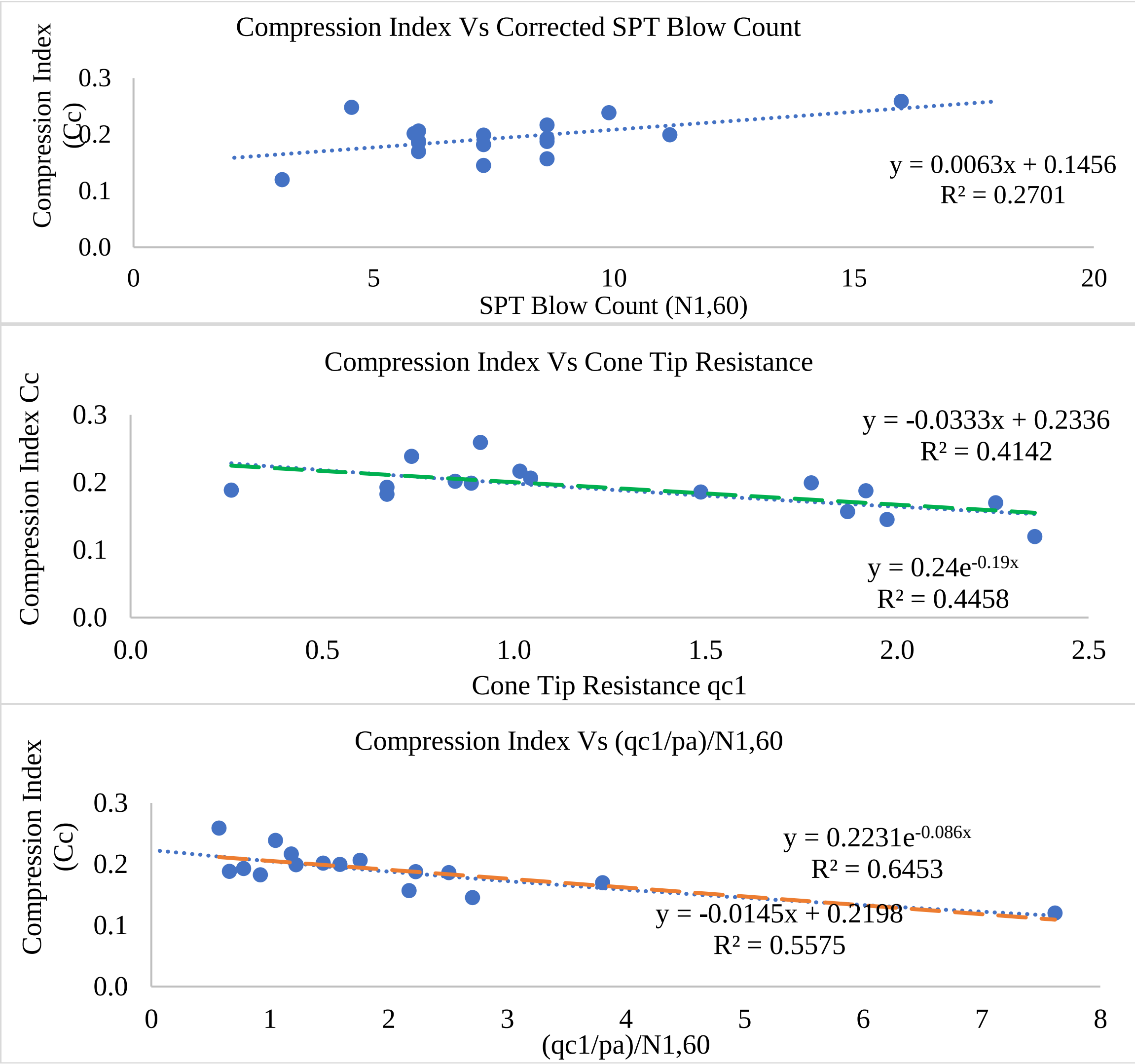


Figure 4: Correlations of Compression Index with In-situ Parameters

Table 4: Observations from Figure 4

Correlation with	Proposed Equation	Coefficient of determinant, R^2
SPT blow count $N_{1,60}$	$Cc=0.01(0.63N_{1,60}+14.56)$	0.27
Cone tip resistance q_{c1}	$Cc=0.24e^{-0.19qc1}$	0.4458
	$Cc=0.2336-0.0333\ q_{c1}$	0.4142
CPT-SPT ratio $(q_{c1}/pa)/N_{1,60}$	$Cc=0.2231e^{-0.086(qc1/pa)/N1,60}$	0.6453
	$Cc=0.2198-0.0145\ (q_{c1}/pa)/N_{1,60}$	0.5575

Conclusion

In this paper, potential correlations between the compression index and field investigation results have been investigated for the first time for Bangladeshi soils along with a comparative analysis of the existing correlation between compression index and index properties of soil. Results of this study indicate that the index properties are more reliable parameters to determine compression index than SPT or CPT data. Nevertheless, it is clearly visible from the study that the new correlations (R^2> 60%) provide useful guidance for preliminary assessments of the compressibility of Bangladeshi coastal soils.

References

Ansary, M.A., Siddique, A. and Safiullah, A.M.M. 1999. “Compressibility and permeability characteristics of selected coastal soil of Bangladesh”, *Indian Geotechnical journal*, 29(2), 162-185.

Mayne, P.W. 1980. “Cam-clay predictions of undrained strength”, *Journal of the Geotechnical Engineering Division, ASCE*, 106(11), 1219–1242.

Nacci, V.A., Wang, M.C., and Demars, K.R. 1975. “Engineering behavior of calcareous soils”, *American Society of Civil Engineers, New York*, 1, 380–400.

Nakase, A., Kamei, T., and Kusakabe, O. 1988. “Constitute parameters estimated by plasticity index”, *Journal of Geotechnical Engineering, ASCE*, 114(GT7), 844–858.

Nishida, Y. 1956. “A brief note on compression index of soil”, *Journal of Soil Mechanics and Foundation Engineering, ASCE*, 82(3),1–14.

Ohira, Y., Kotani, A., and Harada, S. 1969. “Some investigations of the relationship between consolidation pressure and void ratio on the poor soil”, *Memoirs of the Defense Academy*, 9(1), 311– 317.

Shouka, H. 1964. “Relationship of compression index and liquid limit of alluvial clay”, *Japanese Society of Civil Engineers*, 4,40.1–40.2.

Siddique, A. 1986. “Permeability and consolidation characteristics of normally consolidated clays”, *M.Sc Thesis*, Bangladesh University of Engineering and Technology, Dhaka.

Skempton, A.W. 1944. “Notes on the compressibility of clays”, *Quarterly Journal of the Geological Society of London*, 100(2), 119–135.

Yamagutshi, H.T.R. 1959. “Characteristics of alluvial clay”, *Report of Kyushyu Agriculture Investigation Center of Japan*, 5(4), 349–358.

Yin, J.-H. 1999. “Properties and behaviour of Hong Kong marine deposits with different clay contents”, *Canadian Geotechnical Journal*, 36, 1085–1095.

BADLAND DENUDATION PROCESS AND MANAGEMENT: A CASE STUDY OF GARHBETA BADLAND, WEST MEDINIPUR, WEST BENGAL, INDIA

Arindam Sarkar[1]

ABSTRACT

Garhbeta badland is composed of erodible sedimentary rock with duricrust and hardpan. This was formed during Pleistocene age. Objectives are to identify process of soil erosion and management of soil erosion. This area is influenced by high drainage density associated with different rill and gully, less vegetation and lack of substantial regolith. Soil are loose in character and unfertile dry ferruginous nodules area present on surface along with hardpan. Badland is associated with poor growth of vegetation due to low subsoil acidity, high sub surface soil, absence of organic matter in soil, less bonding between soil molecule due to variation of temperature and rainfall. Under this natural condition the badland is extending rapidly by excessive soil erosion. This loss of soil degraded the environment and destroying the natural ecosystem. Some management aid like afforestation Programme, construction of check dam, construction of big dam with reservoir has been implemented in this area. Application jute-textile was very useful in this regards.

*Keywords***:** *Duricrust, hardpan, erosion, gully, management, afforestation, jute-geo textile.*

Introduction

Badland geomorphology includes occurrence of geomorphological processes on the surface structure of the area. Development of badland is associated with rapid soil erosion and formation of different geomorphic features. Actually badland is natural landscape deeply dissected by intensive soil erosion, Lack of vegetation, geological formation soil condition and variation in different component of climate are main responsible factors for soil erosion. Badland is fluvial originated feature of the surface of the earth. Garhbeta and surrounded area is associated with very high drainage density composed of several rills and gullies. Numerous factors and processes influence badland development to produce a complex diversity of landforms of various scale (Bryan & Yair, 1982). Badlands have fascinated geomorphologist for the same reasons that they inhabited agricultural use, lack of vegetation, steep slope, high drainage density, shallow to non-existence regolith and rapid erosion rates (Howard, 1998). Badland is very dry terrain composed of fragile sedimentary rock and alluvium rich soil in the soil horizon. Badlands are often scale dependent with similar for occurring on a variety of scale with in the same region. However, the context to which such scale independent process observations are valid is limited by dimensional and gravitational constraints on particles and hydraulic characteristics (Bloom, 1978). Regardless of their origin badlands are intricately dissected by rills and gullies (Champbell, 1889). Badland especially when coupled with stream network, represent a zone of stream network expansion, an increase in drainage density and stream order (Strahler, 1957). The vegetation of badland is influenced not only by erosion but also human activities (Chiarucci et al. 1995; Masccherini, et al.2011).

Intense human pressure with very frequent fire wood gathering and sheep grazing includes sever phanerogam cover degradation and destruction of lichen crust. In the other case detaches by farmers to protect filed from runoff eroded deep gullies and led to development of badlands (Gallart, 2013). Runoff channels alike rills and gullies are such micro geomorphic features, which not only describe the present geomorphic status but also very useful to predict future modification and transformation of landform (Garland et al ,1994; Brinkeate & Hanvey, 1996) on the surface of the earth. Development of narrow water course like rills has been initiated by rainfall. Rapid flow of water originated by rainfall leads soil erosion (Carey et al, 2001). Thus a wide range of geomorphic changes occurs across the gully basin area (Ghosh, 2015). Laterite formation is frequent in this fringe region between Chhotanagpur plateau and bengal basin, traditionally popular a Rarh plain (Aown & Kar, 2016). These low level lateritic badlands are situated over the unconsolidated secondary deposits in the time of Pleistocene and deformed by subaerial weathering later on. Sever soil erosion and degradation have effected more than 175 million hectors land of India of which about 3.97 million hectors is sunder riverine erosion (Tripathi & Singh,. 1990).The most spectacular and destructive type of soil erosion where gullies are varying magnitude are spreading vertically as well as horizontally and eating away land and soil at a frightful rate (Ahmed,1968).Laterite is heavily leached the sub soil , it gets dries and become rock like due to cementing of ferruginous concretion by iron oxide colloid when it is exposed .It is very sensitive to

[1] *Research Scholar, Department of Geography, University of Calcutta Email: arindam.srkr1@gmail.com*.

variation of temperature and rainfall intensity surface and subsurface layer of soil horizon is associated with laterite duricrust (hardpan).

The undulating erosional plain or Rarh having great variety of ferrallitic-lateritic soils separate the Archean from the recent alluvium are identified as older alluvium deposited over the Bengal shelf between the Cretaceous and Pleistocene (Chakraborty , 1970),this area is denoted as 'shelf of lateritic alluvium' by Spate in the year of 1967.Some localized badlands are located in different part of Birbhum (Santinikatan), Bankura (Sinhati), West Medinipur (Garhbeta) and Purulia district of West Bengal. Account of these badland have been documented by some eminent scholar (Some & Roychaudhuri, 1960; Bhattacharya,1957; Goswami,1980; Biswas,1987; Laha,2011;Bera & Bandopadhya,2013).Specially extensive work has been done on Garhbeta badland of West Medinipur district (Das & Bandopadhyay,1995;Sen, et al 2000;Sen, et al 2004), Khoai (Santiniketan) of Birbhum (Bandopadhyay,1987) and Sinhati of Bankura district (Aown & Kar, 2016).Extensive studies on evolution development process, channel and drainage character, slope character and profile character have been carried out but development of badland in relation to geomorphic expression and installation , evolution and monitoring of management strategies are absent here.Previous work associated with Garhbeta badland was mainly concentrated on development of badland up to 2002-03,but after the installation of management projects like construction of big dam and afforestation some internal changes are there.

Database and methodology

Garhbeta badland (22°49'N and 87°27' E) is situated on the concave right bank of the river Shilabati (Shilai). Garhbeta badland (Fig.1) is locally popular as 'Ganganir danga' (land of fire). It falls under Gangani mouza, Garhbeta-I block, West Medinipur district, West Bengal in India. This area is covering about 3.40 km² of Pleistocene lateritic upland (Sen. et al,2004) with beauty of the wilderness associated with the badlands of the Gangani area of Garhbeta is hard to be describe in language (Roy and Biswas,2002). Garhbeta badland is situated with active riverine processes with intensive gully erosion over the lateritic escarpment facing the river Shilabati. Ground survey was conducted with the help of GPS handset, clinometer, Abneys level, distance meter to study about profile character of gully network. Stream ordering and bifurcation ration was calculated after Strahler (1957). Map measurement has been done in Erdas, ArcGIS and QGIS platform. Profile graphs and cartograms were prepared with field data using Microsoft excel.

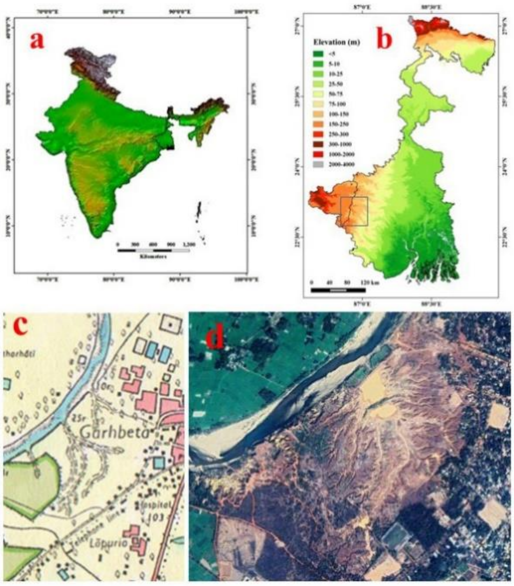


Figure 1. Location of the study area.Map of India (a), Map of West Bengal (b), Topographical view (c),Google image of Garhbeta 2015 (d)

Table 1. Details of data

Data type	Tools and techniques	Data	Source/Reference
Secondary	Remote sensing	Google image (Multidated;2003,2011,2014,2015,2018)	Google earth
	Maps/information's	Topographical map (Sheet no. 73N/5)	Survey of

		R.F- 1:50000 , Published in 1968	India(SoI), Kolkata
		District planning series map (Medinipur) R.F-1:250000	NATMO, Kolkata
		Hydro-geomorphological map	SoI,Kolkata
		Agro climatic region of West Bengal	Deptt. of Agriculture Govt. of West Bengal
		District map	NRDMS GIS Centre Office of DM
		Soil and Land use map and information	NBSS&LUP, Kolkata
		Climatological data	IMD, Kolkata
Primary	Global positioning system (GPS)	Location (Way point)	GPS handset
		Delineation of gully network	
	Triangulation survey	Gully cross and long profile	Prismatic compass Clinometer Abneys level

Result and discussion

Fact of the land

This area is associated with thick mantle of laterite engrossing the elevated tracts along the concave bank of river shilai. Thickness of this laterite capping varies gradually between 6 to 25 meters (Sen, et al, 2004) produced during Pleistocene age, but the thickness rises towards the east (Bengal plain) until they are covered by recent alluvium (Goswami, 1960). This secondary laterite derived from mechanical disintegration of wester primary laterite formation of this area. It has observed top of the soil profile in this area covered with cap of hard duricrust Lateritic formation with duricrust and hardpan is very common in this area. This is composed of ferruginous nodules and quartz pebble of dark reddish brown colour. Thin layer of lithomergic clay present in below the hardpan. Layer of lithomergic clay is underline by clay, silt and sand. This area falls under sub-humid monsoon type climate (Fig.2) associated with hot-dry summer (maximum temperature 45°C), monsoon (maximum rainfall recorded 793 mm, July 2007) and dry-cool winter (Minimum temperature 9°C). Process of laterization, soil erosion as well as formation and development of badland has been accelerated by seasonal fluctuation of temperature and rainfall. Vegetation of this are falls under mixed deciduous forest dominated by sal (Shorea robusta), shimul (Bombax ceiba), jarul (Lagerstroemia speciosa) and mahua (Madhuca indica). Surface soil of this area is loose and dry in character with occasional capping of laterite duricrust (hardpan). with It is not good for plant growth.

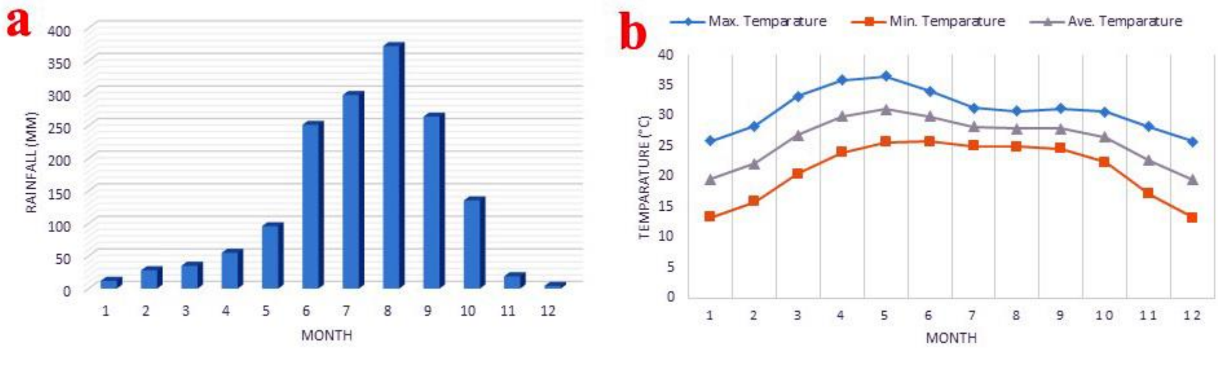


Figure 2. Climatological profile.Monthly average rainfall (a),Monthly maximum,minimum and average temparature(b)

Laterization and soil erosion mechanism

Laterite is heavily leached the sub soil, it gets dries and gets rock like due to cementing of ferruginous concentration by iron oxide collide(Ghosh, 2015) exposed due to erosion. Laterization process has been initiated by the variation of rainfall and temperature of the area. According to last 118 years (1901-2017) temperature, rainfall data this area can be considered as humid tropical monsoon climate. This climate is ideal for laterite formation (Thomas, 1972; Bryan and Yair, 1982; Faniran and Jeje, 1983; Battaglia et al., 2011; Awon and Kar, 2015). Laterite duricrust and mottled layer is common hare. These gives indication of deep weathering process. Thickness of this laterite capping varies gradually between 6 to 25 meters (Goswami, 1960; Sen et al., 2004). Laterite of Garhbeta badland are reddish brown in colour. Soil of this area is less fertile. So rate of growth of vegetation is very poor. Laterite of this badland area is associated with aluminum oxyhydroxide with few an amount of halloysite mineral (Sen et al., 2004). Surface soil is composed of easily erodible red clay on laterite duricrust in different places of the badland.

Range of temperature and short duration monsoon rainfall over this area are playing distinctive role in development of badland through formation and operation of rill and gully. Deforestation is also an important causing factor of development of rill and gully in this area. Different type of erosion produced by water action. Those are the responsible factor for development of badland in this area. Rain drop, overland flow, non-concentrated flow (sheet erosion), concentrated flow (rill and gully erosion) are main geomorphic processes of this area. Occurrence of piping, slumping, mass movement and stream bank collapse are also common here. Overland flow increases during intensive rainfall in monsoon. It also accelerated by less infiltration due to laterite capping. Formation and development of rill and gully initiated by mechanically weak unconsolidated surface soil and less infiltration due to presence of impermeable duricrust. Rill and gully erosion was triggered by poor vegetation cover on the surface and gradient of the terrain. In Indian context greater than 1meter depth of rill channel can be considered as gully. This is a permanent form of rill. Head ward erosion and formation of Knick point are very common in every gully channel in this area. It has been observed that cross section area of gully channel is increasing with time. This is the signature of badland development. Pipping occurs when surface water infiltrate through soil profile and moves downward until it comes to a less permeable layer (Sen. et al,2004). Tunnels forms due to increase of lateral movement of water and enlargement of pipe. Seasonal variation of temperature of this area is about 19°C leads to various processes of mechanical weathering. Climate of this area is associated with less soil moisture with low soil cohesiveness and unfavorable condition for vegetation growth. Laterization, denudation and erosion processes has been accelerated by short duration intensive rainfall due to monsoon current. It has been observed that concentration of over land flow is maximum when slope ranges between 1° to 2°.

Evolution and development of badland

Raindrop erosion and overland flow advocated by less vegetation, erodible bedrock, high range of temperature and short spanned intensive rainfall. Four stages of development of the badland has been identified by the Sen, et al (Table.2) (Fig.3). Formation stage is associated with intensive overland flow and formation of rill with less erosion due to high erosion resistance capacity of surface material. Formation of gully, gully widening and head ward erosion plays important role in development stage. Vegetation stars growing in the cross sectional area of gully during healing stage. When slope of side wall of gully procure stability with growth of sufficient vegetation then badland gets stabilized (Table.3).

Table 2. Development of badland during 1931-2003

Year	Affected area (km^2)	Growth rate (km^2yr^{-1})
1930-31	1.45	0.017
1968-69	2.10	0.031
1995	2.95	0.055
2001	3.28	0.060
2003	3.40	-

Source: Sen, et al. (2004)

Table 3. Development of badland during 2003-2018

Year	Perimeter (km)	area (sq.km)
2003	6.40	0.72
2011	6.0	0.68
2014	6.0	0.63
2015	5.67	0.63
2018	5.58	0.54

*Perimeter and area of polygon on multi-dated Google image.

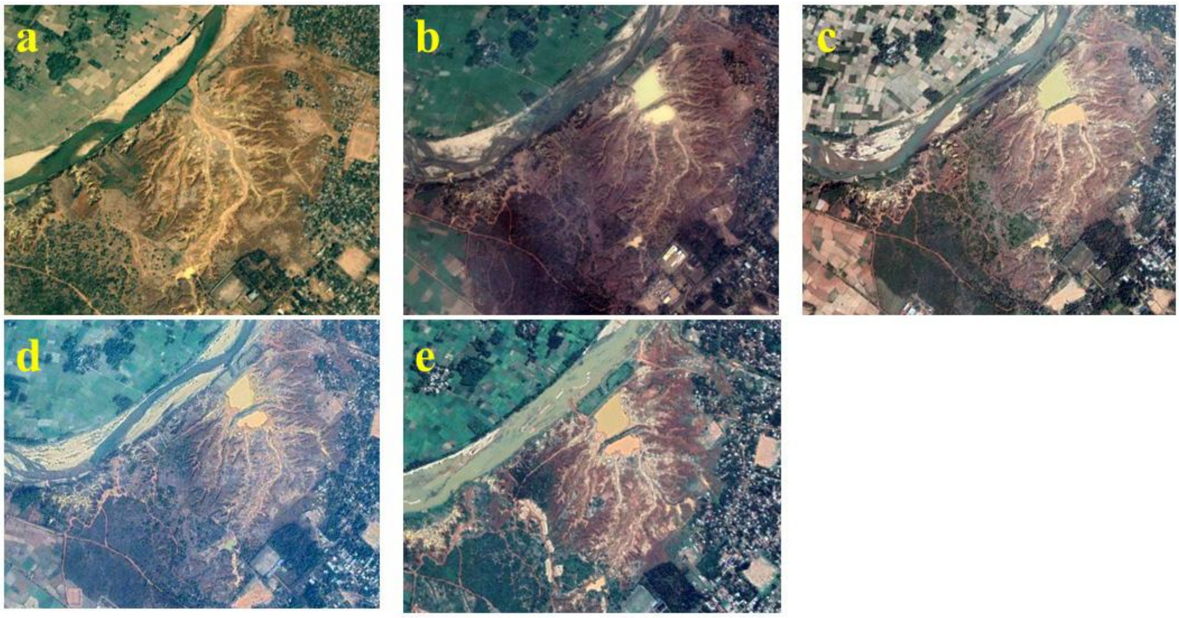


Figure 7. Badland condition in 2003 (a),2011 (b),2014 (c),2015 (d) and 2018 (e)

Table 4. Stream order and Bifurcation ratio

Order of stream/Year	2003		2011		2014		2015		2018	
	No.	Rb	No.	Rb	No.	Rb	No.	Rb	No.	Rb
First order	55	3.23	82	4.55	68	4.25	63	3.70	47	4.7
Second order	17	2.42	18	3	16	3.2	17	3.40	10	5
Third order	7	7.0	6	6	5	6	05	5	2	2
Fourth order	1	-	1	-	1	-	01	-	1	-
	Mean	4.21	Mean	4.51	Mean	4.15	Mean	4.03	Mean	3.9

Morphometric techniques like Strahler's laws of stream ordering (Table.4) were executed to identify the concentration of pluviometric process over this badland area. Highest stream order was identified as fourth order and the mean bifurcation ratio was 4.16(2003-2018) (Table.4). It is very high according to total area. Four significant gully channel were identified from eastern sector of the badland. Those are flowing towards the north-west direction according to the regional slope and meet with the main river Shilabati.

Table 5. Length (m), elevation (m) and slope of different gully channel.

Gully ID	Year	2003	2011	2014	2015	2018
G1	Length	1.25km	1.26	1.30	1.30	1.3
	Max elevation (Gully Head)	59	60	60	59	60
	Min elevation (Gully Mouth)	34	35	34	34	34
	Maximum slope	5.3-2.0	6.0	5.1	5.7	5.3
	Average. slope	2.5	2.4	2.4	2.3	2.4
G2	Length	571m	612	602	610	631
	Max elevation (Gully Head)	53	54	53	54	53
	Min elevation (Gully Mouth)	38	38	38	38	38
	Maximum slope	6.9-2.6	6.6	6.6	6.5	6.4
	Average. slope	2.9	2.7	2.7	2.8	2.7
G3	Length	535	564	544	544	550
	Max elevation (Gully Head)	55	55	55	55	54
	Min elevation (Gully Mouth)	39	39	39	39	39
	Maximum slope	7.4	6.8	6.8	7.1	6.9

	Average. slope	2.9	29	2.9	2.9	2.8
G4	Length	344m	363	372	372	376
	Max elevation (Gully Head)	52	53	53	52	53
	Min elevation (Gully Mouth)	41	41	41	41	41
	Maximum slope	8.9	8.6	8.4	8.4	8.4
	Average. slope	3.2	3.2	3.2	3.1	3.2

Four gully channel of Garhbeta badland has been selected for observation and analysis of development of badland. Length and elevation of the gully channels (Table.5) is increasing day by day. Range of slope (maximum and average) also changed during 2003 to 2018(Fig.4). So it can be said that gully erosion is active here.

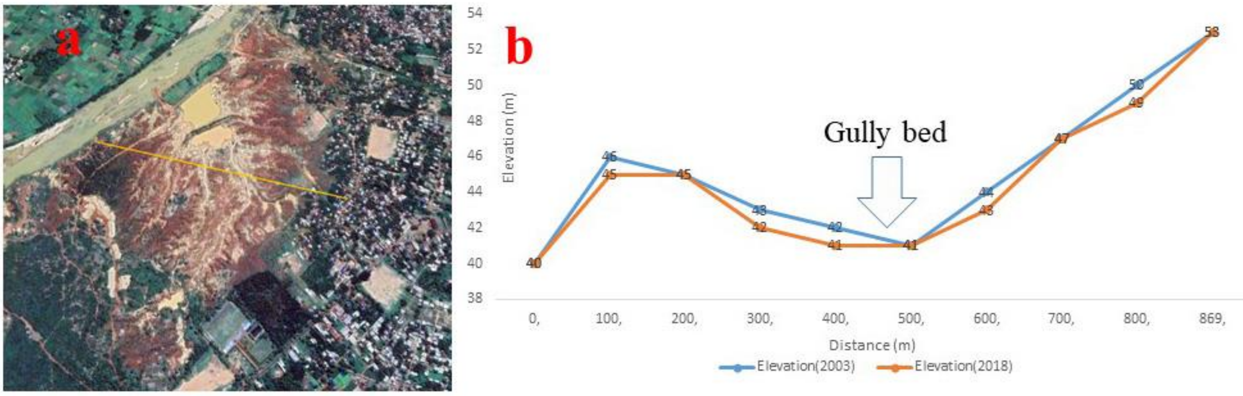


Figure 8. Gully cross section of 2003 and 2018.Cross section made across the badland (W-E).It shows change of elevation due to rapid erosion. Maximum vertical erosion has been recorded around 1 m (2003-2018)

Geomorphic expression

Geomorphic of Garhbeta badland produced by distinctive operation of erosion process. Different meso and micro scale geomorphic feature are present in this area. Laterite duricrust are produced by weathering and laterization processes. Steep escarpment located on the concave bank of river Shilabati. Rill and gully are very common feature of this area. Those are situated at varying width, depth and length. Pipe structure is one of the important feature of this area. Garhbeta badland is associated with mesa and butte like structure, earth pillar with thick duricrust cap, various sizes cave, waterfall and plunge pool with different elevation and echnofossils (Fig.5). Unique depositional feature like gully fan located at the confluence of main gully channel where it meets with the river Shilabati.

Figure 9. Geomorphic features.Rill channel (a), Narrow gully channel (b),Deep gully channel (c),Escarpment (d),Earth piller (e),Thickduricrust cap (f),Cave (g),Fossile bed (h),Gully fan (i)

Management

Soil erosion and degradation of land of this area produced by active riverine action. Due to erosion surface soil of this area lost its fertility as well as productivity. Soil erosion has become serious issue to degradation of soil quality. It has serious impact on ecosystem of this area. It effects on soil-water-plant relationship and environmental water balance. Destruction of vegetation is the main causes of soil erosion and degradation of land. Vegetation protect soil from surface action of water. Actually vegetation cover breaks the flow of surface runoff. The area was covered by dense mixed deciduous forest since 1940.Rapid deforestation makes this area less vegetative. It is essential to take afforestation pregame as well as stop deforestation. Some management strategies were installed in this area for protecting soil erosion and degradation of land. Local panchayat samitee and soil conservation department launched afforestation program (Fig.6.e) once in a year at soil erosion prone area of the badland but it is failed due to unscientific plantation and proper management throughout the year. The allotted amount for per year plantation program near about two lacks. It is not sufficient to total area of badland. Construction of small check dam in gully channel for resist the soil erosion is needed in every gully channel. Check dam (Fig.6.a, b) can arrest eroded and transported sediment. Big check dam with reservoir (Fig.6.c, d) was installed by Western region development ministry fund of Government of West Bengal at the end of the main gully channel where it meets with the river. It became very successful to check soil erosion and development of badland. Department of forest, Government of West Bengal has been construct check dam in some selected gully channel for trial (Fig.6.a, b). It is required to construct small check dam in every gully channel from head of the gully along with end of the gully. Siltation pond was also installed successfully. Jute textile have been found useful for control of surface soil erosion (Dutta, 2009). It can reduce soil erosion, arrest essential nutrient, maintain soil moisture with control of temperature and enhanced favorable condition for plant growth and development. Application of bio engineering process (jute textile technology) become successful in this area (Fig.6.f). Various field trial has been conducted for soil erosion control and establishment of vegetation cover using jute-geotextile since1999.It was observed that rapid root development, enhancement of quality of soil through decomposing mulch. This produce humus of new plant. Beside protect water erosion during rain, it also very useful for protect soil from wind erosion during storms. Some sediment catch pond located at different part of badland for store runoff and overland flow during monsoon. It also very essential to install number of catchment pond in different section of the badland.

Figure 10. Badland management strategies.Badland area (A), Small checkdam on wide gully channel (a), Chcekdam on narrow gully channel (b), Bigdam between at river side (c), Bigdam with lock gate, water storing and water storing pond (d), Previous afforestation project area (e), Plant root developed on geotextile (f), Plantation on the gully head (g)

Concluding note

Degradation of land in laterite upland is important concern of soil erosion and management in humid tropical area. Badland development due to extensive soil erosion decrees potentiality of land in productivity concern. Under this natural condition the badland is extending rapidly by excessive soil erosion. This loss of soil degraded the environment and destroying the natural ecosystem. So it is obviously needed to take some initiatives for conservation of soil erosion and management of badland and have to use the modern tools. Some conventional and modern techniques were installed for prevention of soil erosion. But those are not sufficient for protecting badland and conservation of the badland. It can be suggested that installation of small check dam at the source area of each gully channel able to resist head ward erosion of gully channel. Mulching plantation, grass (jiji, fescue, vetiver) cover might be good alternative for managing soil erosion in this area.

Acknowledgements

My sincere thanks is due to Prof.Sunando Bandyopadhyay, Head of the Department, Department of Geography, University of Calcutta for his guidance during field studies. I would like to convey my gratitude to Prof. L.N. Satpati, Director, UGC-HRDC, University of Calcutta for his guidance during my dissertation. I am grateful to Dr. Jayanta Sen and Dr. Soumen Dey for providing me valuable documents, maps and information. I am also thankful for their suggestions. I am also grateful to Mr. Tarapada Ruidas, inhabitants of Gangani mouza and Mr. Santosh Sil, Officials, Assistant Director of Agriculture office, Garhbeta for helping me during field. I am very thankful to my research guide Prof. Pannalal Das, Department of Geography, University of Calcutta for his motivation and suggestions. I am grateful to Prof.S. R Basu, Department of Geography, University of Calcutta for motivation and valuable suggestions.

Reference

Aown, A., Kar., N.S. (2016) "Lateritic Badland of Sinhati, Bankura, West Bengal: A Geomorphic Investigation", Springer International Publishing Switzerland 2016 B.C. Das et al. (eds.), Neo-Thinking on Ganges-Brahmaputra Basin Geomorphology, Springer Geography,19-31. DOI 10.1007/978-3-319-26443-1_2.

Ahmed, E., (1968) "Distribution and causes of gully erosion" Selected papers, 21st International Geographical Congress,1-3.

Bryan, R., Yair, A. (1982) "Badland geomorphology and piping", Perspectives on studies of badland geomorphology, Geobooks regency House, England.

Bloom, A.L., (1978) "Geomorphology: A Systematic Analysis of Late Cenozoic Landforms" Prentice hall India, New Delhi.

Biswas, A. (1987) "Laterites and lateritoids of Bengal". In: Datye VS, Diddee J, Jog SR, Patil C(eds.) Exploration in the tropics, Pune,137–146.

Brinkcate, T.A., (1996) "Perceptions and attitudes towards soil erosion in the Madebe community, Northwest

Province", South African. Geographical. Journal., 78(1), 75-82.

Bera. K., Bandyopadhyay, J. (2013) "Prioritization of watershed using morphometric analysis through geoinformatics technology: a case study of Dungra Water Sub-Basin, West Bengal, India". International Journal of Advance Remote Sensing GIS 2(1), 1–8

Bhattacharya, J.C. (1957) "Erosion studies in the Lateritic areas of West Bengal". Journal of Indian Society of Soil Science 5,103–108

Bandyopadhyay, S. (1987) "Man-initiated gullying and slope formation in a Lateritic terrain at Santiniketan West Bengal". Geographical Review of India 49(4), 21–26

Bandyopadhyay, S. (1988) "Drainage Evolution in a Badland terrain at Gangani in Medinipur district, West Bengal", Geographical Review of India 50(3), 10–20

Bandyopadhyay, S. et al (2014) "River systems and water resources of West Bengal: a review." In: Vaidyanadhan R (ed.) Rejuvenation of surface water resources of India: potential, problems and prospects. Geological Society of India, Bengaluru, Special Publication 3, 63–84

Battaglia, S. et al (2011) "Dynamic evolution of badlands in the Rogelio basin (Tuscany, Italy)". Catena 86, 14–23

Carey, B. et al. (2001) "Gully Erosion" (a report for the Department of Natural Resources and Mines, The State of Queens land, Australia), NRM Facts Land series;1-4.

Chiarucci, A., et al. (1995) "Biancana badland vegetation in relation to morphology and soil in Orcia valley central ltaly'", Phytocoenologia, 25(1), 69-87

Chakraborty, S.C. (1970) "Some consideration on the evolution of physiography of Bengal". In: Chatterjee, A.B. et al (eds.) West Bengal. Geographical Institute, Presidency College, Calcutta,3pp 16–29

Dutta, U. (2009) "Application of jute-geo textile", Journal of Natural fibers, 4(3)

Das., K., Bandyopadhyay S. (1995) "Badland development over laterite duricrust". In: Jog, S.R. (ed.) Indian Geomorphology 1. Rawat Publication, New Delhi, 31–42

Das, K., Bandyopadhyay. S. (1996) "Badland development in a Lateritic Terrain: Santiniketan, West Bengal." In: Jog, S.R. (ed.) National Geographer 31(1&2), 87–103

Faniran A, Jeje LK (1983) "Humid Tropical Geomorphology". Longman, London, 245–269

Gallart, F., et al. (2013) "Thirty years of studies on badlands, from physical to vegetational approaches. A succinct review" Catena, 106, 4–11.

Garland, G.G. (1994) "Policy, perception and soil conservation-a case study from Cornfield, Natal, Human needs, Resource and Environment, Rep.HSRC, Pretoria.

Ghosh, S. (2015) "Some Observations on Gully Drainage System in Medinipur (West) District, India" American International Journal of Research in Humanities, Arts and Social Sciences, 11(2), 144-148.

Ghosh, R.N., Mujumdar, S. (1981) "Neogene–quaternary sequence of Kasai Basin". In: Neogene–quaternary Field Conference, India, 63–73.

Goswami AB (1980) "Hydrology of lateritic terrain of Bankura and Medinipur districts". In: Proceedings of the international seminar on laterization process, Trivandrum, India, 407–410

Howard, A.D. (1994) "Badlands", In: Abrahms, A.D., Parsons, A.J. (eds.) Geomorphology of desert environments, Springer, Dordrecht.

Kar. A., Bandyopadhyay, M.K. (1974) "Mechanism of Rills: an investigation in Micro-Geomorphology (Garhbeta Badland)", Geographical Review of India 36(3), 204–215

Laha, M. (2011) "Spatio-social impact of mini watershed project at Bhalki, Bardhaman District, West Bengal". Wesleyan J Res 14(1), 10–20

Maccherini, S., et al. (2011). "Determinants of plants community composition of remnants biancane: a hierarchical approach to quantify species–environment relationships". Appl. Veg. Sci. 14, 378–387.

Sen, J. et al. (2004) "Geomorphological Investigation in Badlands-A case study in Garhbeta, West Medinipur, India"; (in) Geomorphology and Environment (edited by S. Singh, H.S. Sharma and S.K. De); ACB Publication; India;204-234.

Strahler,A.N. (1957) "Quantitative analysis of watershed geomorphology", EOS Transaction,38(6),831-1022.

Shome K.B., Raychaudhuri S.P. (1960) "Rating of soils of India" Indian Agricultural Research Institute, Downloaded from www.New.dli.ernet.in/rawdataupload/uploads/insa/…/20005ad5_260.pdf.On 01.01.2015.

Sen J et al (2004) Geomorphological investigation of badlands: a case study at Garhbeta, West Medinipur District, West Bengal, India. In: Singh S, Sharma HS, De SK (eds.) Geomorphology and Environment. ACB Publication, Kolkata, pp 204–234

Thomas MF (1972) Tropical geomorphology. Macmillan, London, 49–82

Tripathi, R.P., Singh, H.P. (1990) "Soil erosion and conservation", Wiley Eastern Limited, New Delhi.

EVALUATION OF INFILTRATION RATE FROM SOIL PROPERTIES USING ARTIFICIAL NEURAL NETWORK

Tahsina Alam[1*], Sagar Barua[2], Humaira Anisa[3] , Mohammad Shariful Islam[4]

ABSTRACT

This study establishes a mathematical relationship between infiltration rate and soil properties of top and subsoil collected from 24 random spots in Bangladesh Agricultural University Farm. Infiltration rate of 9 different elapsed time were measured using double ring infiltrometer for each spot. Results from soil properties tests were used as numerical inputs in the software, assigned in sixteen distinct variables. The variables are percent sand particles in topsoil , percent silt particles in topsoil, percent clay particles in topsoil, percent sand particles in subsoil, percent silt particles in subsoil, percent clay particles in subsoil, bulk density of topsoil, bulk density of subsoil, particle density in topsoil, particle density in subsoil, porosity in topsoil, porosity in subsoil, moisture at field capacity (%) in topsoil, moisture at field capacity (%) in subsoil, hydraulic conductivity in topsoil and hydraulic conductivity in subsoil. 600 datasets were used to generate and validate a model using Artificial Neural Network. Artificial Neural Network model was built using 10 neurons in 2 layers. The model was a feedforward backprop neural network model. The coefficient of variation of regression using output produced by the model and target infiltration rates was 0.90062.

Keywords: infiltration capacity, infiltration rate, Artificial Neural Network.

Introduction

Infiltration of water through soils is one of the most important components of the hydrological cycle. The actual rate at which water enters into the soil at any given time is termed as the infiltration rate (Haghighi et al., 2011; Sihag et al., 2017a). It helps in designing of irrigation, drainage and water supply systems, flood control measures, landslides and many other natural and man-made processes (Igbadun and Idris, 2007). Different infiltration rates are observed at reclaiming location as compared to the infiltration rates at undisturbed locations in the same area (Wenmei and Zhang, 2016). The infiltration study based upon soil characteristics is important for agriculture (Haghighi et al,. 2010), and has attracted the attention of soil and water scientists (Mishra et al., 2003; Swamee et al., 2014). Infiltration rate can be tested through artificial rainfall simulation (Chowdhury et al., 2017)

Artificial Neural Network (ANN) is being used in prediction of infiltration of soil (Karandish and Simunek, 2016). Neural networks are composed of easy components operating in parallel inspired by biological nervous systems. As in nature, the network function is set largely by the connection between the components. A neural network can be trained to perform a specific function by adjusting the values of the connection weights between the elements. Commonly, neural networks are adjusted or trained, so that a particular input leads to a certain output. The network is adjusted, based on a comparison of the output and the target, till the sum of square differences between the target and output value reaches a minimum value. Many such input /target output pairs are used to train a network. (Demuth and Beale, 2001). Polynomial surface fitting model is another method for predicting different soil parameters (Chowdhury et al., 2018).

Physical and Index Properties of Soil

Soil samples were collected from 24 random spots in Bangladesh Agricultural University (BAU) Farm. (Dutta,1993) Percent sand particles in topsoil, percent silt particles in topsoil, percent clay particles in topsoil ,percent sand particles in subsoil, percent silt particles in subsoil, percent clay particles in subsoil, bulk density of topsoil, bulk density of subsoil, particle density in topsoil, particle density in subsoil, porosity in topsoil , porosity in subsoil, moisture at field capacity (%) in topsoil , moisture at field capacity (%) in subsoil , hydraulic conductivity in topsoil and hydraulic conductivity in subsoil were measured in the laboratory for each sample. The mean and coefficient of variation values of soil physical properties are mentioned in Table 1 and Table 2.

Table 1. Percent soil particles, bulk density and particle density of top and sub soil

	Soil Particle in Topsoil (%)			**Soil Particle in Subsoil (%)**			**Bulk Density (gm/cc)**		**Particle Density (gm/cc)**	
	Sand (x1)	Silt (x2)	Clay (x3)	Sand (x4)	Silt (x5)	Clay (x6)	Topsoil (x7)	Subsoil (x8)	Topsoil (x9)	Subsoil (x10)
Mean	28.3	58.0	13.4	28.3	54.5	17.1	1.29	1.39	2.34	2.18
Coefficient Of Variation	27.6	11.6	32.1	15.2	7.7	26.9	5.40	7.19	4.14	4.35

Table 2. Porosity, Moisture at Field Capacity and Hydraulic Conductivity of top and subsoil.

	Porosity(%)		**Moisture at Field Capacity(%wt.)**		**Hydraulic Conductivity(m /day)**	
	Top soil (x11)	Sub soil (x12)	Top soil (x13)	Sub soil (x14)	Top soil (x15)	Sub soil (x16)
Mean	44.36	35.83	31.75	32.10	0.045	0.047
Coefficient Of Variation	6.88	9.10	9.10	13.05	35.55	27.65

Infiltration Rate Measurement

Dutta,1993 measured the infiltration rate at different elapsed time using Double Ring Infiltrometer Method. The mean and coefficient of variation values of infiltration rates for all 24 spots are shown in Table 3.

Table 3. Infiltration rate at (cm/hr) at different elapsed time

	Infiltration rate at (cm/hr) at different elapsed time								
	5 min	10 min	20 min	30 min	45 min	60 min	80 min	100 min	120 min
Mean	8.16	5.50	3.69	2.24	1.38	0.98	0.72	0.71	0.71
Coefficient of Variation	0.58	0.78	0.82	0.87	0.76	0.69	0.67	0.70	0.70

Artificial Neural Network Modelling

Neural Network Toolbox of Matlab (2015) software was used for Artificial Neural Network Modelling. 600 Dataset from Tables 1 and 2 were used. Randomly 500 data were chosen as training data and other 100 were used as validation data. The network was a feed-forward backprop network with two layers and ten neurons in the first layer as shown in Figure 1. 16 variables ($x_1, x_2, x_3 \ldots x_{16}$) were used as input dataset as identified in Tables 1 and 2. Infiltration rates of 9 different elapsed time from Table 3 were provided as target data.

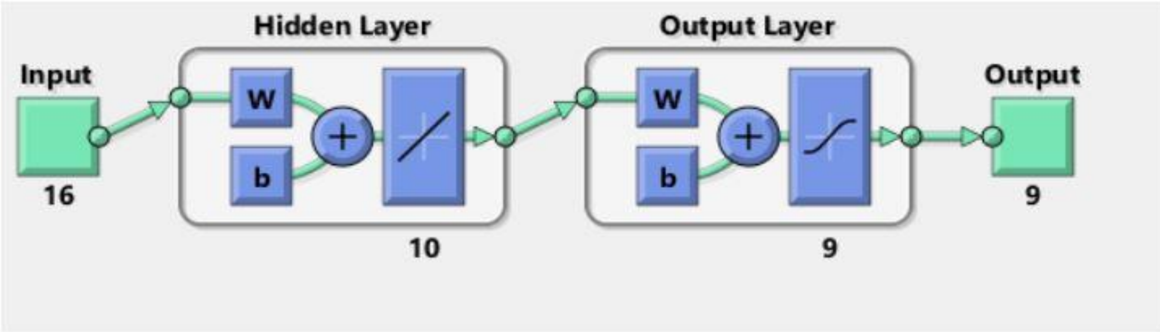
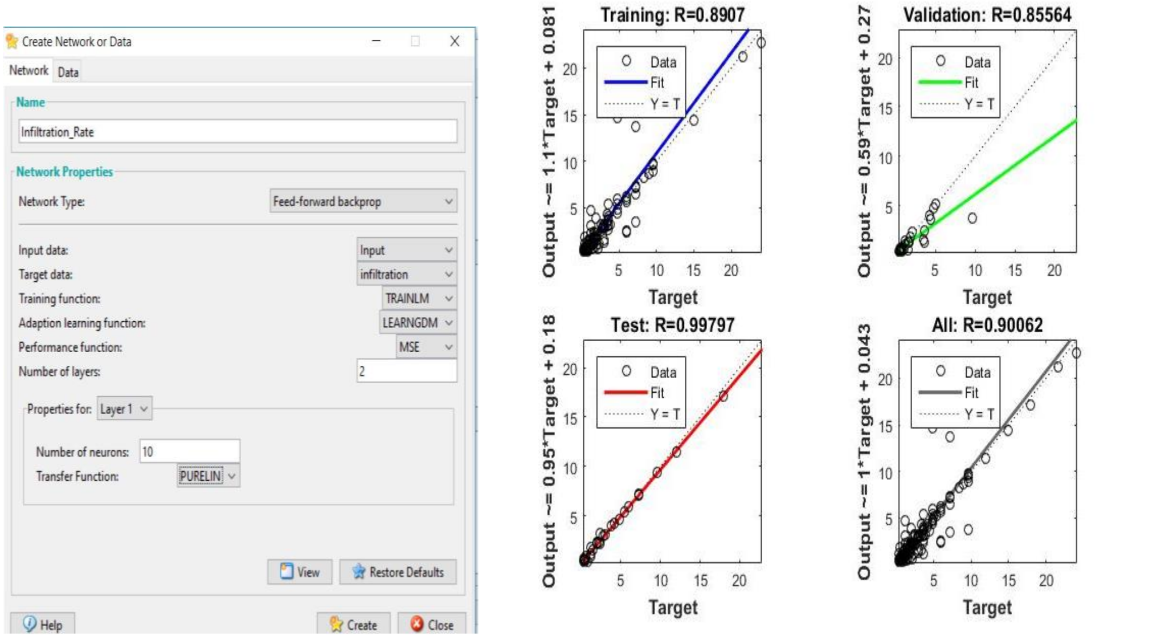


Figure 1. Artificial Neural Network structure with two layers and ten neurons in the first layer.

In the neural network toolbox 'TRAINLM', 'LEARNGDM', 'MSE' and 'PURELIN' were selected as Training Function, Adaption Learning Function, Performance Function and Transfer Function as shown in Figure 2(a).



(a) (b)

Figure 2. (a) Training Function choice in Neural Network Toolbox, (b) Regression plots.

Result

Regression plots with coefficient of determination values are shown in Figure 2(b). The top-left plot shows linear regression between output data produced from training data and target data. The top-right plot shows linear regression between output data produced from validation data randomly taken from input data set and target data. The bottom-left plot shows linear regression between output data produced from test data and target data. The bottom-right plot shows linear regression between output data produced from the combination of above three and target data.

Conclusion

Figure 2(b) shows 89.07 percent match between Artificial Neural network output (training) and Target data, 85.564 percent match between Artificial Neural network output (validation) and Target data,99.797 percent match between Artificial Neural network output (test) and Target data and an overall match of 90.062 percent. The input dataset included soil physical and index properties for only one study area with homogenous characteristics. For input datasets with greater variation, the model may not show similar results.Artificial

Neural Network can be effectively used as a predictor for infiltration rates for different elapsed time without requiring field tests. Further modelling can be done for prediction of infiltration capacity of soil and runoff from soil physical and index properties. The infiltration rate of soil can be used to design irrigation, drainage and water supply systems and flood control measures.

References

Chowdhury,M.E.,Islam,M.A.,Islam,T,Khan,N (2018) "Evaluation of Shear Strength of Cohesionless Soil from Maximum, Minimum Dry Density and Fines Content using Polynomial Surface Fitting Method" *Electronic Journal of Geotechnical Engineering*, 23(1),31-56.

Chowdhury,M.E.,Islam,M.A.Islam,M.S.,Shahriar,M.S.,Alam,T. (2017) "Design, Operation and Performance Evaluation of a Portable Perforated Steel Tray Rainfall Simulator." *Proceedings of 14th Global Engineering and Technology Conference,*Dhaka.

Dutta,S.C.,Matin,M.A. (1993) "Prediction of Equilibrium Infiltration Capacity of Soil." *Journal of Institution of Engineers,Bangladesh,* 21(4),37-44.

Demuth H, Beale M (2001) "Neural network toolbox user's guide Vol. 4." The Math Works, Inc., Natick Haghighi, F., Saghafian, B. and Kheirkhah, M., (2011). "Evaluation of soil hydraulic parameters in soils and land use change." INTECH Open Access Publisher, Rijeka.

Igbadun, H.E., and Idris, U.D. (2007) "Performance evaluation of infiltration models in a hydromorphic soil." Nigerian Journal of Soil and Environmental Research, 7, 53–59.

Karandish F, Simunek J (2016) "A comparison of numerical and machine-learning modeling of soil water content with limited input data.*" Journal of Hydrology,* 543,892-909.

Mishra, S.K., Tyagi, J.V., and Singh, V.P. (2003) "Comparison of infiltration models." *Hydrological Processes*, 17(13), 2629–2652.

Sihag, P., Tiwari, N. K., & Ranjan, S. (2017a). "Estimation and inter-comparison of infiltration models."*Water Science*, 31(1), 34–43.

Swamee, P.K., Rathie, P.N., de SM Ozelim, L.C. and Cavalcante, A.L. (2014) "Recent advances on solving the three-parameter infiltration equation." *Journal of Hydrology*., 509, 188–192.

Wenmei, Ma, and Zhang, X. (2016). "Effect of Pisha sandstone on water infiltration of different soils on the Chinese Loess Plateau." *Journal of Arid Land*, 8(3), 331–340.

INFLUENCE OF PHREATIC SURFACE ON THE ULTIMATE PULLOUT RESISTANCE OF VERTICAL ANCHOR PLATE BY FEM

S. Sakib[1] and M. S. Islam[2]

ABSTRACT

Vertical anchors embedded in soil are structural components used for stabilization of various foundation systems. Due to the complex behavior of surrounding soil, the design of such anchors becomes an arduous task. The fluctuation of phreatic surface adds to the complexity of the design process. In this paper the influence of rising phreatic surface on the pullout resistance of anchor plate was analyzed using finite element method (FEM) in PLAXIS 3D. From the analysis it was observed that when the phreatic level lies just beneath the anchor plate it has no influence on the pullout resistance. However, as the phreatic level rises upwards, ultimate pullout resistance is reduced and when phreatic surface merges with the ground surface ultimate pullout resistance is reduced by almost 50%. This reduction is similar for cohesionless soils with different frictional angles. Such behavior is different from effect of phreatic level on bearing capacity of isolated footing, where the effect is observed when phreatic level lies within a depth equal to twice the width of the foundation beneath the foundation. Sudden reduction of pullout capacity may lead to catastrophic failures such as failure of retaining walls and result in collapse of adjoining structures. While designing vertical anchor plates for those regions, phreatic level must be taken into consideration along with other governing factors.

Introduction

In a riverine country like Bangladesh the fluctuation of the phreatic surface pose a huge threat to the stability of riverside structures. Besides due to unplanned urbanization and pressure of overpopulation numerous structures are built on reclaimed lands. During monsoon heavy rainfall and frequent flooding causes the phreatic level to rise, reducing the soil strength and undermining the foundations of different structures. Earth anchor is one such foundation system, which gives stability to civil engineering structures by resisting pullout forces. Compared to other foundation systems, earth anchors provide an efficient and economic design solution. These earth anchors such as vertical plate anchors are typically attached with the retaining structures and embedded in the soil to sufficient depth so that they resist pullout forces with safety. They derive their resisting force from the passive pressure of the surrounding soil mass. The ultimate pullout resistance of vertical anchor plate depends on few factors including but not limited to anchor embedment depth (H) to anchor height (B) ratio or embedment depth ratio (H/B), anchor length (L) to height (B) ratio or aspect ratio, (L/B), shear strength parameters of the soil (soil friction angle, φ and cohesion, c) and angle of friction at the anchor-soil interface, δ. These terms are illustrated in Figure. 1. Study of the existing literature shows that researchers have focused on determining the capacity of vertical anchors especially for anchor plate. (Hueckel 1957; Ovesen and Stromann, 1972; Neely et al., 1973; Akinmusuru, 1978; Ghaly, 1997; Shahriar, 2018). Furthermore, the works by Bowles (1997), Naser (2006), and Jadid et al. (2018) focused on block anchors. Past researchers favored analytical models to practical models for designing of anchors. The huge cost and labor required for field testing made those unpopular. Numerical analysis was a far better alternative and in the field of anchor design it was found to be pioneered by Rowe and Davis (1982). They assumed the sand to have a Mohr-Coulomb failure criterion and assessed the initial stress state, anchor plate roughness, effect of anchor plate embedment, friction angle and dilatancy for vertical anchor plates. Koutsabeloulis and Griffiths (1989) investigated the trap door problem by the initial stress finite element method. Both plane strain and axisymmetric works were conducted. Upper and lower bound limit analysis techniques have been used by Murray and Geddes (1987, 1989) and Basudhar and Singh (1994) to estimate the capacity of vertical strip anchor plates. Merifield et al. (2006) presented the results of a rigorous numerical work to estimate the ultimate capacity load for vertical anchor plate in cohesionless material. Rigorous bounds have been obtained using two numerical procedures that are based on finite element method of the upper and lower bound of limit analysis.

Although there are much study on the pullout capacity of various anchors in dry soil, the same cannot be

[1]*Postgraduate Student, Department of Civil Engineering, BUET, Dhaka - 1000*
[2] *Professor, Department of Civil Engineering, BUET, Dhaka - 1000*
Email of Corresponding Author – shadmansakib.1353@gmail.com

found for anchors in saturated soils. For designing earth anchors fluctuating phreatic level must be taken into consideration. Ganesh and Sahoo (2017) investigated the vertical pullout capacity of plate anchors with fluctuating ground water conditions. They employed an analytical model and presented the results in the form of non-dimensional uplift capacity factor F_γ^w. They showed that for various embedment depth ratio (*H/B*) and soil friction angle (φ) values, as the depth of phreatic surface (H_w) rises uplift capacity factor F_γ^w decreases. The phreatic surface has no influence on the anchor capacity when it is just beneath the anchor bottom or lower. No further literature is found on the influence of fluctuating phreatic surface on vertical plate anchors. In the current research a finite element analysis was carried out to verify the impact of phreatic surface on the pullout capacity of horizontally loaded vertical anchor plates. The plate anchors are assumed to be embedded in cohesionless soil. The phreatic surface will be placed at different positions beneath the ground surface to observe its effect. The adoption of finite element analysis provides us with the opportunity to study a wide range of circumstances and reinforce our design concept.

Methodology

In this paper, the finite element analysis was done by using PLAXIS 3D. A vertical anchor plate which was modelled with 6 nodded plate element was placed inside a cohesionless soil bed at a certain depth. The boundaries of the soil bed were placed far away from the anchor, so that it does not affect anchor's resistance. The phreatic surface was varied by changing the head in the design borehole. Respective mechanical properties were assigned to the elements of the model. Refer to Table 1 for soil and anchor properties adopted during finite element (FE) modeling. The soil was assumed to follow Mohr - Coulomb failure criterion. To replicate the effect of pullout load, a horizontal point load was applied at the centre of mass of the anchor plate. The process was repeated for a number of embedment depth ratios and phreatic levels (H_w) and the corresponding load vs. displacement data was recorded. The point of anchor plate failure was determined with the instructions provided by Neely et. al (1973).

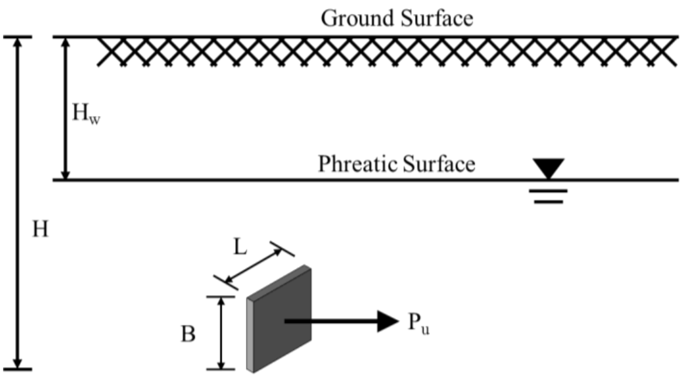


Figure 1. Problem definition; (H - embedment depth; H_w - position of phreatic surface; B - height of the anchor plate; L - length of the anchor plate; P_u = ultimate pullout load)

Table 1. Properties of soil and anchor plate used for the FE analysis.

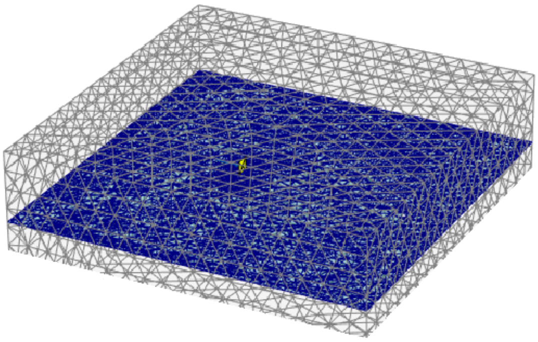
Properties of Soil		**Properties of Anchor Plate**	
Unsaturated Unit Wt. (γ)	16 kN/m^3	Length (L)	0.5 m
Saturated Unit Wt. (γ_{sat})	18 kN/m^3	Height (B)	0.5 m
Poisson's ratio (ν_s)	0.2	Thickness (t)	0.05 m
Interface reduction factor (R_{inter})	0.5	Poisson's ratio (ν_p)	0. 3
Frictional angle (φ)	35°	Unit weight (γ_p)	78.5 kN/m^3
Dilatancy angle (ψ)	5°		
Cohesion (c)	0.01 kN/m^{2*}		

*Though the soil bed is formed of cohesionless soil, the cohesion is not 0 practically.

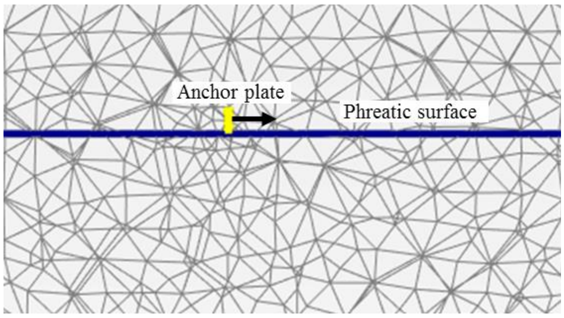
Results and Discussions

Validation of the Finite Element Model

Few researches have worked with FE modelling and employed it to solve geotechnical problems. Out of the few numerical studies, the study by Merifield and Sloan (2006) is the most comprehensive one. The result was presented with of dimensionless anchor breakout factor, $N_\gamma = P_u / \gamma BH$. Their analysis showed that this factor increases with the increase of embedment depth ratio (*H/B*) of the anchor plate i.e. the pullout capacity of the anchor increases with the depth of embedment of the anchor from the ground surface. To validate the use of PLAXIS 3D for the analysis of anchor plate similar approach was taken. The results obtained from the current analysis is presented in dimensionless form and compared with Merifield and Sloan (2016) in Figure. 3. Data from both sources are in close agreement for $H/B \leq 8$ which implies that PLAXIS 3D provides acceptable estimation within this range. The discrepancy at higher embedment depth may be caused by variation of roughness parameter used for the models. Sakib and Islam (2018) also showed the credibility of FE modelling comparing with experimental findings by Choudhary and Dash (2014).



(a) Element contour of the soil bed, plate anchor (yellow) and phreatic surface (blue plane)



(b) Section through the soil bed and anchor plate

Figure 2. Finite element model as viewed in PLAXIS 3D.

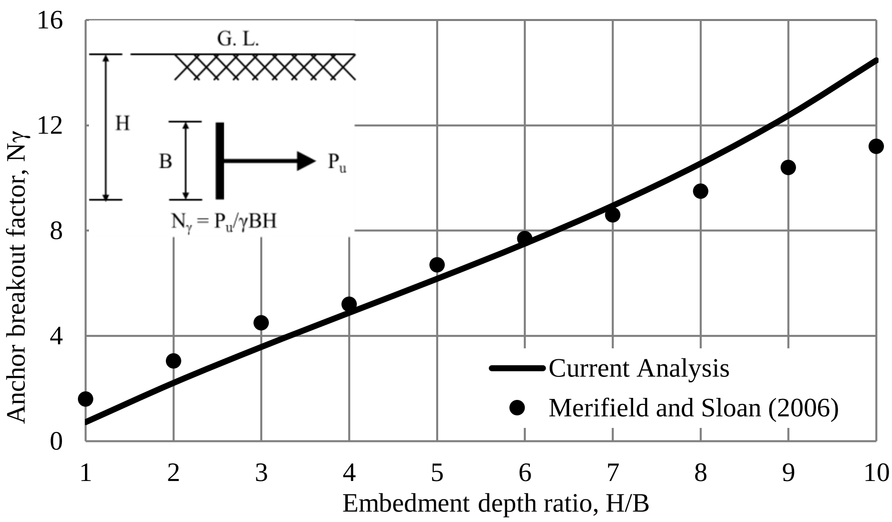


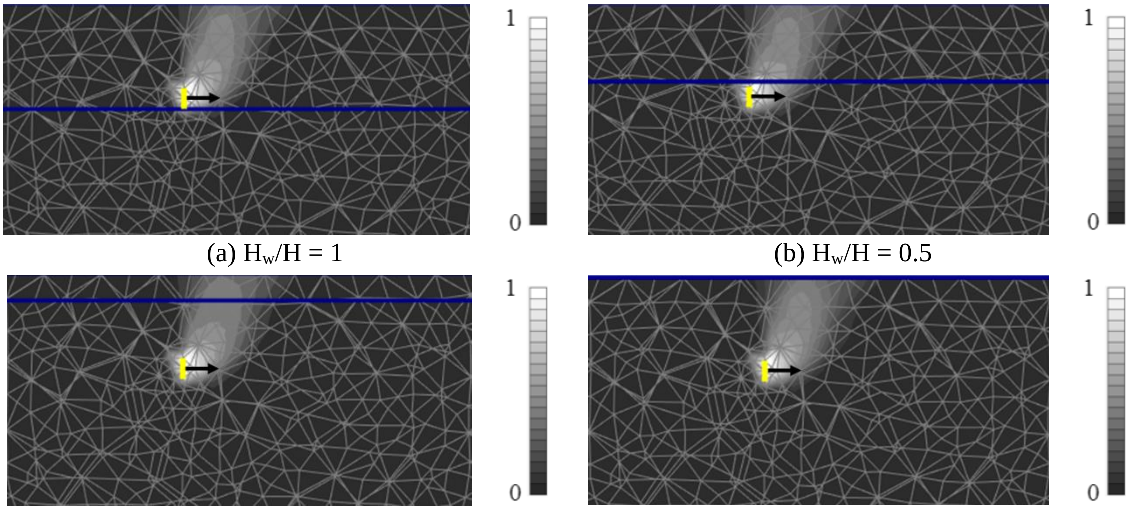
Figure 3. Comparison of current analysis with previous numerical analysis.

Influence of fluctuating phreatic surface

To observe the influence of phreatic surface on the ultimate pullout capacity of vertical anchor plate, the phreatic surface was kept at different depths as shown in Figure. 4 and anchor plate was loaded until failure. The process was repeated for several embedment depths. The analysis showed that the depth of the phreatic surface did not have any effect on the ultimate pullout capacity while it was kept below the bottom of the anchor plate for any embedment depth. The value was identical to the one obtained for phreatic surface at great depths. Since the soil mass just in front of the anchor was not saturated, it did not affect the ultimate pullout capacity. The vertical anchor plate derives it resistance from the passive soil surface in front of it. Again when the phreatic surface was gradually raised, the ultimate pullout resistance started to decline for all embedment depths. As the unit weight of the soil is diminished by the influence of water, the soil surrounding the anchor losses its resisting capacity resulting in lower ultimate pullout resistance. When the phreatic surface reaches the ground surface the ultimate pullout resistance is almost 50 % of the value obtained when the soil was dry. Using soil having different friction angle (φ) values same analysis was carried out and the obtained results were identical. So it can be implied that the influence of the phreatic surface is not dependent on the friction angle (φ) of the soil. At high embedment depths, a logarithmic spiral or a rotational failure mechanism is a more common occurrence (Neely et. al 1973) and as such some soil existing below the bottom of the anchor plate provides some passive resistance. The current analysis shows that its influence on ultimate pullout capacity is negligible.

Use of correction factor for design purposes

To account for this reduction, while designing vertical plate anchors a correction factor as presented in Figure. 5 can be utilized. The correction factor, C_p can be found from the dimensionless normalized phreatic surface depth (H_w/H), which has to be multiplied with the ultimate pullout capacity of the anchor when the soil is in dry condition. The use of the correction factor is illustrated in a simple mathematical problem.



(a) $H_w/H = 1$ (b) $H_w/H = 0.5$

(c) $H_w/H = 0.75$ (d) $H_w/H = 1$

Figure 4. Different depths of phreatic surface (navy blue line) used for numerical analysis and relative displacements of surrounding soil mass at anchor plate (yellow rectangle) failure.

Mathematical Example. A vertical anchor plate of height 750 mm placed at a depth of 5 m fails at a pullout load of 1500 kN when the phreatic surface is at a great depth. What ultimate pullout capacity if the phreatic surface rises to a depth of 1.25 m?
Solution. Given, H = 1 m; $P_{u, dry}$ = 1500 kN; B = 750 mm = 0.75 m; H_w = 1.25 m.
For H_w/H = 1.25/5 = 0.25, from Figure. 5 we get, C_p = 0.74.
Therefore, if the phreatic surface rises ultimate pullout capacity = 0.74 × 1500 = 1110 kN.

Comparison with effect of phreatic surface on bearing capacity

While designing an isolated footing the phreatic level is taken into consideration in two cases as shown in Figure. 6. For the case of vertical anchor plates a correction factor similar to R_{w1} was used and its value was between 0.5 and 1 similar to the isolated footing foundation. However, no factor like R_{w2} was required. From this it is revealed that, the pullout of the vertical anchor plates are not influenced by the phreatic surface in the same manner as shallow isolated footing. Though the failure surface of the vertical plate anchor and isolated footing has much similarity, the design principle for one cannot be match to other.

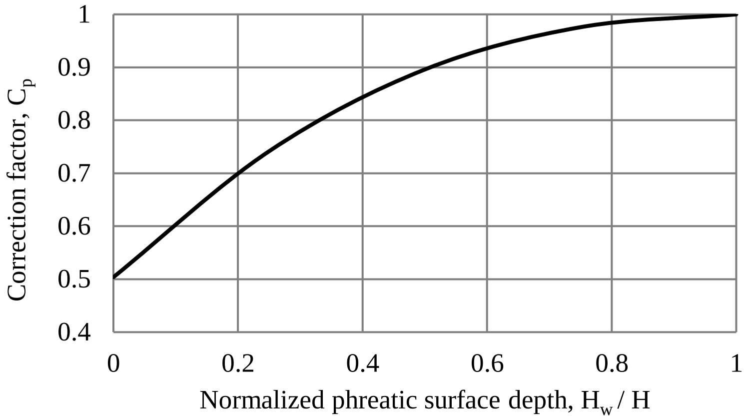
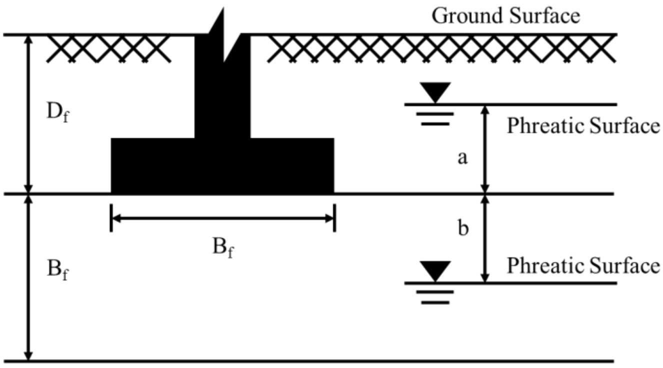


Figure 5. Correction factor for depth of phreatic surface.



(i) When the phreatic surface is below the base of the foundation at a distance 'b' the correction R_{w2}

$$R_{w2} = 0.5 + 0.5 * (b/B_f) \leq 1$$

(ii) When the phreatic surface further rises above the base of the foundation the correction R_{w1}

$$R_{w1} = 1 - 0.5 * (a/D_f) \leq 1$$

Figure 6. Influence of phreatic surface on the bearing capacity of isolated footing foundation. (Df - depth of foundation; B_f - width of the footing; a, b - positions of phreatic surface from the bottom of footing)

Conclusions

In this paper to predict the effect of phreatic surface on the ultimate pullout resistance of vertical anchor plate finite element analysis was used. The model was checked with existing numerical results. From the analysis it was seen that the phreatic surface has profound effect on the ultimate pullout resistance when it lies above the bottom of the anchor and causes a maximum resistance reduction of 50% which is independent of the internal angle of friction of the soil. For designing anchors having possibility of going under the phreatic surface a correction factor was proposed. If the phreatic surface is beneath the anchor plate it has no effect on it and gives maximum ultimate pullout resistance. The research outcomes can be utilized for designing economic foundations for areas having problems with fluctuating phreatic levels and ensure safety from sudden catastrophic collapse.

Acknowledgments

The authors are thankful to the Department of Civil Engineering of Bangladesh University of Engineering and Technology (BUET) and BUET - Japan Institute of Disaster Prevention and Urban Safety (JIDPUS) for providing the necessary support and facilities for conducting this research.

References

Akinmusuru, J. O. (1978). "Horizontally loaded vertical plate anchors in sand." *Journal of the Geotechnical Engineering Division,* ASCE, 104(2): 283-286.

Basudhar, P. K. and Singh, D. N. (1994). "A generalized procedure for predicting optimal lower bound break-out factors of strip anchors." *Géotechnique,* 44(2): 307-318.

Bowles, J. E. (1997). "*Foundation Analysis and Design."* Singapore: The McGraw-Hill Companies, Inc. pp. 778-780.

Choudhary, A. K. and Dash, S. K. (2014) "Pullout behaviour of vertical plate anchor embedded in sand." Proceedings, *Indian Geotechnical Conference IGC-2014*, pp. 1506-1509

Das, B. M. (1990). "*Earth Anchors*." Amsterdam, Netherlands: Elsevier.

Dickin, E. A., and King, J. W. (1997). "Numerical modeling of the load-displacement behavior of anchor walls." *Computers and Structures,* 63(4): 849-858.

Ghaly, A. M. (1997). "Load-displacement prediction for horizontally loaded vertical plates." *J. Geotech. Geoenviron. Engrg*., 10.1061/(ASCE)1090-0241(1997)123:1(74): 74-76.

Hueckel, S. (1957). 'Model Tests on Anchoring Capacity of Vertical and Inclined Plates." Proceeding,*4th Internation Conference on Soil Mechanics and Foundation Engineering*, 2, pp. 203-206. London, England Butterworths Scientific Publications.

Koutsabeloulis, N. C., and Griffiths, D. V. (1989). "Numerical modelling of the trap door problem." *Géotechnique*, 39(1): 77-89.

Jadid, R., Abedin, M. Z., Shahriar, A. R., and Arif, M. Z. U. (2018). "Analytical model for pullout capacity of a vertical concrete anchor block embedded at shallow depth in cohesionless soil." *International Journal of Geomechanics, ASCE,* 10.1061/(ASCE) GM.1943-5622.0001212.

Merifield, R. S., and Sloan, S. W. (2006). "The ultimate pullout capacity of anchors in frictional soils." *Can. Geotech. J.,* 43: 852-868.

Murray, E. J., and Geddes, J. D. (1987). "Uplift of anchor plates in sand." *Journal of Geotechnical Engineering*, ASCE, 113(3): 202-215.

Murray, E. J., and Geddes, J. D., (1989). "Resistance of passive inclined anchors in cohesionless medium." *Géotechnique*, 39(3): 417-431.

Naser, A. S. (2006). "Pullout capacity of block anchor in unsaturated sand." Unsaturated Soils 2006 (GSP 147), Proceedings, *4th Int. Conference on Unsaturated Soils, ASCE.* (pp. 403-414). Arizona.

Neely, W. J., Stuart, J. G. and Graham, J. (1973). "Failure loads of vertical anchor plates in sand." *Journal of the Geotechnical Engineering Division*, ASCE, 99(9): 669-685.

Rowe, R. K. and Davis, H. (1982). "The behaviour of anchor plates in sand." *Géotechnique*, 32(1): 25-41.

Ganesh, R., and Sahoo, J. P. (2015) "Influence of ground water on the ultimate uplift resistance of circular plate anchors" *50th Indian Geotechnical Conference*, Pune, Maharashtra, India.

Ganesh, R. and Sahoo, J. P. (2017) "Vertical uplift resistance of plate anchors with the fluctuations of groundwater table", *Int. J. of Geosynth. and Ground Eng*. 3:8.

Sakib, S., and Islam M. S., (2018). "Numerical investigation of pullout capacity of horizontally loaded vertical anchor plate embedded in cohesionless soil." *4th International Conference on Advances in Civil Engineering (ICACE-2018),* Chattogram, Bangladesh

Shahriar, A. R. (2018). "Development of an analytical model for the analysis of pullout capacity of anchors embedded in frictional soils." *MSc Thesis*, Dept. of Civil Engineering, BUET, Dhaka, Bangladesh

EFFECTIVENESS OF CEMENT STABILIZED FILL SOIL AS A SUSTAINABLE GEOTECHNICAL OPTION

Hasan Shahrier[1], Md. Sabrul Islam[2], Subrata Roy[3], Fariba Hossain[4], Mohammad Atiqul Goni[5]

ABSTRACT

This research provides effectiveness of cement stabilized fill soil as a geotechnical option to increase structural safety while facing natural disaster. The paper contains the study of index and engineering properties of fill soil collected from Elephant Road, Dhaka and variation of strength characteristics for cement treatment of soil using ordinary Portland cement by 2%, 4%, 6% of dry weight of the soil at curing age of 7, 14, 28 days. The soil is detected as (CH) high plastic silty clay having 3% sand, 44% silt and 53% clay contents. Unconfined compression test, direct shear test and CBR test were performed to measure unconfined compressive strength (q_u), initial stiffness modulus value (Ei), undrained cohesion (Cu), undrained angle of friction (Φu) and CBR value for both untreated and treated soil sample. Unconfined compressive strength (q_u) increases rapidly 7% to 85% in 7 days and up to 4 times in 28 days for 2% to 6% cement content. Initial stiffness modulus (Ei) increases significantly from 2.5 times to 4.5 times in 7 to 28 days with the increase of cement contents from 0% to 2%, 4% and 6%. Enhancement of undrained cohesion (Cu) from 6% to 41% in 7 days was observed which increases to 2.7 times in 28 days. But for treated soil, undrained angle of friction (Φu) follows less certain path comparing to undrained cohesion (Cu). CBR values were also increased up to 4.5 to 9.5 times in addition of 2% and 4% cement contents comparing to that of untreated soil.

Keywords: Unconfined compressive strength, CBR value, Angle of friction, Ordinary Portland Cement, Stiffness modulus.

Introduction

Stabilization is the process of blending and mixing materials with a soil to improve the soil's strength and durability. The process may include blending soils to achieve a desired gradation or mixing commercially available additives that may alter the gradation, change the strength and durability, or act as a binder to cement the soil. Cement stabilisation has been recommended to increase engineering properties like compressive strength, cohesion, undrained angle of friction of clay and sandy soil. It is generally recognized that the addition of cement to clay will increase dry density and stiffness modulus of the soil. Investigation into properties of cement stabilised soils would assess the suitability of using cement as stabiliser to reduce swelling of expansive soils. The present study, therefore, has been aimed to investigate the physical and engineering properties of cement stabilised fill soil. The research has been carried out in intention of evaluating engineering properties (e.g. unconfined compressive strength, moisture-density relations, undrained shear strength, California Bearing Ratio) of a fill soil collected from Elephant Road, Dhaka and changes in these strength and deformation properties of the soil after cement stabilization at different percentages for different curing ages.

Instruments and Equipment Used

For untreated soil's Atterberg limit test, Casagrande apparatus and for linear shrinkage test, shrinkage mold have been used. To perform grain size analysis set of sieves and hydrometer have been used. Using

[1] *MSc student, Dept. of Civil Engineering, Bangladesh University of Engineering & Technology (BUET), Dhaka-1000, Bangladesh*
[2] *BSc, Dept. of Civil Engineering, Bangladesh University of Engineering & Technology (BUET), Dhaka-1000, Bangladesh*
[3] *MSc student, Dept. of Civil Engineering, Bangladesh University of Engineering & Technology (BUET), Dhaka-1000, Bangladesh*
[4] *BSc, Dept. of Civil Engineering, Bangladesh University of Engineering & Technology (BUET), Dhaka-1000, Bangladesh*
[5] *BSc, Dept. of Civil Engineering, Bangladesh University of Engineering & Technology (BUET), Dhaka-1000, Bangladesh*
Email of Corresponding Author – shahrier.28.buet@gmail.com, tutulroy110@gmail.com

Pycnometer we determined the specific gravity of soil sample. Again for both treated and untreated soil, compaction test apparatus, unconfined compression test apparatus, CBR test apparatus, direct shear test apparatus have been used.

Figure 1. CBR test apparatus

Figure 2. Unconfined Compression test sampler

Methodology and Laboratory Investigation

An extensive and comprehensive laboratory investigation program was undertaken to examine the physical .index and engineering properties of sub grade soil (Untreated soil). Portland cement type I was used as additive for stabilization. Both soil samples from different depth was thoroughly mixed together and stabilized with Portland cement of 2%, 4%,6% by weight of soil. Table 1 shows the soil sample types used for the project.

Table 1. Soil sample types

Sample Name	**Composition**
Sample A	100% soil
Sample B1	Soil+2% cement
Sample B2	Soil+4% cement
Sample B3	Soil+6% cement

The whole laboratory testing program is consisted of these tests on both treated and untreated soil sample: Index property tests were performed on untreated soil sample which includes Atterberg limit test, linear shrinkage test, specific gravity test, grain size analysis by both wash sieve and hydrometer test. The following tests were performed in untreated soil sample: Standard proctor compaction Test, unconfined compression test on molded cylinder sample of 3 inch height and 1.5 inch diameter, California bearing ratio (CBR) test, direct Shear Test (Quick). On treated sample unconfined compression test on molded cylinder sample of 3 inch height and 1.5 inch diameter, direct shear test (Quick), California bearing ratio (CBR)Test were performed for three different cement content (2%,4%,6%) in different curing ages. CBR test was carried out for five levels of compaction with 20 blows per layer for both untreated and treated soil sample. Unconfined Compression Test was carried out for treated sample at different curing ages of 7, 14, 28 days so did the Direct Shear Test.

Result and Discussion

Various experiments have been performed in the laboratory for both untreated soil sample and treated soil sample with different percentages of cement. Necessary properties and features of the soil have been described below. Basically, the color of the untreated soil sample was yellowish brown and it was too stiff having specific gravity 2.64.

Table 2. Index Properties of Untreated Soil Sample

Physical Description of Soil		**Specific Gravity**	**Atterberg Limits**						
Color	Consistency	**2.64**	Plastic Limit (%)	Liquid Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Shrinkage Limit (%)	Flow Index (%)	Tough-ness Index (%)
Yellowish Brown	Stiff		25	51	26	11	20	17	1.5

About 99% soil passed through No. 200 sieve. As per MIT classification here 3% Sand, 44% Silt and 53% Clay is present in this sample. The summary of soil classification is shown in Table 5.

Table 3. Classification of Soil

Grain Size Distribution				
Sand	Silt	Clay	Unified Soil Classification System (USCS)	AASHTO
3%	**44%**	**53%**	**CH**	**A-7-6**

The index and physical properties determined by various tests in the preliminary investigations imply that the liquid limit is 51% and plastic limit 26% and linear shrinkage is 11%. So the soil according to USCS is CH and according to AASHO 1966 soil which is inorganic silty clay, prone to high linear shrinkage and high plasticity.

From the laboratory test of compaction test, optimum moisture content, $w_{opt}$was found 15.8%and maximum dry density, $\gamma_{dmax}$was found 1.78 (g/cm^3) were determined.This data including energy required for the test are presented in Table 4.

Table 4. Values of Maximum Dry Density and Optimum Moisture Content

Test Method	**Compaction Energy,(lb-ft/ft^3)**	**Dry Density, γ_d (g/cm^3)**	**Dry Density, γ_d(kN/m^3)**	**Optimum Moisture Content, $w_{opt\ (\%)}$**
Standard Proctor Compaction Test	12375	1.78	17.46	15.8

For Standard Proctor compaction energy, the stress –strain relationship is obtained from the unconfined compression test. Performing same test with several untreated soil sample, we found average unconfined compressive strength, q_u=300 KPa which determined by the peak stress of failure strain.

***Table 5.** Unconfined Compression Test result of Untreated Soil*

Test Name	**Compaction Energy,(lb-ft/ft^3)**	**Dry Density,γ_d(kN/m^3)**	**Average Unconfined Compressive Strength, q_u(kPa)**	**Average Undrained Shear Strength, S_u (kPa)**	**Average Initial Stiffness Modulus,E_i (kPa)**
Unconfined Compression Test	12375	17.46	300	150	6200

***Table 6.** Direct Shear Test Results for Untreated Soil*

Test Name	**Compaction Energy, (lb-ft/ft^3)**	**Normal Stress, σ (kPa)**	**Undrained cohesion, c_u (kPa)**	**Undrained angle of friction Φ_u°**

Direct Shear Test	12375	1252550	81	25
		2550100	80	26.9
		5010200	84	25.7

The stress –strain relationship is obtained from the unconfined compression test for Standard Proctor compaction energy for cement content of (2%,4%,6%) and having curing age of 7,14,28 days.

Table 7. Effect of Cement Contents on Unconfined Compressive Strength q_u and Undrained Shear Strength S_u

Cement Content (%)	**Unconfined Compressive Strength q_u,(kPa)**			**Undrained Shear Strength S_u , (kPa)**		
	7 days	**14 days**	**28 days**	**7 days**	**14 days**	**28 days**
0	300	300	300	150	150	150
2	322	348	430	161	174	174
4	398	502	744	199	251	251
6	554	800	1224	277	400	400

The unconfined compressive strength increased about 7%, 33%, 85% for 2%, 4%, 6% cement contents in 7 days and 16%, 67% and about 2.5 times in 14 days. For 28 days the values increases rapidly to 0.5, 1.5, 4 times for 2%, 4%, 6% cement contents comparing that to the untreated soil.

Table 8. Effect of Cement Contents on Dry Density γ_d and Initial Stiffness Modulus E_i

Cement Content (%)	**Dry Density, γ_d (kN/m^3)**			**Initial Stiffness Modulus E_i (kPa)**		
	7 days	**14 days**	**28 days**	**7 days**	**14 days**	**28 days**
0	17.46	17.46	17.46	6200	6200	6200
2	17.48	17.48	17.48	6800	7950	11640
4	17.52	17.52	17.52	7725	10275	17966
6	17.59	17.59	17.59	15600	21500	34033

Initial stiffness modulus increases about 2.5 times for 0% to 6% cement content in 7 days whether it is about 3.5, 4.5 times for 14 and 28 days curing age. The dry density (γ_d) also increases with higher cement content. So, observation implies that for higher cement contents unconfined compressive strength (q_u) increases rapidly than lower cement contents at longer curing ages.

Table 9. Effect of Cement Contents on Undrained Cohesion c_u and Undrained Angle of Friction Φ_u°

Cement Content (%)	**Undrained Cohesion c_u,(kPa)**			**Undrained Angle of Friction Φ_u°**		
	7 days	**14 days**	**28 days**	**7 days**	**14 days**	**28 days**
0	80	80	80	26.9	26.9	26.9
2	86	94	109	27.3	29.5	30.5
4	96	118	150	28.2	30.6	32.6
6	113	146	215	30.2	31.9	38

Undrained cohesion c_u increases 6%, 20%, 41% for 2% to 6% cement content that of untreated soil in 7 days. For 14 days it increases 17% to 82% and for 28 days 36% to 2.7 times that of untreated soil. Undrained angle of friction Φ_u° increases with cement content and curing age slowly to 1%, 5%, 12%. in 7 days 9%,13%,19% for 14 days and 13%, 21%,41% for 28 days respectively for 2%,4%,6% cement contents. So, rapid enhancement of undrained cohesion (c_u) for treated sample is observed though the increase rate of undrained angle of friction (Φ_u) is much slower and follows less definite path.

Table 10. CBR Value Comparison for 0.1inch and 0.2 inch Penetration

Cement Contents (%)	**Blows Per Layer(5 Layers)**	**Compaction energy, (lb-ft/ft^3)**	**Dry Density, γ_d (pcf)**	**4-Days Soaked CBR**	
				At 0.1 in Penetration	**At 0.2 in Penetration**
0	20	20000	109.2	4	3
2			109.3	18	13
4			109.6	38	26

CBR value for 0.1 inch penetration is more than 0.2 inch penetration and increases about 4.5 times for 2% cement treated soil and 9.5 times for 4% cement treated soil than untreated soil sample.

Conclusions

Several aspects of this research require future study. Some of the important areas to pursue on future are listed below

1. Tests can be carried out for different compaction energy (Modified Proctor, 15 Blows). Effect of compaction energy on unconfined compressive strength and other strength properties can be determined.
2. Stress and strain characteristics of the compacted soil can be investigated at dry side and wet side of optimum moisture content.
3. Unconfined compression test for treated sample should be performed several times and average should be taken for more accurate results.
4. Cement in different contents can be used to observe the strength properties and to find optimum additive content which fulfills the necessary requirements.
5. Effect of long time curing (more than 28 days) can be observed for engineering properties of treated sample.
6. The entire project can be revised for different additives like lime, bitumen, fly ash or mixture of additives to find most suitable type for stabilization of soil.
7. CBR test for different no. of blows per layer should be carried out for soil treated with different cement contents.

References

AASHO (1966), "*Standard Specification for Highway Materials and Methods of Sampling and Testing*" Part-1 and Part-2, Specification, Washington D.C., USA.

ASTM D1883-16, "*Standard Test Method for California Bearing Ratio (CBR) of Laboratory-Compacted Soils.*"

ASTM D4318-17e1*, "Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils."*

ASTM D2166/D2166M-16, *"Standard Test Method for Unconfined Compressive Strength of Cohesive Soil."*

EVALUATION OF THE EFFECT OF RAINFALL ON SLOPE STABILITY ANALYSIS BY USING HYDRAULIC UNIT FLUX INFILTRATION PROPERTY

Ahmed Hossain[1], Md. Enayet Chowdhury[2*], Mohammad Shariful Islam[3]

ABSTRACT

Slope stability analysis for evaluating landslide potential excludes the effect of rainfall while determining the Factor of Safety (FOS). This study involves the simulation of rainfall on slopes through hydraulic unit flux boundary condition to evaluate the FOS. Infiltration data taken from perforated tray rainfall simulator was used as the hydraulic unit flux infiltration in slope stability analysis, later the FOS was validated by a conventional procedure. The rainfall simulator is capable of producing storms up to 188 mmh^{-1} within 10 minutes' duration with a drop size distribution slightly greater than the natural rainfall (median diameter of raindrops for simulated rainfall is 4.18 mm at 188 mmh^{-1}, where that for natural rainfall is 3.25 mm). FOS in real time condition was evaluated on the basis of surface runoff which is a common reason of rainfall induced landslides. The result shows that FOS from software analysis excluding rainfall simulation is over estimated with respect to real time FOS analysis.

Keywords: GEO-STUDIO®, Rainfall simulator, Hydraulic unit flux boundary condition.

Introduction

Rainfall induced landslides are a very common occurrence in the hilly region specially when they are composed of finer material like alluvial deposits. To ensure the stability of these slopes, determination of factor of safety is of paramount importance. In a tropical region like Bangladesh, rainfall is considered as the trigger to a landslide, causing the surface runoff of the top layer of soil in absence of vegetative layer or any kind of soil reinforcing materials. Previously, Oh and Vanapalli (2010) have studied the impact of rainfall infiltration on the shearing strength of soil mass and the stability of the slope where Chowdhury et al. (2018) analyzed the variation of shearing strength with varying fines content. Islam (2018) has shown the variation of factor of safety of a slope due to the variation of the degree of saturation. Chowdhury et al. (2017) investigated a mathematical approach for river bank slope stability. Islam et al. (2013) analyzed the effect of root reinforcement of vetiver on the stability of a slope.

In any kind of slope stability analysis, the result will not be a conservative one if the effect of rainfall on the slope failure is not considered as a significant parameter. But the effect of rainfall is not directly considered in contemporary methods like Limit Equilibrium or Strength Reduction method of slope stability analysis. So, in this study, unit flux infiltration property is used to assign rainfall effect coupled with slope stability analysis which follows Limit Equilibrium theorem to determine the rainfall induced factor of safety of slopes.

Physical and Index Properties of Soil

Detailed laboratory experiments were carried out to determine the physical and index properties of the soil samples which were collected from Chattogram hill tracks. Soil composition indicates sand 57.4%, silt 28.3% and clay 14.3%, co-efficient of permeability of the soil is 5.25×10^{-8} ms^{-1}. The soil sample has a specific gravity of 2.75, the bulk density of 16.8 kNm^{-3} and the moisture content at site condition is 15.46%.
The soil has Liquid Limit, Plastic Limit and Plasticity Index of 24, 27 and 7 respectively. The soil is categorized as SM-SC. The direct shear test indicates that the cohesion and angle of internal friction of the corresponding soil sample is 1.8 kPa and 30.2° respectively.

[1] *Undergraduate Student, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka-1000, Bangladesh.*
[2] *Corresponding Author, Undergraduate Student, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka-1000, Bangladesh, E-mail: enayet108@gmail.com.*
[3] *Professor, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka-1000, Bangladesh*

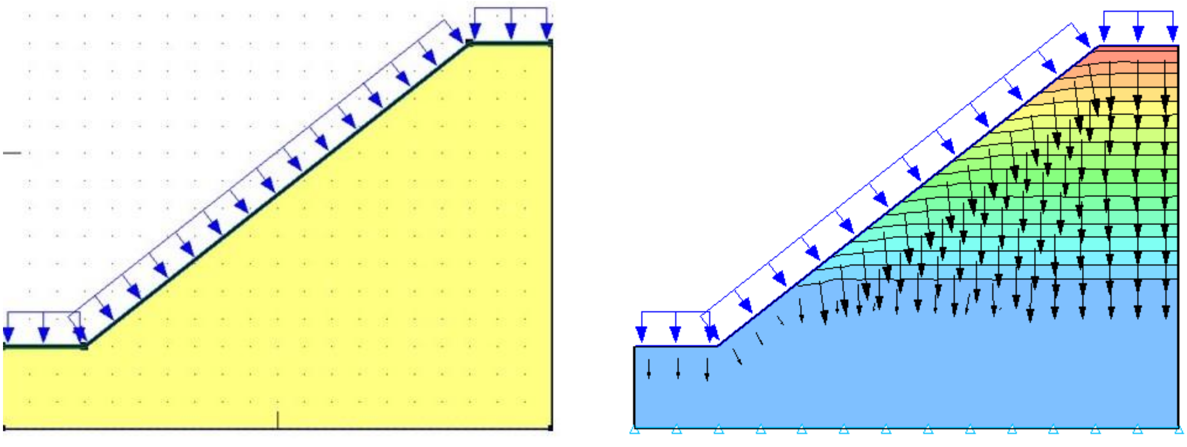
Method of Analysis

A trapezoidal glass model was manufactured by (Islam, 2018) having a slope of 1:1 and dimension of 900mm×600mm×600mm. The glass model was filled with soil and compacted to the extent to attain the desired density (16.8 kNm^{-3}).

A drip-type artificial rainfall simulator (Chowdhury et al., 2017) of 1.11 m^2 (1.22m×0.91m) having a rectangular tray consisting of mild steel with a pipe supply-based water connection system was used to artificially simulate rainfall on a physical model to determine the amount of water infiltrated in the soil and run-off occurred on the slope. The corresponding rainfall simulator is capable of producing storms up to 188 mmh^{-1} rainfall intensity within 10 minutes' duration with a drop size distribution slightly greater than the natural rainfall (median diameter of raindrops for simulated rainfall is 4.18 mm at 188 mmh^{-1}, where that for natural rainfall is 3.25 mm). This greater dimension of the raindrop size with respect to natural rainfall keeps the model as a conservative one because it will cause more surface erosion of the slope soil than the practical condition.

GEO-STUDIO® was used to analyze the Factor of Safety (FOS) of the physical model using limit equilibrium following Morgenstern-Price principle for both dry and after rainfall condition. To assign rainfall effect in slope stability analysis, a boundary condition named unit flux hydraulic boundary condition in SEEP/W module was introduced. This boundary condition is applicable when the precipitation rate is greater than infiltration capacity of soil throughout the duration of rainfall. The ϕ-index value for the situation is used as input for this hydraulic boundary conditions. In cases where the infiltration capacity of the soil is lesser that the precipitation rate, hydraulic flux function needs to be defined for the use of hydraulic boundary condition. Here, the amount of infiltrated water got from perforated tray simulation (Islam, 2018) for 15 min and 30 min of rainfall (0.0014 ms^{-1} and 0.0025 ms^{-1} respectively) was used as the input of unit flux in boundary condition where the hydraulic analysis will be coupled with SEEP/W module which acts as the pore water pressure condition in SLOPE/W stability analysis to determine the rainfall induced FOS of the slope. Throughout the duration of rainfall simulation, it was observed that surface run-off on the slope was present which means the infiltration rate can be used as the input of the unit flux in SEEP/W analysis.

Results



(a) (b)

Figure 1: (a) Unit flux infiltration boundary condition input, (b) Seepage field for 15 minutes rainfall

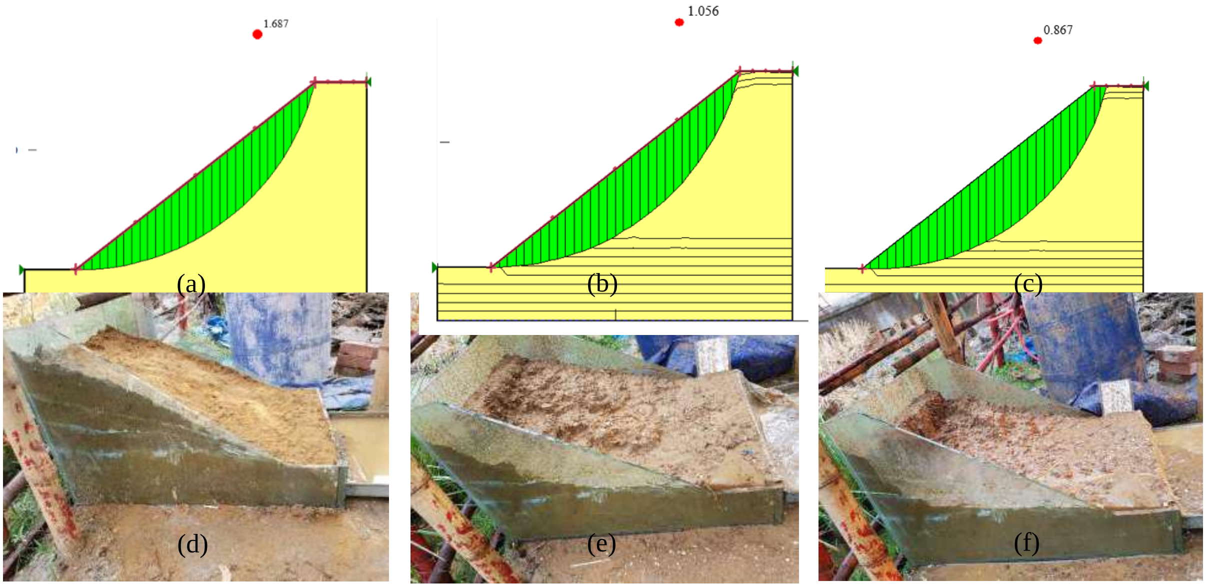


Figure 2: Comparison of the failure pattern of the slope between the physical model and coupled stability analysis in GEO-STUDIO®; (a) & (d) when no rainfall is occurred, (b) & (e) when rainfall duration is 15 min, (c) & (f) when rainfall duration is 30 min.

In Figure 1(a), the assigned unit flux infiltration hydraulic condition is shown where in Figure 1(b) the seepage field for rainfall duration of 15 minutes is provided. The seepage field shows that the vertical percolation of rainwater was assumed and no lateral movement of water is considered. In Figure 1(b), the lighter color in greater depth signifies more moisture content in soil whereas the darker colour in upper portion indicates less moisture content in soil.

Table 1: Comparison of the factor of safety of the slope in various rainfall condition

Rainfall duration	**No rainfall**	**15 minutes**	**30 minutes**
Factor of safety	1.69	1.06	0.87
Comments on slope stability	Ok	Ok but not recommended	Not ok

For dry condition, the model is directly assigned in SLOPE/W module and analyzed where the FOS for this condition was 1.69 (>1.50). It means the slope was stable for this particular condition. For wet condition, coupled analysis of SLOPE/W with SEEP/W module is required to assign the rainfall effect on the slope to analyze rainfall induced FOS of the slope. At first, using hydraulic boundary condition in SEEP/W, infiltration representing rainfall effect is assigned then in SLOPE/W the initial pore water pressure (PWP) condition is set to parent analysis (Previous SEEP/W analysis) and stability analysis was done to attain FOS of the slope for this condition. From the analysis, after 15 min rainfall, the FOS of the slope was reduced to 1.06 which is stable but not recommended. But after 30 min rainfall, the induced FOS lowers to 0.87 which refers that the slope has become unstable.

Discussions and Conclusions

In this study, slope failure envelope analyzed from GEO-STUDIO® intersects the top surface of the slope (for 30 min rainfall duration) which is representative to the practical condition (Figure 2(f)). So, the reduction of FOS in the coupled analysis of SEEP/W and SLOPE/W is validated with the practical condition. In the tropical region, this method can be used to determine the reduced FOS of the slope under the influence of rainfall where conventional methods fail to do so. To be conservative, the soil condition is modeled here as bare surface, thereby neglecting the increase in FOS considering vegetation or reinforcement effect on a slope. Further study can be conducted to observe the influence on coupled analysis-based FOS in vegetated or reinforced slope.

Acknowledgement

The authors are acknowledging GEO-STUDIO® Student Edition License (free version) for conducting this study. They are also grateful to Geotechnical Engineering Laboratory, Bangladesh University of Engineering and Technology (BUET) for providing the opportunity to conduct lab tests.

References

Chowdhury, M.E., Hossain, A. and Muktadir, H.M. (2018) "Evaluation of the river training work of Padma river through a mathematical approach", *Journal of Modern Science and Technology*, 6(1):52-62

Chowdhury, M.E., Islam, M.A., Islam, M.S., Shahriar, M.S. and Alam, T. (2017) "Design, operation and performance evaluation of portable perforated steel tray rainfall simulator", *Proceedings of 14th Global Engineering and Technology Conference*, 29-30 December, 2017, BIAM Foundation, 63 Eskaton, Dhaka, Bangladesh.

Chowdhury, M.E., Islam, M.A., Islam, T. and Khan, N. (2018) "Evaluation of shear strength of cohesionless soil from maximum, minimum dry density and fines content using polynomial surface fitting method", *Electronic Journal of Geotechnical Engineering*, 23(1):31-56

Islam, M.A. (2018) "Measures for landslide prevention in Chittagong hill tracks of Bangladesh", *M.Sc. Thesis*, Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh

Islam, M.S., Arifuzzaman, Shahin, M.H. and Nasrin, S. (2013) "Effectiveness of vetiver root in embankment slope protection: Bangladesh perspective", *International Journal of Geotechnical Engineering*, Vol. 7, Issue 2

Oh W.T. and Vanapalli, S.K. (2010) "Influence of rain infiltration on the stability of compacted soil slopes[J]", *Computers and Geotechnics*, 37(5): 649-657.

EFFECTIVENESS OF OPEN MESH JUTE GEO-TEXTILE (JGT) IN EROSION CONTROL OF SLOPES

S. Hossain[1], M. S. Islam[2], A. J. Khan[3]

ABSTRACT

Failure of road side slope, hill slope, river bank etc. due to erosion is one of the major concerns in Bangladesh. Different techniques are in practice to reduce or restrict soil erosion. As employed, these are often found to be expensive and not environment friendly. However, Jute Geo-textile (JGT) is one of the alternative methods that can reduce erosion of soils. Effectiveness of JGT on runoff and soil erosion reduce has been investigated in this study. Two types of JGTs (500 gsm and 700 gsm) were selected and a glass tank model constructed at the geotechnical laboratory of Bangladesh University of Engineering and Technology. Sandy soil of FM 1.18 was used for preparing the slope at 1V:1.5H gradient. Artificial rainfall was produced using a perforated GI sheet tray (1.22m×0.91m). A rainfall intensity of 150 mm/hr was maintained during the tests. All the test data and observations suggest that open mesh JGT (both 500 gsm and 700 gsm) system reduces the soil erosion by 90-96% in comparison to a bare soil slope. 700 gsm JGT is found to be more effective than 500 gsm JGT in respect to soil erosion by reducing surface runoff. It is concluded that open mesh JGT is effective in controlling erosion of slope.

Introduction

Soil erosion is one form of soil degradation and a naturally occurring process on all lands. Hilly and road side slope are severely vulnerable to it. It may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing serious loss of topsoil followed by ultimate land sliding. In hilly areas, every year occurrence of natural slope stability failure due to rain-cut soil erosion exerts devastating consequences to the people, locality, environment and socio-economic activities emerged on it. In order to address such erosion of top soil for both cases hill slopes and road embankments, a sustainable, eco-friendly and aesthetic solution would be ensured by landscaped vegetation cover. However, it takes about 6 to 9 months for the vegetation cover to grow. For the interim period, a jute geotextiles overlay may be used to withstand the rain drop impact energy, reduce surface runoff and reduce total soil loss. It may be emphasized that the vegetations should be correctly selected, i.e. they must be environment friendly, fast growing, bushy type and deep and widely spread rooted. Usually, 350gsm, 500gsm and 700gsm JGT of 1.2m width are available in the production line. Jute Geotextiles (JGT) has a typical ground cover ratio of 50% to 60% and an absorption capacity of 2.5 to 3.5 times of their air dry weight. They can usually survive two monsoons without any form of biodegradation process.

However, Erosion is a natural process that cannot be prevented, but it can be reduced considerably. The failure of road side slope due to erosion is one of the common problems in Bangladesh (Rahman and Khan, 2009). Since many years, various measures have been taken to prevent soil erosion of side slope of road. The traditional practices for protecting these slopes are expensive and sometimes not effective due to improper design and construction fault. Jute geotextile is an alternative solution for road slope protection (Islam et al., 2014). It has been found effective in road slope management for its eco-friendliness, cost competitiveness and technical stability (Islam et al., 2013). Jute geotextile was first used for mine soil stabilization in 1987 at Uttaranchal in India and soil erosion was reduced to 0.8 kg/m^2 after that geo-jute was used in road slope protection, top soil erosion and embankment protection in India (GOI, 2007). Furthermore, Sanyal et al. and Ghosh et al. also performed some field trials on application of geo-jute in India for top soil erosion control. In Bangladesh also, road side slopes have been stabilized using geo-jute aided vegetation establishment

[1]Graduate Research Student, Department of Civil Engineering, University of Engineering and Technology, Dhaka-1000.
[2]Professor, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000.
[3]Professor, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000
Email of Corresponding Author -shahadathossain.ce@gmail.com

system. Khan and Binoy presented some laboratory simulation test results about to systematically identify the efficiency of geo-jute in reducing soil loss, surface runoff and thus improving overall stability of slopes. However, effectiveness of jute geotextile on runoff and soil erosion has been investigated. But the conditions studied to date have not been enough and are insufficient for the optimization of the selection and application of jute geotextiles for different slope. As a result, systematic studies of various JGT with different slope are still required. The main objective of this paper is to evaluate the performance of jute geotextile for reducing soil erosion by creating slope at 1V:1.5H gradient under simulated rainfall in the laboratory. This study also compares between 500gsm and 700gsm JGT for slope protection by controlling soil erosion

Experimental Program

This soil erosion simulation model is developed to simulate the detail soil erosion process on slope are of roads / hills. The model consists of following parts:

a) Container for Preparing Soil Slope

The soil slope was prepared in an 8mm thick transparent 1.22m×0.91m×0.91m Perspex container. Then 1.07m long, 0.91m wide and 0.76m high soil slope was prepared in container. In front of the container it contains an opening (0.91m × 0.45m) which is associated with toe of slope to help removing the runoff water.

b) Container for Collecting Eroded Soil and Runoff Water

The container for collecting runoff water was 1.83m length, 0.30m width and 0.61m height. Runoff water along with eroded soil was drained here and separated here through the opening at bottom of a face which was 0.91m length and 0.45m height of container and synthetic Geotextile was used for measuring weight of soil eroded.

c) Rainfall Distribution System

A perforated GI sheet was used to make the water distribution uniform throughout the soil slope. This tray looks like a grating of 2 mm opening with 25.4 mm center to center spacing.

d) Slope Characteristics

The soil slope was prepared in an 8mm thick transparent Perspex container which was 1.22m length, 0.91m width and 0.91m height. Then the soil slope was prepared in container. The soil slope (1:1.5) was 1.07 m long, 0.91 m wide, 0.76 m high. Compaction effect was so maintained that the density of sand during compaction was approximately 14 kN/m^3.

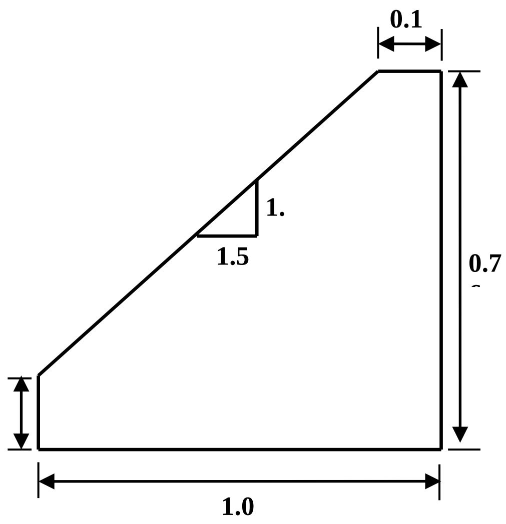


Figure 1: Schematic diagram of slope (all dimensions are in meter)

e) Calibrations for Water Flow Measurement

To confirm the rainfall intensity of 150 mm/hr over an area of 0.97 square meters (1.07 m × 0.91 m) for the slope at 1V:1.5H gradient, a calibration arrangement was made. The basic arrangement was made to maintain a constant the out flow rate (discharge) through the setup.

Methodology

The test method included a laboratory based approach where the whole test system including slope, rainfall, erosion and failure was represented by constructing an experimental model. A Perspex glass tank which contained soil for slope (1:1.5) was included in the model. The tank was placed 0.76m above the ground. In front of the container it contained an opening which is there in order to remove the runoff. Water was supplied through a perforated GI sheet as a form of rainfall. This tray looked like a grating of 2mm opening with 25.4 mm center to center spacing. A container was used for collecting eroded soil and runoff water. A steel frame filter was used instead of weep hole wall to support the toe of soil slopes. Only water was allowed to pass through this filter. Synthetic geo-textile was used as a filter to separate the eroded soil. Eroded soil was air dried after the separation. And weight of eroded soil was measured by a digital balance. This procedure was conducted in three phases namely: i) bare soil slope, ii) soil slope with 500 gsm soil saver and iii) soil slope with 700 gsm soil saver. Test on each phase was carried out under same water supply rate, physical and environmental conditions.

a) b) c) d)

Figure 2: a) Condition of slope for bare soil before rainfall b) Failure state of bare soil slope c) Condition of slope of 500 gsm JGT covered soil after four hours rainfall d) Condition of slope of 700 gsm JGT covered soil after four hours rainfall

Material Used for Model

a) Properties of Soil

Sandy soil of FM 1.18 was used for the simulation test which was collected from local market. D_{10}, D_{30}, D_{50} and D_{60} of the soil were 0.11 mm, 0.18 mm, 0.23 mm and 0.26 mm respectively. The uniformity coefficient (C_u) and coefficient of curvature (Cc) of soil were 2.36 and 1.13 respectively. As C_u less than 6 so the soil was poorly graded soil. The angle of friction of the soil which obtained from direct shear test under consolidated drained conditions was 33^0. The maximum and minimum dry density which also obtained from ASTM test standard D4253 and D4254 were 16.62 kN/m^3 and 13.34 kN/m^3 respectively.

b) Properties of Jute Geotextile

The jute geotextile (soil saver) used for this simulation test was procured from Bangladesh Jute Mills Corporation. This soil saver used for this test was an open mesh type of Jute Geotextile. The weight of jute geotextile was 500 gsm (grams per meter square) and 700 gsm respectively. The width of both jute geotextiles was 1.2m. The absorption capacity of selected JGT was 320% (500 gsm) and 254% (700 gsm) of their dry weight. The aperture of JGT were 23mm × 15mm (500 gsm) and 17mm × 12mm (700 gsm) respectively.

Results and Discussions

Laboratory tests were conducted to determine the soil properties and strength of soil. Model study via simulated rainfall was conducted in order to investigate the performance of bare soil, soil covered with 500 gsm geotextile and soil covered with 700 gsm geotextile against rain induced erosion. In the case of slope at 1V:1.5H gradient it was found that for bare soil slope, 16.63% soil got eroded and the slope eventually failed at 98 minutes. .In that case top soil erosion was noticed and failure initiates gradually with erosion. It was noticed that erosion was started from the toe of the slope. The soil eroded with runoff water was collected in synthetic geo-textile.When the slope was covered with 500 gsm geotextile only 2.12% soil got eroded but the slope did not fail. In this case top soil erosion started slowly but it was not washed way due to geo jute mesh fabrics rather the eroded after eroded soil was accumulates near the toe of the slope which reduces further erosion When the soil was covered with 700 gsm geotextile soil erosion was even less than before (0.71%). This time the slope did not fail as well.

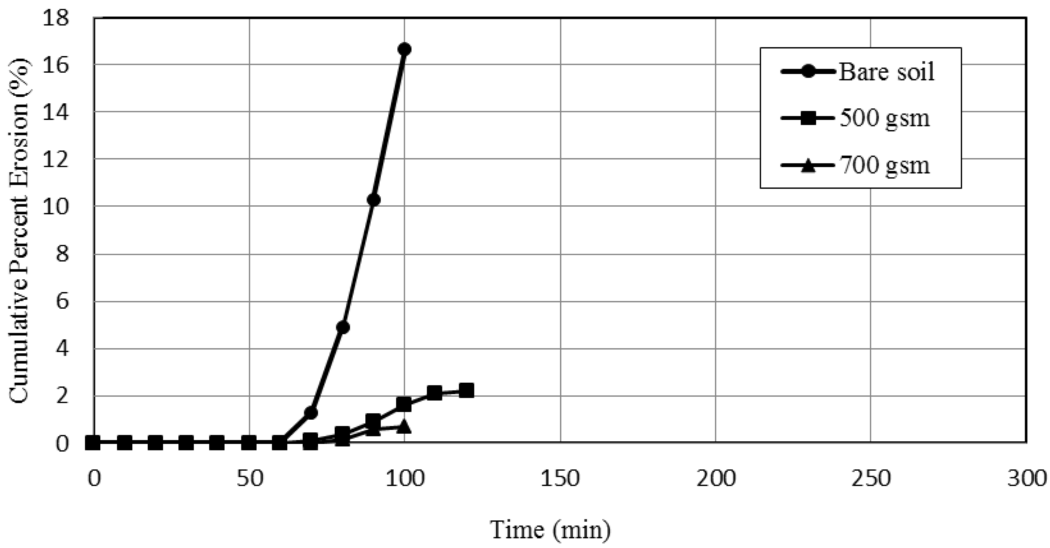


Figure 3: Cumulative comparison of soil erosion – Time graph for bare soil, 500 gsm JGT, 700 gsm JGT

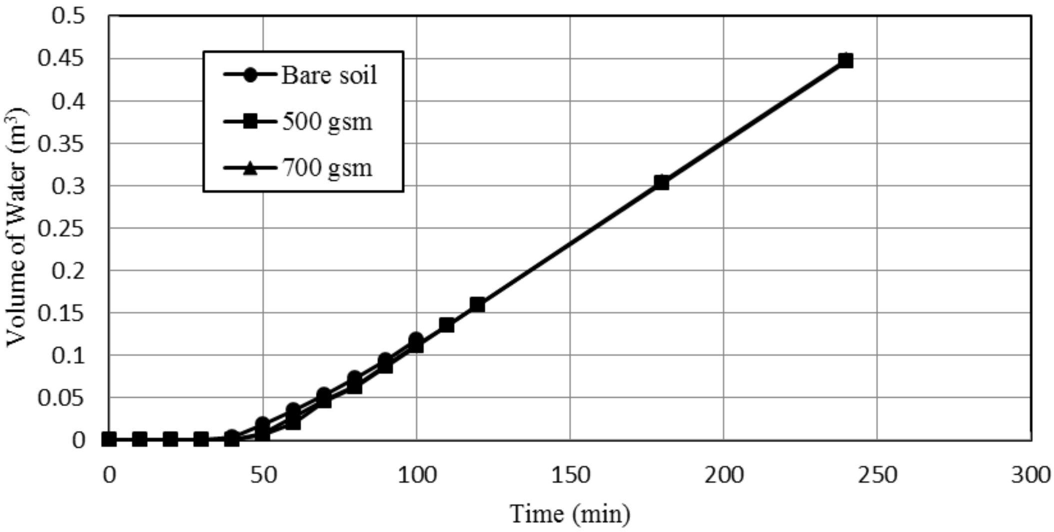


Figure 4: Comparison of Cumulative Runoff -Time graph for bare soil, 500 gsm JGT, 700 gsm JGT

Conclusions

Slope failure due to erosion is a common problem in Bangladesh. Covered JGT system with soil along the slope of road embankment, river banks and hill slope is an alternative environment friendly solution to the problem. Jute geotextile can be used as an interim overlay on the exposed slopes for reducing erosion of the soil mass due to rainfall. It will also increase the stability of a slope for a longer duration of rainfall in absence of vegetation cover. It is found that covered JGT with soil system can be a cost-effective, sustainable, eco-friendly method for the erosion control of slopes in Bangladesh. So, it is observed that 700 gsm jute geo-textile is more effective than 500 gsm jute geo-textile in respect to soil erosion by reducing surface runoff. However, the difference in improvement is not significant but the cost is high. In the cause of cost consideration we can say that 500 gsm JGT is more suitable than 700 gsm JGT.

References

Islam, M.S., Khan, A.J., Siddique, A., Saleh, A. M. and Nasrin, S. (2014), *"Control of erosion of hill slope top soil using geo jute and vegetation",* in National Seminar on Jute Geotextiles, Dhaka, pp. 27-34.

Islam, M.S., Nasrin, S., Moury, F.R. and Islam, M.S. (2013), *"Use of Vegetation and Geo-Jute in Erosion Control of Slopes in a Subtropical Climate",* Journal of World Academy of Science, Engineering and Technology, Vol. 73, pp. 1162-1170.

Islam, M.S. (2013), *"Use of Vegetation and Geo-Jute for Slope Protection",* M.Sc. Engg. Thesis, Department of Civil Engineering, Bangladesh University of Engineering and Technology.

Islam, M.S., Khan, A.J., Siddique, A., Saleh, A.M. and Nasrin, S.(2014), *"Control of erosion of hill slope top soil using geo jute and vegetation",* in National Seminar on Jute Geotextiles, Dhaka, pp. 27-34.

Khan, A.J. and Binoy, T.H. (2012), "Top Soil Erosion Control Using Geo-jute", Proc. of Int. Conf. on Advances in Civil Engineering 2012, pp. 138-142.

Rahman, M.M. (2009), *"Use of Jute Geotextiles in Road Construction",* M.Sc. Engg. Thesis, Department of Civil Engineering, Bangladesh University of Engineering and Technology.

Rahman, M.M., Khan, A.J. (2009), *"Raindrop Erosion Control with Geojute and Vegetation"*, Proc. Of Bangladesh Geotechnical Conference, pp. 208-217.

Hossain, S. (2018), *"Topsoil Erosion Control Using jute-geotextile (JGT) under Simulated Rainfall",* M.Sc. Engg. Thesis, Department of Civil Engineering, Bangladesh University of Engineering and Technology.

A NUMERICAL STUDY ON SLOPE STABILITY ANALYSIS BY FINITE ELEMENT METHOD USING FEMT$_{IJ}$-2D APPLICATION

Md. Wasif Zaman[1], Kazi Samsunnahar Mita[1], Alauddin Al Azad[1], Rezwan Hossain2, Mozaher Ul Kabir[3], and Hossain Md. Shahin[4]

ABSTRACT

Bangladesh has about 21,900 km of road about 65% of this network comprises rural roads. The remainder comprises both National and Regional roads in about equal proportions. This infrastructure in built using local materials which includes alluvial sands and silts, which at time contain mica and varying amount of clay, and organic materials. Substantial sections of the network are subjected to flooding for about three months annually. These conditions pose challenges to designers, who invariable have limited methods of evaluating relevant soil properties for undertaking suitable design, especially when they practice slope stability analysis. Almost all the geotechnical problems solved by finite element method should be related to a non-linear elastoplastic constitutive model since soil is a natural non-linear material. Elastoplastic analysis of geotechnical problems using the finite element (FE) method has been widely accepted in the research arena for many years; however, its routine use in geotechnical practice for slope stability analysis still remains limited. In general, linear problems such as the prediction of settlements and deformations, the calculation of low quantities due to steady seepage or the study of transient effects due to consolidation are all highly amenable to solution by finite elements. In this research we have used an elastoplastic constitutive model for soils, called the extended subloading-tij model used in finite element analyses for the stability analysis of road embankment. Stability of the embankment was analyzed for construction period (i.e. for soil filling). FEMtij-2D application was used to calculate subloading-tij model parameters and analysis of the slope. The highest value of displacement has been found 0.43 meter and it is observed from simulation that settlement is decreasing with depth. At the ground surface, settlement is increasing gradually with distance from centerline and has been found maximum under the slope section. Lateral displacement at embankment toe is increasing with depth. Maximum lateral displacement is occurred at the third layer of soil (9m-18m) filling.

Keywords: Numerical analysis, embankment, slope stability, finite element method, settlement.

Introduction

Elasto-plastic analysis of geotechnical problems using the finite element (FE) method has been widely accepted in the research arena for many years; however, its routine use in geotechnical practice for slope stability analysis still remains limited. Slope stability represents an area of geotechnical analysis in which a nonlinear FE approach offers real benefits over existing methods. Slope stability analysis by elastoplastic finite elements is accurate, robust and simple enough for routine use by practicing engineers. Perception of the FE method as complex and potentially misleading is unwarranted and ignores the real possibility that misleading results can be obtained with conventional `slip circle' approaches. The graphical capabilities of FE programs also allow better understanding of the mechanisms of failure, simplifying the output from reams of paper to manageable graphs and plots of displacements.

Duncan's review of FE analysis of slopes concentrated mainly on deformation rather than stability analysis of slopes; however, attention was drawn to some important early papers in which elasto-plastic soil models were used to assess stability. Smith & Hobbs (1974) reported results of stable slopes and obtained reasonable agreement with Taylor's (1937) charts. Zienkiewicz et al. (1975) considered different slopes and obtained good agreement with slip circle solutions. Griffiths (1980) extended this work to show reliable slope stability results over a wide range of soil properties and geometries as compared with charts of Bishop & Morgenstern (1960). Subsequent use of the FE method in slope stability analysis has added further confidence in the method (e.g. Griffiths, 1989; Potts et al., 1990; Matsui & San, 1992). Duncan mentions the potential for improved graphical results and reporting utilizing FE, but cautions against artificial accuracy being assumed

[1]*Research Assistant, Institute of Water and Flood Management, BUET, Dhaka, Bangladesh*
[2]*2Geotechnical engineer, McDonald Steel Building Products Limited*
[3]*Lecturer, Department of Civil Engineering, Presidency University, Dhaka*
[4]*Professor, Department of Civil Engineering, Islamic University of Technology*

when the input parameters themselves are so variable. Wong (1984) gives a useful summary of potential sources of error in the FE modelling of slope stability, although recent results, including those presented in this paper, indicate that better accuracy is now possible. Nakai and Hinokio (2004) have proposed an elastoplastic isotropic hardening model named subloading tij model, which can suitably consider the influence of the relative magnitude of intermediate principal stress on deformation and strength characteristics of soil by using modified stress tij, the stress path dependency of plastic flow by dividing the plastic stain increment into two components (i.e. the plastic strain increment which satisfies associated flow rule in tij space and the isotropic plastic strain increment under increasing mean stress), and the positive dilatancy during strain hardening and the influence of density and/or confining pressure on the deformation and strength by introducing sub loading surface concept (Hashiguchi and Ueno, 1977; Hashiguchi, 1980). This model has been, furthermore, applied to solve several boundary or initial value problems and the validity of the simulation based on the model are verified by comparing with experimental results of the element tests (triaxial test, hollow cylinder test, true triaxial and others) and those of 1G model experiments on several geotechnical problems such as ground excavation, bearing capacity of foundation and stability of embankment and retaining wall.

The slope stability analyses in geotechnical engineering have followed closely the developments in soil and rock mechanics as a whole. Slopes either occur naturally or are engineered by humans. Slope stability problems have been faced throughout history when men and women or nature has disrupted the delicate balance of natural soil slopes. Furthermore, the increasing demand for engineered cut and fill slopes on construction projects has only increased the need to understand analytical methods, investigative tools, and stabilization methods to solve slope stability problems. Slope stabilization methods involve specialty construction techniques that must be understood and modeled in realistic ways. An understanding of geology, hydrology, and soil properties is central to applying slope stability principles properly. Analyses must be based upon a model that accurately represents site subsurface conditions, ground behavior, and applied loads. Almost all the geotechnical problems solved by finite element method should be related to a non-linear elastoplastic constitutive model since soil is a natural non-linear material. In this research we have used an elastoplastic constitutive model for soils, called the extended subloading tij-model (Nakai et al., 2011) used in finite element analyses.

Methodology

Simulation of the road embankment slope has been done using FEM tij – 2D program developed by Prof. H. M. Shahin and Prof. T. Nakai. At first, finite element mesh was drawn for embankment section. Subloading tij model parameters were determined for the analysis purpose. Numerical analysis using finite element method was used throughout the calculation in the computer program.

Parameters identification for constitutive modelling

An elastoplastic constitutive model for soils, called the extended subloading tij-model (Nakai et al., 2011), is used in the finite element analyses. This model, despite the use of a small number of material parameters, can describe properly the following typical features of soil behaviors (Nakai and Hinokio, 2004 & Nakai et al., 2011):

(i) Influence of intermediate principal stress on the deformation and strength of geomaterials.
(ii) Dependence of the direction of plastic flow on the stress paths.
(iii) Influence of density and/or confining pressure on the deformation and strength of geomaterials.
(iv) The behavior of structured soils such as naturally deposited soils.

Brief description of subloading tij model

Influence of intermediate principal stress is considered by defining yield function f with modified stress t_{ij} (i.e., defining the yield function with the stress invariants (t_N and t_S) instead of (p and q). The yield function is written as a function of the mean stress t_N and stress ratio $X \equiv t_S/t_N$ based on t_{ij} by Eq.**Error! Reference source not found.**.

$$f = ln\frac{t_N}{t_{N0}} + \varsigma(X) - \left(ln\frac{t_{N1e}}{t_{N0}} - ln\frac{t_{N1e}}{t_{N1}}\right) = 0 \quad (1)$$

Here, t_{N1} determines the size of the yield surface (the value of t_N at X=0), t_{N0} is the value of t_N at reference state and t_{N1e} is the mean stress t_N equivalent to the present plastic volumetric strain which is related to the plastic volumetric strain ε_v^p as

$$\varepsilon_v^p = \frac{\lambda-\kappa}{1+e_0} ln\left(\frac{t_{N1e}}{t_{N1}}\right) \tag{2}$$

The symbols λ and κ denote compression index and swelling index, respectively, and e_0 is the void ratio at reference state. In this research, the expression for $\varsigma(X)$ is assumed as,

$$\varsigma(X) = \frac{1}{\beta}\left(\frac{X}{M^*}\right)^\beta \text{ (β: material parameter)} \tag{3}$$

The value of M* in Eq.**Error! Reference source not found.** is expressed as follows using principal stress ratio $X_{CS}\equiv(t_S/t_N)_{CS}$ and plastic strain increment ratio $Y_{CS}\equiv(d\varepsilon_{SMP}{}^{*p}/d\gamma_{SMP}{}^{*p})_{CS}$ at critical state:

$$M^* = \left(X_{CS} + X_{CS}{}^{\beta-1}Y_{CS}\right)^{\frac{1}{\beta}} \tag{4}$$

and these ratios X_{CS} and Y_{CS} are represented by the principal stress ratio at critical state in triaxial compression R_{CS}.
In elastoplastic theory, total strain increment consists of elastic and plastic strain increments as:

$$d\varepsilon_{ij} = d\varepsilon_{ij}^e + d\varepsilon_{ij}^p \tag{5}$$

Here, plastic strain increment is divided into component $d\varepsilon_{ij}{}^{p(AF)}$, which satisfies associate flow rule in the space of modified stress t_{ij}, and isotropic compression component $d\varepsilon_{ij}{}^{p(IC)}$as given in Eq.**Error! Reference source not found.**.

$$d\varepsilon_{ij}^p = d\varepsilon_{ij}^{p(AF)} + d\varepsilon_{ij}^{p(IC)} \tag{6}$$

The components of strain increment are expressed as,

$$d\varepsilon_{ij}^{p(AF)} = \Lambda\frac{\partial f}{\partial t_{ij}} \quad \text{and} \quad d\varepsilon_{ij}^{p(IC)} = K\langle dt_N\rangle\frac{\delta_{ij}}{3} \tag{7}$$

Here, Λ is the proportionality constant, δ_{ij} is Kronecker's delta and <> denotes Macauley bracket. Dividing plastic strain increment into two components as in Eqs.**Error! Reference source not found.** and **Error! Reference source not found.**, for the same yield function, this model can take into consideration feature (ii), i.e., the dependence of the direction of plastic flow on the stress paths. Adding the term $G(\rho)$ in the denominator of the proportionality constant Λ of normal consolidated condition, influence of density is considered. The proportionality constant Λ is expressed as:

$$\Lambda = \frac{\frac{\partial f}{\partial \sigma_{ij}}d\sigma_{ij}}{\frac{1+e_0}{\lambda-\kappa}\left(\frac{\partial f}{\partial t_{kk}}+\frac{G(\rho)}{t_N}+\frac{Q(\omega)}{t_N}\right)} = \frac{df_\sigma}{h^p} \tag{8}$$

$$\text{and} K = \frac{1}{\frac{1+e_0}{\lambda-\kappa}\left(1+\frac{G(\rho)}{a_{kk}}\right)} \cdot \frac{1}{t_{N1}} \tag{9}$$

In feature (iv), the stress-strain behavior of structured soil can be described by considering not only the effect of density described above but also the effect of bonding. Two state variables ρ related to density and ω representing the bonding effect are used to consider feature (iv). The following relationships for $G(\rho)$ and $Q(\omega)$ are adopted in the model: $G(\rho) = sign(\rho)a\rho^2$ and $Q(\omega) = b\omega$ (10)
Where a and b are material parameters.
The parameters of subloading t_{ij} model are fundamentally the same as those of the Cam clay model (Roscoe and Burland, 1968), except for the parameter a, which is responsible for the influence of the density and the confining pressure. Parameter β controls the shape of the yield surface. The performance of the constitutive model has already been checked in numerical simulations (Shahin et al. 2004, Shahin et al., 2011; Nakai et al., 2010).

Table 1. Determined parameters for subloading tij model.

Parameter	Notation	Value			Remarks
		Layer 1 Depth (m): 0-5	Layer 2 Depth (m): 5-9	Layer 3 Depth (m): 9-18	
Compression index	λ	0.1038	0.1-018	0.0819	Same parameters as cam-clay model
Swelling index	k	0.00829	0.00803	0.00983	
Reference void ratio on normally consolidation line at P=98kPa and q=0 kPa	N	0.865	0.868	0.778	
Critical stress ratio	$R_{cs}=(\sigma_1/\sigma_2)_{cs}$ (comp)	3.98	4.00	4.00	
Poisson's ration	μ	0.2	0.2	0.2	
Shape of yield surface (same as original cam clay at β=1)	β	1.60	1.60	1.60	
Influence of density and confining pressure	a	800	850	800	

Finite Element Mesh of the embankment

The different types of finite element mesh are adopted for the analysis of slope section. The element used here are 4- noded quadrilateral type element, 2- noded beam element, 1- noded joint element etc. The 4- noded quadrilateral elements have been used to represent the soil and concrete materials. The 2- noded beam elements have been used to simulated lining, rock bolts and reinforcement in pile. And, the joint interface between pile cap and pile is simulated using the 1- noded joint element.

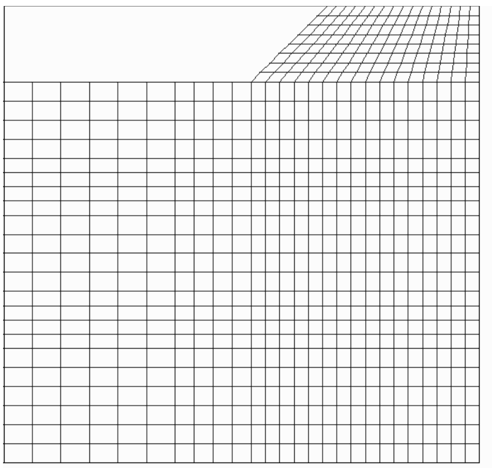


Figure 1. Typical mesh for road embankment.

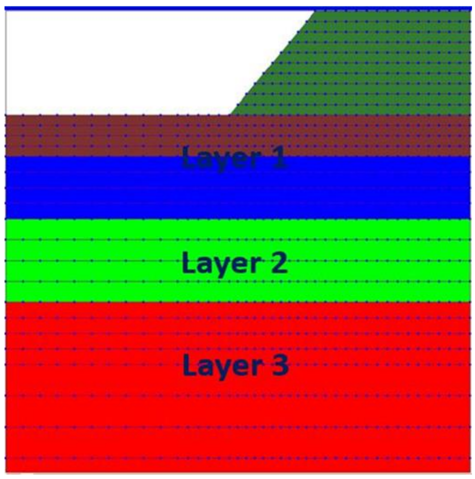


Figure 2. Filling of soil layer by layer.

Results

During the construction of road embankment, we need to do soil filling. The process has been done by filling of soil layer by layer. So, there will be vertically change in stress condition. In the figure 3, it is observed that stress is increasing vertically. It is almost 0 at the slope surface and has been found maximum at the third layer i.e. 16.75*9.81 kN/m^2.

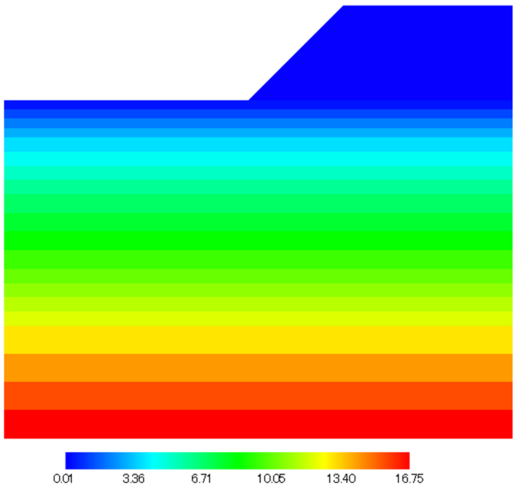


*Figure 3. Vertical stress distribution for soil filling (*9.81 kN/m^2).*

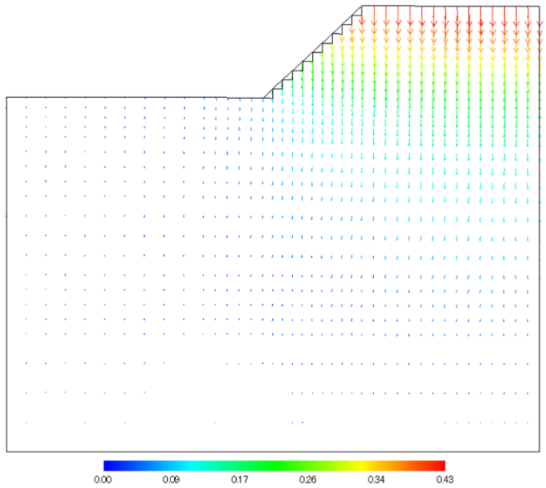


Figure 4. Distribution of displacement vector (Unit in meter).

Settlement at the slope section is shown using displacement vector. The size of displacement vector indicates the magnitude of settlement. From the figure 4, it is observed that maximum settlement is supposed to be occurred at the slope surface. The highest value of displacement has been found 0.43 meter and settlement is decreasing with depth.

Like settlement at slope section, settlement of soil at ground surface has been analyzed. Centerline is taken at the right most corner of the section. Total width of the section is 27 meters. At the ground surface, settlement is increasing gradually with distance from centerline and has been found maximum under the slope section (settlement value is almost 0.2 meter). It is shown in the figure 5.

Lateral displacement at embankment toe is increasing with depth. After the certain level it has started decreasing and found 0 at the bottom of the ground. Maximum lateral displacement would occur at layer 3 (9m-18m) and there will be 0.01m – 0.02m displacement of fill materials.

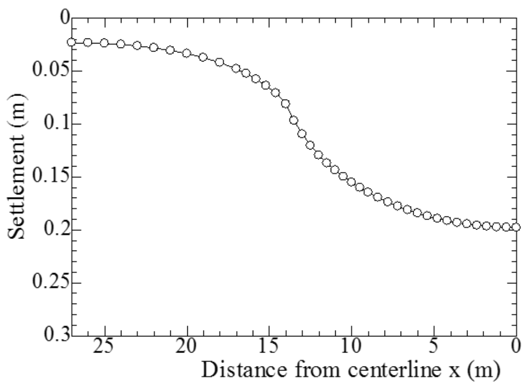


Figure 5. Settlement at the ground surface.

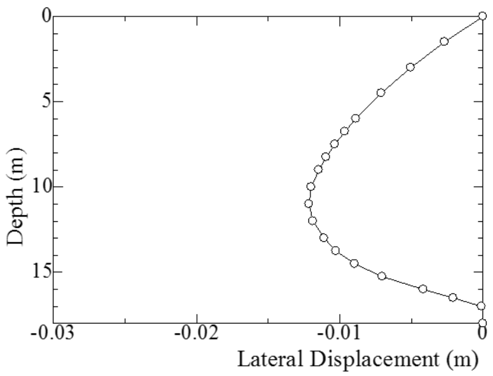


Figure 6. Lateral displacement along the toe of the embankment.

Conclusions

From the slope stability analysis for soil filling condition, we can conclude the following facts:

a) Vertical stress is increasing with depth for soil filling.
b) Ground surface settlement is maximum at center line and gradually decreasing with distance.

c) Lateral displacement at toe has been found maximum at the clayey silt layer.
d) From the settlement analysis at slope section it has been found that highest displacement is happened at slope surface.

However, in this study, soil-water coupling analysis is not considered. Position of water table was remained fixed in the analysis i.e. drainage boundary condition is neglected in this study. Stability analysis of slope need to be conducted by changing the height of the water table in the future.

References

Nakai, T. Shahin, H.M., Kikumoto, M., Kyokawa, H., Zhang, F.and Farias, M.M. (2011). A simple and unified three-dimensional model to describe various characteristics of soils. Soils and Foundations, 51(6), 1149-1168.

Nakai, T., Kyokawa, H., Kikumoto, M., Shahin, H. M. and Zhang, F. (2009(a)): Elastoplastic modeling of geomaterials considering the influence of density and bonding, Proc. of the international symposium on Prediction and Simulation Methods for Geohazard Mitigation, Kyoto, Japan, 367-374.

Kikumoto, M., Nakai, T., Kyokawa, H., Zhang, F. and Shahin, H. M. (2008): A unified method to describe the influence of intermediate principal stress and stress history in constitutive modeling, Proc. of the 2nd international workshop on Geotechnics of Soft Soils Focus on Ground Improvement, Glasgow, United Kingdom, 151-157.

Wroth, C. P. and Wood D. M. (1978). The correlation of index properties with some basic engineering properties of soils. Canadian Geotechnical Journal, 15(2): 137-145.

O'Kelly, B. C. (2013). Atterberg limits and remolded shear-strength water content relationship. Geotechnical Testing Journal, 43(5): 502-507.

Azadi, M. R. E. and Monfared, S. R. (2012). Fall cone test parameters and their effects on the liquid and plastic limits of homogeneous and non-homogeneous soil samples. Electronic Journal of Geotechnical Engineering, 17k: 1615-1646.

Youssef, M. S., El Ramli, A. H. and El Demery, M. (1965). Relationships between shear strength, consolidation, liquid limit and plastic limit for remolded clays. Proc. of the 6th Int. Conf. on Soil Mechanics and Foundation Engineering, Montreal, P.Q., Vol. 1, pp. 126-129.

Skempton, A. W. (1944). Notes on the compressibility of clays. Quarterly Journal of the Geological Society of London, 100C: Parts 1, 2, pp. 119-135.

Casagrande, A. (1947). Classification and identification of soils. Proc. of the American Society of Civil Engineers, 73(6): 783-810.

Waters, T. J. and Vardanega, P. J. (2009). Re-examination of the co-efficient of determination (r2) using road materials engineering case studies. Road and Transport Research, 18(3): 3-12.

Zaman M.W., Asik T. Z., Rumi M. Y., and Hossain H. M. (2016). Geotechnical hazard analysis of river embankment of Bangladesh and its protectability. International Journal of GEOMATE, 10(22): 2050-2057.

Feng, T. (2000). Fall-cone penetration and water content relationships of clays. Géotechnique, 50(2): 181-187.

Houston, W. N. and Mitchell, J. K. (1969). Property interrelationships in sensitive clays. Journal of the Soil Mechanics and Foundations Divisions (American Society of Civil Engineers), 95(SM4): 1037-1062.

AL – Khafaji, A.W and Andersland, O.B. (1992). Equations for compression index approximations. Journal GED, ASCE 118(1):148 – 153.

American Society for Testing and Materials (1985); "Standard test method for classification of Soils for Engineering Purposes", D- 2940 – 74; ASTM, Philadelphia, U.S.A.

Ameen, S.F. (1985); "Geotechnical Characteristics of Dhaka Clay" MSc. Engineering Thesis; Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh

Aminullah, S.A. (2004); "Geotechnical Characteristics of Alluvial deposits of Bangladesh" M.Sc. Engineering thesis, Department of Civil Engineering, Bangladesh University of Engineering & Technology, Dhaka, Bangladesh.

Bashar, A. (2000). "Geotechnical characterization of Dhaka metropolitan area," M. Engineering thesis, Department of civil engineering, Bangladesh University of Engineering & Technology, Dhaka, Bangladesh.

BGS, (1980); "Geological survey of Bangladesh" Bangladesh.

Bhattachariyya, S.K. (2009), "Design of Embankment for Bangladesh." MPhil Thesis, University of Birmingham, UK.

Bjerrum, L. (1972). "Embankment on Soft ground", Proceeding Specialty Conference on performance earth and earth supported structure, ASCE, Vol. 2, pp. 1 -54.

Carrier, D.W., and Beckman, J.F. (1984) "Correlations between index tests and the properties of remolded clays," Geotechnique 34, No.2, 211-228.

Carter and Bentley (1991) "Correlations of Soil Properties".

Das, B. M. (1997). "Principles of Geotechnical Engineering (4th edition)", International Thomson Publishing Inc.

Ferthous, M. (2007). "Geotechnical characteristics of soft soil in Khulna, Bangladesh", M. Engineering thesis, Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh. pp 10 – 57.

Zaman M. W, Hossain M. R, Shahin H. M and Alam M. A. A. (2016). A study on correlation between consolidation properties of soil with liquid limit, in situ water content, void ratio and plasticity index. Proc. of the 3rd Int. Conf. on Geotechnics for Sustainable Infrastructure Development – Geotec, Hanoi, 3, 899-902.

Hunt, T. (1976). "Some geotechnical aspects of road construction in Bangladesh" Geotechnical engineering 7(1): pp. 1 -33.

Murthy, V.N.S. (2003). "Geotechnical Engineering: Principles and Practices of Soil Mechanics and Foundation Engineering". Marcel Dekker, Inc. New York, U.S.A.

Nishida, Y. (1956) "A brief note on compression index of soil," Journal of the soil mechanics and foundation division, ASCE, Vol.82, No SM3, 1027 - -1027 -14.

Renson – herrero, o. (1983), "Universal compression index equation," Discussion, Journal of Geotechnical engineering, ASCE, Vol. 109, No. 10, 1349.

SLOPE STABILITY ANALYSIS OF AN EARTHEN EMBANKMENT FOR DIFFERENT GEOMETRIC AND WATER LEVEL CONDITIONS BOTH FOR COHESION-LESS AND COHESIVE SUBSOIL

M.A.R. Talukder[1], M. Sakibuzzaman[2], A. Muqtadir[3], M.A. Ansary[4]

ABSTRACT

Soil properties, geometric figures, subsoil properties and water level conditions these are some of the factors on which the stability of the soil depends. In this thesis, stability analysis has been done for an earthen embankment considering those factors. Embankment soil properties have been assumed fixed in this study. The analysis has been done for different heights and slope angles both for cohesion less and cohesive subsoil. Three water level conditions have been considered such as high flood level, low flood level and rapid drawdown condition. For cohesion less subsoil, the subsoil has been divided into three layers containing different unit weights, friction angles and zero cohesion. Then the factor of safety has been determined for different heights (6m, 7m, 8m and 9m) and slope angles (26.57, 30.26, 33.69 and 36.87 degree) and different water level conditions through SLOPE/W. For cohesive subsoil, same procedure has been followed to determine the factor of safety for those heights and slope angles and water level conditions. The friction angles have been assumed zero for cohesive subsoil. The change of factor of safety with the change of heights, slope angles, water level conditions have been shown through graph plotting. The comparison of stability between cohesion-less and cohesive subsoil has been shown in a table for different heights, slope angles and water level conditions. For checking the suitability of the geometry, minimum factor of safety has been taken as 1.25. For cohesion-less subsoil, 6m height (26.57 degree) produces factor of safety greater than 1.25 for all water level conditions. So, the maximum allowable height for cohesion-less subsoil is 6m. For cohesive subsoil, The height 8m (slope angle 33.69 degree) produces enough safety for all water level conditions and also ensures less costly construction. So, the maximum allowable height is 8m for cohesive subsoil.

Keywords: Angle, cohesion, factor of safety, height, rapid drawdown, slope stability

Introduction

Slope stability of an earthen embankment depends much on its soil parameters, subsoil conditions, water level conditions and geometry of the embankment slope. Slope stability decreases with the increase of height and slope angle of embankment slope. Weights of manmade structures constructed on or near slopes tend to increase destabilizing forces and slope stability.

Slope Stability Analysis through SLOPE/W

The authors' institutional affiliations and addresses are to be given in single-line form at the bottom of the first page. The last affiliation line should rest on the bottom margin of the page with the topmost affiliation line being directly beneath a two-inch rule. The line should include a succinct address sufficient for sending mail to the author. Example illustrates format.

---

[1]*Graduate Student, Department of Civil Engineering,*
Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh.
Email: nibir1204@gmail.com
[2] *Graduate Student, Department of Civil Engineering,*
[3]*Professor, Department of Civil Engineering,*
[4]*Professor, Department of Civil Engineering,*
Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh.

Subsoil Properties

For analyzing purpose, it needs to assume the parameters of the subsoil of the embankment. Here the soil is divided into the different layers. Then 16, 17, and 18 unit weight in KN/m^3 and friction angle of value 30, 32 and 35 are assumed respectively. And for cohesion-less subsoil the value of cohesion is 0 . Similarly for cohesive subsoil for three different layers 18, 19 and 20 KN/m^3 unit weight and 38, 40 and 42 KPa cohesion are assumed respectively. And for this soil the value of friction angle is 0 degree. Slope stability has been analyzed for different geometric conditions. Table 3 shows the different heights, slope and slope angles for which slope stability analysis has been done. For different layer height (7m, 8m, and 9m) the Geometry of embankment was selected the slope angle 30.26, 33.69 and 36.87 respectively.
The analysis of slope stability has been done for three conditions such as high flood level, low flood level and rapid drawdown. For analysis, here three Flow Conditions are considered. They are :- High Flood level, Low flood level and Rapid drawdown. In case of factor of safety generally, minimum factor of safety for an earthen embankment is 1.2~1.3. Here, minimum factor of safety has been taken as 1.25 considering both safety and cost.

Findings

Variation of Slope Stability with Water Flow Condition for Same height

Analysis shows that the factor of safety is maximum for high flood condition, minimum for rapid drawdown condition and medium for low flood condition for 7m height embankment, which has been shown through graph plotting in the figures 1 and figure 2.

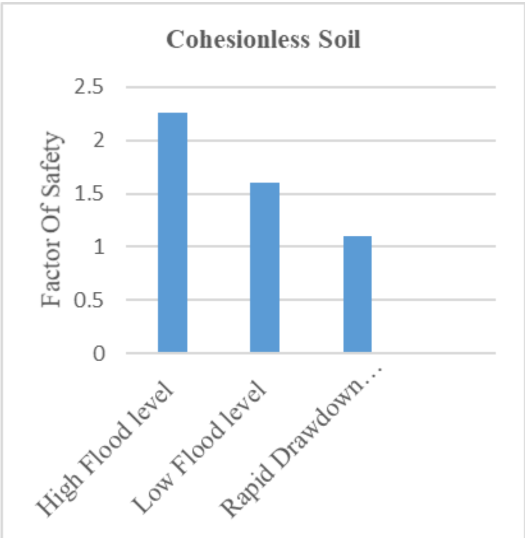


Figure 1. Slope Stability Of Cohesionless Soil for Different Water Level Conditions for 7m Height

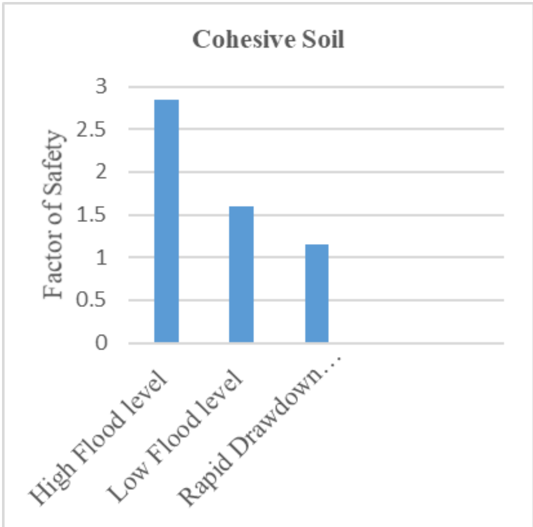


Figure 2. Slope Stability Of Cohesionless Soil for Different Water Level Conditions for 7m Height

Variation of Slope Stability with Slope Angle

The factor of safety decreases with the increase of slope angle for high flood condition. The following Figure 3 and fiqure 4 show the change of factor of safety with the change of slope angle for both cohesion-less subsoil and cohesive subsoil through graph plotting.

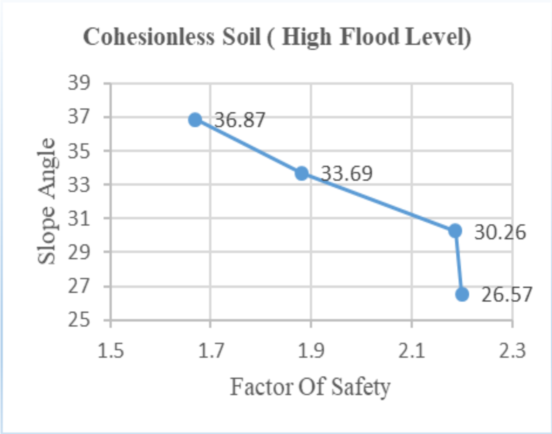


Figure 3. Factor of Safety VS Slope Angle plot for High Flood Level for Cohesionless Soil

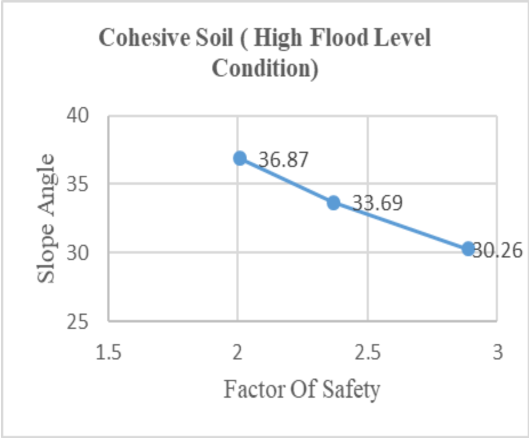


Figure 4. Factor of Safety VS Slope Angle plot for High Flood Level Cohesive Soil

Variation of Slope Stability with Water Flow Condition for Same Slope Angle

Analysis shows that the factor of safety is maximum for high flood condition, minimum for rapid drawdown condition and medium for low flood condition for 30.26 degree slope angle which has been shown through graph plotting in the following figures 5 and fiqure 6 for Cohesionless and Cohesive soil repectively.

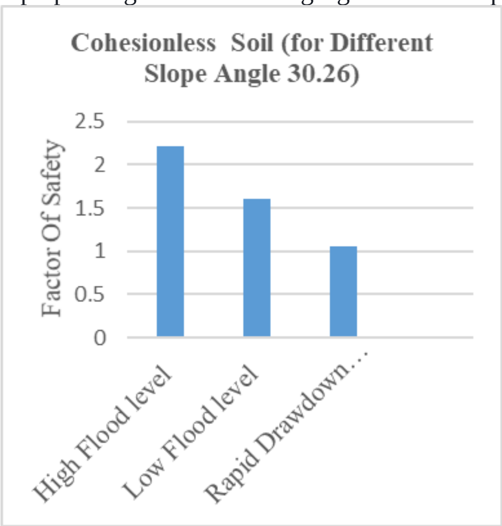


Figure 5. Factor of Safety VS Slope Angle plot for Cohesionless Soil at High Flood Level condition

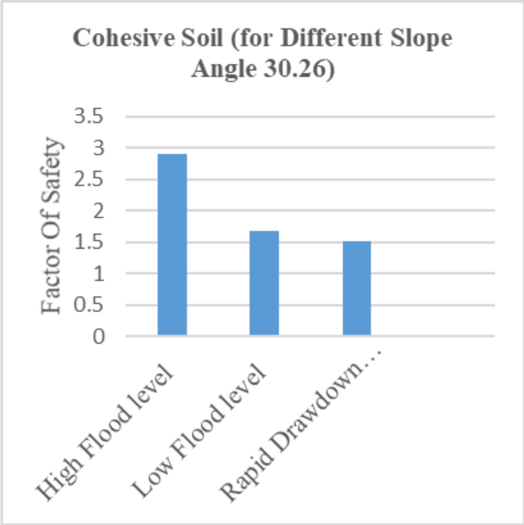


Figure 6. Factor of Safety VS Slope Angle plot for cohesive Soil at High Flood level condition

Variation of Slope Stability with Subsoil Properties

Factor of safety changes with the change of subsoil properties. Analysis shows that the factor of safety of earthen embankment for cohesive subsoil is greater than the factor of safety for cohesion-less subsoil for same height and same water level condition except for 8m and 9m height for low flood condition. 8m and 9m height produce more factor of safety for cohesion-less subsoil than cohesive subsoil. The comparison between cohesive and cohesion-less subsoil is given in the table.

Table 1. Comparison of Slope Stability for Cohesion less and Cohesive Subsoil

Height (m)	Slope Angle (B) degree	Flow condition	Factor of safety for Cohesion-less soil	Factor of safety for cohesive
		High Flood Level	2.187	2.887
7	30.26	Low Flood Level	1.637	1.684
		Rapid Drawdown	1.072	1.587
		High Flood Level	1.881	2.368
8	33.69	Low Flood Level	1.532	1.494
		Rapid Drawdown	0.977	1.407
		High Flood Level	1.669	2.009
9	36.87	Low Flood Level	1.433	1.317
		Rapid Drawdown	0.906	1.248

Conclusions

There are many earthen embankments in Bangladesh. These embankments are very important for the people of those areas because these embankments save them from flooding and failure of these causes huge flooding and immense damage. So, huge research should be done about the failure of the earthen embankments in Bangladesh. In Bangladesh, there are many earthen embankments which are not safe against failure. Many embankments are not being well designed. Even proper designed embankments fail sometimes under unexpected environment and water level conditions. In this research, embankment stability has been analyzed for different heights, slope angles, water level conditions and subsoil properties through SLOPE/W.
Analysis shows that factor of safety decreases with the increase of height and slope angle. Considering water level condition factor of safety is the highest for high flood condition, low flood condition produces less factor of safety than high flood condition and rapid drawdown condition produces the lowest factor of safety. The analysis also shows that cohesive subsoil produces better stability than the cohesion less subsoil except for 8m and 9m heights under low flood condition. From the research, for cohesion-less subsoil, 6m height (Slope angle 26.57 degree) produces enough factor of safety (>1.25). Therefore, the maximum allowable height for the cohesion-less subsoil is 6m (Slope angle 26.57 degree). But for cohesive subsoil, 8m height (Slope angle 33.69 degree) produces enough factor of safety (>1.25) and minimum construction cost. Therefore, the maximum allowable height for the cohesive subsoil is 8m (Slope angle 33.69 degree).
.

References

Alonso, E and Pinyol, N." Slope Stability under rapid drawdown condition" Cragin R.F(2003), " Craig's Soil Mechanics (Seventh Edition)" 147-148

Das B.M.(2002), "Principles of Geotechnical Engineering (Fifth Edition)'457-477

Das, B.M., 2004. Principles of Geotechnical Engineering. 5th ed.s.1.:Thomson Learning

Das, B. M., 2011. Principles of Foundation Engineering. 7th ed. S.1.:Cengage Learning

Fatema, N. (2013), "Slope Stability Analysis of Embankment at Jamuna River". B.Sc. Engng. Thesis, Department of Civil Engineering, BUET.

Guyer, J.P. (2012). "Introduction to Slope Stability and Protection"

Hossain, M. B., Sakai T. and Hossain Z (2011). "River and Bank Failure: A study on Geotechnical Characteristic and stability Analysis". American Journal of Environmental Sciences 7 (2) : 102-107

Holtz, R. & Kovacs, W., 1981. An Introduction to Geotechnical Engineering. Prentice-Hall, Inc. ISBN 0-13-484394-0

Masada,T.(September,2009) " Shear Strength of Clay and Silt Embankment "

Murthy, V., 2003. PRINCIPLES OF SOIL MECHANICS AND FOUNDATION ENGINEERING. 5TH revised ed.s.1.:UBS

Peck, R.B., Hanson, W.E. & Thornburn, T.H., 1974. Foundation Engineering. 2nd ed.s.1.:John Wiley & Sons, Inc..

Sharma, S.(2008), "Geo slope Manual"

Sadek, S. and Khoury, G. (2000). "Soil and Site Improvement Guide", Int. J. Engng Ed. Vol. 16, No.6, 499-508

Teng, W. C., 1962. FOUNDATION DESIGN. 13th ed.s.1.:Prentice-hall Inc.

STUDY OF ROOT-REINFORCEMENT EFFECT ON SHEAR STRENGTH PARAMETERS OF SOIL OBTAINED BY DIRECT SHEAR TESTS

F. F. Badhon[1], M. S. Islam*[2] & T. M. Al-Hussaini[2]

ABSTRACT

The use of vetiver for protecting earth slopes is gaining increased recognition due to its massive root network. In an attempt to evaluate the effect of root-reinforcement on shear strength of rooted soil, laboratory tests have been conducted on vetiver rooted soil in an undisturbed condition. Both cohesive and cohesionless soils have been considered. Vetiver grasses were planted in 300 mm dia PVC pipe containing both clayey and sandy soils. Undisturbed rooted soil samples were prepared from the planted pipes after 180 days of the plantation. Direct shear tests were conducted in Consolidated Undrained condition under normal stresses varying from 10 kPa to 35kPa with moisture content around 19%. From test results, it has been observed that, angle of internal friction has increased compared to that of bare soil but cohesion decreases for the case of both clayey and sandy soil samples. This may occur because vegetation root mainly increases the shear strength by transferring shear stresses into tensile resistance in fiber inclusion. In laboratory test samples, the boundary conditions that usually exist in field samples cannot be achieved. Roots are not sufficiently long and constrained at their ends in laboratory shear tests. So when the shear force comes, the bond between root and clay soil particles fail and in case of sandy soil, friction between root and sand particles cannot contribute to shear strength. Larger specimen with improved boundary conditions is required for evaluating the effect of rooted shear strength.

Introduction

The use of vegetation for slope stabilization started in ancient times. In more recent times, the role of vegetation in some specific geotechnical processes has been recognized. Vegetation may affect slope stability in many ways. Comprehensive reviews may be found in (Islam et al., 2017), (Islam and Badhon, 2017), (Mickovski and van Beek, 2009), (Coppin and Richards, 1990). The stability of slopes is governed by the load, which is the driving force that causes failure, and the resistance, which is the strength of the soil-root system. The weight of plants growing on a slope adds to the load whilst the roots of plants serve as soil reinforcements and increase the resistance. In addition, vegetation also influences slope stability indirectly through its effect on the soil moisture regime. Vegetation increases the shear strength of the soil, thus increases the resistance.

To evaluate the actual performance of vegetation for protection of embankments, it is necessary to estimate the factor of safety against the natural forces. Vegetation most prominently enhances the stability of earthen slopes by root reinforcement (Islam and Shahin, 2013). Different tests were conducted by different researchers (e.g., Verhagen et al., 2008, Islam et al., 2010) to know the strength of vegetation roots for the analysis of the stability of slopes. Islam et al. (2013) conducted the in-situ test and also conducted a direct shear test on laboratory reconstitute soil samples at different root content to know the shear strength of vetiver grass. But Parshi (2015) found that shear strength properties of rooted soil obtained from the laboratory tests on reconstituted samples and in-situ tests are significantly different. This paper aims to present an investigation program of the vetiver root-reinforcement system for slope stabilization using undisturbed samples obtained from PVC pipe.

Methodology

Vetiver grass was planted in 75 mm dia PVC pipe, containing both sandy soil and clayey soil. Sandy soil sample was collected from Buriganga river bed and clayey soil sample was collected from Buriganga river bank.

A series of laboratory tests were conducted to determine the index properties of these soil samples according to ASTM standard test procedure. Undisturbed rooted soil specimen of 62.5 mm diameter was retrieved from pipes after 180 days of plantation. Direct shear tests were conducted on undisturbed samples to determine the shear strength of the soil-root matrix.

[1] *Assistant Engineer, Bangladesh Water Development Board, Dhaka, Bangladesh.*
[2] *Professor, Department of Civil Engineering, BUET, Dhaka, Bangladesh.*
**Corresponding Author<msharifulislam@ce.buet.ac.bd>*

Preparation of sand samples

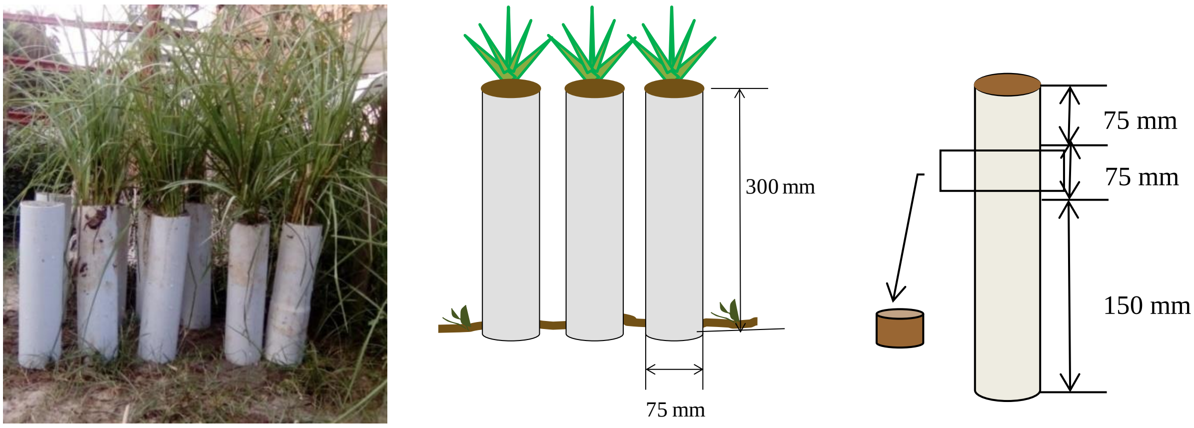
Grease layer was given at the inner side of the pipe so that soil can be extruded easily during testing. Cement (5% of dry weight of sand) was mixed with sand so that sand soil sample does not collapse during testing. 20% water was added to the sand cement mixture. This moist soil sample was poured in 75mm dia and 300mm long PVC pipe. Soil was compacted in three layers having approximately 100mm equal layer thickness. Each layer was compacted by 300mm long steel tamping rod. 25 blows were given in each layer. Vetiver was planted in 8 soil samples, prepared in PVC pipe 20 April, 2016 and 4 samples were kept bare.

Preparation of clay samples

Clay sample was collected from Buriganga river bank. Undisturbed sample from Buriganga river bank has been collected in 75mm dia PVC pipe. Then vetiver clump was planted in the pipes on 30 April, 2016.

Plantation in PVC pipes and collection of undisturbed sample

Vetiver grass has been planted in 75 mm dia PVC pipe (Figure 1), containing sandy soil (collected from Buriganga river bed) with 5% cement and clayey soil (collected from Buriganga river bank). Plantation was done by the early monsoon. Undisturbed samples of rooted soil were retrieved from thus planted pipes after 180 days. Figure 2 demonstrates the procedure of retrieving undisturbed rooted soil specimen of 63.5 mm diameter for direct shear tests. Samples were collected 75 mm below from the top surface as shown in the Figure 1(c) to avoid the disturbance and nonuniformity of top layer soil. In the laboratory, direct shear tests were conducted to determine the shear strength parameters of undisturbed rooted soil and bare soil collected from pipes. The soil sample was placed carefully in the shear box from the ring. Then the desired normal load was applied.



(a) (b) (c)

Figure 1. Vetiver plantation scheme (a) Vetiver grass planted in PVC pipe; (b) Schematic diagram of vetiver plantation in PVC pipe; (c) Schematic diagram of retrieving undisturbed sample from PVC pipe

(a) (b) (c)

Figure 2. Steps of sample preparation (a) Soil retrieved from pipe, (b) Collection of 62.5 mm dia specimen from 75 dia soil sample, (c) Specimen in probing ring

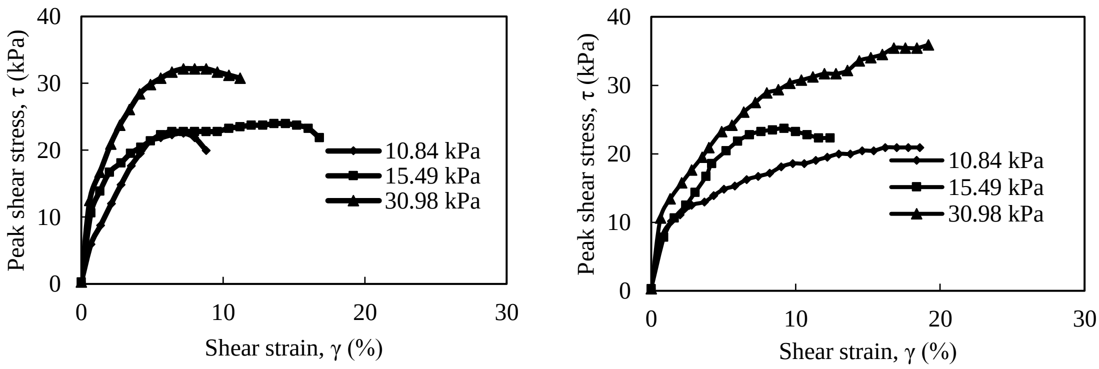
Vertical displacement dial gauge was attached to record the vertical deformation with respect to time. Enough time was allowed for consolidation before applying the shear force. When two consecutive vertical deformation dial readings were same, the shear force was applied to the soil sample with a constant strain rate of 0.75 to 1.25 mm/min. The lateral deformation was recorded by a lateral constant strain rate of 0.75 to 1.25 mm/min. The lateral deformation was recorded by a lateral displacement dial gauge of 25 mm capacity. The applied shear force was recorded by a load dial gauge of 2.22 kN capacity.

Results and Discussions

Direct shear tests were conducted on undisturbed clayey and sandy sample collected from PVC pipes. The cement mixed with sand was Basundhara Portland Composite Cement. Specific gravity of the sandy soil was 2.74 and clayey soil was 2.55. The sand was poorly graded having coefficient of uniformity c_u=1.86 and coefficient of curvature c_c=1.1. The clayey soil sample collected from Buriganga river bank was Clay of low plasticity or Lean clay. Clay, silt and sand content of the soil sample were respectively 11%, 79%, 10%. The liquid limit was 42%, plastic limit was 23% and plasticity index was 19%. Three bare soil specimens and three rooted soil specimens were tested for both sandy soil and clayey soil under three different normal loads. The selected normal loads were 10.84 kPa, 15.49 kPa and 30.98 kPa.

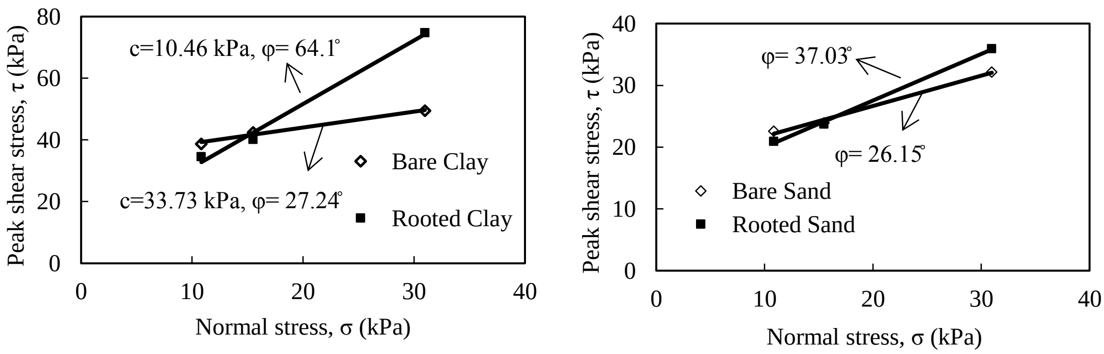
Table 1. Comparison of peak shear strength and shear strain of undisturbed bare and rooted soil

Sample type	σ_n (kPa)	Bare sample		Rooted sample		$\Delta\tau_{max}$	$\Delta\gamma$
		τ_{max} (kPa)	γ (kPa)	τ_{max} (kPa)	γ (kPa)		
Clay	10.84	38.72	2.4	34.51	6.4	-4.21	4
	15.49	42.47	4.2	40.13	0.96	-2.34	-3.24
	30.98	49.5	5.4	74.79	5.24	25.29	-0.16
Sand	10.84	22.57	7.2	20.93	15.4	-1.64	8.2
	15.49	23.91	14.4	23.74	9.2	-0.17	-5.2
	30.98	32.17	8.8	35.91	15.2	3.74	6.4



(a) (b)

Figure 3. Stress vs strain curves for (a) Bare sand sample (b) rooted sand sample



(a) (b)

Figure 4. Shear stress vs normal stress curves for undisturbed (a) clay sample, (b) sand sample

Figure 3 shows the shear stress vs shear strain curves for these normal loads. Water content was 21% for bare and rooted clayey samples and 19% for bare and rooted sandy samples. The direct shear test results have been shown in table 1. From Figure 4, it has been seen that for both clayey and sandy samples, angle of internal friction of rooted sample is higher than that of bare soil but cohesion of rooted sample is lower than that of bare soil for both cases.

From shear test result, it has been observed that the change of shear strength of rooted soil in comparison to bare soil is not consistent. Root fibers increase the shear strength of soil primarily by transferring shear stresses that develop in the soil matrix into tensile resistance in the fiber inclusions via interface friction along the length of imbedded fibers.

The mobilized tensile stress of root fibers depends upon the amount of fiber elongation and fixity of the fibers in the soil matrix. Full mobilization can occur only if the fibers elongate sufficiently and if the imbedded root fibers are prevented from slipping or pulling out. The latter requires that the fibers be sufficiently long and frictional, constrained at their ends and/or subjected to high enough confining stresses to increase interface friction. These may lack in laboratory shear test samples. In case of clay samples when the shear force come, the bond between root and soil particles fails. For sand samples, friction between soil particles and root cannot contribute. So, the effect of root content on shear strength of rooted soil cannot be evaluated through laboratory shear tests.

Conclusions

It has been found that addition of root has influence on shear strength of soil. Due to inclusion of root, shear strength increased up to 51.1%. But in some cases, shear strength decreased for rooted soil in comparing to bare soil. However, no particular relation could be developed from these laboratory test results. Larger specimen with improved boundary conditions is required for evaluating the effect of rooted shear strength.

Acknowledgement

The authors acknowledge the infrastructural and financial support received from Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh for carrying out the research work.

References

Coppin, N.J. and Richards, I.G. (1990). *"Use of vegetation in civil engineering"*, Construction Industry Research and Information Association, Butterworths, London.

Islam, M.A., Islam, M.S. & Islam, T. (2017). *"Landslides in chittagong hill tracts and possible measures"*, International Conference on Disaster Risk Mitigation,Dhaka, Bangladesh.

Islam, M.S. and Badhon, F.F. (2017). *"Sandy slope stabilization using vegetation"*, Proceedings, International Conference on Disaster Risk Mitigation, Dhaka, Bangladesh, September 23-24, 2017

Islam, M.S., and Shahin, H.M. (2013). "Reinforcing effect of vetiver (Vetiveria zizanioides) root in geotechnical structures - experiments and analyses," Geomechanics and Engineering, vol. 5, no. 4, pp. 313-329.

Islam, M.S., Arifuzzaman and Nasrin, S. (2010). *"In-situ shear strength of vetiver grass rooted soil"*, Proc. Of Bangladesh Geotechnical Conf. Natural Hazards and Countermeasure in Geotechnical Engineering, Dhaka, Bangladesh, pp.274-279.

Islam, M.S., Nasrin, S., Islam, M.S., and Moury, F.R. (2013). "Use of vegetation and geo-jute in erosion control of slopes in a sub-tropical climate", *Journal of World Academy of Science, Engineering and Technology (WASET)*, Vol. 73, pp. 1162-1170.

Mickovski, S.B. & van Beek, L.P.H. (2009). "Root morphology and effects on soil reinforcement and slope stability of young vetiver (Vetiveria zizanioides) plants grown in semi-arid climate". *Plant Soil*, vol. 324, pp. 43-56.

Parshi, F.N. (2015). *"Strength-deformation charecteristics of rooted soil"*, M. Sc. Engg. Thesis, Department of Civil Engineering, Bangladesh University of Engineering and Technology (BUET).

Verhagen, H.J., Jaspers F.D.J., Algera, A. and Vu, M.A. (2008). *"The use of vetivers in coastal engineering"*. Copedec VII, Dubai, UAE.

SAR INTERFEROMETRY FOR LAND SUBSIDENCE MONITORING AND DETECTION OF JHARIA COAL FIELD, JHARKHAND, INDIA.

Md. Ali Akbar[1] and Dr. R.S. Chatterjee[2]

ABSTRACT

In the present study, attempts have been made to assess potential ground subsidence phenomena's are the typical characteristics in Indian coal mine areas with special reference to Jharia Coalfield, Jharkhand, India. In-SAR tandem data pair and Cartosat-1 stereoscopic data pairs were used for DEM generation to assess the changes in elevation during 1996 to 2006 due to the emergence of open cast quarry, overburden/coal dump and surface collapse. Several ENVISAT ASAR C-band & ALOS-PALSAR L-band data pairs were used for generating differential interferograms for detection, delineation and measurement of land subsidence phenomenon. Ground based measurements were done by static GPS survey using dual frequency geodetic GPS receiver and digital levelling survey during 2006-2008 for measuring lateral and vertical displacement components. Validation of D-InSAR based results was done with ground based measurements.

Introduction

The Jharia Coalfield is located in the district of Dhanbad, Jharkhand, a state of India. It is one of the best-known coalfields primarily due to its chief sources of prime cooking coal and for its volatile nature. The total proved reserves of Jharia Coalfield is about 11.4 billion tones, out of which about 20-25% has been exploited so far and the remaining reserves are still available. Both opencast and underground mining have been carrying out simultaneously at different zones of the coalfield. Besides, Jharia Coalfield hosts the maximum number of coal fires among all the coalfields in India which poses a major challenge for coal mining activities. The geo-environmental impacts due to coal mining activities are huge and diverse. Some of the major geo-environmental hazards are ground subsidence, slope failure/collapse, overburden dumps, development of huge cracks on the ground and abnormal heating with unstable ground condition. The spatial database on the geo-environmental parameters and their characteristics will be immensely useful in planning appropriate protective an/or reclamation measures. It is also recommended by the previous authors that optical remote sensing data alone is not sufficient enough to map all the geo-environmental parameters precisely and accurately. Mapping of geo-environmental parameters with multi-polarization and interferometric SAR seems much easier. From interferometric phase and coherence information of SAR data, it is also now feasible to delineate many of the environmental parameters related to mining and at a greater level of accuracy than the optical data (Chatterjee, et al., 2006, 2007). At present study, the following objectives are being addressed using interferometric SAR technique:

(I) Evaluation of Interferometric Synthetic Aperture Radar (InSAR) data for mapping environmental parameters related to mining viz., opencast mining area, overburden and coal dumps, abandoned/closed unreclaimed opencast mines and surface collapse areas

(II) Detection and delineation of the subsiding areas and estimate the rate of land subsidence using Differential Interferometric Synthetic Aperture Radar(D-InSAR) technique. Validation of the results has obtained from D-InSAR based studies compared with ground based measurements by optical leveling and from GPS observations over selective ground stations.

[1] *Director (Geology), Geological Survey of Bangladesh, 153 Pioneer Road, Segunbagicha, Dhaka 1000, Bangladesh. E-mail: aliakbar.bd@gmail.com*
[2] *Project Supervisor, Geoscience Division, IIRS, Dehra Dun, India.*

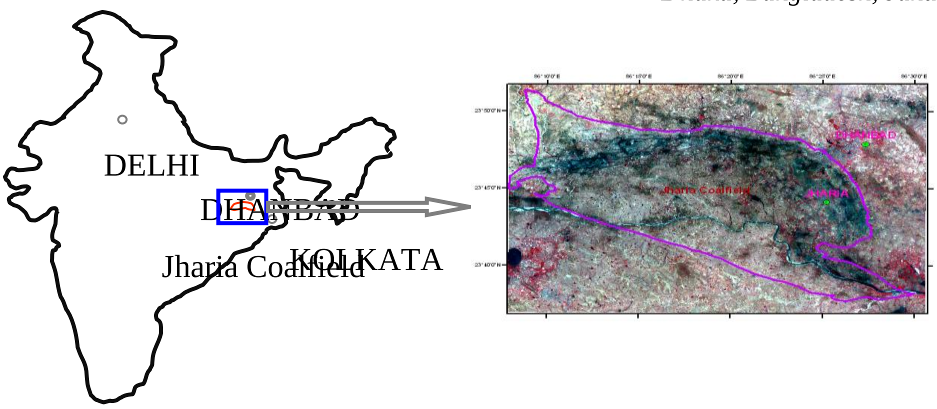


Figure 1. Location map of Jharia Coalfield, Jharkhand, India.

Methodology

Multi-temporal analysis of Synthetic Aperture Radar (SAR) imagery has now days become one of the most relevant tasks to perfume environmental monitoring. It is well known that interferometric SAR (InSAR) is a technology for the generation of high precision Digital Elevation Model (DEM) and the precise measurement of terrain surface deformation. The accuracy of DEM and deformation measurement is highly dependent on the quality of the interferogram which is formed by tow SAR images. The coherence of interferometric SAR is another indicator for quality of Interferogram. The coherence image due to its characteristic coherent inherent property abandon/closed, unreclaimed opencast mines could be delineated.

The following methodologies have been adopted for the current research work.

- Processing of InSAR data for DEM generation and coherence mapping.
- D-InSAR processing of ERS tandem pair and ENVISAT ASAR data pairs for delineating subsiding areas and measuring the subsidence rate.
- Ground based optical levelling and GPS based measurements for calibration and validation of the deformation rates obtained from D-InSAR based measurements.

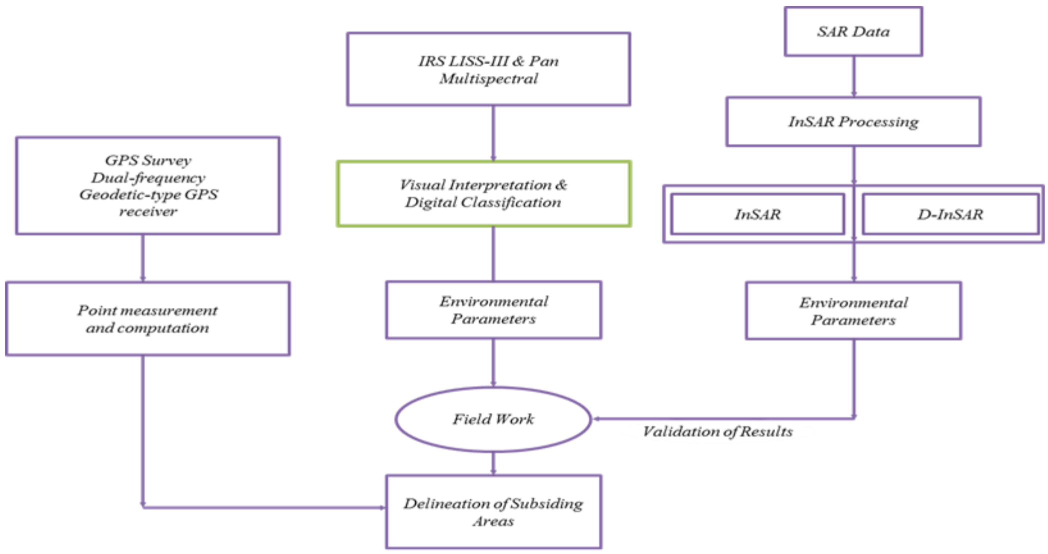


Figure 2. Methodology.

Findings

The InSAR data of ERS-1 & 2 tandem pair of 2004 were processed and amplitude image, coherence image, interferogram and DEM were generated successively during the processing steps. Six (6) ENVISAT ASAR data pairs of 2003, 2004 and 2007 were selected with suitable spatial baseline and processed for analysis. The data pair with longer time intervals (tempora baseline) were not found appropriate for Differential Interferometry (D-InSAR) application due to high temporal decorrelation and changes in the topography for opencast mining activities. From each of the SLC data pair interferogram were generated and further D-InSAR processing was carried out using external DEM of Cartosat-1 and InSAR for topographic phase compensation. Among the six (6) data pairs few are found good with well to fairly well-defined fringes in the different differential interferograms. Additional post processing is required for highlighting the fringes from noise and separating the subsidence fringes from opencast mining related topographic fringes and atmospheric artifacts. Each of the fringes was studied following rainbow color scheme(V/I/B/G/Y/O/Y) in proper sequence starting from violet at the left (edge) and red at the right (centre) representing 2π phase difference due to subsidence otherwise upliftment in reverse order. Land subsidence in Jharia Coalfield has been occurring primarily due to two reasons; one for coal fire at the surface and in the sub-surface coal layers and the other for depillaring of coal from the subsurface in underground mining. Ground subsidence phenomena caused due to depillaring of coal can be depicted easily due to it its wider extent and relatively higher coherence whereas subsidence due to coal fire somewhat patchy and very irregular in shape and with relatively very unstable ground condition. In D-InSAR technique fringes in all the interferogram were identified. Some fringes show reverse order of rainbow colour scheme representing upliftment areas which are due to the emergence of new overburden and coal dumps in the study area. From each of the fringe value was used to calculate ground displacement in that particular year. Fringe centre locations were located on the images and individual fringe polygon was delineated to calculate subsiding areas in multi-temporal images. Later all the fringe polygons were united together using GIS and calculated total subsiding areas.

Conclusion

D-InSAR based measuements provide the rate of subsidence from 2003 to 2007 varies from 5.6 cm/yr (2004) to a maximum of 58.4 cm/yr (2003). Ground based subsidence measurements co-ordinated by digital leveling with the results obtained from InSAR based measurement. Areas affected by subsidence are matching well. Limited matching in rates due to non-linear nature of subsidence.

From InSAR based DEM of 1996 and Cartosat-based DEM of 2006 with comparative relative accuracy (5m) of new opencast quarries and dumps (OBD+Coal dump) could be delineated efficiently. D-InSAR-based study was found to be very useful for detecting and delineating the subsiding areas during the observation period (2003-2007). Total subsiding areas was 3091 hectre (approx).

References

Chatterjee, R.S., Fruneau, B., Rudant, J.P., Roy, P.S., Frison, P.L., Lakhera, R.C., Dadhwal, V.K. and Saha, R. (2006) "Subsidence of Kolkata (Calcutta) City, India during the 1990s as observed from space by Differential Synthetic Aperture Radar Interferometry (D-InSAR) Technique", *Remote Sensing of Environment*, 102, 176-185.

Chatterjee, R.S., Wahiduzzaman, Md., Shah, A., Raju, E.V.R., Lakhera, R.C., and Dadhwal, V.K. (2007) "Dynamics of coal fire in Jharia Coalfield, Jharkhand, India during the 1990s as observed from Space", *Current Science (Indian Academy of Sciences)*, 92(1), 61-68.

Acknowledgements

The authors express their sincere gratitude to the authorities of CSSTEAP for providing all facilities and support during this research under the Post Graduate Diploma course in RS and GIS at IIRS. Thanks are due to the faculty members for their kind help and cooperation and course participants for their moral support and assistance.

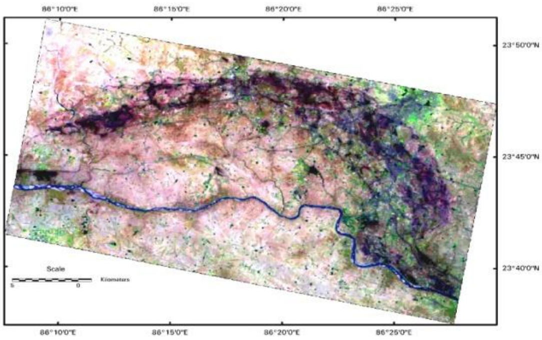


Figure 3. IRS LISS-III Multispectral Optical Image of Jharia Coalfield, Jharkhand, India of 1997.

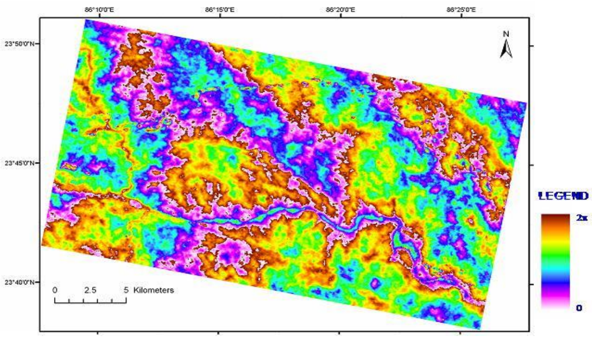


Figure 4. Interferogram of ERS tandem pair of Jharia Coalfield.

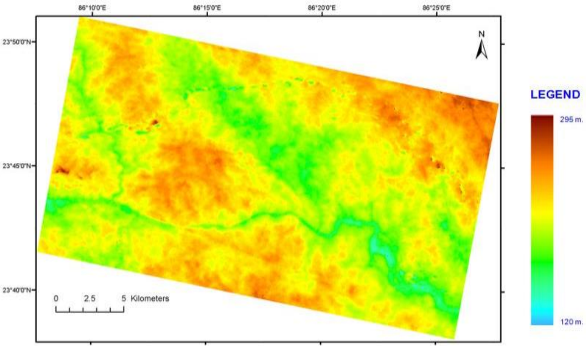


Figure 5. Digital Elevation Model (DEM) generated from the interferometric ERS SAR tandem pair.

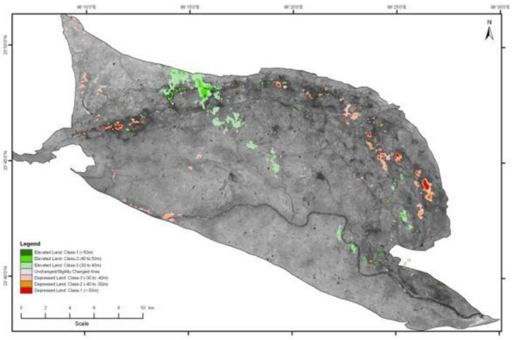


Figure 6. Negative and positive elevation areas (potentially representing quarries/collapse and dumps) in Jharia Coalfield during 1996-2006.

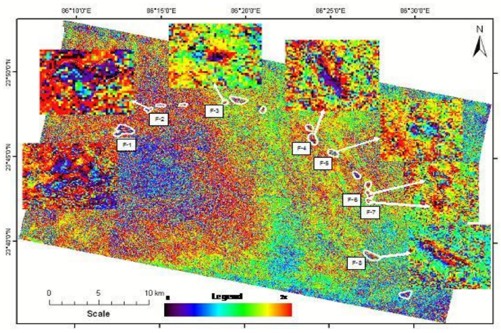


Figure 7. Differential interferogrm generated from ENVISAT ASAR data pair (8833-9334) of Nov.–Dec. 2003 showing proven subsidence fringes.

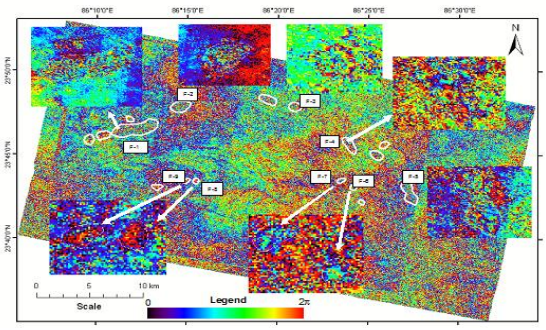


Figure 8. Differential interferogram generated from ENVISAT ASAR data pair (26368 - 26869) of Mar, 2007 – Apr, 2007 showing proven subsidence fringes.

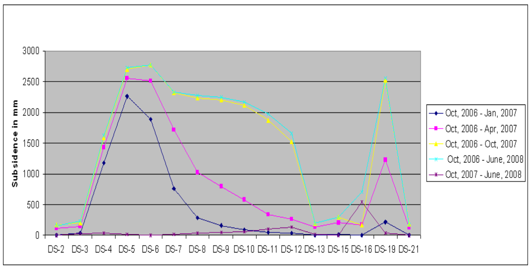


Figure 9. Land subsidence scenario at Jairampur area during the period of 2006-2007 at different monitoring stations as measured by Digital Leveling (CIMFR, Dhanbad).

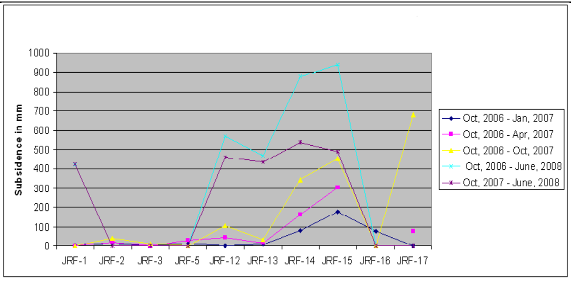


Figure 10. Land subsidence scenario at Dobari area during the period of 2006-2007 at different monitoring stations as measured by Digital Leveling (CIMFR, Dhanbad).

STABILIZATION OF DISPERSIVE SOIL BY USING FLY ASH

Md. Omar Faruk [1], Mohammad Shariful Islam [2] , Mohammad Ziaul Hoque [3] and Marzia Ashraf Shorno[4]

ABSTRACT

Soils that are dislodged easily and rapidly in flowing water generally termed as dispersive soil. These soil are highly susceptible to erosion as they contain high percentage of exchangeable sodium ions. Structures such as roads, embankments, channels and other areas are susceptible to severe erosion when dispersive soils are used for construction. In this study, various index properties of dispersive soils were investigated by chemical test, double hydrometer test and crumb test. The focus was to study the influence of fly ash on the stabilization of dispersive soil found in Bangladesh. It was observed that the addition of fly ash significantly reduces dispersivity of the soil. At the same time, fly ash also increases the overall strength of the soil which was observed in unconfined compressive strength (UCS) tests. The effects of this stabilization with fly ash were studied with crumb tests. A number of crumb tests and unconfined compression tests were carried out which indicated that the least application of fly ash about 9% was suitable to reduce the dispersiveness of the soil sample. Scanning Electron Microscopy (SEM) provided micro fabric arrangement of soil particles before and after addition of fly ash with soil. The cementitious bonds of dispersive soil increase with the increase of fly ash percentage, hence make the soil more stable against dispersion.

Introduction

Dispersive soils are clayey soils containing high percentages of exchangeable sodium ions, Na^+. It can be eroded rapidly by segregation of individual particles when comes in contact with flowing water (Figure 1). Dispersive soils are not suitable for foundation or fill material in the construction of hydraulic earth structures. These soil is a major contributing factor to piping failure of embankment dams (Figure 2). In Bangladesh, presence of dispersive soils has dilemma. Nowadays many mega projects are coming up like, The Padma Rail and Road Bridge Project, Dhaka Mawa Six Lane Road Project, Ruppur Nuclear Power Plant Project and many more. The presence of dispersive soils has been identified in some of the above mega projects which need to be addressed appropriately. So, identification and stabilization of dispersive soil in Bangladesh is a very important issue.

Figure 1. Outlays of dispersive soil.

Figure 2. Failure of embankment constructed on dispersive soil (Missipi,USA)

Many developed countries i.e. USA, Australia, Malaysia and some parts of Europe already experienced failure of structures and earthen embankments due to the presence of dispersive soil (Figure 2). Their experiences can be taken as base line for the management of potential failure of structures and embankments for the various projects in Bangladesh.

[1] *Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh*

[2] *Professor, Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000,Bangladesh*

[3] *Dept. of Civil Engineering, Military Institute of Science and Technology, Dhaka-1216, Bangladesh*

[4] *Dept. of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh*

Suitability of fly ash as a stabilizing agent

The process of stabilization may consist of blending dispersive soils with a stabilizing agent to increase the density and rigidity of the soil. For stabilization of dispersive soils, chemical methods such polymer treatment (Sameer et al, 2011) or cement and lime treatment may be effective (Chandra & James, 1984), although they are relatively expensive for developing country like Bangladesh. Fly ash, a cheap by-product of the combustion of pulverized coal in thermal power plants, has been used as a construction material and a blending agent. As the fly ash can provide an adequate array of divalent and trivalent cations as (Ca^{2+}, $A1^{3+}$) it can promote flocculation of dispersed clay particles by cation (Na^{+}) exchange. Being a pozzolanic material it encourages self-hardening with time, hence, if an appropriate quantity of fly ash is mixed with the dispersive soil and cured for a sufficient period of time, the resulting soil matrix may not only become resistant to erosion, but might also gain strength. Various proportions of multivalent elements in fly ash are shown in Table 1.

Table 1. Chemical composition of fly ash.*

Multivalent element	Percentages
C	24.79
O	22.55
Al	11.23
Si	26.75
Ca	1.78
Fe	6.01

* From XRF test on fly ash sample.

Materials and testing of dispersive soil

In this study the soil samples were collected from various locations of Padma Multipurpose Bridge Site and Padma Railway Project near Bhanga Upazilla of Faridpur District in Bangladesh. And the stabilizer (fly ash) was collected from the byproduct of Boropukuria coal powered thermal power plant. Dispersivity of the soil sample was identified by Chemical test, Crumb test and double hydrometer test. And Chemical composition of fly ash were investigated by X-ray fluorescence (XRF) spectroscopy in the laboratory.

Chemical test

From chemical (Exchangeable Sodium Percentage) test of the soil samples the amount of Na^{+} was found 66.1 %. So the soil can be classified as dispersive soil (Figure 3. Sheard et al,1977)

Table 2. Dispersivity of clay according to % dispersion.

% dispersion	Degree of dispersivity
< 30 %	The soil is probably not dispersive
30% ~ 60%	The soil is probably dispersive
>60%	The soil is highly dispersive

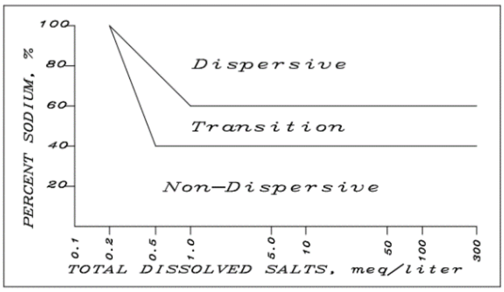


Figure 3. Chart for Plotting Chemical Tests Data.

Double Hydrometer test

The percent of dispersion of pure soil before stabilization was found 46 %. So the soil can be classified as probably dispersive (Table 2, 210-VI-SMN-13, February 1991, USA)

Crumb test

Crumb test was performed on the pure soil to categorize the grade of the soil as per the ASTM D-6572 test standard. After placing the soil crumb into distilled water a considerable reaction with colloidal clouds completely covering the bottom of the beaker and also spreading to its upper regions was observed (Figure 4). So the soil was categorized as Grade-4 dispersive soil.

Stabilization methodology

Several combinations of fly ash-dispersive soil mixtures were investigated to evaluate the effect of fly ash on the engineering characteristics of dispersive soil. The primary objective of these experiments was to determine the optimum content of fly ash required for stabilization of this particular dispersive soil. Crumb test was carried out to investigate the dispersive characteristics of both natural soil and fly ash blended soil (Figure 4). An array of samples prepared by the standard Proctor compaction method was tested to compare the compaction characteristics before and after mixing fly ash (3% ~ 9%) with the natural dispersive soil. In order to investigate the mineralogy of this dispersive clay in detail, the Scanning Electron Microscopy (SEM) was employed.

Investigation of fly ash stabilized dispersive soils

Stabilization of dispersivity

Different percentages of fly ash were mixed with the natural soil to evaluate the performances of the fly ash to reduce the dispersive potential. Investigation showed that an optimum 9 % of fly ash mixing with soil has a better performance. Figure 4 shows the behavior of soil crumb in water at different fly ash percentages.

(a) **(b)**

Figure 4. Crumb test (a) after 2 minutes & (b) after 15 minutes.

Improvement of strength

Samples of natural (dispersive) soil and soil-fly ash mixtures were compacted as per the standard Proctor specifications in a cylindrical mold. The standard compaction curves were established for both natural soil and samples blended with various fly ash contents (3 % to 9 %). The average maximum dry density and optimum moisture content for the natural soil were determined to be 16.5 kN/m^3 and 18 % respectively. The Proctor relationships for the soil-fly ash mixtures showing in Figure 5 revealed that the maximum dry density increases with the increase of fly ash percentages. At 9 % fly ash content the dry density is optimum with comparing to other fly ash percentages. Cylindrical specimens compacted at their optimum moisture content were tested by unconfined compression strength (UCS) test according to ASTM D2166 standard. Figure 6 represents the compressive strength of soil samples after three weeks curing with various fly ash contents. The strength developed in 9 % fly-ash mixed soil is good enough to construct any structure on it. It has been observed that the strength significantly increases after a minimum curing time of three weeks. This implies that the degree of self-hardening attributed to pozzolanic activity of fly ash would approach a peak after three weeks. So during road and embankment construction this curing time shall be considered.

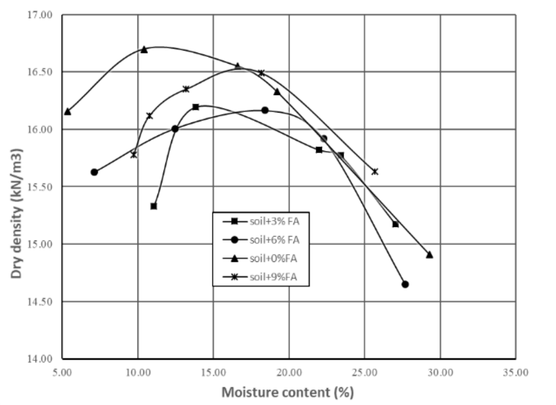


Figure 5. Moisture content vs. Dry density graphs.

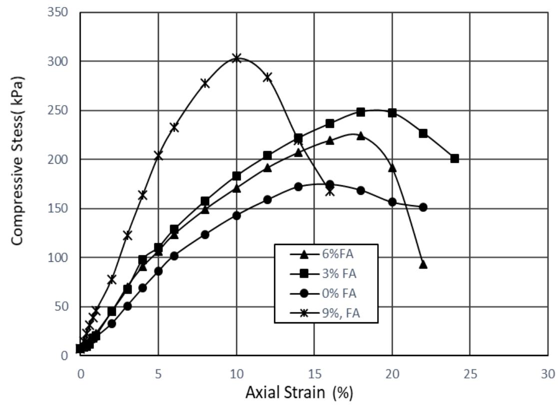
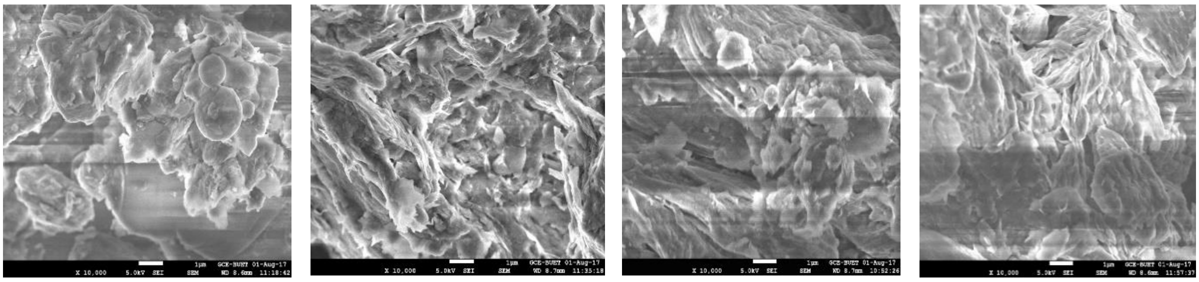


Figure 6. Stress vs. strain behavior after 21 days curing.

SEM analysis

In order to understand the role of fly ash on improving the flocculation characteristics of clay particles in dispersive soil, Scanning Electron Microscopy (SEM) were undertaken on samples with various proportions of fly ash (0, 3, 6 & 9%). The mineralogical behavior of fly ash stabilized soil is shown in Figure 7.



(a) (b) (c) (d)

Figure 7. SEM images of the soil sample with (a) 0% (b) 3% (c) 6% (d) 9% fly ash contents.

SEM image shows that the large voids presented in the untreated soil were gradually reduced with the addition of fly ash. Thus the soil structure becomes more compact and resistive against dispersion.

Conclusions

From the study it was found that an optimum 9% of fly ash content is suitable for the stabilization of the above studied in-situ dispersive soil. It also revealed that 9% fly ash significantly improved the soil's strength and mineralogical structure by reducing inter particular voids through cementitious bonds.

References

Sameer.V and Neelam. P. (2011) “Stabilization of Dispersive Soil by Blending Polymers.” *International Journal of Earth Sciences and Engineering,* 04, 52-54.

Ouhadi V.R. and Goodarzi A.R. (2006) “Assessment of the stability of a dispersive soil treated by alum.” *Journal of Engineering Geology (ELSEVIER B.V.)* 85, 91–101.

Candra, S. and James, C. G. L. (1984) “Improvement of dispersive soils by using different additives.” *Indian Geotechnical Journal,* 14, 202-216.

Sheard, J. L. and Decker, R. S. (1977) “*ASTM Special Technical Publication”* 623, 25-41, 202-239.

EFFECT OF VEGETATION AND NAILING FOR PREVENTION OF LANDSLIDES IN RANGAMATI

T.E. Elahi[1], M.A. Islam[2] and M.S. Islam[3]

ABSTRACT

Landslide occurs almost every year in Chittagong Hill Tracts (CHT) of Bangladesh. Excessive rainfall during monsoon along with deforestation and hill cutting are the primary causes behind the landslides. Undisturbed soil samples have been collected from two different locations of Rangamati hills. Laboratory tests have been performed to determine the index and shear strength properties of the soils and the samples are classified as sandy lean clay (CL) and silty clayey sand (SC-SM). The obtained soil parameters are used to develop a Finite Element Model in PLAXIS 2D® for stability analysis. With the increase of depth of root, FS increases slightly (2.9%) for clayey soil because of deep seated base failure. Contrarily, vegetation is found more effective for sandy soil and increases FS up to 21.9%. Additionally, nailing along with vegetation increases FS up to 61% for sandy soils whereas only 13% for the clayey soil compared to bare slopes. Hence, the combined action of nailing and vegetation can be an effective measure to prevent landslides in sandy soils.

Introduction

Landslide is a very common natural disaster in Bangladesh especially in the south-east region of Bangladesh. Chittagong Hill Tracts (CHT) are affected by landslides almost every year. Rate of occurrence of this disaster is high during the monsoon period. About 72% of the total rainfall in Bangladesh occurs in monsoon season (Ahasan et al., 2010) and so landslide frequency is highest in monsoon. Seepage down of the rainwater saturates the soil mass which triggers downward movement of slopes causing landslides (Islam et al., 2017). Along with deforestation and weak soil structure cutting of hill slope is also responsible for landslides in CHT. Within the last five decades CHT was affected by 12 major landslides (Sarkar and Rashid, 2013) of which the most devastating ones were in 2007 and 2017. Of all the casualties due to landslides in Bangladesh 31% casualties occur in Rangamati district which is the highest compared to other districts (Rahman, 2012). Current practice for protecting hill slopes are RC retaining wall and masonry wall which is very expensive in the context of Bangladesh. Different measures have been taken by Roads and Highways Department (RHD), Local Government Engineering Department (LGED) and Chittagong Hill Tracts Development Board (CHTDB) to prevent landslides. But recent landslide history and casualties prove that the protective measures are not effective all the time. World Bank (WB), United Nations Development Program (UNDP) and some NGOs are trying to raise awareness among people about this disasters. A lot more still needs to be done for mitigation of this landslide hazard. Soil nailing and vegetation are two probable solutions for preventing landslide in the context of Bangladesh (Islam et al., 2017).

Vegetation is currently a recognized method in the world to stabilize slopes and getting popular across the world because of its simplicity, cost effectiveness and efficiency. Stability analysis with plant roots has become a prominent research area all over the world (Islam et al., 2014; Choke et al., 2016). Vetiver grass (*Vetiveria zizanioides*) is one of the most appropriate vegetation for stabilization of hill slopes (Islam et al., 2014; Islam et al., 2017). Roots of vegetation penetrate through soils which give additional reinforcement to strength of soils. Soil nailing is another protective measure which is widely used all over the world (Mittal and Biswas, 2006). Nailing is installation of closely spaced steel bars in slope soils to stabilize the soil mass. It relies upon the transfer of forces generated in nails into ground through friction mobilized at the interfaces. This friction interaction between soil and nail restrains the ground movement.

Numerical analysis of slope stability is commonly performed by Limit Equilibrium Method (LEM) and Finite Element Method (FEM). In FEM analysis can run relatively quickly and deformations, stresses and pressures can be calculated (Hammouri et al., 2008). And like LEM, no assumptions of inter-slice force and slip surface is required. Phi-c reduction method is used for safety calculation where strength parameters will be reduced until slope fails and the ratio of actual parameter to critical parameter is considered FS.

[1] *Under Graduate Student, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh.*
[2] *Graduate Research Assistant, Dept. of Civil Engineering, University of Texas at Arlington, 416 Yates Street, TX 76019, USA.*
[3] *Professor, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh.*
Email of corresponding author- elahitausif@gmail.com

Landslides in Rangamati have a devastating effect on people living there, properties and overall economy of Bangladesh. But there are very few researches regarding efficient prevention technique of this region. Vegetation and soil nailing are two methods which can be effectively used for preventing soil erosion and deep-seated landslide failure respectively. This study aims to analyze the effectiveness of vegetation and soil nailing for stabilizing the hill slopes using FEM software PLAXIS 2D.

Methodology

Two locations of Rangamati have been selected based on landslide that occurred in June 2017. Undisturbed soil samples have been collected using Shelby tubes. Index and engineering properties of collected soil samples are determined from laboratory tests as per ASTM standards which are shown in Table 1. Constitutive soil parameters for numerical model development are determined from literature (Bowels, 1996).

Table 1. Properties of soil used in this study

Properties	Unit	Soil A	Soil B
Dry unit weight	kN/m^3	15.1	14.5
Saturated unit weight	(kN/m^3)	18.9	16.8
Cohesion, c	(kPa)	18	2
Angle of internal friction, ϕ	(^{o})	-	30
Modulus of Elasticity, E	(kPa)	1.0×10^4	2.5×10^4
Permeability, k	(m/s)	3.0×10^{-10}	5.25×10^{-08}

Properties obtained from laboratory tests have been used for the analysis in PLAXIS 2D. Slope height is considered 10m based on observation of hill slopes at the location. Plain strain model, 15-node element and Mohr-Coulomb model is used for analysis in the study. Vetiver grass (*Vetiveria zizanioides*) as vegetation in stability analysis. Vetiver grass can be effectively used against soil erosion due to excessive rainfall (Islam and Islam, 2018). Rooted behavior is simulated by increasing the cohesion parameter up to the depth of penetration of roots and added apparent cohesion due to different depth of roots is shown in Table 2

Table 2. Added apparent cohesion of vetiver grass by different root depth (Vootipreux et al., 2008)

Depth of root zone, h_r (m)	Added apparent cohesion, c_r (kPa)
0.5	2
0.75	4
1.0	6
1.25	8
1.5	12

Soil nail will be considered plate element in this study as per literature (Fan and Luo 2008). Nail inclination is taken 15^o with horizontal as it gives maximum FS (Rawat and Gupta 2016). Four nails of 8m length at a vertical spacing of 2m is used in this study. Axial stiffness, EA, Flexural rigidity, EI and equivalent nail diameter are used 1.38x10^5 kN/m^2, 7.29 kN.m^2 and 25mm based on literature (Rawat and Gupta, 2016; Fan and Luo, 2008). A schematic deformed mesh (Medium) FEM model used in the study is shown in Figure 1.

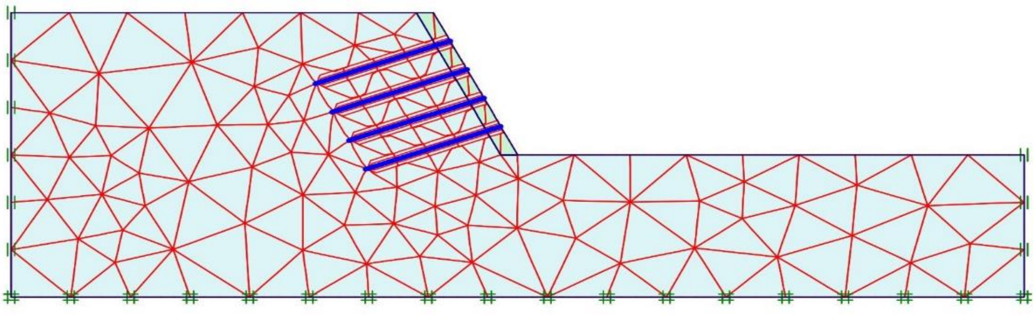


Figure 1. Schematic deformed mesh FEM model used in this study.

Results and Discussions

For analyzing the effect of vegetation for different slope angles and soils variation of FS with different depth of roots is shown in Figure 2.

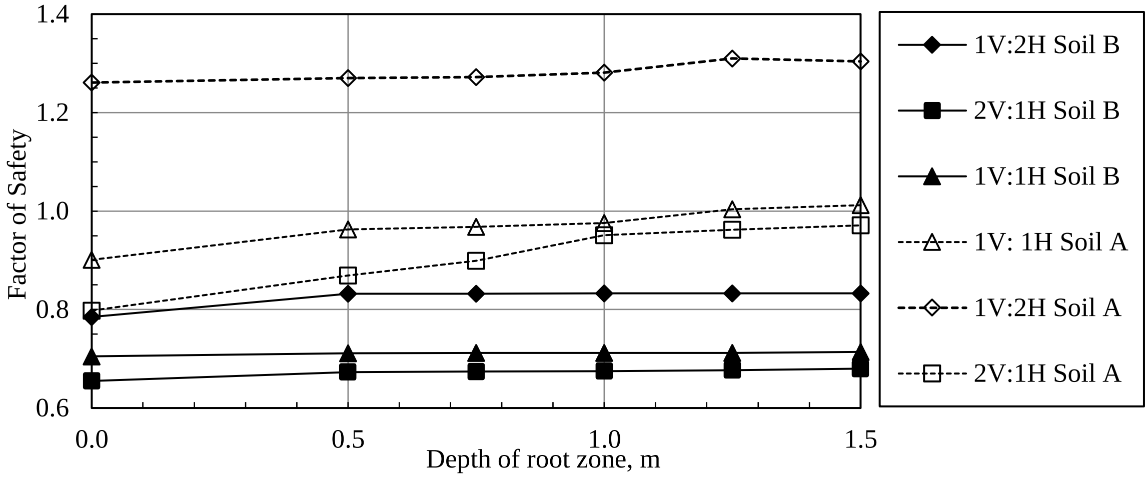


Figure 2. Variation of FS with root depth

From Figure 2 it is seen that for soil B with the increase of depth of root FS increases for all slope angles. But increase in FS because of vegetation is quite small and maximum increase is only 2.9% compared to that of bare slope. Because as soil B is cohesive soil its failure pattern is a deep seated base failure. Whereas roots of vetiver can't penetrate to such depth so rooted soils have little impact on clayey soils. For soil A FS increases with the increase of root depth and maximum increase in FS is up to 21.9% compared to that of bare soil. So vegetation is more effective for soil A than soil B. Because soil A is sandy soil and shallow failure occurs for such soils. It is found that rate of increase of FS is higher for steeper slopes with less cohesion. The finding is in agreement with the literature (Chok et al., 2015). Because failure pattern for such slopes is shallower and failure surface remains closer to the surface and intersects with plant roots. So vegetation is more effective.

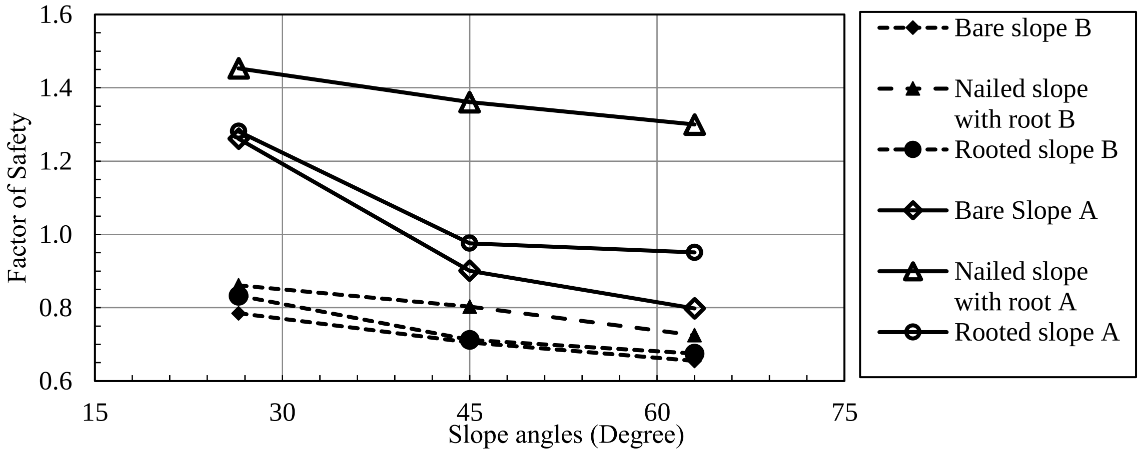


Figure 3. Variation of FS with slope angles for different protective measures

Although it is seen that vegetation increases FS but for soil B for all slopes it is less than 1.3 which indicates slope is unsafe (Stark et al., 2017). So, the effect of nailing along with vegetation is also studied and shown in Figure 3. For this analysis depth of root is taken 1.0m.

From Figure 3, it is observed that for soil B, nailing along with vegetation increases FS by small margin and maximum increase is only 13%. For all the slopes FS is also less than 1 with nailing and indicates nailing with vegetation is not also effective for soil B. Angle of internal friction has the greatest impact on nailed slope followed by cohesion and nail length (Garg et al., 2014). As soil B is clayey soil, the angle of internal friction is low and it has also low cohesive strength. So nailing can't establish good bond strength and it is difficult to stabilize soil mass. Whereas for soil A, it is seen that nailing along with vegetation elevates FS above 1.3 for all slopes and makes the slope stable. Nailing with vegetation increases up to 61% for soil A compared to bare slopes. Nailing has higher impact on soil A because of higher angle of internal friction and can develop good bond strength to stabilize the slopes.

Conclusions

From numerical analyses of this study following conclusions can be drawn:

1. Plantation of Vetiver along hill slopes increases FS up to 21% for sandy soil and only 2.9% for clayey soil compared to bare slope. However for both the hill slopes FS is less than 1.3. So, although vegetation is more effective in case of sandy slope than clayey slope but vegetation alone is not effective against landslide.
2. FS of hill slopes reinforced by nailing and vegetation increases up to 61% for sandy soil and only 13% for clayey soil compared to bare slope. FS of sandy soils for all slope angles is greater than 1.3 but for clay soil less than 1.3. So nailing with vegetation can be an effective way to protect sandy hill slopes.

Acknowledgement

The authors acknowledge the infrastructural and financial support received from Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh for carrying out the research work. Authors would also like to thank BUET-Japan Institute of Disaster Prevention and Urban Safety (BUET-JIDPUS) for technical assistance regarding PLAXIS 2D.

References

Ahasan, M.N., Chowdhary, M.A.M., and Quadir, D.A. (2010) "Variability and Trends of Summer Monsoon Rainfall over Bangladesh" *Journal of Hydrology and Meteorology,* 7(1).

Bowles, J.E. (1996). *Foundation Analysis and Design,* McGraw-Hill, New York.

Chok, Y.H., Jaksa, M.B., Kaggwa, W.S., and Griffiths, D.V. (2015) "Assessing the influence of root reinforcement on slope stablity by finite elements" *International Journal of Geo-Engineering,* 6(12).

Fan, C., and Luo, J. (2008) "Numerical study on the optimum layout of soil – nailed slopes" *Computers and Geotechnics* 35, 585–599.

Garg, A., Garg, A., Tai, K., and Sreedeep, S. (2014) "An integrated SRM-multi-gene genetic programming approach for prediction of factor of safety of 3-D soil nailed slopes" *Engineering Applications of Artificial Intelligence*, 30, 30-40.

Hammouri, N.A., Malkawi, A.I.H., and Yamin, M.M.A. (2008) "Stability analysis of slopes using the finite element method and limiting equilibrium approach" *Bulletin of Engineering Geology and the Environment*, 67(4), 471-478.

Islam, M.A., Islam, M.S., and Islam, T. (2017) "Landslides in Chittagong Hill Tracts and Possible Measures" *International Conference on Disaster Risk Mitigation*, Dhaka, Bangladesh.

Islam, M.S. and Islam, M.A. (2018) "Reduction of Landslide Risk and Water-logging Using Vegetation" *International Conference on Civil and Environmental Engineering (ICCEE),* Kuala Lumpur, Malaysia.

Islam, M.S., Khan, A.J., Siddique. A., Saleh, A.M. and Nasrin, S. (2014). "Control of erosion of hill slope top soil using geojute and vegetation," *National Seminar on Jute Geotextiles,* Dhaka, Bangladesh.

Kokutse, N.K., Temgoua, A. G.R., and Kavazovic, Z. (2016) "Slope stability and vegetation: Conceptual and numerical investigation of mechanical effects" *Ecological Engineering*, 86, 146-153.

Mittal, S., and Biswas, A.K. (2006) "River bank erosion control by soil nailing". *Geotechnical and Geological Engineering*, 24, 1821–1833.

Rahman, T. (2012) "Landslide risk reduction of the informal foothill settlements of Chittagong city through strategic design measure", *M. Sc. Engg. Thesis*, BRAC University, Dhaka, Bangladesh.

Rawat, S., and Gupta, A.K. (2016) "Analysis of a Nailed Soil Slope Using Limit Equilibrium and Finite Element Methods" *International Journal of Geosynthetics and Ground Engineering*, 2:34

Sarker, A., and Rashid, A. (2013) "Landslide and flashflood in Bangladesh," in R. Shaw, F. Mallik and A. Islam, (eds.).*Disaster Risk Reduction Approaches in Bangladesh*, Springer Japan, pp. 165-189.

Stark, T.D., and Ruffing, D.G. (2017) "Selecting Minimum Factors of Safety for 3D Slope Stability Analyses", *Geo-Risk*, Denver, USA.

Voottipruex, P., Bergado, D., Mairaeng, W., Chucheepsakul S., and Modmoltin, C. (2008) "Soil Reinforcement with combination roots system: a case study of vetiver grass and acacia mangium willd" *Lowland Technology International*, 10(2), 56-67.

CONSTRUCTION OF DISASTER RESILIENT RURAL HOUSES USING CSEB MADE WITH RIVER BED SAND

Mohammad Shariful Islam[1], Jafrul Islam[2] and Nashid Mumtaz[3]

ABSTRACT

Abundant use of Fired Clay Bricks is observed both in the urban, semi-urban and rural areas which often exhibit unsatisfactory performance in a disaster prone country like Bangladesh. Raw materials needed in brick production consume 45 million tons of fertile soil. To save valuable natural resources, reduce pollution and increase energy efficiency we must bring shift our interests towards using energy saving and environment friendly Compressed Stabilized Earth Block (CSEB).This paper primarily describes the effect of using fly ash as a stabilizer on the strength characteristics of CSEB and its cost effectiveness. The study focuses the possibility of using fly ash as a partial replacement of clay for brick manufacturing considering the local technology practiced in Bangladesh. Suitable samples of river bed sand for the production of CSEBs were selected from five different locations of Bangladesh. Compressive strength and absorption capacity of fly-ash stabilized CSEBs has been evaluated in this research work. Percentages of fly ash ranged from 5% to 20% by weight, meanwhile the effects of altering cement content and mixing water content will be observed in the block samples simultaneously. Compressive strength and water absorption capacity of prepared cubic samples of CSEBs were determined after 28 days of curing. The maximum compressive strength of CSEB was obtained as 2.53 MPa consisting of 80% sand, 10% fly ash, 10% cement by weight and 20% of mixing water content by total weight of mixture. The concern of using sand and fly-ash in this investigation questions to what extent it will impart strength in the blocks and justify its use as a cost effective building material in rural house construction in Bangladesh.

Introduction

Being a densely populated country, abundant use of Clay Fired Brick (FCB) is observed both in the urban, semi-urban and rural areas of Bangladesh. If earthen blocks can be prepared with as much strength and durability as that of fired bricks it might be a suitable alternative solution to fired brick and can save both money and environment. Bangladesh lies in a seismic vulnerable zone. Recent seismic activities indicate Bangladesh is at high seismic risk. Obviously, this is due to the lack of seismic deficiency of traditionally constructed earthen houses. Seismic deficiencies of earthen structures are primarily due to brittleness and low tensile strength of the block as well as poor bonding between block and mortar. Hence, to improve seismic performance, it is necessary to improve block properties (i.e. strength, ductility, and toughness). This has led to the development of technology using earth in the form of rammed earth and unfired bricks popularly known as Compressed Stabilized Earth Block (CSEB). For six decades remarkable initiatives have been made to make unfired stabilized bricks (Jagadish et al.,2011; Deboucha and Hasim,2011). This is achieved by proper grading of soil mix, proper compaction and stabilization using admixtures, which results in increased density, reduced water absorption, increased frost resistance and mainly increased the compressive strength of masonry blocks (Nagaraj et al., 2014) Presently in Bangladesh, it is estimated that 1.3 million cubic feet of fly ash is produced per annum , dumping from thermal power plants alone, and is estimated to reach an alarming crescendo of 9.5 million cubic feet by 2018.Fly ash is a waste by-product material that must be disposed of or recycled. Waste products like fly ash can replace use of top soil in bricks and serve as an excellent resource for fulfilling demands of green structures. In this paper, attempts have been made particularly to determine the strength characteristics of earthen blocks made with river bed sand and fly ash. The main objectives of this research work are as follows: to determine the characteristics of collected soil sample, cost effectiveness of the fly ash stabilized CSEB blocks over conventional burnt bricks and determine various strength characteristics of proposed CSEB blocks such as compressive strength, water absorption etc. by conducting various laboratory tests.

[1]*Professor, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh*
[2]*Former Undergraduate Student, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh*
[3]*Graduate Student, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh*
Email of Corresponding Author – nashid1989civil@gmail.com

Experimental Procedure

Soil samples were collected from 5 different locations :Meghna River, Narsinghdi (SM), Roktinodi, lawarghor, Durlavpur, Barishal (SRLD) ,Rahmatkhali khal, Laxmipur-Bhola Ferry Route(SRHLV),,Dadpur, Mehendiganj, Barishal (SDMB),Amanatganj khal, Barishal.(SAB).Among the collected soil samples, one soil sample was selected for making Compressed Stabilized Earth Block (CSEB). The selection was completed after a series of investigations namely Grain Size distribution (ASTM C 136), Specific gravity (ASTM D 584) and Atterberg limits (ASTM D 138).With the suitable soil sample ,fly ash (class F) ,cement (OPC) and optimum water content several cubic samples of CSEBs were prepared using fifteen different combinations. The mixtures were compacted with a tamping rod measuring 12.5cm × 25cm × 150cm providing 32 blows in each of the two layers. The effect of fly ash with different replacing ratio (0%, 5%, 10%, 15%, and 20% by weight) of clay on properties of blocks was studied. Meanwhile the effects of addition of 5%, 7% and 10% cement content and 10%, 15%, 20% and 25% mixing water content were observed in the block samples. Air-curing the samples and sprinkling them with adequate water were monitored at regular intervals. After 7, 14 and 28 days the sun-dried samples were withdrawn from curing location. Uniaxial compressive strength test (ASTM D 143) was conducted on these cubic specimens to know the strength characteristics of the block samples. The same test was performed on unstabilized specimen (control: 0% fly-ash). According to ASTM C 62, water absorption capacity test was performed on some block samples too.

Results and Discussions

The main purpose of this research is to investigate the effectiveness of fly ash and cement with soil with different proportions to construct sustainable, environment friendly CSEBs that can be used for building construction. Besides this, absorption capacity of the CSEBs are also discussed here. Soil identification test was conducted to identify the suitable soil for preparation of CSEBs. The grain size distribution curve of collected soil samples which were used for production of CSEBs have been presented in Figure1.

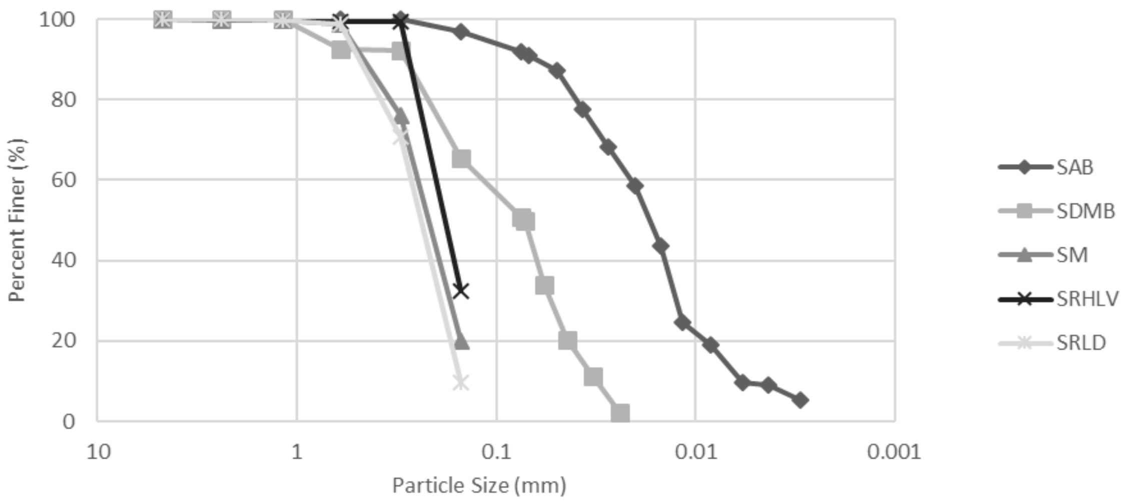


Figure 1. Grain size distribution curve of collected soil samples

The selected soil sample (SM) was collected from Meghna river which consists of 75.6% sand, 24.4% silt and 0% clay having specific gravity of 2.70.Fly ash used in this work for stabilization is Class F fly ash. To know the index properties of fly ash grain size distribution test and Atterberg limits test were conducted on the fly ash. The results of these tests have concluded that the fly ash used contains 100% of silt, has no plasticity index and has a specific gravity of 2.16.

Compressive strength test was performed on the CSEB specimens prepared with the selected soil to compare the strength characteristics of prepared CSEB blocks. The compressive strength of CSEB specimens prepared with 0%, 5%, 10%, 15% and 20% of fly ash content has been plotted respectively in figure 2. Here 'M' stands to identify a specific mixture.

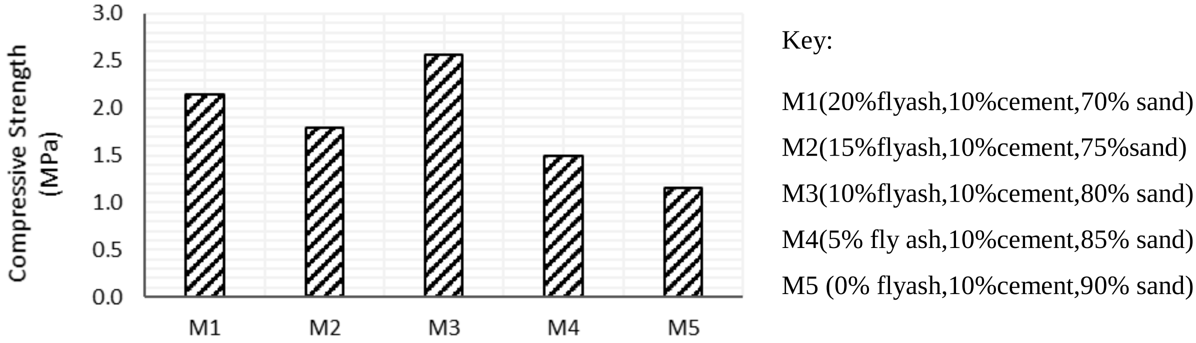


Figure 2. Compressive Strength versus fly ash Content

After 28 days, it was observed that compressive strength decreases from 2.14 MPa to 1.79 MPa with decrease of fly ash content from 20% to 15%. Then it increases up to 2.53 MPa with fly ash content of 10%. Then compressive strength again declines with further decrease of fly ash content. So, utilization of 10% fly ash content is the optimum amount of fly ash content for these CSEB specimens. Variation of compressive strength with water content was also performed where 20% mixing water was found to be the optimum water content for the CSEB specimens.

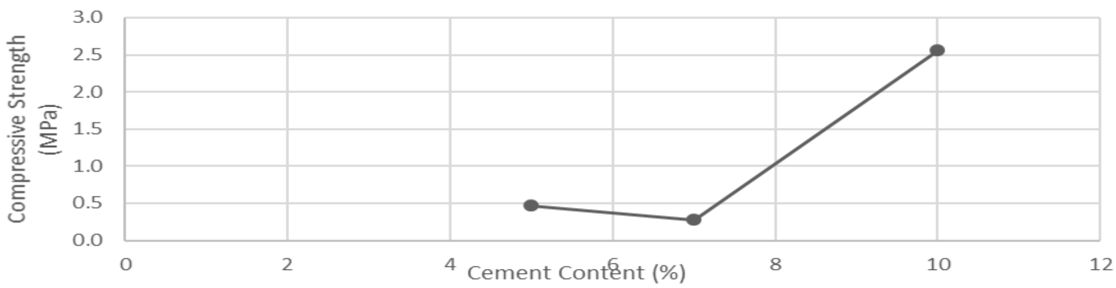
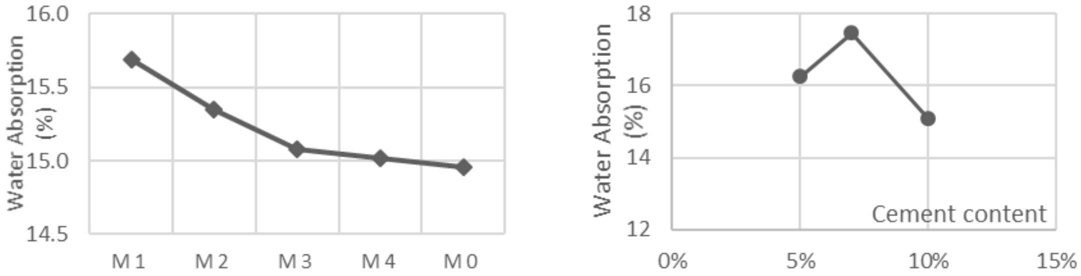


Figure 3: Variation of compressive strength with cement content

In figure 3, compressive strength of CSEB specimens prepared with 5%, 7% and 10% cement content has been plotted after air curing them for 28 days. It has been observed that the compressive strength increases with an increase in cement content percentage. But more than 10% cement content is not used because according to “Standard Norms and Specification for CSEB Blocks” (CSEB Green Buildings in Nepal, 2012) use of cement more than 10% is not cost effective. So, 10% cement content is the optimum cement content for CSEB specimen.



(a) (b)

Figure 4. (a) Absorption capacity vs fly ash content and (b) Absorption capacity vs cement content

In figure 4(a), after 4 weeks of air curing, water absorption capacity of CSEB specimens prepared with 0%, 5%, 10%, 15% and 20% of fly ash content has been plotted. It is seen that the absorption capacity decreases from 15.69% to 14.96% with the decrease of fly ash content from 20% to 0%. So, the lower the fly ash content the lower the water absorption capacity. In figure 4(b), the absorption capacity of CSEB specimens prepared with 5%, 7% and 10% cement content has been plotted. It is seen that the absorption capacity increases from 16.26% to 17.48% with the increase of water content from 5% to 7%. After that the absorption capacity decreases with further addition of cement after 7%. From this it can be concluded that at 10% cement content, water absorption capacity is minimum.

Conclusions

The investigation highlights the feasibility of using CSEB as a building material for construction of rural houses. Strength of these blocks ranged from 1.2-2.53 MPa. Maximum strength of these blocks were received with a combination of 10% fly ash, 10% cement ,80% sand and 20% mixing water by weight. Due to low strength of these blocks its use might be recommendable for partition walls, non-load bearing walls, exterior walls for latrines, etc. Further studies are highly encouraged to strengthen the claim of its application as a construction material which simultaneously will be disaster proof and as well as be cost effective.

Acknowledgement

The authors acknowledge the infrastructural and financial support received from Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh for carrying out the research work.

References

Ahmed, A.(2014) "Evaluation of properties of compressed earth block", *M. Engg. Thesis,* Department of Civil Engineering, Bangladesh University of Engineering and Technology.

Islam.R.,Hasan.M.,Karim.R., Zain.M.F.M.(2015) "Properties of Fly Ash Brick Prepared in Local Environment of Bangladesh," *World Academy of Science, Engineering and Technology International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering*, 9(12).

Nawaz.I.(2013), 'Disposal and Utilization of Fly Ash to Protect the Environment', *International Journal of Innovative Research in Science, Engineering and Technology (An ISO 3297: 2007 Certified Organization)*,2(10).

Pawar A.S. and Garud D. B.(2014), "Engineering Properties of Clay Bricks with Use of Fly Ash", *International Journal of Research in Engineering and Technology*, 3(9), 75 – 80.

Pimraksa K., Wilhelm M., Kochberger M. and Wruss W.(2001), "A New Approach to the Production of Bricks Made of 100 % Fly Ash," *International Ash Utilization Symposium, Center for Applied Energy Research,* University of Kentucky,18 pages.

Riza,V,F.,Rahman, A,R., Ismail and Zaidi,A,M,A., Ahmad(2010), "A brief review of Compressed Stabilized Earth Brick (CSEB)," in *International Conference on Science and Social Research*, pp.999 – 1004.

Tamim, M., Dhar, A., Hossain, S. (2013), "Fly ash in Bangladesh- An Overview", *International Journal of Scientific & Engineering Research,* 4.

EFFECT OF SALINITY ON THE COMPRESSIBILITY AND PERMEABILITY CHARACTERISTICS OF A COASTAL SOIL FROM BANGLADESH

J. R. Mallick[1] and M. S. Islam[2]

ABSTRACT

Salt water intrusion and leaching is a continuous phenomenon in the context of Bangladesh due to the rise of sea level and heavy rainfall. This study includes observing the change in soil compressibility due to the combined effects of loading, salt water intrusion and its leaching. One-dimensional compression tests have been performed on a low plastic silty soil (LL= 28%) collected from Mongla Port area that has been resedimented with distill water, 8g/L, 32g/L and 128g/L NaCl as pore fluid. For each different pore fluid concentration, 3 consolidation tests have been performed changing the outer ring fluid concentration in a ratio of 0.5: 1: 2 with respect to inner ring pore fluid. For a given stress level, due to osmotic consolidation, with the increase in pore fluid salinity reduction of compression index (C_c) up to 19% has been noted. On the other hand, due to the osmotic gradient, NaCl leaching during consolidation has increased C_c value though NaCl permeation has decreased it. Permeability values determined from the coefficient of consolidation (c_v) reveal that, with the increase in pore fluid salinity, the permeability of soil increases.

Introduction

Bangladesh is a low-lying Delta with hundreds of rivers containing sweet water. But, due to global warming and climate change, the sea level of Bay of Bengal is rising day by day causing salt water intrusion in ground water of adjacent areas. So, consequently salt content in ground water is increasing day by day. Also, during monsoon, heavy rainfall causes leaching of salt content. So, salt content leaching and permeation have become a continuous phenomenon in the context of Bangladesh. Since, pore fluid is an important parameter in determining strength, compressibility and index property of a soil, this phenomenon has a huge effect on these soil properties.

The geotechnical behavior of clay soils is dominated by their mineralogical composition, the physicochemical interactions between clay particles, inter-particle forces, pore fluid chemistry, and soil structure. When brine is introduced as pore fluid in the soil, it causes a huge change in the effective stress, physiochemical interaction between clay particles and inter-particle forces which in turn changes index property, compressibility and hydraulic conductivity of the soil.

The effect of salinity is most pronounced for high plasticity clays that contain a large proportion of the clay mineral smectite, and to a lesser extent illite (Lambe and Whitman, 1969). Several researchers have examined how different pore fluids and their concentrations affect the consolidation of expansive soils. The fluids examined in the literature include organic fluids (Chen et al., 2000), different concentrations of fluids containing brine (Barbour and Yang, 1993), and lime (Basma and Tuncer, 1991). Conceptual models were also developed by Barbour and Fredlund (1989) to understand how the properties of a soil mass change with variations in the pore fluid chemistry. Casay et al. (2017) showed the effect of pore fluid salinity on 2 high plastic clays over a wide range of salt concentrations and effective stresses though it addressed the effect of osmotic consolidation only. However, there has been relatively little performed to quantify the effects on natural clayey silts.

This study mainly includes quantifying the changes of compression index due to combined effects of loading and brine permeation/ leaching and observing the change in permeability with increased brine concentration of a coastal soil from Bangladesh. So, this study will help to have an understanding of to what extent these major properties of the coastal soil of Bangladesh will be affected by drastic changes in the salinity level of the surrounding area.

Methodology

The soil sample was collected from Khulna port area and after some basic tests – Grain size analysis and Atterberg limit tests (using distilled water) it was found to be low plastic silt (LL 28%). The initial salinity condition was determined through Electric Conductivity, pH and Cl^- ion in soil extract which indicated that the sample was non saline and had an almost negligible amount of Cl^- ion in the soil. Due to this, the soil

[1]*Under Graduate Student, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh.*
[2]*Professor, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh.*
Email of corresponding author- joyarani.buet13@gmail.com

sample was not leached of its naturally occurring salt prior to resedimentation. Basic properties of the soil have been presented in Table 1.

Table 1. Properties of soil

SL No.	Properties	Results
1	Specific Gravity	2.78
2	Clay (%) Sand (%) Silt (%) (According to ASTM D 422 Classification)	8 13.9 78.1
3	Electrical Conductivity (mS/cm)	0.568
4	pH	7.0
5	Cl- ions in extract (%)	0.05

The resedimentation technique was used to prepare the samples for consolidation testing. In this method, the soil sample was oven dried and then pulverized into fine power. Approximately 4 kg of powdered soil was mixed with distilled water up to its Liquid limit to form a homogeneous slurry. The slurry was then placed into a large consolidation mold having an internal diameter of 20.32 cm and height of 23.88 cm. The sample height was approximately 7.62 cm. Geotextiles were used on top and bottom as a filter ensuring double way drainage. Two porous iron plates were also used at top and bottom after the geotextile and these iron plates were followed by a wooden block. 10 kg load was placed on the top of the wood block and kept for 24 hours (Figure 1(a)). In total 50 kg load (approximately 4 kPa stress) was provided in a period of 5 days for proper hydration and Ko - consolidation. The same procedure was repeated for 8g/L, 32 g/L and 128 g/L NaCl pore fluid and their respective liquid limit were used for each of them while making the slurry.

After 7 days, the soil sample was removed from mold and placed into a fixed ring odometer ring having an internal diameter of 63.5 mm and height approximately 25.4 mm. From each slurry batch 3 sample was taken except the slurry made with distilled water. For each different NaCl concentration, 3 consolidation tests were performed changing the outer ring fluid concentration in a ratio of 0.5: 1: 2 with respect to inner ring pore fluid. But for distilling water, during consolidation test the inner and outer ring fluid concentration was 1:1. Thus in total 10 consolidation tests were performed. During consolidation, the outer ring was tightly closed with a plastic sheet to keep the salt concentration intact and to minimize loss (Figure 1(b)).

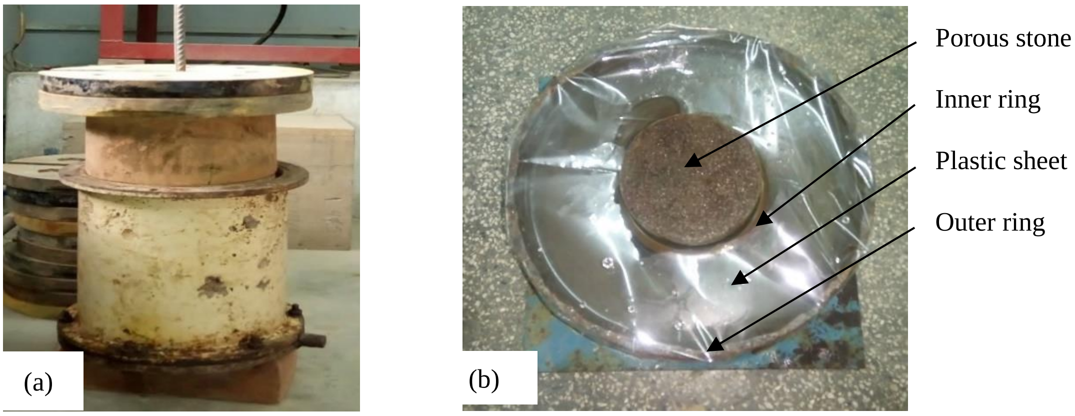


Figure 1. Experimental set-up : (a) consolidation mold and (b) consolidation ring (plan view)

One dimensional consolidation properties were measured using a constant rate of stress increment. The initial effective vertical stress for all the soil mixtures was 25 kPa. For loading stage, this 25 kPa stress was followed by 50, 100, 200,400, 800 kPa and for unloading stage 800,400,100,10 kPa. Each stress increment and decrement duration was constant (24 hours). During the consolidation process, manual measurements were made of change in the specimen height and these data were used to construct e-log p curves.

Results and Discussions

The compressibility is quantified by compression index (C_c) which is the slope of e-log p curve in the loading region. C_c values have been determined from e-log p curves for each consolidation test. Figure 2 shows the variation of C_c with the increase in pore fluid salinity without considering osmotic gradient. From Figure 2, it is evident that with the increase in pore fluid salinity C_c value definitely decreases. Here C_c values have been decreased by 7.8%, 16.2% and 19% compared to distilled water for 8 g/L, 32 g/L and 128 g/L respectively. The reason is, with increasing salt content cation concentration increases which compresses the negatively charged soil particle resulting in an overall decrease in the void ratio as well as C_c value.

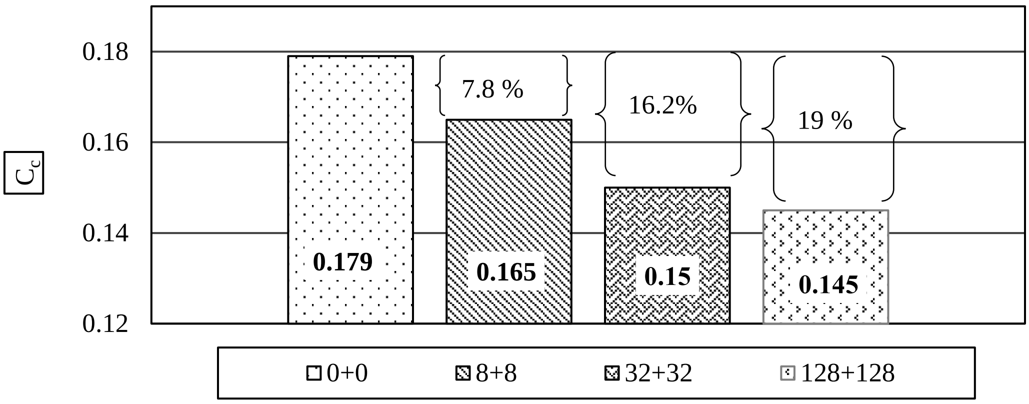
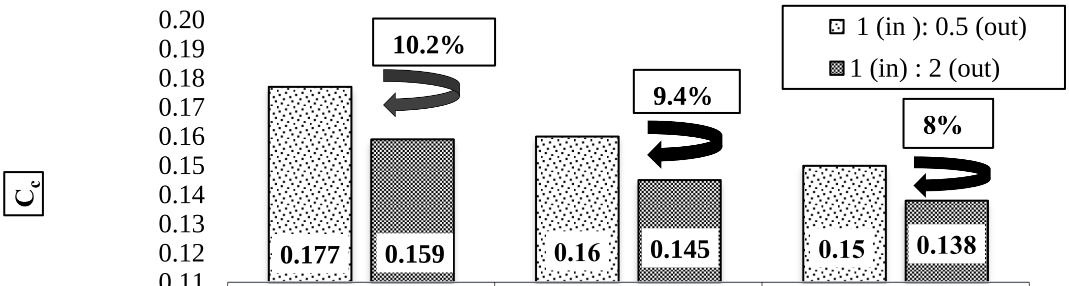


Figure 2. Variation of Cc with increasing pore fluid (inner fluid) concentration

In Figure 3, the variation of C_c due to change in outer ring fluid concentration (taking inner fluid constant) has been shown. It indicates that, for a constant pore fluid, increasing the outer fluid concentration with respect to inner fluid results in a decrease in C_c value, while for decreasing the outer fluid concentration, C_c value increases. From experimental data, it is found that C_c value for soil sample exposed to higher salt concentration decreases by 10.2%, 9.4%, 8% with respect to soil sample exposed to lower salt concentration for pore fluid 8 g/L, 32 g/L and 128 g/L respectively. This mainly occurs due to the osmotic gradient in ionic content between inner pore fluid and outer ring fluid. The lower salt concentration in outer fluid has high water content compared to soil pore fluid. So, to balance this, water flows from outer fluid to inner pore fluid increasing void ratio as well as compressibility or C_c value. Quite opposite happens for higher salt concentration in inner fluid.



	pore fluid (8 g/L)	pore fluid (32 g/L)	pore fluid (128 g/L)
1 (in): 0.5 (out)	0.177	0.16	0.15
1 (in) : 2 (out)	0.159	0.145	0.138

Figure 3. Variation of Cc due to osmotic gradient

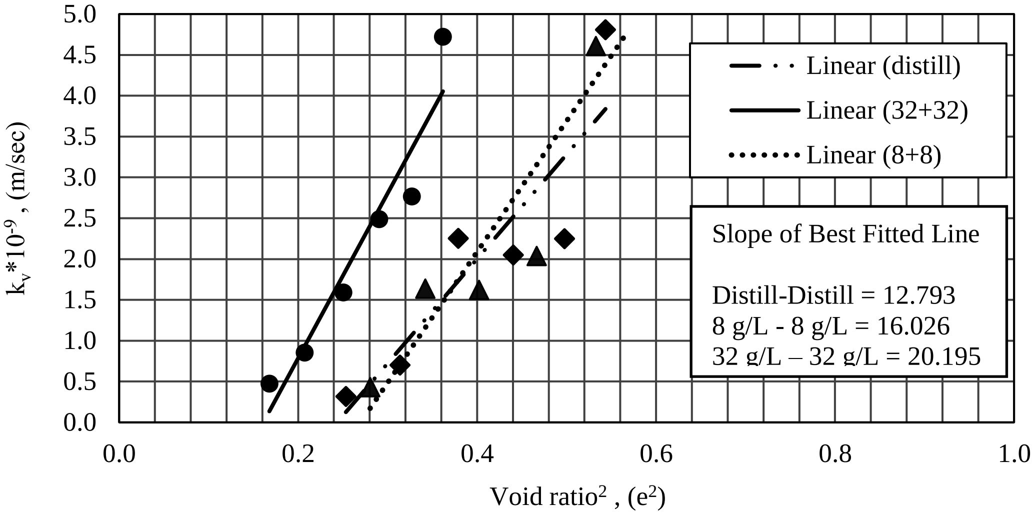


Figure 4. kv Vs e2 Graph for osmotic consolidation

Using √t method, the coefficient of consolidation (c_v) values have been determined and using these c_v values coefficient of vertical permeability values (k_v) have been calculated. The plot of k_v vs e^2 in Figure 4 indicates that, with the increase in pore fluid salinity permeability of soil increases.

Conclusions

Following conclusions can be made from this study:

(1) Salinity intrusion decreases the compressibility and increases the permeability of soil.
(2) Leaching of salt from pore fluid increases the compressibility and decreases the permeability of soil.

For silty soil, these changes of soil compressibility are small. However, for clayey soil these changes might be significant.

Acknowledgement

The authors acknowledge the infrastructural and financial support received from Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh for carrying out the research work.

References

Ajmera, B., and Tiwari, B. (2012), "Consolidation Characteristics of Soft Clays with Saline Water as a Pore Fluid". GeoCongress 2012 © ASCE 2012

Barbour, S.L., and Fredlund, D.G. (1989), "Mechanisms of osmotic flow and volume change in clay soils." Canadian Geotechnical Journal, 26, 551-562.

Barbour, S.L., and Yang, N. (1993), "A review of the influence of clay-brine interactions on the geotechnical properties of Ca-montmorillonitic clayey soils from western Canada." *Canadian* Geotechnical Journal, 30, 920-934.

Basma, A.A., and Tuncer, E.R. (1991), "Effect of Lime on Volume Change and Compressibility of Expansive Clays." *Transportation Research Board*, 1295, 52-61.

Casey, B. (2014), "The Consolidation and Strength Behavior of Mechanically Compressed Fine- Grained Sediments", *Ph.D. Thesis*, Massachusetts Institute of Technology, Cambridge, MA.

Casey, B., Germaine, J. T., and Fahy, B. P. (2017), "Effects of Salinity on the Compression and Shear Behavior of Offshore Gulf of Mexico Sediments". *Geotechnical Frontiers 2017 GSP 280.*

Chen, J., Anandarajah, A., and Inyang, H. (2000), "Pore Fluid Properties and Compressibility Kaolinite." *J.* Geotechnical and Geoenvironmental Engineering,126 (9), 798-808.

Lambe, T.W., and Whitman, R.V. (1969), "*Soil Mechanics"*, John Wiley and Sons, New York.

Mallick, J. R. (2018) "Effect of salinity on the compressibility and permeability characteristics of a coastal soil", *B. Sc. Engg. Thesis*, Bangladesh University of Engineering and Technology, Dhaka.

URBAN ECO-SUSTAINABILITY AND DISASTER RISK REDUCTION BY IMPLEMENTING VERTICAL GARDEN IN DHAKA CITY

Md. Habibur Rahman[1], Tasnim Zafar Khan[2], Rakib Ahmed Raju[3], Muhammad Jahedul Huq[4]

ABSTRACT

Green space in Dhaka city is reducing day by day and affecting urban eco-systems producing multi-dimensional socio economic, cultural and environmental problems. In this scenario, we argue that vertical garden could be a way to mitigate these urban problems. Though vertical gardening is not a new concept in Bangladesh, it has emerged recently because of its diverse uses like reducing the hostile ecological effect of the buildings and greenhouse gas emission, air purification, regulating the temperature and rainfall runoff, providing food and wildlife habitat, as well as creating employment and recreational opportunities. Therefore, the study aims to evaluate the practices of vertical gardening contributing to eco-sustainability and disaster risk reduction in the context of the Dhaka city. Following qualitative approach, the study performed in-depth interviews, participant observation and visual documentation as data collection tools in order to understand contemporary practices and types of vertical gardening, and ecosystem services produced by vertical garden. This study attempts to review the major opportunities and challenges of vertical gardening, through the framework of eco-system services and urban resilience.

Keywords: Vertical Garden, Eco-system services, Disaster Risk Reduction, Urban resilience

Introduction

Urban growth is estimated to increase rapidly in the coming decades. Thus cities will face new and ongoing challenges in case of environment, economic, education, health, food etc. Urban areas are major players in striving for carbon free economic growth and at the same time helping their populations to deal with climate uncertainty and natural disasters. Usually urban areas are characterized by materials of low porosity and shortage of evapo-transpiring surfaces (vegetation). In addition, human activities are also responsible for anthropogenic heat release. Urban areas are riskier than rural areas in case of hazards because of its complex, sophisticated nature and population density. All governments are committed to protect their citizens and resilience can be a public good in this regard (Lall, et al. 2009).

Over the last 50 years, more than 40% the green space was lost due to the development of infrastructure, housing, etc. (Kabir et al. 2018). Clean-Green Dhaka is a Campaign introduced by DNCC which aims to make the city clean and green with integrated effort. As a part of this campaign, more buildings practice rooftop gardening today. City dwellers get a chance contribute to environmental conservation as well as enjoy gardening in the city's limited space. Ecosystem-based approaches draw the attention of the DRR (Disaster Risk Reduction) scholars to response to the extreme disaster events worldwide (Renaud et al., 2013). Such an ecosystem based approach can be vertical gardening. It is a type of gardening that grows upward (vertically) using a trellis or other support system rather than horizontally. Ecosystem-based approaches identify three distinct strengths: they are (1) environmentally sustainable, (2) cost effective, and (3) socially and economically responsible.

Background of the Study

Urbanization in Dhaka City is increasing at a very fast rate which creates several problems leading to deteriorate basic rights of the citizens. Though urbanization brings along economic and social benefits, it has

[1]*Level 4,Department of Disaster and Human Security Management, Bangladesh University of Professionals, Email-hrabir1213@gmail.com*

[2]*Level 4,Department of Disaster and Human Security Management, Bangladesh University of Professionals, Email-tasnimzafar.k27@gmail.com*

[3]*Level 4,Department of Disaster and Human Security Management, Bangladesh University of Professionals, Email-rraajjuu500@gmail.com*

[4]*Assistant Professor, Department of Disaster and Human Security Management, Bangladesh University of Professionals, Mirpur, Dhaka-1216. Email: shovonhuq@gmail.com*

some negative effects. One of the worst negative consequences of rapid urbanization is the degradation of the urban environment on a massive scale, of the kind which is now experienced in Dhaka. Air, water, soil of the city has been polluted to dangerous levels. The eco-system services fall into shortage due to the pollution of the environment caused by rapid urbanization. In response to this problem, our study will evaluate the effectiveness of vertical gardening in Dhaka City. We will examine the services that a vertical garden provides and its contribution in solving urban problems such as environment pollution, noise pollution, carbon footprint, heat wave etc. An in-depth investigation on the implications of vertical gardening will be carried out in a particular area of Dhaka city to identify the opportunities and associated challenges.

Research Aim

- To explore in what ways vertical gardening offers services and support to maintain ecological sustainability and reducing disaster risks in the context of Dhaka city.

Research Objective

- To produce a map of eco-system services from vertical gardening.
- To understand the relation between eco-system services and urban resilience.
- To identify challenges and opportunities of vertical gardening.

Literature Review

Vertical Gardening

Vertical gardening is an agricultural technique, used in high-rise buildings that enables to produce large scale food production by controlling and without controlling the environmental conditions based on technologies, hydroponics and cutting-edge greenhouse methods (Abel, 2010). Rooftop gardening is the most popular and effective practice of vertical gardening. Extensive and intensive are the two types of green roof system. Extensive green roof system has some basic characteristics. They are light-weight; need low maintenance, its average soil depth 5-15cm (2-6 in). So rooftop would have the capacity to bear the weight 70-170kg/sq (14-35 lb. /sq.) if someone want to cultivate this type of rooftop gardening. Generally mosses and herbs are planted in this type of garden. On the other hand Intensive green roof system needs deep soil depth, wide plant range and high capital cost. The average soil depth in the intensive green roof system is ranging from 20-60 cm (8-24 in) and rooftop needs the capacity to bear 290-967.7 kg/sq ft. (60-200 lb. /sq.). Trees and shrubs are planted this type of gardening (Mowla, 2010). China, Japan, Holland, South Korea, Italy, Canada, USA and Singapore already adopted this method to produce more crops and safe their environment (Sivamani, Bae, & Cho, 2013).

Eco-system Services and Urban Disaster Risk Management

From the very beginning of human life, human depends on goods and services from nature for survival. Eco-system in the nature can play a vital role for providing eco-system services. It can help climate regulation, water supply and purification, cycling of water and nutrients (Millennium Ecosystem Assessment, 2005). There are four types of eco-system services. Provisioning services (e.g. food, fresh water), supporting services (e.g. nutrient cycle, water cycle), regulating services (e.g. climate regulation, erosion regulation) and cultural services (e.g. Spiritual and religious values, knowledge system, sense of place) (Millennium Ecosystem Assessment, 2005).

Vertical farming can control storm water run-off. Plants of the garden can capture and hold the heavy rain water. Then it can absorb and release the water in the atmosphere through evaporation and evapotranspiration (Banerjee & Adenaeuer, 2014). Plants in the vertical farming can hold about 70-90% of the precipitation that occurs in the summer. And in winter it can hold about 25-40% of precipitation (Hossain, 2009). Over all precipitation which occurs throughout the year, plants of the rooftop garden retain 50-90% of rainwater (Mowla, 2005). Plants of vertical garden can be used as a shade in the building from solar radiation. Plants can cool down the surrounding environment using their evapotranspiration process and reduce temperature (Afrin, 2009). Rooftop gardening can reduce cooling cost up to 50% and it can reduce about 25% of the surrounding temperature (Specht et al., 2014). But these process are depended on some factors like building size and location, climatic condition of that areas and type of the rooftop garden (Mowla, 2005).

Methods

In this research, we took 15 samples. It was depending on types of vertical gardening. There are three types of vertical gardening that exist in Mirpur DOHS area. For each type we took 5 respondents and in total it is 15. Qualitative study ordered through in-depth interviews with the help of open ended, semi-structured questionnaire.

Study Area Selection

To conduct this research, Mirpur DOHS has been selected as the study area. We have selected Mirpur DOHS as our study area, because the area has existence of vertical gardening practitioners. The area is urbanized hence there is a huge supply of roof space. And no studies have been conducted in this area on this concept before.

Data Collection Tools

Both primary and secondary data were collected for the study. In this study we consider three types of data collection methods for primary data collection. 1) Interview, 2) Participant observation, and 3) Visual documentation. 15 practitioners were interviewed to explore their motivation, types of plants grown, cost of maintenance, benefits and problem faced and other experiences. A questionnaire was prepared which included open ended questions. We observed the types of gardens during field visits and we have seen that in general there were 3 types of vertical gardening methods namely- 1) intensive, 2) semi intensive, 3) extensive. There were mostly 4 types of plants which include various species of - 1) fruits 2) flowers 3) vegetables and 4) ornamentals. One exceptional type that we found was the cultivation of different species of spices. Images were captured during field visits taking the permission of the respondents to keep permanent record of direct observations. Secondary data were collected from literature review. Various secondary information and data were used in this paper which was collected from research articles, newspapers, internet, books and journals.

Data Analysis Method

In our study we used thematic analysis. Why we used thematic analysis? As we conducted a qualitative research, this method helped us to explain the data in an easier way. We turned our quantitative data into qualitative form through this analysis method. We can easily organize our information using this method.

Result

Practicing types of vertical gardening

In Mirpur DOHS area we have found three types of vertical gardening. Existing three types of vertical gardening are A) Intensive vertical gardening B) Semi-intensive vertical gardening and C) Extensive vertical gardening. In Dhaka city, practices of intensive vertical gardening are rare. But in Mirpur DOHS area, scenario is totally different. Including intensive, three types of gardening are available in most of the buildings. They did special treatment on their building rooftops; as a result they can practice the intensive one as well as other types. In Photograph 1 we can see one of the intensive vertical gardens which are practiced in the study area. Generally using 7 – 24+ inches deep soil with a saturated weight increase of 35 - 80+ lbs/ft² in their rooftop for preparing intensive one. They are planting Banana, Mango, Coconut, Jackfruit and Papaya in their intensive garden. In this case, maintenance cost is little bit higher than other types. In the semi-intensive vertical gardening, people are using 5-7 inches deep soil and increase the saturated weight of 25-35 lbs/ft² in their rooftop. They are using some selected perennials, sedums, ornamental grasses, herbs, little shrubs and small tree for preparing this type of vertical gardening. From Photograph 2 we can see the scenario of the semi intensive vertical gardening in the study area. Different kinds of vegetables like hyacinth bean, cucumber, bottle gourd, ribbed gourd, sponse gourd, wax gourd and bitter gourd are cultivating as semi-intensive plants. Photograph 3 represents the extensive type of vertical gardening. In this type soil depth is ranging from 2-5 inch and increase the load of 14-35 lbs/ft² in the rooftop (Mowla, 2010). Respondents are using 3-5 inches deep soils that increase the saturated weight of 15-25 lbs/ft² in their rooftop. Generally most of the species of flowers, ornamentals, spices and some species of vegetables are planted as extensive type of vertical gardening in the study area. In Mirpur DOHS area people are practicing mixed types of vertical gardening. We did not find any rooftop that practices single type of vertical gardening. For cultivating fruits, they prefer intensive vertical gardening. For cultivating vegetables most of the times they prefer semi-intensive vertical gardening and prefer extensive type for planting flowers, ornamentals and spices.

		
Photograph 1: Intensive vertical gardening.	*Photograph 2: Semi-intensive vertical gardening*	*Photograph 3: Extensive vertical gardening*

Figure 1: Types of vertical gardening in the study area.

Source: The authors (Field Survey, 2018)

Ecosystem Services

Table 1: Eco-system Services of vertical gardening in the study area.

Benefits of Vertical Gardening	Eco-system Services			
	Provision	Regulate	Cultural	Support
Storm water quantity		Water		
Storm water quality	Water	Purification		Nutrient cycling
Genetic resources	Seeds			
Heat island		Climate		
Building energy		Climate		
Noise reduction		Sound	Aesthetic	
Air pollution reduction		Air		Nutrient cycling
Temperature reduction		Climate		
Waste management		Waste treatment		
Biodiversity		Pollination	Knowledge	Nutrient cycling
Retard fire			Well-being	
Views			Aesthetic	
Social cohesion			Well-being	
Mental satisfaction			Spiritual well-being	
Vertical agriculture	Food		Educational	Soil formation
Education opportunity			Educational	
Improvement of health condition			Well-being	
Cognitive development and knowledge preservation			Knowledge	
Employment opportunity			Well-being	
Carbon sequestration		Air		

Source: The authors (Field Survey, 2018)

Provisioning Services

Food, freshwater, timber, fibers, medicinal plants obtained from ecosystem are provisioning services (Millennium Ecosystem Assessment 2005). Eco-system services supply for three types of provisioning services i.e. forage, timber, fisheries (Balvanera et al. 2014). Field observation showed the cultivation of various vegetables, fruits, flowers, aromatic and medicinal plants that takes place on the terrace of individual plots. It could be observed that gardeners maintain soil fertility by adding manure and compost with a view to enhancing food production. Some gardeners use kitchen wastes as fertilizer to produce chemical free fruits and vegetables.

Supporting Services

According to The Millennium Ecosystem Assessment (MEA, 2005), 'maintenance of soil fertility' is considered as supporting service, which help to generate other ecosystem services, e.g. the production of food. We found that gardeners use organic wastes to maintain the soil fertility of their gardens. They mentioned vertical gardening as a refuge for many species of birds, bees, and butterflies. Well- designed green roofs can provide habitat for different species.

Regulating Services

Almost all the interviewed gardeners emphasize on the importance of soil fertility. They identified 'local climate regulation' which is understood as urban cooling. As an important benefit from vertical gardens, pollination was only mentioned by some of the interviewers. Pollination was mainly related to flower and ornamental plants. The formation of soil organic matter by flora and fauna and the enrichment of soil fertility through legumes (nitrogen fixation) were recognized. The scientifically undisputed importance of 'pollination' as supporting service for 'food supply' and 'biodiversity' (Andersson et al., 2007) remained undefined by many gardeners. Other remaining regulating services 'local climate regulation', 'air purification' were often described as feelings and related to an increased well-being through nature exposure in vertical gardens.

Cultural ecosystem services

The production of food in vertical gardens is supporting manifold other ecosystem services though most of them are cultural ecosystems services described as the most important services provided by vertical gardens. Field observation has shown that ecosystem services have provided a fulfillment in social cohesion & integration, nature & spiritual experiences (Tidball's 2012). Each and every gardener firmly stated vertical gardening as a means of mental recreation, including 'aesthetical information', 'relaxation & stress reduction', and 'entertainment & leisure' across all garden types. Respondents said that active engagement in gardening activities and exposure to nature creates a source of mental relaxation. Local climate regulations are contextualized among benefits for mental recreation by gardeners.

Opportunity for Vertical Gardening in the Context of Dhaka City

In traditional farming, only one crop can be produced at a time. But in vertical gardening different kinds of products can be produced at the same time. This is the key difference between vertical gardening and traditional gardening. As our horizontal space is decreasing day by day we should go for vertical expansion as early as possible.

Recycling of Organic Waste

Organic wastes which are generated from household can be used as a fertilizer in the vertical garden. We have found that many respondents are using organic wastes in their garden. This process is eco-friendly and do not causes water contamination like chemical fertilizer does. Recycled organic wastes turn into fertilizer for our garden. So there is no need to spend extra money for buying chemical fertilizers. From Table 2, we can see 4 respondents are using their organic waste in their garden as a fertilizer. This is almost one third of the total respondents

Table 2. Types of fertilizer which are used in vertical gardening

Types of fertilizer	No. of respondent
Chemical Fertilizer	5
Organic waste	4

No fertilizer are used	6

Source: The authors (Field Survey, 2018)

Local Job Opportunities

Vertical gardening can create direct or indirect job opportunities for jobless people in the cities. In Mirpur DOHS area some people are working permanently and some other working temporary in the vertical gardening of the respondents. From Table 3 we can see 4 respondents who have one permanent employee whose salary is 9-12 thousand BDT. On the other hand temporary employee works on daily basis. They take the salary 500 BDT per day. Rest of 4 respondents has no employee. They themselves work in their garden. In this way vertical garden can create job opportunity for the local people.

Table 3: Types of employment and number of employee

Types of employment	Number of employee	Salary (BDT)	No. of respondents
Permanent employee	01	(9-12 thousand) per month/person	4
Temporary employee	01	500 per day	7
No employee	none	None	4

Source: The authors (Field Survey, 2018)

Improved Food Security

In our Dhaka city we have limited access or no access to fresh food. Access to available food and access to fresh food are the two different terms. To produce available fresh food people are practicing vertical garden in their rooftop. Respondents cultivate vegetables, fruits and flowers in their rooftop to reduce the dependency of fruits and vegetables in the market which are contaminated with poisonous substances. Price is another factor which influences them to do vertical gardening.

Challenges for Vertical Gardening in the Context of Dhaka City

- The roofs need to be cleaned on a regular basis as the leaves of the plants make the roof unclean. The respondents said that if proper cleaning measures are not taken then it can become an ideal breeding ground for mosquitos and other insects.
- Another problem that was unveiled from the respondent's interviews was about not getting desirable production and not being able to communicate easily with experts regarding the problems they face while practicing gardening.
- When asked about the cost it was found that it was not an issue for those who can afford it. A reasonable set up cost is required apart from that and the maintenance cost is pretty much affordable.
- There is no government intervention or authority to take care of the gardens. The building owners, guards, caretakers (often known as Mali) and sometimes part-time staffs are assigned to take care of the gardens.
- Lack of technological knowledge is also a constraint for practicing vertical gardening. There are very few opportunities for acquiring technological and cultivation knowledge.
- Green roofs are heavier and as such, require more structural support to be implemented. The structure and weight of a roof garden can cause problems for the overall building.

Discussion

Air pollution, sound pollution, carbon emission, urban heat island and water logging are becoming serious urban disaster risks in last few decades. Through evaporation and evapotranspiration it absorbed and released the water in the atmosphere. In summer vertical gardening hold about 70-90% of the precipitation. All the precipitation that occurs throughout the year, it holds 50-90% of rainwater (Mowla, 2005). Vertical gardening can reduce the effect of urban heat island. Vegetation can be used as a shade for building and cool down the surrounding environment by using their evapotranspiration process. Vertical gardening can reduce the cooling cost up to 50% and 25% of the surrounding temperature (Specht et al., 2014). Growing medium of the vertical gardening can reduce the lower sound frequencies on the other hand plants can reduce the higher sound frequencies. Depending on the types of vertical garden, it can reduce sound by 46-50 decibels (Afrin, 2009).

It is well known that trees, shrubs and other natural vegetation affect urban air contaminant levels. Air quality and the overall experience of health and well-being of humans living in urban areas are also affected by these. In response to urban environmental problems some authors have studied the effects of vegetation, particularly trees, on cooling ambient urban air, shading buildings and absorbing gaseous air contaminants. Green-house gas emission added a new dimension in the concept of urban disaster risk. Buildings in the city area like Dhaka, consume about 48% of all energy (Besthorn, 2013). So buildings are responsible for emitting green-house in the urban area. Vertical gardening in the rooftop can cool down the buildings and reduce the buildings' heat consumption.

In terms of urban resilience we consider four parameter of resilience. Parameters are economic, social, infrastructural and environmental (Merrow et al., 2016). In terms of eco-system services there are four types. Provisioning, cultural, supporting and regulating are the urban eco-system services (Bolund and Hunhammar 1999). We show how eco-system services which are generated from vertical gardening can contribute to establish urban resilience. First, provisioning services are food, fuel, genetic resources and fresh water, which come from urban agriculture (Bolund and Hunhammar 1999). By producing seasonal and non-seasonal foods, it can reduce the urban food insecurity. Practicing vertical gardening can ensure available access to fresh food for city dwellers. Creating local job opportunity, it can support local economy. Then cultural services (Spiritual and religious values, Recreation and aesthetic values) develop our mental health and increase our social cohesion (Bolund and Hunhammar 1999). It can help to create better social bonding among the people. Social resilience mainly focuses on some factors like quality of education and information, health access and emphasize on social relationship. Supporting ecosystem services develop the social infrastructure. By practicing vertical gardening we can mitigate the consequences of urban deforestation (Lovell and Taylor, 2013). We actually conserve our forest practicing through this way. We can use organic wastes in our vertical garden as fertilizers. In this way, we can manage our wastes very easily. Waste management itself a big problem in our country as well as outside the world. Regulating services is the most important one which can control or regulate the urban disaster risk (Bolund and Hunhammar 1999). Vertical gardening can hold the rain water and reduce the possibility of water logging in the urban area. It can absorb the dust particles and clean the polluted air. It is working like an insulator and reducing the consequence of sound pollution.

Conclusion

Yet for a significant implementation of the practice of vertical gardening, additional steps can be suggested like, vertical gardening needs more demanding structural standards. Roofs of the existing buildings need to be checked before adoption of vertical gardening whether those can bear the load of vegetation or not. Dying and unhealthy plants may have a negative impact on those observing them. Special attention should be given in appropriate plant selection and correct placement in the garden. Use of chemical must be prohibited as it may have detrimental effects on the health of the people. Adoption of organic fertilizers, mulching, hand weeding, companion planting and adequate spacing of plants etc. can reduce the necessity of using chemicals. Maintenance of drainage system is another most important fact in vertical gardening. Incorporating a drainage layer with a water storage layer below it can work as a reservoir for plants that can draw upon dry weather.

In future research regarding this field, researchers can focus on the infrastructural issue. We only discuss how vertical gardening can reduce the urban disaster risk. But it has a great influence in climate change factor. So future research can be on how vertical gardening reduces the climate impact in urban area and to what extent it can do that. The cost benefit analysis of vertical gardening in the context of social, economic and environmental sector could be a better finding.

References

Abel, C. (2010). The vertical garden city: towards a new urban topology. CTBUH Journal, (2), 20–30. Available at: http://www.et2050.eu/et2050_library/docs/tech/land uses/Verticalgarden.pdf [Accessed September 5, 2010]

Afrin, S. (2009). Green Skyscraper: Integration of Plants into Skyscrapers. (Master's Thesis). Kungligatekniskahögskolan (KTH), Stockholm. Available at: www.infra.kth.se/sb/sp. [Accessed January 15, 2009]

Banerjee, C., & Adenaeuer, L. (2014). Up, Up and Away! The Economics of Vertical Farming. Journal of Agricultural Studies, 2(1), 40. Available at: http://doi.org/10.5296/jas.v2i1.4526 [Accessed January 15, 2014]

Besthorn, F. H. (2013). Vertical Farming: Social Work and Sustainable Urban Agriculture in an Age of Global Food Crises. Australian Social Work, 66(2), 187–203. Available at:

http://doi.org/10.1080/0312407X.2012.716448. [Accessed December 5, 2013]

Bolund, P. and Hunhammar, S., 1999. Ecosystem services in urban areas. Ecological economics, 29(2), pp.293-301.

Hossain, M. M. 2009, Effects of Green Roof Concept on Residential Apartment Buildings in the Context of Dhaka City, unpublished M.Arch term paper under the supervision of Prof. Dr. Qazimowla (the author of this paper) of Bangladesh University of Engineering and Technology, Dhaka.

Kabir, M. H., Sato, M., Habbiba, U. And Yousuf, T.B. (2018) Assessment of Urban Disaster Resilience in Dhaka North City Corporation (DNCC), Bangladesh. Procedia Engineering, [Online] vol 212, p. 1107-1114. Available at: https://www.sciencedirect.com/science/article/pii/S1877705818301693. [Accessed September 12, 2018]

Lall, S.V. and Diechmann, U. (2009) Density and Disasters: Economics of Urban Hazard Risk, Policy research working paper 5161, World Bank, Washington, D.C.

Lovell, S.T. and Taylor, J.R., 2013. Supplying urban ecosystem services through multifunctional green infrastructure in the United States. Landscape ecology, 28(8), pp.1447-1463.

Meerow, S., Newell, J.P. and Stults, M., 2016. Defining urban resilience: A review. Landscape and urban planning, 147, pp.38-49.

Mowla, Q.A. 2005a, "Ecological Imperatives for Sustainable Environment", in International Conference on Geography and Environment – Issues and Challenges, Dec 9-11, 2005, Dhaka.

Mowla, Q.A., 2010, October. Green Roof Concept for Eco-Sustainability in the Context of Urban Dhaka. '. In International seminar on 'GO GREEN: the Architecture of the New Order 'on the occasion of ARCASIA, 0rganized by ACA, Lahore, Pakistan (pp. 25-30).

Sivamani, S., Bae, N., & Cho, Y. (2013). A Smart Service Model Based on Ubiquitous Sensor Networks Using Vertical Farm Ontology. International Journal of Distributed Sensor Networks, 9(12), 161495. Available at: http://doi.org/10.1155/2013/161495 [Accessed April 20, 2013]

Specht, K., Siebert, R., Hartmann, I., Freisinger, U. B., Sawicka, M., Werner, A., Dierich, A. (2014). Urban agriculture of the future: an overview of sustainability aspects of food production in and on buildings. Agriculture and Human Values, 31(1), 33–51. Available at: http://doi.org/10.1007/s10460-013-9448-4. [Accessed January 15, 2014]

TREATMENT OF TANNERY EFFLUENT USING A BIO-ADSORBENT

M. N. Hossain[1], Md. Didarul Islam[2], Ashiqur Rahaman[3], Anamika Roy[4] and M. A. Matin[5]

ABSTRACT

Tannery industry is one of the oldest industries; effluent from tannery industry is heavily polluted and is characterized by high biochemical oxygen demand BOD, chemical oxygen demand COD, total dissolved solid TDS, turbidity, conductivity, sulfide, chloride, and chromium. Untreated tannery effluent when discharged directly into the water bodies' causes serious adverse effect to the environment. Coagulation and flocculation is one of the most widely used treatment processes for industrial effluent treatment. In this study we used Moringa stenopetala seed powder for the treatment of tannery effluent. The maximum removal of BOD, COD, TDS, turbidity, conductivity and chromium was found to be 82.5% (initial BOD 5310 mg/l), 83.4% (initial COD 19000 mg/l), 79.6% (initial TDS 154200 mg/l), 79.3% (initial turbidity 1413 NTU), 79.8% (initial conductivity 308,500 µS/cm) and 90.3% (initial chromium 1038 mg/l), respectively. Generally moringa stenopetala seed powder was found to be effective in the treatment of tannery effluent.

Introduction

Tannery industry is one of the most polluting industries. The aim of the leather industry is to convert putrescible animal hides and skins into non putrescible leather. Leather industry is renowned for its high water consumption. Approximately 30-36 m^3 waste water is discharged to the environment during processing of every 1 ton of leather. Leather is the second largest industry in Bangladesh. It also plays an important role in our economic development. Approximately 200 tanneries were located in Hazaribag area and discharged 22000 m^3 of liquid waste containing 180 mg/l of chromium. Raw tannery effluent causes serious damage to the environmental because it contains organic matters dissolved and suspended solids, Ammonia and several heavy metals; exposure to these pollutants increase the risk of dermatitis, ulcer, nasal septum perforation and cancer. The biggest problem in the effluent treatment is the selection of treatment process because effluent from different operational stages contains different types of pollutions. A number of researches have used several processes such as coagulation, adsorption, electro-coagulation, sedimentation, etc. Recently natural coagulants have been used in effluent treatment; but they have not been very effective. In this study we use moringa stenopetala seeds to treat tannery wastewater. This study describes the ability of this natural coagulant to treat tannery wastewater in terms of BOD, COD, TDS, turbidity and chromium removal.

Material and Methods

Study area

The study area is comprised of Hazaribagh tannery industry area, Dhaka. It is situated between 23º45` to 23º49` latitudes and 90º21.85` to 90º22.15` East longitudes. Three tanneries named as Samina, Ruma and Chowdhury tannery were selected for effluent collection. They export good quality leather to the USA and European countries.

Sample collection

The study was conducted during the year of 2016 and the liming and dying effluents were collected from the outlet of the three selected industries located in Hazaribagh leather processing zone, Dhaka. For the present investigation all samples were collected directly from the discharge point of the industrial tanning stage operation. All the samples were collected by following Pearson method and stored in the polyethylene bottles at 4±1 ºC in the laboratory. It was stored such way until further use.

[1]*PhD Student, Department of Glass and Ceramic Engineering (GCE), BUET, Dhaka-1000, Bangladesh.*
[2] *Author, Department of Applied Chemistry and Chemical Engineering, University of Dhaka*
[3]*Author, Institute of Leather Engineering and Technology, University of Dhaka*
[4]*Author, Department of Chemical Engineering (ChE), BUET, Dhaka-1000, Bangladesh.*
[5]*Associate Professor, Department of Glass and Ceramic Engineering, BUET, Dhaka-1000, Bangladesh.*
Email of Corresponding Author –nazmul.hossain.gce.buet@gmail.com

Preparation of the bio adsorbent

In this study we used moringa stenopetala seed powder as an adsorbent and moringa stenopetala seeds were collected from Hazaribagh area. The seed-coats were removed and washed in deionized water to remove any dirt. The seeds were dried in vacuum oven at 80 °C for 36-48 hours and then powdered using a grinder. Then the powder was stored in vacuum container for further use.

Adsorption experiments

All the adsorption experiments were carried out at room temperature. The adsorption experiments were conducted at 25±5 ºC by agitating 120 pm 10 g of absorbent in 250 ml of effluent solution at 12 hours of contact time. The suspensions were filtered using Whatman filter paper and then the solution was analyzed for physical chemical parameters.

Results and discussion

Characterization of raw tannery effluent

The analysis of raw tannery effluent are shown in Table 1. The BOD, COD, TDS, turbidity, conductivity and pH range of the untreated tannery effluent was found to be 7200 mg/l to 2250 mg/l, 91000 mg/l to 5530mg/l, 220 mg/l to 77 mg/l, 14113 NTU to 715 NTU, 438 ms/cm to 143 ms/cm and 13.2 to 2.4, respectively. This result indicated the untreated effluents contained highly polluting substances which has the potential to significant damage to the environment. High BOD and COD values of the effluent indicate the high organic pollution potential of the effluent. This result illustrated that the pollution loads from these industries were very high

Table 1. physical chemical characteristics of raw tannery effluent and standard value

Name of operation	BOD mg/l	COD mg/l	TDS g/l	Turbidity NTU	Conductivity ms/cm	Chromium mg/l	pH
Soaking	4250	13000	125	900	254		8.1
Liming	7200	19000	220	1413	438		13.0
De liming	5300	14050	198	877	401		8.5
Bating	3150	7300	101	792	198		7.1
Pining	6050	7200	77	715	143		2.4
Chrome tanning	4020	10050	220	950	438	1738	2.8
Neutralization	2250	5530	138	751	274		6.5
Re chrome tanning	3550	9350	171	950	342	1038	3.6
Dyeing	4290	13500	123	1060	242		5.2
Fat liquoring	4750	14450	154	807	308		5.5
Standard value IST 2000/ ISW	30/250	250/400	2.1			0.5	6.9

Reduction of BOD, COD and turbidity

Table 2 illustrated that the effect of bio adsorbent addition on the removal of COD, BOD and the turbidity. The concentration of COD, BOD and the turbidity were decreased in the range of 82.54% to 36.1% 83.72% to 41.78% and 79.26% to 66%, respectively. However, removal of BOD, COD and turbidity did not reach the expected level.

Table 2. Reduction of BOD, COD and turbidity

Name of operation	BOD mg/l			COD mg/l			Turbidity NTU		
	Before treatment	After treatment	Percentage of removal	Before treatment	After treatment	Percentage of removal	Before treatment	After treatment	Percentage of removal
Soaking	4250	1050	75.29	13000	3000	76.92	900	210	76.66
Liming	7200	1400	80.55	19000	3150	83.42	1413	293	79.26
De liming	5310	927	82.54	14050	2790	80.14	877	201	77.26

Bating	31050	1520	51.74	7300	4250	41.78	792	197	75.13
Pining	3050	1950	36.1	7200	4100	43.06	715	181	74.69
Chrome tanning	4020	1510	62.44	10050	4010	60.09	950	323	66
Neutralization	2250	927	58.8	5530	2700	51.18	751	180	76.03
Re chrome tanning	3550	430	59.72	9350	3700	60.43	950	301	68.32
Dyeing	4290	1890	55.94	13500	3450	74.44	1060	190	72.64
Fat liquoring	4750	2240	52.84	14450	3590	75.16	807	187	76.64

Reduction of total dissolved solid TDS and conductivity

Table-3 shows that the effect of bio adsorbents on the removal of TDS and conductivity. The concentration of TDS and conductivity were decreased in the range of 79.57% to 40.89% and 79.71% to 39.62%, respectively. The cost of bio-adsorption is very little compared with other treatment process.

Table 3.: reduction of TDS and conductivity

Name of operation	Total dissolved solid TDS			Conductivity ms/cm		
	Before treatment	After treatment	Percentage of removal	Before treatment	After treatment	Percentage of removal
Soaking	125.2	33.1	73.56	254.1	65.5	74.22
Liming	220.1	54.3	75.33	438.1	107.2	75.33
De liming	198.7	61.2	69.20	401.0	123.1	69.30
Bating	101.4	60.0	40.83	198.9	120.1	39.62
Pining	77.3	34.7	55.11	143.2	67.7	52.72
Chrome tanning	220.8	57.4	74	438.2	1135	74.11
Neutralization	138.6	65.4	52.81	274.7	130.6	52.46
Re chrome tanning	171.0	45.1	73.63	342.6	89.7	73.82
Dyeing	123.2	29.0	76.46	242.0	57.9	76.07
Fat liquoring	154.2	31.5	79.57	308.5	62.6	79.7

Conclusions

From this study we can suggest that this natural coagulant can be used for the treatment of tannery waste water and moringa stenopetala seeds are available all over Bangladesh. The maximum percentage of BOD, COD, TDS, turbidity, conductivity and chromium removal were found to be 82.54%, 83.42%, 79.57%, 79.26%, 79.71% and 90.27%, respectively. These results suggest the effectiveness of this natural coagulat in the treatment of tannery wastewater. Moringa stenopetala seeds could be successfully used in the treatment of tannery waste water.

References

H. Ozgunay, S. Colak, M.M. Mutlu, F. Akyuz (2007) "Characterization of Leather Industry Wastes*", Pol. J. Environ. Stud*. 2007;16(6):867–873.

Khaled Mahmud Shams, Gottfried Tichy, Manfred Sager, Thomas Peer, Ashtar Bashar, Marija Jozic (2009) "Soil Contamination From Tannery Wastes with Emphasis on the Fate and Distribution of Tri- and Hexavalent Chromium", *Water Air Soil Pollut* (2009) 199:123–137, DOI: 10.1007/s11270-008-9865-y

Cooman K, Gajardo M, Nieto J, Bornhardt C, Vidal G. (2003) "Tannery wastewater characterization and toxicity effects on Daphnia spp.*", Environ Toxicol.* 2003 Feb;18(1):45-51..DOI: 10.1002/tox.10094

MA Chaudry, S Ahmad, MT Malik, (1998) "Supported liquid membrane technique applicability for removal of chromium from tannery wastes *", J. Waste Management*. 1998;17(4): 211-218.

Kornhauser C, Wróbel K, Wróbel K, Malacara JM, Nava LE, Gómez L, González R. (2002) "Possible Adverse Effect of Chromium in Occupational Exposure of Tannery Workers*", Ind Health. 2002 Apr;40(2):207-13,* DOI: 10.2486/indhealth.40.207.

Gentiana Shegani (2013) "Cleaner Tannery Wastewater Using Chemical Coagulants*", International Journal of Science and Research (IJSR),* 2013; ISSN (Online): 2319-7064.

Ayoub G.M.; Hamzeh A.; Semerjian L. (2011) "Post treatment of tannery wastewater using lime-bittern coagulation and activated carbon adsorption*", AUB, Scholarwork Repository*, DOI: 10.1016/j.desal.2011.01.045.

Espinoza-Quiñones, F. R. ; Fornari, M. M. T. ; Módenes, A. N. ; Palácio, S. M. ; Silva Júnior, F. G. da ; Szymanski, N. ; Kroumov, A. D. ; Trigueros, D. E. G. (2009) "Pollutant removal from tannery effluent by electrocoagulation.*", Chemical Engineering Journal,* 2009 Vol.151 No.1/3 pp.59-65.

Z Song, C.J Williams, R.G.J Edyvean (2000) "Sedimentation of tannery wastewater*", Water Research*, 2000;34(7): 2171-2176, DOI: 10.1016/S0043-1354(99)00358-9.

Abraham Aynekugnem (2015) "Chromium Removal from Chromium Rich Tannery Wastewater using Eucalyptus camaldulensis Dehnh. Bark Powder as an Adsorbent; the Case of Modjo Tannery, Ethiopia.*",* thesis, Center for Environmental Science, Addis Ababa University.

Z.Song, C.J.Williams, R.G.J.Edyvean (2001) "Coagulation and Anaerobic Digestion of Tannery Wastewater*", Process Safety and Environmental Protection*, 2001;79(1): 23-28, DOI: 10.1205/095758201531103.

INCLUSION OF RETENTION POND TO RETAIN RUNOFF BASED ON IDF RELATIONSHIPS IN RAJUK'S MGC BASED DHAKA CITY AREAS

Mahmud Al Islam[1] & Md. Mafizur Rahman[2]

ABSTRACT

Dhaka is a populous city with 9.254 million people living in an area 300.97 square kilometers and having an astounding density of 30,748 per square kilometer. Uncontrolled construction of building and infrastructure due to this burden of population has encroached the uncovered area. Urban flooding has become a common phenomenon in the last few decades. The present drainage network of Dhaka is unable to manage the peak runoff volume after a heavy rainfall. So to minimize the water logging and urban flooding, retention pond can be designed in between the uncovered space of multiple buildings. In this study, last 30 years (1988-2017) rainfall data was analyzed to find the runoff volume and retention pond depth in different parts of the city. Then the relationship between the uncovered area and the retention pond depth was prepared to find the feasibility of retention ponds in RAJUK's FAR and MGC based areas. Also the land use pattern of different wards of Dhaka city and catchment basins of Dhaka city using the DEM was prepared with ArcGIS as a part of the endeavor.

Introduction

Dhaka is subjected to annual average rainfall of 2,076 mm. The tropical monsoon climate comprises four hydrological seasons: pre-monsoon (April–May), monsoon (June–September), post-monsoon (October–December), and dry season (January–March). At the start of the monsoon and post-monsoon seasons, cyclones with strong winds hit Bangladesh, sometimes causing heavy rainfall in Dhaka city with subsequent urban flooding. About 56 percent of Dhaka was inundated by the 1998 flood, which was unprecedented in terms of duration and damage. Most of the city's eastern portion suffered from river flooding, and 23 percent of its western part was affected by urban flooding (Hasnat,2006). Urban flooding is one of the reason that make city life hideous. The drainage capacity is not enough to capture the storm water after a heavy rainfall in Dhaka city. So as a result most parts of the city goes under water. This system has proven unsatisfactory and it leads severe flooding in low-lying areas. Two separate drainage systems are operating in Dhaka City: one is for managing storm water and the other one is for domestic waste water (Haq, 2006). Although the city had an excellent natural drainage system consisting of 24 natural canals and a large retention wetland pond before 1940 (Haq, 2006), with the rapid and unplanned urbanization, most of the canals have been illegally occupied by real estate companies and this has resulted reduced carrying capacity of storm water of the city. About 85 % of the city is now drained through 40 (lined) channels to the surrounding rivers (Tawhid, 2004) which is not enough.

Methodology

Urbanization changes the way water flows through a catchment. The volume of runoff on urbanized areas are greater. So the uncovered spaces in between some buildings have been calculated in the selected areas through ArcGIS soft-wares. The areas are divided into several blocks including 4 to 8 no of buildings. The runoff was calculated using the design rainfall. The uncovered spaces in between closely spaced structures have been calculated in the selected areas through ArcGIS and Google Earth Pro. The minimum uncovered space among several blocks was used as the retention pond area. The runoff was calculated using the design rainfall. Then the required depth of the Retention pond was calculated from the runoff volume.

Study Area

Uttara sector 14 was selected as the study area. The area is under RAJUK's DAP (Detailed Area Plan) project. The area covers the Uttara lake which collects the storm water from runoff.

[1] *Department of Civil Engineering, Bangladesh University of Engineering and Technology.*
[2] *Professor, Department of Civil Engineering, Bangladesh University of Engineering and Technology.*
E-mail of Corresponding Author- omemahmud@gmail.com

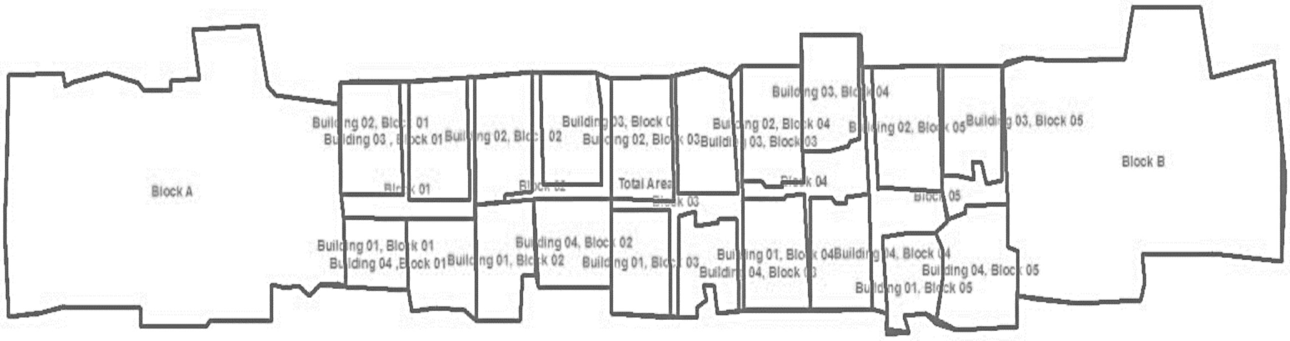


Figure 1. Screenshot of Shape file of Uttara sector 14 showing plan area using ArcGIS

Catchment Delineation

From the catchment basin the area no.4 of Figure 2 was determined from shape file using polygon tool and polyline tool under the editor feature. From the attribute table feature the area is calculated by the ‘calculate geometry’ command. The area of the catchment was found to be A = 304,665,994.6 m^2. Maximum length of travel of water, L = 5,972 m.

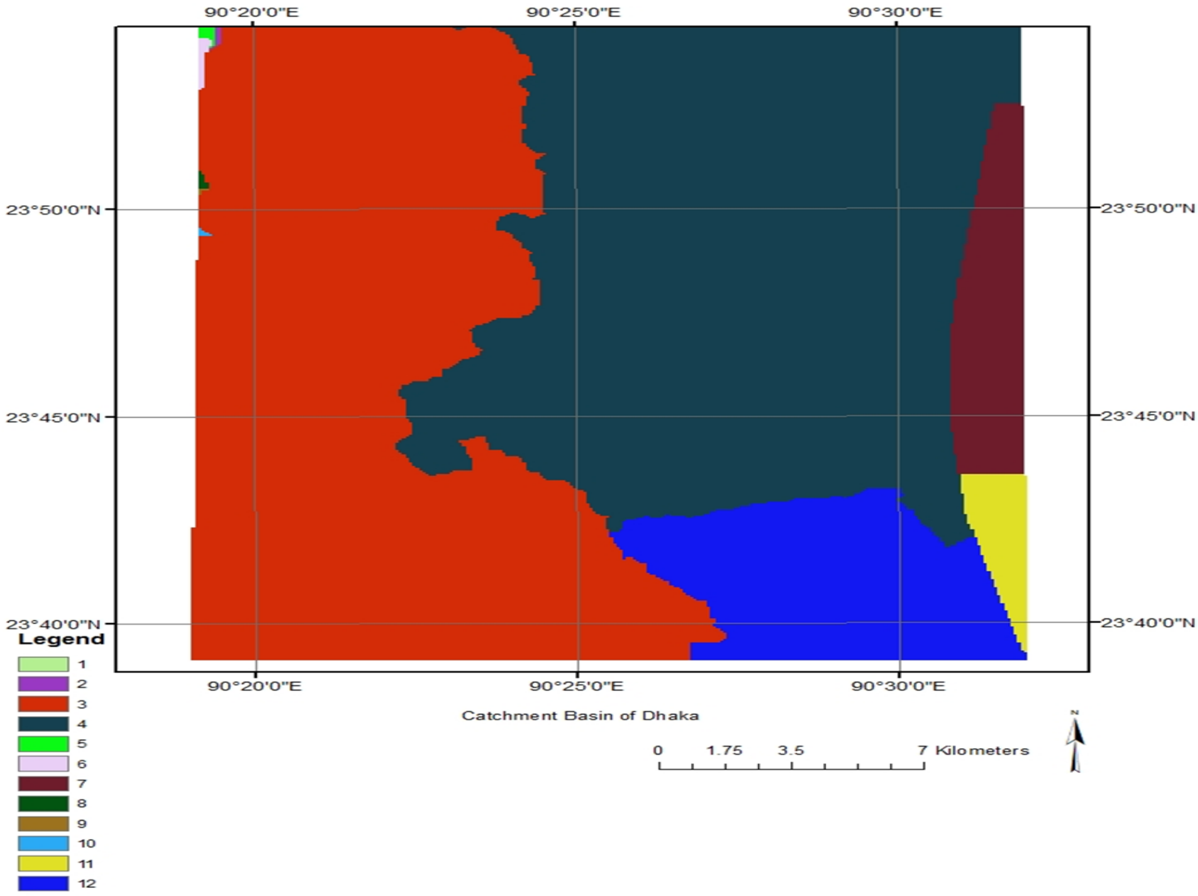


Figure 2. Different Catchment basins of Dhaka City from DEM analysis on ArcGIS

RAJUK’s MGC Based Areas

RAJUK (RAJDHANI UNNAYAN KARTRIPAKKHA) monitors the rule for Maximum Ground Coverage(MGC) and Floor Area Ratio(FAR) for any construction. If the ratios were properly followed, the total uncovered area would be much larger than it is now. According to Table 1 the uncovered area is 395.74

m^2 for block 2; but the actual uncovered area found from block is 138.38 m^2 which is the smallest among the five blocks. All the areas are calculated by geo-referencing the image on ArcGIS. The image was collected from Google Earth Pro.

Table 1. MGC and FAR calculation in Block 2(Uttara Sector-14).

Denoted Area	Area	MGC	Available Area	Total Area of the Blocks	Covered Area	Uncovered Area
Building 01, Block 02	250.999	62.5	156.874	1055.32	659.58	395.74
Building 02, Block 02	280.124	62.5	175.077			
Building 03, Block 02	259.907	62.5	162.442			
Building 04, Block 02	264.290	62.5	165.181			

*All areas are in square meter

IDF Relationships and Rainfall Analysis

Time of concentration is calculated after delineating the DEM of Dhaka in ArcGIS. The data derived from the catchment were required to calculate the time of concentration of the catchment. The slope of the study area was also required which was taken to be 0.009 which is the average slope of Dhaka city.

Table 2. Time of Concentration.

Description	Equation	Time of Concentration(t_c), (min)
Kirpich formula	$0.01947 \times L^{0.77} \times S^{-0.385}$	96.5
Bransby-Williams formula	$\frac{FL}{(A^{0.1})\ (S^{0.2})}$	127.1

The intensity of rainfall decreases with the increase of storm duration and a storm of any given duration will have a larger intensity if its return period is large. Considering the above values of time of concentration (Table 2), the time of concentration for the catchment was taken as 96.5 min. The highest maximum recorded rainfall in Dhaka was 210 mm on 27 July, 2009 at a 3-hour interval analyzing the data of the last 30 years (1988-2017) from Bangladesh Meteorological Department. So for designing a more intense rainfall with less probability to occur and more return period Table 3 was produced for return period 20,50 and 100 years. The highest intensity is found for Hershfield method with an intensity of rainfall 103.5 mm/hr.

Table 3. Intensity of Rainfall for different Return Period from IDF Relationship.

Description	Indian Method	Hershfield Method
Equation	$I = \frac{629.36 * Td^{0.239}}{Tr^{0.673}}$	$I = \frac{619.15 * Td^{0.202}}{Tr^{0.595}}$
For return period of 50 Years Intensity (mm/hr)	74.0	90.0
For return period of 20 Years Intensity (mm/hr)	59.5	74.8
For return period of 100 Years Intensity (mm/hr)	87.4	103.5

Storm Water Runoff Volume and Retention Pond Volume

The areas of different blocks were calculated using the attribute table features over the shape files of Figure 1. To find out the feasibility of retention pond for large areas some areas have been combined. From the rainfall analysis and IDF relationship the rainfall was taken as 10.35 cm/hr. The peak storm water runoff volume was calculated using rational method (Eq. 3).

$$\{V\}=[C][I][A]\{tc\} \quad (1)$$

where, {V} = storm water runoff volume; [C] = runoff coefficient; [I] = rainfall intensity; [A] = catchment area; {tc} = time of concentration. The weighted average of runoff coefficient of composite developed area (roof and pavement) was assumed as 0.9. However, runoff coefficient of green fields of Dhaka was considered as 0.20 as suggested by Ahmed and Rahman, (2010). The retention pond area was found from the uncovered space of block 2, which is 138.4 m^2 and the depth is considered 1.5 m. So the volume of the pond is calculated to be 207.6 m^3. Table 4 shows the volume of runoff for different blocks and the volume of retention pond.

Table 4. Volume of Runoff and Retention Pond Volume

Denoted Area	Area, A (sqm)	Intensity of Rainfall, I (cm/hr)	Time of Concentration, tc (min)	Total Volume of Runoff, V=CIAtc (m^3)	Retained Water in Retention Pond (m^3)
Block 1	1147.695	10.35	96.5	172.0	207.6
Block 2	1193.705	10.35	96.5	178.8	207.6
Block 3	1224.571	10.35	96.5	183.5	207.6
Block 4	1282.562	10.35	96.5	192.1	207.6
Block 5	1426.949	10.35	96.5	213.8	207.6
Block1&2	2341.400	10.35	96.5	350.8	207.6
Block2&3	2418.276	10.35	96.5	362.3	207.6
Block3&4	2507.133	10.35	96.5	375.6	207.6

Result and Discussion

From Table 4 it is clear that a retention pond performs well if the catchment area considered is relatively small. With the increasing area the volume of runoff and the depth both increases. If we compare the total volume of runoff generated from a block and retention pond volume the following graph (Fig. 3) can be produced. From the graph it is evident that retention pond performs well under a single block of area less than 1400 m^2. If two or more adjacent blocks are combined the runoff produced cannot be retained in a single pond.

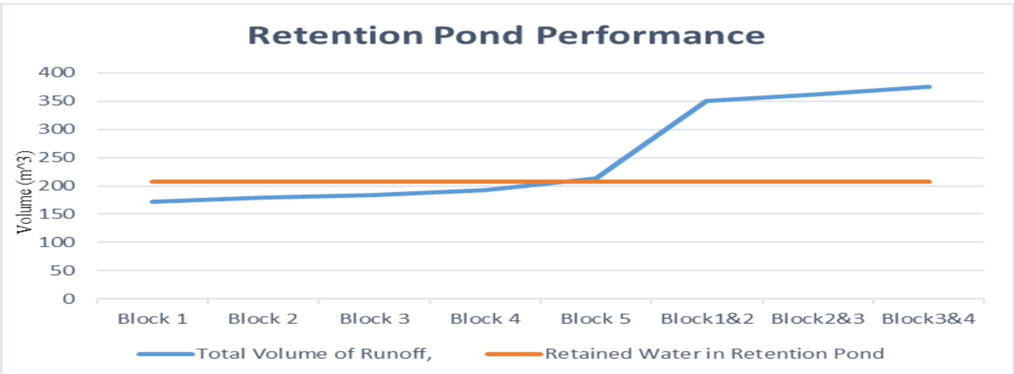


Figure 3. Retention Pond Performance Based on Runoff and Retained Water

Conclusions

The idea of retention pond is yet to be introduced in Dhaka city but it appears to be feasible and could provide the solution for urban flooding. The water retained can be used for firefighting in case for any emergency, for gardening in the nearby buildings and for gardening beside the streets, for producing a green field, for non-potable use, for car wash and other cleansing purposes, for ground water recharge. From the study it is clear that if RAJUK's MGC ratio can be applied there will be a lot more vacant space to construct retention ponds. Most of the cities of under-developed and developing countries in the world are facing the urban flooding problem because of rapid and unplanned growth. Natural water bodies are often encroached for industries or habitats. So the water after a storm event has no place to be retained. This sustainable solution can provide a good option for any urbanized settlements like Dhaka to reduce urban flooding. The study allows a better use of the unused land in between multiple structures to solve urban flooding problem. As a result, less water will get into the storm sewers. With minimum cost the idea can be implemented, but the Government and NGOs should raise awareness before implementation. This study has showed the capacity of the modelling system for urban drainage in a combination with GIS as a powerful analyses tool for urban flooding problems. Further integration of mathematical modelling and GIS will contribute to even more efficient and versatile studies.

Acknowledgments

The author acknowledges Mrs Farida Shaheen of Bangladesh Meteorological Department for providing the daily and 3-hour rainfall data of Dhaka. The author is also grateful to Mr. Premanondo Debnath of CEGIS for his help throughout the study.

References

Ahammed, F., Hewa, G. (2011) "Adaptation to climate change on water resources in Bangladesh", *Proceedings of the 34th IAHR World Congress and 33rd Hydrology and Water Resources Symposium*, Brisbane, Australia 718–725.

Ahammed, F., Hewa, G.A., Argue, (2012) "Introducing leaky-well concept for stormwater quantity control in Dhaka", *Bangladesh, Appl Water Sci*(2013) 3:115-123.

Hasnat, M. A. (2006) "*Flood Disaster Management in Dhaka City. In Options for Flood Risk and Damage Reduction in Bangladesh*", edited by K. U. Siddiqui and A. N. H. A. Hossain, Dhaka: University Press Limited and Institute of Water Modelling.

Mushfiqul, D. M. (2017) "Estimation of Land Use and Infiltration: Dhaka City", *B SC Engg. Thesis*, Civil Dept., BUET.

Rahman, A. K. M. F. (2006) "*The Impact of Floods on Major Highways and Mitigation Options, In Options for Flood Risk and Damage Reduction in Bangladesh*", edited by K U Siddiqui and A N H A Hossain, Dhaka: University Press Limited and Institute of Water Modelling.

Rimi, S. S., Matin, M. A. (2016) "Analysis of Rainfall Data for Generation of Intensity-Duration_Frequeny Relationships for Selected Urban Cities of Bangladesh", *3rd International Conference on Advances in Civil Engg.*, CUET.

EXPLORING THE RELATION BETWEEN GROUNDWATER LEVEL CHANGES AND TELECONNECTION ENSO INDICES IN NORTHWESTERN PART OF BANGLADESH OVER 1981-2017

Roquia Salam[1], Shakibul Islam[1] and A.R.M. Towfiqul Islam[1,*]

ABSTRACT

Groundwater based irrigation in the northwestern part of Bangladesh is considered to hold the key for economic growth and poverty reduction. However, the associated consequences of the groundwater level declination are not clearly understood due to lack of adequate monitoring wells and scientific investigation. In this study, we present the first time attempt to explore the relationship between groundwater level changes and teleconnection ENSO indices (IOD, MEI, NAO, SST and SOI) using Pearson Correlation Matrix in the northwestern part of Bangladesh. The analysis reveals a very weak positive correlation between groundwater level declination and teleconnection ENSO indices, except SST which shows a very weak negative correlation with groundwater level declination in the study area. So, it can be said that teleconnection ENSO indices have little or no effects on declining the groundwater level in the northwestern part of Bangladesh.

Keywords: Groundwater level, Northwestern part of Bangladesh, Pearson correlation, Teleconnection ENSO indices.

Introduction

Groundwater is one of the most important renewable resources which play a vital role in nation's livelihood, economies and agriculture sector. The water stored underground both in the aquifers and void spaces within soil is known as ground water. It is a resource which is both natural and dynamic. Ground water depletion is the common concern around the world and its effect is more prominent in the developing countries like Bangladesh. Bangladesh is an agricultural based country and here, the agricultural irrigation is totally depending on groundwater, particularly in the northwestern part of Bangladesh. Irrigation aided by ground water is used for the cultivation of high-yielding rice in the dry period of the year, where Bangladesh is the fourth biggest rice producing nation in the world (Scott and Sharma, 2009). Approximately 75% of groundwater is used for irrigational purposes in the northwestern part of Bangladesh (Jahan et al., 2015). Rainfall variability which may be a consequence of ENSO teleconnection is responsible for groundwater storage changes. Ever increasing ground water abstraction for irrigation and no increase in rainfall have caused the groundwater level falls to the extent of not getting fully replenished in the recharge season causing the overdraft in the northwest Bangladesh (GoB, 2002). The problem is becoming progressively more acute with the growth of population and extension of irrigated agriculture. Depletion of water table is a growing matter of concern for the global as well as regional food supply. Both human intervention and variation in climate affect the groundwater recharge, including excess withdrawal and abstraction of groundwater. Understanding and determination of how these climate variations affect components of the hydrologic cycle and occurrences, intensities, and locations of extreme events is one of the major challenges for scientists and decision makers. Climate variability cycles (teleconnection ENSO indices), such as Southern Oscillation Index (SOI), Pacific Decadal Oscillation (PDO), Atlantic Multi-Decadal Oscillation (AMO) and North Atlantic Oscillation (NAO), Indian Ocean Dipole (IOD) etc are responsible and also can alter the behavior of hydrological cycle leads to ground water storage changes (IPCC, 2001). So far, yet any study is carried out to explore the relation between groundwater level and teleconnection ENSO indices, not only in the northwestern part of Bangladesh but also in other region of Bangladesh. Therefore, this study focuses on the relationship between ground water levels with teleconnection ENSO indices (IOD, MEI, NAO, SST and SOI) in the northwestern part of Bangladesh.

Literature review

Zafor et al., (2017) analyzed the groundwater table inconstancy in Sylhet region, Bangladesh, using nonparametric Mann-Kendall (MK) Test, Sen's slope of estimator, Geostatistical Method, Spatial Prediction Method and Generation of Best Fitted Models. The consequence of this study confirmed the downward trend

[1]*Department of Disaster Management, Begum Rokeya University, Rangpur 5400, Bangladesh, Author:ruquiasalam@gmail.com, mrshakib2010@yahoo.com,,*Corresponding author: towfiq_dm@brur.ac.bd*

of groundwater level indicates that the floor of water level is actually lowering day by day. However, this study does show the relationship between ground water table variation and teleconnection ENSO indices.

Rahman et al., (2016) determined and evaluated the spatial and temporal variations in the groundwater table for the period of 1991–2009 and probable causes of depth of water table changes in the northwestern part of Bangladesh. The final results show lowering trends in dry as well as monsoon seasons and mean yearly groundwater level other than several discrepancies in NW Bangladesh. However, this study does not show any linkage among SOI, NAO, MEI, SST, IOD and changes of water table depth in the northwestern part of Bangladesh.

A study carried out by Mitra et al., (2014) to analyze the effect of ENSO-augmented climate variability on groundwater levels in the lower Apalachicola-Chattahoochee-Flint river basin by using Wavelet analysis and Mann-Whitney tests. Final results reveal a powerful relationship between groundwater level variances and ENSO. However, this study does not reveal the linked of ground water level to NAO, IOD, MEI, SST, MOI etc teleconnection ENSO indices.

Barco et al., (2010) analyze the groundwater level constancy and correlation between climate variability and groundwater levels in Calleguas Creek watershed located in southern California using Prewhitening methods, correlation matrix, fast Fourier transform and Mann-Kendall test. It has been noticed that the reaction of groundwater levels is highly impacted by longer-persistence climate activities like the Pacific Decadal Oscillation and also El Niño Southern Oscillation (ENSO). However, this study does not show the spatial distribution of groundwater level for the study area.

Methodology

Data source

The montly groundwater level data of Rangpur, Dinajpur, Rajshahi, Bogra and Pabna districts, for the period of 1981-2017, were obtained from the Bangladesh Water Development Board (BWDB) and Monthly values of SOI, MEI, IOD and NAO are obtained from the National Oceanic and Atmospheric Association (NOAA) Climate Prediction Center (CPC) for the period of 1981-2017.

Method

Pearson's Correlation Matrix

Pearson's correlation is a measure of the direct connection between's two variables X and Y, giving a worth amongst +1 and −1 comprehensive, where 1 is all out positive correlation, 0 is no correlation, and −1 is complete negative correlation. Assume that there are two variables X and Y, each having n values X_1, X_2, . …, X_n and Y_1, Y_2, . . . , Y_n respectively. Let the mean of X be $\bar{X}$ and the mean of Y be $\bar{Y}$. Pearson's r is ((Tomar et al., 2016):

$$r = \frac{\sum(X_i-\bar{X})(Y_i-\bar{Y})}{\sqrt{\sum(X_i-\bar{X})^2\sum(Y_i-\bar{Y})^2}} \quad \text{..........} \quad (1)$$

Where, the summation proceeds across all n possible values of X and Y.

Study area

Geographically, northwestern part of Bangladesh extends from 26^0 N to 24^0 N latitude and from 88^0 E to 89^0 E longitudes (Jahan et al., 2010). It has 34,600 km^2 in area (Figure 1). This area belongs to three main climate as winter, premonsoon and monsoon. There are 5 selected districts are included in study area from NW region which are Rangpur and Dinajpur districts in Rangpur division and Rajshahi, Bogra and Pabna districts in Rajshahi division.

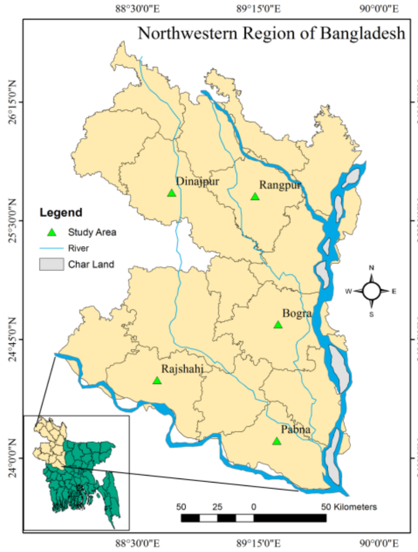


Figure 1. Location map showing the study area

Result

Figure 2 shows the Pearson correlation among groundwater level, SOI, NAO, MEI, SST and IOD. In Pearson correlation r and p value are proportional to each other indicating with the increase of r value, p value also increase or with the increase of p value, r value also increase. If absolute value of r >0.7, then it poses a strong relationship. If absolute value of r is 0.5 < r < 0.7, then the two variables show a moderate relationship. If absolute value of r is 0.3< r <0.5, then the two variables show a weak relationship. Finally, if absolute value of r <0.3, then it poses a very weak relationship (Moore et al., 2013). Figure 2a shows the relation between GWL and IOD, where r=0.044 (< 0.3) and p=0.36, indicating a very weak positive correlation. Figure 2b shows the relation between GWL and MEI, where r=0.011 (< 0.3) and p=0.82, indicating a very weak positive correlation. Figure 2c shows the relation between GWL and NAO, where r=0.061 (< 0.3) and p=0.2, again indicating a very weak positive correlation. Figure 2d shows the relation between GWL and SST, where r= -0.001 (< 0.3) and p=0.97, indicating a very weak negative correlation. Figure 2e shows the relation between GWL and SOI, where r=0.061 (< 0.3) and p=0.2, also indicating a very weak positive correlation. All of the teleconnection ENSO indices show insignificant correlation with groundwater level. Although SOI, NAO, IOD and MEI have an insignificant positive correlation with groundwater level which indicates that they are poorly responsible for decreasing the groundwater level of the study area, SST has an insignificant negative correlation with groundwater level indicating with the increase of SST, groundwater level increase and with the decrease of SST, groundwater level decrease of the study area.

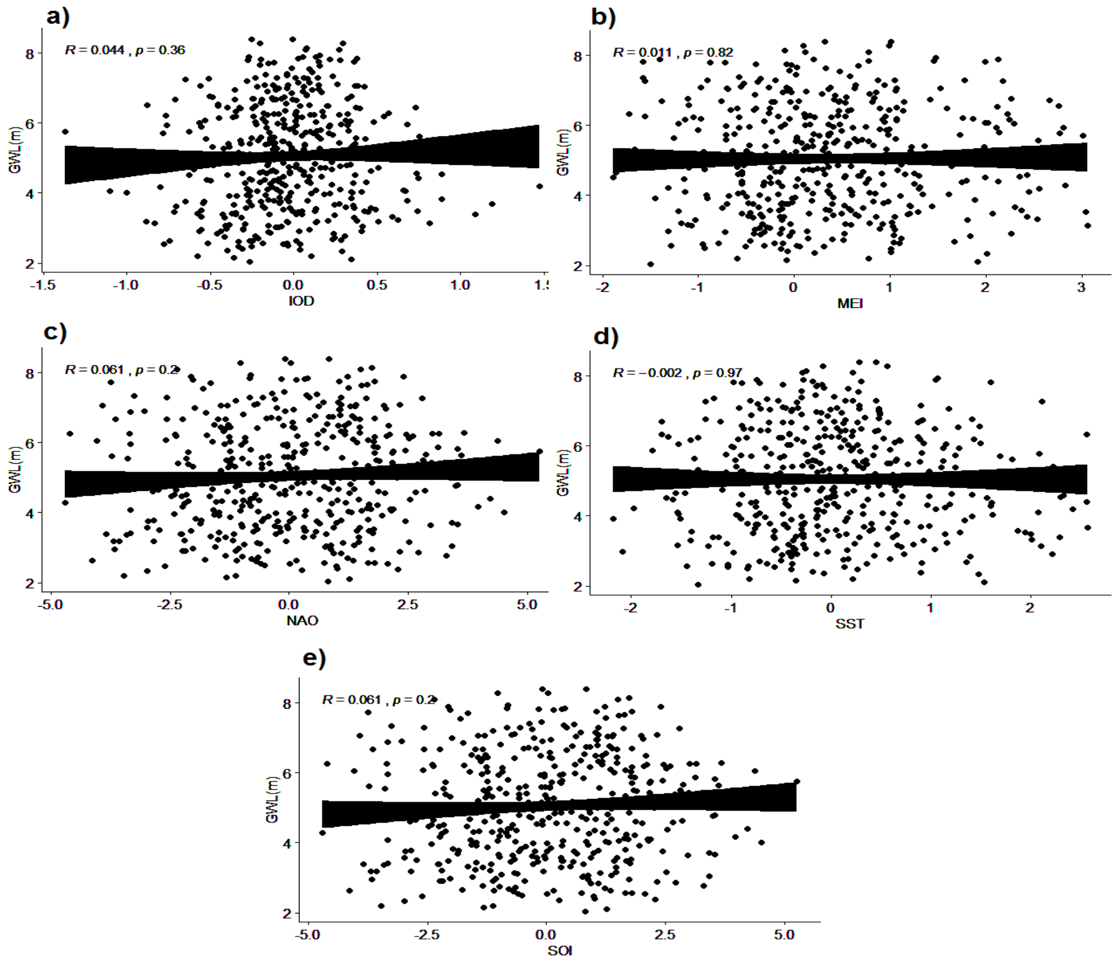


Figure 2. Pearson correlation between a) GWL and IOD; b) GWL and MEI; c) GWL and NAO; c) GWL and SST and d) GWL and SOI.

Discussion

Pearson correlation reveals that teleconnection ENSO indices have little effect on lowering the groundwater level of the study area. Out of five teleconnection ENSO indices, four indices (IOD, MEI, NAO and SOI) have weakly positive correlation with groundwater level indicating that with the increased of the value of these four indices, groundwater level is slightly decreased gradually. This may be due to geographical, geological and climatic condition of the study area. However, SST shows an insignificant negative correlation with groundwater level. This may due to the impact of climate change, as sea surface temperature increased due to climate change which is responsible for expanding the sea surface as well as salt water intrusion is the ultimate result for balancing the water level mostly in dry period leading to both increasing groundwater level and depletion groundwater quality (Rahman et al., 2009). This result is similar to Ahmed et al., (2016) who revealed that the precipitation (annual or monsoon) of whole Bangladesh and almost all of the spatial regions did not show any significant correlation with ENSO events, except the average IOD values showed significant correlation only in monsoon precipitation of western region.

Conclusion

Correlation analysis between groundwater level and teleconnection ENSO indices focuses a weak correlation of teleconnection ENSO indices for decreasing groundwater level in the study area which may be due to hydro-geological and climatic setting in the study area. It can be said that ENSO could not affect groundwater level depletion. An interesting finding is that SST shows negative correlation with groundwater level depletion, this is may be due to the impact of climate change. Out of 16 districts in northwestern part, only 5 districts are used for this study which is a limitation for this study.

Acknowledgement

Thanks to the Bangladesh Water Development Board (BWDB) and National Oceanic and Atmospheric Association (NOAA) Climate Prediction Center (CPC) for providing some important data for this research.

References

Ahmed, M. K., Alam, M. S., Yousuf, A. H. M. and Islam, M. M. (2016), A long-term trend in precipitation of different spatial regions of Bangladesh and its teleconnections with El Niño/Southern Oscillation and Indian Ocean Dipole, Theor Appl Climatol, DOI 10.1007/s00704-016-1765-2

Barco, J., Hogue, T. S., Girotto, M., Kendall, D. R., and Putti, M. (2010), Climate signal propagation in southern California aquifers. Water resources research, 46:5, DOI: 10.1029/2009WR008376.

Government of Bangladesh. (2002), Second national report on implementation of United Nations convention to combat desertification. Bangladesh. Government of Bangladesh (GOB) Report, Ministry of Environment and Forests, Dhaka.

IPCC. (2001), Climate Change 2001: Impacts, Adaptations, and Vulnerability. Contribution of working group II to the third assessment report of the Intergovernmental Panel on Climate Change, Cambridge, U.K., Cambridge University Press.

Jahan, C. S., Mazumder, Q. H., Islam, A. T. M. M., and Adham, M. I. (2010), Impact of irrigation in Barind area, NW Bangladesh—an evaluation based on the meteorological parameters and fluctuation trend in groundwater table. Journal geological society of india, 76:134–142, DOI : 10.1007/s12594-010-0085-x

Jahan, C.S., Mazumder, Q.H., Kamruzzaman, M. and Rahman, A.T.M.S. (2015), Stress on Groundwater Resource in Drought Prone Barind Area, Bangladesh: Study of Climate Change and Irrigation Effect, In: M. Thangarajan, C. Mayilswami, P.S. Kulkarni and V.P. Singh (Eds.) Groundwater Prospecting, Evaluation and Management of Aquifers, Cambridge Scholars Publishing, UK. Accepted on 18 January, 2015.

Mitra, S., Srivastava, P., Singh, S., and Yates, D. (2014), Effect of enso-induced climate variability on groundwater levels in the lower Apalachicola-Chattahoochee- flint river basin. American society of agricultural and biological engineers, 57(5):1393-1403, DOI 10.13031/trans.57.10748

Moore, D. S., Notz, W. I and Flinger, M. A. (2013), The basic practice of statistics (6th ed.), New York, NY: W. H. Freeman and Company.

Rahman, D.A., Alam, M.M., Mainuddin, M.K., Ali, M.L., Alauddin, M.S.M., Rabbani, M.M.G., Miah, D.M.M.U., Uzzaman, M.M.R. and Amin, M.S.M.A. (2009), The probable impacts of climate change on poverty and economic growth and the options of coping with adverse effect of climate change in Bangladesh (Policy study), supported to Monitoring PRS and MGDs in Bangladesh, General Economics Division, Planning Commission, Government of the People's Republic of Bangladesh and UNDP Bangladesh

Rahman, A. T. M. S., Kamruzzaman, M., Jahan, C. S., Mazumder, Q.H., and Hossain, A.(2016), Evaluation of spatio-temporal dynamics of water table in northwest Bangladesh: an integrated approach of gis and statistics, Sustainable water resource management, 2:297–312, DOI 10.1007/s40899-016-0057-4

Scott, C., and Sharma, B. (2009), Energy supply and the expansion of groundwater irrigation in the Indus-Ganges Basin. International journal of river basin management, 7:119-124

Tomar, A. S., Srivastava, A., and Kumar, S. (2016), An implementation of pearson correlation method for predicting items to user in e-commerce. International journal of engineering sciences & research technology, 5 (7).

Zafor, M. A., Alam, M. J. B., Rahman, M. A., and Amin, M. N. (2017), The analysis of groundwater table variations in Sylhet region, Bangladesh. Environmental engineering research, DOI: 10.4491/eer.2016.152

ADAPTATION TO CLIMATE CHANGE THROUGH DISASTER-RESILIENT HOUSING PRACTICE IN THE COASTAL ZONE OF BANGLADESH.

M. R. Rahman[1], A. A. Muhaymin[2] and M. M. Rahman[3]

ABSTRACT

The coastal area of Bangladesh has experienced frequent cyclones associated with storm surges in the last few decades. After the 1990s, activities like construction of cyclone shelter, early warning system, and awareness building program plays a very effective role to reduce the fatalities and damages due to disaster in the coastal area. Though the actions were effective still a large number of houses are damaged due to disaster on a regular basis and cause repetitive economic losses and distresses to the people. From several studies on post-disaster shelter response, has highlighted the need for more contextual approaches such as the construction of the individual housing unit using a participatory approach to make a community more resilient. The aim of the paper is to systematically capture the hazard responses of the individual housing unit, which was developed based on the participatory design process in the coastal zone of Bangladesh. Including absorbing shocks, securing food and water safety, the house can relocate and its materials could be preserved to reduce the repair cost after disaster for ensuring resilience. A schematic prototype house is offered which can adapt to the impact of cyclone-induced storm-surges of the coastal area is under study. Furthermore, upgrading the existing design by addressing the limitations through monitoring and evaluation will enhance the resilience of construction of individual housing unit in the future.

Keywords: Adaptation, hazard response, participatory approach, resilience

Introduction

Bangladesh is one of the most vulnerable countries of the world in the event of climate change (Ali, 1999) and experiences 40% of the total cyclone-induced storm surge events of the world (Murty & El-Sabh, 1992). The coastal zone of Bangladesh is a most vulnerable area for such hazards because of low-lying and relatively flat terrain, geographical setting at the edge of the Bay of Bengal, high tidal range, high density of population and fragile coastal protection system (Dasgupta et al., 2010). In the last decades, the most disastrous events were Sidr in 2007 and Aila in 2009, which mostly affected the housing sector. Because of illiteracy and lacking an idea of a modern house, these coastal people built their non-engineering houses by using locally available woodcraft, artesian using wood, bamboo, tin, and thatches for living somewhat only (Zisan et al., 2013). Henceforth, they have to lose their houses every year even a normal storm condition. Lacking proper knowledge, selection of material and affordability, they will not able to repair their house in a precise way. Aila in 2009, across 11 of the nation's 64 districts, approximately 600,000 thatched homes were damaged or destroyed. Unluckily, Bangladesh National Building Code-93 (BNBC-93) doesn’t provide any provision for wind and surge resistant design for above mentioned non-engineering housing (Zisan et al., 2013). To minimize the losses of housing units and for ensuring the safety of basic needs, it’s essential to develop new regulation and guidelines for the non-engineering rural house with a minimum construction and repair cost. Considering the above facts, the aim of the paper is to link this knowledge gap through a participatory approached prototype construction in the coastal area.

Concepts of Disaster Resilient House as an Adaptation

Adaptation includes the adjustments to climatic changes, including moderating potential damage, taking advantage of opportunities, and coping with the consequences (Schipper, 2007). On the other hand, International Strategy for Disaster Reduction (ISDR) defines resilience as the capacity of a system, community or society that is potentially exposed to a hazard, to adapt to it by resisting changing so that it reach and maintain an acceptable level of functioning and structure (Sadeka et al., 2013). Therefore, resilience perspective on adaptation emphasizes learning, self-organization, and flexibility as crucial ingredients for navigating complex feedbacks, thresholds, and system changes (Berkes et al., 2003). Ultimately, the proper adaptation of a system reduce its vulnerability and enhance the resilience to observed and anticipated impacts

[1] *Research assistant, DECCMA, Institute of water & flood management, BUET, Dhaka- 1211, Bangladesh.*
[2] *Lecturer, Department of architecture, BUET, Dhaka – 1211, Bangladesh.*
[3] *Professor, Institute of water & flood management, BUET, Dhaka- 1211, Bangladesh.*
Email of the Corresponding author – peyash.in@gmail.com

of climate change. In disaster-resilient housing concept, it refers to those structures that are expected to not collapse or be destroyed but may still suffer some damage that can be restored. Disaster resilient housing means to build structures and a community considering the disaster resiliency strategies and risk reduction measures so that the houses can withstand the impact of any natural hazard. Besides absorbing shocks of disaster, the house will also ensure the food and water safety during a critical time. After that, it will give enormous support to the restoration of normal time rapidly. A disaster resilient housing does not only depend on the structure, material, design, and construction of the houses but also depends on the socio-economic conditions, administrative and local governance of the community.

Design Concept and Responses of House

The design has focused on generating resilient home structure for present socio-economic and climatic contexts adopting 'Participatory design' process to define and resolve the present challenges; generating climate, culture, economy, and gender responsive issues in the coastal area. It has involved the community including women and children to exploit local wisdom and technocrats would contribute through incorporating appropriate technology to adapt and mitigate the prevailing challenges. The design has adapted through the consultation with community mason and craftsmen and they are able to implement the design using locally available natural materials such as bamboo, golpata, timber etc. So if necessary they would be able to rectify any flaws generated in any given situation and time.

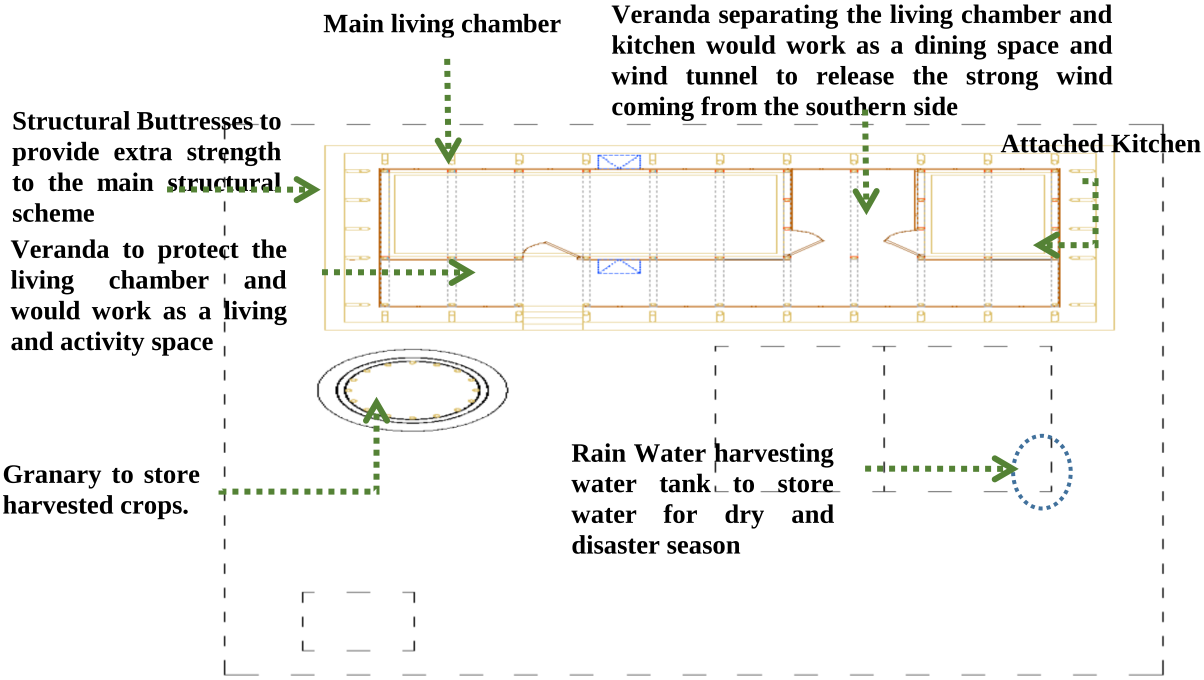


Figure 1. Proposed housing plan.

The proposal of house design made with a bedroom, a kitchen, and space, which can work as a dining space and wind tunnel to release the strong wind coming from the southern side. The house plan is rectangular and symmetrical shape to allow high winds to go around them. The whole design also includes a granary to store crops and a rainwater harvesting system to secure enough water to adapt during dry and disaster times shown in figure 1.

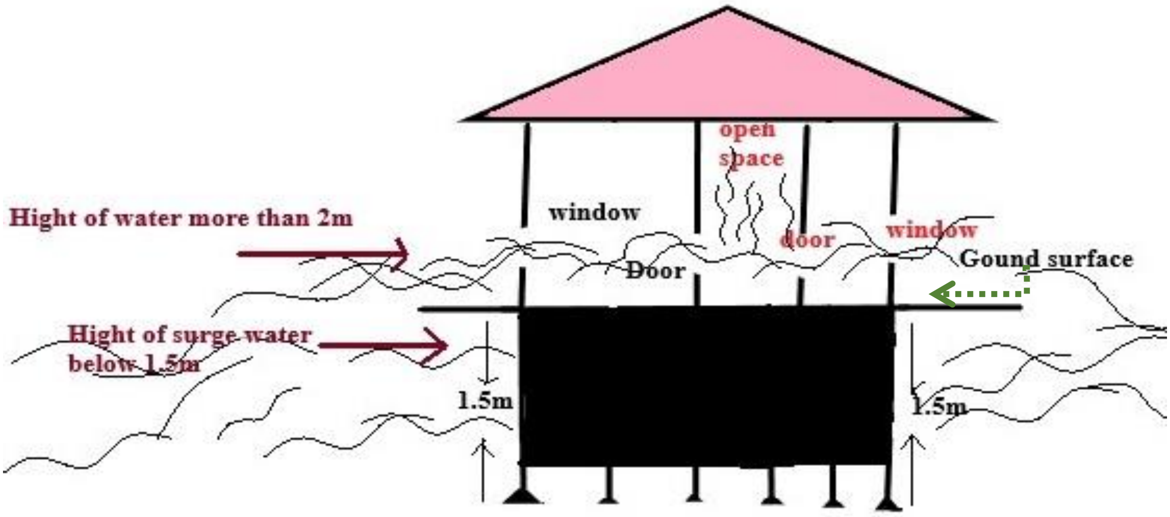


Figure 2. Schematic responses of the house against flood condition.

Figure 2 represents how the house will response during a flood condition. Where plinth height of the house been raised about 1.5 m above the existing ground levels to prevent floodwater entering the house. For storm surges such as Aila, openings have provided near the bottom of walls to allow floodwater to move through the house without causing it to collapse. To prevent the walls from collapsing due to the high pressure caused by the water, doors, and windows were placed in opposite walls to allow water from floods to flow out of the house.

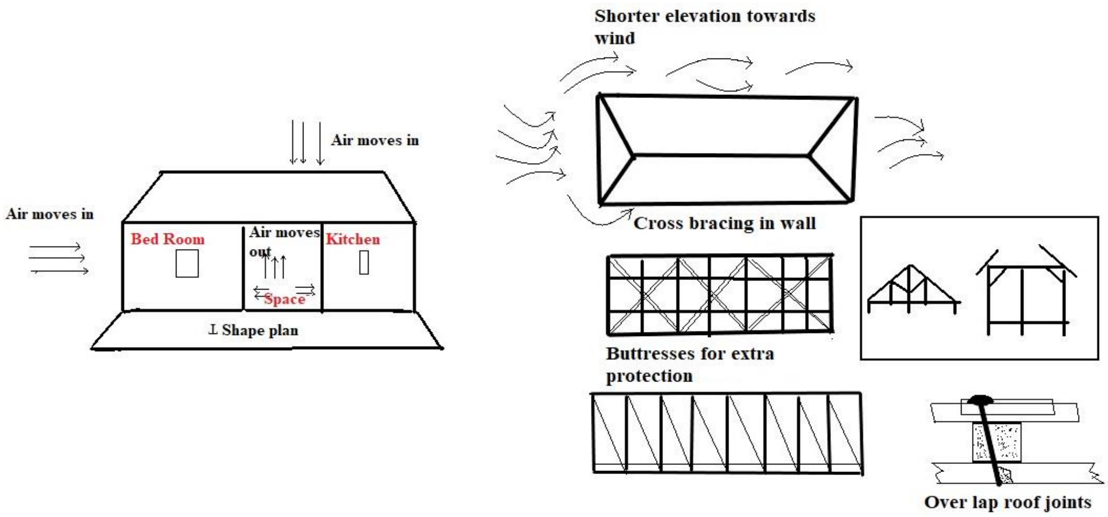


Figure 3. Schematic features of design and responses against wind speed.

The design plan also includes options for sustaining against cyclonic wind speed. Figure 3 gives the idea of house features that used for construction and how it will respond during a cyclonic event. Where it represents the space between bedroom and kitchen specially designed as a dining space and wind tunnel to release the strong wind coming from the southern side. The shorter elevation of the house has faced towards the dominant direction of strong winds to reduce wind pressure on the construction. During construction, the roof materials have properly tied with the roof structure with extra protection over it to avoid any pressure that could blow away the roof. Bamboos were strongly fixed to each other and the frame includes buttresses that will provide extra protection of the main structural system against strong and lateral forces and avoid the building lifting off the ground shown in figure 4(b). The walls have made strong with vertical and horizontal bamboos and with sufficient cross bracing to reduce the wind load on the structure.

(a) (b) (c)

Figure 4. Implementation of design. (a) Structural frame of the house. (b) Structural buttresses to provide extra protection of the main structural system against strong and lateral forces. (c) Granary for food security.

Monitoring and Evaluation

In December 2017, the design has implemented at Dacope of Khulna district in Bangladesh. Dacope is known for Aila affected area. After implementation, the house is still in routine basis monitoring program. Last one year we tried to keep in touch of users especially in the time of natural calamities such as northwester, heavy rainfall, flooding condition, and natural depression etc. to find out how the house is responding against disaster and design lacking. Through user's feedback, it has been evaluated that they are psychologically satisfied by using it and seems that this housing unit improves their social status in society. Until any extreme event as Aila 2009 didn't hit that area but the house has faced 5 times low to medium types of natural calamities in last one year, which has described in Table 1. Major damage hasn't occurred yet and a very small amount of cost was required for repair and restoration.

Table 1. Systematically capturing information of hazard responses of the house.

Date	Types of Hazard	Magnitude	Impact on house	Types of damage	Repair cost
March, 2018	Northwester	Warning signal 3	No impact	No damage	NA
April, 2018	Northwester	Warning signal 3,4	No impact	No damage	NA
July, 2018	Heavy rainfall	----------------	Small impact	Small hole in roof	Significant
September, 2018	Depression in Bay of Bengal	Warning signal 3	No impact	No damage	NA
October, 2018	Cyclone Titli	Warning signal 2,3,4	No impact	No damage	NA

Conclusions and Recommendations

The coastal area of Bangladesh is vulnerable to cyclone-induced surges, which directly affect the housing sector. The proposed design conceived as an action research work, which covers the adaption through housing unit during a hazard that could enhance the resilience of a community. This paper would let us explore in real context and issues which would be very vital to generate the resilient building structure in near future. However, from monitoring and evaluation of the house performance, recommendation for further research would be that the design materials are natural, which are susceptible to decay. Its need to take all the possible measures to increase the longevity of the materials. Besides, users of the design should be aware of that fact and need to conduct routine basis monitoring and maintenance of structure for more robustness against disaster.

References

Ali, A. (1999). "Climate change impacts and adaptation assessment in Bangladesh", *Climate Research,12,109–116.*

Berkes, F., Colding, J., and Folke, C. (2003). "Navigating social-ecological systems: building resilience for complexity and change", *Cambridge University Press,* Cambridge, UK.

Dasgupta, S., Huq, M., Khan, Z. H., Ahmed, M. M. Z., Mukherjee, N., Khan, M. F., and Pandey, K. D. (2010), "Vulnerability of Bangladesh to cyclones in a changing climate: potential damages and adaptation cost", *World Bank Policy Research Working Paper Series,* 5280.

Murty, T. S., and El-Sabh, M. I. (1992). "Mitigating the effects of storm surges generated by tropical cyclones: A proposal", *Natural Hazards, 6(3), 251-273.*

Sadeka, S., Reza, M. I. H., Mohammadand, M. S., and Sarkar, M. S. K. (2011). "Livelihood Vulnerability due to Disaster: Strategies for Building Disaster Resilient Livelihood", *2nd International Conference on Agricultural, Environment and Biological Sciences (ICAEBS '2013),* Pattaya, Thailand.

Schipper, E. L. F. (2007). "Climate change adaptation and development: exploring the linkages*", Working Paper 107, Tyndall Centre for Climate Change Research,* Norwich, UK.

Zisan, M. B., Alam, M.R., Hasan, M.M., and Akter, S.S. (2013). "Cyclone Resistant Low-Cost Housing in Coastal Ares of Bangladesh", *International Journal of Science, Environment, 2(1),* 48 – 55.

DESIGN OF STORMWATER DRAINAGE NETWORK WITH LIMITED RAINFALL DATA USING GEOSWMM: CASE STUDY FOR DINAJPUR CITY

Sayedul Kibria[1], Rahul Biswas[2]

ABSTRACT

Climate change will affect water resources through its impact, variability, timing, formation and intensity of precipitation. Improved management of storm water is critical, if addressed inadequately. Urban flooding is significantly different from rural flooding as urbanization leads to developed catchments, which in turn increases the flood peaks and flood volumes. Such urban flooding is basically due to the defective and inefficient urban drainage systems, and cause damage to public and private buildings and disrupts public life. Significant progress in urban growth and infrastructural development has been observed in Dinajpur city and as result; provision for adequately planned drainage network has become mandatory. This study focuses on designing an adequate drainage system with limited rainfall data available. The drainage line and sub catchments are defined using percentage of imperviousness and further divided according to elevation. The catchment is divided into small sub catchments, conduits, with several junction nodes. Daily rainfall data is obtained from nearby rain gage station. ArcGIS used for processing Digital Elevation Model. Modeling approach is used to generate catchment runoffs. In conclusion of the study minimum cross- sectional area of each conduit has been calculated from the conduit discharge obtained from the model GeoSWMM output. It has been found that as the intensity of rainfall for 10 years return period is higher than that of 5 years return period, the design cross sections of 10 years return period are greater.

Introduction

Adequate scientific evidence (4th Assessment Report, IPCC) exists now to show that the global climate is changing. Urbanization causes extensive changes to the land surface beyond its immediate borders, particularly in ostensibly rural regions, through alterations by agriculture and forestry that support the urban population (Lambin et al, 1999). Rapid urbanization has increased the volume of storm water runoff by increasing imperviousness. Managing the drainage system to safely and adequately drain this excess runoff is a crucial issue. Paucity of data makes it even more difficult to make provisions for designing proper drainage system. One of the prime objectives of this study is the determination of runoff of different sub catchment associated with Dinajpur Sadar Upozilla.The study also proposes the design of drainage network with the limited data. Previously no study on drainage management of Dinajpur has been carried out and hence we cannot compare our results of this study with other studies. The storm water flow can be determined by using the rational method, hydrograph method, rainfall-runoff correlation studies, digital computer models, inlet method or empirical formula. In addition to this, several hydrological models are also available for urban flood management that includes HEC-1(US ARMY CORPS OF ENGINEERS), US EPA SWMM, PCSWMM, HEC-HMS. GEOSWMM (developed by Streams Tech, Inc.) is a hydraulic, hydrologic and water quality model integrated with ArcGIS. It allows users to simulate flow, velocity of water, depth of water, and water quality for projects ranging from a simple site development to a complex urban watershed involving open channels, sewers, pumps, hydraulic structures and Best Management Practices (BMPs). EPA's SWMM 5 is the most widely used model for urban drainage as well as sanitary sewer systems. GeoSWMM is built upon EPA's SWMM 5 model which requires users to manually enter data through its interface. GeoSWMM makes the input data preparation extremely easy and efficient through ArcMap based tools, geodatabase and mapping features.

Study Area

Dinajpur is the largest district among all sixteen northern districts of Bangladesh. Dinajpur sadar upazila is in the Dinajpur district and Rongpur division which has an area of 354.34 sq km, located in between 25°28'

[1]*MS student, Dept. of Water Resource Engineering, Bangladesh University of Engineering and Technology, City-Dhaka, Bangladesh*

[2]*Assistant Engineer, Bangladesh Water development Board, City-Cox'sbazar, Bangladesh*

Email of Corresponding Author – kibria.sayedul@gmail.com

and 25°48’north latitudes and in between 88°34’ and 88°46’east longitudes. Dinajpur sadar is bounded by Kaharole and Khanshama upazila in the north, West Bengal state of India on the south and Chirirbandar upazila on the east and Biral upazila on the west. Punarbhaba and Atrai are the two main rivers of Dinajpur district. Ramshagor Dighi is also notable water body located in Dinajpur. Punarbhaba and Atrai rivers flow alongside the border of Dinajpur sadar. Punarbhaba Enters Dinajpur at Abidpur and leaves at Gangarampur. Punarbhaba is a river of Bangladesh and West Bengal with a length of about 160km. Dinajpur is located on the east bank of Punarbhaba. River Atrai originates in Siliguri (West Bengal) and after flowing through Dinajpur district it enters India again. It linked with Jorapani River (India), Fuleswari River (India) and Karatoya River.

The elevation ranges from 29m to 44m above mean sea level and Dinajpur area can be categorized as a flat topographic area. It experiences a hot and humid tropical climate. It has a distinct monsoon season with an annual average temperature of 25°C (77°F).

Methodology

For Storm Water Drainage analysis, Digital Elevation Model (DEM) and rainfall data of the study area are required. For this study, ASTER Global DEM data of the study area was collected from USGS Earth Explorer website. For urban drainage design it is a common practice to use 2 hour- 5 years return period rainfall data. But that data was unavailable to us. Daily rainfall data at Dinajpur station for the time period of (1981-2017) have been collected from Bangladesh Meteorological Department (BMD). These data have been analyzed for annual variation. For the design of drainage of sewer systems, estimation of extreme rainfall intensities are required. Therefore, the annual maximum series, which is the set of maximum values observed during a period (minute(s), hour(s), or day) in each year are analyzed. The Gumbel Distribution was seleted to estimate extreme rainfall during the considered period. It is widely used probability distribution function for extreme values in hydrologic studies for prediction of flood peaks, maximum rainfall etc. Existing stream network is digitized from google earth for the creation of “AGREE DEM” and for the better examination of the portrayed streams with the actual streams of the study area, watershed delineation of the study area is done using GeoSWMM software.

Calculations

Maximum rainfall value for each year was identified and added in a separate worksheet in Microsoft Excel which is used for rainfall analysis using Gumbel’s Distribution.

Here,

N = sample size = 37

$\bar{x}$ = Mean of the variate= 182.324

$\bar{\sigma}$ =Standard deviation of the sample= 91.3716

$\bar{Y}$ =Reduced Mean= 0.5418

S_n=Reduced standard deviation of the sample= 1.13

For Return Period T= 5 years

Reduced variate, Y_T = - (0.834+2.303 log log (T ÷ (T-1)))

= - (0.834+2.303 log log (5 ÷ (5-1)))

=1.50039

Frequency Factor, K= (Y_T- $\bar{Y}$) ÷ Sn

= (1.5004 - 0.5418) ÷1.13

= 0.848

Value of the variable X with a return period T=5 years,

$X_T = \bar{x} + K\,\bar{\sigma}$ = 182.324+0.848 × 91.3716 = 259.807 mm

Similarly, for Return Period, T= 10 years X_T= 320.3 mm which means a rainfall of 320.3 mm will occur at least once in 10 years in our study area.

According to JICA reports, percentage of the rainfall with 5 years and 10 years return period is determined for different time steps.

Table 1. For 5and 10 years Return Periods, Percentage of Rainfall for different Time Steps.(According to JICA Reports)

Time Step (Hour)	Percentage	T=5Years X_T=259.807 mm	T=10Years X_T=320.3 mm
0-4	9	23.38	28.83
4-8	15	38.97	48.04
8-12	44	114.32	140.93
12-16	16	41.57	51.24
16-20	9	23.38	28.83
20-24	7	18.19	22.42

From the above table it is evident that 10 year return period rainfall intensity is higher than the 5 year return period rainfall.
For delineation watershed of Dinajpur City, ASTER DEM files were collected. Then this raster is clipped according to the Sadar Upozilla shapefile. The DEM is clipped taking extra area outside the study area to avois the missing of some subcatchments within the study area. Stream network from google earth was digitized which was then used for stream burning. After generating an Agree DEM a stream shapefile is generated from the Agree DEM Raster file. Some outlet points were generated automatically. The average slope of the subcatchment found from the model is 0.25%. The average width calculated from the model is 1748 m. The total sub catchment area of the study area is 391.7 km^2 . The N values for imperviousness, perviousness, depression storage imperviousness, depressin storage perviousness are assumed to be 0.1,0.1,0 and 100 respectively.
Flow rate, average water depth, flow velocity, volume of water are obtained from model simulation. The cross sectional areas of the conduits are designed according to the continuity equation. For designing cross section non-silting and non-scouring velocity, 0.8 m/sec is taken as design velocity. Maximum conduit flows are obtained from model simulation.

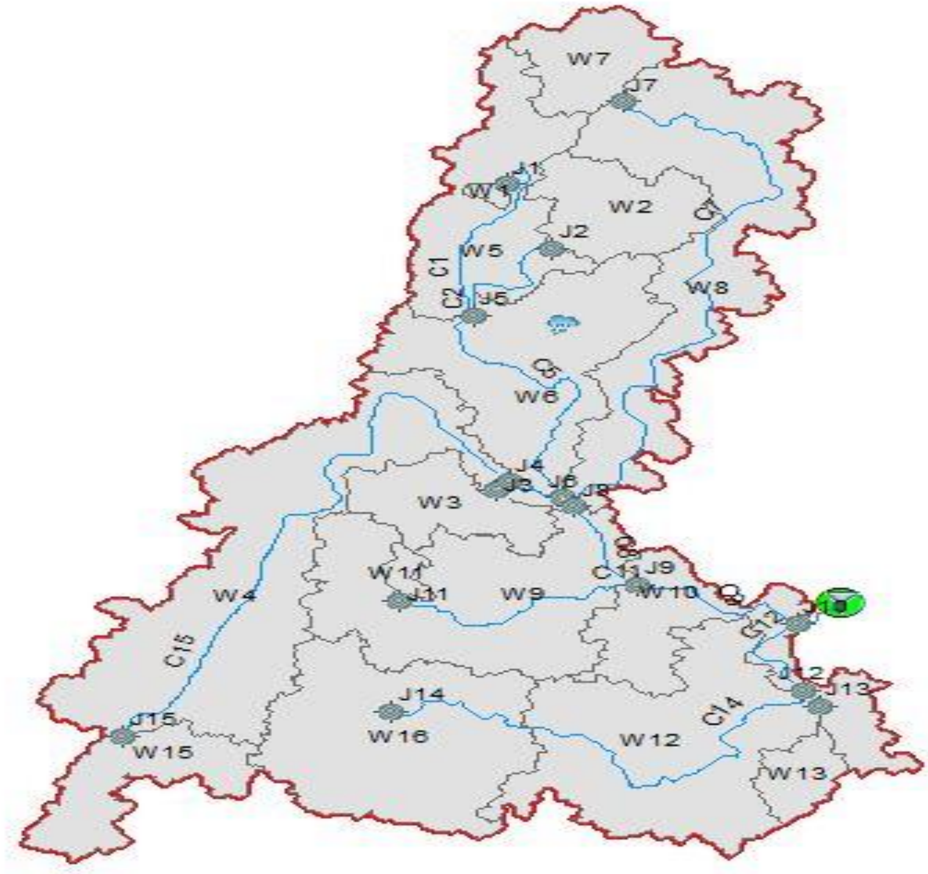


Figure 1. Delineated Watershed of Study Area using GeoSWMM

Result and Analysis

Watershed Delineation using GeoSWMM provides us with 15 sub-catchments divided by the canal network. The runoff values of each sub-catchment are given in Table 2 & 3. The values match with the values of runoff coefficient estimated using the land use map. The peak runoff for 5 year return period is 87.65 CMS in W4 sub- catchment and for 10 year return period the value is 118.67 CMS, again in the W4 sub-catchment. The total runoff for 5 year return period is around 125.176 mm and for 10 year return period it is 161.63 mm.
Flow rate, flow velocity (m/sec), Time of maximum flow occurence of link such as conduit, outlets are obtained from GeoSWMM simulation. Table 4&5 illustrate the conduit flow summary derived from GeoSWMM simulation. Table-6 illustrates the proposed cross sections of the conduits.

Table 2. Sub-catchment runoff for 5 years return period (simulated by GeoSWMM)

Subcatchment	Total Precipitation (mm)	Total Runoff (mm)	Peak Runoff (CMS)	Runoff Coefficient
W1	259.81	162.38	1.84	0.625
W2	259.81	149.29	24.41	0.58
W3	259.81	149.8	21.3	0.58
W4	259.81	133.52	87.65	0.51
W5	259.81	118.27	33.03	0.46
W6	259.81	109.24	40.94	0.42
W7	259.81	83.64	9.51	0.32
W8	259.81	97.54	48.14	0.38
W9	259.81	132.32	57.33	0.51

W10	259.81	115.29	20.22	0.44
W11	259.81	163.65	3.45	0.63
W12	259.81	95.83	48.94	0.37
W13	259.81	95.15	5.37	0.37
W15	259.81	129.96	20.12	0.5
W16	259.81	141.76	62.3	0.55

Table 3. Sub-catchment runoff for 10 years return period (simulated by GeoSWMM)

Subcatchment	Total Precipitation (mm)	Total Runoff (mm)	Peak Runoff (CMS)	Runoff Coefficient
W1	320.29	201.78	2.45	0.63
W2	320.29	196.21	33.26	0.61
W3	320.29	192.72	28.98	0.60
W4	320.29	177.02	118.67	0.55
W5	320.29	157.78	44.77	0.49
W6	320.29	134.52	55.29	0.42
W7	320.29	113.79	13.01	0.36
W8	320.29	128.12	65.33	0.40
W9	320.29	169.75	77.83	0.53
W10	320.29	147.33	27.51	0.46
W11	320.29	204.99	4.68	0.64
W12	320.29	128.12	66.53	0.40
W13	320.29	124.91	7.27	0.39
W15	320.29	160.15	27.2	0.50
W16	320.29	187.22	85.11	0.59

Table 4. Conduit flow summary, simulated by GeoSWMM for 5 years return period.

Link	Type	Maximum Flow (CMS)	Day Of Maximum Flow	Hour of maximum flow	Maximum Velocity (m/sec)
C1	CONDUIT	2.34	1	0:35	0.07
C2	CONDUIT	5.7	1	6:13	0.16
C3	CONDUIT	30.66	0	21:42	0.8
C4	CONDUIT	23.02	0	21:45	0.29
C5	CONDUIT	19.82	1	12:07	0.18
C6	CONDUIT	31.98	1	4:18	0.42
C7	CONDUIT	3.6	1	4:18	0.15
C8	CONDUIT	12.11	1	4:18	0.15
C9	CONDUIT	48.47	1	4:00	0.49
C10	CONDUIT	66.81	1	4:00	7.28
C11	CONDUIT	12.63	0	22:02	0.14
C12	CONDUIT	1.87	1	4:00	0.03
C13	CONDUIT	5.36	1	4:02	0.2
C14	CONDUIT	30.05	0	19:54	0.29
C15	CONDUIT	13.45	1	13:16	0.14

Table 5. Conduit flow summary, simulated by GeoSWMM for 10 years return period

Link	Type	Maximum Flow (CMS)	Day Of Maximum Flow	Hour of maximum flow	Maximum Velocity (m/sec)
C1	CONDUIT	3.54	0	22:55	0.1
C2	CONDUIT	8.63	0	23:02	0.16

C3	CONDUIT	33.14	0	19:08	0.8
C4	CONDUIT	24.99	0	19:11	0.29
C5	CONDUIT	21.42	1	19:09	0.18
C6	CONDUIT	43.54	1	4:08	0.55
C7	CONDUIT	4.90	1	4:08	0.16
C8	CONDUIT	16.58	1	4:08	0.16
C9	CONDUIT	48.72	1	0:11	0.49
C10	CONDUIT	74.13	1	0:11	7.52
C11	CONDUIT	16.33	0	20:46	0.17
C12	CONDUIT	2.08	1	0:11	0.03
C13	CONDUIT	7.27	1	4:01	0.21
C14	CONDUIT	31.18	0	18:12	0.29
C15	CONDUIT	18.48	1	11:33	0.18

Table 6. Conduit Cross Section Design (Circular Conduit)

Link	Design Velocity (m/sec)	Area (for 5 years return period) (m^2)	Area (for 10 years return period) (m^2)
C1	0.8	2.925	4.425
C2	0.8	7.125	10.788
C3	0.8	38.325	41.421
C4	0.8	28.775	31.238
C5	0.8	24.775	26.781
C6	0.8	39.975	54.425
C7	0.8	4.500	6.125
C8	0.8	15.138	20.725
C9	0.8	60.588	61
C10	0.8	83.513	92.663
C11	0.8	15.788	20.413
C12	0.8	2.338	2.600
C13	0.8	6.700	9.088
C14	0.8	37.563	38.975
C15	0.8	16.813	23.100

Calibration

.For any study which requires modeling, it is crucial to do calibration and validation of the model in order to ascertain the performance of the model simulation. Land use map was collected from CEGIS (Center for Environment and Geographic Information Services) for the purpose of hydrological pseudo calibration. With the help of the land use map the surface cover of every catchment can be determined and the runoff coefficient can be calculated accordingly. The types of land use are divided into the following catagories- built ups, vegetation, waterbodies and barren land. All the types are digitized as “Polygon Shapefile”.

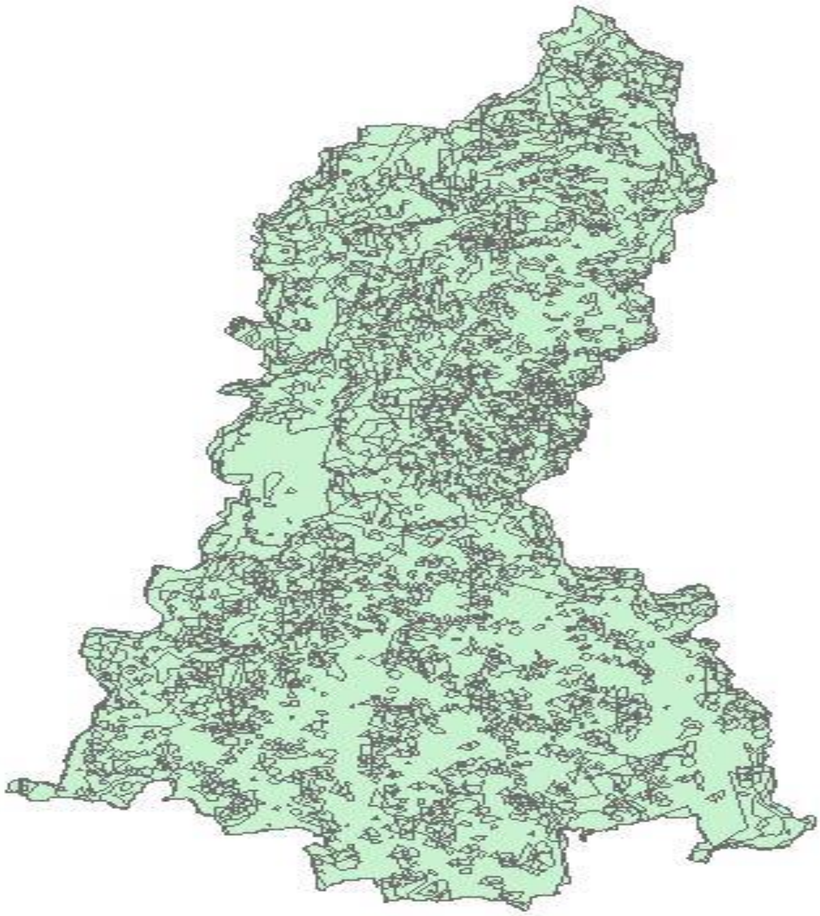


Figure 2: Land Use Map of the Catchment

According to the Ohio Department of Transportation Hydraulics Manual,

Table 7: Runoff Coefficients for Different Land Use Type Given by ODOT

Type	**Runoff Coefficients**
Residential builtups RB	0.6
City Business areas or City Builtups CB	0.85
Cultivated lands or Vegetation V	0.55
Barren Lands BL	0.3
Water Bodies WB	0

Depending on the land use, the runoff coefficient for a catchment is obtained by,
Runoff Coefficient = A ÷ 100
Where, A = (% RB × 0.6) + (% CB × 0.85) + (% V × 0.55) + (% BL × 0.3) + (% WB × 0)

Table 8: Calculation of Runoff Coefficients for Different Sub Catchments

Catchment	RB %	CB %	V%	BL%	WB%	RunOff Coefficient
W1	37	36	10	10	7	0.613
W2	41	31	10	7	11	0.585
W3	39	32	10	6	13	0.579
W4	27	25	20	11	17	0.517
W5	14	10	30	43	3	0.463

W6	13	9	28	38	12	0.422
W7	9	5	23	33	30	0.322
W8	14	8	26	30	22	0.385
W9	15	6	53	24	2	0.504
W10	13	12	27	40	8	0.448
W11	38	36	12	9	5	0.627
W12	12	10	24	30	24	0.379
W13	13	9	22	31	25	0.368
W15	12	8	49	28	3	0.493
W16	40	22	19	9	10	0.558

Table 9: Summary of Calibration (for 5 Years)

Estimated Runoff Coefficient	Runoff coefficient from runoff simulation
0.613	0.625
0.585	0.580
0.579	0.580
0.517	0.510
0.463	0.460
0.422	0.420
0.322	0.320
0.385	0.380
0.504	0.510
0.448	0.440
0.627	0.630
0.379	0.370
0.368	0.370
0.493	0.500
0.558	0.550

Conclusion

GeoSWMM is a robust and powerful tool for analyzing the effective urban flood water control and management for our study area. There is no existing study on drainage management of Dinajpur city. This study aims to fill the study gap by providing the design of an adequate drainage management system. Catchment delineation was not accurate according to our expectation. A Digital Elevation Model with finer resolution would help us getting accurate catchment delineation. Existing drainage system was not incorporated in this modeling. Future steps needed to be applied, could have been predicted more effectively if existing drainage system data were incorporated. Existing drainage system can be improved if proper maintenance works are undertaken by Municipal Authority. Short duration rainfall data of study area would impart more accurate modeling outcome. Here we had used 24 hour rainfall data of Bangladesh Meteorological Department (BMD). 24 hour-5years and 24 hour-10 years has been considered which has resulted in huge peak runoff rate and subsequently a huge area of the conduit. For urban drainage design it is a common practice to use 2 hour- 5 years return period rainfall data. But that data was unavailable to us. If we could collect that data, the result would be more accurate and the study would impart more reasonable conduit size. Adjusting the roughness coefficient “n”, the runoff coefficients obtained from model simulation for rainfall of 5 year return period were matched to the estimated values to perform calibration. Similar procedure was followed for 10 year return period.The validated results by the model confirm that GeoSWMM has been validated. There was a scope for storm flood inundation modeling using Hec-Ras. That would definitely increase our insight about storm water management of our study area.

Acknowledgement

Authors wish to thank Bangladesh Meteorological Department for providing rainfall data. Also authors are thankful to the Department of Water Resource Engineering, BUET for providing necessary guidance. CEGIS provided the land use map of the study area for which authors are really grateful. Special thanks and appreciation is extended to Streams. Tech. Inc. for providing the GeoSWMM manuals without which this design would be an impossible task.

References

Garg, S. K. (1976) "*Irrigation Engineering and Hydraulic Structures",* Khanna Publishers, New Market,Delhi , India

Maliha, M. and Khan, S. M. (2018) *"*Design of Storm Water Drainage Network with Limited Data Using GeoSWMM:case Study for Bogra City*",Journal of Modern Science and Technology,*6(1),63-77

Lambin, E. F., Baulies, X., Bockstael, N., Fischer, G., Krug, T., Leemans, R., Moran, E.F., Rindfuss, R.R., Sato, Y., Skole, D., Turner, B.L., and Vogel, C. 1999, "Land Use and Land Cover Change (LUCC): Implementation Strategy", *IGBP Report* No.48, IHDP Report No. 10, Stockholm, Bon.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change,Intergovernmentl Panel on Climate Change(IPCC),2007.

JICA 1987, "Study on Storm Water Drainage System Improvement Project in Dhaka City", *Main Report,* DPHE, Government of Bangladesh, Dhaka

EXPLORING THE VARIABILITY PATTERN OF TEMPERATURE AND RAINFALL IN DIFFERENT REGIONS OF BANGLADESH: A STUDY RANGING 20 YEARS' SPAN

M. K. Alam[1], M. S. Hossain[1] and N. Majed[1*]

ABSTRACT

This study explores the seasonal variability of maximum, minimum, mean temperature and monthly rainfall in selected four different regions of Bangladesh analyzing past 20 years' (1994-2013) data collected from 35 weather stations of Bangladesh Meteorological Department. The analysis revealed that in general, monsoon season (June- September) is getting warmer and post-monsoon (October- November) season is getting cooler in all the regions. The highest maximum temperature change of 0.56 ^{0}C/decade was observed during monsoon at Northern region and the highest minimum temperature change of 0.48 ^{0}C/decade was found at the Eastern region of the country during the summer period. With the highest seasonal rainfall change of -208.6 mm/decade at the north region, a decreasing trend of rainfall during monsoon season was evident from the observation. Strong negative correlation was observed between seasonal maximum temperature and seasonal rainfall data.

Keywords: Temperature, Rainfall, Trend analysis, Seasonal change, Bangladesh

Introduction

Bangladesh is a sub-tropical country in South Asia. The country is known for six different seasons having distinct characteristics. But in recent years, the distinct characteristics of each of these seasons can rarely be observed. Rather, the weather is increasingly getting dominated by three seasons; Summer, Rainy and Winter seasons. The visual changes in the variability of temperature and rainfall patterns are the underlying reasons behind this abrupt seasonal changes in Bangladesh. However, this seasonal temperature and rainfall patterns have also caused an alteration in farming rotations in Bangladesh, which is eventually leading to an adverse effect on the crop production (Climate change fallout, 2018).

Past studies (Rajib et al. 2011) performed calculation on the heat index of Bangladesh dividing the whole country in four different regions. The study found the heat index to be high in both Northern and Southern regions of the country with significant change in temperature during the last 20 years. Other studies (Islam 2009; Shahid et al. 2012) initiated to understand the trend analysis of temperature by analyzing the weather data of (1961-2008) and (1941-2007) durations respectively. While (Shahid et al. 2012) tried to understand the temperature range in four different seasons and (Islam 2009) provided analysis for different months of the year. However, the variation of temperature across different years was not attempted to be analyzed concomitantly in these studies. In addition, the seasonal rainfall trend and variability has been observed in another study (Shahid 2010) for Bangladesh from the weather data (1958-2007). This research puts an effort to understand the temperature trends in different seasons for four different regions in Bangladesh with emphasis to identify the impact of climate change.

Data and methodology

The real time monthly temperature and rainfall data was obtained from Bangladesh Meteorological Department (BMD) for a period of 1994-2013 along with weather data from 35 weather stations of BMD. Adopting the technique utilized by Rajib et al. (2011), the whole Bangladesh was divided into four different geographic regions as shown in figure 1: i) Northern Region (NR) ii) Southern Region (SR) iii) Central Region (CR) and iv) Eastern Region (ER). Moreover, the data analysis was done through identifying four different seasons of our country: i) Winter (December- February) ii) Summer (March- May) iii) Monsoon (June-September) and iv) Post-monsoon (October- November) to understand the trend of temperature variability with the seasonal changes like (Shahid et al. 2012). The weather trend has been

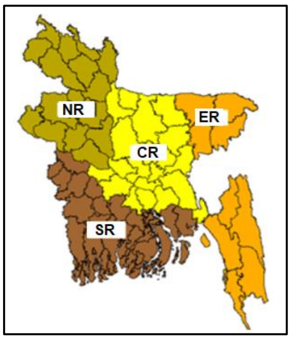


Figure 1. Identified regions of Bangladesh from the study (Rajib et al.2011)

[1] *Department of Civil Engineering, University of Asia Pacific, Dhaka*
**Corresponding Author*
Email of corresponding author: nehreen-ce@uap-bd.edu, nehreen23@gmail.com

identified using the Mann-Kendall test and Sen's slope method has applied to estimate the magnitude of trend like previous study (Basher et al. 2018). The statistical analysis has been done using SPSS 20 and the statistical significance has been set at 95% confidence level. Coefficient of variation was calculated from the formula, COV = SD/M; where SD= standard deviation and M= mean data; following the study (Rehman 2010).

Results and discussions

Temperature and rainfall range characteristics

Average yearly maximum, minimum temperature and annual rainfall data of different regions in Bangladesh from 20 years' weather data are presented in the figures 2, 3 and 4 respectively. For temperature, highest ranges of maximum temperature (30.6 to 31.6 ⁰c) has been found in Southern region, whereas the lowest ranges of minimum tamperature (20 to 21 ⁰c) has been observed in Norther region. Meanwhile, in Central and Eastern region temperature range is observed to be very similar ranging from 30.1 – 31.3⁰c for maximum and from 20.7 - 22⁰c for minimum temperature.

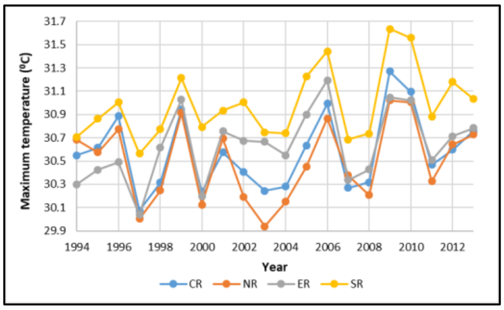


Figure 2. Average yearly maximum temperature in different regions of Bangladesh

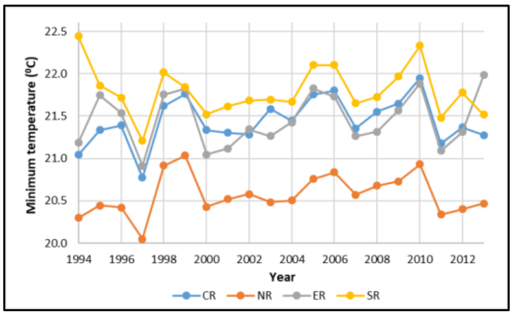


Figure 3. Average yearly minimum temperature in different regions of Bangladesh

Though, the northern region is known as the hottest region of the country but the data showing this region has comparatively lower temperature than the other regions. The reason is maybe due to the high flactuation of temperature in this region, it eventually gets lower in average data than the actual scenario. The variability pattern may lead to the answer to understand the actual scenarion. On the other hand, the annual rainfall has been found way higher in Eastern region ranging from 2893 to 3845 mm, while all the other regions experience annual rainfall within 1210 to 2490 mm. Noticeably, the Norther region has lowest rainfall than any other region in Bangladesh. In brief, the rainfall is found to be reducing since the year 2006 to 2013.

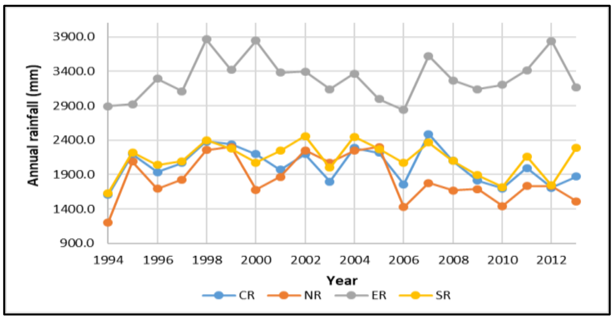


Figure 4. Annual rainfall in different regions of Bangladesh

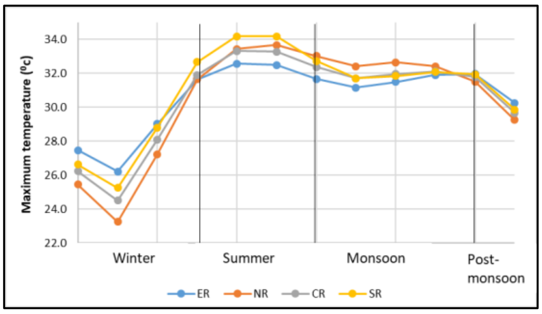


Figure 5. Seasonal distribution of maximum temperature in different regions of Bangladesh

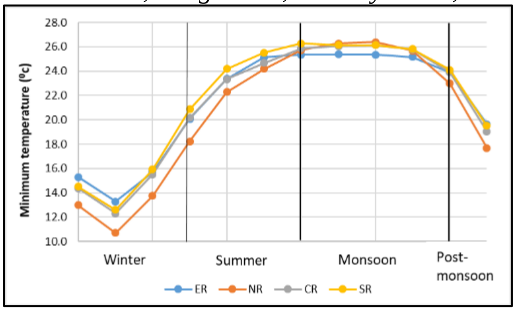


Figure 6. Seasonal distribution of maximum temperature in different regions of Bangladesh

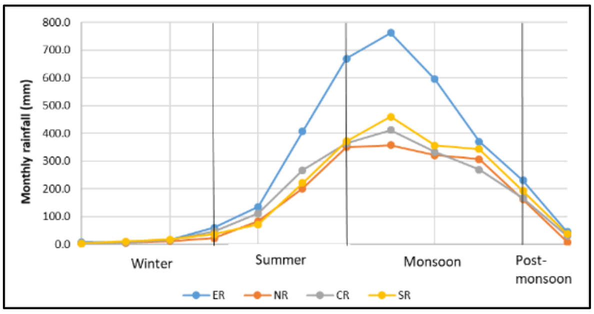


Figure 7. Seasonal distribution of monthly rainfall in different regions of Bangladesh

The seasonal average levels of maximum, minimum temperature and monthly rainfall in different regions of Bangladesh from 20 year's data are presented in the figures 5,6 and 7 respectively. The maximum temperature has been observed as highest during monsoon season in Northern region, while during summer season the temperature is highest in Southern region. Although during monsoon and summer seasons, Northern region experiences higher temperature but during winter and post monsoon season the temperature was recorded to be the lowest in this region. Similarly, for minimum temperature, Northern region has been observed to experience the highest temperature in monsoon and the lowest during winter and pre monsoon season compared to any other regions in the country. In East region, both the maximum and minimum temperature have been recorded to be lowest during monsoon season. On the other hand, Eastern region has been observed to experience way higher rainfall during all the selected seasons than other regions, while Norther region has the lowest rainfall than the other regions.

Temperature and rainfall trend

Region wise trend analysis of temperature has been performed using temperature and rainfall data from the weather stations under each selected region. The details of the maximum, minimum temperature and rainfall trends are presented in Table 1 for the selected regions in Bangladesh. The trend for the increase in maximum temperature has been found at 95 % level for monsoon season with a variation of 0.24 to 0.56 ^{0}c/decade across different regions, while during the post monsoon period the maximum temperature trend varied from -0.30 to 0.16 ^{0}c/decade being the lowest trend per decade than the other seasons. Highest maximum temperature trend during monsoon season was observed 0.56 ^{0}c/decade in Northern region and the lowest 0.24 ^{0}c/decade being at Eastern region. Most notably, though the maximum temperature of Northern region has showed a highest increasing trend during monsoon but during summer the trend was found lowest at 0.10^0 c/decade. This shows that monsoon is getting warmer compared to the summer season in northern region. However, maximum temperature trend during summer has been found increasing for other regions with the highest trend being 0.43 ^{0}c/decade in Southern region. Meanwhile, during winter season the temperature is increasing in Eastern zone with 0.29 ^{0}c/decade but in northern and central zone the temperature is decreasing which gives a sign that winter season is getting cooler in these two regions.

Table 1. Temperature and rainfall trend per decade in different regions of Bangladesh

Regions	Winter			Summer			Monsoon			Post monsoon		
	Max ^{0}c/d	**Min ^{0}c/d**	**Rain mm/d**	**Max ^{0}c/d**	**Min ^{0}c/d**	**Rain mm/d**	**Max ^{0}c/d**	**Min ^{0}c/d**	**Rain mm/d**	**Max ^{0}c/d**	**Min ^{0}c/d**	**Rain mm/d**
ER	0.29	-0.18	-13.31	0.29	0.48	23.68	0.24*	0.13	92.97	0.16	-0.30	8.46
NR	-0.23	0.02	-9.08	0.10	0.28	31.96	0.56*	0.23*	-208.6	0.10	-0.34	-21.11
CR	-0.15	0.17	-10.39	0.34	0.31	-57.10	0.34*	0.22*	-41.82	-0.06	-0.50	-4.65
SR	0.04	-0.17	-9.16	0.43	0.02	-33.11	0.37*	0.23	-15.62	-0.3	-0.47	7.07

***trend at 95% level**

On the other hand, the minimum temperature trend has been found to be higher during summer season and varies within 0.02 ^{0}c/decade to 0.48 ^{0}c/decade across different regions. The minimum temperature scenario is different than the maximum temperature, as the increasing trend of minimum temperature during summer is higher than the monsoon. In contrast, the minimum temperature of post monsoon season is decreasing in all the regions and has been found to vary between -0.30 to -0.50 ^{0}c/decade. The highest decreasing trend has been observed at central region with -0.50 ^{0}c/decade. This shows that post monsoon temperature in Bangladesh is decreasing at a noticeable rate since the last two decades. The situation is happening both in Southern and Eastern regions as minimum temperature of winter is also decreasing at a rate -0.17 and -0.18^0 c/decade respectively.

The maximum seasonal rainfall trend has been found in Northern region during monsoon with a decreasing trend of -208.6 mm/year. Though the trend shows that during the summer season maximum seasonal rainfall has increased at a rate of 31.96 mm/decade, meanwhile, the trend of seasonal rainfall shows that the rainfalls are decreasing in central and southern regions noticeably as the trend was found to be decreasing for Winter, summer and monsoon in these two regions. However, the seasonal rainfall has been found to be increasing with a trend of 23.68, 92.97 and 8.46 mm/decade in Eastern region for summer, monsoon and post monsoon seasons respectively.

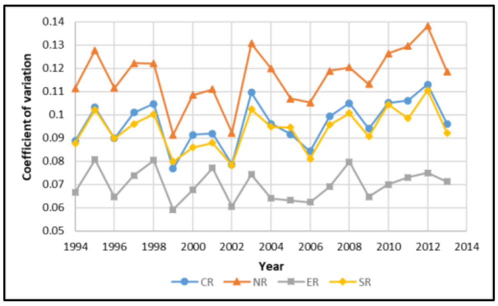


Figure 8. Coefficient of variation of maximum temperature

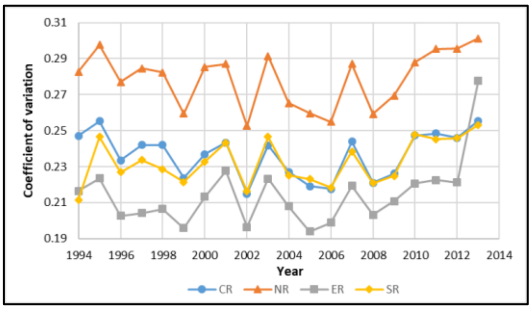


Figure 9. Coefficient of variation of minimum temperature

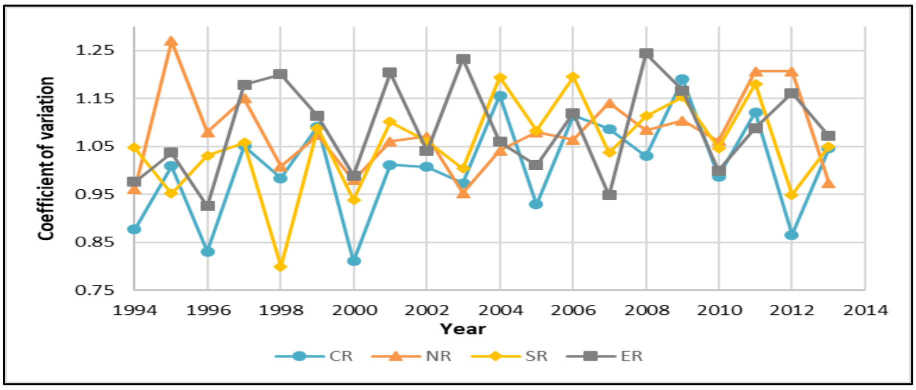


Figure 10. Yearly coefficient of variation of rainfall in different regions of Bangladesh

Variability of temperature and rainfall

The coefficient of variation of yearly maximum and minimum temperature for four different regions of our country are presented in the Figures 8 and 9 respectively. For maximum temperature, the coefficient of variation has lower value than minimum temperature and varies between 0.06 to 0.14, whereas for minimum temperature the data range is between 0.19 to 0.30. For both the maximum and minimum temperature, the temperature fluctuates the highest in Northern region and the lowest fluctuation happens in Eastern region. Meanwhile, from 2010 the minimum temperature variation is increasing in every four region of Bangladesh. The yearly coefficient of variation of rainfall in four different regions of the country is presented in the figure 10. The highest coefficient of variation can be observed in Northern region, whereas the lowest is observed in Southern region. The high variation denotes the abrupt change of seasonal rainfall within the year. After 2010, the coefficients tend to fall and shows the seasonal changes in rainfall is reducing in recent years. The high variation value (>1) is significantly observed in East and Northern regions, which can be explained by the increasing trend (92.97mm/decade) during monsoon rainfall in Eastern region and decreasing trend (-208.6 mm/decade) in Northern region. It is important to mention that rainfall value of CV larger than 1 is also observed in the study by (Jeong et al. 2011) to understand the variability of rainfall in Nekdong river.

Correlation between temperature and rainfall

Pearson correlation coefficient was calculated between the seasonal rainfall and temperature which is presented in the table 2. The maximum temperature of different seasons has been found to hold strong negative correlation with seasonal rainfall than the minimum temperature. The negative correlation coefficients suggest, due to reduced amount of rainfall the temperature significantly increases in different seasons. Correlation coefficients for maximum temperature have been found significant for winter, summer and monsoon season. In contrast, during the post monsoon season the coefficients are comparatively smaller than the other seasons. The highest correlation of -0.691 has been found for consecutively summer and monsoon seasons in Northern region. Comparing the regional data, Eastern zone exhibit smaller correlation coefficients and varies between -0.351 to 0.246. This might have been caused by the high vegetation and hilly areas in the Eastern zone, which reduce the impact of rainfall on temperature. On the other hand, in the northern region, maximum temperature has significant negative correlation with seasonal rainfall during all the seasons manifested by strong correlation between maximum temperature and rainfall. Figure 11 shows the graphical representation of the temperature and rainfall data averaged for each year over a 20 years' span for the whole country which depicts more clearly the general negative correlation between the temperature and the rainfall across the country.

Table 2. Pearson correlation coefficient between seasonal rainfall and maximum and minimum temperature.

Region	Winter		Summer		Monsoon		Post monsoon	
	Max	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**
Eastern	-0.256	0.121	-0.339	0.176	-0.304	-0.256	-0.351	0.246
Northern	-0.554*	-0.409	-0.691*	-0.184	-0.691*	-0.299	-0.562*	0.211
Central	-0.683*	-0.275	-0.602*	-0.469*	-0.622*	-0.245	-0.487	-0.014
Southern	-0.635*	-0.107	-0.641*	-0.628*	-0.589*	-0.611*	-0.377	0.106

***significant at 0.05 level**

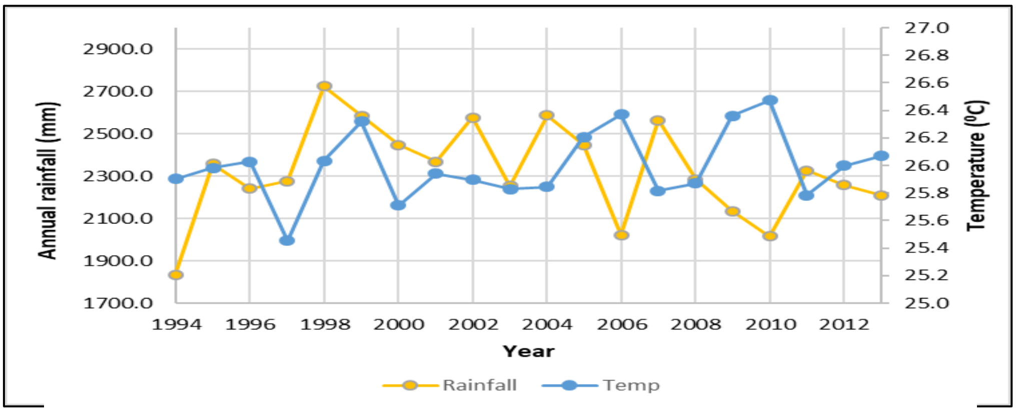


Figure 11. Average yearly mean temperature and annual rainfall in Bangladesh

Conclusions

The increasing temperature and decreasing rainfall trend over a 20 years' span in Bangladesh across different regions portray about the major weather changes in the country. Due to the increase of temperature in past two decades, the rainfall frequency has proved to be significant to ease the heat impact. The Norther region of Bangladesh is undoubtedly going through major weather changes as the temperature of monsoon season is increasing while winter becoming cooler. Moreover, the monsoon rainfall is also decreasing at an alarming rate in this region. In contrast, the Eastern zone is experiencing lesser temperature variation with increasing rainfall trend during summer and monsoon.

References

Climate Change Fallout: 13.4cr people to be hit hard (2018, September 27), The Daily Star. Retrieved from https://www.thedailystar.net/country/climate-change-in-bangladesh-temperature-rise-affect-134m-people-world-bank-1638907

Islam, A. S. (2009). Analyzing changes of temperature over Bangladesh due to global warming using historic data. Young Scientists of Asia Conclave, Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), 15-17.

Jeong, K. S., Kim, D. K., Shin, H. S., Yoon, J. D., Kim, H. W., & Joo, G. J. (2011). Impact of summer rainfall on the seasonal water quality variation (chlorophyll a) in the regulated Nakdong River. KSCE Journal of Civil Engineering, 15(6), 983-994.

Rajib, M. A., Mortuza, M. R., Selmi, S., Ankur, A. K., & Rahman, M. M. (2011). Increase of heat index over Bangladesh: impact of climate change. Change, 2010(33.470C), 32-280C.

Rehman, S. (2010). Temperature and rainfall variation over Dhahran, Saudi Arabia, (1970–2006). International Journal of Climatology: A Journal of the Royal Meteorological Society, 30(3), 445-449.

Shahid, S. (2010). Rainfall variability and the trends of wet and dry periods in Bangladesh. International Journal of Climatology, 30(15), 2299-2313.

Shahid, S., Harun, S. B., & Katimon, A. (2012). Changes in diurnal temperature range in Bangladesh during the time period 1961–2008. Atmospheric Research, 118, 260-270.

Basher, M. A., Stiller-Reeve, M. A., Islam, A. S., & Bremer, S. (2018). Assessing climatic trends of extreme rainfall indices over northeast Bangladesh. Theoretical and Applied Climatology, 134(1-2), 441-452.

ANALYSIS ON THE CHANGING TRENDS OF THE CHANNEL PATTERN OF HALDA RIVER AND PUBLIC-PRIVATE PARTNERSHIP (PPP) AS A CATALYST FOR THE SUSTAINABLE DEVELOPMENT

P. Saha[1], J. T. Oyshi[2], S. T. B. Haider[3], S. N. Nipa[4], R. Khanum[5]

ABSTRACT

Halda, a major tributary of Karnaphuli River is the only source of naturally fertilized eggs of carp fishes in South Asia and a great pioneer to the national economy. However, due to overexploitation of the physical resources, the river is becoming a less favorable place for aquatic life. Excessive dam construction, sand mining, brick kilns alongside the river and water withdrawal for irrigation purposes in the dry season are continuously degrading the river conditions. Hence, it is essential to study the changing trends and identify the primary reasons behind extreme degradation in the water body of the river. To study the alterations in Halda River, a hydrological trend analysis was carried out to learn the temporal changes in river planform, water level changes and seasonal fluctuation. Moreover, a number of FGD and KII has been conducted at the surrounding locations of the river to acknowledge the problems faced by the local community. Finally, a public-private partnership model is recommended to ensure the sustainable usage of physical resources in the river. The model aims to prove a smooth partnership between the public and private sector ensuring the sustainability of the Halda River.

Introduction

Halda is well known as the country's main spawning ground of major carps. 19 branch canals and 17 hilly fountains are the primary sources of water of the Halda (The Daily Star, 2014). These carp fries are supplied to different regions of the country for aquaculture (MoFL, 2016). Obstructions made on the river course are blocking the natural river flow and degrading the fish habitat condition in the river. Due to these obstructions in the river course, minimum required flow for fish habitat and fish spawning is not being fulfilled by the existing flow in the river. Moreover, salinity intrusion, siltation, erosion and climate change will also deteriorate the hydrologic conditions and endangering the ecosystem of Halda River (Akhter & Ali, 2012) (Patra, Ronald, & Azadi, 1985). In this context, measures must be taken into account to save this mighty river and can be minimized through the Public-private partnership (PPP) model.

Literature review

River Halda is a great pioneer to the national economy. Nearly 30% of the local respondents recognized egg collection is their main profession and 50% of the egg collectors diversified with their occupations (MoFL, 2016) and this river possesses a closed aquatic ecosystem which supports various species of plants, fish and other organisms. However, the current situation of Halda River has become less favorable to marine life. The primary data of fertilized egg collection and fish fry production analysis shows that the blockage of water in tributaries and 36 connected canals and fountains of Halda River, construction of the dam, sand mining and water withdrawal through this dam are the main reasons of the present critical ecological condition of Halda River (MoFL, 2016). This withdrawal of water from Halda River is not only disturbing the aquatic life but also cause side effects such as bank erosion, saline intrusion. The integration of river bank lines of the year 2004, 2009 and 2015 revealed that the Halda River had shifted its bank line drastically (MoFL, 2016). The brickfields, one of the primary reasons for water pollution, are precisely at the edge of the river, which means dumping of their waste and debris into the river by default during the hide tide, which do not dissolve in the water and cause severe sedimentation, along with changing the chemical balance of the river water (Zaman, 2014). (Islam, et al., 2017) showed in their study that water quality assessment and land-based sources of pollutants are discharged into the Halda River through four major canals. Besides brick industries, another

[1] *Student, Institute of Water and Flood Management, BUET, Dhaka- 1000, Bangladesh*
[2] *Student, Dept. of Civil Engineering, BUET, Dhaka- 1000, Bangladesh*
[3] *Research Associate, C3ER, BRAC University, Dhaka-1212, Bangladesh*
[4] *Lecturer, C3ER, BRAC University, Dhaka-1212, Bangladesh*
[5] *Lecturer, C3ER, BRAC University, Dhaka-1212, Bangladesh*
Email of corresponding author- probal1421@gmail.com

study showed that the Halda River is being polluted due to industrial waste (53%), sewage contamination (20%), tobacco farming (13%), rubber dam (8%) and sand extraction (6%) (Islam, Akbar, Akhtar, Kibria, & Bhuyan, 2017). The dams and sluice gates are also hampering navigation through drying up of downstream. Through the studies above, it is clear that due to extensive usage River Halda is losing its resources and stability day by day which will deteriorate both ecological and economic condition. (Patra, Ronald, & Azadi, 1985). Experts say that there is an excellent potential for applying the Public-Private Partnership (PPP) model in environmental protection, but this has not happened because of a missing proper legal framework (Viet Nam News, 2014).

Methodology

Study Area

Halda River originates from the Badnatali Hills range in Ramgarh Upazila in the Chittagong Hill Tracts, flows through the Fatikchhari Upazila, Hathazari Upazila, Raozan Upazila, Kotwali Upazila and flows into the Karnaphuli River at about 35 km from the Bay of Bengal.

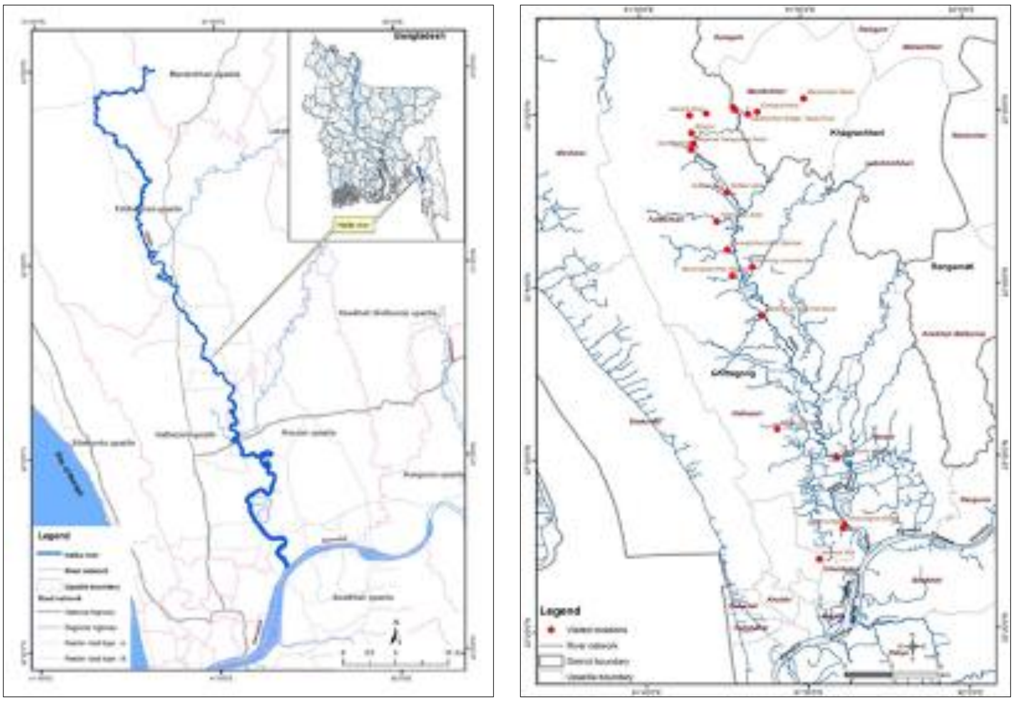


Figure 1. Halda River Reach and Field visit locations

Field Visit

An initial field visit was done to assess and observe the Halda River situation. A team of 12 members visited Halda River during October 2017. The group consisted of water resources expert, biodiversity expert and Halda River expert. Several Fish breeding locations, Dams, industrial areas, sand mining places were visited, and FGD and community meetings were carried out. Some interventions like encouraging the use of the solar boat instead of engine boat, stop catching female fish to save Halda River resources were already going on within the community. The local representatives identified some issues which were mainly responsible behind the fish declination in River Halda. Such as, salinity, unusual sand mining (manual and dredging), dam, poultry wastages are the prime causes behind the critical scenarios of River Halda.

Table 1. Notable Spots Visited During the Visit

Locations	Observations	Problems
Anonna R/A	Drainage channel	Blackwater and bad smell
Fatikchhari Khal	Black shell oyster of saline water observed	Fish eggs production dropped
Bhujpur rubber dam	The downstream section found dried up	Reducing flow and fisheries
Soilkupa village	Sand mining spot	Dredged areas cause bank collapse

Gazaria Sluice Gate	The sluice gate is for irrigation purpose	Interrupts the fish movement
Dhurang Dam	Water is stored by lifting for irrigation	Causes drought in the downstream

Problem Analysis

The Halda River is the primary source from where fertilized carp fish's eggs are collected by local fisherman and egg collectors during April to June almost every year for time immemorial. Each year, the amount of eggs spawned by mother fishes decreases at a notable rate. Recently, from March to June, waiting for every auspicious moment, only three times they got sample eggs of 12kg from there. According to experts, the decrease of Rui's spawn in Halda has led to this state. This natural breeding zone for carp fish is getting degraded day by day. Halda's destiny is now stricken with dredging, waterlogging, and unplanned hydraulic structures. Considering the problems identified by the community, six significant issues of Halda River were selected with expert opinions:

- ***Unplanned development of hydraulic structures:*** Dam and Barrage has significant impacts on the river flow due to low maintenance & management. It causes lowering and drying of Halda River. Moreover, abrupt water flow due to dam opening causes extreme bank erosion. As a result, there is erratic seasonal water level depletion which is lowering the laying of fish eggs.
- ***Dumping of wastages by industrial and residential usage:*** Dumping of Wastages by Tobacco, Tannery industries & Brickfields along with the residential wastages polluting the river and lowering the water quality for fish breeding. Moreover, the use of poultry wastages as fish food is also polluting the river. Eco-friendly fish foods need to be introduced for sustainable river environment.
- ***Unplanned Sand Mining & Dredging:*** Unplanned Sand mining & dredging causes bank erosion and damages the fish eggs significantly. Manual sand extraction places are naturally filled up by the bed sediment movement. However, the dredged areas cannot be filled with the natural process and cause bank collapse which damages public property.
- ***Over-extraction of water due to tobacco and tea cultivation:*** Excess water usage by tobacco and tea cultivation farms are one of the major causes of over-extraction of water from Halda River.
- ***Loop Cutting and Riverbank Erosion:*** Loop Cutting and Straightening of the river are destroying the fish breeding areas. If the fish breeding areas are damaged, the collection of fish eggs will also be reduced enormously.
- ***Salinity intrusion and temperature change***: Being in the coastal zone, salinity intrusion due to tidal effect is a natural phenomenon. However, day by day the salinity intrusion is increasing which is a threat to the fish breeding. The fish eggs cannot survive in the saline environment. Moreover, radical change in water temperature is also harmful to the survival of fish eggs.

Results & analysis

River Planform Analysis

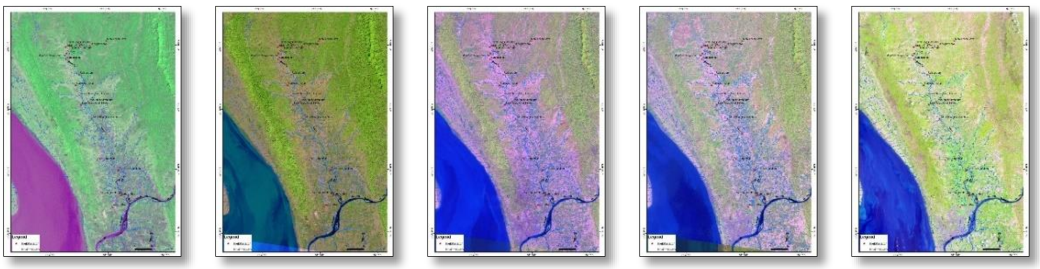


Figure 2. Landsat Images of Halda Basin Area (1984, 1989, 2003, 2010, and 2014).

Observations

- ✓ River channels are in a complex network, and enough streams in the river basin are identified.
- ✓ River flow is adequate in the river reach during 1984, 1989 but inadequate for 2003, 2010, 2014.
- ✓ The number of canals around the river basin is decreasing gradually year by year.
- ✓ There are indications of land deposition and water flow scarcity in the basin area.

River Trend Analysis (the Year 1985-2014)

Narayanhat (Bhujpur), Panchpukuria (Fatikchhari), Telpari (Raozan), Enayethat (Chandgaon) stations are located at the bank of Halda River in Chittagong District. Trend Graphs has been plotted against Water Level data collected from BWDB from 1985 to 2014.

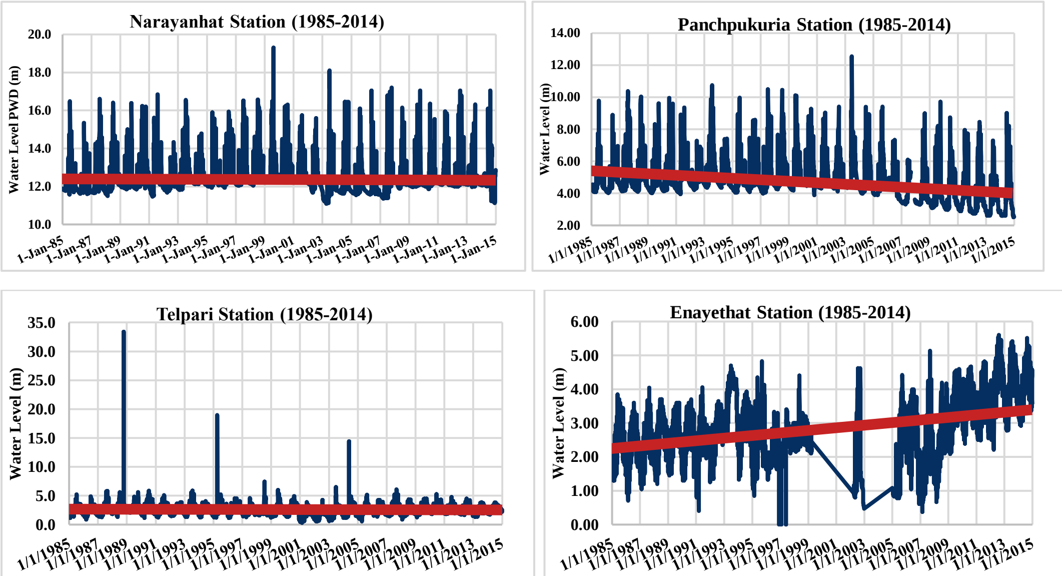


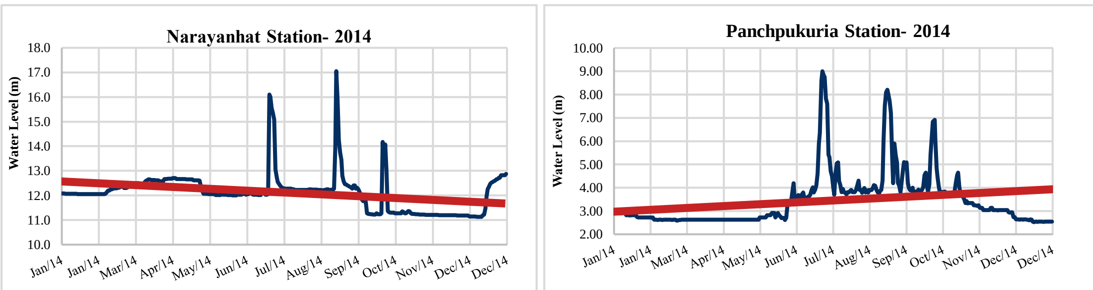
Figure 3. Water Level Trend Analysis (Source: BWDB)

Observations

- ✓ Water Level trend has almost been similar for, decreasing for Panchpukuria and increasing for Enayethat in the last 30 years,
- ✓ Average water levels are 12.36m, 4.71m, 2.60m, 2.81m PWD.
- ✓ Max WL is 19.30 m PWD and Min WL is 11.09 m PWD; Max WL is 12.54m PWD, and Min WL is 2.52m PWD; Max WL is 33.40m PWD, and Min WL is 0.30m PWD; Max WL is 5.13m PWD, and Min WL is 0.37m PWD.
- ✓ Narayanhat & Telpari region of the river is non-tidal, Tidal ranges for Panchpukuria and Narayanhat are 1.66m &2.39m.

Seasonal Analysis (the Year 2014)

The report will also provide a short overview of the present condition of the Halda River based on climate change and seasonal impacts. Impacts of high tide and water level in the region will also be discussed here.



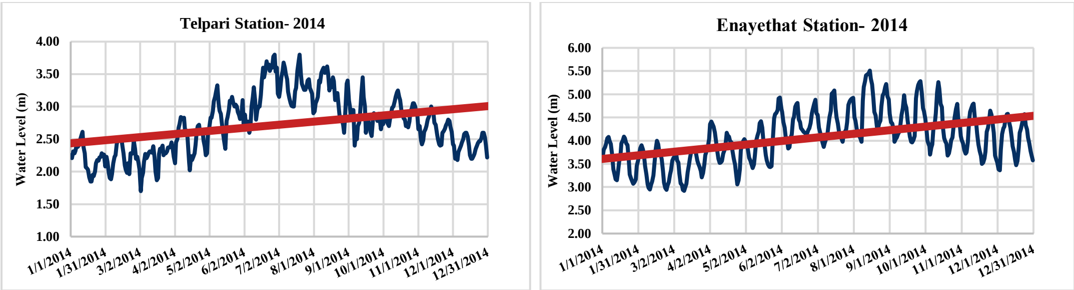


Figure 4. Seasonal Trend Analysis

Observations

- ✓ Water Level increases during Jan to July and is as high as 17.05 m PWD in Narayanhat.
- ✓ Water Level decreases from August to December and is as low as 1.70 m PWD in Telpari.
- ✓ WL is high during Monsoon (June-October) and low during Winter (November to April)

Public-Private Partnership Model

PPPs can be defined as co-operation between public and private actors with a strong character in which actors develop mutual products and/or services and in which risk, costs, and benefits are shared (Klijn & Teisman, 2003). Public-private partnerships (PPPs) take a wide range of forms varying in the space of involvement and risk taken by the private party. The context of a PPP is typically set out in a contract or agreement to specify the responsibilities of each party and allocate risk. The application of PPPs as a management tool requires active and continuous examination of rendered services to determine whether the private sector more appropriately and expertly performs them. Governments want to establish PPPs that are sustainable over time.

PPP Model

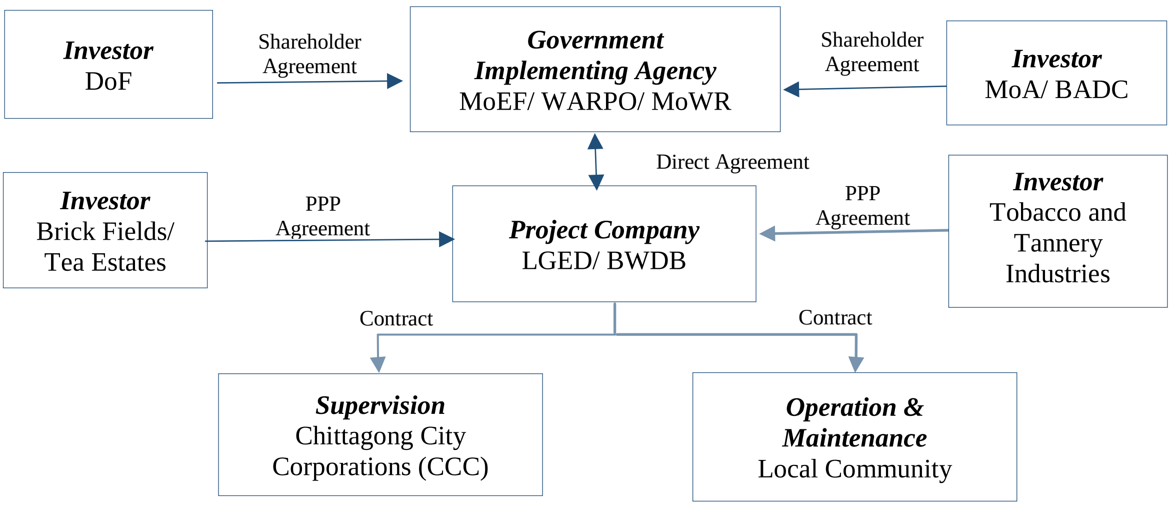


Figure 5. PPP Model for Hydraulic Infrastructures

Responsible stakeholders and benefits

Table 2. Responsible stakeholders and their benefits

Problems	Responsible stakeholders	Benefits
Unplanned development	BWDB, LGED, Chittagong CC, Fisheries Dept.	Relocate, repair and maintain the hydraulic infrastructures.

Dumping of wastages by industrial and residential usage	Tobacco and tannery Industries (TTI), Brick Fields (BF), Chittagong CC, (LGED)	Protect the river from pollution, extract clean water from the river and increase of fish resources.
Unplanned Sand Mining & Dredging	BWDB, LGED, Chittagong CC	The increase of River flow, sand mining and survival of fish resources.
Over-extraction of water	Tobacco and tannery Industries, Tea estates, BADC, BWDB	Ensuring steady supply to all sectors and maintain river flow.
Loop Cutting and Riverbank Erosion	BWDB, LGED, Chittagong CC, Department of Fisheries	Protect the fish breeding areas, an increase of fish resources and eggs in Halda.
Salinity intrusion and temperature change	MoWR, MoA, MoEF	Protection from salinity, maintain river flow and optimal temperature for fish survival.

Conclusions

Halda River is one of the most important rivers in Bangladesh. The large fish breeding and egg collection prospect in Halda River is facing an extinction threat. From the trends, the collection of fishes and eggs has decreased significantly over the years due to the degradation of water quality and low flow. The hydrological alteration of Halda River is reviewed based on Trend Analysis, Planform analysis, seasonal analysis, and frequency analysis. The trend analysis shows that discharge has been almost flat at Narayanhat but has been an increasing trend for Telpari, Enayethat and in decreasing trend for Panchpukuria below the Dam for the last 30 years. The planform analysis shows that canals and tributary rivers have been encroached over the years and the number is reducing. The seasonal analysis shows that water level is high during monsoon but low during winter in 2014. To address the issues and save the Halda River, a joint effort from government and the private organization has become essential. So to solve the issues, a no of key stakeholders has been listed out, who has jurisdiction and responsibility for Halda River. The key stakeholders have to work jointly to save the river and its fish resources from extinction. To make a successful involvement of Public and private institutes, Public-Private-Partnership Model is developed for each major issue in Halda River. To solve the major issues, all the major government ministries like water, agriculture, fisheries, and environment must work together. To support them local institutes like tobacco & tannery industries, Brickfields, tea estates, Chittagong city corporations, and local community must be partnered to work for the survival of Halda River. Working together each of them will find direct benefits and success. So for the survival of Halda River, Public-private partnership model has become essential.

Acknowledgments

The study was conducted by Centre for Climate Change and Environmental Research, BRAC University under the funding received from the United Nations Development Programme, Bangladesh UNDP-BD/CPS/2017 under grant agreement no. 011 (*Conduct three feasibility studies on Halda River*).

References

Akhter, A., & Ali, M. H. (2012). Environmental flow requirements assessment in the Halda River, Bangladesh. *Hydrological Sciences Journal, 57:2*, 326-343.

Alam, M. S., Hossain, M. S., Monwar, M. M., & Hoque, M. E. (2013). Assessment of fish distribution and biodiversity status in Upper Halda River, Chittagong, Bangladesh. *International Journal of Biodiversity and Conservation*, 349-357.

Islam, M. S., Akbar, A., Akhtar, A., Kibria, M. M., & Bhuyan, M. S. (2017). Water Quality Assessment Along With Pollution Sources of the Halda River. *Journal of the Asiatic Society of Bangladesh, Science*, 61-70.

Kabir, M. H., Kibria, M. M., Jashimuddin, M., & Hossain, M. M. (2013). Economic Valuation of Tangible Resources From Halda– The Carp Spawning Unique River Located at Southern Part of Bangladesh. *International Journal of Water Research*, 30-36.

Khan, M. N., Haider, M. S., & Akter, A. (2012). Cost Effective Bank Protection for Halda River.

International Conference on Civil Engineering for Sustainable Development. Khulna: Khulna University of Engineering and Technology.

Klijn, E.-H., & Teisman, G. R. (2003). *Institutional and Strategic Barriers to Public-Private Partnership: An Analysis of Dutch Cases.* Public Money & Management.

MoFL. (2016). *Impact Assessment on Upstream Water Withdrawal to Conserve Natural Breeding Habitat of Major Carps in the River Halda.* Dhaka: Department of Water Resources Engineering, Ministry of Fisheries And Livestock.

MoFL. (2016). *Impact Assessment on Upstream Water Withdrawal to Conserve Natural Breeding Habitat of Major Carps in the River Halda.* Dhaka: Department of Water Resources Engineering, Ministry of Fisheries and Livestock.

Patra, Ronald, W., & Azadi, M. A. (1985). Hydrological conditions influencing the spawning of major carps in the halda river, Chittagong, Bangladesh. *Bangladesh J. Zool. 13(1)*, 63-72.

The Daily Star. (2014, May 29). *Rubber dams render blow to ecosystem*.

Viet Nam News. (2014, December 23). *PPP could benefit environmental protection.* Retrieved 1 4, 2018, from http://vietnamnews.vn/environment/264349/ppp-could-benefit-environmental-protection.html#Bcg83h3KpqI2PWyl.97

Zaman, F. (2014). *River Halda Awakening: A Research Training and Awareness.* Dhaka: Department of Architecture, BRAC University.

MULTIVARIATE ANALYSIS ON MONTHLY RAINFALL OVER BANGLADESH

Md. Mahmud Reza[1], A.R.M. Towfiqul Islam[2],

ABSTRACT

The analysis of rainfall spatiotemporal patterns is of great significance for developing flood and drought early warning system. However, spatiotemporal patterns of rainfall in Bangladesh are poorly understood because of erratic distribution creates rainfall diversity over time and location. For that reason, this study aims to understand the homogeneity and difference of rainfall spatiotemporal patterns based on monthly rainfall dataset over 30 meteorological stations in Bangladesh during 1975-2017. The homogeneous stations are divided into five clusters (C1, C2, C3, C4 and C5) based on clustering analysis. A linear regression technique was employed to a time series dataset and a reference. The reference time series data was estimated from the average rainfall within a cluster, using neighbor stations with higher Spearman correlation coefficient. All stations showed a linear spatiotemporal trend using Mann-kendall and Sen's Slope test ($p<0.05$). The first cluster 1 (C1) consists of stations located over the southeastern regions facing area of the coastal lowlands (Coxsbazar), a long hill tract range in the coastal Southeastern region. Third cluster 2 (C2) contains stations in the lowlands over the south-central region. Cluster 3 (C3) contains northern region including Rangpur. The fourth cluster 4 (C4) consists of stations over eastern parts including Sylhet region. while cluster 5 (C5) has stations over the northeastern regions (Srimangal) with high rainfall distribution area.

Keywords: Spatiotemporal rainfall patterns, clustering analysis, homogeneous rainfall regions, multivariate analysis.

Introduction

Bangladesh is a sub-tropical country of South Asia whose climate is characterized by high rainfall during summer monsoon and low in the remaining period of year (M. A. Rahman et al.). Having an agriculture-based economy, the country's food security and economic developments are highly vulnerable to the effects of climatic variability and climate change. Rainfall has the highest impact on agricultural production than other climatic factors for its contribution to crops' water demand. In addition, it is related to country's flood control, drought mitigation, water resource management, transport system and many other forms of infrastructural development. Changing climatic behavior from global to regional to local scale influences the rainfall patterns where Bangladesh is considered as one of the most vulnerable countries to climate change (IPCC 2007; Richard 2012). Moreover, Rainfall is the climate variable associated with the greatest social and economic impacts to society. Its impacts can be related to excess (floods) or scarcity (drought) (Kamruzzaman et al. 2011, 2016; Lyra et al. 2014), which directly affects the production of crops, for instance, among other productive activities. For this reason, rainfall variability in space and time has been researched using different methods and approaches, such as principal component analysis (PCA) (Pandzˇic´ 1988) or standard regression models (Kamruzzaman et al. 2015). The understanding of rainfall variability has become an imperative issue in recent decades, especially when considering the possible effects of climate change and associated extreme events (Pandzˇic´ 1988; Willems 2013). The understanding of spatial–temporal distribution of rainfall is essential to support the formulation of specific public policies and the implementation of economic activities and public services in many areas such as forestry, agriculture, monitoring of natural disasters, weather forecast, and hydropower energy supply, among others.

Literature Review

Multivariate statistics concerns understanding the different aims and background, and it can be explained, how different variables are related with each other or one another. The practical implementation of

[1] *Md. Mahmud Reza, Department of Disaster Management, Begum Rokeya University, Rangpur 5400, Bangladesh*
Email – mahmudrezarasel@gmail.com
[2] *A.R.M. Towfiqul Islam, Assistant Professor, Department of Disaster Management, Begum Rokeya University, Rangpur,*
Corresponding author, Email: towfiq_dm@brur.ac.bd

multivariate statistics to a particular problem may involve several types of univariate and multivariateanalysis in order to understand the relationship among variables and their relevance to the actual problems being studied **(Johnson and Wichern, 1996)**. **Yeh et al. (2000)** applied the simple quantitative method of statistical average linkage cluster analysis to the task of objectively classifying precipitation patterns over Northern California in to paternally homogenous regions. The new climatic classification derived from multivariate statistics compared to traditional Chinese classification allows a more dynamic interpretation of the climatic cluster patterns**. Penarrocha et al. (2002)** classified the daily rainfall patterns in a Mediterranean area with extreme intensity levels. The classification was obtained by applying cluster analysis and principle component analysis to the rainfall data of 1981-1990. **Cretat et al. (2010)** investigates the influence of some modes of climatic variability on the spatiotemporal rainfall variability over South Africa by using an agglomerative hierarchical clustering approach to classify daily rainfall patterns recorded at 5352 stations from December to February 1971 to 1999. Five clusters are retained for analysis. Among them, one cluster looks most like the rainfall and circulation mean picture. Another one representing 37 per cent of the days describing negative rainfall anomalies over South Africa resulting from a regional barotropic trough-ridge-trough wave structure and moisture divergence. The pre-monsoon, monsoon and post-monsoon seasons are basically the rainy seasons (**Islam et. al., 2008).** Monsoon rainfall accounts for approximately 85% of the total rainfall while occurrences of wet days are rare in the dry season. This monsoon rainfall is caused by monsoon depressions in the Bay of Bengal **(Rahman et. al., 1997)**. This makes Bangladesh a highly humid zone with a mean annual rainfall of 2488 mm. The pre-monsoon period is characterized by warm temperatures (27 °C on average) and the occurrence of thunderstorms with rainfall ranging from 15 mm/year in the western central region to more than 80 mm/year in the northeast region. This pre-monsoonal rainfall and thunderstorms are dominated by the moist air from the Bay of Bengal. The effect of the Bay of Bengal coupled with that of the Himalayas creates extremely high rainfall levels during the monsoon season **(Mirza 2004; Sanderson 1979).**

Methodology

Bangladesh is located between 24° 00' North latitude and 90° 00' East longitude. The country has borders with Siliguri, India in the north, Bihar in the northwest, West Bengal in the southwest, Bay of Bengal in the south, Mizoram and Myanmar in the southeast, Tripura in the east and Meghalaya and Monipur in the northeast and eastern part of the country. On the south is a highly irregular deltaic coastline of about 580 kilometres (360 mi), fissured by many rivers and streams flowing into the Bay of Bengal.

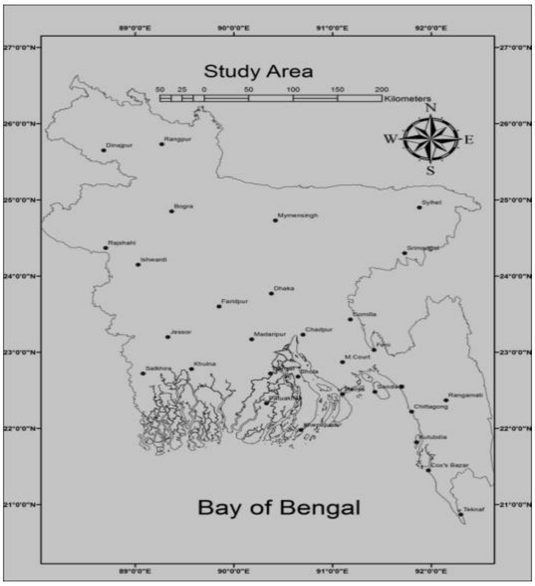


Figure 1. Study area

Data

Monthly rainfall data from 30 meteorological station overall Bangladesh are collected for perform this study. All the stations are randomly situated throughout the country and in this study in 1987-2017 data were used. The data were obtained from the Bangladesh Meteorological Department (BMD). The stations are located more or less evenly over the study area (Figure:1) Summing up the rainfall data for each station seasonal and annual rainfall obtained and analyzed. The mean of rainfall for each station were calculated by the summing of monthly rainfall and dividing it by the total month for each station.

Gap filling of missing data

Simple linear regression (Kite 1988) was used to fill gaps in the time series of monthly rainfall. The regression was carried out between each series and a reference, which was composed of averages of stations with homogeneous rainfall. The homogeneous stations were determined using the clustering analysis and Pearson correlation coefficient. The gap-filling was carried out according to the Eq (1) below;

$$Y_i = \beta_0 + \beta_1 X_i \quad \text{.........................} (1)$$

Where Yi, in mm, is the monthly rainfall gap (dependent variable), Xi, in mm, is the rainfall for the ith month in the reference series (independent variable), and b0 (intercept) and b1 (slope) are the regression coefficients. The regression coefficients and respective standard errors were previously calculated using a least square method, together with paired observations between rainfall data and reference series. In this analysis the following hypothesis were tested H0: b0 = 0 and Ha: b0 = 0; H0: b1 = 0 and Ha: b1 = 0. The hypotheses were tested using the t-test and evaluated based on p-value. If the p-value is lower than 0.05 then the null hypothesis is not accepted, which leads to the alternative hypothesis being true (b0 different from zero). At the same time, hypothesis Ha is accepted, leading to the slope (b1) being statistically different from zero. In this case, it is assumed that a linear relationship exists between the dependent and independent variables.

Regions of homogeneous rainfall

The regions with homogeneous rainfall, i.e. similar monthly totals, were determined by applying Clustering Analysis (Everitt and Dunn 1991; Wilks 1995) to the set of 30 stations over the country. The analysis was implemented using the SPSS software. The technique is based on the relationship between elements (pluviometric stations), whose characteristics (monthly rainfall) are homogeneous within a group. Another assumption is that the shorter the distance between elements, the higher is their similarity. The hierarchical method of Ward (1963) was used when grouping the stations. This method considers the squared Euclidian distance as a measure of dissimilarity (Everitt and Dunn 1991; Wilks 1995), according to the following expression:

$$d_e = \sqrt{\sum_{j=1}^{n} (P_{p,j} - P_{k,j})^2} \quad \text{.......................................} (2)$$

Where de is the Euclidean distance, and Pp,j and Pk,j are the variables representing elements p and k, respectively.

Ward's method is a hierarchical agglomerative clustering method, in which groups are established so that the internal error between elements is the lowest possible. In this method, groups are created in steps where each pair of elements is tested, choosing a group with the lowest internal error (Everitt and Dunn 1991). The method considers the sum of squares within groups W, which is calculated using the homogeneity within groups and the heterogeneity outside the group, according to the following expression:

$$W = \sum_{i=1}^{n} x_i^2 - \frac{1}{n}\left(\sum x_i\right)^2 \quad \text{...........................} (3)$$

where n is the number of elements and xi is the ith element of the group. When applying the method, the average monthly rainfall (avg. x, in mm) was calculated for each series, as well as the coefficient of variation (CV, %). The data was arranged in a matrix so that columns represented the stations while lines contained the averages and CVs. Then each pair of stations was combined until only one group was found. Having determined the groups of stations with homogeneous rainfall in space and time (month), the next step was to investigate the annual cycle for each group. Rainfall was then showed by month using bar plots, which help to visualize different statistical properties in the data.

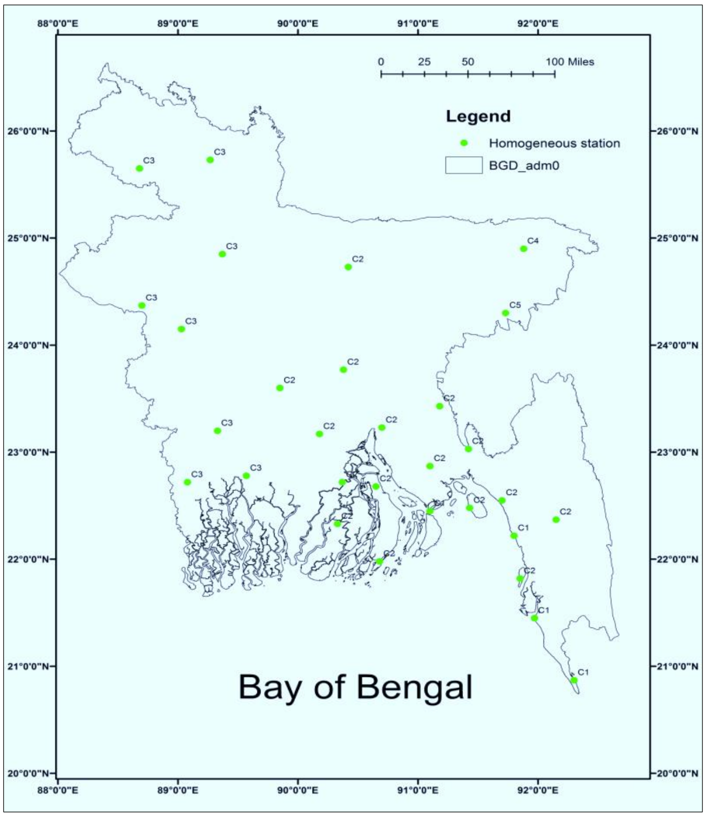


Figure 2. Homogeneous rainfall area

Cluster Analysis

Cluster analysis or clustering is the task of assigning a set of objects into groups (clusters), so that the objects in the same cluster are more similar to each other than to those in the other clusters. Cluster analysis itself is not one specific algorithm, but the general task to be solved (Romesburg, 1984). The appropriate clustering algorithm and parameter settings (including values such as the distance function to use, a density threshold or the number of expected clusters) depend on the individual data set and intended use of results (Richard, 2007). Cluster analysis is an exploratory data analysis tool for organizing observed data in to meaningful taxonomies, groups, or clusters based on combination of variables, which maximizes the similarity of cases within each Cluster while maximizing the dissimilarity between groups that are initially unknown. In this sense, cluster analysis creates new grouping without any preconceived notion of what cluster may arise (Singh and Chowdhery, 1985). Cluster analysis is the obverse of factor analysis. Whereas factor analysis reduces the number of variables by grouping them into a smaller set of factors, cluster analysis reduces the number of observations or cases by grouping them . On the other hand, Nouri *et al*. (2011) stated that the main advantage of using Principle component analysis over cluster analysis is that each variable can be allocated one group only. Most popular agglomerative clustering methods are (1)

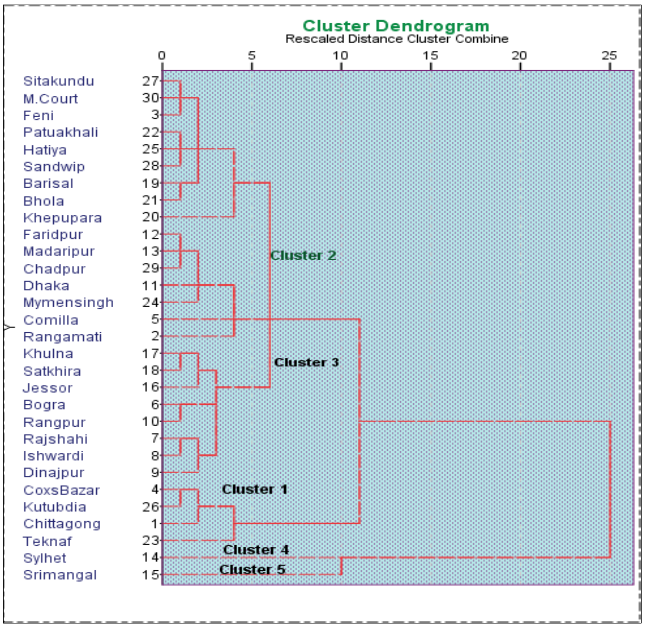


Figure 3. Cluster Dendrogram

Single linkage (nearest neighbor approach), (2) Complete linkage (furthest neighbor), (3) Average linkage, (4) Ward's method and (5) Centroid method (Everitt, 1993). into a smaller set of clusters (Johnson and Wichern, 1996).

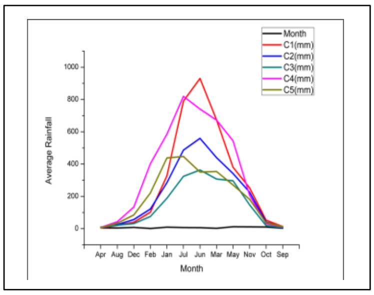
Results

Temporal pattern of average monthly rainfall

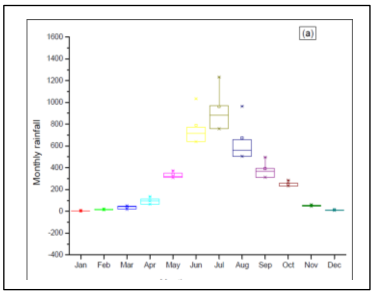
The rainfall pattern of Bangladesh is fluctuated in location and time. It shows that the rainfall is some place in higher rate and some place in lower rate. For understanding the highest pick of monthly rainfall and the lowest peck of rainfall are aggregated through the daily datasets of rainfall. In cluster one the july month is the highest rainfall month in that group and is about 930.5081 mm and the lowest pick is about 4.78mm which occurred in the month of January .Another group of the rainfall station C2, C3, C4 and C5 have 559.37mm, 363.28mm, 819.67mm, 447.07mm rainfall respectively except the June month in the C4 group of the station. Among the entire group the highest rainfall (819.67mm) occurred in the Sylhet region. All the group have least amount of rainfall C1 to C5 about 4.78mm,6.14mm, 6.10mm, 6.55mm and 5.39mm in the month of January except the C3 group which have least rainfall in December.

Month	C1(mm)	C2(mm)	C3(mm)	C4(mm)	C5(mm)
Jan	4.78	6.14	9.27	6.55	5.39
Feb	20.36	24.58	21.39	42.50	33.82
Mar	39.39	56.21	31.66	133.90	84.94
Apr	102.42	122.00	75.28	402.03	220.53
May	327.10	284.74	188.34	585.26	438.00
Jun	790.02	486.74	323.58	819.67	447.07
Jul	930.51	559.37	363.28	741.19	350.61
Aug	672.93	439.79	307.08	672.73	353.97
Sep	380.37	341.32	296.48	544.19	271.03
Oct	252.58	225.58	147.28	206.40	181.43
Nov	52.15	39.76	18.53	30.23	35.94
Dec	12.66	8.93	6.10	11.40	13.60
Annual Rainfall(mm)	3585.27	2595.16	1788.30	4196.06	2436.32

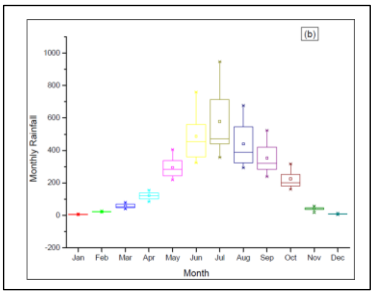
Note: C1, C2, C3, C4 and C5 are the clusters representing monthly rainfall in mm over the country.



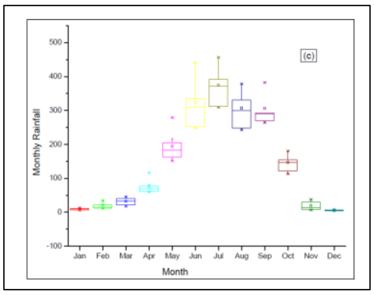
1



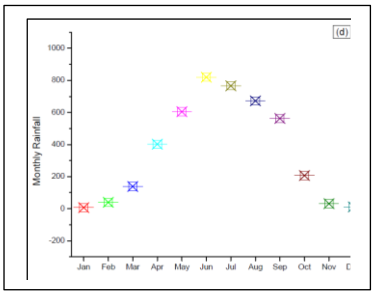
2



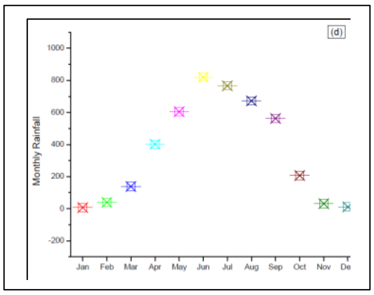
3



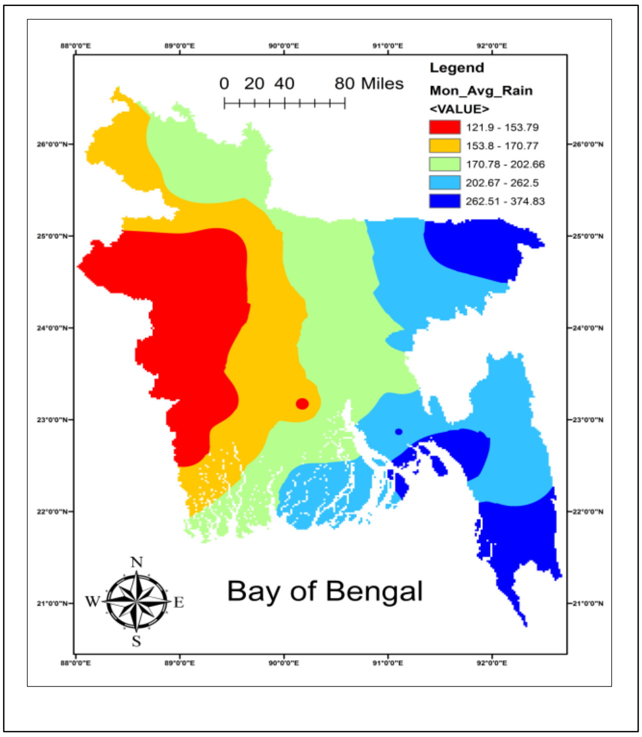
4



5



6



Note: figure 1 shows the temporal variations and figures 2, 3, 4, 5, 6 show the boxplot of the rainfall of the clustering groups. And the last spatial map shows the monthly mean rainfall distribution over Bangladesh.

Conclusion

From this study, rainfall pattern and trend and their homogeneous space and location are identified using various types of software and data visualization tools and techniques. As Bangladesh is the largest delta and surroundings with mountain range, high proximity coast and situated in the downward part of the Himalayan mountain area, it faces various types of hydrological problems along with high apprehend rainfall causing flood and deficiency of rainfall create drought in the certain area of the country, this study help to categorize the total area of the country which is abundance with rainfall and which portion are fall in deficiency and take necessary steps for various developmental issues. The integrated GIS image help to realize the ratio of the rainfall covering area and detect the upcoming drought or flood situation regard the chronically study of the rainfall data. It is also help to develop the agro-economical sector for irrigation system and also the commerce related to the fisheries. By analyzing the monthly rainfall situation authority could take necessary steps for further monthly task for positive GDPs. The study covers the mathematical calculations for identifying the situation for monthly mean, maximum and minimum rainfall over the country. All the calculation done through the use of Statistical Software R, for data visualization and graph and spatial distribution done through ArcGIS 10.5, Origin Pro 8 and SPSS. The calculation, distribution and grouping of the rainfall area by the historical data from the meteorological department of Bangladesh which collected for this study only.

References

Johnson, R.A and Wichern, D.W. 1996. Applied Multivariate Statistical Analysis. Prentice- Hall of India

Pvt.Ltd., New Delhi. 1- 4.

Penarrocha, D., Estrela, M and Millan, M. 2002. Classification of daily rainfall patterns in a Mediterranean area with extreme intensity levels: The Valencia region. International Journal of Climatology. 22: 677-695.

Islam, M.N.; Rafiuddin, M.; Ahmed, A.U.; Kolli, R.K. Calibration of PRECIS in employing future scenarios in Bangladesh. Int. J. Climatol. 2008, 28, 617–628.

Rahman, M.R.; Salehin, M.; Matsumoto, J. Trends of monsoon rainfall pattern in Bangladesh. Bangladesh J. Water Resour.1997, 14, 121–138.

Yeh, H.Y., Wensel, L.C and Turnblom, E.C. 2000. An objective approach for lassifying precipitation patterns to study climatic effects on the treec growth. Forest Ecology and Management. 139: 41-50.

Cretat, J., Richard, Y., Pohl, B., Rouault, M., Reason, C and Fauchereau, N.010. Recurrent daily rainfall patterns over South Africa and associated dynamics during the core austral summer. International Journal of Climatology. 32: 261-273.

AGRICULTURAL ADAPTATION MEASURES TO COMBAT SALINITY PROBLEM IN SOUTHWESTERN BANGLADESH

J. Ferdous[1], M. A. Habib[1] and M. T. U. Rahman[2]

ABSTRACT

Agricultural practices in coastal Bangladesh are under threat due to the effects of salinity intrusion into the soil layers and fresh water scarcity. This study aims to investigate the extent of usage of adaptation measures to combat the salinity intrusion and fresh water scarcity problem from the perceptions of farmers through a questionnaire survey, targeting farmers (N=300) from 15 random locations of Tala and Shyamnagar Upazilas. Measures such as applying gypsum (77% in Tala and 80% in Shyamnagar) and shifting to shrimp culture (74% in Tala and 83% in Shyamnagar) got a high response. On the other hand, use of low water consuming crops got the least popularity among the farmers. There is still a significant scope of implementing agricultural adaptation measures in both the study areas. Independent t-test and Mann-Whitney 'U' test were carried out on the perceptions and it has been observed that the opinions of the respondents of the two areas had no significant statistical differences.

Introduction

Salinity intrusion in coastal regions causes severe land degradation and abandonment of agricultural lands (Li et al., 2011). Both natural (flood and storm surge) and anthropogenic (excessive use if fertilizer and shrimp culture) causes trigger salinity intrusion in coastal Bangladesh and Satkhira, Khulna, Bagerhat, Borguna, Patuakhali, and Barisal districts are the worst victims (Disaster Management Bureau, 2010; Islam et al., 2012; Wu et al., 2008). The well-being of the coastal people must need to be considered for the development of Bangladesh, as the coastal region is the home to a population of 36.8 million people and over 30% of the net cultivable land is in the coastal area (Akanda and Howlader, 2015; Islam et al., 2012). The primary occupation of coastal people is agriculture, which is one of the most disaster-affected sectors. Salinity is the most prominent controlling factors of crop production and 36.8% of arable lands in the coastal and off-shore area are affected by varying degrees of salinity (Asib, 2011). Coastal farmers extract groundwater for irrigation at the beginning of winter period and exaggerate salinity intrusion into the aquifers (Haider and Hossain, 2013; Murshid, 2012). Agricultural lands have lost their productivity, which eventually declines net food production, due to this salinity intrusion and irrigation with saline groundwater (Islam et al., 2012; SRDI, 2010). Researches have reflected that salinity intrusion has significant negative impacts on the livelihood strategy of the local farmers and on crop production and yield (Baten et al., 2015; Haider and Hossain, 2013). To cope with this adverse situation, farmers have to adapt some effective measures.

Haider and Hossain (2013) tried to trace out the impact of salinity on livelihood strategies of farmers and responses of farmers to solve the salinity problem, studying four villages from two unions in Assasuni Upazila of Satkhira district, Bangladesh. The study found that though salinity intrusion negatively influences income, expenditure and employment opportunity for the farmers, it positively influences shrimp culture-led land-use activity and farmers try to handle the salinity problem at their own levels through applying lime, gypsum etc. The impacts of salinity on crop agriculture in the south-central coastal zone of Bangladesh have been studied by testing irrigation water collected from the lower Meghna at Gosairhat Upazila in Shariatpur district and interviewing experts and local farmers. Salinity concentration has already put a threat to crop production, crop yield, farmers' livelihood, income generation and food security (Baten et al., 2015). Effect of salinity intrusion on rice production in Satkhira district has been explored and saline-tolerant rice cultivars have been identified as the most important adaptation measure, though this has not been enough to deal with the sudden increase in salinity after cyclone AILA in 2009 (Rabbani et al., 2013). Islam et al. (2012) have attempted to know the present extent of salinity and how much agricultural land has reduced gradually during last decade studying Satkhira district and also tried to identified suitable land use practices and available adaptation measures to adapt to a certain level of salinity. Very few researches have been made in Tala and Shyamnagar Upazilas of Satkhira district, which appear to be severely affected by salinity. This study aims to identify the

[1]*Research Officer, Climate Change Lab, Dept. of Civil Engineering, Military Institute of Science and Technology, Dhaka-1216, Bangladesh*
[2]*Professor, Dept. of Civil Engineering, Military Institute of Science and Technology, Dhaka-1216, Bangladesh*

risk reduction strategies in practice and other potential methods to reduce the risks associated with salinity intrusion in the farmlands from the perceptions of farmers. Therefore, the objective of this study is to explore the extent of usage of the agricultural adaptation measures to combat the effect of salinity intrusion in Tala and Shyamnagar Upazilas of Satkhira district.

Study Area

Atulia, Nurnagar, Kaikhali, Shyamnagar, Padmapukur, Ishwaripur, Gabura and Harinagar of Syhamnagar Upazila and Nagarghata, Kumira, Patkelghata, Tala, Islamkati, Khalishkhali, and Khosra of Tala Upazila were selected as study locations from Satkhira district of southwestern Bangladesh (Figure 1). The majority of the people in Shyamnagar Upazila earn their living through shrimp farming, as agriculture is seemingly getting difficult due to the degradation of land through salinity intrusion and sustaining agriculture has become costlier than shrimp farming. Therefore, the shift in the land use pattern has been a major issue for Shyamnagar Upazila (Alauddin and Rahman, 2013). On the other hand, during field visit, it was observed that Tala has a better balance between shrimp farming and agriculture but persistent waterlogging in some locations has made the lives difficult for the local people.

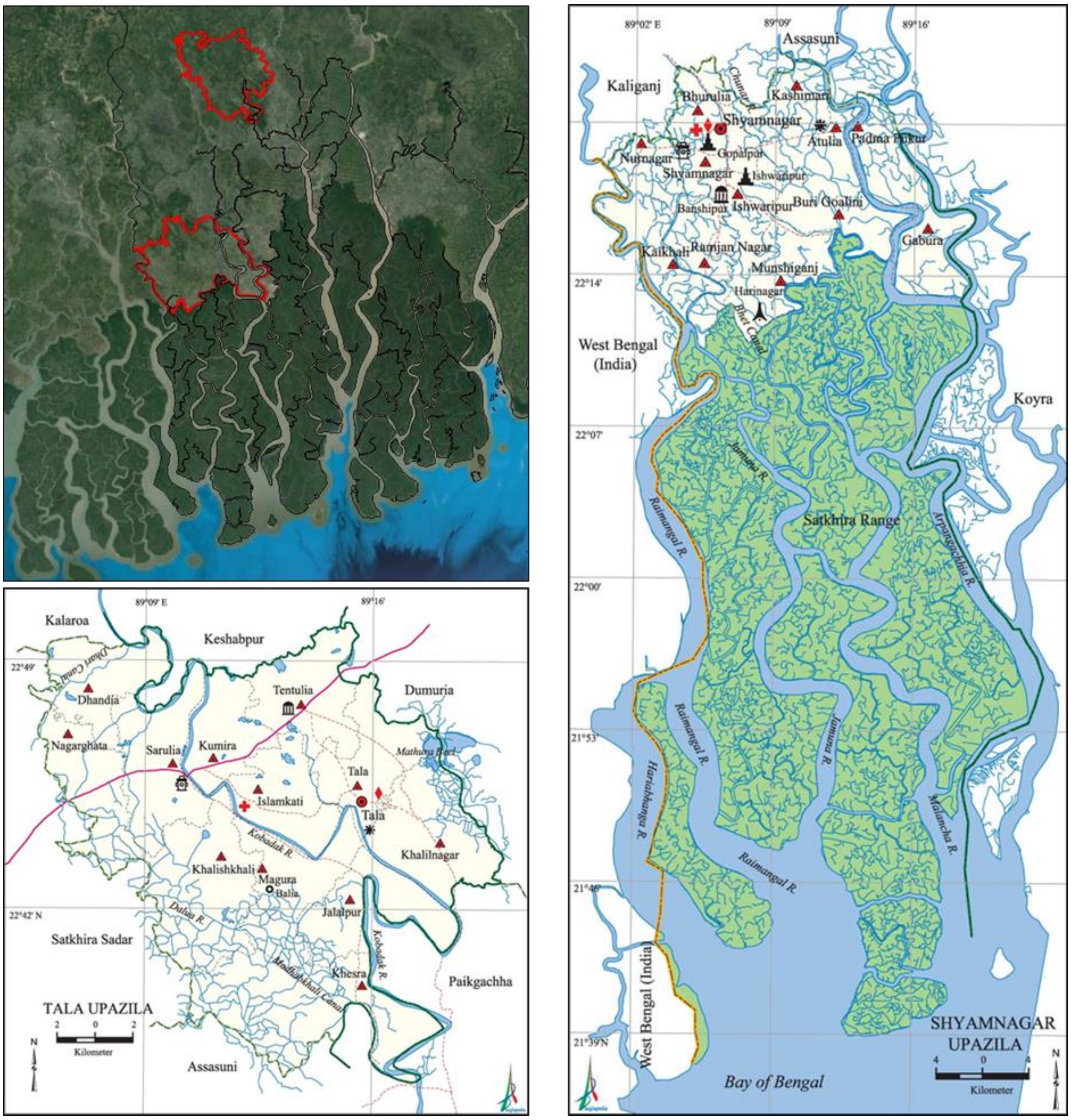


Figure 1. Location of study area (Tala and Shyamnagar Upazila)

The study area forms a part of the southwest coastal region of Bangladesh, where the rapid conversion of rice fields to shrimp 'ghers' (the local name given to shrimp farming lands) has been termed as the 'Blue Revolution'. The amount of rice production seems to have therefore decreased over the years as the rice fields have been modified into 'ghers' (shrimp farm) in the southwest coastal region (Ahmed et al., 2010). As a result, there may be a shortage of food production in the area and in the near future food might be needed to be brought in from other areas of the country to meet the demands of the southwest coastal region (Islam et al., 2015). The significance of this area being chosen for the study is the rate at which agricultural lands are slowly being converted to other land use categories. Sustainable agricultural methods need to be in practice to bring in a balance in the land use category. So, risk reduction in agricultural practices can be a sustainable way of practicing agriculture and the perception of the farmers need to be known before implementing risk reduction strategies.

Methodology

To collect the primary data regarding the farmers' perception of agricultural adaptation measures, a field trip was organized during Mach 2016. Perceptions of the farmers to what extent do they applied agricultural adaptation practices were collected by a semi-structured questionnaire. The adaptation practices included in the questionnaire were more focused on reducing water usage in agricultural activities, as in-field observation concluded the presence of water scarcity in the study area. The questionnaire format was kept as simple as possible for better and quick understanding of the farmers keeping their literacy level in concern. General information on the type of farmers was collected prior to the questionnaire survey to finalize the samples for the questionnaire survey. It was ensured that all types of farmer participated in the questionnaire survey. 95% confidence interval and ±5% level of precision was used for calculating the sample size of the study area and the approximate sample size was 300. Among the respondents, there were 105 owners, 27 owner-cum tenants and 18 tenants in Shyamnagar and 100 owners, 35 Owner-cum tenants and 15 tenants in Tala Upazila. With the semi-structured questionnaire, 300 farmers of different categories had been interviewed. For an effective and participatory collection of perceptions from the farmers, the local government representatives from Shyamnagar and Tala enlightened the research team and helped with his knowledge of the local communities and agricultural lands.

Four focus group discussions have been arranged in four Unions of two Upazilas, Nagarghata, and Tala of Tala Upazila and Gabura and Shyamnagar of Shyamnagar Upazila. Around 10-12 members were present in each FGD. Chairmen and some of the members of Union Parishads and some representatives from local NGOs were present in the discussion. The overall salinity condition and its consequences on the agricultural practice of the area were the key topics of the discussions. The Upazila Nirbahi Officers (chief executive of an Upazila) of the two Upazilas have been interviewed also.

Independent t-test was carried out using IBM SPSS 20.0 software on the perceptions. This was to observe whether the opinions of the respondents of the two areas had any significant statistical differences or not. Mann-Whitney 'U' test was also carried out to further bolster the fact of statistical differences. If the 'p-value' of the equal variance independent 't' test is larger than the value of 0.05, then it can be said that the perceptions of the respondents in the two Upazilas did not differ significantly. On the other hand, the critical value for the Mann-Whitney 'U' test is dependent on the number of options (N). The critical value is 13 when N is 8 and 17 when N is 9. If the obtained value is greater than the critical value, then it means that the response of the farmers in the two Upazilas does not vary significantly. If the statistical differences are not significant then the risk reduction measures can be applied commonly to both the locations due to the fact that both the areas are exposed to or are suffering from the same type of hazards.

Results and Discussions

Researchers have identified 9 agricultural adaptation measures for the study area from literature review and own knowledge. Selected adaptation measures are applying Gypsum, shifting to Shrimp/Crab culture, manuring and composting, reuse of sullage water, mulching technique, multi-cropping/intercropping, retention irrigation, changing irrigation techniques for conserving water and low water consuming cropping pattern. Farmers were asked which agricultural risk reduction measures they use and Figure 2a and 2b show their responses on different agricultural risk reduction measures in Tala and Shyamnagar respectively. Almost all the risk reduction measures gathered less to very less response. The use of low water consuming crops got the least popularity (up to 81% respondents putting "very less" response) in Tala.

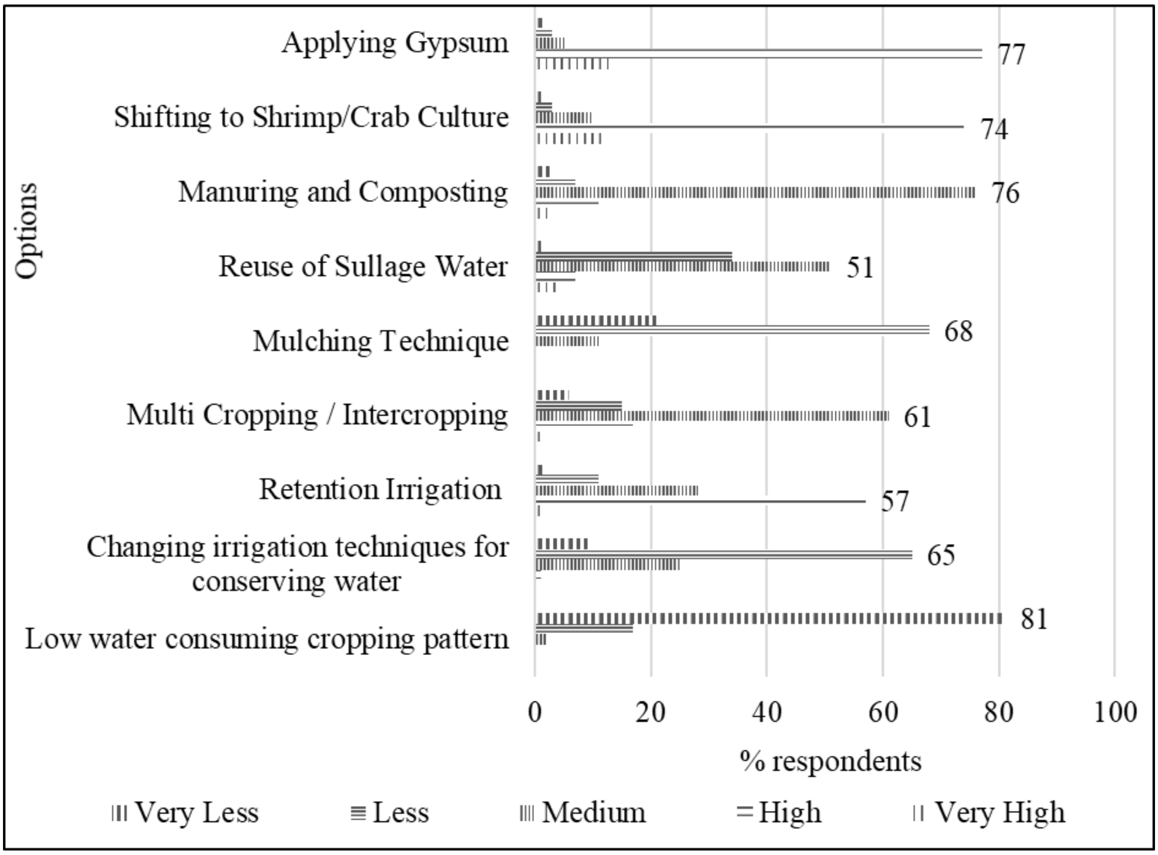


Figure 2a. Perceptions of the farmers about agricultural risk reduction measures in Tala

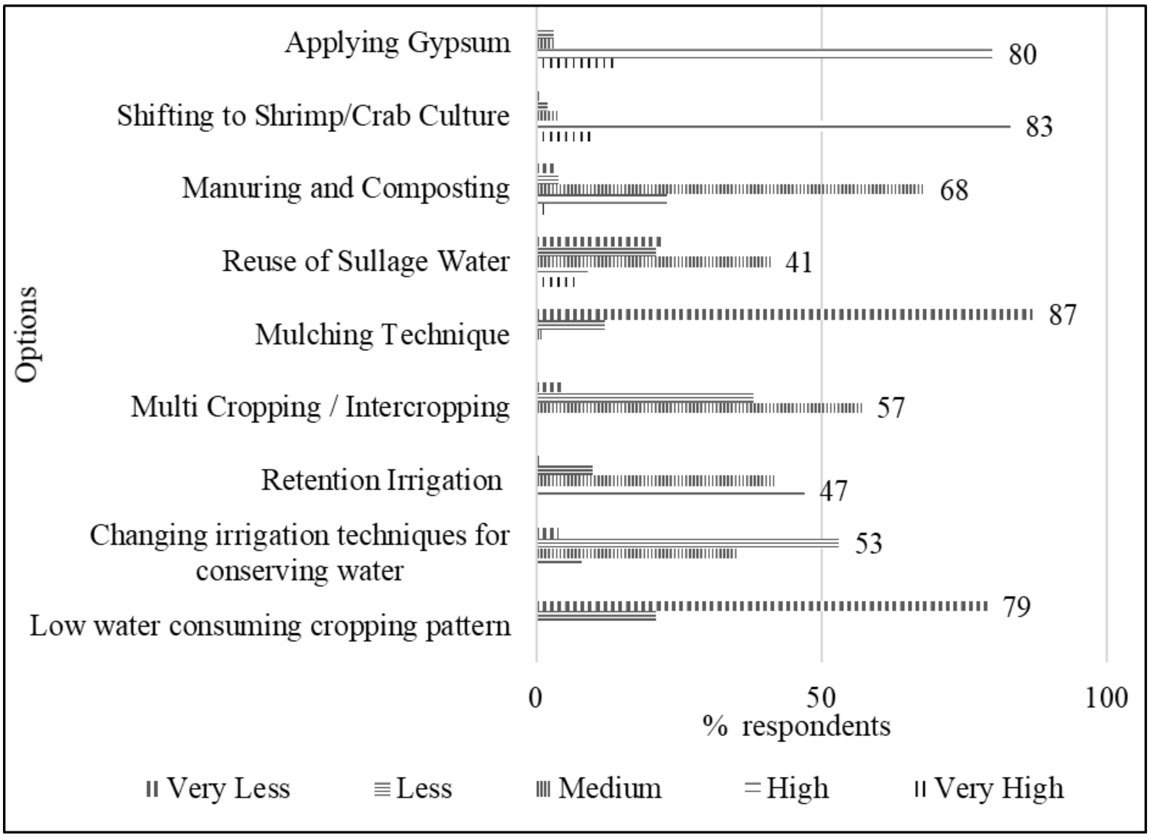


Figure 2b. Perceptions of the farmers about agricultural risk reduction measures in Shyamnagar

Retention of irrigation water gathered "high" response and other techniques such as manuring and composting got a medium category of response. Shrimp culturing and applying gypsum were in high practice according to the respondents with 74% and 77% respondents putting "high" response to these risk reduction methods respectively in Tala. The mulching technique seemed to be the least practiced and known risk reduction measure in Shyamnagar, with 87% respondents revealing that it is the least practiced and known risk reduction measure. Searching for low water consuming crops or planting them also appeared to be a very less known practice in Shyamnagar. 79% respondents put their opinion in this category. The highest practiced risk reduction practice in Shyamnagar was found to be switching to shrimp cultivation (83%) and applying gypsum (80%) to the croplands to reduce the effects of salinity. Retention irrigation through rainwater harvesting was pretty popular with 47% respondents putting "high" response to this method (Fig. 2b). The 'p-value' was calculated to be 0.967 and that the sample size was big enough for the Mann-Whitney test to be conducted, the U value came out to be 40. Both the statistical tests suggest that the perception reactions did not significantly vary statistically.

Adaptation measures are the modern way out to tackle the impact of hazards and some of them have already been practiced in the study area. Owner of the lands are better suited to switch to appropriate adaptation at a fast rate than others, as they have the control on the choice. Over 50 % farmers of the study area own agricultural lands, which is a positive indication. Researchers have found the advisory board regarding various agricultural adaptation measures in Shyamnagar. The advisory board tells about practicing retention irrigation, allay cropping, multi-cropping/intercropping, reusing of sullage water and mulching technique for reducing the effects of soil salinity as adaptation measures (Figure 3).

Figure 3. A colorful advisory board about agricultural adaptation measure, written in the local language of Bengali in study area

The current level of administrative support to combat the risks associated with agriculture is not satisfactory. The farmers are receiving support in small monetary terms for agriculture but there is yet lack of infrastructure support to provide irrigation water. Crop insurance may be an effective method to combat the immediate negative effects of crop failures. Farmers suffer a significant amount of financial setback in the event of crop failures. But crop insurance facilities are almost absent in the study area. The arrangement of water supply tankers for monthly irrigation support was found to be almost negligible with a few water purification plants being operated by the Non-Governmental Organizations (NGOs) but was only limited to drinking water purposes. The water purification plants established by private entrepreneurs appeared to deliver water at increased costs and that also for only drinking purposes.

Community-based rainwater harvesting tanks and solar power based salinity removal plant can be pioneered by the administrative bodies by providing long-term loan facilities to the farmers. In this way, the poor farmers can have the opportunity to sustain agricultural activities. The local respondents insisted on the national authorities disbursing short term loans so that they may set up rainwater harvesting plants at the community levels.

Conclusions

Agricultural practices in the southwestern coastal Bangladesh have been affected significantly due to scarcity of irrigation water free of salinity. To sustain agriculture in these crisis prone areas, farmers' perception is a useful tool in designing adaptation measures. The farmers' perceptions reflected their concern regarding salinity intrusion and contamination and unavailability of fresh irrigation water. Measures such as retention irrigation, composting and manuring and reuse of sullage water are some of the self-driven adaptation measures that the farmers are practicing in the study area, but certainly not in large numbers. Rather adaptation techniques such as switching to shrimp farming and applying gypsum to soil layers were found more popular in the study areas. Vigorous practice of shrimp farming may in turn affect the overall ecological diversity of the study area and might result in monoculture. So, an integrated and well-coordinated agricultural adaptation measures should be immediately taken into concern for this area.

References

Ahmed, N., Allison, E. H., and Muir, J. F. (2010) “Rice fields to prawn farms: a blue revolution in southwest Bangladesh”, *Aquacult Int.,* 18 (4), 555–574.

Akanda, M. G. R., and Howlader, M. S. (2015) “Coastal farmers' perception of climate change effects on agriculture at Galachipa upazila under Patuakhali district of Bangladesh”, *The Global Journal of Science Frontier Research,* 15 (4), 31-39.

Alauddin, S. M., and Rahman, K. F. (2013) “Vulnerability to Climate Change and Adaptation Practices in Bangladesh”, *Journal of SUB,* 4 (2), 25-42.

Asib, A. (2011) “Some of the major environmental problems relating to land use changes in the coastal areas of Bangladesh”, *A review Journal of Geography and Regional Planning,* 4 (1), 1-8.

Baten, M. A., Seal, L., and Lisa, K. S. (2015) “Salinity intrusion in interior coast of Bangladesh: challenges to agriculture in south-central coastal zone”, *American Journal of Climate Change,* 4, 248-262.

Disaster Management Bureau (2010) *“National Plan for Disaster Management 2010-2015”,* Dhaka.

Haider, M. Z., and Hossain, M. Z. (2013) “Impact of salinity on livelihood strategies of farmers”, *Journal of Soil Science and Plant Nutrition,* 13 (2), 417-431.

Islam, M. A., Rahim, M. A., and Iqbal, T. M. T. (2015) “Effect of Irrigation and Mulching on Growth and Yield of Ginger”, *Bangladesh Agron. J.,* 18 (1), 27-36.

Islam, M. S., Rahman, M. A., Sultana, N., Nath, B., and Paul, A. (2012) “Using geospatial techniques to assess the salinity impact on agricultural landuse: a study on Shyamnagar Upazila, Satkhira”, *Journal of Agriculture and Environment for International Development,* 106 (2), 157-169.

Li, D. J., Chun, W. M., and Tiyip, T. (2011) “Study on soil salinization information in arid region using remote sensing technique”, *Agricultural Science in China,* 10 (3), 404–411.

Murshid, S. M. (2012) “Impact of sea level rise on agriculture using groundwater in Bangladesh”, *MSc. Thesis,* CoMEM Programme, University of Southampton.

Rabbani, G., Rahman, A., and Mainuddin, K. (2013) “Salinity-induced loss and damage to farming households in coastal Bangladesh”, *International Journal of Global Warming,* 5 (4), 400-415.

Soil Resources Development Institute (SRDI) (2010) *“Saline Soils of Bangladesh”*, Dhaka.

Wu, J., Vincent, B., Yang, J., Bouarfa, S., and Vidal, A. (2008) “Remote sensing monitoring of changes in soil salinity: a case study in Inner Mongolia, China”, *Sensors,* 8 (11), 7035–7049.

AUTONOMOUS BUILDING PROCESS FOR ADAPTING THE CLIMATE CHANGE IMPACTS: LEARNING FROM THE URBAN INFORMAL SETTLEMENT IN KHULNA

Shantanu Biswas Linkon[1] and Nur Mohammad Khan[2]

ABSTRACT

Due to geographic location, Khulna in one of the most climatically vulnerable settlements in Bangladesh, and already been experiencing different climate-change-induced impacts and urban problems like summer heat stress, drainage congestion, water logging, reduced freshwater availability etc. Alongside, more than twenty-five percent of the total population of Khulna city are living in different densely populated informal settlements, who are most vulnerable to the impacts of climate change and often do not get enough support from formal institutions. Therefore, a majority of them build their house autonomously and have developed various adaptation processes, as a part of their survival strategies. Meanwhile, authorities are working to lessen these climate-change-induced impacts, but mostly without considering dwellers' autonomy; and there is no institutional framework to recognize these autonomy. To this end, this research aims to investigate two inter-related issues – firstly, how climate change impacts are affecting urban informal settlements both at dwelling unit and neighborhood level, and secondly, how these poor urban people adapt different impacts by their autonomous building process. By adopting a fact-finding case study approach, this qualitative research focuses on to depict these autonomous building process. Based on the empirical findings, this paper proposes some guidelines for the development of adaptive informal settlements and argues that recognition of these autonomy is important for making a resilient and adaptive city.

Keywords: Autonomy, Adaptation, Climate Change, Informal settlement

Introduction

In present we are facing the impacts of climate change, a long discussed phenomenon. Researchers has identified that the impacts of climate change has increased the frequency of natural disasters (Solomon et al., 2007). Bangladesh is expected to be worst affected by it due to its large population, high population density, inadequate infrastructure, and lack of institutional capacity (ADB, 2011). Significantly, situation is becoming worse for the densely populated informal settlements, occupied by the urban poor (CUS, 2006). Besides, acceleration of urbanization is happening due to dislocation of a greater number of people from disaster-affected areas. Bangladesh is experiencing a rapid urbanization rate of 3.2% (BBS, 2015). Alongside rapid urban transformation, urban poverty and poor people is increasing. And these people, who live in the informal settlements, are mostly facing the impacts of climate change. In Khulna, more than 25% of the urban population are living in informal settlements (BBS, 2015). KDA revealed that, in the past 10 years nearly 99% population was affected by disasters like – river flood, cyclone, water logging, heat stress and salinity (KDA, 2012). Nonetheless, belonging to the bottom of the power structure, millions of poor people are living in informal settlements; build their house autonomously and have developed innovative strategies to adapt climate-induced urban vulnerabilities. However, dwellers remain vulnerable despite of numerous projects against climate change for the lack of involvement of autonomous building process. Therefore, this research discusses the issue- "How can climate change impact be adapted by urban informal dwellers through autonomy in building process?"; and investigates two interrelated queries – firstly, how climate change impacts are affecting built-environment, economic and social system of informal settlements? and secondly, how these poor urban people are adapting different climate-change-induced vulnerabilities by autonomy in building process, both at the dwelling unit and neighborhood level?

Climate Change Impacts in Informal Settlements of Bangladesh: Surviving with Disasters

The UN (UNSTAT) in 2005 (Alemie et al., 2015) defines informal settlements as: 1) areas where groups of housing units have been constructed on land that the occupants have no legal claim to, or occupy illegally; 2) unplanned settlements and areas where housing is not in compliance with current planning and building

[1]*Part-time teaching staff, Architecture Discipline, Khulna University, Khulna-9208, Bangladesh*
[2]*Lecturer, Architecture Discipline, Khulna University, Khulna-9208, Bangladesh*
Email of Corresponding Author – linkonku@outlook.com

regulations. Khulna city is facing rapid urbanization with shortage in infrastructures, housing, services and utilities and uncontrolled growth of informal settlements. The plain flat land of Khulna city is only about 2.5m above from sea level. The main reason for ground water salinity is the intrusion of sea water in Rupsha and Bhairab river (KDA, 2012). The city experiences frequent water logging during rainy season due to inadequate drainage. The possible increase in precipitation due to climate change coupled with sea level rise will make the situation even worse (ADB, 2011). Besides, both increasing of hard surfaces, and loss of green spaces and natural water bodies are making Khulna hotter. A report on Khulna (KDA, 2012) and key climate change studies at national level (BCAS et al., 1996; van Scheltinga et al., 2015), have identified the following climate change impacts for Khulna: 1) More frequent cyclonic storm with higher strength; 2) Increased river flooding and water logging, both in terms of extent and frequency; 3) Increased salinity intrusion in ground water; and 4) Hotter heat waves during summer. Concerning this context, informal settlements will be affected by these impacts in future.

Defining "Autonomy" in Building Process: Features and Attributes for Informal Settlements

Although the basic activity of housing is not different; but autonomous building process is different from context to context. Nevertheless, the basic conception of autonomy in housing is same for all (Turner & Fichter, 1972). Autonomy refers to 'freedom of action constrains by cost'; a pragmatic answer both to the shelter deficit and to frequent mismatch of shelter and essential needs (Turner & Fichter, 1972). Autonomy in building process means self-help that is, self-determination at local level where a person still retains their identity (Maslow, 1971). Based on Turner's standpoint (1977) autonomy in built environment can be described ass - When dwellers control or take the major decisions and are free to make contributions in the design; construction techniques; management; and are able to retain their own identity; both this process and the produced environment can be referred as autonomy in building process. Autonomy in building process is low-in-cost and effective, but its social values are more superior. For the deprived, autonomy signifies greater access to goods and services than is available to them at present, and this access should be obtainable through greater inputs of time, labor, and collective bargaining (Turner, 1977). In the context of poverty, autonomy increases quantity (Turner & Fichter, 1972).

According to Burton (1997), adaptation to climate change is the process through which people reduce the adverse effects of climate on their health and well-being, and take advantage of the opportunities that the climatic condition provides. As far as communities are concerned, adaptation involves adjustments by individuals and the collective behavior to reduce vulnerabilities to climate change. Adaptations vary not only with respect to their climatic stimuli, but also with respect to other non-climate trends (Smit et al., 2000). Researchers have identified different types of adaptation - 1) planned; 2) autonomous; 3) passive; 4) reactive; and 5) anticipatory adaptation (Levina & Tirpak, 2006). Autonomous adaptations are initiated without the intervention of a public agency; as a consistent reactive response to climatic stimuli. The need for planned, anticipatory adaptation can be evaluated against the baseline formed by autonomous adaptation (Smit et al., 2000).

To this end, autonomy for adapting the climate-change-induced vulnerabilities are measured from built-environmental, economic, and social province in two interrelated scales: 1) dwelling unit level; and 2) neighborhood level. Dwelling unit level entails autonomy in five sub-domains: i) built form; ii) construction materials and techniques; iii) maintenance process; and iv) income-generating activities & space; v) spatial pattern & use. While, neighborhood level entails autonomy in five sub-domains: i) location; ii) accessibility; iii) livelihood activities; iv) infrastructure & utilities; and v) community services and amenities.

Approaching Autonomy in Building Process to Adapt the Climate Change Impact: The Case of Railway Slum in Khulna

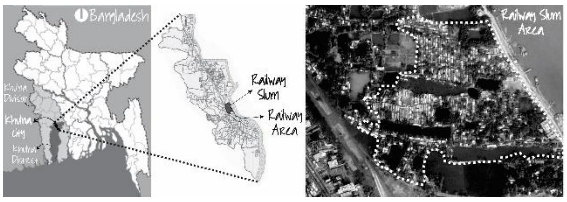


Figure 1. Location of railway slum area (left and middle one); study area (left one) (source author)

One of the largest of slums of Khulna is the railway sum, where about 25,000 poor people are living with and inadequate basic services such as sanitation, drainage, electricity, water supplies. The settlement, in the administrative Ward 21(figure 01), consist about 1148 house-holds. The whole settlement can be divided into three parts – 1) Montu Colony, 2) Greenland Bosti, and 3) Sweeper Colony. In this research Greenland Bosti is taken as the 'unit of analysis.' Traditionally this settlement is vulnerable due to geographic location. But, people has been adapting the increasing climate change impacts both. Total population of the intervention areas is 700 people in 105 households. By adopting purposeful sampling to reach most vulnerable persons, 35 SSI and 4 FGD (consisting 8, 9, and 10 persons accordingly) were conducted.

Autonomy in Building Process practices at the domain of Dwelling Unit

i) Built form: Autonomously constructed built forms both in the row and cluster type organizations and are built by the side of the internal streets. Built forms, constructed autonomously, are mainly single story- built form on plinth (mud or masonry) and built form on stilt (Figure 02). Most built forms are sited on very low plinth (+6 in. to +1ft from street). Due to low plinth during flood, tidal flood and water logging, water gets into the dwelling unit. The built forms on stilt and upper part are less vulnerable to these. In case of orientation, there is little scope to maintain climatic orientation. During summer houses facing west get very hot. Dwellers adapt heat stress by–1) Building semi-outdoor space at front; 2) Providing large openings without shutter in facades; 3) Creating perforated enclosures; and 4) Vegetation on the roof.

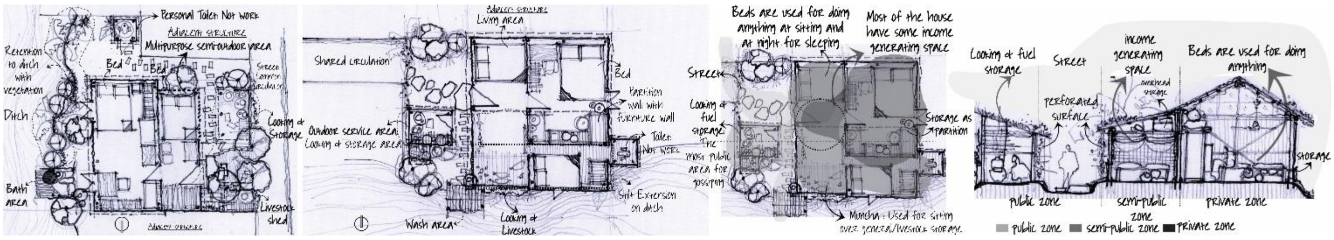


Figure 2. Built form in the railway slum mud plinth (left), stilt type (right); multiple use of single space in plan (left); and in section (right) (source: author)

ii) Construction materials and techniques: Mostly, two types of autonomously built dwelling units are found in this settlement: 1) *kutcha* house- built with organic materials such as bamboo, wood, nipa palm, thatch, mud, and found materials such as plastic sheets, hardboard, paper etc.; 2) s*emi-pucca* house- built with the combination of organic and permanent materials (such brick, tali, CI sheet and concrete). Plinth is mostly made of mud/ brick (Figure 03); or wooden platform supported by bamboo/ wood for built form on stilt (Figure 04). During flood and water logging, soil is washed away from plinth. Alongside driving rain enhances the erosion of the plinth. Additionally, tidal flood or water logging causes salinization of the soil.

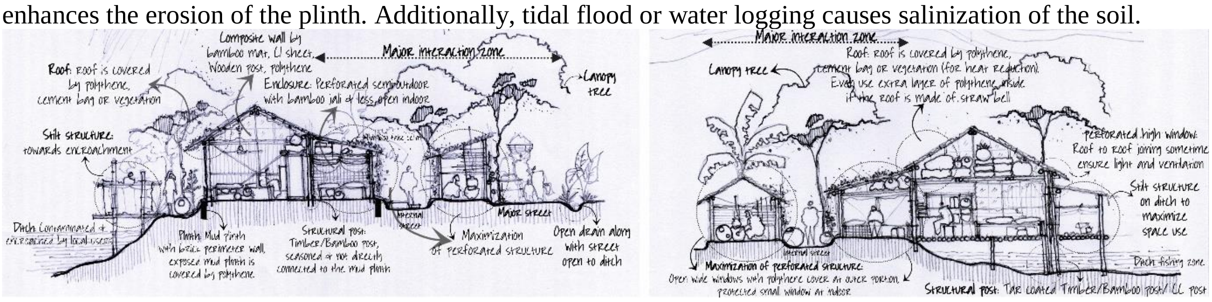


Figure 3. Construction materials and techniques of a mud plinth (left) and a stilt type (right) dwelling unit (source: author)

Dwellers adapt the water level rising by increasing height of mud plinth, surrounded by brick perimeter walls to protect it from washed away (Figure 03). Besides, some make masonry plinth and use of mud-concrete is found to prevent salinity. For structure of both *kutcha* and *semi-pucca* houses, people use bamboo and wooden post for *khuti*; frame is also made with bamboo and wood. Organic materials decay due to sunlight, rain, fungi, and high humidity. Besides, salinity makes these more vulnerable. Dwellers coat the exposed portion of timber with motor oil or tar. They make a brick layer at the base of the vertical posts to avoid salinity. To make roof structures strong, dwellers use bamboo bracing, ropes and iron bolts at joints. Anchoring of vertical posts and roof frames are also seen. Enclosures of dwelling units mostly are made of wood, however, in few cases use of brick wall are seen. Having windows and perforation over the windows for better ventilation is good for local climate. But too much perforation make the dwelling unit vulnerable to cyclonic storm. Dwellers living close to the river bank adapt this by minimum openings in enclosure. In general, dwellers autonomously adapt heat stress in unique ways – i) use of Perforated window 'jali', ii) open windows without shutter for adequate cross ventilation, and use of heat absorbing materials. During rainy season, due to heavy rain, these enclosures get leakage. Besides, driving rain makes the dwelling unit more vulnerable. Adaptations are made by using cement bags and polythene in the vulnerable portion. Besides, the roofs are extended to a level which protects the driving rain from entering into the living area. Cyclonic storms and rainwater are a guiding factor for the form and shape of roofs. Sloped or pitch roof are used for better drainage of rainwater. Lightweight materials are used particularly for overhead. (Figure 03). Leakage appears on the roof due to deterioration for sunlight, rain, and high humidity. Sometimes, dwellers use polythene, a cement bag, or banner cloth for an extra layer of protection.

iii) **Maintenance process:** Generally, dwellers maintain their house on a 2–3 year cycle. During rainy season, people- 1) add extra mud at vulnerable positions, 2) use polythene and cement bags on exposed surfaces of plinth, 3) add brick layer to make the plinth stronger. Posts and frames of structure deteriorate due to rain and humidity. Formerly, these are used as cooking fuel. Sometimes, dwellers transform the lower portion of posts into brick or concrete to protect it from salinity. Roof and enclosures generally deteriorates due to heavy rain and high pressures. Dwellers add Nipa Palm, thatch, polythene, cement bags, and banner paper for sealing the leakage.

iv) Spatial pattern & use: Autonomously built dwelling units, mostly have a single space living area with partition. Dwellers have maximized the social logic of both typologies by using a single space in multiple purposes (Figure 03). For example, in row houses the streets and in clustered houses the common spaces are used as an extension of houses. This multiple use of space gets disrupted during disasters. In most cases service portion (kitchen and bath) is found in front part. Considering heat stress, dwellers place kitchen near door. Regarding floods and water logging, dwellers have a secondary facilities for cooking (temporary one like cooker). Storage facilities on *muncha* under the roof are found. The main autonomous adaptation by dwellers include: 1) shifting belongings on bed or higher *muncha* during flooding and water logging; 2) sending things to a neighbor's house if necessary, 3) Hanging a box to put poultry and or building '*muncha'* to put livestock on it; (4) constructing partition wall (low heighted +1'6"- +2') for protecting the living area from the heat of the cooker (Figure 02).

v) Income-generating activities and space: For their economic survival, dwellers invented diversified ways to accommodate different economic and domestic activities in a single space. Dwellers perform income generating activities like tailoring, food/fish processing, katha sewing, carpentry, handicraft, etc. (Figure 02). Dwellers have also found to put poultry in box-space under bed, or pocket space under kitchen shelf. Sometimes, livestock are also found. Poultry or livestock are moved to muncha during flooding. Almost every household has provision of kitchen garden, mainly found on the roof or in front/backside of house to minimize living cost.

Autonomy in Building Process practices at the domain of Neighborhood

i) Location: Historically, this settlement has developed by filling the lower land, pond and ditch area. The area is about 4'-5' lower from the level of embankment. The area along the embankment is of relatively higher elevation, while the area around the rail station and rail line is of much lower elevation. The community is mainly vulnerable to tidal floods and water logging for its lower elevation. The initial settlers autonomously adapted the regular tidal floods at individual level by building the houses on stilt on relatively higher land. Settlers are adapting this by increasing the elevation of land by sand fills. But it has caused the loss of natural canal and water bodies.

ii) Accessibility: This settlement is directly accessible from two ways – i) from BIWTA ghat area and ii) from rail station area, through 4'-5' narrow pedestrian lanes. Numerous narrow pedestrians branched out from these primary lanes. These access lines are have dead-ends, which constrain evacuation in emergency situation. The primary lanes are paved with poor quality concrete, while the secondary pedestrians are made with brick. Some are made of mixed of mud and brick soling. During rainy season and tidal flooding, these accessibility lines get destroyed. Autonomous adaptation implemented by dwellers- 1) making temporary walkways by putting brick and cement bag during water logging; 2) development of bamboo bridges *'sako'* for access lines.

iii) Livelihood activities: Dwellers in this settlement has a varied range of livelihood activities. Livelihood activities includes day labor, rickshaw pulling, building construction, hawking, fish/food processing (home-based or outside), and self-employment with micro investment. During water logging and storm, some of the livelihood options especially the home-based get disrupted. One of the most notable fact is that dwellers have better adapted the impacts due to their varied livelihood options. Autonomous adaptations are – 1) maintaining more than one occupation; 2) gender dimensions—including women in income-generating activities; 3) Involving male members in household work; 4) Changing to alternative income source during disaster period.

iv) Infrastructures & basic utilities: Infrastructure and basic utilities (i.e. water supply, drainage, sanitation, waste management and electricity) are highly inadequate here. Salinity intrusion in water is a concerning effect. The Rupsha River and tube-wells (deep and shallow) are the main sources of water. Drinking water is only available from deep tube-well (one tube well for 30-40 households) (Figure 04). Dwellers use shallow tube-wells for utility purpose. Maximum dwellers travel to outside (1/2 km) to collect drinking and cooking water. Some dwellers also harvest rain water. Dwellers living close to Rupsha River use river water for bathing and washing. The embankment protects the settlement from tidal flooding and storm surge. During cyclone Aila dwellers tried to prevent the water surge by piling cement bags on embankment. Due to increasing sedimentation and climatic change slow draining causes water logged here. The internal drainage system consists two types of drains – primary drainage lines (box-culvert), and secondary drainage lines (open drains) (Figure 04). Narrow open drains are found in most area and most are not linked with primary drains. Dwellers dig some open drains and connect them with open ditch. Dwellers often dump wastes in the ditch and open drains for absence of an integrated waste management system. During post flood and water logging period these drains becomes highly risky for health. Dwellers generally use recycled material like woods, paper board, and so on, as fuel for cooking. Very few use electricity for cooking as it is high in cost. In case of sanitation, shared toilets (one toilet for 25-30 households) are found provided by NGOs, maintained by dwellers communally.

v) Community facilities and amenities: As like other urban informal settlements, there is lack of neighborhood space, or children play area. Dwellers autonomously adapt this by converting the compact spaces (the dwelling unit and adjacent circulation) into multidimensional social spaces. Dwellers accomplish both their domestic and communal activities within this compact system (Figure 04). The streets are not only are used as circulation but also used for – cooking, bathing, poultry rearing, child rearing, children play area, vending, and community interaction. This is an extreme example of using a single space in multiple activities.

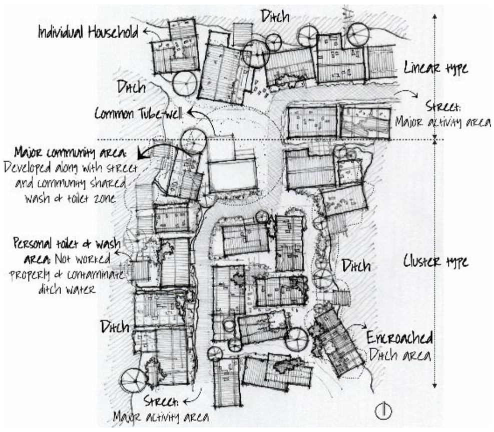


Figure 05. People's perception about most vulnerable part dwelling unit (left) and neighborhood (right) (source: author)

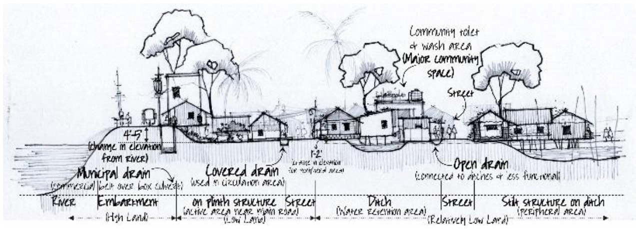


Figure 4. Settlement pattern (left) and Sectional elevation of the settlement showing the relation of built-form and space order (right) of Railway slum (source: author)

In people's perception, for dwelling unit level, dwellers specified "income-generating activities and space" as the most vulnerable, as most dwellers lost the income generating spaces within house during disaster. "Plinth" is another vulnerable portion. Most vulnerable parts at dwelling unit level are successively :(i) income-generating space, (ii) plinth, (iii) roof, (iv) structure (Figure 05). Regarding neighborhood level, dwellers have identified "accessibility" as the most vulnerable. Authority focuses mostly on the development of primary access line but secondary accessibility often remains ignored. At neighborhood level most vulnerable are successively :(i) accessibility, (ii) infrastructure & utilities, (iii) livelihood activities, (iv) location, and (v) community facilities and amenities (Figure 05).

Autonomy in Urban Informal Settlements: Key Findings and Suggested Guidelines

The main recommendation for dwelling unit level is the provision of income generating activities during disaster and development of a stable plinth. For neighborhood level, it is important to improve secondary accessibility lines and infrastructure & utilities like drainage, water source etc. In light of the adaptation practices, this research advises 26 specific guidelines for developing adaptive informal settlements (Table 01).

Table 1. Key guidelines for the development of adaptive urban informal settlements

Sub-domain of Adaptation	**Guidelines for development of adaptive coastal settlements**
Dwelling unit level	
Built-form	1. Maintaining proper orientation for ensuring cross ventilation
	2. Increasing height of plinth above the flood level (3'-4' from existing street level)
	3. Building semi-outdoor space (veranda) at the front side for shadow casting in the living area
Material and construction techniques	4. Making plinths and lower part of wall built with permanent material
	5. Building plinth with masonry construction or mud-concrete
	6. Treating bamboo or wooden posts with old tar or motor oil coating or making half-length brick column
	7. Anchoring of roof and posts through rope and wire into the ground
	8. Constructing sloped or pitch roof for better drainage of rain water
	9. Making perforated enclosures and free façade to ensure adequate cross ventilation
	10. Using perforated window *'jali'*;open windows without shutter
	11. Constructing roof at minimum slope angle and minimum overhang beyond vertical claddings
	12. Making roof with heat absorbing materials and using light weight material in the roof
Spatial pattern and use of space	13. Providing enough semi-outdoor space facing at the entry for private, semi-private, and public use
	14. Ensuring enough provision for dynamic arrangements of multiple activities within single indoor space
	15. Placing kitchen near the door or outside at the entry point far from living area
income-generating space	16. Providing income-generating space within or adjacent to dwelling unit
	17. Provision of own kitchen garden in front/backside near dwelling unit
Neighborhood level	
Location	18. Building on raised earthen mounds, height will be closer to the embankment or main accessibility line
Accessibility	19. Development of high street network with brick soling/CC casting, closer to the main accessibility line
Livelihood activities	20. Creating secondary source of income like poultry rearing, gardening, cattle raising
	21. Provision for women to involve in income generating activities
Infrastructures & basic utilities	22. Construction of proper drainage system and drain-covers along the pedestrian
	23. Extending the implementation of rainwater harvesting for drinking water
	24. Providing shallow tube-wells and constructing shared toilets, which will be maintained by community
	25. Planning an integrated waste management system
Community facilities	26. Providing community spaces (children play area, neighborhood space, and playground) by considering dwellers' unique socio-spatial characteristics

Conclusion

In developing country like Bangladesh where slum demolition and denial of land security is common, informal settlements has been continuing to grow with increasing in-migration of destitute from disaster-prone rural areas; and people are living in temporary shelters without infrastructure and municipal services. But these people has every right to live in better condition and lead a better life. Increasing climate change impacts has necessitated a fresh approach to the way in which disasters are handled. Emphasis has moved towards a more sustainable approach incorporating hazard mitigation and vulnerability adaptation. Therefore, this research attempted to inquire how autonomy empowers dwellers of informal settlements to adapt vulnerabilities. Based on empirical investigation, recommendations for urban informal settlements are made. To achieve SDG it is important to develop city in a resilient and adaptive manner. And these recommendations will help to develop a resilient and adaptive city. To this end further research is suggested considering these issues.

References

ADB. (2011). Adapting to Climate Change: Strengthening the Climate Resilience of Water Sector Infrastructure in Khulna, Bangladesh. Philippines: Asian Development Bank (ADB).

Alemie, B. K., Bennett, R. M., & Zevenbergen, J. (2015). A socio-spatial methodology for evaluating urban land governance: the case of informal settlements. *Journal of spatial science*, *60*(2), 289-309.

BBS. (2015). Census of Slum Areas and Floating Population 2014. *Statistics and Informatics Division, Ministry of Planning, Dhaka*.

BCAS, BIDS, & BUP. (1996). Climate change country study Bangladesh. *Climate Change Study Programme US Government. Bangladesh Centre for Advanced Studies (BCAS), Bangladesh Institute of Development, Studies (BIDS), Bangladesh Unnayan parishad (BUP), Dhaka*.

Burton, I. (1997). Vulnerability and adaptive response in the context of climate and climate change. *Climatic Change, 36*(1-2), 185-196.

CUS. (2006). Slums of urban Bangladesh: Mapping and census, 2005. Centre for Urban Studies Dhaka, Bangladesh: National Institute of Population Research and Training.

KDA. (2012). Preparation of Detailed Area Development Plan for Khulna Master Plan (2001) Area: Survey Report. Khulna: Development Design Consultant Ltd, Data Expert Private Ltd, Khulna Development Authority (KDA).

Levina, E., & Tirpak, D. (2006). Adaptation to climate change. Key Terms.

Maslow, A. H. (1971). *The farther reaches of human nature*: Arkana/Penguin Books.

Smit, B., Burton, I., Klein, R. J., & Wandel, J. (2000). An anatomy of adaptation to climate change and variability *Societal Adaptation to Climate Variability and Change* (pp. 223-251): Springer.

Solomon, S., Qin, D., Manning, M., Averyt, K., & Marquis, M. (2007). *Climate change 2007-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC* (Vol. 4): Cambridge university press.

Turner, J. F. (1977). *Housing by people: towards autonomy in building environments*.

Turner, J. F., & Fichter, R. (1972). *Freedom to build: dweller control of the housing process*: Macmillan.

van Scheltinga, C. T., Quadir, D. A., & Ludwig, F. (2015). Baseline Study Climate Change–Bangladesh Delta Plan: Bangladesh Delta Plan.

UNDERSTANDING SOCIAL VULNERABILITY OF A COMMUNITY FOR EARTHQUAKE: A STUDY ON WARD NO. 14, MYMENSINGH MUNICIPALITY, BANGLADESH

Tamanna Akter[1], Uttama Barua[2], Md. Aminul Islam[3], Dr. Ishrat Islam[4], Dr. Mohammad Shakil Akther[5], Dr. Mehedy Ahmed Ansary[6], Dr. Raquib Ahsan[7]

ABSTRACT

Earthquake vulnerability increases due to the complex nature of social factors of exposed communities. Loss and damage in an area after an earthquake is increased due to the complex nature of local social vulnerability. This study aims to explore different dimensions of the social vulnerability of a community for an earthquake in Bangladesh. Seismic exposure and historical evidence indicate severe earthquake risk of Mymensingh Municipality, Bangladesh. Therefore, Ward 14 of Mymensingh Municipality has been considered as study area to assess social vulnerability. A sample of 700 household questionnaire survey in the study area was carried out. The study reveals that, in spite of lower participation in earthquake-related program, most residents are aware of earthquake vulnerability of the area. But such awareness encompasses very limited knowledge. Very few of the residents have knowledge about precautionary measures to be adopted at the event of an earthquake. They also lack proper understanding of earthquake preparedness and response. Despite such lack of knowledge, most of the residents expressed their willingness to work as a volunteer for earthquake risk reduction in the study area. But young adults have expressed lower interest which might be a concern. This study has the opportunity to be replicated in other areas of Bangladesh as well as other countries with necessary modifications considering respective contexts and other hazards. The findings of such study will guide to understand different contexts of social vulnerability of a community and thereby help to take initiatives accordingly to mitigate potential risk as well as enhance resiliency at the community level.

Keywords: Community, Earthquake, Socio-economic Vulnerability, Awareness.

Introduction

Earthquake is one of the most deadly natural hazards and can be defined as a sudden, rapid shaking of the earth surface (Jimee *et al*, 2012; FEMA, 2013). Apart from casualties, it results in extensive damage of physical and social infrastructures, assets, disrupt life-sustaining facilities of buildings, other physical infrastructure and facilities destruction of an area as well as a country (Shinozuka, 1998 & CDMP, 2014). In recent years, the world has witnessed the devastating nature of earthquakes destroying major cities and large-scale havoc in the surrounding environment (Goda *et al*, 2015). Potential earthquake damage depends on different aspects of vulnerability. Vulnerability of a system can be defined as susceptibility to harm resulted from exposure to environmental and social change or disturbance (Gallopín, 2006). Social vulnerability is the outcome of social disparities which influence the susceptibility of a community to a hazard. Although inhabitants of the hazard-prone area are most vulnerable, social aspects of vulnerability increase disaster risk. It is closely related to local culture, social norms and other different contexts which varies significantly at different communities. Thus to increase resiliency and thereby reduce the impact of an earthquake on a community, it is necessary to understand different social vulnerability perspectives of the community for an earthquake.

Bangladesh is located in a moderately seismic-prone region, it is positioned at the junction of three plates which results in the generation of active faults (Akhter, 2010). Mymensingh is located in Zone 3 and considered as one of the most vulnerable to an earthquake (Hussaini et al, 2012). A severe earthquake will result in massive impact on this area which includes serious human casualty, damages of infrastructures,

[1]Graduate Student, Department of Urban and Regional Planning, BUET, Dhaka-1000, Bangladesh.
[2]Lecturer, Department of Urban and Regional Planning, BUET, Dhaka-1000, Bangladesh.
[3]Lecturer, BUET Japan Institution of Disaster Prevention and Urban Safety, Dhaka-1000, Bangladesh.
[4,5]Professor, Department of Urban and Regional Planning, BUET, Dhaka-1000, Bangladesh.
[6,7]Professor, Department of Civil Engineering, BUET, Dhaka-1000, Bangladesh.
Email of Corresponding Author – sorna.urpbuet@gmail.com

social loss, destruction of economic structure etc. (Alam et al, 2008). Rapid urbanization, population growth, migration and development of economic activities also prompt high vulnerability (CDMP, 2014). Complex social context also contributes to increase vulnerability for earthquake, which varies at different locations.
From the above discussion, the importance of social vulnerability at the community is apparent for an earthquake risk reduction. In this background, this study aims at understanding social vulnerability for earthquake to recognize potential risk, preparedness, and impacts at the community level.

Methodology of the Research

Study Area Selection

Mymensingh town (Figure 1) lies in an active earthquake-prone area of Bangladesh. Different studies reveal high liquefaction susceptibility in Mymensingh Municipality (Figure 2) implicating severe damage or destruction during major earthquakes in town (Sarker *et al,* 2010 & CDMP, 2014). This area falls in Zone 4 with a seismic coefficient of 0.36g (GoB, 2015). Considering the seismic vulnerability, this research aimed to assess the social vulnerability of local community in Ward No. 14 of Mymensingh municipality. It has an area of 0.54 sq. km. (Figure 3) and total population is 12,142. Ratio of male and female population is 47.06 percent and 52.94 percent respectively. Total number of households in the area is 2,194 and average family size is 4.5. The primary occupations of people in the study area are service (80.6%), agriculture (11.7%) and others. Major land use of the study area; residential, health facility and mixed-use (BBS, 2015).

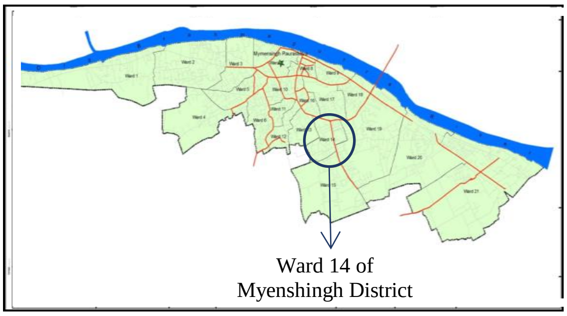


Figure 2. Map of Mymenshingh District

Figure 1. Map of Mymenshingh Division

Figure 3. Map of Mymenshingh Ward 14

(Source: Mymensingh Pourashava, 2017)

Selection of Factors for Understanding Social Vulnerability

Social impacts of a hazard are influenced by a number of factors i.e. physical, social, economic, and environmental factors of a community (Flanagan *et al,* 2011). Respondent's awareness about earthquake, risk perception of their residence, earthquake response and participation in disaster management programs are considered as social vulnerability indicators. These aspects were analyzed with different social and physical components such as age, gender, education, occupation, physical disability, structural safety etc.

Data Collection and Analysis

After the selection of social vulnerability indicators, a household questionnaire survey of 700 respondents was carried out. A total of 430 owners and 270 tenants were surveyed to accommodate the local community's perception about earthquake vulnerability (Jimee *et al,* 2012). Another study was conducted to assess existing building vulnerability. After data collection, statistical analyses were performed by using MS-Excel 2007, SPSS 21 to recognize earthquake vulnerability of the area.

Results and discussion

Social Profile of the Study Area

In the study area, total family members of 700 surveyed households are 2,630 people. Majority of the population (54%) belongs to age group 20-59 years. About 14% of the people are children (<10 years) and 6% are elderly people (>60 years), who are most vulnerable to an earthquake (Doocy *et al,* 2013).

Again, physically challenged people are considered as 'vulnerable group' at the occurrence of any disaster (i.e. earthquake) and would need assistance for evacuation from the affected areas (Hemingway *et al,* 2014). In the study area, 0.34% (10 out of 2630) of the total population is physically disabled who will face difficulties to escape from their residence and need special attention (Lord *et al,* 2016). About 45% of the surveyed families (among 700 households) live in this area for more than 20 years. Only 7% of them have been living in this area for less than a year. They have better knowledge about the area and a strong sense of belonging.

Awareness of the Respondents about Earthquake from Social Context

People's awareness about disaster plays a crucial role for precautionary measures and disaster response (Jimee *et al,* 2012). Among 700 surveyed respondents, 85% have claimed to be aware of earthquake. Their awareness status was analyzed with social context and sources of awareness. It was evident from the analysis that, awareness among male and female respondents are almost the same. Nevertheless, knowledge of the respondents about earthquake differs with their age. Young adults (21-30 years) are more aware of earthquake (17% out of 19%) compared to others. Again, educated people are expected to know more about earthquake than the less educated or uneducated ones, which is also apparent in the study area. Majority of them learned about earthquake from television, radio, newspaper, textbook and self-realization.

Only 61 respondents have attended earthquake-related program, among whom the majority are male (39 respondents) and literate (59 persons). Again participation of young people (less than 30 years) in earthquake-related program is low (15 respondents) which indicates the inability of earthquake-related programs to reach the majority of population including female, illiterate and young residents. Participation of young adults in these programs is insignificant, it represents lower awareness about earthquake.

Only 83 respondents learned about earthquake through conversation with people, 76% (530 out of 700) respondents discuss about earthquake, especially with their family members (485 respondents). Only 195 respondents discuss with the local people, whereas 178 respondents discuss with building users (Table 1). Mainly female members, middle-aged and literate people mostly take part in such discussions.

Table 1. Comparison of the respondents' awareness about earthquake with different factors

Factors / Awareness	Aware about earthquake	Not aware about earthquake	Total
Gender			
Male	42.8%	7.4%	**50.2%**
Female	42.2%	7.6%	**49.8%**
Total	**85%**	**15%**	**100%**
Age group			
Children (<10 years)	0%	0%	**0%**
Young (11-20 years)	4%	1%	**5%**
Young adults (21-30 years)	17%	2%	**19%**
Middle aged (31-60 years)	43%	7%	**50%**

Factors \ Awareness	Aware about earthquake	Not aware about earthquake	Total
Elderly (>60 years)	8%	1%	**10%**
No response	13%	3%	**16%**
Total	**85%**	**15%**	**100%**
Education level			
Illiterate	3%	2%	**6%**
Primary	9%	2%	**11%**
Secondary	20%	4%	**24%**
Higher secondary	13%	2%	**15%**
Graduate	17%	1%	**18%**
Post graduate and above	10%	1%	**10%**
No response	13%	3%	**16%**
Total	**85%**	**15%**	**100%**

(Source: Field survey, 2017)

Perception about Earthquake Vulnerability of the Area

Many respondents (44%) believe that the study area is vulnerable to earthquake. This perception is higher among male, middle-aged and educated people. Duration of stay in the study area has no influence on such perception since both new and old residents have expressed similar perception about earthquake vulnerability. In contrary, most of the tenants don't consider the area is vulnerable (Table 2). It is assumed, tenants stay in an area for a temporary basis so they are less worried about the vulnerability of the area.

Table 2. Comparison of the respondents' perception about earthquake vulnerability of the area

Factors \ Perception	Area vulnerable to earthquake	Area not vulnerable to earthquake	Total
Gender			
Male	23.4%	26.8%	**50.2%**
Female	20.6%	29.2%	**49.8%**
Total	**44.0%**	**56.0%**	**100.0%**
Age group			
Children (<10 years)	0%	0%	**0%**
Young (11-20 years)	2%	3%	**5%**
Young adults (21-30 years)	8%	11%	**19%**
Middle aged (31-60 years)	22%	29%	**50%**
Elderly (>60 years)	4%	6%	**10%**
No response	9%	7%	**16%**
Total	**44%**	**56%**	**100%**
Education level			
Illiterate	2%	4%	**6%**
Primary	3%	7%	**11%**
Secondary	10%	15%	**24%**
Higher secondary	7%	8%	**15%**
Graduate	8%	10%	**18%**
Post graduate and above	5%	5%	**10%**
No response	9%	7%	**16%**
Total	**44%**	**56%**	**100%**
Building ownership status			
Owner	26%	35%	61%
Tenant in private housing	15%	20%	35%
Tenant in government housing	1%	3%	4%
Total	**44%**	**56%**	**100%**
Awareness about earthquake			

Factors \ Perception	Area vulnerable to earthquake	Area not vulnerable to earthquake	Total
Aware	41%	44%	85%
Not aware	3%	12%	15%
Total	**44%**	**56%**	**100%**

(Source: Field survey, 2017)

When the respondents were asked about the reasons of this vulnerability, they have mentioned geographic location, the unplanned establishment of buildings and high population density in the area as prime reasons by most of the respondents (Figure 4).

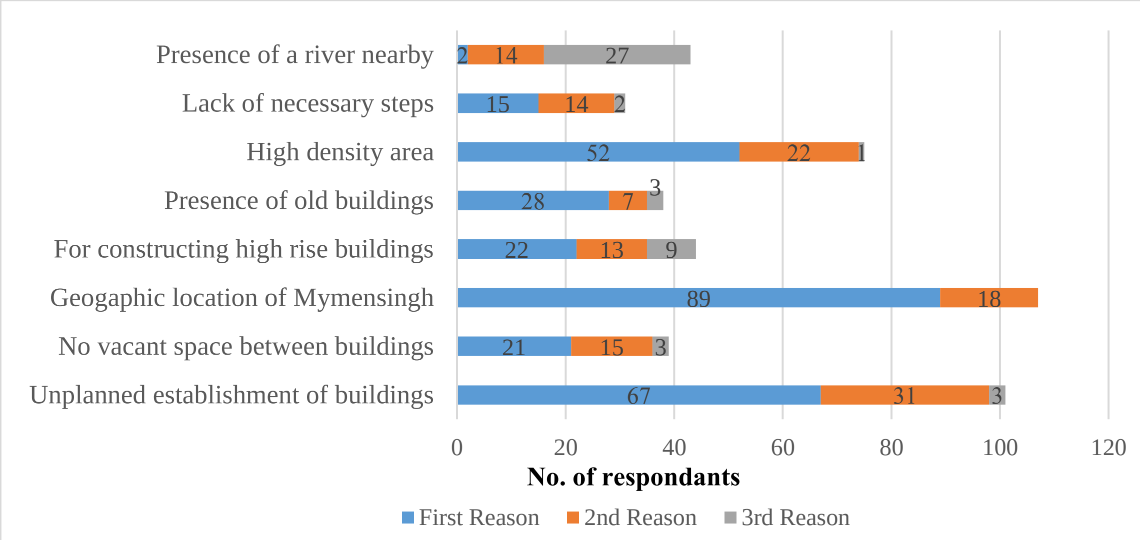


Figure 4. Ranked reasons of earthquake vulnerability of the area according to the respondents

(Source: Field survey, 2017)

Perception about Earthquake Vulnerability of Their Building

Although 37% of buildings in the study area are actually vulnerable to earthquake, only 26% (180 out of 700) respondents are aware of building vulnerability. When compared with the ownership status of respondents, it has been found that most owners and tenants do not consider their building as vulnerable. The buildings constructed before 1995 are considered as most vulnerable by the respondents compared to newly constructed buildings. Again most of the residents (46%) think that neither the area nor their building is vulnerable to earthquake. Comparing actual vulnerability with their perception it can be stated that, only 10% of respondents from vulnerable buildings think that their building is vulnerable (Table 3). Residents may lack clear concept about building vulnerability and ignorant about the impact of earthquake on their lives.

Table 3. Comparison of the respondents' perception about earthquake vulnerability of their building

Factors \ Perception	Building vulnerable to earthquake	Building not vulnerable to earthquake	Total
Building ownership status			
Owner	14%	47%	61%
Tenant	10.6%	24.4%	35%
Government service holder	1.4%	2.6%	4%
Total	**26%**	**74%**	**100%**
Peoples' perception about earthquake vulnerability of the area			
Area vulnerable to earthquake	16%	28%	44%
Area not vulnerable to earthquake	10%	46%	56%
Total	26%	74%	**100%**
Actual vulnerability of buildings			

Factors / **Perception**	**Building vulnerable to earthquake**	**Building not vulnerable to earthquake**	**Total**
Building vulnerable to earthquake	10%	27%	37%
Building not vulnerable to earthquake	16%	47%	63%
Total	**26%**	**74%**	**100%**

(Source: Field survey, 2017)

When they were asked about the reasons of building vulnerability, 76 respondents have identified old building as the first reason for their building being earthquake-vulnerable. Construction fault and visible cracks are also major reasons for building vulnerability. Also, some buildings were built after filling canals so underneath soil may not be capable of resisting earthquake and considered as earthquake-vulnerable (Figure 5).

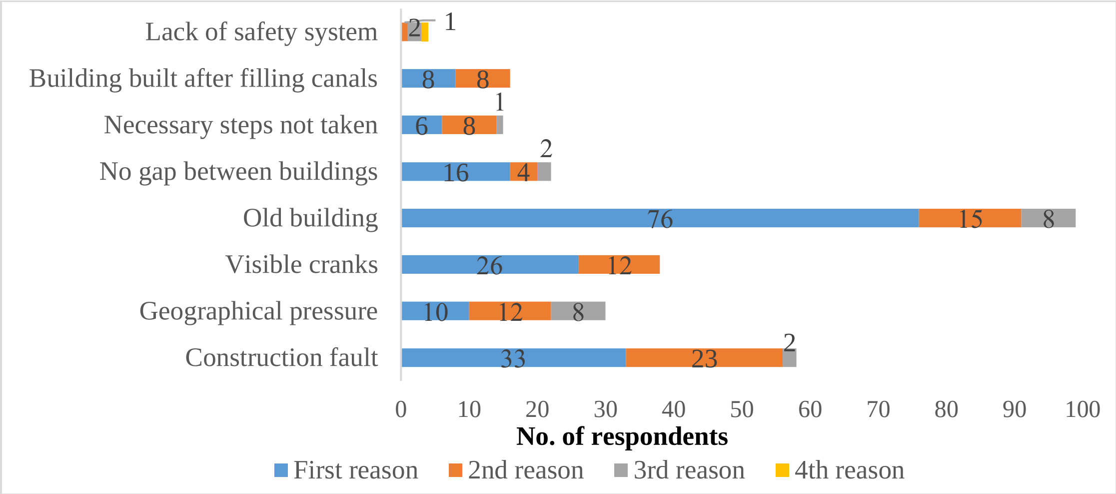


Figure 5. Ranked reasons of earthquake vulnerability of the buildings according to the respondents

(Source: Field survey, 2017)

Perception about Participation in Disaster Management Activities

Participation of community people in any disaster-related activities is necessary for effective disaster management plan (Van Krieken *et al*, 2017). Community level participation helps to integrate with national and international level complement which is very important to ensure proper management after an earthquake.

According to the Disaster Management Act 2012, every Ward of this area should have a Ward Disaster Management Committee (WDMC). But unfortunately, very few people know about it. Only 16% (109 out of 700) respondents know about WDMC. So there is a lack of communication between the authority and the inhabitants of the area. But when they were asked about their interest to get involved in disaster management work, 44% of respondents showed their interest to get involved. So if WDMC makes provision of training and assistance for those interested people, they can be of great help during a disaster.

Disaster management volunteers are engaged in various activities during pre and post-disaster periods (Alexander, 2010). And the role of local volunteers is very important as they will be the first responders during or after an earthquake and their knowledge about the area (Leigh *et al*, 2011). So when the respondents were asked, 67% (471 out of 700) of them expressed willingness to voluntary works. Among them, most (14% and 32% respectively) are young adults and middle-aged people (21 years to 60 years old). Table 4 shows the distribution of the mentioned duties ranked according to potential volunteers. Most respondents have given priority to the rescue mission and showed interest to participate in this operation. If they are provided with proper training, technical and financial facilities, they can be of great help.

Table 4. Preference of the respondents for duties as volunteer

Duties	Preference (Frequency)						
	1st	**2nd**	**3rd**	**4th**	**5th**	**6th**	**Total**
Rescue Mission	247	56	23	14	8		**348**
First Aid	100	134	38	22	12	16	**322**
Attend mental health	54	69	60	27	36	46	**292**
Management of temporary shelter	17	34	32	57	52	36	**228**
Food preparation	38	83	95	60	33	25	**334**
Communication establishment	17	36	62	51	41	46	**253**

(Source: Field survey, 2017)

Conclusion

From the findings of social vulnerability assessment, it can be stated that 14 no. ward of Mymensingh is vulnerable to earthquake. This research on the study area has delineated social factors that require interference to reduce earthquake vulnerability. The respondents' knowledge about earthquake is analyzed with their socio-demographic condition to realize their awareness level. Ten households with physically challenged people have been identified through this study within the study area. Potential earthquake response and the actions taken during an earthquake was identified to know people's perception level. Moreover, this study was conducted on vulnerability at the micro level of administrative boundary in Mymensingh Municipality. It can be used as a reference for assessing vulnerability in other parts of the Municipality area.

Acknowledgement

Authors would like to thanks United Nations Development Programme (UNDP) and Mymensingh Municipality for their support and assistance.

References

Alexander, D. (2010). The voluntary sector in emergency response and civil protection: review and recommendations. *International Journal of Emergency Management*, *7*(2), 151-166.

Bangladesh Bureau of Statistics. (May, 2015). *Bangladesh Population and Housing Census 2011. Community Report, Zila: Mymensingh*. Retrieved 4th April, 2017 from: http://203.112.218.65/WebTestApplication/userfiles/Image/PopCen2011/Com_Mymensingh.pdf

CDMP. (2014). Scenario Based Earthquake Contingency Plan of Mymensingh Municipality Area. Comprehensive Disaster Management Programme (CDMP), Ministry of Food and Disaster Management, Government of the People's Republic of Bangladesh.

Doocy, S., Daniels, A., Packer, C., Dick, A., & Kirsch, T. D. (2013). The human impact of earthquakes: a historical review of events 1980-2009 and systematic literature review. PLoS currents, 5.

Flanagan, B. E., Gregory, E. W., Hallisey, E. J., Heitgerd, J. L., & Lewis, B. (2011). A social vulnerability index for disaster management. *Journal of homeland security and emergency management*, *8*(1).

Gallopín, G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. *Global environmental change*, *16*(3), 293-303.

Goda, K., Kiyota, T., Pokhrel, R. M., Chiaro, G., Katagiri, T., Sharma, K., & Wilkinson, S. (2015). The 2015 Gorkha Nepal earthquake: insights from earthquake damage survey. *Frontiers in Built Environment*, *1*, 8.

Hemingway, L., & Priestley, M. (2014). Natural hazards, human vulnerability and disabling societies: a disaster for disabled people?. *Review of Disability Studies: An International Journal*, *2*(3).

Jimee, G. K., Upadhyay, B., & Shrestha, S. N. (2012). Earthquake awareness programs as a key for earthquake preparedness and risk reduction: lessons from Nepal. In The 14th World Conference on Earthquake Engineering.

Leigh, R., Horton Smith, D., Giesing, C., José León, M., Haski-Leventhal, D., Lough, B. J., ... & Hockenos, P. (2011). State of the world's volunteerism report, 2011: universal values for global well-being.

Lord, A., Sijapati, B., Biniya, J., Chand, O., & Ghale, T. (2016). Disaster, Disability, & Difference: A Study of the Challenges Faced by Persons with Disabilities in Post-Earthquake Nepal.

Shinozuka, M., Rose, A., & Eguchi, R. T. (1998). Engineering and socioeconomic impacts of earthquakes.

Van Krieken, T., Kulatunga, U., & Pathirage, C. (2017). Importance of community participation in disaster recovery. In *13th IPGRC 2017 Full Conference Proceedings* (pp. 860-869). University of Salford.

RECONSTRUCTING 'FAITH' AS A SOCIAL CAPITAL AT THE DISASTER PRONE COASTAL COMMUNITIES IN BANGLADESH

Imamur Hossain[1]

ABSTRACT

Culture- being observed as an essential intangible feature of a community, has recently been incorporated in the Disaster Risk Reduction initiatives in the field of Disaster Management. Religion- which is often interpreted as an integral part of a marginal community's identity has yet to be comprehended in the formal disaster management platforms. For decades, the term 'faith' served as a sort of conceptual scaffolding at the theological premise when it comes in the discussion regarding the belief system, ideological doctrine and optimism. The primordial interpretation of disaster was always been associated with the belief system of a community, and often it shaped the social identity of the settlements at the disaster-prone locations. It is often regarded by the scientific community that religious narratives misinterpret 'disaster' with ignorance, superstition and backwardness. But often, members of an affected community exhibit cognitive, behavioral and psychosomatic effects as an aftermath of natural disaster, where 'faith' can play a vital role in the recovery process during and after the calamities. Though the coastal communities are economically active, socially dynamic, and physically mutating, the advent of disasters has always caused havoc in the community's properties. The critical role of religious faith in the small communities at the disaster-prone areas has often been uninvestigated and this paper explores it as 'social capital' and reimagines to give an architectural interpretation to incorporate adequately in the disaster management system.

Introduction

Religion has a significant effect at the time of disaster, especially in Bangladesh where it plays an important role of the people in the marginal communities in their daily activities. It may influence the believer of the community both on preparedness before the fatality and the management at post-disaster crisis. Although the topic of religion is being new to be considered at the system of disaster management, some scholars have started focusing on the role of religion in terms of disaster management or disaster risk reduction internationally. However, it can be stated that there has not been any systematic research conducted to examine the role of religion in disaster management and reduction system and there is a gap in design research to metamodel the architectural interpretation of the faith-based institutions at the communities prone to disaster. This paper aims to bridge the gap between these two subdivisions. By analyzing the existing studies, the paper investigates the scope of Islam and Hinduism- the two major religion to be operated according to community-oriented management approaches. The theological premises from the scriptures have been analyzed and discussed to emphasize the potential policy measures.

It can be said that the impact of faith can rectify the social crisis and faith-based institutions can contribute physically in the management of the aftermath of the disasters. Many of the disasters like Aila or Sidr are still having repercussions across a range of institutions and the communities. The discussion of this paper begins with analyzing the scope of social capital and would argue whether faith could create a space-place dialectic to augment communities' resilience through religious institutions by fostering social trust, construct refuge and empower community members. The second section develops a framework for an attempt to metamodel the institutions with architectural interpretation, followed by a description of investigation for design research and its prospect.

Religious Faith as Social Capital

According to (Bowles, 2002), social capital rests, among other things, on the trust, trustworthiness, and altruism between individuals, and on self-enforcing norms of behavior, all of which allow trades between two agents to be completed informally, with lower transactions costs than required by complex contracts. According to Louis Hanifan, Social capital can be elaborated as social goodwill, fellowship and mutual

[1]*Lecturer, Dept. of Architecture, Sonargaon University, Dhaka-1217, Bangladesh*
Email of Corresponding Author – imamur.hossain@gmail.com

sympathy among a group of individuals who make a social unit. (Portes, 1998) suggested that the concept being adopted to multiple disciplines based on the involvement and participation of the groups in impacting positive consequences for the individual and communities. It can be stated that social capital is the aggregate of the actual or potential resources that are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance or recognition (Bourdieu, 1985). This definition from Bourdieu focuses on the resources that are being generated by the interaction of the members of social networks. Although inextricably linked with economic capital, social capital cannot be reduced simply to economic form. (Putnam, 2000) in his book 'Bowling Alone' described that the role of social capital in generating the benefits beyond individuals at the community level. He defined social capital as networks, trust and norms which facilitate actions and cooperation for mutual benefit and as a feature of social organizations. The National Social Capital Benchmark Community Survey from Harvard University (2000, 2006) asses social capital through the individual's senses of belonging in community and groups, memberships and their activities in religious, social, recreational activities and even the frequency of visiting with neighbors and friends. (Cardenas, 2008) asses the social capital through laboratory experiments whereas (Levitt, 2008) has undertaken the experiments out in the field with the advantages of natural conditions or at randomized control trails.

(Baum, 2000) stated, though the economic, social and physical characteristics of a community may affect the level of social capital of it, the community itself is considered as central to the social capital. Hence, religious views and norms, being an integral part of the community's sense which offers the belongingness at the community and members construct commitments for the members to be together. The social networks in the community, participation in both voluntary and involuntary forms, trust, reciprocity and social inclusion can be governed by religious thoughts, ideas, norms and belief.

The religious faith plays a positive role by encouraging individuals and communities to behave morally. Hence the religious philosophy has the potentiality as counseling in various phases in the crisis response. By providing refuge to get shelter in the religious centers and by engaging with the recovery phase with the direction from the religious leaders, religious faith can constructively contribute to enhancing social capital of a community.

Theological Interpretation of Disaster at the Marginal Communities

Beside the scientific explanations, a great variety of ideas and interpretations of the reason for the disaster coexists in the affected communities. The symbolic and religious interpretations are highly important in the aftermath of a disaster to recognize and facilitate the community's recovery process. (Schlehe, 2010) explained that modern values, consumerisms, moral decay, corruption and individualism, human intervention in the natural ecosystem are often regarded as 'ill of modernity' sometimes seems like a threat to the religious culture and heritage values of the communities living in marginal areas. In her article of Anthropology of religion: Disasters and the representations of tradition and modernity, it is believed by the people of the affected communities from the Javanese island on Indonesia after the advent of major earthquakes before 2010 that disasters have revealed cultural and moral cries which are related to modernization. The relation of the quacks to other socio-political factors was also interpreted by the communities. Her interview with the representatives of the two of the largest Islamic organizations demonstrated two different opinions. The traditionalist school inferred the disaster with the evidence of unwillingness inability of the ruling government to conserve the tradition and culture. The other school alleged the disaster being linked with mixing Islam with local mythological spirits (Schlehe, 2010).

(Chester, 2005) in his work referred that the deities symbolize and invoked as the causal agent of death and destruction. Although the responses vary from the place, culture, religious traditions etc. The research and study of geomythology demonstrate the supernatural interpretations of the disaster believed in the communities although the view is changed later as the conventional wisdom marks it with superstitions and backwardness.

The events of disasters are omnipresent in the tradition of both the practicing monotheist and polytheist religion among the communities. The unexpected, uncertain and unscheduled form of disasters is somewhat linked with the traditional faith which resembles the impacts of moral decay and materialism to a certain extent. Rather than viewing as a rare and extreme phenomenon (Hewitt, 1997) and (Maskrey, 1989) viewed it as an amplifier of daily hardship and emergency. They recommended to undertake the non-engineering measures as poverty reduction, fare access to land and resources, better services etc. and emphasizes community-based disaster risk reduction. (Schipper, 377-393) in his studies demonstrated the theological aspect of belief system in the context of minimizing the disaster hazard and climate change induced risks. Although (Meril, 2010) emphasized on the power of nature as a consequence of human failure, (Paradise, 2005) explained the disaster as a form of divine action and retribution from Islamic perspective.

Islam, one of the largest monotheistic religion being widely practiced in Bangladesh, the interpretation of disaster in this religion is a form of collective punishment, divine action and retribution. (Adisaputri, 2016) stated in her study that the ‘sura’ or verses of the Holy Scripture ‘Qur’an’ the concept is widely elaborated as- earthquake (Al-A’raf:91, Al-Ankabut: 37), flooding (Al-Ankabut:14, Saba’:6), typhoon (Al-Haqaah:6), drought (Al-A’raf:30). The idea of *Qaeda* and *Qadr* is associated with Islam as the event of disaster being written as fate and almost unchangeable unless the will of almighty. Islamic theology foregrounds the concept of the peaceful life and the reconstruction from a socially organized manner. Also the constructive voluntary works and the notion of devotional labor at the time of crisis are interpreted as the act of worshipping God in the religion of Hinduism and providing the hand on relief in crisis stimulate and enhance the devotional sense of the community.

Scope of the Faith Based Institutions in DRR Practices

David K. Chester, Angus M. Duncan, and Christopher J. L. Dibben in their work reflect upon that disaster response are not independent of religion and cultural practices of a community (Chester D. K., 2008). (Schlehe, 2010) in her writings stipulated the impact of disaster associated with the traditional culture and religious belief system and showed how to shape, interpret and negotiate disaster impact. With proper coordination, the religious institutions can be the part of the process in the management techniques used in the field of disaster management as emergency operation planning, hazard identification, leadership, decision-making, emergency information distribution, communication management, personnel evaluation, risk analysis, coordination strategies among multiple stakeholders (Ha, 2016). Although not being coordinated in a strategical manner, the global practices envolve the religious institutions and the preachers to deliver sermons regarding disaster scripted from the traditional religious accounts.

Crisis moments can bring out many acts of compassion and generosity where faith based institutions can outplay a major role. Extensive emergency relief campaigns can be formed by mobilizing gratitude through the networks of religious institutions. The individuals who have faith upon religion has an impact on her social health, mental health and has the scope in developing mental rehabilitation. As (Chester, 2005) identified and examined the successful response of local culture as a key role playing in the disaster-affected community, the implication of the cultural institution should be a part of the process in the local emergency planning as well. The problem that can be seemed from the recent events of the disasters that the inadequacy of the government responses to the need of the fatalities, the widespread crisis of food and shortage of health facilities. Voluntary engagement from different social organizations with a range of activities like relief works, cleanup operations are one part of the crisis management but sometimes for not being part of the systematical management process, is unorganized. The government’s effort to restore the disaster affected settlement

Religious institutions can nurture a large social vision and mobilize the members for various forms of social (and to some extent secular) engagements. Through its elaborate and systematic operations, more coordinated and effective response to the crisis of natural disasters especially like cyclones can be settled. As in Bangladesh, almost 85 percent of the people live in rural areas (Dasgupta, 2010) and the religious institutions as mosques and temples act as the center of the social activities in these settlements (Hossain, 2016). Showed that religion plays an important role in the life of Bangladeshi people to acquire strength and cope with disasters.

Architectural Interpretation: Design Research

The religious institution’s headquarters are mostly intended to ascertaining the condition of its branches after the major disasters and limited its involvement in donating money and calling for fundraisers. Its role can be expanded to encompass responses to the disaster by offering aid to nonmembers too. The design of the institutions has the scope of removal of debris through the volunteer activities, distribution of pure drinking water and saline packets, dried meals and material aid.

The idea of rethinking and reimaging the religious institutions was the primary concern of the design studio project of the second year student's of Department of Architecture, Sonargaon University of Summer 2018 semester, where they have given an actual site in Moheshkhali to interact with the community people to learn their needs and demands. Later they were engaged to analyze the possible cyclone shelter formation considering the religious practices of the community maintaining the guidelines of CBDM approaches. Here, the idea was not only to engage the local community to become part of creating plans and decisions but also to engage them in the process of implementation.

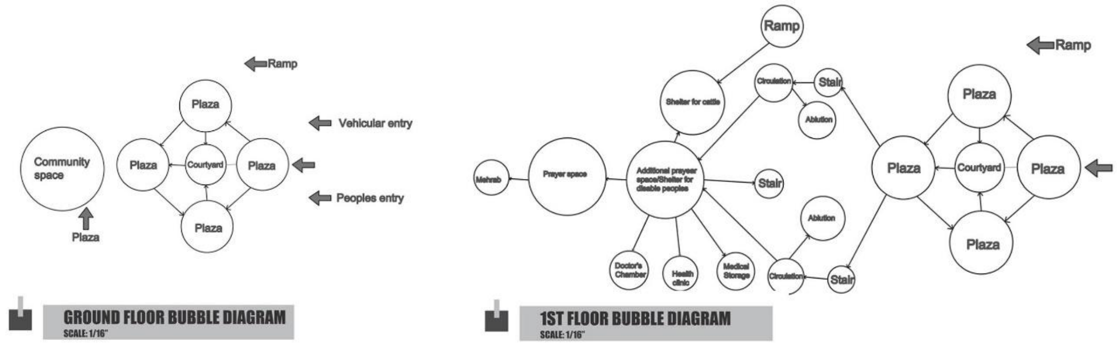


Figure 1. The schematic design layout of reimagining mosques as cyclone shelter by the students.

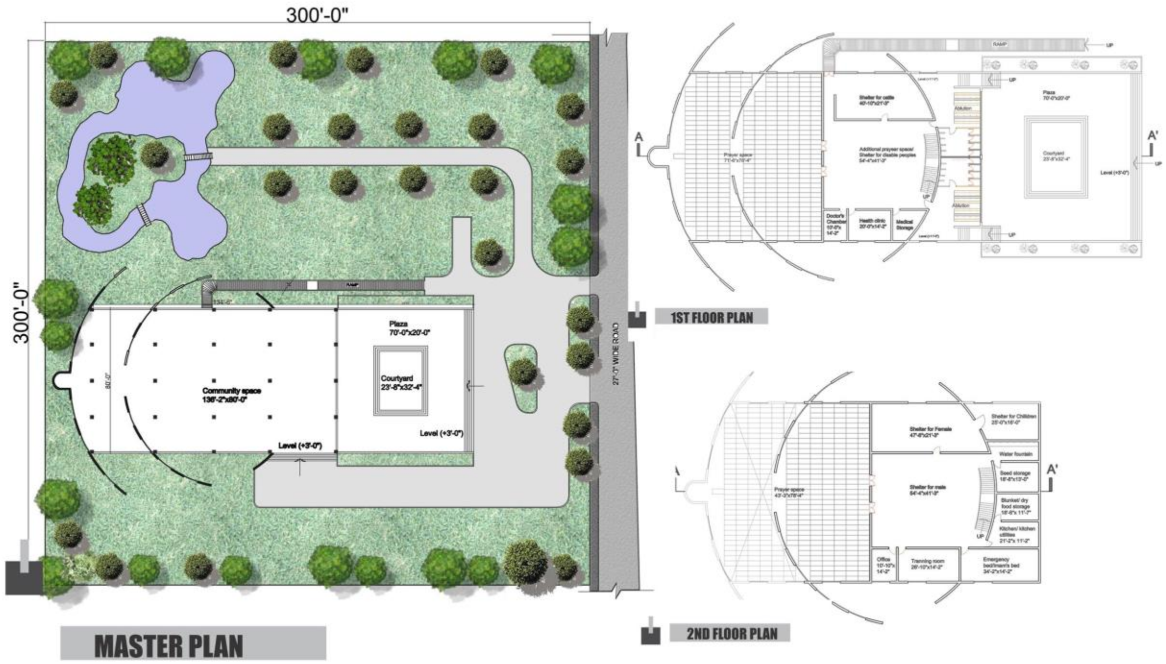


Figure 2. Master plan and details of the mosque reimagined as a community development and cyclone shelter.

The primary guidelines for the reimagined shelters as installing toilets on the raised ground, raised water sources, food and medicine preservations, and community based initiatives empowerments strategy have been followed by the standards from previous design research (Hossain, 2016). As the religious places are communal meeting and decision making space, the scope of creating a space-place dialect by incorporating the possibilities from the religious perspective with the notion of empowering the community for a holistic secure-livelihood approach to enhance sustainability was the design criteria. Also as learning from the previous study (Hossain, 2016) to perform disaster awareness, mitigation, preparedness, response and recovery through the mosques and temples with the transparency of activities and dissemination of knowledge and information to encourage people's participation in activities was practiced in the studio.

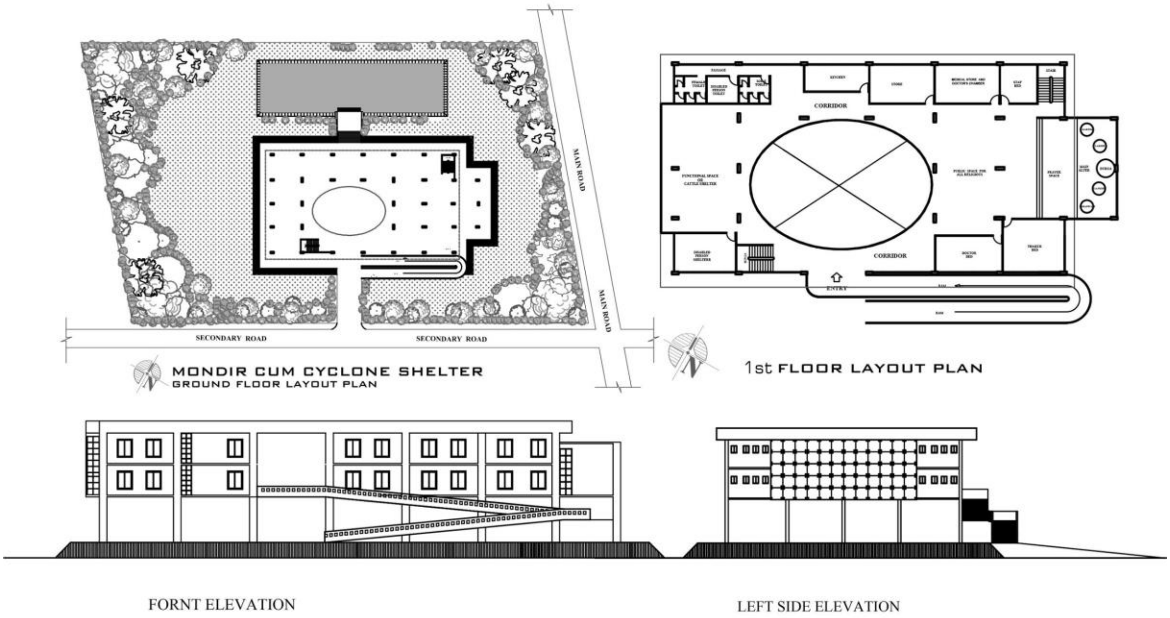


Figure 3. Master plan and details of a temple reimagined as community development and cyclone shelter.

Conclusion

Religious institutions have the potential to involve the community people to the disaster management system by fostering trust and thus enhancing social capital. Mosques or temples in the remote settlements can empower the voluntary sector by nurturing grassroots energy. Not only by involving people in the recovery and restoration process as a form of compassion and generosity, but the fundamental social change can also be possible by incorporating these institutions in the DRR system with proper training and evaluation. Through its elaborate and systematic operations, more coordinated and effective response to the crisis of natural disasters especially like cyclones can be settled.

Acknowledgments

The study is based on a design research done as an academic studio project conducted by the author himself as the design mentor with Level 2 Term 3 students of Department of Architecture, Sonargaon University, Bangladesh in Summer 2018 term. Also this paper is formatted as an elaborate study after a previous publication of the author himself published in Australian Journal of Basic and Applied Sciences in 2016.

References

Adisaputri, G. (2016). “The role of religious beliefs and practices in disaster: The case study of 2009 earthquake in Padang City, Indonesia”. *Doctoral dissertation*. Auckland University of Technology.

Baum, F. E. (2000). “Epidemiology of participation: an Australian community study”. *Journal of Epidemiology & Community Health*, 414-423.

Bourdieu, P. (1985). “The forms of capital”. In J. G. Richardson, *Handbook of theory and research for the sociology of education* (pp. 241-258). New York: NY: Greenwood.

Bowles, S. a. (2002). “Social capital and community governance”. *The Economic Journal*, 419-436.

Cardenas, J. C. (2008). “Behavioural development economics: Lessons from field labs in the developing world”. *Journal of Development Studies*, 337-364.

Chester, D. K. (2005). “Theology and disaster studies: the need for dialogue”. *Journal of Volcanology and geothermal research*, 319-328.

Chester, D. K. (2008). “The importance of religion in shaping volcanic risk perception in Italy, with special reference to Vesuvius and Etna”. *Journal of Volcanology and Geothermal Research*, 216-228.

Dasgupta, S. M. (2010). “Vulnerability of Bangladesh to cyclones in a changing climate: potential

damages and adaptation cost". *World Bank Policy Research Active Paper Series*.
Ha, K.-M. (2016). "Inclusion of People with Disabilities, their Needs and Participation, into". *Environmental Hazards*, 1-16. Retrieved from Environmental Hazards.
Hewitt, K. (1997). Regions of Risks: A Geographical Interpretation to Disasters. Longman: Harlow.
Hossain, I. &. (2016). "Scope of Mosques as a potential institution in cyclone prone settlements of Bangladesh". *Australian Journal of Basic and Applied Sciences*, 122-126.
Levitt, S. a. (2008). "Field experiments in economics: The past, the present, the future". *European Economic Review*, 1-18.
Maskrey, A. (1989). "Disaster Mitigation: A Comunity Based Approach". Oxford: Oxfam.
Meril, C. (2010). "Context-bound Islamic theodicies: the tsunami as supernatural retribution vs. natural". *Religion*, 104-111.
Paradise, T. (2005). "Perception of earthquake risk in Agadir, Morocco: A case study from a Muslim community". *Environmental hazards*, 167-180.
Portes, A. (1998). "Social capital: Its origins and applications in modern sociology". *Annual Review of Sociology*, 1-24.
Putnam, R. (2000). "Bowling Alone: The collapse and revival of American community". New York: Simon and Schuster.
Schipper, E. L. (377-393). "Religion as an integral part of determining and reducing climate change and disaster risk: an agenda for research". *Der Klimawandel*, 2010.
Schlehe, J. (2010). "Anthropology of religion: Disasters and the representations of tradition and modernity". *Religion*, 112-120.

SEAWALLS OR GREEN WALLS: SAVING THE COASTAL COMMUNITY AGAINST CYCLONES AND TSUNAMIS

Dr. Mahfuzul Haque[1]

ABSTRACT

The coastal zone of Bangladesh in particular and South Asia in general, is extremely vulnerable to climate-induced disasters. Because of the conical shape of the Bay of Bengal, the coastal region of south-west Bangladesh and the Eastern Ghat of India in particular is regularly visited by cyclones and associated tidal surges. Because of the low-lying coast, the region gets inundated with water surges. Moreover, due to tsunamis, more areas are flooded causing loss of properties and human lives. In Bangladesh, the Department of Forests has undertaken massive "Green Belt" project in order to protect the coastal people from cyclonic storms. It was found that the Sundarbans, the largest mangrove forests of the world did save lives of many people and the habitat from the cyclonic storm Sidr in 2007. The forests subsequently acted as a buffer zone between the sea and the human habitat during the cyclone Aila in 2009. Besides, plantation of forests, the local community has developed some indigenous knowledge and practices in order to face the natural calamities over the generations. On the other hand, some of the developed countries, like Japan has constructed massive concrete sea walls all along the north-eastern coast to protect its inhabitants from the tsunami related disasters. The paper argues that instead of a structural solution, like sea-walls, break-water or dykes, perhaps there could be least-costly, non-structural solutions like plantation of forests and thereby raising "Green Walls" as a survival strategy based on local indigenous knowledge and practices.

Keywords: Afforestation; Bangladesh Coast; Green Wall; Sidr; Seawall; Tsunami

Introduction

Coastal community over the generations has been living with natural hazards like cyclones, tsunamis and associated tidal surges. By now they have developed some community-based adaptation practices related to these disasters. Early warning systems based on their indigenous knowledge and practices played a pivotal role in saving many lives. Since the knowledge and practices are not documented and mostly in oral form, they get lost in the process. Some of the measures (both structural and non-structural) undertaken by the coastal people of Bangladesh and Japan have been closely examined and a comparison between the two done on the basis of the respective country's disaster preparedness programme, resilience of the people, viability and cost effectiveness of those measures.

Bangladesh Experience: Green Walls

The geographical location and climatic condition of Bangladesh are responsible for cyclone and other natural disasters. In coastal areas, afforestation is a proven cost-effective method to dissipate wave energy and reduce inundation during storm surges. Because of the conical shape of the Bay of Bengal, the coastal region of south-western Bangladesh and West Bengal and Odisha of India are periodically subjected to cyclonic storms and associated tidal surges. The location of the off-shore islands and the triangular funnel shape of the Bay of Bengal have made the coastal areas susceptible to cyclone and tidal surges. Out of 35 million people in 710 km long stretched coastal areas of Bangladesh, 7 million people live in high disaster risk. The government has made considerable success in managing natural disaster in Bangladesh. Although the loss of properties was huge during the cyclones of *Sidr* in 2007 and *Aila* in 2009, the loss of human lives were only 3,406 and 190 respectively due to effective networking and coordination between and among various levels of the Government and NGOs concerning disaster risk reduction and preparedness programs. During the earlier days, loss of lives and properties was very severe during disasters like floods and cyclones. Cyclones of 1970 and 1991 killed as many as 300,000 and 138,882 people respectively in the coast of Bangladesh (Bangladesh Met Office 1990). However, due to effective disaster management during pre-disaster, disaster and post-disaster period, loss has been substantially reduced.

[1] The author is a former Secretary of the Government of Bangladesh and currently teaches at the Department of Development Studies, University of Dhaka and Bangladesh University of Professionals as an adjunct faculty on issues related to sustainable development; disaster risk reduction; natural resource management; climate change and biodiversity conservation.
Correspending email: drmahfuzulhaque@yahoo.com

Over the years, the Sundarbans, the largest mangrove forests covering Bangladesh and India, played a protective role as a buffer zone between the storm-induced surges and the human habitat and reduced loss of lives and properties to a great extent. During the cyclonic storm Sidr in 2007, the forests faced the disasters and saved many lives. Moreover, the paradigm shift in disaster management from relief, restoration and rehabilitation to disaster risk reduction and community resilience programmes was effective in reducing the loss of lives and properties. Study showed that the impacts of coastal afforestation on inundation due to cyclone generated storm surges found to be much less (Sakib *et al*, 2016) Afforestation could reduce the inundated area and lessen the impacts on the human habitation. Government has adopted the Standing Orders on Disaster (SOD) 2010. The Standing Orders detailed out risk reduction; activities to be undertaken by various agencies during the warning period; during disaster and post disaster period. SOD has become a unique document for the volunteers and officials engaged in disaster management. Due to shifting from relief and rehabilitation to disaster warning and disaster risk reduction, as laid down in SOD, casualties decreased a lot. The other plans and guidelines are National Plan for Disaster Management (NPDM) 2010-2015; Bangladesh National Disaster Management Guidelines, 2015; and Disaster Management Act 2012. They have been playing a positive role in reducing disaster risk.

The age-old community based knowledge and practices of the coastal people played an effective role before and after a cyclone-induced tidal surge. The color of the clouds, temperature of the air, wind direction, movement of birds and animals were significant in understanding the degree of disasters. These signs were mainly early warning of the disasters. Cautions by the Red Crescent volunteers, taking refuge in cyclone shelters, availability of emergency dry foods and clothes are all contributing to reducing the death tolls to a great extent.

Japan Experience: Seawalls

In recent years, Japan has been hit by repeated tsunamis and concomitant tidal surges causing loss of lives and properties. The devastating tsunamis took place in 1933; 1960; 1968; 1994; and 2010. The great east Japan earthquake and tsunami in 2011 killed 18,500 people of the coast. Besides, loss of lives, properties were damaged, rice fields, agricultural lands, forests got inundated. Tsunami left an enormous amount of waste and debris requiring years to remove. In order to ensure safety of the coastal community from tsunami and tidal surges, a number of engineering structures, like sea walls, levees, break-water were constructed. By now, a 15 meter high 245 km of seawalls at a cost of US$ 12 billion have been constructed on the north eastern coast of Japan. It will stretch 400 km along Japan’s north coast. Seawalls not only permanently obstructing views, but also damaging the prospect of tourism, ecology and fisheries in the coast.

The paper argues that instead of a structural solution, there could have been least-costly non-structural solutions based on local indigenous knowledge and practices. Land zoning, relocation of vulnerable population to higher grounds, evacuation, massive tree plantation could have been among a number of viable options other than construction of the sea walls.

Coastal Afforestation

Coastal vegetation has been widely recognized as a natural method to reduce the energy of storm surges and tsunami waves. Afforestation can alter surface properties relevant to climate, generate favorable atmospheric circulations for precipitation, control groundwater, and increase evaporation. Using afforestation to induce favorable climate has been discussed over many years It was evident during cyclone Sidr but couldn't play the desired role in reducing inundation area as the landfall location was not exactly at the Sundarbans. In a study, hypothetically one km wide mangrove forest has been considered along with the coast from the shoreline (Sakib *et al*, 2016). The impact of this afforestation on storm surge inundation is studied by imposing a Sidr strength cyclone to make landfall on different locations along the Bangladesh coast. A study concluded that around 30% velocity, 32 to 35 % thrust force and 11.41% inundated area are reduced due to coastal afforestation (Sakib et al, 2016). It was further revealed that loss of lives and properties lessened much due to massive presence of the forests. Afforestation along the coastal belt is the cheaper and ecologically more beneficial than any other measure to protect the coastal areas and offshore islands from cyclone and storm surges. Mangrove forests are the most productive ecosystem on the earth and they perform a variety of useful ecological, bio-physical and socio-economic functions, which bring multiple benefits to coastal populations.

Japan, on the other hand, went for a total engineering solution of tsunami related disasters. It constructed the sea walls as the only option to protect the coastal community from the wrath of tsunamis. There are a number of developing countries in the Asia Pacific region need urgent recovery plan in the face of a tsunami. It could be mentioned here that during the 2004 Asian tsunami, 2,30,000 people in 14 countries died spanning a long coast from the Aceh province in Indonesia to coastal islands in Sri Lanka, India and Thailand. Construction of seawall as a solution could be difficult for resource constraint countries in South Asia or the Pacific island nations. For them, applying their indigenous knowledge and practices, like early warning, shifting to safer ground, reading various signs in nature and wildlife could be the best options.

Conclusion

During the cyclonic storm, Sidr in 2007, presence of the Sundarbans and afforestation reveal the following: a) coastal afforestation plays an important role in decreasing inundation area, depth and velocity magnitude; b) reduces polder overtopping incident; c) coastal afforestation works as a buffer in reducing thrust force; d) local Indigenous knowledge and practices were found to be very handy for the coastal community; e) afforestation along the coast can play a significant role as an adaptive measure by working as a buffer against the cyclone-generated storm surge flooding. As the natural disaster hit the coastal areas every year and hence a need for the creation of greenbelts has long been recognized. Mangrove and other coastal forests can reduce wind and storm wave impact as well as current velocities. The dense forests along the coastline can protect human habitation, lives, properties, and agricultural crops from extreme weather events resulting from climate change.

Coastal greenbelts are proven ‘soft’ measure that can effectively reduce the height and energy of storm surge and strong winds associated with tropical storms (CEGIS, 2016). A contiguous greenbelt has been proposed by the CEGIS study that will extend from eastern boundary of the Sunderbans to the southwest tip of Teknaf in 37 upazilas of 9 coastal districts. Greenbelts are also a ‘green adaptation’ that helps in sequestering carbon in significant quantity. They can enhance land accretion by trapping sediments. To mitigate the risk from such climate driven coastal hazards, which may become more intense with the changing climates, a greenbelt along the coastal region of Bangladesh, India and Sri Lanka can play a significant role in rescuing the community from tsunami related disasters.

References

CEGIS (2016). Final Report of Technical Study for Mapping of Potential Greenbelt Zone in the Coastal Regions of Bangladesh under Climate Resilient Participatory Afforestation and Reforestation Project. Bangladesh Forest Department, Dhaka.

Government of Bangladesh, Bangladesh Meteorological Department. (1990). Dhaka.

Islam, S.A., Rahman, MM. (2015). Coastal afforestation in Bangladesh to combat climate change induced hazards, *J. Sci. Technol. Environ. Inform. 02(01)*: 13-25

Sakib, M., Nihal,F., Akter, R., Maruf,M., Akter, M, Rimi, S N R A R, Haque, A., Rahman, M (2016). Afforestation as a Buffer against Storm Surge Flooding along the Bangladesh Coast, 12th International Conference on Hydro-science & Engineering *Hydro-Science & Engineering for Environmental Resilience* November 6-10, 2016, Tainan, Taiwan.

INDIGENOUS HOUSING AND DESIGN ACCLIMATIZATION WITH SUSTAINABLE MATERIALS FOR HOUSING DEVELOPMENT IN DINAJPUR

Shahin Sultana Eity[1]

ABSTRACT

Bangladesh has a different ecological and micro-climatic zone, and the hereditary inborn knowledge of people lead to indigenous housing and planning in the different regions with locally available materials. Mud is widely used in Dinajpur area for its low-cost, low-tech building efficiency, as well as thermal comfort, eco-friendly impact (Babuly and Eity, 2017). It was the most affordable material for hundreds of years' history of Dinajpur. Due to climate change effects, the natural calamities are striking abruptly and more extensively, and mud cannot withstand its consequence as a material anymore. In the meantime, the housing design and planning has changed due to socioeconomic aspects. This research study explores the century-long history and practice of housing design in Dinajpur, the changes in its qualitative characteristics, and the future prospect of adaptation of indigenous practice for disaster resilient housing development in Dinajpur with sustainable building materials.

Introduction

Background

Bangladesh comprises the world's largest delta in the Bengal basin - the most alluvial, fertile, and green among them all (Islam and Gnauck, 2008) (Islam S., 2012). Dinajpur District is situated on the upper side of the Ganges delta, and the physical geography of the land is a floodplain (Alam et. al., 2003) (Ahmed K., 1991). This distinctive part of land and the people face numerous different hazard and disaster, and a flood is a frequent event from the time being (Islam and Sado, 2000) (Kundzewicz and Takeuchi, 1999). Topographically, geopolitically, and socioculturally Dinajpur is a significant district in the northern part of Bangladesh and sustained its importance for a long period of time (Buchanan (Hamilton), 1833). Unequivocally, a flood is a common hazard that the inhabitants have to face and this phenomenon is one of the sources of abundant alluvial soil which are widely used as an affordable building material. The traditional mud houses and the indigenous housing sustained the calamities and influx of fire burnt bricks and C.G.I tin sheets until the drastic effect of climate change impact and flash flood in 2017 (Eity and Babuly, 2018).
This particular flood exceeded all the records set by previous disastrous flood and the traditional mud houses

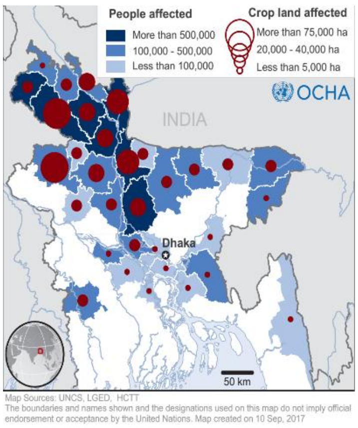


Figure 1. Flood map, 2017 ((UN, 2017)

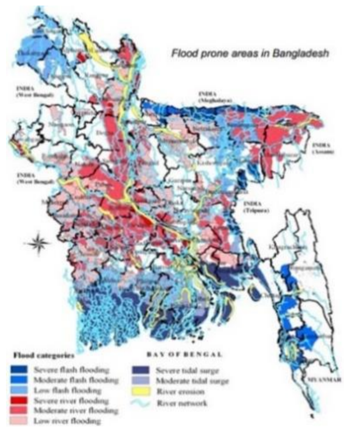


Figure 2. Flood Prone Areas, (Climate Change Cell, 2006)

which withstand the yearly hazard of flood in a floodplain was turned into rubbles (Tribune Desk, 2017) (Nicholson, 2017) (The Daily Star, 2017) (Nirapad, 2017).

[1]*Graduate Student, Dept. of Urban and Regional Planning, BUET, Dhaka-1000, Bangladesh.*
Email of Corresponding Author – sseity07@gmail.com

Figure 3. A family sitting over the wrecked house in August 2017 (Nicholson, 2017)

Figure 4. Dilapidated mud house in Mohonpur Village, Dinajpur (Tribune Desk, 2017)

Rural Habitation: The Challenge of Urbanization

Undoubtedly, urbanization is a global phenomenon and it is a great challenge for a country where agriculture is still the spine of the economy (BBS, 2011) (BBS, 2014) (UN, 2018). In many ways, we address the climate change impacts on our inbound rural-urban migration along with the socio-economic opportune influences and discuss the urbanization prospects and planning for the challenges in the future. The UN reported the World Urbanization Prospects in their revision for 2018, and the capital will face double population density in the year of 2030 (UN, 2018). Moreover, different statistical and medical evidence based studies indicate on declining growth of population in rural areas within 2025 (Streatfield and Karar, 2008) (BBS, 2011). This information point out the need to focus on the rural population and their housing design and architecture to ensure an inclusive, safe and resilient settlement. Sociopsychologically, this sense of belongingness and secure living at home will restrain the trend of inbound migration.

Research Methodology

The indigenous houses by local inhabitants of Dinajpur did not sustain for more than hundred years or so. The primary idea and goal for housing were not focusing on it too. Opportunely, being an important and large province; the pieces of literature, extensive geographic studies, mapping, official reports comprise particulars and substantial remarks, data, and information about the indigenous housing and materials. This research follows the available books, reports, descriptions, and reliable pieces of evidence and studies them to depict the context and apprehend the housing design, architecture, use of available local material and technology, and the rationale behind it. Furthermore, this study follows the researcher's personal observation over the recent years while studying the settlements of the Barind Tract.

Literature Review

After the extensive mapping of Indian Geography by Major James Rannell, the explicably detailed survey and personal observation by Dr. Francis Buchanan is one of the most authentic and acceptable resources to review the traditional housing settlement, indigenous architecture, and local building materials in Dinajpur. (Buchanan (Hamilton), 1833) The description of traditional houses and their indigenous design of Dinajpur were found in Hamilton's work (1833).

"Where the materials admit, the walls of the hut are made of mud, and the floor is always raised a foot or two above the level of plain, but not always so high as to above water in the rainy season; so that a platform of bambus is then constructed at one end of the hut, and upon this the family sit and sleep, while they must wade through the mud to reach the door. Where the soil is too loose for making walls, the sides of the hut are formed of hurdles, which are usually made of straw, grass or reeds, confined between sticks or split bambus that are tied together."

Furthermore, Buchanan described the use of local materials and the significant status symbols for affluent habitants by using wooden post and beams, the neat art of cow dung and clay, the fire hazard preparedness through using clay over the floor made of bamboo, and multitude use of house for local business extending the roof to five to six feet wide and creating a gallery space locally named 'Hatina' or 'Osra'. The doors are made as horizontal operable valve and tied with hurdle (Jhap). Very few households comprised garret and trap-stair to reach there, thus the place becomes habitable. However, in the traditional housing pattern of Bangladesh, this garret space is used as storage. Moreover, the development of 'Bangalow' by the European, the inspiration and development is briefly described here. Buchanan observed the dilapidated homestead made of brick and tried to explain the features. Surprisingly, the features are relatable to the design pattern of traditional mud houses that are still found in Barind Tract; the Moorish style brick houses had inadequate, shallow steps, low floor height, distinctively small rooms, and small openings as windows (Eity & Babuly, 2018).

After the aggressive flood in 1988, the plane of this delta experienced an erratic disaster. Housing and Building Research Institute (HBRI) observed the 'World Habitat Day' on 3 October 1988. The title of the keynote was 'Rural Housing after floods in Bangladesh', which was contemporary and apposite at that moment. The main research article of that ceremony cited the 1981 census report, which shows that 86.2% of people lived in villages and 13.8% people lived in cities. People are migrating toward cities for many different reasons. Housing and Building Research Institute (HBRI) conducted a census over 18 Districts of Bangladesh in 1985 on 'Common methods of construction of housing and housing material'. The information from the extensive survey and census on rural housing shows that 62.41% roof of households are made of straw, 21.48% are made of Kerosene Tin, 5.37% are made of Corrugated Tin , 4.70% are made of leaves, 4.70 are made of concrete, and 1.34% is made of other material. The information from the survey also shows that 60.40% of walls of the households are made of mud, 13.52% are made of bamboo Chatai (চাটাই), 8.55% are made of jute stick (পাটখড়ি) and mud, 8.05% are made of bamboo Chatai and cement mortar, 5.45% are made of bricks, 3.36% are made of bamboo Chatai and mud, and 0.67% are made of corrugated tin (Alam M. A., 1988).

One of the 'long term planning' needed recommendations for this research article was to inspire people to use sustainable and resilient materials. The extensive promotional campaign for the sustainable and resilient materials was recommended. The training programs conducted by Housing and Building Research Institute (HBRI) joint ventured with other GO and NGOs were recommended. It was a promising effort from the institute yet was not conducted into action for different reasons (Alam M. A., 1988).

After a year following, the institute organized 'National Rural Housing Exhibition' in January 1990 where several GOs NGOs and CBOs participated to demonstrate their effort and housing models. Among them all, the initiative from Grameen Bank and RADOL was notably appreciated due to addressing the spirit of home as a fundamental expression of belongingness and use of alternative building materials.

The master's thesis report of Ahmed (Ahmed K., 1991) is a notable resource for understanding the physiography, hazard, and disaster in Bangladesh. However, it is a surprising fact that the handbook for housing design and construction for flood prone rural areas does not comprise Dinajpur in the map. (Ahmed K. I., 2005)

Recently, HBRI published a standard guideline for disaster prone areas rural housing - an apposite initiative (Housing and Building Research Institute, 2018). However, despite many evidence, data, and information, the guideline does not address the Dinajpur area as a floodplain and propose a design solution.

Bangla Academy took initiative to familiarize the present state of folklore of every district in Bangladesh. Consecutively, they published a series of book and one of them represents Dinajpur. However, there was an effort to obtain information from local builders; (Bangla Academy, 2014) the outcome is not all-inclusive when it is the matter of local housing and architecture.

Study and Findings

Design Acclimatization - Indigenous Housing

The consecutive effects of disasters as flood, river erosion, and heavy rainfall are common to the inhabitants of Dinajpur. Accordingly, their living patterns, occupations, housing settlements depict their hereditary knowledge about the topography, environment, and microclimate. However, for the last seventy years, (Ahmed K., 1991) there is a notable trace of change in the perpetual life style due to climate change impact, socioeconomic aspects, and technological inventions. Surprisingly, the sustainability measure and adaptive capabilities of the inhabitants are effective in their housing pattern, form, and function of design. The intelligent use of the plinth as a platform is one of the notable directives by the inhabitants (Babuly & Eity, 2017). The ingenious use of the space underneath the platform correspondingly indicates their spatial cognition and sense of security. They stopped having mud plinth due to avoid threat of theft; Sindel-theives (the thief who dig the mud plinth silently and gets into the house unnoticeably) are now not allowed to cut off the bamboo platform silently.

The housing pattern and details of indigenous form and design are undisputedly similar to the description by Buchanan. Only the uses of polyethylene, CGI Sheets are adapted due to the acceptance of new technology. From the review above, we can clearly identify, that the inhabitants never adopted executed design by others or building materials that are not depicting their indigenous housing pattern, form, and design or drastic improvement of the existing one. However, they followed their own ingenious way to perform a subtle improvement. In this matter, we can agree with Rashid (Rashid, 2007) here about the changing pattern. This is quite a learning for the aspiring architects, designers, and the policymakers. The design acclimatization and adaptive response for indigenous housing remind us, that the approach should be from bottom-up, from the marginal user, who will be the beneficiary and the sufferer as well.

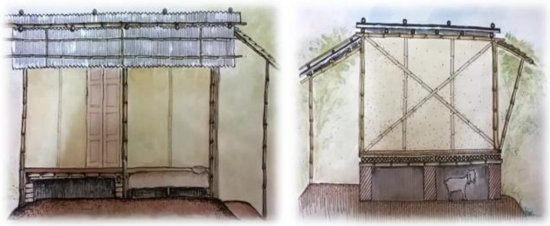


Figure 5. Section of the habitation and use of space (Babuly & Eity, 2017)

Figure 6. Existing House (F. Polin Babuly, 2016)

Sustainability and Building Materials

The three-pillar model - trichotomy of social, ecological and economic indicators are the preliminary framework for sustainable development indication (Hueskes, Verhoest, & Block, 2017). There are many more aspects for this framework, however, for this study, I will focus on this elementary framework. How can we define a sustainable building material for housing development in a district situated in the geographical borderline of this country? For assessing sustainable building materials, I am looking for an appropriate, affordable, and available resource that can comprehend the three-pillar model. HBRI – the let alone national housing and building research institute worked on developing different eco-friendly and affordable materials since its' establishment. The adobe block, micro concrete such as Ferrocement, rammed earth technique, modified Ekra wall, we can discuss numerous affordable and appropriate materials that are developed to use here in Bangladesh. The only impediment was the availability of these materials as well as social incorporation with the marginal level users. I am discussing particularly these materials because these all are appropriate and affordable alternative for traditional mud wall. Remarkably, the precast Ferrocement posts are ubiquitous in the local building materials market for rural housing. However, it is a supportive structural material, replacing mostly bamboos and there is an argument whether the users are comfortable with the new material or the abundance of bamboos is no more a reality due to unplanned cut down, deforestation hence the price hiked.

Table 1. Best Quality CGI Sheet – Price, size, thickness. (SAFE and Healthhabitat, 2015)

Company name and Thickness	PHP 0.420 mm	PHP 0.340 mm	T.K. 0.420 mm
Length	Price per piece in Taka*		
10 Feet	964	828	960
9 Feet	843	725	793
8 Feet	750	644	705
7 Feet	675	580	635
6 Feet	562	483	529

*Standard pricing in Dinajpur and Dhaka

Imported CGI sheets became popular after 1950s as an available building material, shiny look with new appearance. (Ahmed K., 1991) Though the tin gets rusty after enduring a few rainy seasons, it was popular for its lightweight, availability in local market, easy application in 'Chauyari' roof (Buchanan (Hamilton), 1833) instead of thatch and straw as it allows change of material without any change or drastic modification in design of the traditional house. Despite much corrosive quality, this is still one of the most popular building materials for rural housing in Bangladesh.

The above-mentioned appropriate and affordable materials could not reach to the population as CGI sheets.

Recently, CI sheet made of cement and cotton pulp is available in local market as well as in the neighboring countries market in Asia. This is considered as alternate for the CGI tin sheet.

Table 2. CGI cement Sheet – Price, size, thickness (SAFE and Healthhabitat, 2015)

Thickness	Width	Length	Price/Sheet in taka
4 mm*	2 to 6 Feet Wide	3’	165
		4’	260
		5’	325
		6’	390
		7’	455
		8’	520
		9’	608
		10’	675

*10x thickness than conventional CGI tin sheet

Table 3. Cost of constructing a 17’ long house roof (approx.) (SAFE and Healthhabitat, 2015)

CGI Metal Sheet	Cement Sheet
15,000 tk.	10,200 tk.*

*30% cheaper than metal sheet

Imaginatively, the outlook and the size of this cement are copied from CGI tin Sheet, so the builders will feel familiar to use these materials for building houses. The advertisement also compares it with the properties of the CGI tin sheet. These cement sheets are compressed and stabilized cement mixture along with cotton pulp, quite similar to stabilized block developed by HBRI using jute pulp, coconut fiber etc. (Housing and Building Research Institute, 2018) Remarkably, the properties of this cement sheet is similar to stabilized blocks. These are of course, rust free, saline resistant, thermally insulated and comfortable during different season, non-active with the contact with chemicals and acid rain, comparatively durable, and better fire resistant. Noticeably, these are cheaper than the CGI tin sheet, which is attracting the rural inhabitants and the environment concerned development organizations. According to appropriateness, affordability, and importantly availability in the local market is influencing me to consider this material instead of traditional use of alluvial mud for building sustainable and resilient house in Dinajpur.

Conclusion

To recapitulate, nationally standardizing the sustainability framework and indicators will allow us to promote disaster resilient housing for marginal people and respect their choice and way of living to mitigate the gap over understanding their belief, life, and indigenous architecture.

References

Ahmed, K. (1991). "Up to the waist in mud! : the assessment and application of earth-derivative architecture in rural Bangladesh." Massachusetts Institute of Technology, Massachusetts Institute of Technology. Dept. of Architecture. Massachusetts: Massachusetts Institute of Technology. Retrieved from http://hdl.handle.net/1721.1/62899

Ahmed, K. I. (2005). *Handbook on Design and Construction of Housing for Flood-Prone Rural Areas of Bangladesh.* Dhaka: Asian Disaster Preparedness Centre - ADPC. Retrieved from https://www.adpc.net/igo/category/ID189/doc/2013-p74Wob-ADPC-handbook_complete-b.pdf

Alam, M. A. (1988). Rural housing after floods in Bangladesh. (pp. 1-30). Dhaka: Housing and Building Research Institute - HBRI. Retrieved 2018

Alam, M., Alom, M., Curry, J., Chowdhury, M., & Gani, M. (2003, February). An overview of the sedimentary geology of the Bengal Basin in relation to the regional tectonic framework and basin-fill history. *Sedimentary Geology, 155*(3-4), 179-208. doi:10.1016/S0037-0738(02)00180-X

Babuly, F., & Eity, S. (2017)."Insearch of resilience: exploring mud houses in Dinajpur, Bangladesh" (P. D. Maheshwari, Ed.) *Amity Journal of Engineering and Technology, 2*(2). 54-68.

Bangla Academy. (2014). *Present state of Folklore in Dinajpur District* (1 ed.). Dhaka: Program for the development of Folklore, Bangla Academy. Retrieved 2018.

BBS. (2011). *Population and Census - 2011.* Bangladesh Bureau of Statistics, Staistics and Informatics Division. Dhaka: Ministry of Planning. Retrieved January 4, 2018

BBS. (2014). *Bangladesh population and housing census, 2011. National report.* Dhaka: Bangladesh Bureau of Statistics, Statistics and Informatics Division, Ministry of Planning, Bangladesh, Government of the People's Republic of Bangladesh.

Buchanan (Hamilton), D. (1833). *A geographical,historical,statistical description of the District or Zilla of Dinajpur in the province or Soubah of Bengal* (1 ed.). Calcutta: The East India Company; The Asiatic Society. Retrieved december 2017, from https://books.google.com.bd/books?id=xIUIAAAAQAAJ&printsec=frontcover#v=onepage&q&f=false

Climate Change Cell. (2006). Component 4B Comprehensive Disaster Management Program. (CDMP, Compiler) Dhaka: CDMP. Retrieved 2018

Eity, S. S., & Babuly, F. (2018). "Sustainable Settlements: Resilience in Deltaic Landscape." In D. M. Islam (Ed.), *Volume of Abstracts of the papers presented at the Special Conference on Flood, Waterlogging and Landslide* (pp. 19-20). Dhaka: BAPA-BEN. Retrieved January 2018

Housing and Building Research Institute. (2018). *Standard guideline for rural housing in disaster prone areas of Bangladesh* (1 ed.). Dhaka, Dhaka, Bangladesh: Housing and Building Research Institute; Ministry of Housing and public Works; GoB. Retrieved February 2018

Hueskes, M., Verhoest, K., & Block, T. (2017). Governing public–private partnerships for sustainability. *International Journal of Project Management, 35*(6), 1184-1195. doi:10.1016/j.ijproman.2017.02.020

Islam, M., & Sado, K. (2000). "Development of flood hazard maps of Bangladesh using NOAA-AVHRR images with GIS." *Hydrological Sciences Journal, 45*(3), 337-355. doi:10.1080/02626660009492334

Islam, S. (Ed.). (2012). *Banglapedia:National Encyclopedia of Bangladesh* (2 ed.). Dhaka, Bangladesh: Asiatic Society Bangladesh.

Islam, S., & Gnauck, A. (2008,). "Mangrove wetland ecosystems in Ganges-Brahmaputra delta in Bangladesh." *Frontiers of Earth Science in China, 2*(4), 439-448. doi:10.1007/s11707-008-0049-2

Kundzewicz, Z., & Takeuchi, K. (1999). "Flood protection and management: quo vadimus?" *Hydrological Sciences Journal, 44*(3), 417-432. doi:10.1080/02626669909492237

Nicholson, P. (2017). *After Floods in Bangladesh.* Caritas. Caritas. Retrieved December 2017, from https://www.caritas.org/2017/09/after-floods-in-bangladesh/

Nirapad. (2017). *Bangladesh: Flood Situation- August 2017.* Nirapad. Nirapad. Retrieved January 2018, from http://https://reliefweb.int/sites/reliefweb.int/files/resources/Situation_Report%20of%20Flood%20_Updated%20on%20August_22%2C%202017.pdf

Rashid, R. (2007). "Traditional House of Bangladesh: Typology of house." *Virtual Conference on Sustainable Architectural Design and Urban Planning*, (p. 11). Retrieved from AsiaSustainabilityNet.upc.edu

SAFE and Healthhabitat. (2015). *Bangladesh Sanitation Program.* Building Works . Dinajpur: SAFE. Retrieved from https://www.slideshare.net/UzzalRoy/e-safe-bangladesh-sanitation-program-building-works-201214-copy

Streatfield, P., & Karar, Z. (2008). "Population challenges for Bangladesh in the coming decades." *Journal of Health, Population, and Nutrition, 26*(3), 261-272. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2740702/

The Daily Star. (2017, August 15). *Flood hits 20 districts: Five more killed in Dinajpur raising death toll to 20 in three days; nearly six lakh people affected.* Dinajpur: The Daily Star. Retrieved December 2017, from https://www.thedailystar.net/frontpage/bangladesh-flood-situation-2017-hits-20-districts-1448749

Tribune Desk. (2017, May 30). Dhaka Tribune. *12 major cyclones from the past*. Dhaka, Dhaka, Bangladesh. Retrieved February 23, 2018, from http://www.dhakatribune.com/

UN. (2017, September). Bangladesh Floods 2017. (U. O. Affairs, Compiler) UN Office for the Coordination of Humanitarian Affairs. Retrieved January 2018, from https://reliefweb.int/sites/reliefweb.int/files/resources/BGD_sitrep_170910.pdf

UN. (2018, May 16). *World Urbanization Prospect: Revision 2018.* UN, Department of Economic and Social Affairs. UN. Retrieved September 2018, from https://www.un.org: https://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html

PREDICTING SPATIOTEMPORAL CHANGES OF HEAT STRESS OVER BANGLADESH UNDER CLIMATE CHANGE CONDITION DURING 1985-2070

Mahzabin Binte Rahman[1] and A.R.M. Towfiqul Islam[2]

ABSTRACT

This study aims to predict the spatiotemporal change of heat stress over Bangladesh under present and future climate change conditions using by heat index (HI). The HI was calculated by the daily dry bulb temperature and humidity data from twenty meteorological stations during 1985-2015 which downscaled by statistical downscaling model (SDSM) using the AR5 daily climatic data. The simulated data of the heat stress were generated for the period of 2041-2070 under the three representative concentration pathways (RCPs) scenarios viz., RCP2.6, 4.5 and 8.5. The results showed that a significant monotonic trend was identified using a modified Mann-Kendal test, Sen's Slope estimator and linear regression model. The northern, northwestern, northeastern and southeastern regions demonstrated the increasing trend while southwestern, south-central regions showed the decreasing trend under historical and future time periods. The results of HI value gradually increased at an alarming rate for most of the climatic regions, except for the northwestern and southwestern regions, suggesting a severe condition in humid summer for far future period. The predicted HI value exhibited that northern, north-eastern, western and southern regions demonstrated high heat stress, whereas northwestern region showed the low heat stress condition. Thus, early warning system, mitigation and adaptation strategies are strongly recommended to cope with this alarming risk; also to deal with caution the future heat stress arising critical condition across Bangladesh.

Keywords: Heat stress, SDSM model, spatiotemporal change, Northern Bangladesh, early warning.

Introduction

Climate change-stimulate intense heat events that are becoming a global concern in various regions of the world, particularly in developing countries like Bangladesh. Climatic variables like humidity and temperature are rising in the past three decades and its figure out that relative humidity over 40 percent when temperatures surpass 80 degrees Fahrenheit**.** The people of Bangladesh are not aware of the dangerous impact of heat stress arising from climate change. There is no such definition about the level of heat stress for Bangladesh. Lack of available data, inadequate models, and limits on their spatial resolution are the major constraint contributing to a person's heat exposure to account for in forecasting. Heat early warning systems are known to save lives by improving preparedness and should form an important component of a climate change adaptation strategy. This study can help to identify the heat stress vulnerable area and will help in early preparedness and adaptation strategy for future climate change. Therefore, this study is an important attempt to assess heat stress over Bangladesh's people health in terms of the time and the space of occurrence that helps us to categorize and identify high risks areas for future adaptation plan. Nowadays, a great problem for Bangladesh that outrageous temperature occasions all over the country especially amid summer. Summer season has drawn out while winters have turned out to be short in Bangladesh. Therefore, the objective of the study is to predict the spatiotemporal change of heat stress over Bangladesh under present and future climate change conditions using by heat index (HI) modeling.

Literature Review

The future prediction of heat stress arising from changing climate is lacking behind, especially for Bangladesh (Modarres et al. 2018). This investigated future heat stress condition over Iran under climate change. They found a rise in the heat index and extreme caution conditions for summer and spring seasons for most parts of Iran at present and future climate change scenarios. Heat stress related study is relatively new in Bangladesh, but similar patterns in mortality and morbidity can be found in literature (Burkart et al. 2014; Burkart and Endlicher 2011; Nissan et al. 2017). For example, Nissan et al. (2017) defined and predicted heat waves in Bangladesh using a generalized additive regression model. Climate change and heat wave related assessment in Bangladesh has been attained a lot of concern, no study has focused on heat stress over Bangladesh's population health. Rajib et al. (2011) investigated the heat index over Bangladesh and its impact

[1] *Department of Disaster Management, Begum Rokeya University, Rangpur 5400.*
[2] *Assistant Professor, Department of Disaster Management, Begum Rokeya University, Rangpur.*
Email of Corresponding authors:Zabinmehzabin@gmai;.com; towfiq_dm@brur.ac.bd

of climate change. This study investigated the increasing rate of heat index according to the normal HI calculation in four regions of Bangladesh. The findings of this study are that the highest increase in heat index value has been observed in areas of south-west region and north-west region. The highest change in average heat index has been found in Jessore by almost 5.50 °C. No future prediction assessment has been done.

Methodology

Daily climatic data of the dry bulb temperature and humidity were collected from Bangladesh Meteorological Department (BMD) (available at http:\\bmd.gov.bd). Data of total 20 meteorological stations for more than 30-year period (1985–2015) daily data took into consideration. Although this study is the selected stations are almost evenly distributed all over the country which assumed to be representative of the whole country. Additionally, this study showed the HI changes in the seven climatic zones across Bangladesh. The historical data projected the mid-century (2041-2070) daily data of temperature for the stations by the SDSM downscaling method. HI is constructed for both the historical and future time period based on the following Eq. (1)-

$HI= c_1 + c_2T + c_3R + c_4TR + c_5T^2 + c_6R^2 + c_1T^2R + c_8TR^2 = c_9T^2R^2$…...……………………..(1)

Where, HI=heat index, T=dry bulb temperature, R=relative humidity.

The historical trend, non-parametric Modified Mann-Kendal test, sen's slope estimator and linear regression model is applied to detect the significant change in the time series. Additionally provided the PDF, statistical summary and time series analysis to find out the climatic zones HI changes across Bangladesh.

Calibration and validation of climatic data

Calibration and validation of the simulated and observed data are required for the downscaling the future data generation through the SDSM software. This is the test of accuracy and quality of the predicted data and it can observe how much error occurs in the modeled data. For the calibration, observed climatic variables (1985–2005) were used as the predictand and National Center for Environmental Prediction (NCEP) data (resolution 2.8° × 2.8°) (1961–2005) of the respective factors were picked as the indicator amid adjustment with the end goal to prepare the model. The daily model type used in this study, the predicted data was temperature so the process was selected as unconditional. The necessary bias correlation was performed where needed. The calibrated data of each station which is extracted from SDSM were tested for coefficient of determination (R-squared value; R^2), standard errors (SE) and Durbin-Watson tests (DW). Srimangal, Sylhet, Rajshahi, Rangpur, Chandpur, Chittagong stations value were given in a table for instance (Table 1). R^2 value of the calibration results for maximum temperature varies in between 0.35 to 0.00 for the observed and predicted model data, indicating the reasonable accuracy of the model. The SE and DW test range for the designated stations between 0.27 to 0.01 and 0.21 to 0.01, suggesting data within a reasonable limit.

Table 1:Mean annual SDSM model calibration(1985-2005) results of temperature for several stations

Test	Srimangal	Sylhet	Rangpur	Rajshahi	Satkhira	Chandpur	Chittagong
Observed R^2	0.34**	0.32**	0.13**	0.02	0.37**	0.15**	0.04*
	0.25	0.13	0.10	0.09	0.27	0.09	0.13
S.E	0.31	0.56	0.29	0.06	0.25	0.29	0.11
D.W							
RCP 2.6 R^2	0.06*	0.00	0.07*	0.01	0.12*	0.01	0.03*
	0.02	0.02	0.02	0.02	0.02	0.02	0.02
S.E	0.16	0.01	0.20	0.03	0.34	0.03	0.09
D.W							
RCP 4.5 R^2	0.01	0.03*	0.00	0.01	0.02	0.07*	0.05*
	0.02	0.02	0.02	0.02	0.01	0.01	0.02
S.E	0.02	0.07	0.02	0.07	0.08	0.17	0.12

D.W								
RCP 8.5	R^2	0.09*	0.07*	0.02	0.05*	0.06*	0.17**	0.35**
		0.05	0.05	0.07	0.06	0.07	0.05	0.04
S.E		0.21	0.16	0.05	0.11	0.10	0.40	0.69
D.W								

Note: R^2-coefficient of determination, S.E-Standard Error, D.W-Durbin Watson test and (** significance level at 0.01) and (* significance level at 0.05).

For the output model validation, selected the time period for (2006-2015). Firstly summary statistics were calculated for both the observed and modeled data for the period (2006-2015) during the extraction of the data. These summary statistics include mean, maximum, minimum, sum and variance. Then, the summary statistics of observed and model data were compared and examined using bar, line and plots.

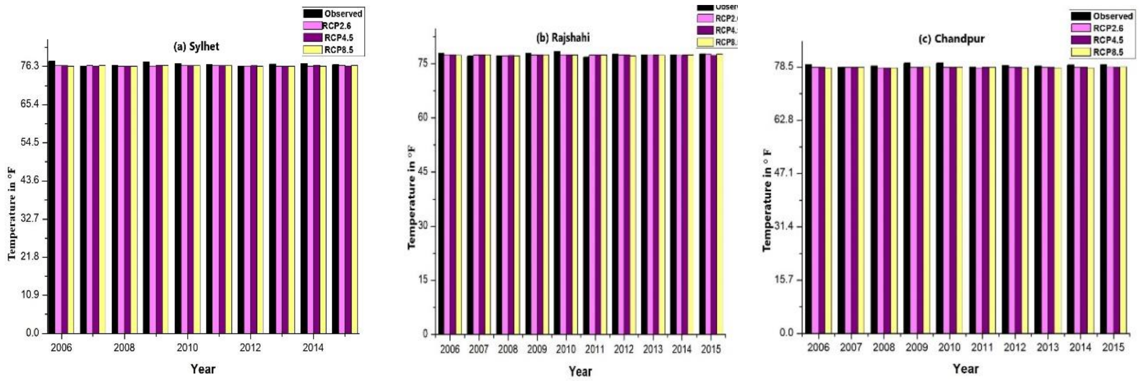
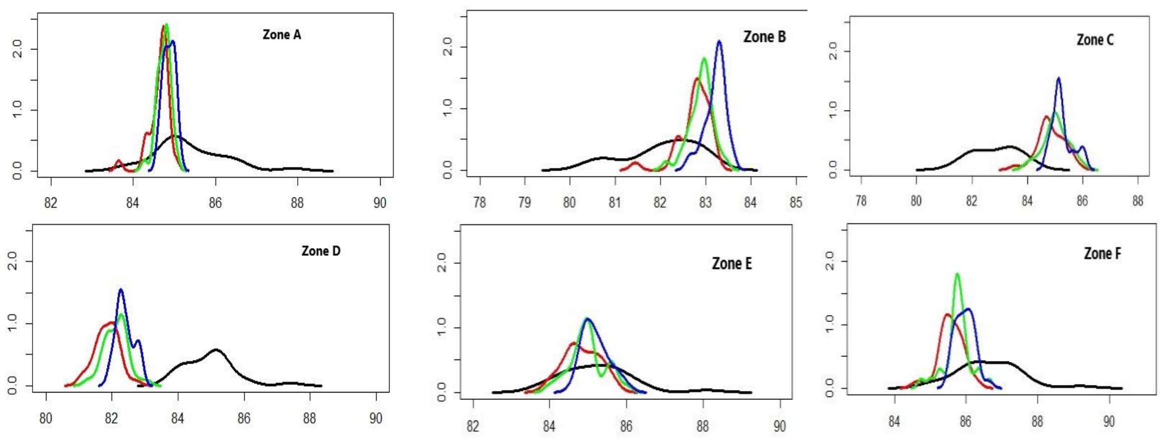


Figure 1. Validation (2006-2015) for the SDSM model output for Sylhet, Rajshahi and Chandpur stations against observed data.

Figure 1 represents the validation of the model output for temperature summary statistics of Sylhet (north-eastern), Rajshahi (western) and Chandpur (south-central) stations. As for Fig. 3.3, modeled data of all climatic variables were agreed well with the observed data, only a few differences are observed among the observed and modeled data of these stations. Thus, it can be said that the model output was within the desired quality, with little deviation.

Results

PDF of HI values in climatic zones



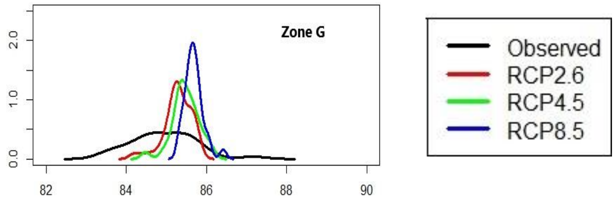


Figure 2. Probability density Function (PDF) of heat index. Black line represents observed (1985-2015) data. Red, Green and Blue lines indicate RCP 2.6, RCP 4.5 and RCP 8.5 in the mid-century or near future (2041-2070, NF) respectively for the climatic zones of Bangladesh

Moreover, the change in the probabilistic conduct is likewise explored (Fig. 2) by showing the probability distribution functions (PDFs) of the HI for the climatic zone of Bangladesh. It is additionally seen that the state of the PDFs will change significantly. For instance, a move to right in future expanding pattern in HI where it is clearly shifted for zone B (north-eastern), Zone C(northern), Zone G(south-central) and zone E (south-eastern), zone A(western) and zone F(south-western). Zone D (north-western) has the remarkable decreasing rate of Heat index for future period.

Spatial changes of HI in Bangladesh

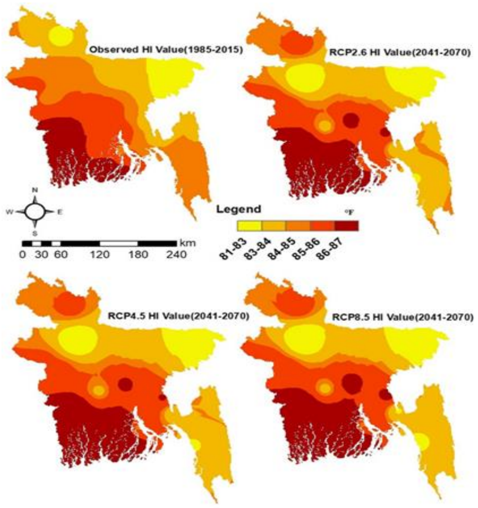


Figure 3. Spatial changes of HI values during climatic period 31years observed (1985-2015) and 30 years of modeled data (2041-2070) under three different scenarios over Bangladesh.

Figure 3 shows how the observed data for thirty-one years and the modeled data of thirty years for the three different future scenarios are changed. It can easily identify that the HI range of Rangpur (northern) increases the rate as (85-86) °F. This is really huge changes for an area. It is evident that the northern region temperature is increasing day by day than before. The Heat index of Chandpur (south-central), Comilla (south-central) and Rajshahi (western) are also increasing at the alarming rate as already demonstrated that their trend of increasing heat stress is high. On the other hand, surprisingly, the heat index value for Bogra (north-western), Chittagong (south-eastern) and Faridpur (south-western) will decrease in near future period.

Conclusion

The average change of heat index for future period is not much in comparison with historical period but it varies at locally and regionally over the country for the hot summer and humid summers. This shows that HI value gradually increases in the northern region while the HI value decreases in the north-western region. The observed (1985-2015) and modeled data (2041-2070) for three different scenarios of hot and humid summers indicate that the HI of the hot summer increases for maximum climatic zones from caution to extreme caution and in humid summer, the HI value increases as medium extreme caution to high extreme caution. The condition of HI will turn into danger in far future, e.g., some southwestern zones like Barisal. It is noted that relative humidity is a key component for computing HI in this study, and the relative humidity took as a constant value of (1985-2015) from the past used in future without change. Vulnerability was not recognized by this investigation, which is another issue for anticipating climate change impacts. Thus, the outcomes of the study should be carefully applied for developing emergency services, management instruments, or early cautioning frameworks except if the vulnerability in relative stickiness is considered for HI computation. Additionally, if information accessibility winds up solid, it will assist us with conducting more research on Heat Index over our nation. In light of the result of this investigation, additionally research will be conducted on these ways: firstly, the future study will aim to establish a correlation between ENSO with heat index considering the whole country. Secondly, it is likewise proposed that diverse downscaling methods and climatic models will be connected in future to contrast and consequences for further investigation. These deserve future investigation and also a promising extension of the present work.

References

Burkart, K. and Endlicher, W., (2011) a. Human bioclimate and thermal stress in the megacity of Dhaka, Bangladesh: *Application and evaluation of thermo physiological indices.* Health in Megacities and Urban Areas, Krämer, A., Khan, M. H., and Kraas, F., Eds., 153–170.

Burkart K, Breitner, S., Schneider, A., Khan, M. H., Kramer, A. and Endlicher, W., (2014) b. An analysis of heat effects in different subpopulations of Bangladesh. *International Journal of Biometeorology*, 58, 227–237, doi: 10.1007/s00484-013-0668-5.

Modarres, R., Ghadami, M., Naderi, S. and Naderi, M., (2018). Future heat stress arising from climate change on Iran's population health, *International Journal of Biometeorology*, doi: 10.1007/s00484-018-1532-4.

Nissan, H., Burkart, K., De perez, E. C., Van Aalst, M. and Mason, S., (2017), Defining and Predicting Heat Waves in Bangladesh, *journal of applied meteorology and climatology,* vol: 56, doi: 10.1175/JAMC-D-17-0035.1.

Rajib, M. A., Mortuza, R., Selmi, S. and Ankur, A. K., (2011). Increase of Heat Index over Bangladesh: Impact of Climate Change, Researchgate, *World Academy of Science, Engineering and Technology, 58* 2011.

IMPACT OF CLIMATE CHANGE IN WATER AVAILABILITY OF THE BRAHMAPUTRA RIVER BASIN: BASED ON DIFFERENT GCM PREDICTION

Md. Shahadat Hossain[1], M. Monowar Hossain[2], Md. Sohel Masud[3], Tashrifa Sultana[4], and Xuan Ji[5]

ABSTRACT

Around 800 million people are contingent on water from the Brahmaputra basin. Hydrology of Brahmaputra Basin is one of the most vulnerable in the world which is subject to combined effect of snow melting and extreme monsoon rainfall. Climate change has the potential to intensify the hydrological cycle, leading to more intense precipitation with associated changes in the temporal and spatial distribution of water availability in the Brahmaputra basin. To what extent climate change will impact on river flow of Brahmaputra Basin is not clear yet. Many researches have been done, however, the assessment of climate change impacts on the basin-scale hydrology by using well calibrated hydrologic modeling has seldom been conducted in the Brahmaputra basin due to the lack of observed data for calibration and validation. Most of the model study has been calibrated only at Bahadurbad point on Brahmaputra (Jamuna) river in Bangladesh. As a result, the uncertainty of impact of climate change effect on upper and middle part of Brahmaputra basin is inevitable. This study efforts to assess impact of change on water availability of Brahmaputra river basin using MIKE HYDRO Basin, it is a multi-purpose, conceptual lumped type decision support tool for integrated river basin analysis, planning and management. In this study, we have calibrated Brahmaputra Basin (BRB) Model at 5 different locations in different sub-catchments in the whole basin and well agreement between observed and simulated river flow is found. The calibrated model is applied 10 GCM output under two representative concentration pathway (RCP). It is observed that out of ten analyzed scenarios almost nine cases show a similar trend i.e. increase of flow due to climate change. Most of climate scenario show significant change of flow in basin in April, May and June. However, a very strong change in peak flow is projected, which may lead to a devastating flood in future.

Introduction

The Brahmaputra is the 4th largest river in the world by annual flow, and it is one of the major rivers of the Ganges-Brahmaputra-Meghna (GBM) system carries more flow and sediment to the Bay of Bengal through China, India, Bhutan, and Bangladesh than other rivers of this system (Ray et al., 2015). It is the main source of water for 130 million people and socioeconomic condition (e.g., poverty, regional development, crop production, etc.) of this region depend on Brahmaputra river basin (BRB) (Alam et al., 2016; Ray et al., 2015). Moreover, this basin is the most vulnerable area under the impact of climate change (Gain et al., 2011). Since 1920, the temperature of the planet is increasing; the number of warm years is exceeded than expected range of variability (Ghosh & Dutta, 2012). The mean surface temperature of the planet is increasing 0.65 to 1.06ºC over the period 1880 to 2012 (IPCC, 2015). Change in temperature is one of the driving forces to alter the hydrological process in water cycle (Milly et al., 2008). Among the river system of the BRB, the impact of climate change on river hydrology is expected to be particularly strong. Flow of upstream part of the BRB is strongly influenced by the melt of snow and ice. Cryospheric processes are deemed to be important when topographic elevation higher than 2000m, as 60% area of BRB is elevated more than 2000m (Gain et al., 2011). Projected rise in temperature will lead to increase summer flow for few decades by increasing snow and glacial melt; therefore, after few decades snow and ice will be disappeared and lead to accelerate the scarcity of upstream flow (Immerzeel, 2008). This scenario is particularly true when water availability is crucial for irrigation system and threatening the food scarcity of an estimated 26 million people in BRB (Immerzeel et al., 2010). On the other hand, BRB is highly influenced by the extreme monsoon and flooding (Mirza, 2002). If the intensity and variability of monsoon change due to climate change, it will affect both high and low flows leading to increase flood intensity but also flow variability is increased both space and time (Postel et al., 1996). The important fact that discharge during flood and wet season cannot be used during lean period unless large reservoir system in there (Oki & Kanae, 2006). Lastly, climate change leads sea level

[1,4]Junior Specialist, Institute of Water Modelling, Dhaka-1206, Bangladesh
[2]Executive Director, Institute of Water Modelling, Dhaka-1206, Bangladesh
[3]Director, Flood Management Division, Institute of Water Modelling, Dhaka-1206, Bangladesh
[5]Assistant Professor, Institute of International River and Eco-security, Yunnan University
[*]Email of Corresponding Author – sht@iwmbd.org

rise and riverine flooding by causing back-water effect of the GBM basin along the delta (Agrawala et al., 2003).

In the past, several studies have been done to focus on the rainfall and discharge relationship in BRB and GBM basin by identifying the correlation among the discharge, sea surface temperature and El-Nino (Chowdhury & Ward, 2004; Mirza et al., 1998; Nishat & Faisal, 2000), analyzing observed data compare to the reanalysis data (Kamal-Heikman et al., 2007), and verifying the historical flood events (Islam et al., 2010; Mirza et al., 2003). Different type of statistical methods was used in the aforementioned studies instead of hydrological modeling. In recent year, a number of global-scale hydrological model (including Brahmaputra Basin in this domain) result have been published (Haddeland et al., 2011; Haddeland et al., 2012; Pokhrel et al., 2012) but these global-scale models are not fully liable to water management sector or other future studies due to the lack of calibration on basin scale. On the other hand, there are several studies conducted on the impacts of climate change on water availability in BRB and GBM basin (Gain et al., 2011; Ghosh & Dutta, 2012; Immerzeel, 2008; Kamal et al., 2013; Mirza & Dixit, 1997; Seidel et al., 2000). In most of the aforesaid studies, future streamflow is predicted using linear regression between precipitation and stream flow based on historical data. Immerzeel (2008) used multi-regression model in his study to predict future stream flow at Bahadurabad under the climate forcing parameter (precipitation and temperature) using statistically downscaled GCM output. Nevertheless, since most hydrological events are not linear, they cannot predict hydrological process accurately using extrapolating regression model (Masood et al., 2015). Alam et all, (2016) applied a physically based semi-distributed hydrological model, namely, soil and water assessment tool (SWAT) at the BRB, but their study is only focused on the Bahadurabad station. The alternatively for the assessment of future streamflow on basin-scale hydrology is via well-calibrated hydrological model, but it rarely been conducted for the BRB.

In the present study, an attempt has been made to develop a hydrological model for long simulation in which the calibration and validation is based on a rarely obtained long term (climate normal period 1981-2010 (Arguez et al., 2012)) observed data in BRB collected from different sources and to investigate the present condition of water availability and trend in both high low flow for BRB under climate change. Compare to the previous BRB studies, it is believed that the available quality observed data lead to better estimation of model parameters, near to earth observed hydrological simulation and predict reliable future projection.

Study Area

The Brahmaputra is a major transboundary river which originates from the great glacier mass of Chema-Yung-Dung in the Kailas range of southern Tibet (China) at an elevation of 5,300 m above the sea level (m.a.s.l). The river traverses 3410 km, flowing through China (1995 km), India (983 km) and Bangladesh (432 km) before emptying into the Bay of Bengal. The Brahmaputra river drains an area of around 530,000 km^2 through the four different countries: China, India, Bhutan, and Bangladesh (Biswa et al., 2017; Immerzeel, 2008). The basin comprises quite diverse environments as the cold dry plateau of Tibet, the rain-drenched Himalayan slopes, the landlocked alluvial plains of Assam and the vast deltaic lowlands of Bangladesh (IWM, 2013). As categorized by (Immerzeel, 2008), the Brahmaputra basin into three different physiographic zones: Tibetan Plateau (TP), Himalayan belt (HB), and the floodplain (FP). TP (with elevation is greater than 3500 m.a.s.l) covers 44.4%, HB (elevation between 100 and 3500 m.a.s.l) covers 28.6% whereas an elevation of less than 100 m a.s.l is considered as FP and comprise about 27% of the entire basin. The climate of the basin is mainly driven by the monsoon (June to September), which accounts 60-70% of the annual rainfall in the basin, while the pre-monsoon season from March through May produces 20-25% of the annual rainfall (Immerzeel, 2008; IWM, 2013). And total rainfall in the lower part of the basin is 2354 mm (Gain et al., 2011; IWM, 2013).

Total water use estimated in the BRB is around 27457 Mm^3/year, out of which above 90% is used in India and Bangladesh. Sector-wise water uses in the basin are: 89 % in agriculture, 9 % in domestic, and 2 % in industrial sector (IWM, 2013). Actually, BRB is the main source of water, energy and food for an estimated 130 million people living within the basin, and where the river flows through the most highly disputed areas in South Asia. As a result, BRB’s water resources that have been largely undeveloped by the conflict of interest of the downstream states (Yang et all., 2016). Now that upstream countries are enacting water develop plans, these plans have a potential to increase the conflict between counties. Except Zangmu dam, there is no significant intervention in the main course of BRB. Most of the dam is built on the tributaries through the Bhutan, Assam, Nagaland, Sikkim, Tibet and Lasha (Alam et al., 2016; Rahaman, 2012). Other than hydropower, river water is diverted for irrigation purposes. India, China and Bangladesh have been operating more than 20 barrages on several tributaries (Yang et al., 2016).

The Brahmaputra is a perennial river and its annual average, highest recorded and low recorded discharge are 21066 m^3/s, 98300 m^3/s, 1653 m^3/s respectively (Immerzeel, 2008; IWM, 2013). 85% of the total annual stream flow throw out the wet season is available and the remaining 15% is available in dry period (Alam et al., 2016). Annual water demand estimated in the Brahmaputra basin is around 36535 Mm^3 for four special sectors: Domestic (2373 Mm^3), Irrigation (31606 Mm^3), Industrial (2076 Mm^3), and Livestock (480 Mm^3). Monthly water demand in the basin varies ranges from a minimum of 411 Mm^3 (in wet months) to a maximum of 8513 Mm^3 (in dry months) (IWM, 2013).

Methodology

MIKE HYDRO Basin

MIKE Hydro Basin is a water management tool developed by DHI. MIKE HYDRO Basin is a multi-purpose, map-centric decision support tool for integrated river basin analysis, addressing water allocation, conjunctive water use, reservoir operation, or water quality issues. A mathematical representation of the river basin is defined including the configuration of river and reservoir systems, catchment hydrology and water user schemes with rainfall-runoff processes, river routing, surface water-groundwater interaction, and water quality processes. Rainfall-runoff model that is part of the MIKE Hydro Basin. The NAM (NedborAfstromnings Model) is deterministic, lumped and conceptual rainfall-runoff model that operates by continuously accounting for the moisture content in three different and mutually interrelated storages that represent overland flow, interflow and base flow (DHI, 2017).

Input Data

The basic data requirement for the MIKE HYDRO Basin model are digital elevation data, meteorological data and discharge data for model calibration. In this study, publicly available global datasets have been utilized to develop the MIKE HYDRO Basin model for BRB. The Shuttle Radar Topography Mission (SRTM) generated Digital Elevation Model (DEM) of 90 m resolution (Jarvis, Reuter, Nelson, & Guevara, 2008) was used to delineate the sub-basins and river network. Weather data from the National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR) (Stopa & Cheung, 2014) are used as climate input data, including precipitation, temperature (http://globalweather.tamu.edu/). Evaporation data are also used as climate input data it collected from ECMFWF.
Streamflow data for 5 river points along the Brahmaputra river and various tributaries representing the outflow from different sub-basins are used to calibrate and validate the BRB model. Details of the various points and data sources are provided in Table 2 and the spatial positions are shown in Figure 1.

Table 1. Model input data and sources.

Data Type	Source	Spatial Resolution	Temporal Resolution
Digital elevation model (DEM)	SRTM	90m	
Rainfall, Temperature	CFSR	0.5º	Daily
Evaporation	ECMWF	0.5º	Daily
Rainfall (Observed)	NMIC, BWDB		Daily
Streamflow	HY, ICIMOD, BWDB, Immerzeel, 2013		Daily

***** NMIC: China National Meteorological Information Center, HY: Hydrological Yearbook issued by the Ministry of Water Resources of China, CFSR: Climate Forecast System Reanalysis, SRTM: Shuttle Radar Topography Mission, BWDB: Bangladesh Water Development Board, ICIMOD: International Centre for Integrated Mountain Development, ECMWF: European Centre for Medium-Range Weather Forecasts

Table 2. Model coparison point and data availability.

Location Name	Longitude (deg.)	Latitude (deg.)	Sub-Basin Name	Data Type	Data Source	Available Data Period
Bahadurabad	89.66	25.18	Whole Brahmaputra	Measured	BWDB	1981-2016
Kaunia	89.11	26.10	Teesta	Measured	BWDB	1988-2016
Dihang	91.88	29.28	All Tibetan sub-basins in the upper Brahmaputra	Simulated Result from HI-SPHY	ICIMOD	2002-2007
Subansiri	94.15	28.08	Subansiri North			

Manas	91.23	27.03	Manas East	Model		
Yangcun	91.88	29.28	All upstream sub-basin of Yangcun	Measured	HY	1956-1982

For climate change impact assessment, two RCP scenarios (i.e., RCP 4.5 and 8.5) with four GCMs of each representing four climatic conditions (i.e., total eight GCMs) were selected. RCP 4.5 considers a less extreme future climate with radioactive forcing stabilizing at an emission rate of 4.5 Wm-2 by 2100. RCP 8.5, on the other hand, is more extreme condition with radioactive forcing stabilizing at an emission rate of 8.5 Wm-2 (Thomson et al., 2011). One RCM is also used based one two RCP 8.5 and 4.5 (**Table 3**).

Table 3. Selected Climate Change Prediction scenarios.

Sl No	Description	RCP	Selected Model
1	Dry, Cold	RCP45	GIS-E2-R-r4i1p1_rcp45
2	Dry, Warm	RCP45	IPSL-CM5A-LR-r4i1p1_rcp45
3	Wet, Cold	RCP45	CCSM4-r5i1p1_rcp45
4	Wet, Warm	RCP45	CanESM2-r4i1p1_rcp45
5	Dry, Cold	RCP85	GFDL-ESM2G-r1i1p1_rcp85
6	Dry, Warm	RCP85	IPSL-CM5A-LR-r4i1p1+rcp85
7	Wet, Cold	RCP85	CSIRO-Mk3-6-0-r3i1p1_rcp85
8	Wet, Warm	RCP85	CanESM2-r4i1p1_rcp85
9	-	RCP45	BCCR
10	-	RCP85	BCCR

MIKE HYDRO Basin Model Setup

Development of model using MIKE HYDRO Basin includes several steps: (i) sketching of the river system, (ii) delineation of sub-catchments, (iii) computation of mean rainfall and evaporation for each sub-catchment, (iv) set up hydrological / rainfall runoff model, (v) set up of MIKE BASIN model, and (vi) simulation as well as calibration of the model. At the start of MIKE HYDRO Basin modeling, flow direction has been calculated using land terrain data of SRTM. Subsequently, main stream and tributaries of the Brahmaputra river have been sketched using the available tool. Rivers that sketched in the basin are: Brahmaputra river, Dibang, Lohit, Buri Dihing, Dhansiri, Kopili, Subansiri, Kameng, Manas, Sunkosh, Dudkumar, Dharala, and Teesta. The entire Brahmaputra river basin has been sub-divided into 52 sub-catchments which are as shown in Figure 1. The sub-catchments in the basin have been delineated using the available tool of MIKE BASIN. Total basin area under the hydrological model is 521144 sq. km. A rainfall runoff model has been developed using NAM model of DHI. The NAM model comprises 52 sub-catchments. It is to be noted that the rainfall runoff model (NAM) comprises four conceptual storages: snow storage, surface storage, sub-surface/root zone storage, and ground water storages.

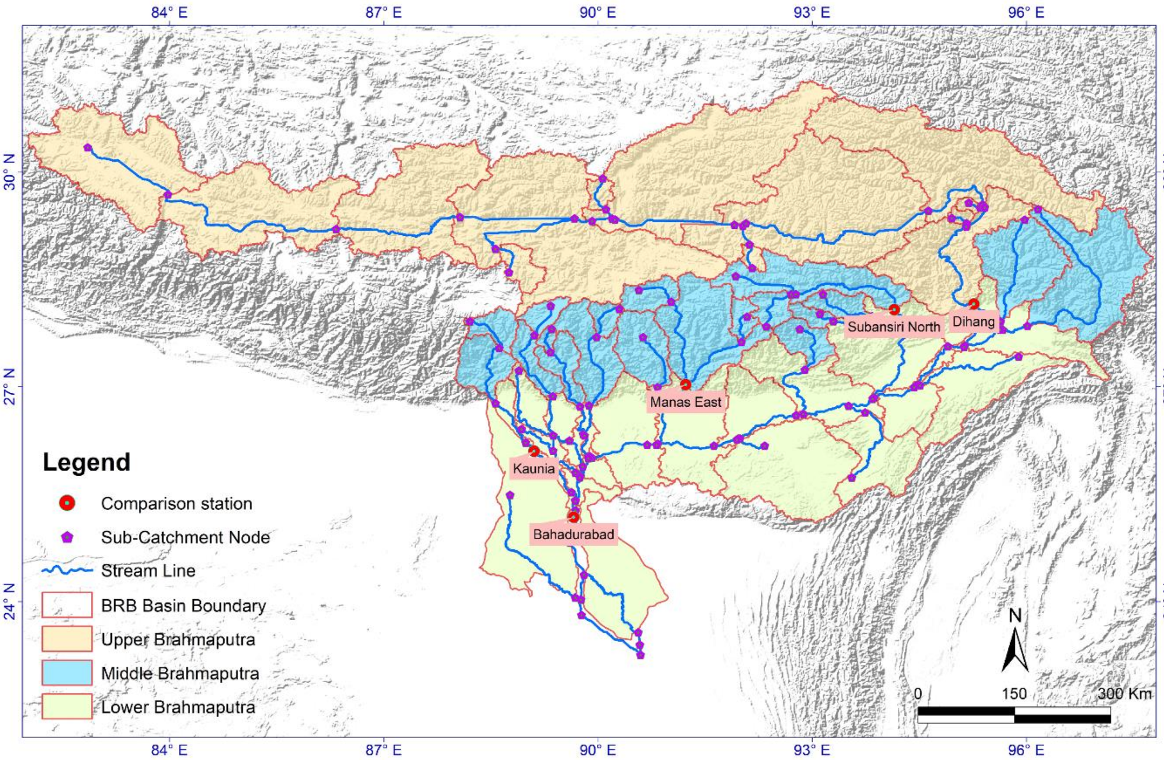


Figure 1. River network, sub-catchments, catchment nodes and comparison station of the MIKE BASIN based model of Brahmaputra basin.

Model calibration and validation

The BRB MIKE HYDRO Basin model was run for 1979–2010. First two years discard from calibration and validation period as a warmup period; the first 15 years (1981–1995) were taken as the calibration period and the next 15 years (1996–2010) as the validation period at five different locations of BRB. In the calibration and validation stage, model performance was evaluated by statistically and graphically (Figure. 2). It is found that the observed and simulated data is in a good agreement for dry and monsoon period based on Table 3.

Statistically, the performance of the BRB model has been evaluated using Nash-Sutcliffe efficiency value (NSE), the ratio of the root-mean-square error between the simulated and observed values to the standard deviation of the observations (RSR), percent bias (PBIAS) and the coefficient of determination (proportion of the variance in the observations explained by the model, R^2). Figure. 3 demonstrate that model has been performed well in validation and calibration stage.

Table 4. Definitions of Goodness-of-Fit Statistics and General performance ratings for recommended statistics for a monthly time step (Moriasi et al., 2007; Rossi et al., 2008).

Performance Rating	RSR	NSE	PBIAS
Very good	0.00 ≤ RSR ≤ 0.50	0.75 ≤ NSE ≤ 1.00	PBIAS ≤ ±10
Good	0.50 < RSR ≤ 0.60	0.65 < NSE ≤ 0.75	±10 < PBIAS ≤ ±15
Satisfactory	0.06 < RSR ≤ 0.70	0.50 < NSE ≤ 0.65	±15 < PBIAS ≤ ±25
Unsatisfactory	RSR > 0.70	NSE > 0.50	PBIAS > ±25

*NSE = Nash–Sutcliffe efficiency; PBIAS = mean relative bias; RSR = root mean square error-standard deviation ratio

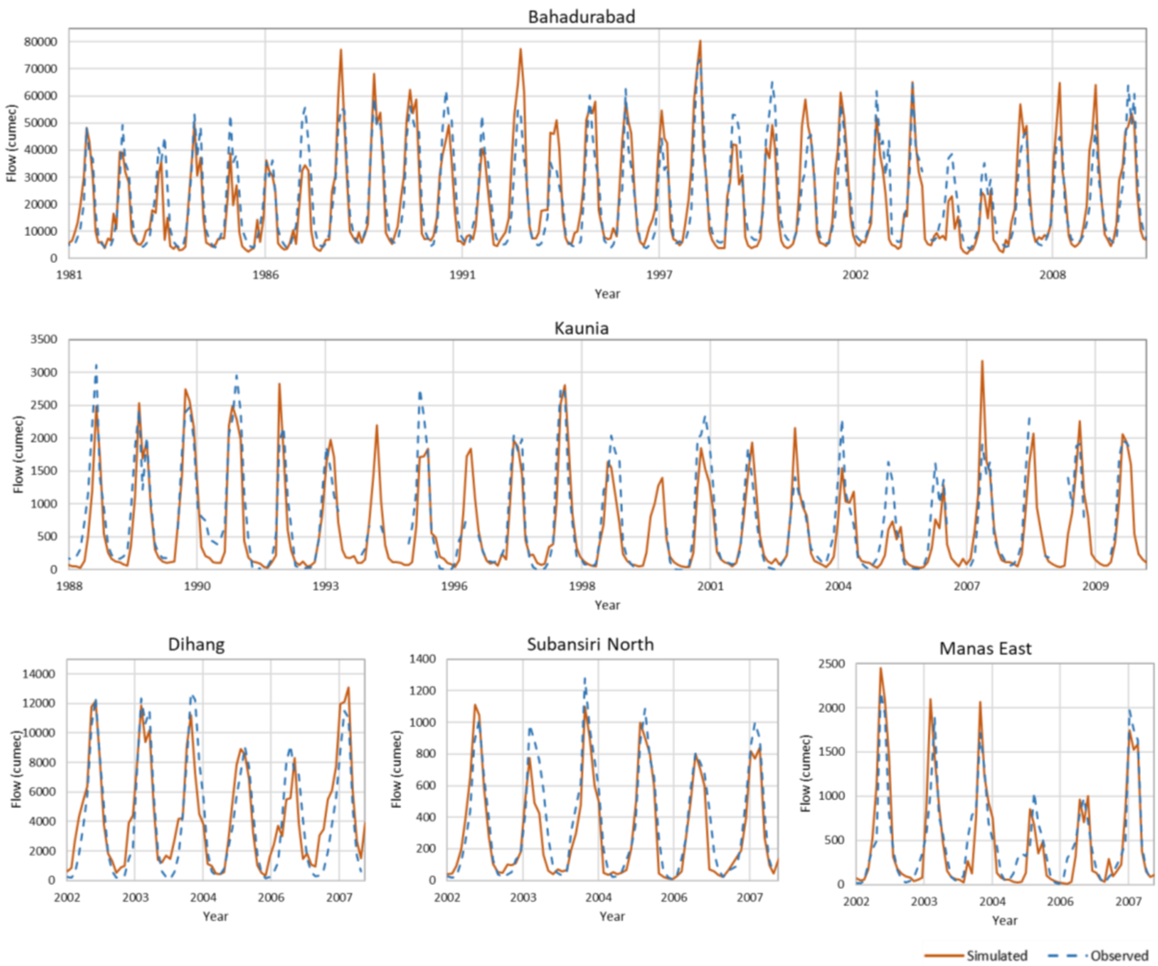


Figure 2. BRB model performance at the river points shown in Figure 1. The blue line represents the observed streamflow and the yellow represents the model simulation.

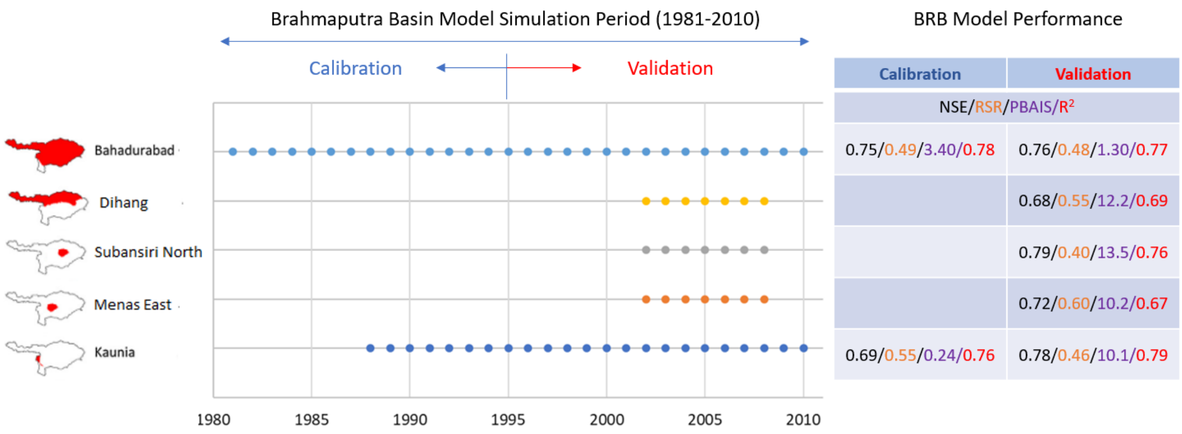


Figure 3. BRB model performance for different sub-basin with 4 metrics.

Result and Discussion

Water Availability in BRB

Water availability has been calculated in the BRB based on model simulated flow for the period of 1981 to 2010 at Bahadurabad, outlet of BRB in Bangladesh. In the BRB, the annual average water availability is around 667400 Mm^3. The monthly average water availability varies ranging from around 12986 Mm^3 in driest month to around 130414 Mm^3 in wettest month which is as shown in Figure 4(a). At the outfall, the annual average flow rate of the Brahmaputra basin is around 21066 m3/s, whereas the monthly average flow rate varies ranging from 4848 m^3/s in driest month to 48691 m^3/s in wettest months in Figure 4(b). Furthermore, over the last 30 of normal climate period (1981-2010), yearly maximum stream flow is rising in Figure 4(b) and in Figure 4(d), yearly minimum flow is almost in constant although recent years trend is falling.

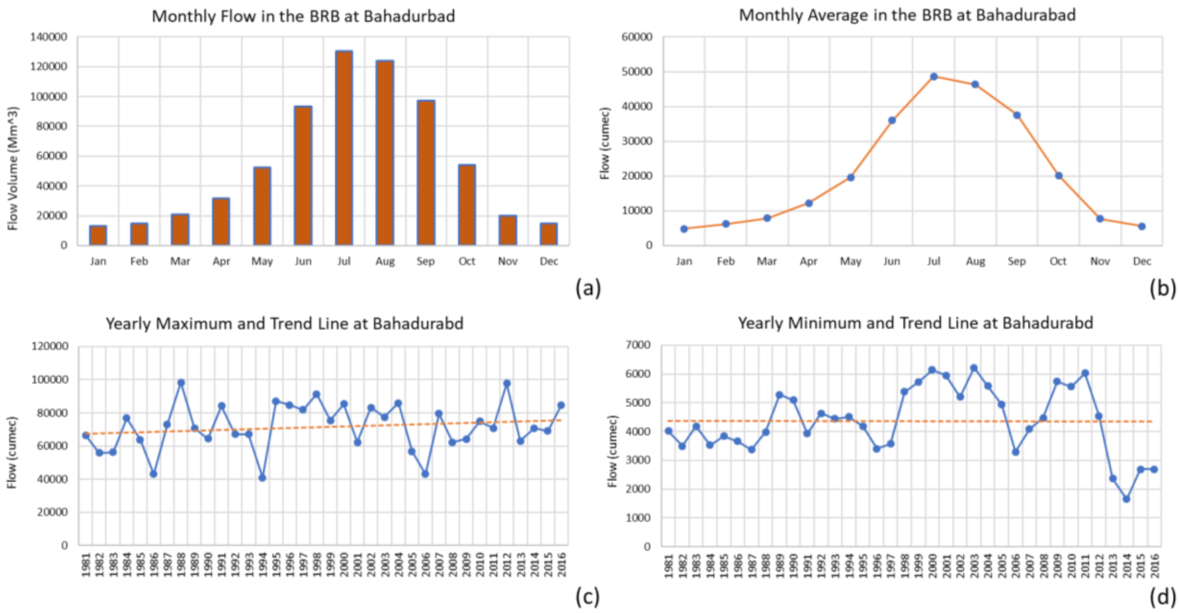


Figure 4. (a) Average monthly flow, (b) Monthly average flow rate, (c) yearly maximum flow rate and trend and (d) yearly minimum flow rate in BRB over the period (1981-2010).

Effect of Climate Change on Water Availability

The effect of climate change on the water availability is determined for ten climate change scenarios and three decades: 2030, 2040 and 2050. The analysis has been carried out on the water availability at the outlet of the Brahmaputra basin.

Under this present study, raster (gridded) data files of monthly CC projected change in temperature and precipitation for the BRB region were collected from ICIMOD, Nepal and delta for each temperature and precipitation data point utilized in the BRB model development was estimated. The rainfall and temperature data for CC BRB simulations were then prepared by applying this delta (projected change in temperature and precipitation) to the base precipitation and temperature data of 1981–2010. The above-mentioned method, usually referred as delta method, is widely used in regional and local CC studies (Arnell, 1999; Lutz et all., 2016).

It is observed that out of ten analyzed scenarios almost nine cases show the similar trend i.e. increase of flow due to climate change. The model: CSIRO-Mk3-6-0r3i1p1_rcp85 shows decrease in flow during July and August. Only one model: IPSL-CM5A-LR-r4i1p1+rcp85 shows decrease trend of flow during dry, pre-monsoon and monsoon months. With long future, the potential impact of climate change becomes significant i.e. change of flow in the basin increases. Most of the models scenario show significant change of flow in the basin in April, May and June. In future 2030, the change of flow obtained from the scenarios vary ranging from -2.5 to 16 % in the months of August to February; the highest change of flow is observed in April which is around -10 % to 11 %. Moreover, in future 2050, the average change of flow vary ranging from -3 to 18 % in the months of August to February, and that is about -25 % to 28 % in April. Figure 4 shows the changes of flow in the Brahmaputra basin due to climate changes in all five models with two RCPs in future 2030, 2040 and 2050.

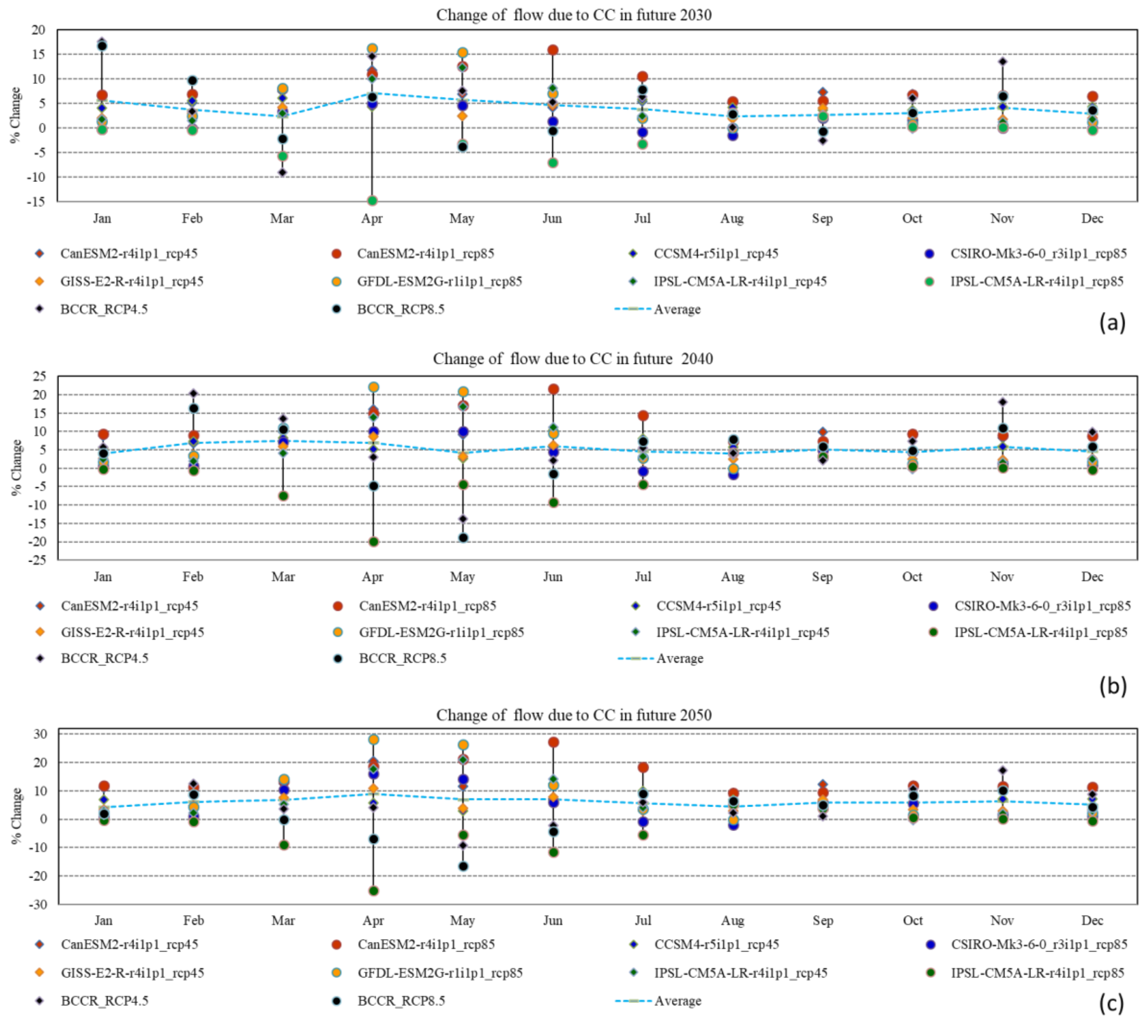


Figure 5. Change of flow in the BRB due to CC in future 2030(a), 2040(b) and 2050(c) based on different GCM output.

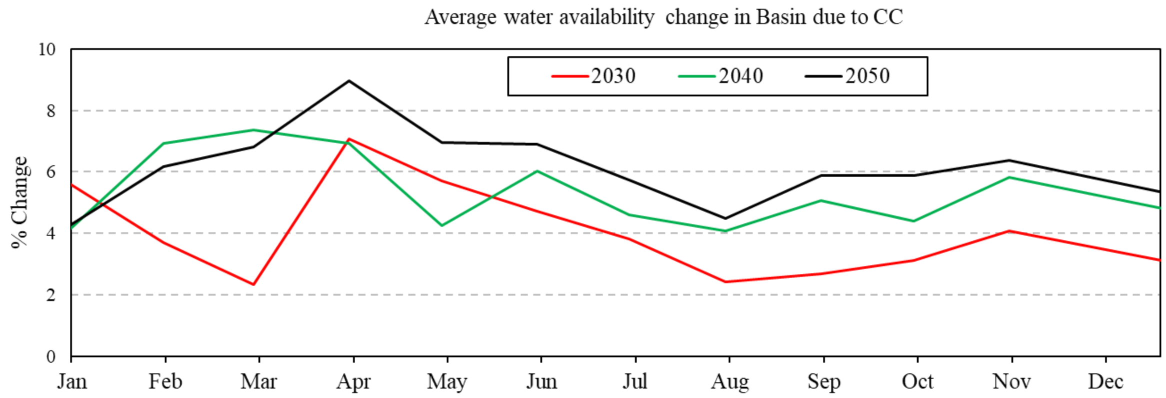


Figure 6. Average change of flow in the Brahmaputra basin due to climate change obtained from five models with two RCPs

The average changes of flow of all models and RCPs vary in different months of the years, and also in different future time line. The average change in flow in the basin is minimum in post-monsoon and dry months, and that is maximum in pre-monsoon months i.e. April and May. In future 2030, the average increase in flow is as low as 2.34 % in March and that is as high as around 7.07 % in April. In future 2050, the average change in flow is as low as 4.4 % in January to as high as 9 % in April. Average changes of flow in the basin due to climate change for four different future decades are as shown in Figure 6.

Conclusions

In this study, a well calibrated MIKE HYDRO Basin model is developed for BRB. Different calibration parameter and routing method have been found by auto calibration method and literature review.

The annual average water availability in the Brahmaputra basin is around 667400 Mm^3 at Bahadurabad. The monthly average water availability varies ranging from around 12986 Mm^3 in dry months to around 130414 Mm^3 in wet months. The annual average flow rate of the Brahmaputra basin is around 21066 m^3/s whereas the monthly average flow rate in the basin varies ranging from around 4848 m^3/s in dry months to around 48691 m^3/s in wet months. The water availability mentioned above is calculated based of MIKE BASIN based model simulated discharge for the period of 1981 to 2010. It is to be mentioned that there is limitation in calibration of the model in dry months. Therefore, care should be taken before using the above specified figures of water availability in dry months.

The effect of climate change on water availability in the Brahmaputra basin has been analyzed using predicted rainfall, evaporation of five climate prediction models with two RCPs. It is observed that most of the scenarios simulated show increase trend of flow due to climate change. With long future, the change of flow in the basin increases, and becomes more significant in pre-monsoon months: April, May and June. In future 2030, the flow is likely to be changed about -2.5 to 16 % in the months of August to February; the highest change of flow is observed in April which is around -10 % to 11 %. Moreover, in future 2050, the flow is likely to change about 0 to 10 % in the months of August to February, and that is about -25 % to 28 % in April.

The average change of flow is likely to be increased in future 2030 by amount of about 2.34 % in March and that is as high as around 7.07 % in April. The same is as low as 4 % in January and as high as around 9 % in April in future 2050. Although, combined effect of all scenario show average flow is increasing, some climate scenario like IPSL-CM5A-LR-r4i1p1+rcp85 and BCCR_RCP85 indicate pre-monsoon flow is decreasing as -25%, and it could be led to arise adverse impact on agriculture and river ecosystem. On the other hand, most of the climate models output show flow will be increased in monsoon period under climate change. Thus, there could be an adverse impact on flood flow leading to increase in enhanced recurrent flood in the floodplains of the Brahmaputra river mostly located in Assam of India and in Bangladesh.

The present study has used a calibrated BRB model for simulating future streamflow in a climate change using 8 GCM and 2 RCP climate model. In future extension of this study, this calibrated model will be used (1) for estimating sub-catchment wise water resources which will provide more insight detail and which sub-catchment is more vulnerable under climate change and (2) evaluating satellite predicted rainfall and other meteorological data from different sources, which are suitable for this region.

Acknowledgments

This study was undertaken under the "Water Resources Vulnerability and Security Assessment of the Turlung Tsangpo-Brahmaputra Transboundary River Basin" which is implemented jointly by Institute of Water Modelling and Institute of International River and Eco-security, Yunnan University is Funded by NSFC (Grant No. 41661144044). The views and interpretations in this publication are those of the authors. They are not necessarily attributable to IWM and do not imply the expression of any opinion by IWM concerning the delimitation of frontiers or boundaries.

References

Agrawala, S., Ota, T., Ahmed, A. U., Smith, J., & Van Aalst, M. (2003). *Development and climate change in Bangladesh: focus on coastal flooding and the Sundarbans*: Citeseer.

Alam, S., Ali, M. M., Islam, Z., fshdg, sgdjsg, & sdfs. (2016). Future streamflow of Brahmaputra River basin under synthetic climate change scenarios. *Journal of Hydrologic Engineering, 21*(11), 05016027.

Arguez, A., Durre, I., Applequist, S., Vose, R. S., Squires, M. F., Yin, X., . . . Owen, T. W. (2012). NOAA's 1981–2010 US climate normals: An overview. *J Bulletin of the American Meteorological Society, 93*(11), 1687-1697.

Arnell, N. W. (1999). Climate change and global water resources. *J of Global environmental change, 9,* S31-S49.

Biswa, B., Md. Tohidul, I., Shenduli, P. R., Andel, V., Schalk, J., & Masih, I. (2017). Improving hydrological prediction with global datasets: experiences with brahmaputra, upper awash and kaap catchments. *37th IAHR World Congress.*

Chowdhury, M. R., & Ward, N. (2004). Hydro-meteorological variability in the greater Ganges–Brahmaputra–Meghna basins. *J International Journal of Climatology, 24*(12), 1495-1508.

DHI, D. W. E. (2017). *MIKE BASIN: Rainfall-runoff modeling reference manual*: DHI, Denmark.

Gain, A. K., Immerzeel, W., Sperna Weiland, F., & Bierkens, M. (2011). Impact of climate change on the stream flow of the lower Brahmaputra: trends in high and low flows based on discharge-weighted ensemble modelling. *J of Hydrology Earth System Sciences, 15*(5), 1537-1545.

Ghosh, S., & Dutta, S. J. J. o. e. s. s. (2012). Impact of climate change on flood characteristics in Brahmaputra basin using a macro-scale distributed hydrological model. *121*(3), 637-657.

Haddeland, I., Clark, D. B., Franssen, W., Ludwig, F., VOß, F., Arnell, N. W., . . . Gerten, D. (2011). Multimodel estimate of the global terrestrial water balance: Setup and first results. *Journal of Hydrometeorology, 12*(5), 869-884.

Haddeland, I., Heinke, J., Voß, F., Eisner, S., Chen, C., Hagemann, S., & Ludwig, F. (2012). Effects of climate model radiation, humidity and wind estimates on hydrological simulations. *J Hydrology Earth System Sciences, 16*(2), 305-318.

Immerzeel, W. (2008). Historical trends and future predictions of climate variability in the Brahmaputra basin. *International Journal of Climatology, 28*(2), 243-254. doi:10.1002/joc.1528

Immerzeel, W. W., van Beek, L. P., & Bierkens, M. F. (2010). Climate change will affect the Asian water towers. *Science, 328*(5984), 1382-1385. doi:10.1126/science.1183188

IPCC, I. P. o. C. C. (2015). *Climate change 2014: Mitigation of climate change* (Vol. 3): Cambridge University Press.

Islam, A. S., Haque, A., & Bala, S. K. (2010). Hydrologic characteristics of floods in Ganges–Brahmaputra–Meghna (GBM) delta. *J Natural hazards, 54*(3), 797-811.

IWM. (2013). Water availability, demand and adaptation option assessment of the Brahmaputra river basin under climate change. *Institute of Water Modelling*.

Jarvis, A., Reuter, H., Nelson, A., & Guevara, E. (2008). Hole-filled SRTM for the globe Version 4, available from the CGIAR-CSI SRTM 90 m Database, available at: ht tp. *J srtm. csi. cgiar. org, 25*.

Kamal-Heikman, S., Derry, L. A., Stedinger, J. R., & Duncan, C. C. (2007). A simple predictive tool for lower Brahmaputra River basin monsoon flooding. *J Earth Interactions, 11*(21), 1-11.

Kamal, R., Matin, M., Nasreen, S. J. J. o. W. R., & Science, O. (2013). Response of river flow regime to various climate change scenarios in Ganges-Brahmaputra-Meghna Basin. *J Journal of Water Resources. Ocean Science, 2*(2), 15-24.

Lutz, A. F., Immerzeel, W. W., Kraaijenbrink, P. D., Shrestha, A. B., & Bierkens, M. F. (2016). Climate Change Impacts on the Upper Indus Hydrology: Sources, Shifts and Extremes. *PLoS One, 11*(11), e0165630. doi:10.1371/journal.pone.0165630

Masood, M., Yeh, P.-F., Hanasaki, N., & Takeuchi, K. (2015). Model study of the impacts of future climate change on the hydrology of Ganges–Brahmaputra–Meghna basin. *J of Hydrology and Earth System Sciences, 19*(2), 747-770.

Milly, P. C. D., Betancourt, J., Falkenmark, M., Hirsch, R. M., Kundzewicz, Z. W., Lettenmaier, D. P., & Stouffer, R. J. J. S. (2008). Stationarity is dead: Whither water management? *, 319*(5863), 573-574.

Mirza, M., Warrick, R., Ericksen, N., & Kenny, G. (1998). Trends and persistence in precipitation in the Ganges, Brahmaputra and Meghna river basins. *J Hydrological Sciences Journal, 43*(6), 845-858.

Mirza, M. M. Q. (2002). Global warming and changes in the probability of occurrence of floods in Bangladesh and implications. *Global Environmental Change, 12*(2), 127-138. doi:https://doi.org/10.1016/S0959-3780(02)00002-X

Mirza, M. M. Q., Warrick, R., & Ericksen, N. J. (2003). The implications of climate change on floods of the Ganges, Brahmaputra and Meghna rivers in Bangladesh. *Journal of Climatic Change, 57*(3), 287-318.

Mirza, M. Q., & Dixit, A. (1997). Climate change and water management in the GBM Basins. *Journal of Water Resources, 5*(1), 71-100.

Moriasi, D. N., Arnold, J. G., Van Liew, M. W., Bingner, R. L., Harmel, R. D., & Veith, T. L. (2007). Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. *Transactions of the ASABE, 50*(3), 885-900.

Nishat, A., & Faisal, I. (2000). An assessment of the institutional mechanisms for water negotiations in the Ganges-Brahmaputra-Meghna system. *J International Negotiation, 5*(2), 289-310.

Oki, T., & Kanae, S. (2006). Global hydrological cycles and world water resources. *J Science, 313*(5790), 1068-1072.

Pokhrel, Y., Hanasaki, N., Koirala, S., Cho, J., Yeh, P. J.-F., Kim, H., . . . Oki, T. (2012). Incorporating anthropogenic water regulation modules into a land surface model. *Journal of Hydrometeorology, 13*(1), 255-269.

Postel, S. L., Daily, G. C., & Ehrlich, P. R. (1996). Human appropriation of renewable fresh water. *J Science, 271*(5250), 785-788.

Rahaman, M. M. (2012). Hydropower ambitions of South Asian nations and China: Ganges and Brahmaputra rivers basins. *J International Journal of Sustainable Society, 4*(1-2), 131-157.

Ray, P. A., Yang, Y.-C. E., Wi, S., Khalil, A., Chatikavanij, V., & Brown, C. (2015). Room for improvement: Hydroclimatic challenges to poverty-reducing development of the Brahmaputra River basin. *Environmental Science & Policy, 54*, 64-80. doi:10.1016/j.envsci.2015.06.015

Rossi, C., Dybala, T., Moriasi, D., Arnold, J., Amonett, C., & Marek, T. (2008). Hydrologic calibration and validation of the Soil and Water Assessment Tool for the Leon River watershed. *Journal of soil water conservation, 63*(6), 533-541.

Seidel, K., Martinec, J., & Baumgartner, M. F. (2000). *Modelling runoff and impact of climate change in large Himalayan basins.* Paper presented at the International conference on integrated water resources management (ICIWRM), Rorkee, India.

Stopa, J. E., & Cheung, K. F. (2014). Intercomparison of wind and wave data from the ECMWF Reanalysis Interim and the NCEP Climate Forecast System Reanalysis. *Ocean Modelling, 75*, 65-83. doi:https://doi.org/10.1016/j.ocemod.2013.12.006

Thomson, A. M., Calvin, K. V., Smith, S. J., Kyle, G. P., Volke, A., Patel, P., . . . Clarke, L. E. J. C. c. (2011). RCP4. 5: a pathway for stabilization of radiative forcing by 2100. *109*(1-2), 77.

Yang, Y. C. E., Wi, S., Ray, P. A., Brown, C. M., & Khalil, A. F. (2016). The future nexus of the Brahmaputra River Basin: Climate, water, energy and food trajectories. *Global Environmental Change, 37*, 16-30. doi:https://doi.org/10.1016/j.gloenvcha.2016.01.002

STUDY ON CLIMATE VARIABILITY, CLIMATE EXTREMES OVER DHAKA CITY AND PEOPLE'S PERCEPTION ABOUT ITS IMPACT

Farzana Mahbub[1], Md. Marufur Rahman[1], Md. Abdul Mannan[2] and Fatima Akter[3]

ABSTRACT

Under the present global warming scenario, area specific analysis of climate variability and extremes are in high demand especially for an ever-growing urban place like Dhaka city, having huge exposure of people and property. A successful urban planning of the city prerequisites a profound study about its vulnerabilities where climatic extremes play a significant role. Trend and anomaly analysis of climate variability and extremes of Dhaka city during 1981-2017 disclosed that the annual rainfall is decreasing at a rate of -9.87mm (-11.71 Sen's slope) per year while both maximum and minimum annual temperature are increasing about 0.017ºC and 0.028ºC per year respectively, which will be 30.6°C and 25.9°C by 2075 according to projection. Recent decades showed higher standard deviations, shifting of distribution (rainfall) and mean (temperature) and also sudden increases of both parameters. Thus the city climate is becoming extreme and threatened by more frequent heat waves while rainfall is becoming extreme in July and August making the southern part of Dhaka city vulnerable to flooding situations. Due to the negative correlation between parameters, rainfall extremes are less likely to take places in the years of temperature extremes. In spite of some contradictory findings with scientific analysis; survey result of perception study reveals that the climate variability and extremes are well perceived by the city people who also wisely depicted the factors of changes, affected sectors, and requirements for better preparedness as well as disaster management.

Introduction

Climate variability means the annual or seasonal deviation or fluctuations of climatic parameters (rainfall, temperature etc.) from the mean. The range of the variability reveals characteristics of extremes in terms of intensity and shape of frequency distribution (Solomon and Qin, 2013; Loo, Billa, & Singh, 2015; Rahman & Lateh, 2017). Such changes may often be statistically significant that persist for a long period of time or over a specific area, which can be defined as temporal or spatial variability of climate respectively; both are analyzed to characterize a climate and to deduce evidence of climatic change at local to global scale (Priyan, 2015). The IPCC (2013) (intergovernmental panel on climate change) in their AR5 report predicted that- "extreme precipitation events over wet tropical regions will very likely (90-100% probability) become more intense and more frequent as global mean surface temperature increases. Changes in local extremes on daily and sub-daily timescales are expected to increase by roughly 5 to 10% per 1°C of warming (medium confidence)." Islam (2009) has predicted on his study that at least 5.3% annual rainfall in Bangladesh will be increased by 2018. While most of the climate change studies conducted over Bangladesh agree on increasing trend of annual rainfall, the central seem to show opposite changes but with more extreme climatic behavior. Study regarding Dhaka city shows increasing trend (2.7 mm/year for 1979-2009, mostly influenced by last 10 years) of annual maximum daily rainfall and extremes(more events in last 5 years) from both observed data analysis and projection (used Regional climate modelling- PRECIS) (Murshed, Islam and Khan, 2011). The city has a humid sub-tropical monsoon climate and receives approximately 2000mm of rainfall annually (lower than country average of 2456.38 mm), more than 80% of which falls during the monsoon season from June to September (Pramanik and Stathakis, 2016). Again, almost 60% of the greater Dhaka city lies below the mean annual maximum water level from the surrounding rivers and as the ever growing urbanization is taking place towards north and eastern flood prone area of the city, there is a strong possibility that in near future Dhaka might strike by continual water logging events if extreme/erratic rainfall events tend to accelerate and are accompanied by mismanagement of storm water drainage. For instance, 40% of the Dhaka west region was inundated by the highest ever recorded daily rainfall (about 341mm/day) on September 2004; the study further claims that extreme rainfall event will increase with time and >10mm/day amount of rainfall can cause water logging by obstructing surface runoff (Murshed, Islam and Khan, 2011). Majority of the rainfall studies used station based data that are sparsely distributed all over the country and only one station in Dhaka; therefore, to get better spatial variation at macro level, gridded data can be utilized.

[1] *Dept. of Disaster Science and Management, University of Dhaka, Dhaka, Bangladesh.*
[2] *Bangladesh Meteorological Department, Agargaon, Dhaka, Bangladesh.*
[3] *Dept. of Geography and Environment, University of Dhaka, Dhaka, Bangladesh*
E-mail of corresponding authors: fmhridita@gmail.com, mamannanbmd2015@gmail.com

As rainfall depends on factors like- relief of landmass, direction of humid/moisture wind and temperature; abrupt change of any factor could alter rainfall pattern positively or negatively. The impact of climate change again depends on physiographic settings of a particular area and its interaction with the change(Kabir and Golder, 2017). The combined effect of urbanization and climate change could raise urban temperatures to levels that the city area may have 2-3ºC higher temperature in hot summer than surrounding countryside as a consequence of urban heat island (UHI) (Alam and Rabbani, 2007). Projection exhibits rise of average temperature about 1.3ºC for Bangladesh where more warming of temperature would take place in winter (1.1 ºC) than in summer (0.8 ºC) (Shourav et al., 2016). The vulnerable group (urban poor, children, elderly etc.) would be the worst sufferer towards climate extreme impacts such as frequent heat waves, alteration to infectious disease vectors distributions, scarcity of safe water and productivity. Therefore, this study aims at comprehensive investigation of climate variability to understand the escalating vulnerability implied by extremes in Dhaka city and how people perceive the risk. In order to assist in policy making, Dhaka city and its surrounding (area under DAP) have been taken under consideration.

Materials and Methods

Point observation data of rainfall and temperature for past 37 years (1981-2017) have been collected from Bangladesh Meteorological Department (BMD) and with the help of satellite data (CHIRPS) gridded rainfall data (0.25°x0.25°resolution) has been generated for better spatial analysis. Spatial variability of rainfall is obtained by Kriging interpolation which performs better for monthly data and final output is the weighted average of the nearby stations derived through CHRIPS. Comparison between two datasets is done by percent bias calculation which is explained by following formula:

$$PB = 100\frac{\sum(C-G)}{\sum G} \qquad (1)$$

Where, *PB*= Percent bias; *G*= rain gauge rainfall estimation; *C*= CHIRPS-based rainfall estimate. For climate projection, ACCESS 1.0 version of coupled model was incorporated to get Coupled Model Intercomparison Project Phase 5 (CMIP5) data (for RCP 4.5 scenario) from Climate Explorer managed by the Royal Netherlands Meteorological Institute (KNMI). Microsoft Excel 2013, MAKESENS (1.0) and RClimDex (1.0) has been utilized to analyze temporal variability through linear regression (best-fit line considering all variables) which determines existence and degree of monotonic changes (consistently increasing or decreasing trends). The Mann-Kendall test done in MAKESENS (1.0), is a simple non-parametric trend test (applicable for all distributions/assumptions) which follows pair-wise comparison method (each data is compared to all subsequent data) of observed values yi, yj of the random variable. Each pair is then inspected to find out whether yi>yj or yi<yj (if former pair=P & later pair=M); then S statistics is calculated by: S = P−M. The Z statistic is calculated from S statistic and variance, positive or negative value of Z indicates an upward or downward trend. The Sen's estimator of slope shows the magnitude of changes in data where slope of all data value pair is calculated by following formula:

$$Q_i = \frac{x_j - x_k}{j-k} \text{ ; (Where, j>k)} \quad (2)$$

If there are *n* values *xj* in the time series we get as many as *N = n(n-1)/2* slope estimates *Qi*. The Sen's estimator of slope is the median of these N values of *Qi* (Salmi *et al.*, 2002). The RClimDex (1.0) software is designed to calculate indices of climate extremes according to user delivered threshold values that requires daily time scale data as input and delivers best fit trend lines with magnitude/slope value, slope error and significance (P value). For more comprehensive analysis, Precipitation anomaly percent has been computed through following equation:

$$P_a = \left(\frac{P-\bar{P}}{\bar{P}} \times 100\right)\% \qquad (3)$$

Where, *P*= average rainfall of certain period/year and $\bar{P}$= long-term average rainfall. Moreover, standard deviation and Pearson correlation have also been calculated in Microsoft Excel 2013 for this study. The Easy fit 5.6 professional software is used to compute fitted probabilistic distributions by Kolmogorov–Smirnov test (goodness-of-fit test) to analyse rainfall distribution pattern and its changes through decadal periods form 1981-2017 (Mehrannia and Pakgohar, 2014). The test provided fitted distributions for probability density functions and cumulative distribution functions along with mean and standard deviations to investigate level of risk and extremity. Furthermore, a structured questionnaire survey has been materialized to determine the gap between actual information and knowledge, and preferred action to minimize so. Hence, perception study is necessary for understanding practical manifestation of scientific information.

Results and Discussions

The observed rainfall data is taken from Agargaon station while other five distinctive stations were selected for their unique values and relatively even distributions based on the data from CHRIPS. The stations are located in Gazipur, Gulshan, Motijheel, Narayanganj, and Rupganj; in some cases, they show variant results compared to observed data (Agargaon) which may be due to the distance and methodological differences of data acquisition. in comparison with observational data, CHRIPS data has overestimated in pre-monsoon season and underestimated the rainfall of winter as depicted in Figure 1. CHRIPS performs better in cases of annual, monsoon and post-monsoon rainfall estimation and shows least difference (less than 5%) in monsoon season.

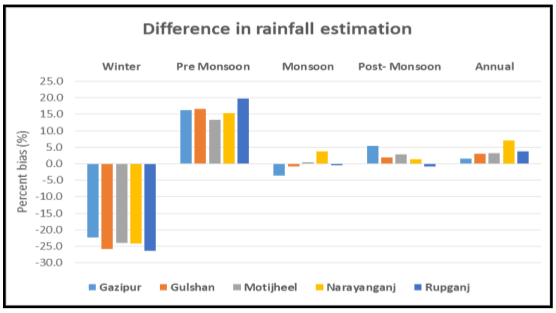


Figure 1. Annual and seasonal difference in rainfall estimation compared with observed rainfall in Dhaka during 1981-2017

Although the region experiences a good amount of rainfall annually (observed annual average rainfall 2059.9 mm with standard deviation of 489.08), but trend shows degradation in total amount of annual rainfall at a high rate of -9.86 mm per year (Sen's Slope value -11.731mm per year) which is delineated in Table 1 along with seasonal trend values. Unlike other seasons, monsoon has the highest amount of rainfall (increasing) and HR events of which July and August showed positive rainfall trend and highest number of heavy rainfall (HR≥44mm/day) events. The number of non-rainy days (<1mm/day) showed decreasing to no change for July and increasing to no change for August; hence total rainfall and HR events will spread through July causing prolonged/erratic rainfall and for August, it would be extreme due to increasing intensity of one-day precipitation. Other rainy months (March-October) are heading towards drier weather due to the increasing number of non-rainy days and decreasing trend of annual rainfall and number of HR events. These may affect urban poor by creating water logging in wet season and safe water scarcity in dry season. Also, sudden increase in prolonged heavy amount of rainfall and daily maximum rainfall is depicted in particular years after 2000. The last half of study period (2000-2017) shows consecutive pattern of less and heavy rainfall including sudden extensive high values; for instance, prolonged rainfall (2007 and 2017) and one day maximum rainfall (2004 and 2009) after the year 2000 indicating to an unusual and extreme climatic pattern. In addition, Monthly maximum consecutive 5-day precipitation amount showed an upward trend about 0.507 mm increase of rainfall per year. Even consecutive dry days (relative rainfall<1mm) is increasing significantly at 1.027 rates showing extensive high values found after 2000 and consecutive wet days (relative rainfall≥1mm) decreasing at a rate of -0.083 days per year. Therefore, rainfall will be high in remaining less number of wet days i.e. extensive high values in one-day precipitation will occur. According to Table 2, rainfall pattern is changing with time and shows high variability with occasional extremes which are verified by changes in distribution pattern and also by decreasing mean (μ) with increasing standard deviation (SD,σ) (except for 2011-2017, due to short period data). As in 2001-2010 period, shift from normal to logistic distribution reveals that rainfall pattern was extreme for that period; as long positive tail (positively skewed) denotes larger range (difference between maximum and minimum rainfall) and higher kurtosis (peakedness) results from rare extreme deviations, hence higher SD with lower mean resulted in sudden extreme rainfall as seen in Table 2 for maximum rainfall.

Table 1*. Seasonal & annual distribution and trend of rainfall in Dhaka city during 1981-*

Time/seasons	Average rainfall	MK Test (Sen's Slope)
Winter	35.3	-0.580
Pre Monsoon	472.1	-7.884 **
Monsoon	1353.6	0.563
Post- Monsoon	196.7	-1.453
Annual	2059.9	-11.713

** if $\alpha = 0.01$ level of significance

Table 2. Decadal variation of distribution of rainfall

Period	Mean □□□	Normal (σ)	Logistic (σ)	Max. rain(mm)
1981-1990	6.04	15.99	8.82	176.0
1991-2000	5.71	15.46	8.52	158.0
2001-2010	5.69	17.08	9.42	341.0
2011-2017	4.90	13.37	7.37	149.0

(shaded block represents best-fitted distribution)

Spatial distribution of rainfall in Figure 2 revealed that south and south eastern regions are exposed to heavy rainfall (≥50 mm per day) and high amount of annual rainfall as well; which resembles with the monsoon rainfall pattern of whole Bangladesh (i.e. south and south eastern part gets the most rainfall than north and north western part).

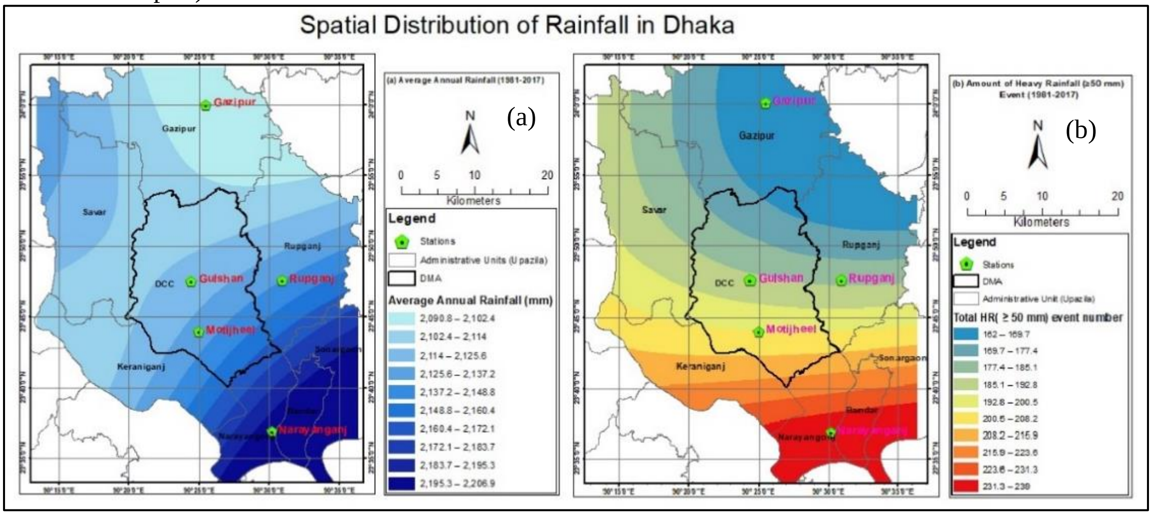


Figure 2. Spatial distribution of (a) average annual rainfall; (b) amount of HR (≥50 mm per day) event in Dhaka during 1981-2017

The average maximum and minimum annual temperatures are 30.83°C and 21.92°C with SD about 0.52°C and 0.47°C respectively. Both day and night time temperatures are increasing significantly at a rate of 0.017°C and 0.028°C; where, monsoon day time (especially May) and winter night time (especially December) showed rapid increase. The change of maximum temperature from the average resembles a consecutive pattern (fluctuates around average in a decadal manner) but change of minimum temperature shows quite obvious shift from below average line to above it. The diurnal temperature variation is decreasing as 99th and 1st percentile value of maximum temperature decreases with increasing percentile values of minimum temperature. It's found that the nights are warming up at a higher rate where day time temperature will show high variation with more possibility of heat wave rather than cold wave. Additionally, warm spell duration indicator shows increasing trend at a rate of 0.17days per year. Although, number of days having high daytime temperature decreases, extensive values in one day maximum temperature would be seen due to the higher standard deviation (see Table 3). Furthermore, due to decreasing SD, minimum temperature would not fluctuate rapidly; however, warm nights would be observed very frequently. Shifting of the average temperature will result in frequent extreme climatic events. For instance, 2011 has lowest daytime temperature about 17.9°C (1st percentile) while its immediate previous year (2010) has 63 days of high daytime temperature (≥35°C) and 42 days of high night time temperature (≥28°C).

***Table 3**. Decadal variability of maximum and minimum temperature in Dhaka during 1981-2017*

Maximum	1981-1990	1991-2000	2001-2010	2011-2017
99th percentile	37.50	37.35	36.80	37.04
1st percentile	22.20	21.60	20.65	19.91
Average	30.77	30.83	30.79	31.02
SD	3.31	3.50	3.60	3.77
Minimum	**1981-1990**	**1991-2000**	**2001-2010**	**2011-2017**
99th percentile	28.40	28.50	28.70	28.90
1st percentile	10.34	9.60	11.00	10.91
Average	21.74	21.67	22.10	22.39
SD	5.13	5.32	4.83	4.96

There is a negative correlation between temperature and rainfall for all seasons except in post-monsoon season when minimum temperature seems to avail rainfall occurrence (Pearson's r =0.074). Since the annual rainfall is decreasing with increasing temperature (inverse relationship), it can be stated that the wet years / extreme rainfall years may not experience temperature extremes and it is likely to be reversed for dry years. Rainfall seems to act more contrariwise with response to the changes of maximum temperature than with minimum as depicted in Figure 3.

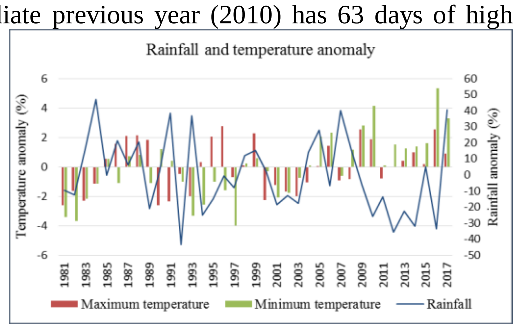


Figure 3. Rainfall and temperature anomaly during 1981-2017 in Dhaka city

Since there is consistency between hindcasts and observed temperature data, projection has been made where maximum and minimum temperature show about 0.04°C and 0.02°C increase of temperature per year respectively as shown in Figure 6. The day and night temperature which are 27.9°C and 24.0°C now (2017), will be 30.6°C and 25.9°C by 2075. Due to the inconsistency of model derived data with observed rainfall (showed opposite trend), the future climate may not uphold the foreseen rainfall condition precisely for future.

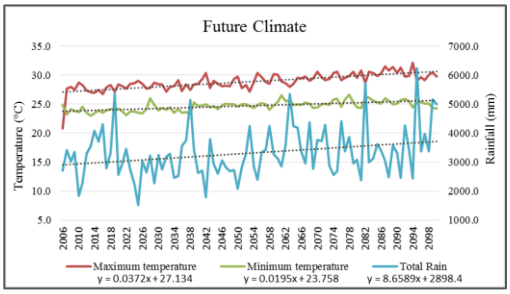


Figure 6. Future climate scenario in

Although most of the people (70%) agreed with the scientific findings (increasing temperature but decreasing rainfall) still they believe that both temperature and rainfall are increasing (76%) and they suspect that it will be extreme (81%) in future. It is perceived by 80% people that anthropogenic factor is playing a vital role in exaggerating the climate change impact in the study area and they pointed out major factors of causation as seen in Figure 4. A significant number of people seem to be unaware about urban heat island (UHI) and among the people who know, 73.3% agreed that UHI exists in Dhaka city and it intensifies the negative impact posed by increasing temperature (63.3%). A large number of people think they are moderately vulnerable to climate extremes and its associated hazards which mostly affects them in following terms as represented in Figure 5.

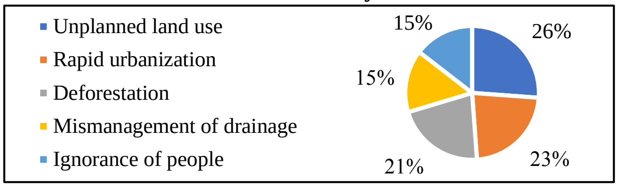


Figure 4. Major anthropogenic factors responsible for enhancing climate impact

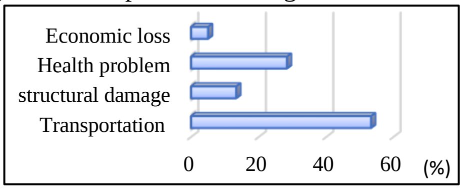


Figure 5. Most affected sectors for climate extremes in Dhaka city

People think that disaster and crisis management, energy and water resource management and urban planning will be the most challenging sectors which can be met by strengthening existing management system in and within those sectors. About 45% responders preferred awareness raising programs for better preparedness while 38% people preferred sharing of latest scientific information/ knowledge on climate extremes. Some major associated hazards have been depicted by the people such as- water logging(24%),health hazards (23%), heat waves (22%), heavy rainfall (15%) etc. Figure 6 gives better picture of such hazards and their sources of information. In most of the cases news broadcasting on television or newspaper are seen to be effective and reliable source of information to people. They also preferred phone or internet as an emerging most effective source.

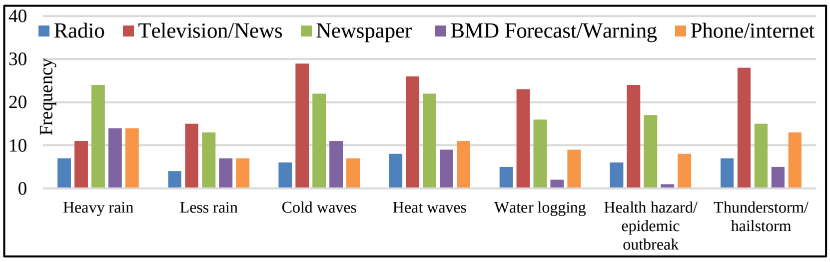


Figure 6. Hazard specific sources of information and warning

Conclusions

Rainfall behavior shows changing tendency with significant indication that the rainfall is becoming extreme in terms of maximum one day precipitation. A comprehensive analysis of rainfall has been conducted for a detail spatial distribution in city domain. A better result can be computed if longer period microclimatic data are available and incorporated in the study. As southern part of the city appears more vulnerable to heavy rain and monsoon shows positive trend with erratic and sudden extreme behavior in July and August, better preparedness measures should be taken especially for that place and time. Again, both day time and night time temperature were seen to be increasing which refers to the shift of average and increases the probability of heat waves; nights are warming at a higher rate as well as the winter season. Recent period shows more extreme behavior (sudden extensive values and consecutive pattern) than previous time for both parameters. As they are inversely related, a sudden increase in temperature may cause a sudden fall in rainfall and vice-versa. The concept of climate variability, correlation as well as extremes are well perceived by the people. Unplanned land use is thought to be the major anthropogenic reason that influencing the change while they suggested to enhance capacity of the related fields which are at risk due to the changing climate. The people living in the study area also recommended that taking preparedness will be easier to them if the information is transmitted through quicker and reliable sources such as news broadcast, phone message or internet.

References

Alam, M. and Rabbani, G. M. D. (2007) 'Vulnerabilities and responses to climate change for Dhaka', *Environment and Urbanization*, 19(1), pp. 81–97. doi: 10.1177/0956247807076911.

Islam, M. N. (2009) 'Rainfall and Temperature Scenario for Bangladesh', *The Open Atmospheric Science Journal*, 3(1), pp. 93–103. doi: 10.2174/1874282300903010093.

Kabir, H. and Golder, J. (2017) 'Rainfall Variability and Its Impact on Crop Agriculture in Southwest Region of Bangladesh', *Journal of Climatology & Weather Forecasting*, 05(01), pp. 1–20. doi: 10.4172/2332-2594.1000196.

Loo, Y. Y., Billa, L. and Singh, A. (2015) 'Effect of climate change on seasonal monsoon in Asia and its impact on the variability of monsoon rainfall in Southeast Asia', *Geoscience Frontiers*. Elsevier Ltd, 6(6), pp. 817–823. doi: 10.1016/j.gsf.2014.02.009.

Mehrannia, H. and Pakgohar, A. (2014) 'Using EASY FIT Software for Goodness-Of-Fit Test and Data Generation', *International Journal of Mathematical Archive*, 5(1), pp. 118–124.

Murshed, S. B., Islam, A. S. and Khan, M. S. A. (2011) 'Impact of Climate Change on Rainfall Intensity in', *3rd International Conference on Water & Flood Management (ICWFM?2011)*, pp. 1–8.

Pramanik, M. M. A. and Stathakis, D. (2016) 'Forecasting urban sprawl in Dhaka city of Bangladesh', *Environment and Planning B: Planning and Design*, 43(4), pp. 756–771. doi: 10.1177/0265813515595406.

Priyan, K. (2015) 'Spatial and Temporal Variability of Rainfall in Anand District of Gujarat State', *Aquatic Procedia*. Elsevier B.V., 4(Icwrcoe), pp. 713–720. doi: 10.1016/j.aqpro.2015.02.092.

Rahman, M. R. and Lateh, H. (2017) 'Climate change in Bangladesh: a spatio-temporal analysis and simulation of recent temperature and rainfall data using GIS and time series analysis model', *Theoretical and Applied Climatology*. Theoretical and Applied Climatology, 128(1–2), pp. 27–41. doi: 10.1007/s00704-015-1688-3.

Salmi, T. et al. (2002) Detecting Trends of Annual Values of Atmospheric Pollutants by the Mann-Kendall Test and Sen's Solpe Estimates the Excel Template Application MAKESENS, Finnish Meteorological Institute, Air Quality Research. doi: 456-789X.

Shourav, S. A. *et al.* (2016) 'Historical trends and future projection of climate at Dhaka city of Bangladesh', *Jurnal Teknologi (Sciences & Engineering)*, 78(2), pp. 69–75. doi: 10.13140/RG.2.1.2236.8880.

Solomon, S. and Qin, D. (2013) Climate Change 2007 The Physical Science Basis The, Journal of Chemical Information and Modeling. doi: 10.1017/CBO9781107415324.004.

CLIMATE CHANGE EFFECT ON POTENTIAL EVAPOTRANSPIRATION IN BANGLADESH

Jannatun Nahar Jerin[1]and A.R.M. Towfiqul Islam[1]

ABSTRACT

Potential evapotranspiration (ET_o) is considered one of the key factors under changing climate which plays a pivotal role in irrigation schedule and water resource management. However, how much ET_o affected by climate change has been less understood in Bangladesh. This study aimed to estimate monthly, annual and decadal ET_o using the FAO-56 Penman-Monteith (FAO-56 PM) model based on daily data of 25 meteorological stations across Bangladesh from 1975-2017. To detect ET_o trends, the Mann-Kendall (MK) technique was employed to compare trends with standard. The Sen's slope estimator was adopted to calculate the magnitude of trend lines. The results show that approximately 82.67% of the monthly ET_o time series had declined trends, out of which 39.67%, 16.33% and 31% of monthly ET_o time series were shown statistically significant at 0.10, 0.01 and 0.05 levels, respectively. Only 17.33% of the monthly ET_o time series had demonstrated a significant increasing trend. The dominant significant increased trend ($p<0.01$ level) was found in February at the Chittagong station, while the dominant significant decreased trend ($p<0.01$) was noticed at Mymensing station. Based on an annual and decadal timescale, over 92% and 73% of the stations had the decreased trend lines; but the ascending trends were observed at Rangamati, Barisal and Bhola stations, respectively. As a whole, ET_o are moving on a decline tendency pattern for almost every station over Bangladesh; suggesting a paradoxical shifting under background of the global warming.

Keywords: ET_o trend, Water use, Bangladesh, Global warming, Penman-Monteith model

Introduction

Potential evapotranspiration study is crucial for irrigation and water resources development and management in Bangladesh. A better assessment of potential evapotranspiration is important for efficient irrigation management, crop production, environmental assessment, ecosystem modelers and solar energy system. According to the fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC), the global warming trend, which is mainly caused by the increasing amount of greenhouse gas emissions, will increase continue in future 2100 (IPCC 2014). Bangladesh is already experiencing the effects of climate variability and climate change (Ali 1996; Mirza 2002; Karim and Mimura 2008; Climate Change Cell 2008,). Different sectors of natural system such as agriculture, hydrology, and ecosystem have been affected by climate change. Potential evapotranspiration is expected to increase due to temperature increases. However, the decrease of observed ETo has been widely detected over recent decades in many areas (Yin et al. 2010;Limjirakan and Limsakul2012; Darshana et al. 2013). This phenomenon of a discrepancy between expected and observed trends in evaporation is known as the ''evaporation paradox' 'Evapotranspiration (ET), one of the primary elements of the hydrologic cycle that is influenced by climate change. There are a number of climatic parameters that have been identified to change in ET_o. The variation of ET_o not only influence by the increased air temperature, but also other primary climatic factors such as relative humidity, vapor pressure, wind speed and solar radiation. The changing of ET_o at particular station may be influenced by these meteorological parameters. Although different aspects of ETo in different parts of Bangladesh have been investigated to some extent; however, no detailed study has yet been conducted on impact of ET_o trend in Bangladesh. This region is known as an agricultural region. Rain-fed cereal production is done most part of the Bangladesh. Unfortunately, some area has suffered from prolonged droughts during summer season in recent years. Moreover, over exploitation of groundwater has depleted underground water reservoirs. Drastic shrinkage of major rivers has created serious problems in its ecosystem and hydrologic balance. In order to meet these challenges, it seems that a study to detect trends in ET_o in Bangladesh is needed.

The objective of this study was to detect monthly, annual and decadal trends of ET_o using the FAO-56 Penman-Monteith (FAO-56 PM) model based on daily 25 meteorological stations data in Bangladesh in the past 4 decades and estimate their magnitudes from 1975-2017 using non-parametric methods, such as MK and Sen's estimator.

[1] *Department of Disaster Management, Begum Rokeya University, Rangpur 5400, Bangladesh*
*Author:khan.jerin2018@gmail.com, *Corresponding author: towfiq_dm@brur.ac.bd*

Methodology

Study area

Bangladesh Meteorological Department (BMD) has 34 weather stations. In this study, 25 stations were selected (Fig.1) to calculate ETo.Data were checked for quality. These data were used to estimate daily ETo using the FAO-56 PM method.

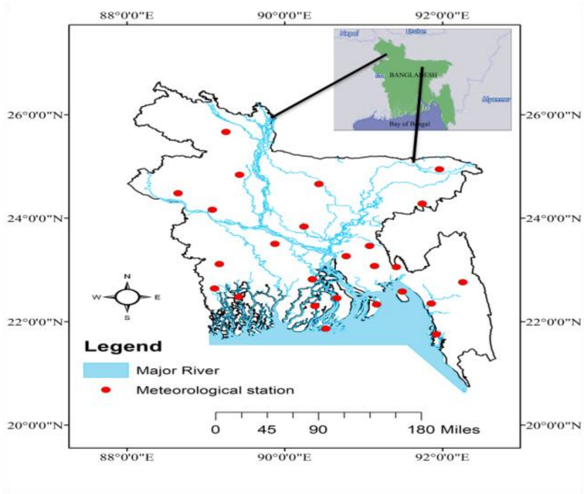


Figure. 1: Location of the study area and the meteorological stations.The dataset was provided by BMD.

Methods

FAO-56 Penman-Monteith (PM) method is considered as a standard approach to calculate ET0, which reads:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{(T+273)} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where ET0: potential evapotranspiration [mm day−1]; Rn: net radiation at the crop surface[MJm−2 day−1];G:soil heat flux [MJ m−2 day−1]; T: daily mean air temperature at 2 m height [°C]; u2: wind speed at 2 m height [m s−1]; es: saturation vapor pressure[kPa];ea: actual vapor pressure [kPa]; es −ea: saturation vapor pressure deficit [kPa]; Δ: slope of the vapor pressure curve [kPa °C−1]; and γ: psychrometric constant [kPa °C−1].

The detailed method of MK and Sen's estimator can be found in the literature (Rahman et al. 2016). In order to investigate the spatial variability of ET0, the inverse distance method (IDW) was used. This method directly implements the assumption that a value of an attribute at a non-sampled location is a weighted average of known data points occurring within a local neighborhood surrounding the non-sampled location. That is, things close to one another are more alike than those that are far away. It is known as an exact interpolator scheme (Burrough and McDonnell 1998).

Results

Preliminary observations and analysis

Table 1 represents descriptive statistics summary of monthly ET0 data obtained from historical climate of all the stations along with their locations, data standard errors (SE), Range, standard deviation (SD) and coefficient of variances.

Monthly ET_o trends

The spatial distribution of monthly ETo values in the selected station represented in **Figs.2 and 3**.During the study period from 1975 to 2017, the highest value of monthly ETo was 236 mm/month (in May), while the lowest monthly ETo value was 41.2 mm/month (in December).The lowest value of Z in monthly time series was observed in January at the Mymensing Station (Z=-5.46). On the other hand, some of the monthly ETo times series had upward trends in which, the largest one belonged to the Chittagong station in February which was equal to 3.27 ($p<0.01$) [**Table-2**]. This station is located in the south-eastern region of Bangladesh.

Annually ETo trends

By summing the monthly values of ETo at each of the selected stations, the annual ETo values obtained [Fig 4]. The overall average of annual ETo was found as 1374.1 mm. As can be seen from the last column of Table 2, above 92% of the stations exhibited downward trends (**Table 2**). However, only 8% of the stations showed upward increasing trends. This increased up to 4 % at the 10% level. The largest and smallest values of Z were equal to 3.14 ($p < 0.01$) and – 4.65 ($p < 0.10$), respectively. These two opposite trends belonged to the cox's bazar and Hatia stations, respectively.

Table 1: Detailed the geographic and statistical characteristics of the selected stations across Bangladesh

Station name	Lat. (N)	Long. (E)	Alt., m amsl	Mean (m)	Median (m)	Skew	Range	Standard Deviation	Standard Error	Kurtosis
Barisal	22.43	90.22	2.1	108.96	106.00	0.43	122.50	25.64	1.13	-0.54
Bogra	24.51	89.22	17.9	113.46	113.05	0.18	160.60	28.62	1.26	-0.50
Comilla	23.26	91.11	7.5	112.20	113.65	0.19	132.70	25.09	1.10	-0.30
Chandpur	23.14	90.42	4.88	113.55	113.20	0.18	129.10	26.05	1.15	-0.65
Feni	23.02	91.25	6.4	112.87	113.36	0.17	130.90	25.43	1.12	-0.51
Coxs bazaar	21.27	91.58	2.1	122.44	117.60	0.69	106.50	22.39	0.99	-0.38
Chittagong	22.13	91.48	5.5	125.74	121.60	0.52	117.50	22.91	1.01	-0.28
Swandip	22.29	91.26	2.1	124.09	118.80	0.69	98.55	21.87	0.96	-0.40
M.court	22.52	91.06	4.87	121.87	117.34	0.59	102.25	22.14	0.97	-0.39
Khepupara	23.59	90.41	1.83	117.99	113.31	0.63	108.10	21.87	0.96	-0.42
Faridpur	23.36	89.51	8.1	114.23	112.54	0.21	127.73	26.93	1.19	-0.73
Dhaka	23.46	90.23	8.45	114.90	112.55	0.26	129.40	28.05	1.23	-0.74
Hatia	22.27	91.06	2.44	111.89	108.70	0.53	124.20	22.80	1.00	-0.26
Khulna	22.47	89.34	2.1	120.58	114.36	0.59	155.48	33.31	1.47	-0.42
Jessore	23.12	89.2	6.1	124.45	117.80	0.63	167.90	36.21	1.59	-0.33
Satkhira	22.43	89.05	3.96	116.71	111.10	0.54	143.65	30.55	1.34	-0.49
Mymensing	24.44	90.25	18	106.27	106.95	0.17	150.20	26.05	1.15	-0.31
Patuakhali	22.2	90.2	1.5	109.04	105.30	0.50	113.20	23.69	1.04	-0.52
Bhola	22.41	90.39	4.3	109.00	105.88	0.46	116.40	24.41	1.07	-0.56
Rajshahi	24.22	88.42	19.5	115.76	113.90	0.42	183.00	32.30	1.42	-0.23
Ishurdi	24.09	89.02	12.9	114.61	114.00	0.28	171.80	30.18	1.33	-0.42
Rangamati	22.22	92.09	68.89	111.07	109.60	0.25	109.20	24.70	1.09	-0.65
Rangpur	25.44	89.16	32.61	107.72	110.00	0.00	136.20	27.92	1.23	-0.70
Srimongol	24.18	91.44	21.95	104.69	108.00	-0.12	145.00	29.03	1.28	-0.85
Sylhet	24.54	91.53	33.53	108.63	106.00	0.42	119.60	21.24	0.94	-0.18

Note that the values in the Table are statistical characteristics. Lat. Means Latitude, Long means Longitude, Alt means altitude, mamsl meters above the mean sea level, N means north, E means east.

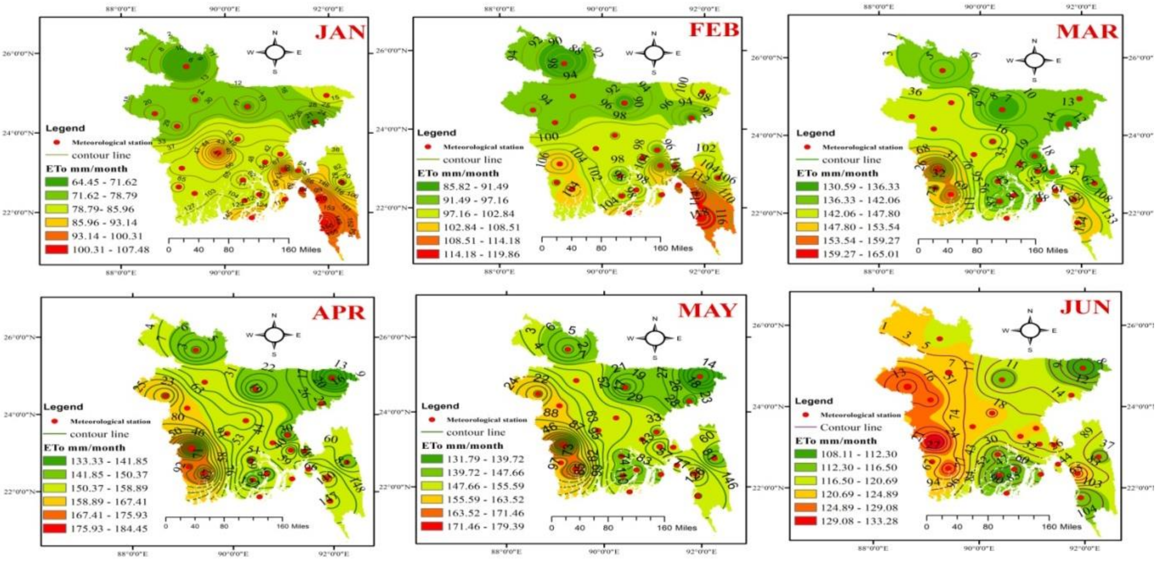


Figure 2. Spatial distribution of monthly ET0 (mm) in the 1st six months

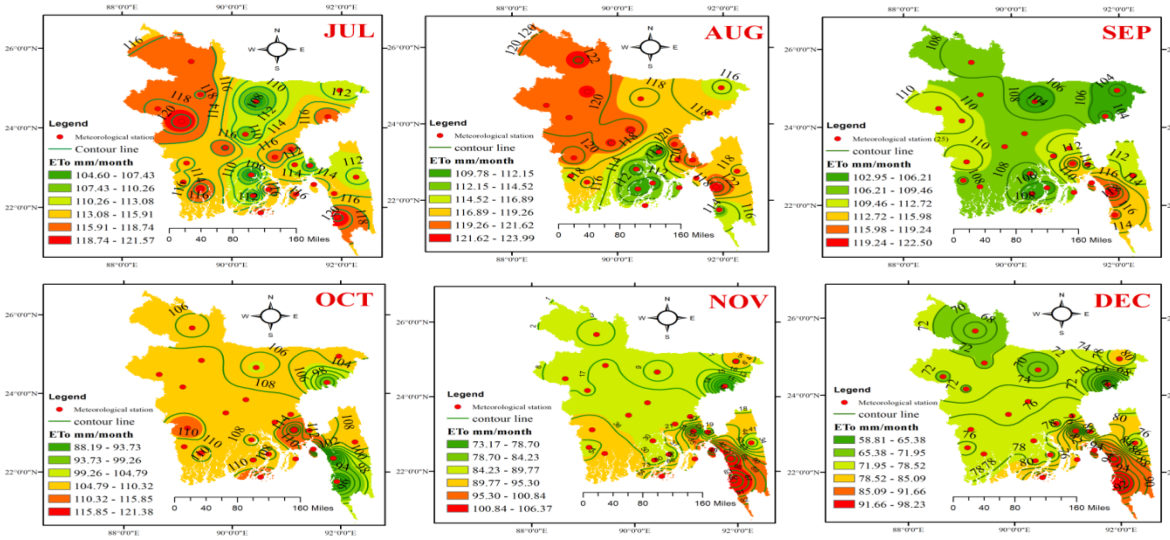


Figure 3. Spatial distribution of monthly ET0 (mm) in the 2nd six months

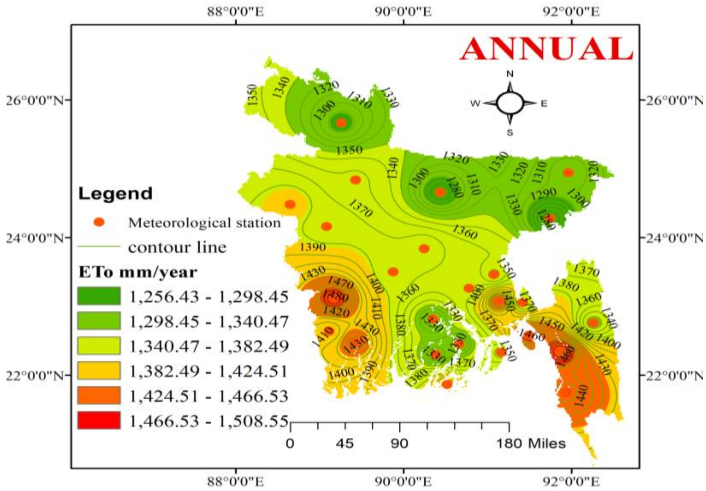


Figure 4. Spatial distribution of Annual ETo (mm) in Bangladesh

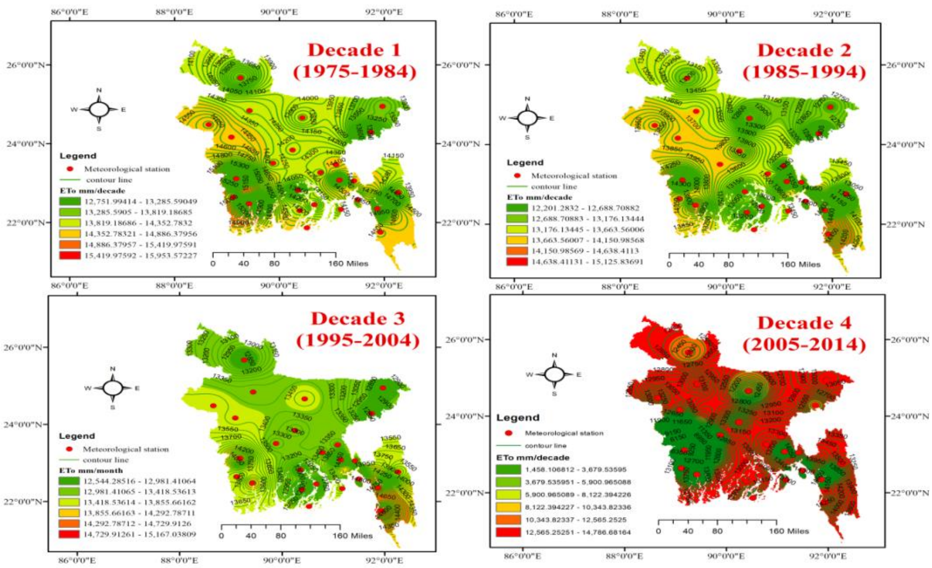


Figure 5. Spatial distribution of decadal ETo in Bangladesh

Decadal ETo trend

The spatial distribution of decadal ETo values in the selected station represented in Fig 5. By summing the 10 years values of ETo at each of the selected stations, the decadal ETo values obtained. The overall average of decadal ETo value was found as 13727.8 mm.The highest value was 15954.1 mm in Jessore station during 1st decade (1975-1984), whereas the lowest was 11936.6 mm located in Mymensing station during 4th decade (2005-2014)..Results indicated that at the decadal timescale, about 73% of the stations exhibited decrease trend. Among them, 14 and 19% showed decreasing ETo trends at 5 and 10% significance level respectively. Meanwhile, only 27% of the decadal ET_o time series had displayed an increasing trend (**Table-2**).

Table 2. The values of MK Z statistics for the ETo in monthly, annual and decadal timescales across Bangladesh

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	D1	D2	*D3*	D4
Barisal	***-3.30****	-0.06	**-1.89**	-0.29	-0.33	0.49	**1.85**	-0.07	-1.10	-0.74	**-1.77**	***-3.77****	***-1.65****	-1.61	-1.43	-0.18	-0.89
Bogra	-5.12	**-2.02***	***-3.06****	**-1.88**	-0.47	-0.47	**1.85**	-1.32	-0.24	-1.59	**-2.37***	***-3.45****	***-4.05****	***-2.15****	-0.18	-1.43	-0.36
Comilla	-4.27	-1.49	**-2.22***	-0.47	**-1.97***	0.49	**1.75**	-0.33	-0.38	**-2.14***	-0.86	***-3.60****	-1.61	***-1.97****	***-2.15****	1.43	-0.72
Chadpur	-4.68	-1.11	-1.51	-1.35	-1.25	-0.32	**1.87**	-1.37	-1.43	***-2.73****	**-1.79**	-3.91	-2.28	***-2.15****	-0.72	1.07	-1.07
Feni	-4.43	-1.38	**-1.81**	-1.00	-1.44	-0.07	**1.64**	-0.67	-1.16	***-2.59****	**-1.77**	***-3.76****	***-1.80****	***-2.15****	-1.43	1.25	-0.72
Coxsbazar	-1.12	0.85	-1.25	1.25	0.06	**1.84**	1.19	1.06	-0.63	-0.95	-1.04	**-1.65**	3.14	-0.54	-0.36	-1.25	***-1.79****
Chittagong	***3.12****	***3.27****	-0.02	**-2.00***	-5.42	-1.13	-0.38	**-2.65***	**-2.41***	-4.94	***-3.39****	-0.97	-2.53	0.36	-1.43	-0.54	-0.72
Swandip	**-1.76**	0.79	-1.51	0.03	-1.11	1.40	0.45	-0.27	**-1.89**	**-1.92**	-1.22	**-1.65**	**-1.80**	-0.18	-1.25	-0.89	-1.61
M.court	**-2.18***	-0.17	**-2.41***	-1.40	**-2.20***	0.21	-0.18	-1.42	**-2.38***	**-2.43***	-1.42	**-1.85**	**-3.10**	-0.36	-1.25	-0.72	-1.07
Khepupara	***-3.09****	-0.90	***-2.83****	-1.17	**-2.30***	0.61	0.36	-0.86	**-1.99***	***-2.74****	**-2.39***	***-2.69****	***-3.50****	-0.36	-1.61	-1.07	-1.61
Faridpur	-4.17	-0.90	-1.32	**-1.66**	-1.02	-0.43	**1.66**	**-2.38***	**-1.96**	***-2.68****	**-2.21***	***-3.75****	***-2.51****	-1.25	-0.54	1.07	-1.07
Dhaka	***-3.49****	-0.27	-0.93	**-1.66**	-0.68	-0.69	1.37	**-2.56***	**-2.20***	***-2.64****	**-1.93**	**-2.55***	**-2.22***	-1.25	-0.18	1.25	-1.07
Hatiya	***-3.31****	**-2.56***	***-3.34****	**-2.30***	**-2.48***	-0.90	0.39	-1.06	**-2.11***	***-3.41****	***-2.77****	***-3.67****	***-4.65****	-0.72	**-2.15***	-0.72	-1.25
Khulna	-4.72	**-1.92**	**-2.30***	**-1.92**	-0.36	0.96	**1.85**	-0.36	-0.86	***-2.96****	***-3.86****	-4.85	-3.39	***-2.50****	***-1.97****	0.01	1.07
Jessore	-4.61	**-2.04***	**-2.30***	**-2.05***	-0.69	1.25	**1.80**	-0.74	-0.97	***-3.33****	-4.10	-4.77	-3.58	***-2.50****	***-1.97****	0.18	1.43
Sathkhira	-4.39	-1.45	**-2.46***	**-1.98***	-0.52	0.64	**1.65**	-0.42	-1.38	***-2.71****	***-3.59****	-5.14	-3.08	***-1.79***	***-1.79****	0.18	0.72
Mymensing	-5.46	***-3.20****	**-2.46***	**-1.98***	-0.52	0.64	**1.65**	-0.42	-1.38	***-2.71****	***-3.59****	-5.14	-4.20	0.01	**-1.35**	-1.61	-1.07
Patuakhali	***-3.61****	**-2.01***	**-2.23***	-1.55	-1.55	-1.28	-0.37	**-2.01***	-1.94	-1.50	-1.35	***-4.03****	-1.40	0.18	***-1.97****	1.07	-0.36
Bhula	***-3.88****	-1.41	**-2.39***	-1.28	-0.95	-0.71	0.26	-1.55	**-1.88**	**-1.79**	**-1.77**	***-4.66****	***-1.78****	-1.25	***-1.79****	0.72	-0.54
Rajshahi	***-5.00****	**-1.85**	**-2.08***	**-2.42***	**-1.79**	-0.12	1.49	-1.00	-0.89	***-2.91****	***-3.22****	***-5.09****	***-3.67****	1.07	-1.25	0.18	0.72
Ishurdi	***-5.07****	**-2.52***	***-2.67****	**-2.45***	-0.93	-0.51	1.62	-1.18	-0.93	**-2.49***	***-3.24****	***-4.50****	***-4.04****	-0.36	-0.72	0.01	0.54
Rangamati	**-1.66**	1.06	-0.98	-0.98	-1.55	0.45	1.49	-0.87	-0.25	***-2.94****	***-2.73****	***-3.04****	***-1.64****	***-2.15****	-0.18	0.36	-0.72
Rangpur	***-4.62****	**-2.16***	***-3.69****	***-3.18****	-1.05	-1.59	1.55	-0.76	-0.08	-1.04	-1.52	-1.32	-3.99	0.72	0.01	***-2.15****	-0.72
Srimonggol	0.86	**1.75**	0.63	-0.50	**-1.98***	-0.76	1.11	-0.28	0.09	-0.15	0.79	0.51	3.14	1.53	***-1.79****	-0.18	0.01
Sylhet	**-2.51***	0.86	0.46	0.50	-0.43	-0.45	**1.84**	-0.65	0.99	-0.96	**-1.75**	-0.91	-0.31	***-2.33****	-1.61	1.43	-0.18

Note that the values in the Table are Z statistics. Significant trends (at the p<0.10 level) indicated by bold numbers, significant trends (at the p<0.05 level) indicated by an asterisk on the numbers, and significant trends (at the p<0.01 level) indicated by italicized numbers

Discussion

ETo trend analysis and its driving factors

all climatic factors don't influence the ETo change equally. ETo is positively related with temperature, solar radiation, wind speed and negatively correlated with relative humidity and rainfall.

Impact on ecology and vegetation restorations

The change in ETo trends would affect regional ecology. We found that monthly, annual and decadal ETo had a decreasing trend which represents a decline in evaporative demand. Decreases in wind speed may be responsible for weak atmospheric circulation. Increasing drought would hinder the growth of vegetation and may even lead to increase soil erosion in this fragile ecosystem in the study area.

Influence on water resources and agricultural production

The change in ETo trends would affect regional agricultural production and food security **et al.2018**.The quality of groundwater is repo. Rising ETo trends in the upcoming years will adversely affect the agricultural production of the country (**Rahman** rted to have become poor in the catchment area located in the study area. It is mentioned that Chola Lake, which is known as the Bay of Bengal in the world, would vanish in foreseeable future.

Figure 6: Shrinkage of the Kholpatua river in southwestern Bangladesh

Conclusion

Possible impact of ETo in Bangladesh due to climate change in past four decades are observed in this study. The study shows that a significant decreasing ETo trend most of the selected station.ET0 times series is changing from positive to negative in upcoming years, which significantly influenced the change in ETo trends in future.The findings of the study would contribute in irrigation water management and planning of the country and also in furthering the climate change study using modelled data in the context of Bangladesh. In order to conserve available fresh water and save the sustainability of water-related activities in the study area, efficient practical decisions should immediately be made by decision-makers.

Reference

Ali A (1996) Vulnerability of Bangladesh to climate change and sea level rise through tropical cyclones and storm surges. Water Air Soil Pollut 92:171–179

Ayub R, Miah MM (2011) Effects of change in temperature on reference crop evapotranspiration (ETo) in the northwest region of Bangladesh. In: The fourth annual paper meet and 1st civil engineering congress, December, 2011, Dhaka, pp 978–984

Chauhan S, Srivastava RK (2008) Performance Evaluation of Reference Evapotranspiration Estimation Using Climate Based Methods and Artificial Neural Networks. Water Resour Manage (2009) 23:825–837. DOI 10.1007/s11269-008-9301-5

Dinpashoh Y, Asl SJ, Rasouli AA, Foroughi M, Singh VP (2018) Impact of climate change on potential evapotranspiration (case study: west and NW of Iran). Theoretical and Applied Climatology.https://doi.org/10.1007/s00704-018-2462-0

Karim MF, Mimura N (2008) Impacts of climate change and sea-level rise on cyclonic storm surge floods in Bangladesh. Glob Environ Chang 18:490–500. https ://doi.org/10.1016/j.gloen vcha.2008.05.002

Limjirakan S, Limsakul A (2012) Trends in Thailand pan evaporation from 1970 to 2007. Atmos Res 108:122–127

Mirza MMQ (2002) Global warming and changes in the probability of occurrence of floods in Bangladesh and implications. Glob Environ Chang 12:127–138. https ://doi.org/10.1016/S0959-3780(02)00002 -X

Mojid MA, Rannu RP, Karim NN (2015) Climate change impacts on reference crop evapotranspiration in northwest hydrological region of Bangladesh. Int J Climatol 35:4041–4046. https ://doi. org/10.1002/joc.4260

Rahman MA, Yunsheng L, Sultana N, Ongoma V (2018) Analysis of reference evapotranspiration (ET0) trends under climate change in Bangladesh using observed and CMIP5 data sets. Meteorology and Atmospheric Physics.https://doi.org/10.1007/s00703-018-0596-3

PADDY PRODUCTION UNDER SALINITY CONDITIONS IN COASTAL BANGLADESH: PRODUCTION FUNCTION APPROACH

M. H. Iqbal[1] and M. E. Hossain[2]

ABSTRACT

A major portion of the cultivable land of Bangladesh is located in its south-west coastal region and this land has been contributing to provide food security and support livelihoods of the people. However, in the recent past, cultivable land in this region has decreased due to salinity, which caused to degrade productive land and diminish crop productivity. Thus, this study aims to estimate the production functions for Aus, Aman and Boro paddy taking into account the salinity effects in the south-west coastal region and salinity free situation in the north-west non-coastal region for comparison. The Translog production function model is employed on primary data collected from sample farmers of south-west and north-west regions of Bangladesh, who were selected following the random sampling procedure and interviewed using a structured questionnaire. During the survey, water and soil salinity (dS m^{-1}) of the farms were tested by a salinometer. The findings suggest that proper dose of Triple Super Phosphate (TSP) and Urea played important roles to improve per acre paddy productivity under the salinity prevailed condition in the south-west coastal region of Bangladesh.

Introduction

The coastal region of Bangladesh comprises of 19 districts and covers 32% of land area and 25% of population of the country (BBS, 2015). The coastal region is vulnerable to climate change and is often exposed to natural hazards like cyclones, storm surges, sea level rise and salinity intrusion. All these natural processes cause to accumulate salinity in the soil and water in the coastal areas. The brackish water shrimp cultivation has aggravated the salinity problem in soil and groundwater aquifers in these areas even more. It is already recognized by academics that the south-west Bangladesh is heavily affected by salinity intrusion and the problem would worsen in the years to come.

About 9.9 million people live in south-west Bangladesh and of them 5.9 million are extremely poor (Solidarites International, 2012). Salinity has resulted in a reduction in crop yield and income of farm households, and consequently led to migration of farm households from this region to other areas (Pingali, 2001). Therefore, adaptation to salinity related problems has cast top priority in the development agenda of the government. Salinity is a problem caused by the presence of soluble salts of carbonate, bicarbonates, chlorides and sulfates of sodium, calcium, magnesium and potassium in concentrations in the soil that hinder crop growth and yield (Provin & Pitt, 2017). The soil reactions, EC, ESP are some of the indicators that reflect the degree of soil and water salinity. Generally, soil with a pH < 8.5, ESP < 15 and EC > 4 dSm^{-1} are categorized as saline soils and for alkali soils, the parameters are pH > 8.5, ESP > 15 and EC < 4 dSm^{-1}(Chhabra, 2004). Presence of soluble salts in the soil affects the transmission and availability of nutrients to plants. The excess salts become toxic to plants and in the long term damage the soil reversibility. The salinization of land contaminates groundwater aquifers through seepage of salts and affects quality of water used for irrigation.

In the above mentioned background, this study sets the objective to estimate the impacts of salinity on paddy yield and to identify the vulnerable paddy varieties that are susceptible to salinity conditions. The study also aims to identify the most suitable fertilizer to be used in this condition and its optimum dosage. Moreover, the study aims to develop an approach of management strategy that would facilitate higher yield and productivity even salinity spreads.

Study Area, Methodology and Research Plan

The study is based on primary data collected from three coastal districts and one non-coastal district of bangladesh. The coastal districts are Khulna, Satkhira and Bagerhat located in the south-west region of Bangladesh, and this region is part of an active delta of large Himalayan Rivers and is vulnerable to natural

[1]Assistant Professor, Dept. of Economics, Government Edward College, Pabna-6600, Bangladesh
[2]Professor, Dept. of Economics, University of Rajshahi, Rajshahi-6205, Bangladesh
Email of Corresponding Author: vaskoriqbal@gmail.com

hazards due to its disadvantaged geographical location, and its flat and low-lying topography. The region is hot and humid in the rainy season with about 1840 mm of the annual rainfall, the winter is predominately cool and dry, and the summer is hot and dry interrupted by occasional heavy rainfall (BBS, 2010). Salty clay or clay in texture is the common characteristic of soil of this region. When the salty land dries, it becomes hard and cracks develop, making tillage operation difficult. Due to strong presence of salinity, most of the cultivable lands remain fallow during the pre-monsoon (March-June period) and post-monsoon (October-February period) seasons. Major portion of the land is used for aquaculture (mainly shrimp farming) and with regard to crop agriculture, paddy is the main crop usually grown two times a year with the monsoon or rainy season paddy is the main one.

The study also considers the salinity free northwest region, taking Pabna district as the bench mark region, to compare its paddy production status with that of the salinity affected south-west coastal region. Pabna is selected as the bench mark region because it is free from shrimp cultivation and salinity intrusion condition; it is not geographically close to the coastal region of Bangladesh; and the district is not an island, hilly or a geographically exotic area. Paddy, jute, wheat and other cash crops are grown well in the region and high crop rotation is practiced by the farmers of this region. Moreover, agriculture in Pabna district is highly leaned towards paddy production.

The empirical investigations were undertaken in two ways. The first part comprised a pilot survey and mini version of a full-scale study to observe and understand the current situation of salinity and its impact on paddy production. The first part of the survey was undertaken in March 2014. The findings were of great value since no study or information on this issue was found. So, the first part investigation helped to finalize the questionnaire and variables for this study. As the study is based on farm specific primary data, a questionnaire survey was performed on farm specific characteristics of the sample farm households.
Input-output data were collected from paddy farmers who grew paddy in all the three seasons. The sample size was determined in such a way that appropriate findings against each objective can be achieved properly. Thus, using random sampling technique 715 paddy farmers in the salinity affected south-west region and 511 paddy farmers in the salinity free north-west region were selected for interview. Soil and water samples were taken from the respondents' paddy farm at the time of interview. The survey was completed by a group data collectors, who were active in the selected villages of the 35 (22 in south-west and 13 in north-west) unions under this research. The second part of the survey was undertaken during September 2014 and February 2015. No proxy data were considered in the study for monsoon paddy. It is important that year long data for salinity could have justified the results better because salinity is a dynamic entity. It varies from time to time and location to location. But it was not possible due to major constraints of time, fund and logistic resources.

The technical relationship between paddy production and its determinant inputs is estimated using the Transcendental Logarithmic Production Function. The Translog production function provides a greater variety of substitution and marginal possibilities. The general form of the Translog production function is expressed as:

$$lnY_i = \beta_0 + \sum_{i=1}^{n} \beta_i lnX_i + \frac{1}{2}\left\{\sum_{i=1}^{n}\sum_{i=1}^{n} \beta_{ii} lnX_i lnX_j\right\} + \sum_{i=1}^{n} \lambda_s lnS_s \tag{1}$$

Where, InY_i is log of the value of per acre paddy production; lnX_i is the log of the value of input X*i* and lnS_s is the log of salinity level in paddy farm.

Salinity is a natural shock and farmers have no control over the salinity intrusion. It directly affects the farmer in resource allocation and resource transformation (Singh & Singh, 1995). Thus, salinity (dSm^{-1}) is associated with other inputs and takes additive form in the production function. After estimating the function the elasticity of output is calculated with respect to the factors by taking the partial derivative of output with respect to the factor under consideration. For example, like other factors of production the elasticity of salinity (*S*), is derived in calculated in this study as it is associated with production in the south-west coastal region:

$$\varepsilon = \frac{\delta InY}{\delta lnS} = \lambda_s \tag{2}$$

The marginal productivity of salinity is written as:

$$\rho = \frac{\delta Y}{\delta S} = \frac{\delta InY}{\delta lnS} * \frac{Y}{S} = \varepsilon \frac{Y}{S} \quad (3)$$

Estimation and Discussion of Results

The study first estimates the factor share of the salinity free paddy model. Prior to imposing assumptions, the coefficient restrictions are tested by the Wald test so as to confirm asymptotically how much the data set fits these restrictions. After that, the study focused on the estimation side of the salinity free Translog model. As shown in table 1, most of the variables are found significant except for all paddy varieties at the convenient 1%, 5% and 10% levels of significance with the expected hypothesized relationship.

In the salinity free north-west region, urea and TSP exert positive impacts on all varieties of paddy production as shown by the lower *P*-value. This indicate that further increase in urea and TSP or doubling the amount of urea and TSP will lead to decrease all varieties of paddy production except urea on Aman paddy. However, the contribution of the labor input did not appear significant in all varieties of paddy production. This might happen in case when all farms use labor input equally per unit of land. Moreover, the insignificance of labor can be understood as the improper utilization of labor in the salinity free area to produce paddy. The main reason is that most of the labor force comes from the paddy farmer's own household. This is supported by the field survey information. Generally, family supplied labors are employed on a voluntary basis and they are considered as unskilled compared to the hired labor. Based on the estimated results, the impact of salinity on different varieties of paddy production is not clearly observed. It is because crop farms are not affected by salinity and the soil quality maintains the tolerance level of salinity.

Table 1. Parameters estimate of salinity free Aus, Aman and Boro paddy models

		Aus model	Aman model	Boro model
Variable	Parameter	Estimates	Estimates	Estimates
	β_0	4.479223***	6.197348***	8.923175***
ln Urea	β_U	0.182520*	0.468275***	1.410184 ***
ln TSP	β_T	0.157826**	0.059151***	0.202367***
ln Labor	β_L	0.413194	0.205251	0.63167
ln Urea^2	β_{UU}	-0.089802***	-0.012858	0.15826
ln TSP^2	β_{TT}	-0.051803*	-0.116088***	0.081855*
ln Labor^2	β_{LL}	-0.137576	-0.167063	-0.037630
ln Urea*ln TSP	β_{UT}	-0.062886***	-0.162688***	0.01973
ln Urea*ln Labor	β_{UL}	0.095492	0.293142*	0.30273
Pseudo R-squared		0.540298	0.583774	0.599771

Note. ***, ** and * indicate significant at the 1% level, 5% level and 10% level, respectively

The values of Pseudo R-squared, which measures the goodness of fit, are 0.540298, 0.583774 and 0.599771, respectively, implying that 54%, 58% and 59% of the total variation in the outcome variables-Aus, Aman and Boro yields, can be explained by the variation of explanatory variables.

Following the same estimation process for the salinity free paddy model, the study first estimated the factor shares of the salinity affected paddy model. Like the previous estimated results of the salinity free paddy model, all variables are found significant except for a few at the convenient 10% level of significance and show the expected hypothesized relationship, details of which are shown in Table 2. In the salinity affected south-west coastal region, TSP and labor exert positive impacts on all varieties of paddy production. Like TSP and labor, fertilizer urea is found statistically significant, but it is negatively related to all varieties of paddy production. The negative sign of the relationship between urea and paddy production in the salinity affected coastal area implies that most of the paddy farmers do not apply appropriate or recommended dose of urea in the production stage of paddy.

These results indicate that further increase in TSP and labor or doubling the amount of TSP and labor will lead to decrease all varieties of paddy production. At this stage, production cost would be increased and the paddy farmer would be looser while cultivating paddy. Another finding from the estimated results reveals that paddy farmers get more production if they double the amount of urea at this production stage. Based on the intercept of different paddy models, it is said that Aus and Boro are the paddy varieties, which are significantly vulnerable to salinity. The values of Pseudo R-squared, that measure the goodness of fit of the models, are 0.475869, 0.287205 and 0.612332, respectively, which imply that 47%, 28% and 61% of the total variations in the outcome variables can be explained by the variations of explanatory variables.

Table 2. Salinity affected Aus, Aman and Boro Paddy models

Variable	Parameter	Aus model Estimates	Aman model Estimates	Boro model Estimates
	β_0	2.064458***	9.766713***	4.743198***
ln Urea	β_U	-0.695450**	-0.109069***	-0.154111***
ln TSP	β_T	0.937989***	0.325787**	0.092015***
ln Labor	β_L	0.407764***	0.516401***	0.245898***
ln Urea^2	β_{UU}	0.125260*	0.066296***	0.192883***
ln TSP^2	β_{TT}	-0.154895***	-0.212500***	-0.056085
ln Labor^2	β_{LL}	-0.744306***	-0.243268***	0.175853***
Pseudo R-squared	β_{UT}	0.475869	0.287205	0.612332
n		715	715	715

Note. Significant at the 1% level, ** Significant at the 5% level, and *Significant at the 10% level

The marginal returns for the factor inputs are calculated from the parameters of the models as well as their concerned elasticities, which are provided in Table 3. The marginal returns showed that urea, TSP and labor played an important role to increase different varieties of paddy production in the salinity free north-west region. For example, 1 percent increase in expenditure on urea will lead to increase of Aus, Aman and Boro paddy production, calculated in value, by 9.36 percent, 23.88 percent and 76.28 percent, respectively, when other things remain constant. This proposition is also true in the salinity affected coastal region.

Table 3. Marginal returns of input

Variable	Marginal return (Salinity free north-west region)			Marginal return (Salinity affected south-west region)		
	Aus	Aman	Boro	Aus	Aman	Boro
Urea	9.36	23.88	76.28	40.16	6.58	8.92
TSP	39.95	11.58	45.77	25.53	88.22	18.26
Labor	37.11	18.98	23.38	23.76	34.54	14.78

Conclusions

Like other second generation climatic problems (sea level rise and intensity of droughts), salinity creates negative impacts on paddy production and badly hampers food security and coastal livelihoods. All paddy varieties are not equally vulnerable to salinity. Aus and Boro paddy are mostly affected by salinity. As a rain-fed verity, Aman paddy is less affected by salinity, because rain and flood water wash out and reduce the level of salinity. Salinity intrusion is a natural hazard or climatic shock, so paddy farmers have no control over the salinity. Coping with this salinity intrusion condition, some management techniques need to be devised that would help grow more paddy under this condition in the south-west coastal region. Proper application of inputs of production has significantly increased per acre paddy production in the salinity affected region. But in reality, the paddy farmers of the salinity affected south-west coastal region used the least amount of essential inputs to produce paddy. Paddy farmers should give more importance on the appropriate amount of inputs usage and that is essential to produce paddy in the south-west coastal region. Farmers should cultivate high yielding salt tolerant varieties of Aus and Boro paddy that can ensure sustainable paddy production in the south-west coastal region. Government intervention is also highly required in this respect. Government can induce the farmer's decision to change the input patterns by providing more subsidies on essential fertilizer of paddy. It is to note that this study suffered from obtaining systematic information on some issues related to salinity of lands and also lacked to get proper information on irrigation water usage from paddy farmers, this is why irrigation could not be included in the Translog model. Thus, this study recommends for further study that will include major inputs of paddy along with irrigation water under the salinity presence condition with covering wide areas in the coastal region.

References

BBS, (2010) "Year Book of Agricultural Statistics of Bangladesh", Ministry of Planning, Dhaka, Bangladesh.

BBS. (2015) "Population density and vulnerability: A Challenge for Sustainable Development of Bangladesh. Population Monograph, Statistical and Informatics Division (SID)", Ministry of planning, Dhaka, Bangladesh.

Chhabra, R. (2004) "Classification of salt-affected soils", *Arid Land Research and Management*, 19(1), 61-79.

Pingali, P. L. (2001) "Environmental consequences of agricultural commercialization in Asia", *Environmental and Development Economics*, 6, 483-502.

Provin, T., & Pitt, J.L. (2017) "Managing soil salinity", Texas A&M Agrilife Extension.

Singh, J., & Singh, J.P. (1995) "Land degradation and economic sustainability", *Ecological Economics*, 15, 77-86.

Solidarities International. (2012) "Chronic Poverty in the Southwest Coastal of Bangladesh", Dhaka.

VULNERABILITY ASSESSMENT OF CLIMATE CHANGE INDUCED FLOODING: LESSON LEARNT FROM A MUNICIPALITY IN THE PHILIPPINES

A.S.M. Saifullah[1], Mario R. Delos Reyes[2]

ABSTRACT

The municipality of Angono in the province of Rizal of the Philippines is the worst victim of flood for a long time. This municipality is affected by flood in almost three years interval. The vulnerability of flooding in this municipality was assessed using Participatory Learning Approach (PLA), FGD, trend analysis; transect survey, household survey, and weight-based ranking. There revealed a change in climatic factors like temperature, rainfall and seasonal pattern in the whole Philippines. Heavy precipitation in the wet season cause overflow of the river and Laguna de Bay of Angono thus, four major lakeshore Barangays (village/ward) go under water. Among ten Barangays, four lakeshore Barangays are impacted by flooding an area comprising about 17% of the total land area of the municipality. Children and old people are mostly exposed to the flooding and adversely impacted by the hazard. Poor people are found more affected than the rich and middle class. It is also reflected that the poor are mostly victimized due to their location of houses in the unprotected areas and poor housing. The elevation of the affected area is as low as 0-5 % from the sea level which is also another cause of flooding. Moreover, the depth of the lake is decreasing due to sedimentation and cannot hold excess water. Marginalized people located in the low-lying waterfront are impacted either by the loss of livelihood or lowering of earning during and after the flood period. Almost 76% of the household heads in the area have no alternative livelihood and are the worse victim of flooding. Health and sanitation facilities are highly impacted by the flood including disruption of potable water supply, overflow sewerage system; dysfunction of toilets. About 99% of the households experienced different kind diseases during and after the flooding. Among the affected people, 45% were within 0-14-year age bracket. Critical infrastructure like health care center, fire and police station, government and private offices, educational institutes were also impacted during the flood. Loss of agricultural properties, damage in road networks, buildings, and other infrastructure cause economic drawback instantly and also create a long-term problem in communication, housing, and food security. Farmers are mostly marginalized; once their products are lost or damaged due to flooding this community loss their way of livelihood and become poorer. Erosion of soil in the upland area cause sedimentation in the lakes and lakeshore area, grassland, and vegetation covers are damaged which later make the area more erosion-prone. In the context of coping capacity, the municipality has a local disaster management council called MDCC along with MSWDO and BDCC in Barangays level whose mandate is to take necessary action in pre-disasters, in-situ and post-disaster event. Local Disaster Coordinating Councils (LDCCs) which include PDCC, MDCC, and BDCC were found with weak coordination which hinders the proper rescue and evacuation of the flood-affected people.

Keywords: Flood vulnerability; Climate change; Municipality; Philippines

Introduction

Flood is a climate-caused natural disaster sometime described as the excess of river flow that exceeds the channel that has been specified for it. It can also be described as the very high flow of water overtopping the artificial or natural bank inundating the entire surrounding area Flood is considered the most disastrous and damaging and causes more economic loss than other natural or technological disaster (Huang 2008).

Floods are considered by many to be the hazard that affects more people and causes more damage to property than any other. They are produced by a variety of factors in different parts of the world. Most commonly these include: overbank flow on rivers and lakes due to heavy precipitation exacerbated in denuded watersheds by accelerated runoff; urbanization which complicates flooding events by increasing the area of impermeable surfaces by the encroachment of roads, housing, and other land uses onto floodplains; the silting of canals and riverbeds or the obstruction of waterways due to improper construction activities; and the incidence of storm surges in coastal areas that are already experiencing slow acting land subsidence further

[1]*Department of Environmental Science and Resource Management, Mawlana Bhashani Science and Technology University, Santosh, Tangail-1902, Bangladesh.*
[2] *School of Urban and Regional Planning, University of the Philippines, Diliman, Quezon City, Philippines.*

magnified by rising sea levels. Flood is characterized by its depth, the rate at which they arrive and subside, among others. Floods often cause damage to homes and businesses if they are placed in natural flood plains of rivers. While flood damage can be virtually eliminated by moving away from rivers and other bodies of water, since time out of mind, people have lived and worked by the water to seek sustenance and capitalize on the gains of cheap and easy travel and commerce by being near water. That humans continue to inhabit areas threatened by flood damage is evidence that the perceived value of living near the water exceeds the cost of repeated periodic flooding.

The intense and frequency of flooding is increasing all over the world. It is believed that abrupt climatic change in the last couple of years acting as a driving force for increased intensity and frequency of flooding. The impact of climate change is quite visible in the Philippines and it is revealed from several types of research that the mean temperature of the country is increasing, night time temperature is also on the rise, pathways of intense typhoons are shifting, and the number of rainy days is decreasing. These changes are pushing the country to climate-related disasters like tropical cyclones, floods, and landslides.

Study reveals that from 1948 to 1991, 869 typhoons have passed the Philippine area of responsibility (PAGASA, 1992). The country experiences an average of 19.6 typhoons a year in its area of responsibility. The normal high incidence of typhoons brings in heavy rains when it coincides with the southwest monsoon occurrence in the months of June to September and causes flooding in most of the areas of the country. Storm surges accompany tropical depressions and cause extreme flood occurrences. They devastate many low-lying coastal areas. The floodplains of Agno, Agusan, Bicol, Cagayan, Cotabato, Pampanga and Panay river systems are highly susceptible to severe flooding (ADB, 1994). Low-lying agriculturally developed and economically productive lands in Bicol, Central Luzon, Eastern Mindanao, Central Samar, and Northern Samar regions are also frequently devastated by extreme flooding events (Benson, 1997). According to The Inquirer (2009) on Nov. 5, 1991, issue massive flash floods descended on Ormoc City in Leyte, killing about 8,000 people, including some 4,000 who were never found as walls of mud and water roared down the mountains, washing away shanties and sweeping people into the sea. In September 1998, more than 900 families living along the Pasig, Pateros, Marikina, and Napindan (Taguig) rivers were swamped by floods after continuous rains. The floods and high tides submerged 85 percent of Malabon and flooded 26 primary and secondary roads in Metro Manila. In November 2006, Supertyphoon "Reming" (International Code Name: Durian) caused widespread floods and power outages, especially in the Bicol region. More than 700 were killed, over 700 others were missing and more than 2,000 were injured. Over 3.5 million people were affected. At least 500 people died in the wake of Typhoon "Frank" (International Code Name: Fengshen), which triggered severe flooding in Western Visayas in June 2008. Nearly 400,000 families, or almost 2 million people, were affected. At least 2,500 others were injured. More than 300,000 people, or over 50,000 families, were evacuated. The areas affected by Frank included Iloilo, Antique, Aklan, Capiz, Guimaras, and Negros Occidental. Aklan's capital town of Kalibo was covered with mud and was without potable water and electricity weeks after the typhoon struck. In January, heavy rains spawned by the tail-end of a cold front caused floods, landslides and tidal surges that displaced nearly 200,000 people in many parts of the country. Thirty-eight municipalities and 11 provinces from northern Luzon to Mindanao were affected.

Angono, a municipality of the Rizal province of the Philippines known as the art capital of the country and it is the worst victim of such climate change induced typhoon and floods. On November 3rd, 2000 a huge flood ravaged the town, which caused loss of lives and damage to properties of community-dwellers along the riverside and again September 2009 another flood due to Typhoon Ondoy caused huge damage to the town. It is estimated that total damage to roads, bridges and other public structures due to typhoon Ondoy was about PhP 452,919,943 (Rizal,2009). The flood that was caused by Typhoon 'Ondoy' in September 2009 and Pepeng in October 2009 gave rise to the specific research. Though the municipality is facing severe problem due to typhoon and flood there is no vulnerability assessment of flooding. The main concern of this research is to assess the vulnerability of flooding of the Angono municipality.

Angono Municipality essentially serves as a catchment valley of the runoff originating from the uplands of Antipolo, Teresa, and Binangonan. This situation is aggravated by the denudation of the forest cover of the said areas. Due to the loss of vegetation cover surface, run-off becomes more pronounced as vegetation cover usually assist in the percolation of rainwater throughout the soil. Specifically, coastal barangays of Angono along Laguna Lake are susceptible to inundation. During the rainy season when the lake water swells, close to 30% of Barangays Kalayan, San Vicente, Poblacion Ibaba and Bagumbayan become flooded (CDP, 2001). It is revealed from the past experience that often, flood water reaches a depth of about six (6) feet near the river channels. In the town proper, specifically in the proximity of municipal hall, the water extends about a foot deep. Typhoon Ondoy which hit the Philippines in September 2009 caused a huge damage in this municipality. According to the Rizal Province Government Office, due to the typhoon Ondoy resulted in the death of 13 people died, 11,959 families affected 1,325 houses partially and 17 houses- fully destroyed. The provincial government office also reported that the total cost for the loss due to Ondoy is approximately Philippino Peso(PhP) 51,309,500. The population of the municipality is increasing rapidly and migrant people are settling continuously around the lakeshore area and the number of households victimized by floods is rising every year.

The vulnerability assessment integrates the analysis of the conditions and the characteristics of a system that is exposed to a certain type of natural hazard. It is a concept with multiple dimensions (ecological, economic, social and institutional) and it represents the degree in which a system can be affected by the impact with a perturbation or stress factor and its capacity of recovering or adaptation to the consequences of the impact (Kasperson et al., 2002, Turner et al., 2003). The vulnerability can be defined as " a human condition or process resulting from physical, social, and environmental factors which determine the likelihood and scale of damage from the impact of given hazard" (UNDP, 2004). Hazard is defined as "A potentially damaging physical event, phenomenon, and/or human activity, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation" (ISDR, 2002). Vulnerability quantification model considers vulnerability as the result of the interaction between a potentially harmful event (hazard) and the system components that are exposed to this event which can be expressed in a formula:

$$\text{Vulnerability} = \text{Exposure} \times \text{Hazard}$$

So, in vulnerability assessment, exposed components are to be identified and related hazards are assessed. For the purpose of this study, emphasis is given on social, economic, environmental and institutional perspectives.

Realizing the frequency and magnitude of flooding in the Philippines and especially in the study area of Angono Municipality, this study assessed the vulnerability due to floods and exposed components to risk and hazard caused by a natural disaster like a flood. This study primarily concerns about the assessment of vulnerability posed by floods and for this Participatory Learning Approach (PLA) was used to focus the community people's perception about the flood, its extent, and frequency, causes of the flood, hazard caused due to floods and exposed resources to flooding. This also has opened a window for the local planers to use a participatory approach in flood vulnerability assessment and to integrate it in the local development plan. This study intends to address some question such as, how vulnerable the study area to flooding encompassing social, environmental and economic perspectives? Likewise, how can vulnerability assessment findings be integrated into a local level plan to reduce the risk and hazards of flooding? The objectives of the study were to identify exposed and vulnerable components and their associated risk in the study area;to delineate vulnerable area along with associated resources and user group; to get the level of institutional involvement in a probable measure for the reduction of risk and vulnerability; and to integrate these findings into the local development planning process of the municipality.

Materials and Methods

Study Area

The municipality of located in the Rizal province of Philippines and comprises of four Barangays namely San Vicente, Kalayaan, Poblacion Ibaba, Bagumbyan are most vulnerable to flooding and for this reason, those above-mentioned barangays have been chosen for the study. All of these above-mentioned barangays are located in the lakeshore area and are severely prone to flooding. High population density in this area also led to dense establishments including commercial, residential, industrial and some extent in the lakeshore area. The total population of four flood barangays is 31,323 and the total land area is 2.974601 km^2. So, population density is 10,530 km^2. Hence population density is high due to the proximity of Angono to Metro Manila the National Capital Region (NCR) of the country.

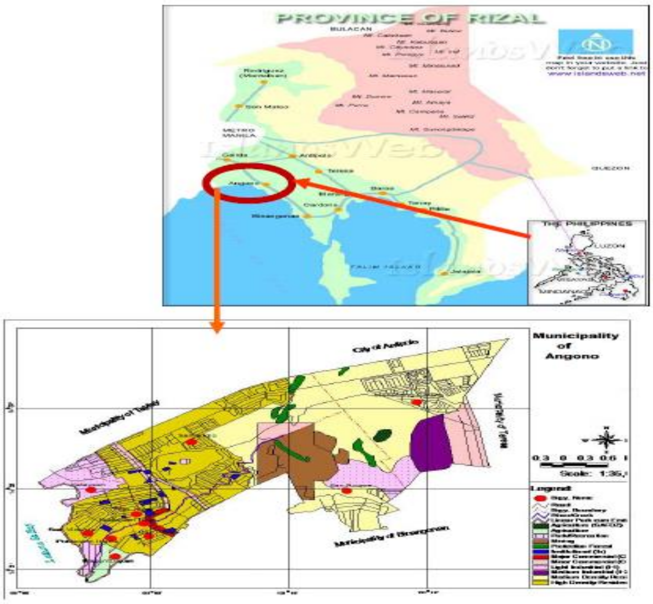


Figure 1. Study area map.

Research Design

The study of flood vulnerability has a wide range of activities to be undertaken, which include flood hazard and associated risk, exposed components, causes of flooding, aggravating factors, records of flooding and its connection with a change in climate and this research also intends to address those issues.

This research also emphasizes the integration of the vulnerability into the local level planning. For this purpose, it was necessary to review the existing planning system of the study area, existing disaster risk management system and its implementing organizations. Both qualitative and quantitative analysis was done for assessing the vulnerability of flood in the study area based on the result of a purposive community survey, FGD, Key Informant Interview (KII). It began with the morphological analysis of the flood-prone area through review of existing literature, transect survey. Data were collected from primary and secondary sources. The study was designed to perform in two stages. The first stage of the research included a review of related literature and collection of secondary data from relevant sources and to collect primary data using survey, FGD and transect survey.

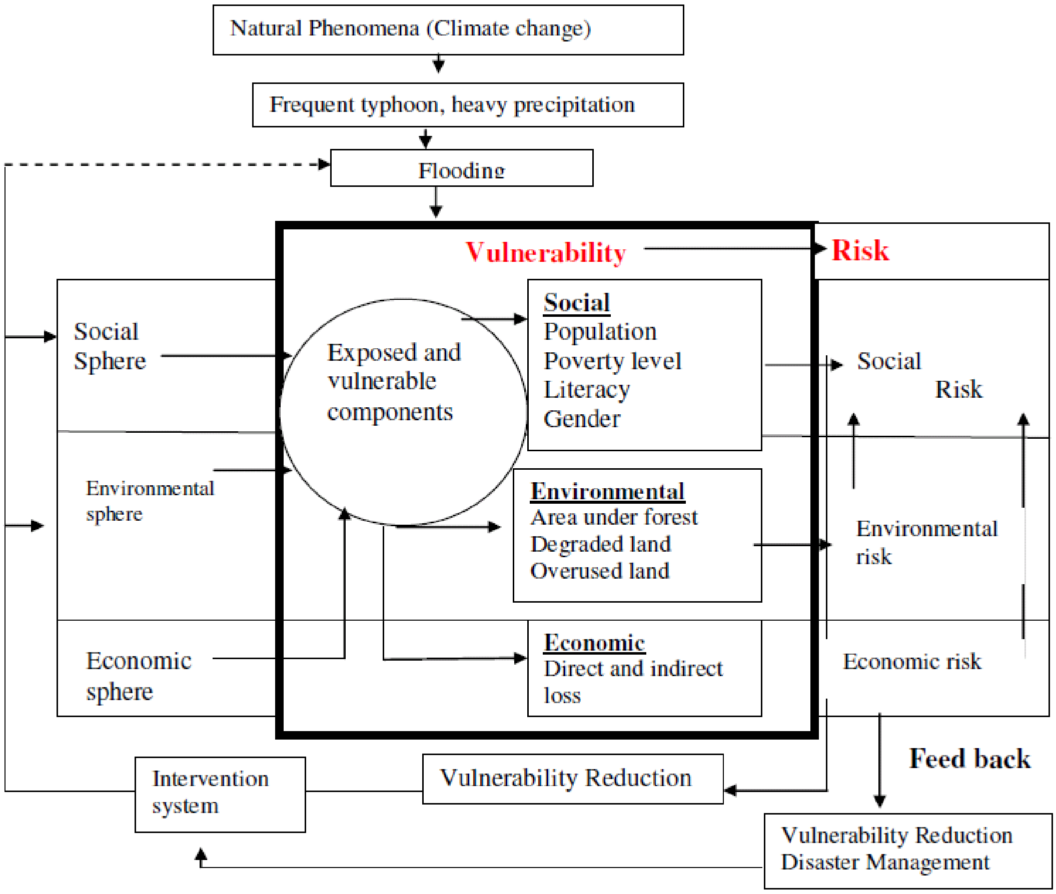


Figure 2. Conceptual Framework

The second stage dealt with the analysis of the collected spatial and aspatial data. Participatory Learning Approach (PLA) was used for gathering primary data. The PLA tools also included three learning approaches: a) Transect survey: to get complete topographical information of the target area; b) Social Mapping: to identify risk and resources in the targeted area and c) Mobility chart: to know about people's shelter at the time of disaster. Apart from those above-mentioned approaches supplementary tools were used to gather hazard information from the community such as; Timeline: to remind the community about the extent of damages by different disasters during the last decade (2000-2009), where did they take shelter, which institutes they think more effective to help them during the disaster.

Following tools and techniques were used for the vulnerability assessment

i. Physical exposure: It includes building, infrastructure, emergency facilities, agriculture etc.
ii. Social exposure: Vulnerable group, livelihood, local institutions
iii. Economic exposure: Direct and indirect loss
iv. Environmental exposure: Loss of natural resources, protected zones, cultural heritage, forest cover

Results and Discussion

Influence of Climate Change on Flooding

The Philippines has experienced temperature spikes brought about by climate change. It has been observed that warming is experienced most in the northern and southern regions of the country, while Metro Manila has warmed less than most parts. In addition, the regions that have warmed the most (northern Luzon, Mindanao) have also dried the most(Fig.3). It is revealed from several studies that mean temperature over the country is increasing and it fluctuates abruptly nighttime temperature is also in the rise, seasons are shifting and there is also a trend of Changing pathway of intense typhoons(Perez,2008). The record shows that the largest precipitation trends are about 10 percent during the 20th century. This increased precipitation over the country has given rise a number of floods over the last decades. A study led by meteorological department of the Philippines (PAGASA) estimates that a 1-meter rise by 2025 will flood over 5,000 hectares and displace more than 2 million people around Manila Bay. Sea-level rise will increase the risk of flooding and storm damage. Waterlogging after heavy rains may also affect infrastructure. It will also enhance the danger of ground liquefaction brought about by earthquakes and will influence shifts in tidal action in rivers and bays (Perez, 2001). It is reported that hot days or the frequency of days with maximum temperature above the mean 1961-1990 mean 99th percentile, warm nights or frequency of days with minimum temperature above the mean 1961-1990 mean 99th percentile. The abrupt change in climate is causing high prevalence of typhoon, heavy rain fall and long dry season. The country experiences around 26 tropical cyclones in five year intervals and 20 typhoons visit Philippines every year and incidence of flooding is higher in the country than anywhere else (Juanillo,2010).

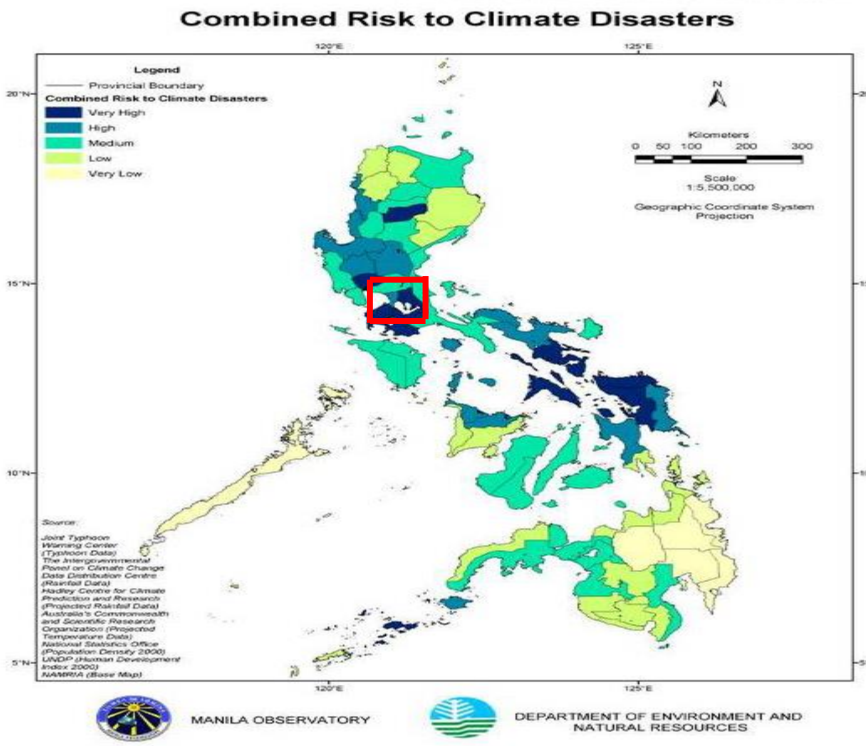


Figure 3. Map showing disaster risk in different regions of the Philippines, Rizal is in high risk area for climate disasters (Source: Villarian et al., 2008)

Flood Prone Area in Angono Municipality

It is revealed from the Focus Group Discussion (FGD), transect survey and review of Comprehensive Development Plan (CDP) and Comprehensive Landuse Plan (CLUP) that four Barangays of the Municipality are most prone to flooding (Fig. 4). The geographical location that is proximity to the Laguna de Bay makes them flood prone. The record shows that flood caused by the Typhoon Ondoy in 2008 (International name Ketsana) 70% of the Barangay Kalayaan, 60% of Barangay Poblacion Ibaba, 75% of San Vicente and 65% of Barangay Bagumbayan was submerged into water. Participants of the social mapping showed that almost whole areas of those aforesaid Barangays were impacted by previous floods in the last decade. It is reported that during the heavy rainfall, the discharges of the Angono River and water flow from upland of Mahabang Parang barangay over flow in the low-lying Barangays and cause flooding. Community people as well as Municipal Environment and Natural Resource Officer (MENRO) of the municipality opined that upland of the municipality is not affected by flood except for some wash down effects. So, the water from heavy rainfall come towards the lakeshore low-lying Barangays and the over flow of the lake together cause flooding to those Barangays. The Angono River network works as a natural drainage for the municipality and collects around one third of total rainfall water. This river confluences low-lying Barangays and finally drains to the Lake Laguna. As the river is becoming narrow for encroachment on its course and also loosing its depth, most of the time it cannot hold excess water and floods low lying banks. So, these aforesaid Barangays usually got flooded most of the time.

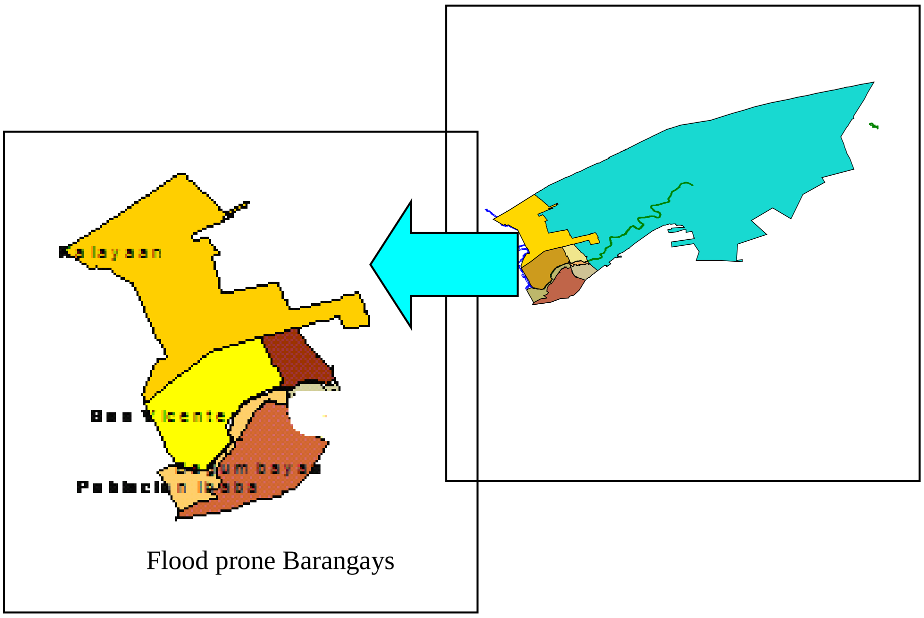


Figure 4. Flood prone Barabgays of Angono Municipality

Flood proneness Ranking of the Barangays

Geo-physical feature of the flooding area

Physical feature of the study area has been drawn using secondary information and transect survey and the social map prepared by the community. It is clear that the flooded area has lower elevation above the water level of the Laguna Lake. Soil map of Angono municipality shows that Barangay Kalyaan, Barangay Bagumbayan and Barangay San Vicente have boulevard clay soil and slope ranges from 0-2% and this soil is also slightly eroded. Soil map of the municipality shows those areas as severely flooded due to their low elevation and erosion prone soil (Fig. 5). The FGD participants opined that during the rainy season water coming from the upland area of Barangay Mahabang Parang carries huge sediments. This statement agrees with the findings of Lee (1997). The dry months (December to March) have an average of 30 mm of rainfall per month while during the rainy season (June-September) rainfall amount can exceed 400mm in a month. Lee (1997) noted that this peaky rainfall pattern leads to periods of heavy runoff and soil erosion. Eroded sediments from uplands drains directly to the Laguna Lake through rivers and drains and on the way to the lake a portion of the sediments deposit in the river and drains but major portion gets its way to the lake and deposits there which cause loss of depth of the lake.

Barangays were ranked on the basis of the average of the total weight where Barangay Kalayaan hits the first rank having average weight 0.60 out of 1. Second worse case is reported as Barangay San Vicente which scores o.56, and consecutively Barangay Poblacion Ibaba and Bagumbayan ranked 3rd and 4th. These ranks also comply with the situation that perceived from the report of MSWDO(2009) which also points out Barangay Kalayaan as worst victim of floods and consecutively Barangay San Vicente, Poblacion Ibaba and Bagumbayan.

Table 1. Weight-based ranking for the flood-prone Barangays of Angono Municipality

Barangay	**Average score per Barangay**				
	The rise of water level (Max=1 and lowest 0.265)	**The depth of water (Max=1 and lowest 0.265)**	**Duration (Max=1 and lowest 0.265)**	**Average weight**	**Rank**
San Vicente	0.55	0.55	0.60	0.56	2
Kalayaan	0.55	0.50	0.75	0.60	**1**
Poblacion Ibaba	0.60	0.45	0.60	0.55	3
Bagumbayan	0.500	0.65	0.44	0.53	4

Flood risk and vulnerability

Flood risk, vulnerability, and sensitivity were assessed using weight-based ranking. FGD participants were provided with suggestions of weight on the basis of criteria in a format of the table to put weights to measure exposure and sensitivity of population, places, activities, and infrastructure system. In case of place agricultural zone was found more exposed and sensitive to flood (Table 2).

In case of population, women are most exposed and sensitive than men to the flooding, While, in case of age group, children are more exposed and sensitive than other groups (Table 2). In social classes, poor are more exposed and sensitive to flood than the reach group. It may be because of housings of poor people in low-lying area. In the same manner, in terms of activity again agriculture was found most exposed and sensitive to flood. In terms of infrastructure sector, road and other transports were found most exposed and sensitive.

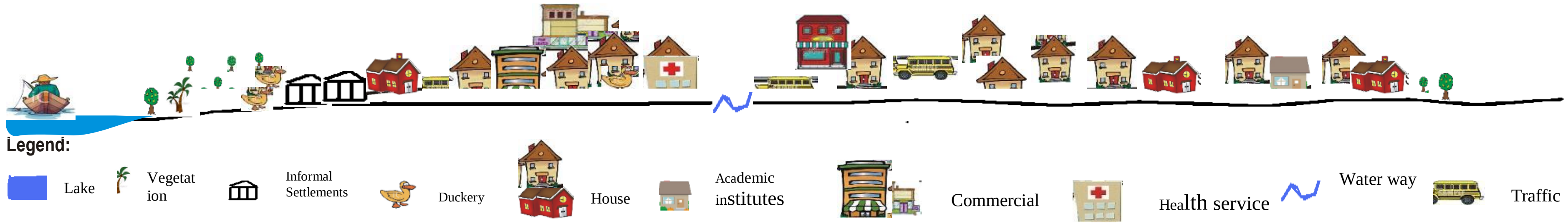
Social Vulnerability

Social vulnerability involves a combination of factors that determine the degree to which someone's life and livelihood are put at risk'. Social vulnerability scholars examine why types of persons locate in hazardous places, live in inadequate homes, fail to anticipate, resist, and/or recover from the aftermath of a disaster, and analyse the economic and social forces that mould and determine these dynamics

Table 2. Exposure and sensitivity assessment

Flood Risk, Vulnerability and sensitivity Assessment		
	Exposure	Sensitivity
Who/ what will be affected?	**Probability or likelihood of impact**	**Possible adverse impact**
Population		
Gender		
Men	0.70	0.72
Women	0.85	0.92
Age		
Children	**0.95**	**0.97**
Old people	**0.95**	0.94
Class		
Poor	**0.77**	**0.75**
Middle class	0.52	0.47
Rich	0.41	0.5
Places		
Built up area	0.8	0.83
Agricultural zone	0.93	0.97
Forest/ watershed area	0.75	0.61
Others	0.46	
Activity sector (Local economy and lifelines)		
Trading	0.65	0.72

Tourism	0.65	0.75
Agriculture (Fishing/ farming)	0.85	0.94
Service-oriented livelihoods	0.75	0.792
Infrastructure systems		
Bridges	0.57	0.58
Communications	**0.72**	**0.72**
electric power	0.62	0.69



Barangays	San Vicente		Kalayaan	Poblacion Ibaba	Bagumbayan
Ecosystem	Lakeshore area,	Built-up area	Built up area, has the essence of the urban and rural environment	Built up area with dense settlements	Built up area, River
Soil	Sanluis clay		Bulevard clay and Antipolo clay	Antipolo clay	Antipolo clay
Slope	0-18		0-18	0-18	0-18
Land use	Farming, Informal settlements, comprising little vegetation Fish sanctuary, kankun(Vegetable) gardening, Duckery, informal settlements	Mixed land use, both residential and commercial activities.	Mixed land use: housing, health service (hospital, clinic, and drug stores), government offices, commercial establishments (restaurants, sari-sari store), slaughter house, covered court, homestead garden, light industry,		
Major activities	Fishing, fish sanctuary, vegetable gardening	Housing, business, street vending, transport	educational activities (schools, college), hospital, restaurant, repair workshop,	Education, health services, light, repair workshops,	Housing, Use for commercial purpose
Minor activities	Water transport , tourism	Duckery ,fish sales, junkshops	Education, health services, minor industries, quarry, cemetery, repair workshops, eco centre	Informal business sector like street vending, cottage industry. Eatery, grocery shops	Vegetable gardening in the lakeshore area, duckery, slaughter house
Problems	Sedimentation on coast, solid waste dumping, loss of navigability, overflow of lake water cause flooding	Flood prone, lack of drainage narrow roads, traffic congestion, car park for commercial and institutional activities, high density,	Flood in almost all rainy seasons, clogged drains	High land conversion from agriculture to other uses, lack of proper drainage, water logging	narrow road, traffic congestion, informal settlements, land conversion from agriculture to settlement, river siltation,
Opportunities	Dike along the lakeshore for transport and Mass water transport, power generation, source of water for domestic & industrial purposes, tourism, fisheries, water hyacinth can be processed into	Tourism, poultry, small businesses	Serves as central business district in the municipality, tourism, commercial, education, health service, job	job opportunity, education, health service, A transition zone to rural setting.	open land in lakeshore area suitable for conservation, land is suitable for agriculture,
Suggested recommendations	**Overcoming problems:** Ban on waste disposal in lake, dredging for navigability, **Utilizing opportunities:** introducing methods for making handicraft from water hyacinth, Revitalizing tourism activities, Utilizing water for power generation and other	**Overcoming problems:** Adequate drainage can reduce flooding, contruct dikes along the bank of river and bay to control flood, proper traffic meant, mass transport can be introduced, purchase land or partial rights for open space	Serve as a central business district in the municipality, tourism, commercial, education, health service, job opportunity,	**Overcoming problems:** Control density, purchase land or partial rights for open space	Elevation of low area,

Figure 5. Spatial findings of the transect survey

Age group

In terms of age group of the population, 46% of the total population under age group 0-14 years were found most impacted by flood. It revealed that this age group comprises infants, children and juveniles. The participants of the social mapping in the Kahayan covered court temporary flood victims' rehabilitation area opined that during the last flood caused by Ondoy in 2009, children were mostly impacted with disease, injuries and infants were in scarcity of food also. The second most vulnerable group comprises age of 60+ (21%). It is believable that old people are most of time incapable to move to the safer place, going to doctor for medication, to market for buying daily necessaries. It is also revealed that age group 0-14years old scored the highest percentage (45%) in terms of susceptibility to disease followed by age group 60+ years in second position scoring 19% whether 10% for each age group 15-29 and 30-44 were found impacted in health by flood.

Housing

The concrete made houses are more resistant to wind, water and other type of forces which can cause harm to the structure. Most of the people who lost their houses in floods were found to have poor housing which was mostly made of bamboo and wood. Most of the houses specially the informal settlements were found to have very poor in structural condition. Community people in the Barangay Bagumbayan informed that about 80% of the informal settlements in lakeshore area of the Barangay were washed away during flood of typhoon Ondoy in 2009 and even houses made of concrete were also partially damaged.

Livelihood

It is revealed from the survey that 83% respondents' livelihood is impacted by flood. It is important for the community people to have secured livelihood. During social mapping in Barangay Poblacion Ibaba community people shared that most of the tricycle driver got their tricycles damaged, fishing folk lost their nets and boats; vegetable farmers lost their vegetable garden and could not restore the previous livelihood within 6 months of the disaster. Alternative livelihood is also an indicator for assessing vulnerability. It is evident that if the individual has two sources of incomes one can support if another is impacted. If primary source is affected then secondary source can help. So, individuals who have only one source of livelihood been at risk.

Physical Vulnerability

Settlements exposed to flood

When respondents were asked about the mostly exposed establishments' type, 45% opined regarding residential establishments followed by 41% commercial establishments (shopping centre, market, sari sari store etc) and industries (small and medium scale), 10% health establishments (Hospital, clinic, diagnostic centres, day care centres) and 4% educational institutes. About 5,541 buildings are present in the flood prone barangays of Angono municipality (GIS data, 2004). Most of the buildings are for residential purposes and rest are meant for institutional and commercial purposes. It is observed that in the built up area height of water was 4 feet and all the buildings were to the level of roads. So, any rise of water level could inundate those buildings (Table 3).

Table 3: Buildings exposed to flooding in flood-prone Barangays of Angono (Source: GIS, 2004)

Name of vulnerable Barangay	No. of Buildings in the flood-prone area
San Vicente	2,312
Kalayaan	2,250
Poblacion Ibaba	418
Bagumbayan	561
Total no. of buildings	5,541

Road networks

It is revealed from the existing data in CDP (2004) that the four flood-prone barangays have 25 roads connecting different sub-divisions and the total length of that road network is around 10.5 km. Key Informants, as well as community people, informed that all the roads were underwater during flood due to Ondoy in 2009 and usually these roads inundate with an elevation of the water level of Laguna Lake or due to heavy rainfall. Record shows that last devastating flood due to Typhoon Ondoy in 2009 damaged huge infrastructure in the Municipality of Angono.

Critical facilities

Critical facilities are defined as those structures from which essential services and functions for victim survival, continuation of public safety actions, and disaster recovery are performed or provided. Shelters, emergency operation centres, public health, public drinking water, sewer and wastewater facilities are examples of critical facilities. According to 89% respondents, some critical facilities were impacted. Among those 25% mentioned that health care centres were impacted by flood followed by 20% educational institutes, 19% police and fire station, 15% govt and private offices, 11% historical places.

Economic vulnerability

Angono enjoys a location quotient of plus 1 in these sectors when compared to the economic structure of the Philippines. Relative to the economic structure of Rizal province, the town similarly specializes in agriculture, fishery and forestry, and manufacturing.

Loss of in Household level

It is revealed that 47% of the households lost cost of properties amounts 25001-35000 PhP, followed by 17% lost properties of 5000-15000 PhP, 12% lost properties of 15001-25000 PhP, 10% o of the Households lost property of 35001-45000 PhP, whereas 2% opined that the cost of their lost and damaged property would be worth more than 60,000 PhP and only 2% did not loss and property during the last flood. The output of the survey also shows that last flood in 2009 damaged property of 97% of the households in the flood affected barangays of the Angono municipality (Table 4). Out of which 25% got damaged of their appliances like TV, Fridge, and other electronics while 58% of the household respondents opined that their Utensils and furniture got lost or damaged due to flood and 14% of the respondent’s houses were washed away by the flood water.

Table 4. Cost of damage in household level due to flood

			Estimated cost of loss (PhP)	
Type of impact	**Percentage**		**Range of Cost**	**Percentage**
No economic impact	3.8		5000-15000	17
Low direct and/or indirect costs	19.0		15001-25000	12
Low direct and high direct costs	48.6		25001-35000	47
High direct and low indirect costs	16.2		35001-45000	10
High direct and high indirect costs	12.4		45001-60000	9
Total	100		60000+	2
			None	3
			Total	100

Agriculture

The highest ratio of tropical cyclone damage to agricultural output was 4.21% in 1990, followed in 1988 by 4.05%. Typhoon damage rose to more than 1% of GDP in 1984, 1988, and 1990 (at 1.17%, the highest). The decline in production and productivity will possibly threaten the country's food security (PTFCC, 2010). Due to rapid urbanization agricultural space and activity in the municipality of Angono is shrinking day by day but still there are some spaces along the lake shore area which is used for vegetable gardening, rice cultivation, duckery, fisheries (specially the Laguna Lake) and for some piggeries.

Environmental Vulnerability

In this line, HH respondents were asked about the impact of flood on environment in their neighbourhood. Forty one percent (41%) of the respondents claimed that there was overflow of garbage in the street, whereas 31% of the respondents stated that water got polluted due to flood. Followed by 24% opined about the mudflow which cause sedimentation in the Laguna Lake as well as block water flow of the river. Only 4% of the respondents opined that vegetation cover was destroyed by flood. It was observed during the transect survey that this area has small and scattered vegetation cover and the occurrence of flood cause loss of vegetation again. Due to the absence of sufficient vegetation cover incidence of erosion was also severe.
According to Williams and Kaputska (2000), environmental vulnerability can be seen as “the inability of an ecosystem to tolerate stressors over time and space”. Villa and McLeod (2002) stated that environmental vulnerability can be either intrinsic or extrinsic. Intrinsic vulnerability is related to factors internal to the system (ecosystem health and resilience), to the system (present exposure and external hazard).

Conclusion

Municipality of Angono is the worst victim of flood in the Province of Rizal for long time. It is observed that this municipality is affected by flood in almost three years interval. The change in climatic factor is observed as change in temperature, rainfall and seasonal pattern in the whole Philippines. Trend shows that there is an increase in prevalence of flooding with change in climate. Heavy precipitation in the wet season cause overflow of river and lake of Angono and four major lake shore barangays go under water. Among total ten barangays, four lakeshore barangays are impacted by flooding and area comprise about 17% of the total land area of the municipality. Data analysed from 1960- 2008 shows that the frequency of flooding in the Philippines is increasing rapidly with the change in climate. With the increment of flooding, the magnitude, damages and extent of flooding also spreading. Trend line analysis shows that the last flooding in 2009 in the Municipality of Angono was more severe than those previous ones. It is revealed from the study that children and old people are mostly exposed to the flooding and similarly adversely impacted by the hazard. Poor people were found more affected than the rich and middle class. It is also reflected that poor are mostly victimized due to their location of houses in the unprotected areas, poor housing which cannot resist against strong floods. The elevation of the affected area is 0- 5% which is also another cause of flooding as the lake water get swell for heavy rainfall. The overflow of water is influenced by loss of the depth of the lake due to huge sedimentation. Marginalized people living in the hazard area are impacted either by loss of livelihood or lowering of earning during and after the flood period. Survey output shows that 76% of the household heads in the area have no alternative livelihood. People who do not have alternative livelihood are worse victim because if only one way of livelihood is affected then there is no any other option for the victim to cope with the changed situation. These loss of livelihood increase more poor people which finally give rise to poverty in the country.

References

Asian Development Bank (ADB). (1994). Climate change in Asia: Philippines country report: regional study on global environmental issues. Manila: ADB.

Benson, C. (1997). The economic impact of natural disasters in the Philippines. (Working paper 99). London: Overseas Development Institute.

Centre for Disaster Preparedness (CDP), 2007. Child Oriented Participatory Risk Assessment and Planning: a Toolkit, pp. 1-20, Quezon City, Philippines.

Haase D. (2003) Holocene floodplains and their distribution in urban areas – functionality indicators for their retention potentials. *Landscape and Urban Planning* 66: 5-18.

IPCC, 2007. Climate Change, 2007. Synthesis Report – An Assessment of the Intergovernmental Panel on Climate Change. IPCC Secretariat, World Meteorological Organization, Geneva, Switzerland.

International Federation of Red Cross and Red Crescent Societies (IFRC and RCS), 2001.

World Disaster Report. Focus on Recovery. London: Eurospan, Bloomfield: Kumarian Press Inc.

International Strategy for Disaster Reduction(ISDR). .2002. Terminology: Basic terms of disaster reduction. Available at: http://www.unisdr.org/eng/library/lib-terminology-eng%20home.htm

Juanillo L.Edna. 2010. Overview on climate change/trends and impacts. Power pint presentation. Available at http://dprm.pids.gov.ph/PDFs/Climate%20ChangeDLSU%20%5BCompatibility%20Mode%5D.pdf.

Kasperson, Jeanne X., Kasperson, R.E., Turner II,.L., Hsieh, W., Schiller, A. (2002),Vulnerability to global environmental change, inThe human dimensions of global environmentalchange, Dieckmann, A., Dietz, T., Jaeger, C.,Rosa, A.E., (editori), MA: MIT Press

Municipal Environment and Natural Resource Office. 2010. Municipality of Angono.

Penning Rowsell,E.C. and Green, C.H. 2000. New insights in to the appraisal of the flood alleviation benefits. I. Flood damage and flood loss information. J.Inst. Water Environ.Manag. 14, 347-353.

Perez, R.T., Amadore, L.A. & Feir, R.B. (1999). Climate change impacts and responses in the Philippines coastal sector. Climate Research, 12: 97–107.

Perez. 2001. Country report Philippines. Paper presented in the conference on The economics of climate change in Southeast Asia: A regional review. ADB. Manila.2001

Presidential Taskforce on Climate Change (PTFCC). New risk and pressure.

Available at http://www.doe.gov.ph/cc/nrp.htm. Last accessed on June 19, 2010

Turner, B.L., Kasperson, R.E., Matson, A.P.,McCarthy, J.J., Corell, R.W., Christensen, L.,Eckley, N., Kasperson, J.X., Luers, A., Martello,M.L., Polsky, C., Pulsipher, A., Schiller, A., (2003), A framework for vulnerability analysis in sustainability science, Proceedings of the National Academy of Sciences, 100(14), 8074- 8079

UNDP 2004. Reducing Disaster Risk. A Challenge for Development. United Nations Development Programme, Bureau for Crisis and Recovery.

United Nations - Economic and Social Commission for Asia and the Pacific (UN- ESCAP). (1990). *Urban flood loss prevention and mitigation*. (Water resources series No. 68). New York: UN - ESCAP.

UNESCO-IHE 2010. Flood Vulnerability indices. Available at http://www.unesco-ihe-fvi.org/ Last access on 5th June 2010.

CLIMATE CHANGE AND SEASONAL BEHAVIORAL DISRUPTION OF CLIMATE PARAMETERS: A STUDY OF RAJSHAHI CITY

M. S. A. Salan[1] and M. S. Reza[1*]

ABSTRACT

Bangladesh is a country of divergent climatic condition throughout the year which has a complex influence in economic and social aspects, mainly for its geographic location and physiographic condition. Rajshahi division, located to the north western part of Bangladesh has a tropical wet and dry climate. The climate of Rajshahi is generally marked with monsoons, high temperature, considerable humidity and moderate rainfall. The objective of this study is to conduct a climatic study with 30 years (1987-2016) of climate data (rainfall, temperature, relative humidity, sunshine and wind speed) in order to observe the climate variability and to provide the projected changes in the climate variables for the next 20 years to ascertain the future seasonal variation for climate change. The station of Rajshahi city is selected for this study as Rajshahi is situated on the Barind track for which it is more vulnerable in case of drought. In order to fulfill the requirement of the objective secondary data from the Bangladesh Meteorological Department (BMD) has been collected. Trend analysis and regression analysis using SPSS and Excel software have been conducted to analyze the variation and trend line of climatic parameters during 1987-2016. The regression equations and the coefficient of determination (R^2) have been obtained through linear regression. The study found that the climate of Rajshahi is changing gradually which has a significant impact on the seasonal variation of climate parameters. The annual maximum temperature of 1987-2016 increased but the annual average rainfall showed a decreasing trend over the Rajshahi region by 5.64 mm per year. Again it is seen that July was the maximum monsoon rainfall month and December was the lowest rainfall month. The annual average relative humidity was found to increase. During summer season, approximately 4 hours sunshine is intense all over the year but during the winter season, which lasts for three months, intense sunshine is reduced to 2 hours. The monthly average wind speed in Rajshahi is about 3 knots or 5.56 km/h.

Keywords: Climate Change, Humidity, Rainfall, Sunshine, Seasonal Variation, Wind Speed.

Introduction

The impact of Climate change is now a regular phenomenon of the LDC's and middle income countries. According to the Intergovernmental Panel on Climate Change (IPCC) report, Bangladesh is under danger due to climate change along with the most vulnerable countries in the world (IPCC 2007). As a result, seasonal variability is becoming prominent with the change of temperature, rainfall, relative humidity, sunshine, wind speed and other climatic events due to climate change (Rakib, 2018).

The study area is Rajshahi which is located on the north western part of Bangladesh, situated on the bank of Padma river which is 120 km long and 4-8 km wide coming from the river of Ganga as a main distributary flowing towards Meghna river. But, Rajshahi city is experiencing unstable seasonal change and extreme heat variability during the recent years despite having a river like Padma (Sayeed and Mahmud, 2015). The construction of Farakka Barrage might also play a vital role in changing the climate as it interrupts the natural flow of the Padma river over the year (Karmakar and Hassan, 2018). For the geographical location of Rajshahi, there occurs extreme heat in summer and excessive cold in winter naturally which is now becoming acute and longer in a year for the reason of the excess use of underground water for the unplanned cultivation as there has a shortage of river water and rainfall (Sayeed and Mahmud, 2015).

Bangladesh is called a country of six seasons. But, after 90's the season was started to change unpredictably due to the adverse impact of climate change (Rahman, Jiban and Munna, 2015). Now-a-days, there has seen only three seasons (summer, rainy season and winter) in Rajshahi. But, due to climate change, the rainfall is also becoming irregular in rainy season which also accelerates higher temperature on the other side. The study has found out the change of the seasonal variation variability since 1987 and will give a prediction of the future change which is a continuous process due to climate change.

Materials and Methods

[1]*Graduate, Department of Urban and Regional Planning, Rajshahi University of Engineering and Technology, Rajshahi-6204, Bangladesh.*
Email of Corresponding Author – salmanreza91@gmail.com

Climate change affects the changing pattern of seasonal behavior and there has some prime variables (rainfall, temperature, relative humidity, sunshine and wind speed) work behind the reason of seasonal variability which is considered to assess the climatic condition. The prime variables data of Rajshahi was collected from the Bangladesh Meteorological Department (BMD) for the period 1987 to 2016. After analyzing the data, there also have made a forecast of the next 20 years in the future up to 2036. Central moving average (CMA) for 4 years has been calculated during the regression analysis to get a clear view of the seasonal fluctuation of climate variables from the baseline. To accomplish the analysis, trend analysis and regression analysis are wielded by the SPSS and Excel software. The result is discussed on the basis of analyzed SPSS data which will help to give a clear view of the climate variability of Rajshahi city.

Results and Discussions

The annual maximum temperature during the period 1987-2016 is 43.7 °C. Shaikh, (2004) reported that the average temperature of the season December –January, February-March, April-May, June-July, August-September, October-November is about 18.07, 22.80, 29.34, 29.91, 29.21 and 24.61°C The excessive temperature occurs in Rajshahi during June-July. The maximum temperature (about 29.91 °C) occurs in this time and the variation of temperature at this time is also maximum (about 0.70 °C). The annual maximum temperature showed a decreasing trend (Figure. 1) over Rajshahi region by 0.04 °C /year. The value of the coefficient of determination is 0.049046, which is significant at 0.23954 level.
Again, the study found that January is the coldest month (17.3 °C) in Rajshahi. From February till June temperature is found to be constant (not to increase) and from September up to January temperature tends to decline rapidly.

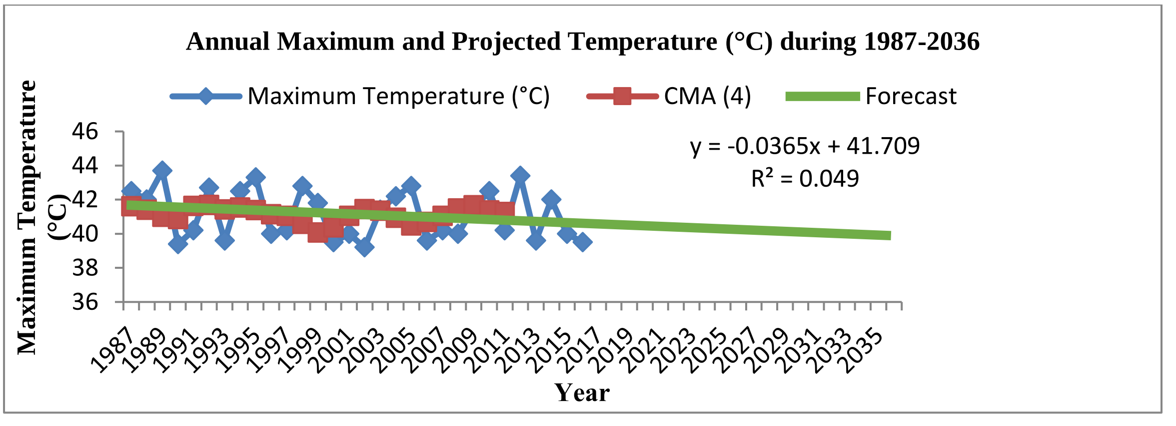


Figure 1. Annual maximum temperature, 4-year central moving average (CMA) and trend line during 1987-2036.

(Source: BMD, 2016)
The annual rainfall during the period 1987-2016 is 1995 mm/year. Average of the temporal variation of 360 months average rainfall record is 116 mm. The excessive rainfall occurs in Rajshahi during May-October. The maximum rainfall (about 300 mm) occurs in July. The annual average rainfall showed a decreasing trend (Figure. 2) over Rajshahi region by 5.64 mm/year. The value of the coefficient of determination is 0.0351, which is significant at 0.321 level.

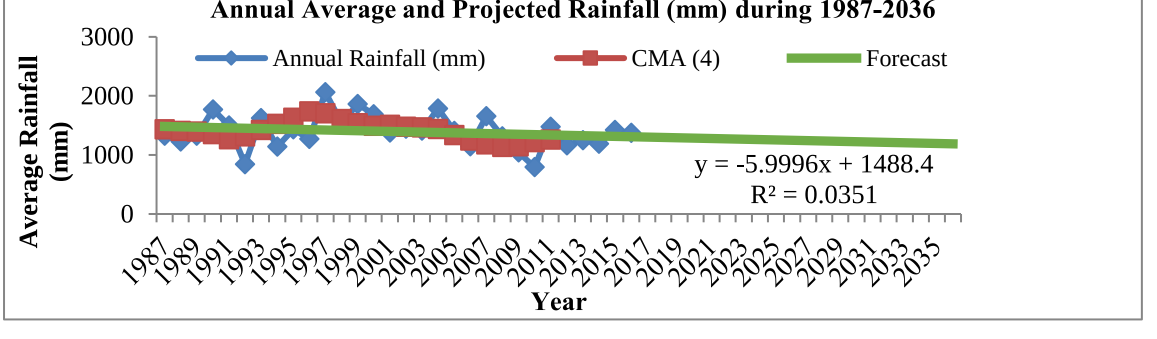


Figure 2. Annual average rainfall, 4-year central moving average (CMA) and trend line during 1987-2036.

(Source: BMD, 2016)

The annual average humidity during the period 1987-2016 is 938 %/year. Average of the temporal variation of 360 months average humidity record is 78 %. The excessive humidity occurs in Rajshahi during June-October. The maximum humidity (about 79 %) occurs in July. The annual average humidity showed an increasing trend (Figure. 3) over Rajshahi region by 0.1 %/year. The value of the coefficient of determination is 0.03514, which is significant at 0.076953 level.

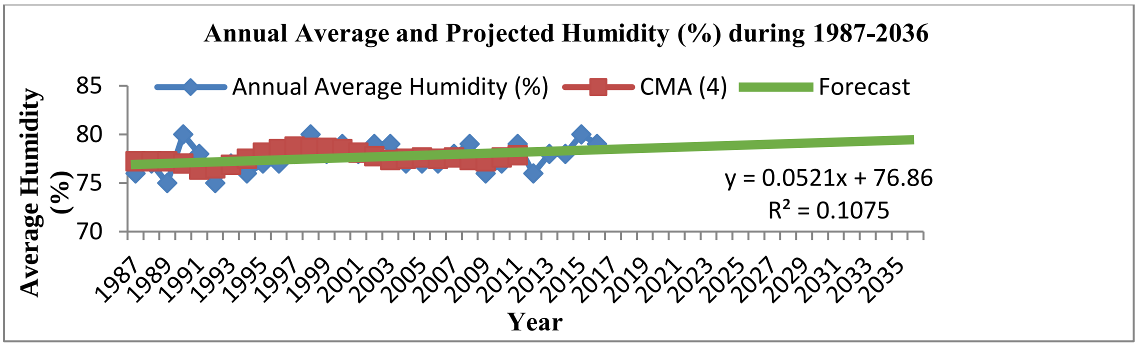


Figure 3. Annual average humidity, 4-year central moving average (CMA) and trend line during 1987-2036.

(Source: BMD, 2016)

The annual average sunshine during the period 1987-2016 is 73.5 hr/year. Average of the temporal variation of 360 months average sunshine record is 6.1 hr. At Rajshahi, during the summer season, approximately 4 hours of sunshine is intense all over the year. During the winter season, which lasts for three months, intense sunshine is reduced to 2 hours. The annual average sunshine showed a decreasing trend (Figure. 4) over Rajshahi region by 0.06 hr/year. The value of the coefficient of determination is 0.125066, which is significant at 0.055216 level.

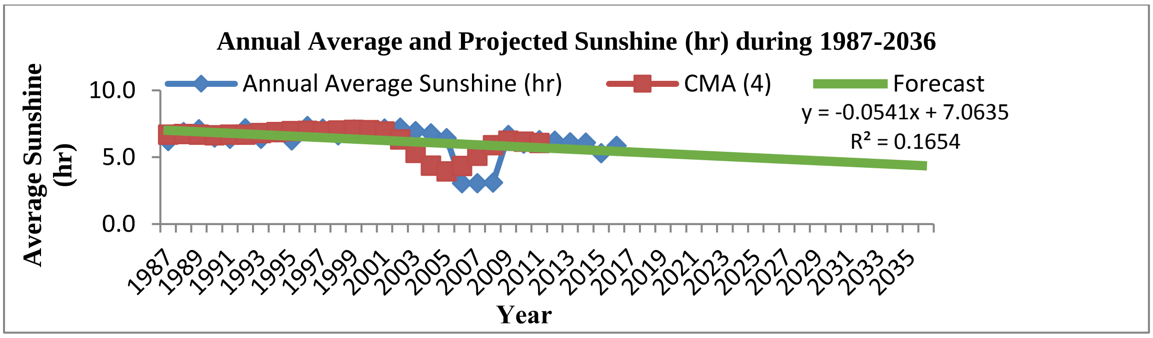


Figure 4: Annual average sunshine, 4-year central moving average (CMA) and trend line during 1987-2036.

(Source: BMD, 2016)

The annual average wind speed during the period 1987-2016 is 2.73 knots/year. Average of the temporal variation of 360 months average sunshine record is 2.73 knots. The monthly average wind speed in Rajshahi is about 3 knots or 5.56 km/h, which is regarded as a light breeze according to the international description (Shaikh, 2011). The annual average sunshine showed a decreasing trend (Figure. 5) over Rajshahi region by 0.04 knots/year. The value of the coefficient of determination is 0.655342, which is significant at 6.06E-08 level.

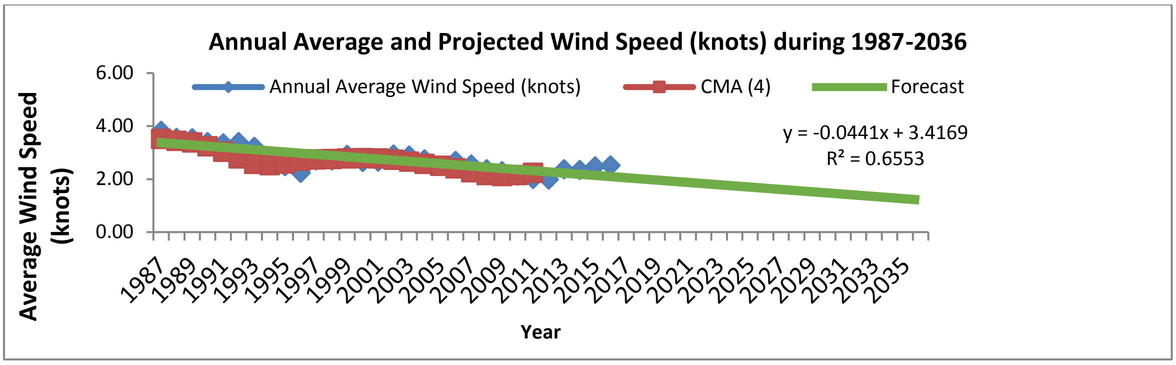


Figure 5. Annual average wind speed, 4-year central moving average (CMA) and trend line during 1987-2036.

(Source: BMD, 2016)

Conclusions

From the study, it can be concluded that the average rainfall, temperature, sunshine and wind speed show a decreasing trend and the average humidity shows an increasing trend. The seasonal components fluctuate greatly from the base line, which tends to cause seasonal behavioral disruption of climate parameters in the near future. Again, this study will help in future development control of the city. The knowledge derived from this study about the past, present and future rainfall, temperature, humidity, sunshine and wind speed will help in the development of any disaster risk reduction and climate change scenarios of Rajshahi which in turn support sustainable development goals and national, regional and community based resilience building frameworks.

References

Shaikh, M. N. U. (2011) "Hydro-morphological characteristics of the river Ganges (Bangladesh portion) and its impact on environment", Institute of Environmental Science (IES).

Rakib, Z. (2018) "Characterization of Climate Change in Southwestern Bangladesh: Trend *Analysis of Temperature, Humidity, Heat Index and Rainfall*", Climate Research, 76(3), 1616-1572, DOI: https://doi.org/10.3354/cr01535

Sayeed, M. A., and Mahmud M. A. K. (2015) "Vulnerable Climate in Rajshahi City Induced a *Great Effect of Temperature Due to Padma River*", International Conference on Recent Innovation in Civil Engineering for Sustainable Development, Department of Civil Engineering, DUET, Gazipur, Dhaka

Karmakar, S., and Hassan, A. (2018) "Climate chage and its impact on environment, agriculture *and water use at Rajshahi*", Journal of Engineering Science, 09(1), 075-4914.

Rahman, A., Jiban, M. J. H., and Munna, S. A. (2015) "*Regional Variation of Temperature and* Rainfall in Bangladesh: Estimation of Trend", Open Journal for Statistics, 5, 652-657 WOMEN'S

WOMEN'S VULNERABILITY DUE TO CLIMATE CHANGE IN THE COASTAL AREA OF BANGLADESH

Syed Monibul Hasan[1], Md.Be-Nozir Shah Shovon[2]

ABSTRACT

The study has been conducted to identify the women vulnerabilities, and explore the consequences of climate change on women in Kaikhali and Ramjannagar union under Shyamnagar upazila in Satkhira district. A detailed questionnaire survey has been carried out to achieve the key objectives of the study. A total of 142 household respondents, especially women have been selected by using simple random sampling. The study has found that the important roles and responsibilities of women in the family make them more vulnerable such as food collection and preparation (85.21% as first important responsibility); taking care of the children, elderly and sick (75.35% as second most important responsibility) during and after a disaster. The tendency to save their domestic materials and animals (92.25%), not taking decisions during emergency period (86.61%) and wearing traditional sari (89.43%) are the main barriers for the women to move to a secured place during disaster. Women is highly affected by different water borne diseases during disaster such as skin disease (76% in rank one), diarrhoea (60% in rank two). The study has found that the cyclone shelters in the study area are not women friendly. The destruction of houses and homestead (94.36%), crop production loss (92.25%), and livestock death (revealed by 81.69%) affect on women's economic livelihoods during cyclone and tidal surges. Adolescent girls are forced into early marriage (55.63%), their educational activities (89.43%) are disrupted; lactating mothers are severely affected with the lack of balanced nutrition (92.25%), and pregnant women don't get proper health care services (75.35%) in the aftermath of a disaster. The scarcity of safe drinking water (71.84% in rank one), and lack of proper shelters (41.55% in rank two) are the most important difficulties and complications for women during post disaster.

Introduction

Background of the Study

The southwest coastal region of Bangladesh is the most disaster-prone area in Bangladesh and is very vulnerable to the effects of the rise in sea level caused by climate change. It is estimated that the sea level in the region has been rising by 3-4 mm per year for last 30 years (Tanner, 2007). The horrible disasters, cyclones, tidal surges, floods, repeated water-logging, river erosion and land subsidence are common in this part of Bangladesh, shaping the lives and livelihood patterns of the people living in this part of the country.

Climate change affects everyone, it is not gender neutral. Climate change magnifies existing inequalities, reinforcing the disparity between women and men in their vulnerability and capability to cope with climate change (UNDP, 2007). During natural disasters, often more women die than men because they are not warned, cannot swim or cannot leave the house alone (UNFCCC COP, 2005). Women and children are more vulnerable to cyclones for various reasons. Women's unwillingness to leave their homes, a mother's protective instinct (being prepared to die trying to save her children), and the saree (women's clothing) and long hair of Bangladeshi women (hindering movement while trying to swim in tidal waves) have all been cited as reasons (Haque and Blair, 1992).

In the south-west region of Bangladesh, water logging has emerged as an alarming concern with health consequences. Women are often the primary caregivers of the family, shouldering the burden of managing and cooking food, collecting drinking water, and taking care of family members and livestock. Because of these responsibilities, women cannot avoid being exposed to hazardous living conditions like water borne diseases, and malnutrition. Women are forced to stay close to the community and drink unhygienic water, as tube-wells frequently become polluted. Pregnant women have difficulty with mobility and marooned in slippery conditions and thus are often forced to stay indoors and untimely fall victim to unhygienic reproductive health conditions (Neelormi, 2009). Women also rear children and collect firewood, so they cope with enormous physical burdens on a daily basis (Oxfam, 2006).

Since water sources in the neighborhood are all affected by high salinity, women need to travel long distances, sometimes up to ten kilometers by boat or raft every day over rough terrain, in search of potable water. This

[1] *Assistant Director, Program, Shushilan, Dhaka-1212, Bangladesh*
[2] *Monitoring Officer, TDH Italia in Bangladesh, Dhaka-1212,Bangladesh*
-palash@asia.com;md.benozirshah@gmail.com

consumes an enormous amount of their time (Fatema *et al*., 2008). Young girls often sacrifice their academic activities in a bid to fetch no saline water. Even during their pregnancy women are forced to fetch water irrespective of the distance between the source and their dwellings. Women and girls suffer from various gynecological problems in the long run for taking over extra hurdle of work in their daily life and by using saline water during menstruation. Premature birth, abortion and still birth are reported alarmingly high in numbers in these areas (Sharmin and Islam, 2013).

For girls and women, poor nutritional status is associated with an increased prevalence of anemia, and increased rates of intrauterine growth retardation, low birth weight and prenatal mortality (FAO, 2002). In addition, young mothers are often unable to successfully complete their pregnancies under famine conditions. This phenomenon is more critical when the mothers are pregnant with male infants because the male fetus requires more nutritional intake (Gebriel and Sevenhuysen, 1988). Women who are weakened by shortages of key elements of nutrition can suffer fatigue and loss of appetite, and consequently have lower

This aimed at assessing the vulnerability of the women due to climate change in Kaikhali and Ramzannagar union under Shyamnagar upazila of Satkhira district, attempts to identify the major women vulnerabilities due to natural disasters and to explore the consequences of climate change on women.

Justification of the Study

The biophysical and socio-economic condition in the south west coastal zone of Bangladesh is highly vulnerable to salinity intrusion, sea level rise, erosion, cyclone and tidal surges, water logging, which will be aggravated further under warmer climate particularly due to sea level rise. During extreme events such as, cyclone and tidal surges and other climate-related disasters, women are often the most affected. Women living in poverty generally have less access to local natural resources for their livelihoods. They represent the majority of the poor, the most malnourished, and the least educated, and face additional risks, due in large part to gender inequities that result in women bearing the disproportional brunt of disaster impacts.

Objectives of the Study with Specific Aims

The overarching goal of the research is to build an information source on specific aspects of vulnerability of women which would expose the scenario of vulnerability of women under natural disasters. Towards meeting the goal, the following appears to be the specific objectives of the study.

- To identify the women vulnerabilities due to natural disaster in the study area.
- To explore the consequences of climate change on women in the study area.

Scope of the Study

The study has been described in relation to women vulnerability in south west coastal zone of Bangladesh. Women experience acute and differential impacts given the accelerated pace of disaster vulnerability. These impacts exacerbate existing inequities in socially constructed roles, responsibilities, perceptions and skewed power relations that tend to disadvantage women.

Limitation of the Study

The primary obstacle for this study has been limited budget and time. The study has been done with very limited budget and in very short time. There have been some other obstacles as well. Collecting data from various offices was very tough.

Methodology

Study area of this study are-Kaikhali and Ranzannagar unions of Shyamnagar upazila is geographically a disaster prone area where two massive disasters (SIDR and AILA) have left serious mark on entire environment and human life. The women are more severely affected by those two devastating cyclones and they have been in all sorts of troubles since then. It is feasible to select this area for investigating the overall condition of women security (food security, shelter security, health security, social security etc) as this area is highly prone to natural disaster.Two types of data is considered-1. Primary Data: Field-level questionnaire survey.2. Secondary Data: Different printed and electronic materials.The Primary data are those which are collected afresh and for the first time, and thus happen to be original in character (Kotheri, 2009). In order to collect the primary information the following sequential order was to be followed:

The initial step of collecting of primary data is questionnaire preparation. It is very important in any social survey. The draft questionnaire was prepared on the basis of the data got by the reconnaissance survey on safe water supply, health and sanitation issues. The questionnaire was made as if it fulfilled the objectives of the study.Random sampling technique has been applied as sampling procedure. Primary data has collected mainly through questionnaire survey at November 2013. Different types of information have been collected from the local people. Some data has been collected through the self observation.

The Secondary data on hand are those which have already been collected by someone else and which have already been passed through the statistical process (Kothary, 2009). Secondary data is collected from the various sources. They are as follows:Bangladesh Bureau of Statistics, Khulna;Bangladesh Meteorological Department, Dhaka;Internet/ journal articles/web articles;Different related books;Published/Unpublished research report;Upazila Parishad;Union Parishad;Non-Government Organizations etc.

There are 35 villages (22 in Kaikhali and 13 in Ramzannagar) in this study area and from those villages, 142 women of different ages, conditions (married- unmarried, pregnant, adolescent etc) have been randomly selected as the sample of this study. They have their opinions on various issues regarding women security. Sometimes there have been similarities and dissimilarities regarding same issue which are accordingly presented in the result discussion chapter.Duration of the study wasFrom October 1, 2013 to December 31, 2013 (Three Months).

Field Findings and Analysis

Barriers for Women to Maneuver to Secured Place during Disaster

During disasters such as cyclone and tidal surges, women in general face some greater trouble while swimming or moving in the presence of wind and water, making it difficult for them to maneuver. The study has found the following troubles. Figure 4.4 shows 92.25% of respondents have revealed that the women tendency to save their domestic materials and animals,

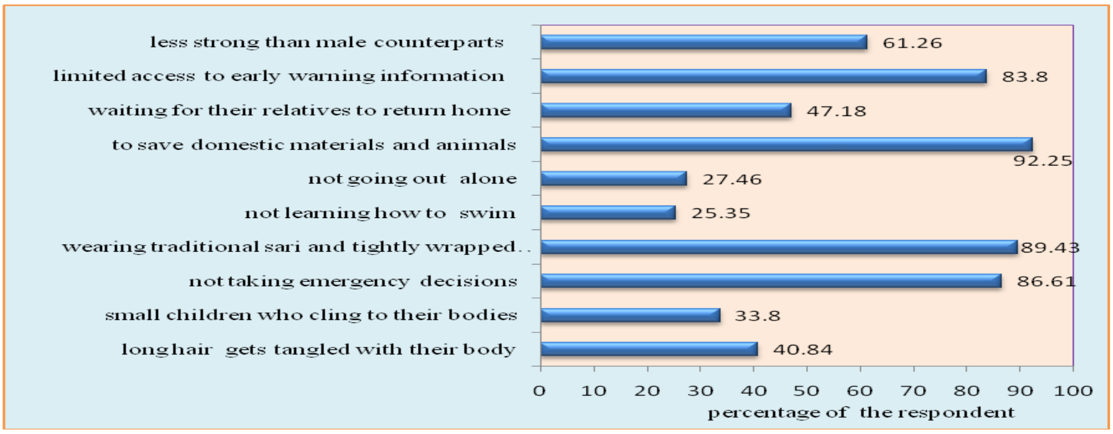


Figure 1. Barriers for women to maneuver during disaster

Impact on Women's Physical Security and Dignity

Women in the study areas still experience various types of violence such as physical, sexual, and mental that increases women vulnerability during and after a disaster.

Harassment in Relief Queues

Figure 4.7 represents the different harassment on women and adolescent girls while collecting relief during or after a disaster.

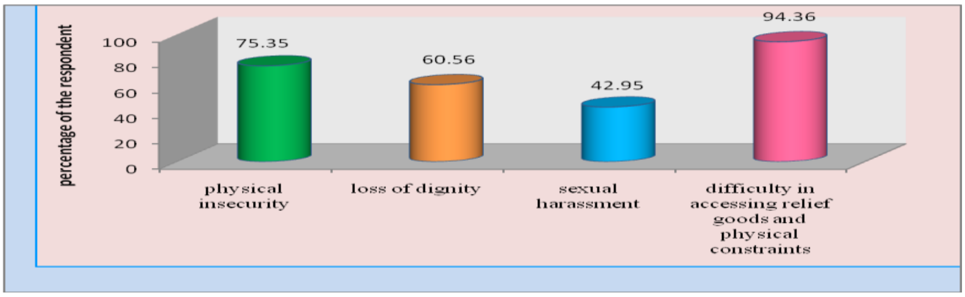


Figure 2: Harassment on women during collecting relief goods

Insecurity of Women in Cyclone Shelter

Cyclone shelter is the most important factor to secure lives during disaster. Although there are some cyclone shelters in the study areas, but that is not adequate compared to the demands of the community. The condition of cyclone shelters in the study areas is not found to be women-friendly, as reported by coastal cyclone vulnerable women. Women often do not go to the cyclone shelters due to an insecure environment there and hence, they prefer to stay back in residing spaces during a cyclone. The study has found that there are some troubles in the cyclone shelter and those troubles discourage women to go there.

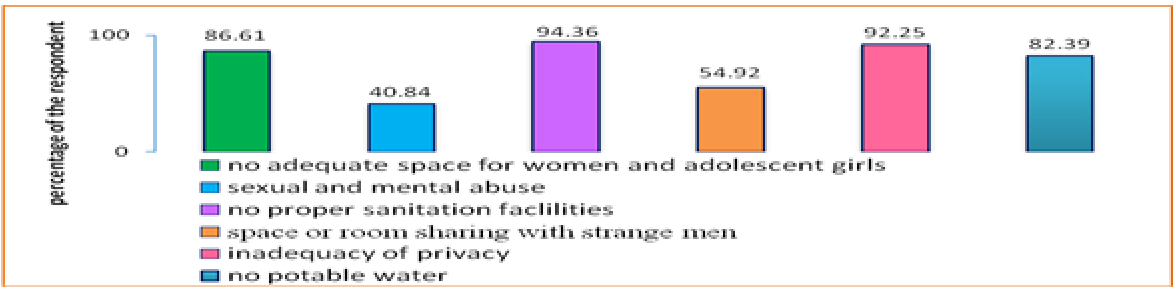


Figure 3: Causes that discourage women to go to the cyclone shelters

Women's Economic Contribution in the Aftermath of Disaster

Cyclone and tidal surges damage livestock, poultry, and fisheries. During and after weather disasters, the lack of fodder for livestock and poultry results in reduction of milk and meat production. Women play an important role in a wide range of income-generating activities in the aftermath of disaster, but their contribution to the national economy is largely uncounted for.

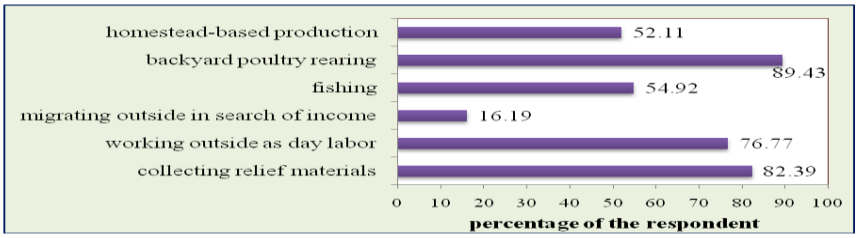


Figure 4: Women's economic contribution in the aftermath of disaster

Consequences of Environmental Vulnerabilities on Women Security

Adolescent girls, pregnant women, lactating mothers, the disabled and the aged make up particularly vulnerable groups in the aftermath of natural disaster through the different way. In the course of determining the impact of both natural and conflict-induced disasters on these social groups, it is imperative to note that their vulnerability to disasters can be created by certain social and economic processes. Underdeveloped infants increases. 83.80% respondents have revealed that inadequate access to food by pregnant women will severely compromise both the health of the woman and the fetus. 88.73% respondents have revealed that in case of pregnancy, women face even greater disadvantages regarding these self-rescue attempts due to their limited mobility, and are dependent on the support of husbands and other family members. 39.43% respondents have revealed that during and after disaster, family disruption occurs and support mechanisms are disappearing; 82.39% respondents have revealed that pregnant women cannot stroll in marooned condition; they are forced to stay back inside the residence and untimely fall victim to unhygienic reproductive health conditions.

Overall findings of the study are summarized below:
The study reveals that the respondents are staying for 11 to 20 years (44.37%), 21 to 30 years (26.05%) in the study area. So they have a good understanding of knowledge about differential vulnerability of women due to natural disasters. The study reveals that women have been affected by different climatic disasters in the study area, but the effect level is not same, almost all the respondents have considered that cyclone and tidal surges are the most influential disaster. Those women, who are more caring for their family (94.36%); poor; (86.61%), lactating and pregnet (97.57%), are more vulnerable in the study area. The tendency to save their domestic materials and animals (92.25%), not taking emergency decisions (86.61%), wearing traditional sari (89.43%) etc. are the greater trouble to maneuver to secured place during disaster. Women's roles and

responsibilities in the family make them more vulnerable to environmental changes such as food collection and preparation (85.21% as first important responsibility); taking care of the children, elderly and sick (75.35% as second most important responsibility); fetching water (40.85% as third most important responsibility), collecting cooking fuel, and cleaning of domestic waste materials etc. The community people, especially women is highly affected by water borne diseases during disaster such as skin disease (76% in rank one), diarrhoea (60% in rank two), dysentry (76% in rank three), cholera, and fever etc. About 94.36% respondents have revealed that they often face physical insecurity while collecting relief during or after a disaster. The study has found that there are some troubles in the existing cyclone shelter and those troubles discourage women to go there such as no proper sanitation facilities (94.36%); no adequate privacy (92.25%), no potable water, no adequate space, space sharing with unknown men, sexual and mental abuse etc.

The women economic livelihoods is demolished by the destruction of houses and homestead based production (94.36%), crop production loss (92.25%), and livestock death (81.69%), no access the market to buy or sell food such as milk, eggs, vegetables or other products due to the damages in infrastructure and communication system, reducing employment opportunities, especially for women working in agricultural fields etc. during cyclone and tidal surges. Adolescent girls are forced into early marriage (55.63%), their educational activities (89.43%) is disrupted during and after a disaster; and pregnant and lactating mothers are severely affected by lack of balanced nutrition (92.25%), and their health security and privacy is violated (93.66%) in the aftermath of a disaster. The women face the different difficulty and complication in the context of life by scarcity of safe drinking water (71.84% as first most important difficulty), lack of proper shelter (41.55% as second most important difficulty), lack of proper sanitary facilities, outbreak of diseases, limited access to food, and limited access to medical assistance during post disaster in the study area.

Conclusions

The harmful effects of climate changes can be felt in the short-term through natural hazards, such as cyclone and tidal surges, floods and water logging, salinity and in the long-term, through more gradual degradation of the environment. The adverse effects of these events are already felt in the study area, including in relation to agriculture and food security; biodiversity and ecosystems; water resources; human health; human settlements and social protection, and communications etc. In that situation, the community people, especially women are more vulnerable in different ways in the study area.

References

Action Aid International, 2005. *Participatory Vulnerability Analysis: A step-by-step Guide for Field Staff.* Web address: http://www.actionaid.org.uk/doc_lib/108_1_participatory_vulnerability_analysis_guide.pdf>

Aguilar, L. 2004. Climate Change and Disaster Mitigation- Gender Makes the Difference. Available on-line: Web address: <http://www.iucn.org/congress/women/Climate.pdf>

Ariyabandu, M.M. and Wickramasinghe, M. 2003. *Gender Dimensions in Disaster Management: A Guide for South Asia*, Colombo: ITDG (Intermediate Technology Development Group) South Asia Publications. Available from: ITDG South Asia, 5 Lionel Edirisinghe Mawatha, Kirulapone, Colombo 5, Sri Lanka. Pp. 45.

Baten, M. A. and Khan, N. A. 2010. Gender issue in climate change discourse: theory versus reality. Unnayan Onneshan: The Innovators. Dhanmondi, Dhaka, Bangladesh.

BBS, 2011. Population and Housing Census. Community Report, Khulna Zila. Statistics and Informatics Division Ministry of Planning, Dhaka. Web address: (http://www.bbs.gov.bd/dataindex/stat_bangladesh.pdf).

Bern, C.; Sniezek, J. and Mathbar, G. M. 1993. Risk factors for mortality in the Bangladesh Cyclone of 1991. Bulletin of the World Health Organization, 71: 73-78.

Bradshaw, S. 2004. Socio-economic Impacts of Natural Disasters: a gender analysis. United Nations Economic Commission for Latin America (ECLA). Serie Manuales 32.

Cannon, T. 2002. Gender and climate hazards in Bangladesh. Gender and Development, 10: 45-50.

Dankelman, I. 2008. Gender and Climate Change: local security in an era of global environmental change. Draft. Radboud University, Nijmegen.

FAO, 2000. Gender and Nutrition. On-line document, Retrieved on December 24, 2012. Web (URL) address: http://www.fao.org/sd/2001/PE0703a_en.htm.

FAO, 2002. The state of food insecurity in the world: Food insecurity – when people must live with hunger and fear of starvation Rome, Food and Agriculture Organization.

Farhana, S. 2011. Suitability of Pond Sand Filters As Safe Drinking Water Solution in Storm Surge Prone

Areas of Bangladesh: A Case Study Of Post-Aila Situation In Shyamnagar, Satkhira District, Khulna.

IUCN, 2007. Gender and Climate Change: women as agents of change. Climate change briefing paper.

Islam, A. 2010. Women’s Views on News. Natural disasters impact women worse than men. Retrieved on December 15, 2012. Web address: http://www.womensviewsonnews.org/wvon/2010/natural-disasters-impact-women-worse-than-men/

IUCN, 2009. How Natural Disasters Affect Women. Web address: http://www.iucn.org/knowledge/news/events/isdr/?3373/How-natural-disasters-affect-women

A STUDY ON THE NATURE OF CLIMATE CHANGE INDUCED HAZARDS IN THE URBAN AREAS OF BANGLADESH.

Nawshin Tabassum[1], Dr. Ishrat Islam[2]

ABSTRACT

Bangladesh is one of the most vulnerable countries to climate change which is facing consequent diversified natural hazards because of its location, unique physiographic feature and different socio-economic factors. The urban areas of Bangladesh have been facing the impact of climate change on infrastructure system, water supply system, energy system, wastewater management system, transportation system, housing sector and human health sector etc. The aim of this paper is to identify the most vulnerable urban areas in Bangladesh due to climate change along with the nature of climate change induced hazards. Most of the vulnerable urban areas due to the impacts of climate change are situated on the south side of Bangladesh. Twelve A class Pourashavas, four B class Pourashavas, three C class Pourashavas and two city corporations are situated in the most vulnerable zone due to climate change. These urban areas face multiple climate change induced hazards. Magura Pourashava, Narail Pourashava and Satkhira Pourashava are facing severe climate induced flood, drought and temperature rise while Paikgacha Pourashava faces climate change induced drought, saline intrusion and temperature rise. This research would help policy makers, planners and other stakeholders to identify the most vulnerable urban areas facing climate change and thereby take necessary steps to improve the condition.

Keywords: Climate change, Urban areas, Hazards, Vulnerable.

Introduction

Bangladesh is one of the most vulnerable countries to climate change which is facing climate change induced hazards such as rising sea levels and storm surges, heat stress, extreme precipitation, inland and coastal flooding, landslides, salinity intrusion, drought, increased aridity, water scarcity and air pollution (Das and Hossain, 2017; Ayers et al., 2014; Kabir, 2014; Ahmed 2012; Das, 2010; Rahman and Alam, 2003; Huq, 2001; Revi et al., 2014, Rashid et al., 2009). These impacts are increasing with widespread negative impacts on people, their health, livelihoods and assets and also on local and national economies and ecosystems (Revi et al., 2014). According to Ministry of Environment and Forests (2012), Bangladesh loses 1.5% of its Gross Domestic Product (GDP) due to increased frequency and intensity of these climate change induced hazards. Sustainable Development Goal 13, Seventh five-year plan (FY 2016- FY 2020), National Environmental Policy (2013), Bangladesh Delta Plan (2100), Perspective Plan of Bangladesh (2010-2021) etc. also aim at taking actions to combat climate change and its impacts (United Nations, 2015; Bangladesh Planning Commission, 2012; Bangladesh Planning Commission, 2015; Bangladesh Planning Commission, 2018; Ministry of Environment and Forests, 2013)

Urban areas of Bangladesh are categorized as city corporations, A, B, and C class Pourashavas based on the minimum of annual revenues collected over last three years (Local Government Engineering Department, 2017). There are twelve City Corporations and 318 Pourashavas in Bangladesh which accommodate 36.5% of the total population (Local Government Engineering Department, 2017; Department of Economic and Social Affairs, 2017). According to Department of Economic and Social Affairs (2017), urban population of Bangladesh will exceed rural population by 2030. About 60% of the urban population reside in the city corporations (Parvin et al., 2013). Economic opportunities are also concentrated in the largest cities of Bangladesh (Ahmed and Ahmed, n.d.). The contribution of these urban areas to GDP was about 65% in 2012 (Ahmed and Ahmed, n.d.). Climate change will increase rural urban migration which would add to the existing challenges of the cities of Bangladesh from socio-economic and environmental contexts (Martin et al., 2013; International Organization for Migration, 2010).

Intergovernmental Panel on Climate Change (2014) shows that, climate change would have influence on water supply systems, built infrastructure, energy systems, food systems and security, transportation and communication systems, key economic sectors, livelihoods and access to basic services in urban areas. Globally a number of cities such as Greater Manchester, Dar es Salaam, Durban, London, New York city,

[1] Lecturer, Dept. of Urban and Regional Planning, BUET, Dhaka-1000, Bangladesh.
[2] Professor, Dept. of Urban and Regional Planning, BUET, Dhaka-1000, Bangladesh
Email of Corresponding Author – nawshin@urp.buet.ac.bd

Denver, Lagos, Santiago de Chile, Mexico City, Leicester City, Esmeraldas, Milwaukee etc. have been facing these impacts of climate change and already have taken mitigation and adaptation policies, plans and programs (Revi et al., 2014; Gill et al., 2007; Bulkeley and Betsill, 2013; Rosenzweig et al., 2011)
As, most of the population and income generating activities are concentrated in the urban areas, climate change would have huge impact in urban areas of Bangladesh. This research aims at exploring the impact of climate change in different urban areas of Bangladesh and identify the most vulnerable urban areas.

Research Framework

Data has been collected from secondary sources. Maps showing climate change induced drought, flood, storm surge inundation, salinity intrusion, temperature rise and excessive precipitation have been collected from Bangladesh Planning Commission (2018), Matthew et al. (2015), Rabbani and Haq (2016) and BCAS (2010). GIS Shape file showing the urban areas of Bangladesh also has been collected from Rahman et al. (2018). Vector overlay has been used to identify the most vulnerable urban areas due to climate change. Table 1 shows the parameters used, indicator of the parameter, weight given on the parameter, rank of the type of parameter etc. for vector overlay. Natural Break (Jenks) method has been used to classify the overlay values into less vulnerable (0-0.8), vulnerable (0.9-1.5) and most vulnerable (1.6-2.5) clusters.

Table 1. Suitable range of criteria for vector overlay (Author, 2018)

Parameters	Indicator	Weight	Types	Suitability parameter	Rank	Source
Climate change induced drought	Severity of drought	0.167	Unaffected	Not vulnerable	0	BCAS, 2010
			Moderate	Less vulnerable	1	
			Severe	Moderate vulnerable	2	
			Very severe	Most vulnerable	3	
Climate change induced saline intrusion	Inundation risk zone	0.167	Unaffected	Not vulnerable	0	PC, 2018
			1-5 ppt	Less vulnerable	1	
			5-15 ppt	Moderate vulnerable	2	
			>15 ppt	Most vulnerable	3	
Climate change induced flood	Flood depth	0.167	Unaffected	Not vulnerable	0	Rabbani and Haq, 2016
			< 30 cm	Less vulnerable	1	
			30-60 cm	Moderate vulnerable	2	
			> 60 cm	Most vulnerable	3	
Climate change induced storm surge	Inundation risk zone	0.167	Unaffected	Not vulnerable	0	PC, 2018
			1-3 m	Less vulnerable	1	
			3-6 m	Moderate vulnerable	2	
			> 6 m	Most vulnerable	3	
Temperature change	Annual average temperature	0.167	24.49 -25.61^{0}C	Not vulnerable	0	Matthew et al., 2015
			25.62 -26.31^{0}C	Less vulnerable	1	
			26.32 -27.01^{0}C	Moderate vulnerable	2	
			27.02 -28.15^{0}C	Most vulnerable	3	
Climate change induced precipitation	Annual average precipitation (in mm/day)	0.167	3.06- 4.98	Not vulnerable	0	Matthew et al., 2015
			4.99- 7.67	Less vulnerable	1	
			7.68-10.19	Moderate vulnerable	2	
			10.20-12.37	Most vulnerable	3	

Urban areas of Bangladesh

Pourashavas

According to LGED (2017), the Pourashavas have been classified into three types based on the minimum of annual revenues collected over last three years. A class Pourashavas has income more than BDT 6 million while B Class has income BDT 2.5 to 6 million and C Class Pourashavas has income less than BDT 2.5 million (LGED, 2017). There are 154 A class Pourashavas, 99 B class Pourashavas, 61 C class Pourashavas among the urban areas (Rahman et al., 2018).

City Corporation

There are 12 city corporations in Bangladesh. The city corporations are Chittagong City Corporation (CCC), Comilla City Corporation (COCC), Dhaka North City Corporation (DNCC), Dhaka South City Corporation (DSCC), Gazipur City Corporation (GCC), Narayanganj City Corporation (NCC), Barisal City Corporation

(BCC), Khulna City Corporation (KCC), Mymensingh City Corporation (MCC), Rajshahi City Corporation (RCC), Rangpur City Corporation (RACC) and Sylhet City Corporation (SCC). (City Corporations of Bangladesh, 2014)

Urban Areas in Different Climate Change Induced Hazard Zones

Table 2 shows the distribution of urban areas facing different types of climate change induced hazards such as drought, saline intrusion, flood, storm surge, temperature rise and extreme precipitation. The table shows that, two city corporations faces severe drought (GCC and RCC), one faces severe saline intrusion (Cox's Bazar city corporation), three faces severe flood (BCC, KCC and NCC), two faces temperature rise (KCC and RCC) and two faces extreme precipitation (SCC and Cox's Bazar city corporation).

Table 2: Distribution of urban areas facing different types of climate change induced hazards

Type of hazard	**Impact**	**Type of urban area***				**Total**
		A	B	C	City Corporation	
Climate change induced drought	Unaffected	53	39	23	3	118
	Moderate	31	8	13	5	57
	Severe	40	28	14	2	84
	Very severe	30	24	11	2	67
Climate change induced saline intrusion	Unaffected	137	91	57	9	294
	Less saline intrusion (1-5 ppt)	13	3	0	1	17
	Moderate saline intrusion (5-15 ppt)	3	4	1	1	9
	Severe saline intrusion (>15 ppt)	1	1	3	1	6
Climate change induced flood	Unaffected	79	50	33	7	169
	Less flood depth (< 30 cm)	28	24	15	1	68
	Medium flood depth (30-60 cm)	24	12	4	1	41
	Severe storm surge (> 60 cm)	23	13	9	3	48
Climate change induced storm surge	Unaffected	119	80	50	8	257
	Less storm surge depth (1-3 m)	11	6	4	3	24
	Medium surge depth (3-6 m)	16	10	3	1	30
	Severe storm surge depth (> 6 m)	8	3	4	0	15
Temperature change	Unaffected (24.49^{0}C -25.61^{0}C)	6	2	3	1	12
	Less (25.62^{0}C -26.31^{0}C)	20	9	11	1	41
	Moderate (26.32^{0}C -27.01^{0}C)	76	57	33	8	174
	Severe (27.02^{0}C -28.15^{0}C)	52	31	14	2	99
Climate change induced precipitation	Less (3.06- 4.98 mm/ day)	23	17	8	1	49
	Less medium (4.99- 7.67 mm/day)	91	61	32	8	192
	Medium (7.68-10.19 mm/day)	37	17	21	1	76
	Severe (10.20-12.37 mm/day)	3	4	0	2	9

**Compiled by author from Bangladesh Planning Commission, 2018; Matthew et al., 2015; Rabbani and Haq, 2016; Bangladesh Centre for Advanced Studies, 2010 and Rahman et al., 2018*

Figure 1-6 shows the spatial distribution of the urban areas in different climate change induced hazard prone areas. Figure 1 shows that the west side of Bangladesh is in the climate change induced drought prone area and 30 A class Pourashavas, 24 B class Pourashavas and 11 C class Pourashavas are situated here. Similarly, figure 2, 3 and 4 shows that, most of the climate change induced flood, salinity intrusion and storm surge will occur in the south side of Bangladesh. Figure 5 and 6 shows the climate change induced temperature change and precipitation in Bangladesh.

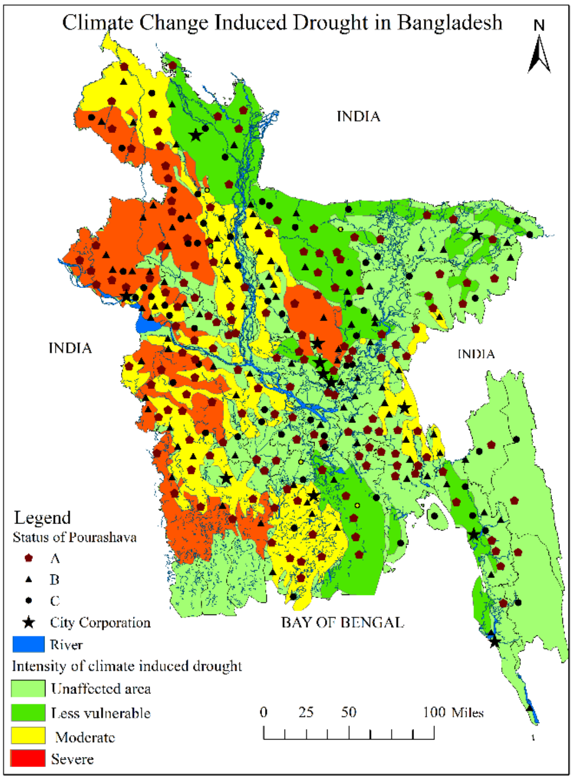


Figure 1: Urban areas facing climate induced drought in Bangladesh. (Base map source: Bangladesh Centre for Advanced Studies, 2010)

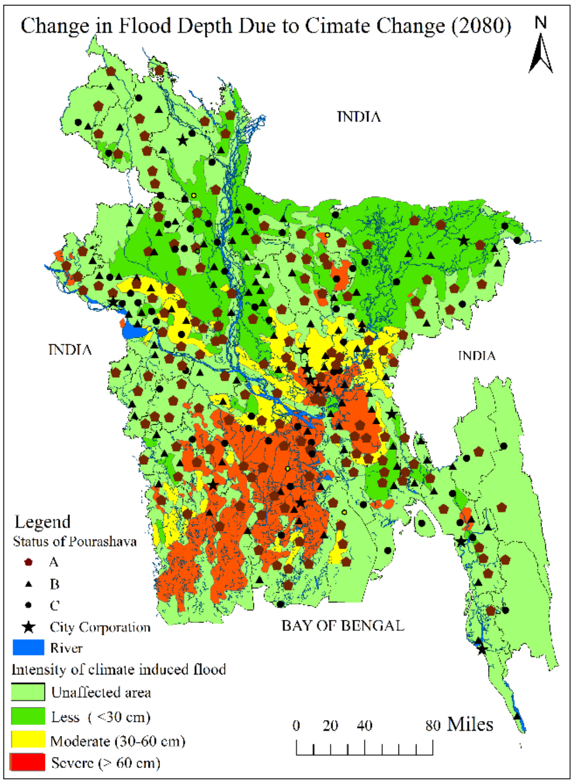


Figure 2: Urban areas facing climate induced flood in Bangladesh. (Base map source: Rabbani and Haq, 2016)

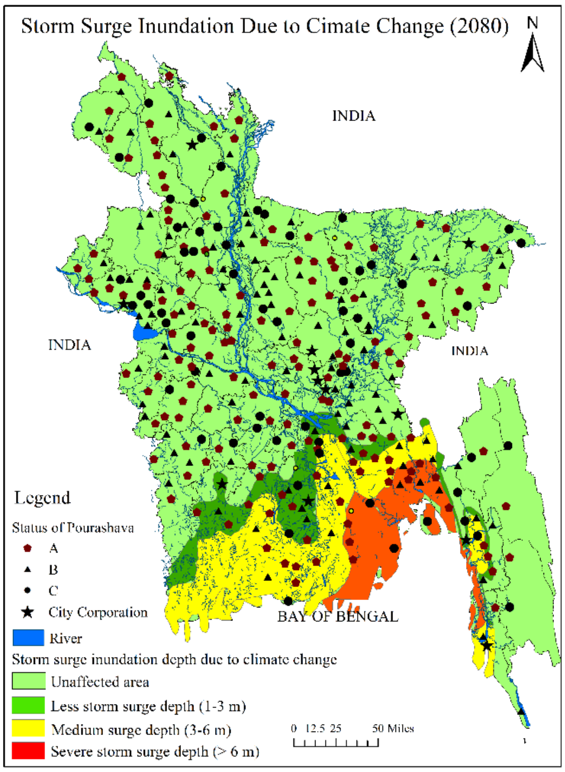


Figure 3: Urban areas facing climate induced storm surge in Bangladesh. (Base map source: Bangladesh Planning Commission, 2018)

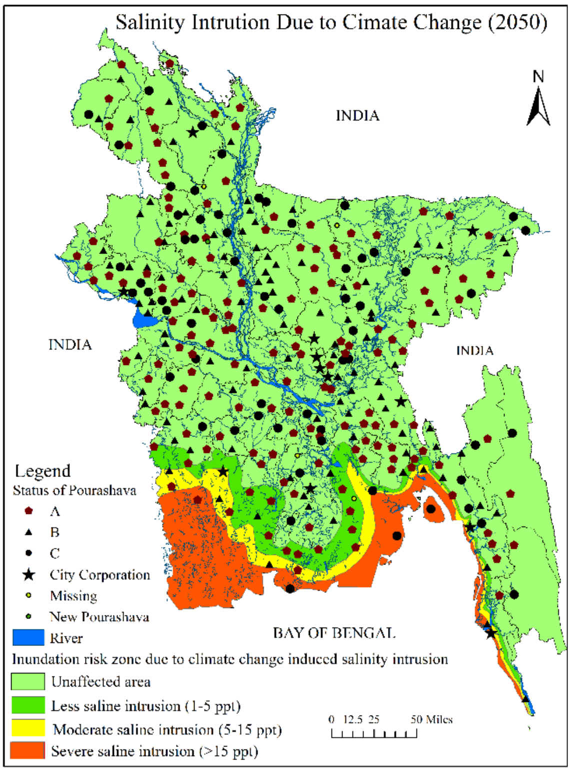


Figure 4: Urban areas facing climate induced salinity intrusion in Bangladesh. (Base map source: Bangladesh Planning Commission, 2018)

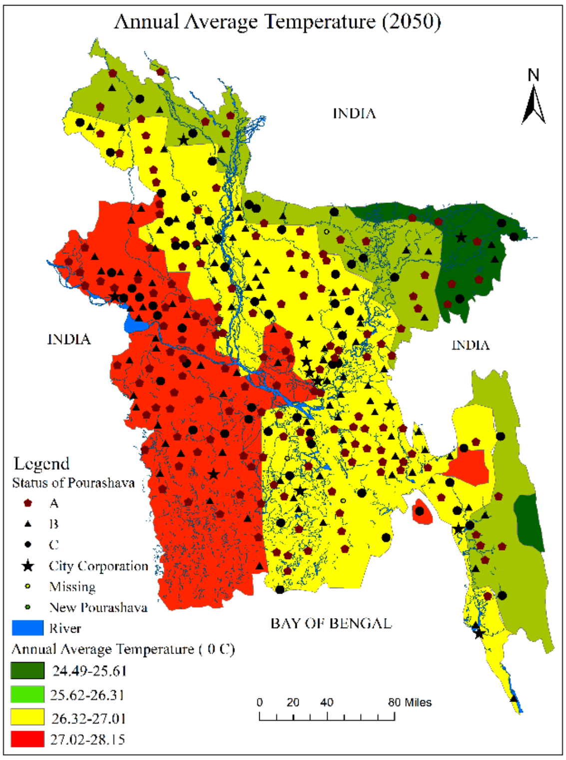


Figure 5: Urban areas facing climate induced temperature rise in Bangladesh. (Base map source: Matthew et al., 2015)

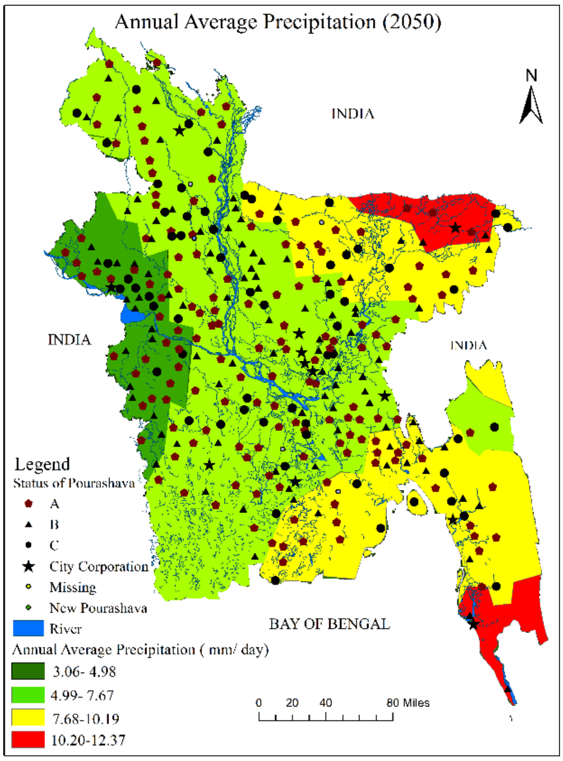


Figure 6: Urban areas facing climate induced precipitation in Bangladesh. (Base map source: Matthew et al., 2015)

These urban areas in the most vulnerable zones face multiple climate change induced hazards (Figure 1-6). Magura Pourashava, Narail Pourashava and Satkhira Pourashava are facing severe climate induced flood, drought and temperature rise. Feni Pourashava faces severe draught, moderate temperature rises and extreme precipitation. On the other hand, Paikgacha Pourashava faces drought, saline intrusion and temperature rise.

Vulnerability of the Urban Areas Considering Climate Change Induced Hazards

After performing vector overlay, the most vulnerable urban areas due to climate change induced hazards has been identified. Table 3 shows that, there are twelve A class Pourashavas, four B class Pourashavas, three C class Pourashavas and two city corporations in the most vulnerable zone due to climate change.

Table 3: Vulnerable urban areas considering all the climate change induced hazards

Type of urban area	Less vulnerable	Vulnerable	Most vulnerable
A Class Pourashavas	75	67	12
B Class Pourashavas	43	52	4
C Class Pourashavas	33	25	3
City Corporation	5	5	2
Total	156	149	21

Figure 7 shows the spatial distribution of the urban areas in the vulnerable zone of climate change. A class Pourashavas in the vulnerable zones are Pirojpur Pourashava, Feni Pourashava, Magura Pourashava, Amtali Pourashava, Burhanuddin Pourashava, Kalapara Pourashava, Lalmohan Pourashava, Mongla Port Pourashava, Satkhira Pourashava, Bagerhat Pourashava, Narail Pourashava and Paikgacha Pourashava. B class Pourashavas in the vulnerable zones are Morrelganj Pourashava, Baufal Pourashava, Chalna Pourashava and Maheshkhali Pourashava. Again, C class Pourashavas in the vulnerable zones are Hatiya Pourashava, Ramgati Pourashava and Sandwip Pourashava. KCC and Cox's bazar city corporation are also situated in the most vulnerable area.
Allocation of BCCTF (Bangladesh Climate Change Trust Fund) shows that, among the most vulnerable 21

urban areas, BCCTF funded projects have been taken in only 12 urban areas (BCCT, 2017). Nine projects have been taken in A class Pourashavas (Pirojpur Pourashava, Feni Pourashava, Magura Pourashava, Amtali Pourashava, Burhanuddin Pourashava, Kalapara Pourashava, Lalmohan Pourashava, Mongla Port Pourashava and Satkhira Pourashava), two projects have been taken in B class Pourashavas (Morrelganj Pourashava and Baufal Pourashava) and one project has been taken in KCC (BCCT, 2017). Again, no project has been taken in the most vulnerable C class Pourashavas (BCCT, 2017). BCCT (2017) also shows that, four projects have been taken in Pirojpur Pourashava, three projects in Feni Pourashava and two projects in Magura Pourashava and Morrelganj Pourashava.

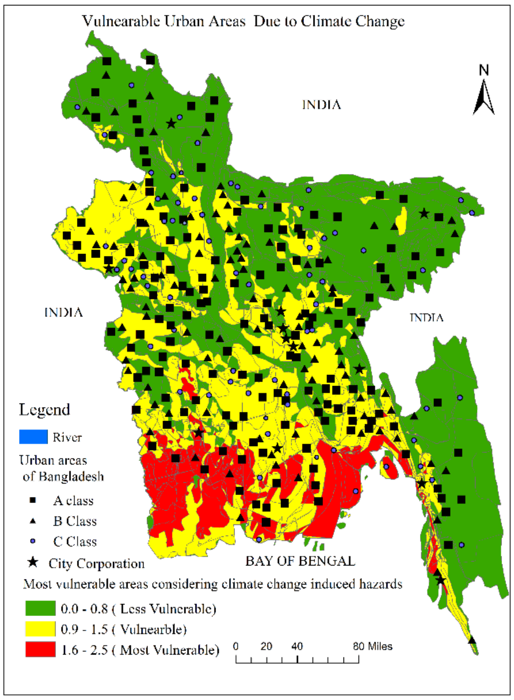


Figure 7: Urban areas of Bangladesh in the vulnerable areas of climate change induced hazards.

(Source: Author, 2018)

Conclusions

The urban areas of Bangladesh are facing climate change induced drought, flood, storm surge inundation, salinity intrusion, temperature rise and excessive precipitation etc. which have influence on water supply systems, waste water system, green built infrastructure, energy systems, food systems, transportation and communication systems, housing sector, human health sector etc. This research identifies the most vulnerable urban areas of Bangladesh along with the type of climate induced hazards in the urban area. Most of the vulnerable urban areas facing climate change induced hazards are situated on the south side of Bangladesh. This research also shows that, twelve A class Pourashavas, four B class Pourashavas, three C class Pourashavas and two city corporations are situated in the most vulnerable zone. So, necessary adaptation and mitigation measures should be taken for addressing the climate change induced hazards in these vulnerable urban areas. Future climate fund allocation should also consider these vulnerable urban areas.

References

Ahmed, F.R.S. (2012). *Climate Change Issues in Bangladesh & Need for Adaptation to Climate Change.* Retrieved November 17, 2017, http://www.ilo.org/wcmsp5/groups/ public/@asia/@ro-bangkok/@ilodhaka/documents/presentation/wcms_181127.pdf

Ahmed, S.S., Ahmed, M. (n.d). *Urbanization and Economic Development of Bangladesh: The Primacy of Dhaka and Competitiveness.* Retrieved November 17, 2017, from http://bea-bd.org/site/images/pdf/new17/4.pdf.

Ayers, J. M., Huq, S., Faisal, A. M., & Hussain, S. T. (2014). Mainstreaming climate change adaptation into development: a case study of Bangladesh. Wiley Interdisciplinary Reviews: *Climate Change, 5(1),* 37-51. Retrieved 5 November, 2017 from www.academia.edu/download/44499422/Mainstreaming_climate_change_adaptation_20160407-30460-g32qx1.pdf

Bangladesh Centre for Advanced Studies (BCAS). (2010). *Case study: Local Capacity Building for Advancing Adaptation to Climate Change in Floodplains and Coastal Areas of Bangladesh*. Retrieved November 19, 2018, from https://www.slideshare.net/SCRpresentations/bcas-casescrregional-wp-readonly

Bangladesh Climate Change Trust (BCCT) (2017). *Bangladesh Climate Change Trust Fund*, Available from Ministry of Environment and Forests, Government of Bangladesh, Dhaka.

Bangladesh Planning Commission (PC). (2012). *PERSPECTIVE PLAN OF BANGLADESH 2010-2021*.Government of the People's Republic of Bangladesh. Retrieved November 19, 2018, from http://bangladesh.gov.bd/sites/default/files/files/bangladesh.gov.bd/page/6dca6a2a_9857_4656_bce6_139584b7f160/Perspective-Plan-of-Bangladesh.pdf

Bangladesh Planning Commission (PC). (2015). *SEVENTH FIVE YEAR PLAN, FY 2016- FY 2020.* Government of the People's Republic of Bangladesh. Retrieved 19 November, 2018, from http://www.lged.gov.bd/UploadedDocument/UnitPublication/1/361/7th_FYP_18_02_2016.pdf

Bangladesh Planning Commission (PC). (2018). *Bangladesh Delta Plan 2100*. Government of the People's Republic of Bangladesh.

Bulkeley, H. & Betsill, M.M. (2013). *Cities and climate change*. Routledge. Retrieved November 19, 2018 from https://zodml.org/sites/default/files/%5BHarriet_Bulkeley%2C_Michele_Merrill_Betsill%5D_Urban_.pdf

Das, A., & Hossain, N. (2017). APPRAISING CLIMATE CHANGE IMPACT MITIGATION STANDARDS TO GROUND REALITIES: THE LESSONS FROM BANGLADESH CLIMATE CHANGE TRUST FUNDED PROJECTS. Proceedings, *International Conference on Disaster Risk Mitigation, (pp. 1-4).* Dhaka. Retrieved November 15, 2017, from https://www.researchgate.net/publication/320297889_APPRAISING_ CLIMATE_CHANGE_IMPACT_MITIGATION_STANDARDS_TO_GROUND_REALITIES_THE_LESSONS_FROM_BANGLADESH_CLIMATE_CHANGE_TRUST_FUNDED_PROJECTS

Das, P. (2010). *Climate Change and Education, Bangladesh. Genesis*. Retrieved November 17, 2017, from http://www.unisdr.org/files/16355_climatechangeedbangladesh.pdf

Department of Economic and Social Affairs. (2017). World Population Prospects: The 2017 Revision. Retrieved November 12, 2018, from *Worldometers:* http://www.worldometers.info/world-population/bangladesh-population/

City Corporations of Bangladesh. (2014). Retrieved February 9, 2018, from https://www.bdweb24.com/index.php/2014-01-27-07-01-53/city-corporations-of-bangladesh

Gill, S. E., Handley, J. F., Ennos, A. R., & Pauleit, S. (2007). Adapting cities for climate change: the role of the green infrastructure. *Built environment*, 33(1), 115-133. Retrieved November 19, 2018 from https://www.fs.usda.gov/ccrc/sites/default/files/Gill_Adapting_Cities.pdf

Huq, S. (2001). Climate change and Bangladesh. *Science*, *294(5547)*, 1617-1617. Retrieved 16 November 2017 from http://science.sciencemag.org/content/294/5547/1617

Intergovernmental Panel on Climate Change. (2014). *Climate Change 2014–Impacts, Adaptation and Vulnerability: Regional Aspects.* Cambridge University Press.

International Organization for Migration. (2010). *Assessing the Evidence: Environment, Climate Change and Migration in Bangladesh.* Retrieved November 17, 2017, from https://iom.org.bd/wp-content/uploads/2017/06/Environment-ClimateChange-and-Migration-in-Bangladesh-1.pdf

Kabir, S. E. (2014). *Effective Utilization of Climate Change Trust Fund in Adaptation Programs in Bangladesh: A Focus on Stakeholder Participation.* BRAC University, Institute of Governance Studies. Retrieved November 5, 2017, from https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwjUppG91LTXAhXFRo8KHXiQBcIQFggmMAA&url=http%3A%2F%2Fdspace.bracu.ac.bd%2Fxmlui%2Fbitstream%2Fhandle%2F10361%2F3533%2F13372008.pdf%3Fsequence%3D1%26isAllowed%3Dy&usg=A

Local Government Engineering Department (LGED). (2017). Retrieved February 9, 2018, from *Urban Management Unit:* http://www.lged.gov.bd/UnitAbout.aspx?UnitID=10

Martin, M., Kang, Y. h., Billah, M., Siddiqui, T., Black, R., & Kniveton, D. (2013). *Policy analysis: Climate change and migration Bangladesh.* Retrieved November 17, 2017, from http://admin.indiaenvironmentportal.org.in/files/file/climate%20change%20and%20migration%20bangladesh.pdf

Matthew, S., Mujica, A., Chiappe, F., & Ross, I. (2015). *Climate finance and water security: Bangladesh case study.* Oxford Policy Management. Retrieved November 19, 2018, from https://washmatters.wateraid.org/sites/g/files/jkxoof256/files/Climate%20finance%20and%20water%20security%20%20Bangladesh%20case%20study_0.pdf

Ministry of Environment and Forests. (2012). *National Report on Sustainable Development.* Peoples' Republic of Bangladesh. Retrieved November 16, 2018, from https://sustainabledevelopment.un.org/content/documents/981bangladesh.pdf

Ministry of Environment and Forests. (2013). *National Environmental Policy.* Government of the People's Republic of Bangladesh.

Parvin G.A., Ahsan S.M.R., Shaw R. (2013) Urban Risk Reduction Approaches in Bangladesh. In: Shaw R., Mallick F., Islam A. (eds) Disaster Risk Reduction Approaches in Bangladesh. Disaster Risk Reduction (Methods, Approaches and Practices). Springer, Tokyo

Rabbani, G., & Haq, S. (2016). *The effects of changes in flooding, sea level rise and changes in salinity on multidimensional inequality.* Retrieved November 19, 2018, from https://wess.un.org/wp-content/uploads/2016/07/WESS-2016-BP_Rabanni_Jul2016.pdf

Rahman, A., & Alam, M. (2003). *Mainstreaming adaptation to climate change in least developed countries (LDC). Bangladesh Country Case Study.* Retrieved 16 November 2017 from http://pubs.iied.org/pdfs/10003IIED.pdf?

Rahman, S., Mohiuddin. H., Kafy, A.A., Sheel, P.K., & Di, L. (2018). Classification of cities in Bangladesh based on remote sensing derived spatial characteristics. *Journal of Urban Management.* Retrieved 22 December 2018 from https://www.sciencedirect.com/science/article/pii/S2226585618301316

Rashid, A. M., Kendra, D. S., & Imam, H. (2009). *Climate Change Vulnerability in Bangladesh (Strategic Position of DSK/DCA in the field of climate change adaptation initiatives in Bangladesh).* Dustha Shastha Kendra. Retrieved November 25, 2018, from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.458.9307&rep=rep1&type=pdf

Revi A, Satterthwaite D, Aragón-Durand F, Corfee-Morlot J, Kiunsi RB, Pelling M, ... & Sverdlik A (2014). Towards transformative adaptation in cities: the IPCC's Fifth Assessment. *Environment and Urbanization, 26(1),* 11-28. Retrieved 10 November 2017 from http://journals.sagepub.com/doi/full/10.1177/0956247814523539

Rosenzweig, C., Solecki, W. D., Hammer, S. A., & Mehrotra, S. (Eds.). (2011). *Climate change and cities: First assessment report of the urban climate change research network.* Cambridge University Press. Retrieved November 19, 2018, from https://www.researchgate.net/profile/Roberto_SanchezRodriguez/publication/285117257_Climate_change_water_and_wastewater_in_cities/links/585caf3408ae8fce48fad58d/Climate-changewater-and-wastewater-in-cities.pdf

UNITED NATIONS. (2015). *TRANSFORMING OUR WORLD: THE 2030 AGENDA FOR SUSTAINABLE DEVELOPMENT.* Retrieved November 17, 2017, from https://www.un.org/pga/wp-content/uploads/sites/3/2015/08/120815_outcome-document-of-Summit-for-adoption-of-the-post-2015-development-agenda.pdf

ASSET BASED PROFILE APPROACH FOR UNDERSTANDING DIFFERENTIATED VULNERABILITY AND RESILIENCE OF COASTAL HOUSEHOLDS IN THE CONTEXT OF CLIMATE CHANGE

N.M. Ha-Mim[1], M.Z. Hossain[2] and S.M. Moniruzzaman[3]

ABSTRACT

There is growing recognition that people living in the coastal area are highly vulnerable to climate variability and change but they are also resilient as they already, consciously and/or unconsciously, adapting to climate change impacts, both in physical and behavioural terms. The level of vulnerability and resilience are differentiated in nature, depending on assets and capabilities of the households. Therefore, this research intends to identify differentiated nature of vulnerability and resilience of households in the context of climate change through using 'asset-based profile approach'. The mixed method research strategy was adopted in this research. Specific methods utilised for the data collection process included questionnaire surveys and 98 households are considered as the samples for this study. The significance of the results was in the differences of the vulnerability and resilience of the households into different asset profile which revealed a complex relationship within asset, vulnerability and resilience. This research also highlighted that the households with limited asset and high vulnerability could be highly resilient through adopting a significant number of adaptive strategies to deal with climatic hazards with also having the results in contrast where households rich in asset profile and with low vulnerability prove to be less resilient. Moreover, this research is an attempt to reveal the role of assets in understanding differentiated nature of vulnerability and resilience of coastal households in Bangladesh that would be helpful to develop an effective disaster risk reduction framework in the context of climate change.

Keywords: Climate change, index, asset profiles, vulnerability, and resilience.

Introduction

In the recent time a serious exploration is conducting by the scientific community to conceptualize the relationship between asset, vulnerability and resilience, particularly in the context of climate change. This research is framed to contribute this integrated thinking of asset, vulnerability and resilience that may provide a useful framework in the context of climate change. As policy planning, decision making and planning for adaptation gained currency among the governments, organizations and stakeholders, the framework integrates asset, vulnerability and resilience will be more powerful concept to guide it.

The asset based approach traces its beginnings to Amartya Sen`s vulnerability conceptualization, focusing on famine and food insecurity to explain vulnerability to famine due to production failure and shortage of food which leads to failure to entitlements and shortage of capabilities (Sen,1981). It does not explain differential vulnerability and resilience within some communities and between same communities facing the same crisis event. Most of the researchers on vulnerability has focused only the negative qualities and characteristics of vulnerability without considering the inherent resilience or capacities of an individuals or communities on which programs and resource can built to resist, recover and cope with climate change and extreme events (Joakim, 2008). Though a community is experiencing vulnerability it can have some resilience and capacity to adopt and transform. Usamah et al. (2014) stated that, settlement may have signs of vulnerability associated with poverty and exposure to hazards, but simultaneously they can have aspects contributing to their resilience such as social cohesion and social networks that can counterbalance the vulnerable condition.

To understand differentiated nature of vulnerability and resilience of coastal population, it is essential to analyse asset, vulnerability and resilience nexus, though only a few researches have attempted to build an interrelationship between asset, vulnerability and resilience. Incorporating these three concepts into an integrated framework can advance research thinking, policy and practice in the context of climate change, particularly when the knowledge gained from asset and vulnerability research will integrated with the concept of resilience.

---

[1]*Undergraduate Student, Urban and Rural Planning Discipline, Khulna University, Khulna-9208, Bangladesh*
[2]*Professor, Urban and Rural Planning Discipline, Khulna University, Khulna-9208, Bangladesh*
E-mail of Corresponding Author: zakirurp9913@gmail.com
[3]*Undergraduate Student, Urban and Rural Planning Discipline, Khulna University, Khulna-9208*

Study Area

Chila and Burirdanga Union of Mongla Upazila under Bagerhat District is selected as the study area in this research. These two union is located in between 22°20'55.687" and 22°34'33.198" north latitudes and in between 89°33'26.107" and 89°43'10.86" east longitudes. World largest mangrove forest is situated at the southern part of this union with having Poshur river in the west.

Methodology

Data Collection

Data were collected through questionnaire survey of 98 sampled households. The data were collected between August 01 and August 30, 2018. Stratified random sampling technique is adopted to conduct this research. At first, Mongla Upazila is divided into five zones based on the distance from the cost and a number of random grids is generated using ArcGIS 10.3 for Chila and Burirdanga union. Among all of the grids six grid is randomly selected for each of the union which also incorporated equal distribution of grids among the zones. At the end, number of samples was allocated based on the concentration of the households in each grid using google earth.

Analytical Framework

To establish the asset, vulnerability and resilience differential of the households the asset index, household vulnerability index and resilience index was calculated. The variables that are selected for the calculation of these indices are given in the Appendix.
Indexing Method: As each of the sub-components used is measured on a different scale, it is first normalized to make the sub-components comparable using the methodology developed for the calculation of the Human Development Index (UNDP,2007) to calculate the life expectancy index. Eq.1 is used for the normalization of the sub-components with positive functional relationship and Eq.2 is used for the normalization of the sub-components with negative functional relationship.

$$Index\ S_{B_x} = \frac{S_{B_x} - S_{min}}{S_{max} - S_{min}} \quad (1)$$

$$Index\ S_{B_x} = \frac{S_{max} - S_{B_x}}{S_{max} - S_{min}} \quad (2)$$

Here, $Index\ S_{B_x}$ is the normalized index value of the sub-components for a household, S_{B_x} is the original value of the sub-components of a household, and S_{max} and S_{min} are the maximum and minimum values, respectively, for each sub-components determined using data among the households. After normalization, the sub-components are averaged using Eq. 3 to calculate the value of each major component. The same approach was used by Hahn et al (2008) for the calculation of livelihood vulnerability index.

$$M_{Bx} = \frac{\sum_{i=1}^{n} Index_{Bx^i}}{n} \quad (3)$$

M_{Bx} represents the value of one of the major components for a household, $Index_{Bx^i}$ is the subcomponents, indexed by i, that makes up each major component and n is the number of sub-components in each component. The household level asset index (AI), livelihood vulnerability index (LVI) and resilience index (RI) is calculated as the weighted average of the nine major components using Eq. 4

$$AI\ or\ LVI\ or\ RI = \frac{\sum_{i=1}^{7} W_{Mi} M_{Bx}}{\sum_{i=1}^{7} W_{Mi}} \quad (4)$$

Where, AI, LVI and RI are respectively the asset index, livelihood vulnerability index and resilience index for a household and W_{Mi} is the weightage of the major components.

Results and Discussion

The asset index (AI) is juxtaposed with livelihood vulnerability index (LVI) and resilience index (RI) here, so as to classify households with different asset profile in terms of these two indices. The results of the juxtaposition of the asset and vulnerability indices and asset and resilience indices computed for the purpose of this study, are shown graphically in Figure 01 and Figure 02 respectively.
It can be seen that the household’s asset and vulnerability indices and asset and resilience indices represented by the blue markers respectively in Figure 01 and Figure 02, occupy the four quadrants of the diagram, with households registering varying asset profile, vulnerability and resilience group. The boundaries of the quadrants were set as the average score of each of the indices. At last, vulnerability and resilience differential in different asset profile is discussed following the preceding analysis Figure 03.

Juxtaposing Asset, Vulnerability and Resilience

The predictive power of the linear regression model juxtaposing asset and vulnerability shown in Figure 01 is significant ***($R^2 = 0.40$, $p \leq 0.001$)*** and it is statistically 40% successful while predicting the household's livelihood vulnerability in terms of their asset. The equation for the fitted line between the asset and vulnerability is ***LVI= 0.747669-(0.742622*AI)*** and a strong negative correlation with ***Pearson Correlation Coefficient -.630*** is also evident which elicit that with the increase in the asset of the households the vulnerability is reduced**.** Likewise, for asset and resilience juxtaposition, predictive power of the linear regression model shown in Figure 02 is significant ***($R^2 = 0.35$, $p \leq 0.001$)*** and it is statistically 35% successful while predicting the household's resilience in terms of their asset. The equation for the fitted line between the asset and resilience is ***RI= 0.180516+(0.770513*AI)*** and a strong positive correlation with ***Pearson Correlation Coefficient .593*** is also evident which elicit that with the increase in the asset of the households the resilience power also increases.

Though it is only one side of the coin, for more detail understanding of the asset, vulnerability and resilience differential, asset in terms of vulnerability index (LVI) and resilience index (RI) is juxtaposed. Four possible categories are identified for both the asset and vulnerability juxtaposition and asset and resilience juxtaposition into which households can be placed according to their asset, vulnerability and resilience characteristics. For asset and vulnerability juxtaposition four categories are identified which are respectively represented as households with high asset profile and high vulnerability, households with high asset profile and low vulnerability, households with low asset profile and high vulnerability and households with low asset profile and low vulnerability Figure 01.

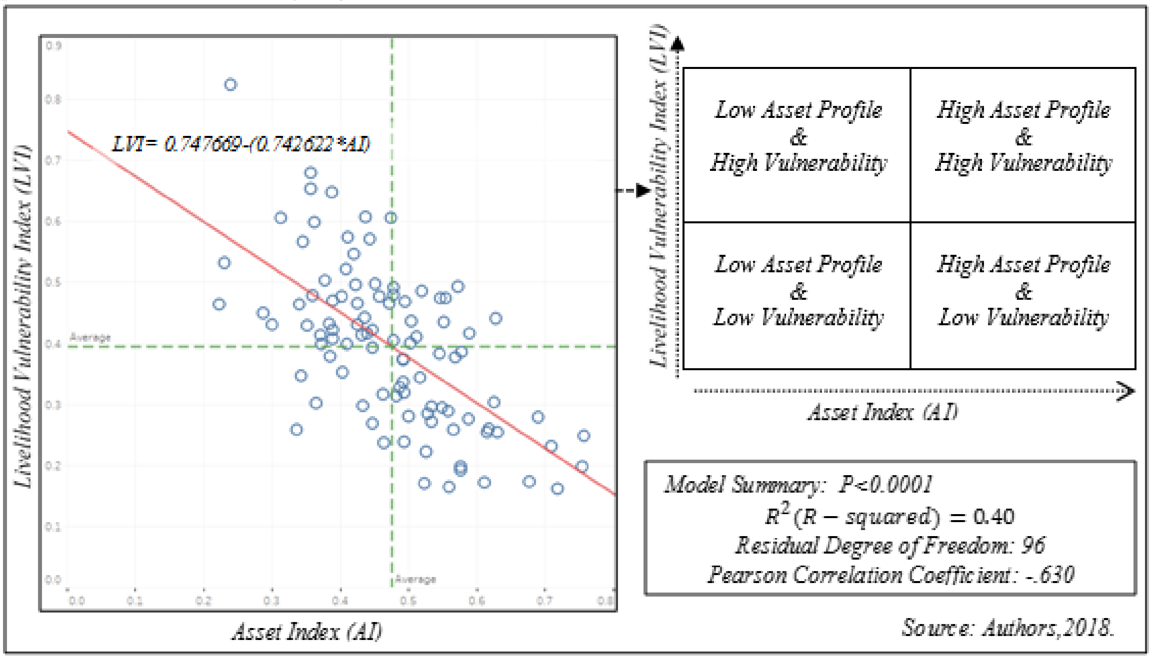


Figure 1. The asset and vulnerability indices, juxtaposed

Likewise, for asset and resilience juxtaposition four categories are identified which are respectively represented as households with high asset profile and high resilience, households with high asset profile and low resilience, households with low asset profile and high resilience and households with low asset profile and low resilience Figure 02.

Vulnerability and Resilience Differential in Different Asset Profile

The preceding analysis revealed that a household with low asset profile can have low vulnerability and high

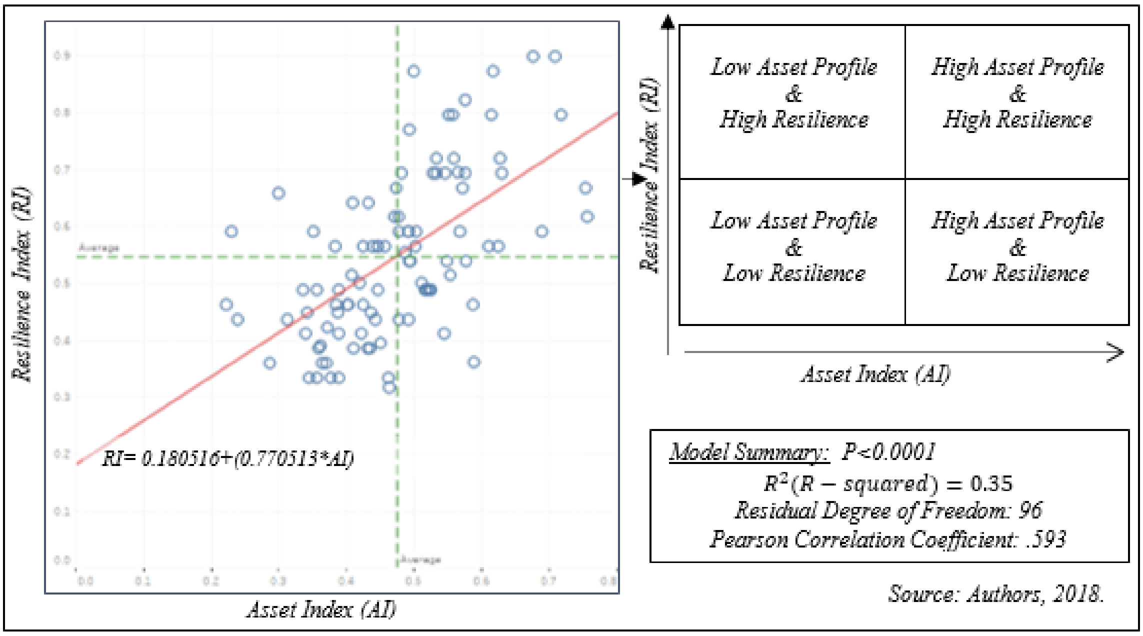
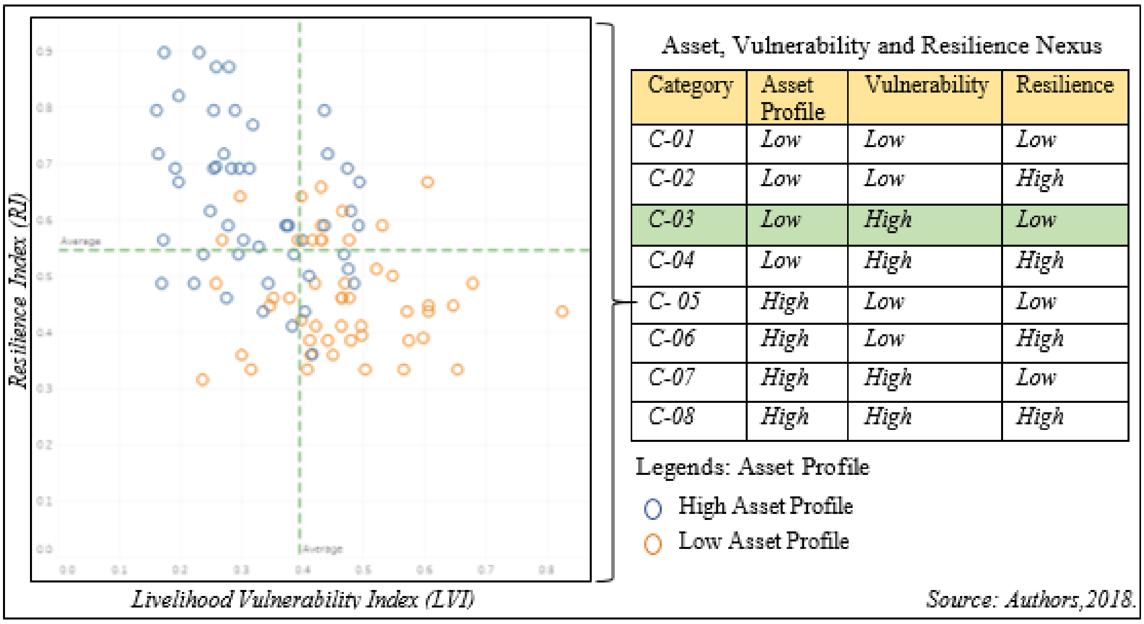


Figure 2. The asset and resilience indices, juxtaposed

resilience power whereas in some case households with high asset profile can be more vulnerable and less resilient in the context of climate change. It is different than the common scenario of asset, vulnerability and resilience relationship where the increase of the asset of the household's will always decrease vulnerability and increase resilience power. To categories households in terms of their asset, vulnerability and resilience differentials resilience index (RI) and livelihood vulnerability index (LVI) is overlapped with the asset profile and eight categories are identified which are illustrated in Figure 03.

So, in terms of asset, vulnerability and resilience differential a household can be categorized under any of



Category	Asset Profile	Vulnerability	Resilience
C-01	Low	Low	Low
C-02	Low	Low	High
C-03	Low	High	Low
C-04	Low	High	High
C- 05	High	Low	Low
C-06	High	Low	High
C-07	High	High	Low
C-08	High	High	High

Figure 3. Vulnerability and resilience differential in different asset profile

these eight categories. In decision making consideration of asset, vulnerability and resilience is important for the selection of appropriate beneficiaries or participants such as, category three households need to give the highest priority in terms of any crisis event as their asset is low with having high level of vulnerability and low level of resilience.

Conclusion

Households with different asset profile experiencing similar exposure to a climatic extreme can have different level of vulnerability and resilience over time. Although they are faced with vulnerability relating to geographical location, tenure insecurity, social exclusion, inadequate infrastructure and political bias in resource distribution, they have perceived themselves resilient in terms of climatic variability and change due to having strong social cohesion, economical and physical adaptation practices, where physical, social, natural, financial and human capital plays differentiated role. The discrete view of asset, vulnerability and resilience can mislead planners and decision makers to manage crisis event. To achieve a deeper understanding of disaster risk reduction framework it is essential to focus on the nexus between asset, vulnerability and resilience that would help to assess hazards more holistically.

References

Hahn, M.B., Riederer, A.M., and Foster, S.O. (2008). The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change—A case study in Mozambique.

Joakim, E. (2008). Assessing the 'Hazards of Place'model of vulnerability: A case study of waterloo region.

Sen, A.K. (1981). Poverty and Famines: An Essay on Entitlement and Deprivation. Clarendon, Oxford.

UNDP. (2007). Human development reports. http://hdr.undp.org/en/ (accessed 25 October, 2018).

Usamah, M., Handmer, J., Mitchell, D. & Ahmed, I. (2014). Can the vulnerable be resilient? Co-existence of vulnerability and disaster resilience: informal settlements in the Philippines. *International journal of disaster risk reduction, 10*,178-189.

Appendix

Indexing Type	Major Components and Sub-Components
Asset Index	***Human Capital:*** Skilled member, able bodied member, no. of earning member, vocational training, disaster management training, knowledge about modern farming techniques. ***Natural Capital:*** Acreage of Land ownership, access to open water fishing, access to khas land, access to firewood from forest. ***Financial Capital:*** Have cash savings, have savings in Bank/NGOs, amount of remittance, family members employed in formal sector. ***Social Capital:*** Having assistance from relatives/friends/ extended family members, having inherited property, having membership in the NGO`s microfinance project, having membership in locally organized committee or samiti, having contracts with local elites, number of social safety nets. ***Physical Capital:*** Having television or radio, types of housing, number of owned bicycles, hygienic sanitary latrine, access to cyclone shelter, having affordable means of transport, drinking water quality, adequate water supply, water reservoir ownership, access to electricity, having jewelry.
Livelihood Vulnerability Index	***Physical Vulnerability:*** Number of natural disasters during the last 10 years, average. months/days homesteads remained inundated due to cyclone or flooding, duration of stagnant water due to rain or flood, duration of waterlogging in the agriculture field, frequency of flash flood, average height of water during flood, average time to reach nearest health center, average time to reach nearest vehicle station, average cost of reaching health center, acreage of land ownership, average time to reach to the cyclone shelter, amount paid to buy water from private /NGOs developed water plant, chance of losing land due to river erosion, do not have access to rehabilitation aid after disaster, unavailability of vehicles to evacuate people and livestock, do not have access to food relief in disaster time, do not have access to early warning system, drinking water sources

	affected/damage during heavy rains, cyclone, storm surge and storms, households do not have vehicles to use for evacuation, condition of dwelling unit, unhygienic sanitation. ***Social vulnerability:*** Disconnected from extended family members/relatives/friends, excluded from the community, having seasonality effect on household's income and consumption, HH head/adult members engage in hazardous and risky activities, existence of women insecurity, child labor in the family, having disability/chronically illness in the family, access to social safety nets program, amount of remittance support, amount of loan. ***Political Vulnerability:*** HH heads and adult members have lack of mobility in community activities, tenure insecurity, political violence in the community, political bias in distributing safety nets, government development activities fail or have minimal effects on minimizing impacts of climate induced hazards, political influence in rehabilitation programs, corruption of political leaders in post hazard reconstruction programs, political bias in hazard time relief distribution
Resilience Index	***Housing:*** Making houses on raised plinths, elevated courtyard, tree plantation around the house, repair or rebuild house with hardy materials, climate proofing construction, change of housing location, special techniques for hazard mitigation, elevated latrines to avoid spread of diseases, cooking on elevated platforms. ***Livestock:*** Raised platforms used for cowsheds, poultry kept inside houses during hazard, move the animals to elevated platforms or land. ***Fish:*** Changes of fishing locations, build embankment to reduce risk of being flooded shrimp and open water aquatic resources, fishing ponds protected with nets and barriers. ***Agriculture and crops:*** Adopt crop varieties, adopt climate resilient crop types, changing irrigation techniques, use of canals for irrigation. ***Source of water:*** Renovation of ponds for freshwater and aquaculture, build rain water reservoir in the house/ community, involving with community-based water supply system, establish tube well in newly built house. ***Infrastructure:*** Regular maintenance of infrastructure of the village, canal rehabilitation through channelization, removal of obstacle in drainage system to reduce congestion, collective maintenance of common facilities such as school and mosque for emergency response, construction of robust infrastructure. ***Dykes:*** Raise elevation of the dykes, planting tree near the river bed, conservation of mangrove plantation. ***Social adaptation:*** Regular saving from family income, adoption of weather information products, attending capacity building training provided by GO/NGO, household making coalition with NGO`s/ Donor`s organizations, HH engaging in community-based organization, participating in social convention, having membership of the political party, maintaining networks with political elite.

Proceedings on International Conference on Disaster Risk Management,
Dhaka, Bangladesh, January 12-14, 2019

DISASTER AND MIGRATION NEXUS: A STUDY OF MIGRATION PROCESS OF THE DISASTER INDUCED MIGRANTS OF DHAKA CITY CORPORATION AREA

M. M. K. Alis[1], M. R. Islam[1], I. Islam[2]

ABSTRACT

Bangladesh faces frequent natural disasters such as cyclone and storm surge, riverbank erosion, flood and others that displace people from their place of origin. People who migrate because of natural disasters usually end up in slums of big cities. This research is aimed at understanding the process of disaster induced migration i.e. how the disaster induced migrants end up in slums of Dhaka. A questionnaire survey has been conducted on 400 households from 40 slums of DSCC and DNCC areas to find out whether they chose directly to end up in the slums of Dhaka city or stayed in other places before moving to Dhaka. The findings suggest that most of the respondents (17.75%) have been from Kurigram district. Two- third (66.5%) of the respondents migrated directly to Dhaka after they had encountered disasters. About 27.25% of the respondents migrated directly because of river erosion. This research provides a useful insight to understand the pressure of migration on big cities. Necessary supports from government and NGOs during and post disaster period, employment opportunities in nearby districts, village level volunteering forces are some of the recommendations suggested to minimize the effects of disasters to reduce the influx in big cities.

Introduction

Bangladesh is frequently thought to be one of the most vulnerable countries of the world in terms of natural disasters. Natural disasters lead to widespread human, material, economic or environmental losses for a community (UNISDR, 2009). Bangladesh has been identified as the fifth most natural disaster-prone country in the world (Garschagen, et al., 2016). More than 50 million people are affected in Bangladesh by disaster events every five years (Shamsuddoha, et al., 2012). The country was hit by cyclone SIDR and AILA resulting in the displacement of 650,000 (Ahmed, et al., 2014; Akter, 2009), and 200,000 people (IIFC, 2010) respectively. It has been estimated that more than 20 million people in the near future are to be displaced in Bangladesh due to disasters (MoEF, 2009). The displaced persons target the slums of urban areas for habitation (Ahmed & Neelormi, 2008; Walsham, 2010). Urban slums in Bangladesh have been growing at quite a fast rate of 4% per year (Khatun, 2013). Displaced persons with fewer resources are forced to relocate to the slums of Dhaka or Chattogram (Displacement Solutions, 2012). Slums of Dhaka city are dwelling choice for many migrants of disaster-prone regions of Bangladesh (Walsham, 2010). Around 600,000 people are living in slums of both Dhaka North City Corporation (DNCC) and Dhaka South City Corporation (DSCC) including the disaster induced migrants (BBS, 2015).

Several researches have been carried out (Ahmed & Neelormi, 2008; Akter, 2009; Khanom & Tanzinia, 2016) on disaster induced migrants of Bangladesh. Ahmed and Neelormi (2008) demonstrated that the proliferation of slums in urban areas following the major high intensity events is due to failed livelihoods caused by hazards and disasters. Results of the research indicated that many households had migrated into nearby urban centres and beyond, while a few others have rebuilt their dwellings twice or thrice in the same island in anticipation of a possible cessation of erosion. Akter (2009) depicted displacement of people in the light of natural disasters and adverse impacts of climate change and found that several natural disasters such as cyclone and storm surge, flood, riverbank erosion, salinity, water logging induce mass displacement of population. However, the studies did not focus on the migration process of disaster induced migrants.

The institutional framework of Bangladesh consists of different disaster management committees at different levels comprising government, non-government, voluntary, and other relevant stakeholders. The National Disaster Management Council (NDMC) headed by the Prime Minister is the highest-level forum for the formulation and review of disaster management policies. The Government of Bangladesh (GoB) has taken many steps to address the issue such as development of the Bangladesh National Adaptation Programme of Action 2005 (NAPA) (MoEF, 2005), the Bangladesh Climate Change Strategy and Action Plan 2009 (BCCSAP) (MoEF, 2009), and the National Plan for Disaster Management (DMB, 2010). The NAPA

[1] *Department of Urban and Regional Planning, BUET, Dhaka – 1000, Bangladesh*
[2] *Corresponding Author, Professor, Department of Urban and Regional Planning, BUET, Dhaka – 1000, Bangladesh*
Email of Corresponding Author - ishratislam.buet@gmail.com

identified that some of the effects of climate change have links with migration; however, these links were not expressed in concrete terms. However, the National Plan for Disaster Management (NPDM) (2010-2015) has been developed to reduce the vulnerability of the poor to the effects of natural, environmental and human induced hazards to a manageable and acceptable humanitarian level.
The process of migration shows that the respondents end up in slums of DCC area. It helps to understand the pressure of migration on Dhaka and also on other big cities which in turn helps to implement strategies through national frameworks for disaster induced migrants to rehabilitate them within their places of origin or distribute them efficiently in nearby cities.

Methodology

Dhaka North City Corporation (DNCC) and Dhaka South City Corporation (DSCC) of DCC area have been selected for the primary questionnaire survey of disaster induced migrants. DNCC consists 1,639 slums and DSCC consists of 1,755 slums (BBS, 2015). Since the displaced persons target the slums of urban areas for habitation, the slums of DNCC and DSCC have been selected as the study frame for the research. DNCC consists 1,639 slums and DSCC consists of 1,755 slums (BBS, 2015). Among them 40 slums have been selected as study area after conducting a reconnaissance survey. The location of slums has been shown in map (Appendix A). The study period has been set to 2007-2016 to get an idea of the situation over a 10-year period. The respondents have been identified following the purposive sampling method. Purposive sampling is also known as judgmental, selective, or subjective sampling. Only those respondents were chosen who were affected by a disaster and thus migrated to Dhaka within the time frame stated above. 400 disaster induced respondents i.e. households have been identified from the selected 40 slums and interviewed face-to-face using a structured questionnaire from May 15th – June 15th 2017.

Results and Discussions

Socio-economic Profile

More than three – fourth (77.50%) of the respondents has been male. However, availability of respondents has been difficult during daytime, especially of working days, as they were at work. Thus most of the respondents have been approached in the afternoon or early evening period. The mean age of the respondents has been found 42 years. The income and expenditure of the respondents have increased dramatically after the migration. About 84% of the respondents have a family income of more than BDT 8000 whereas only 16% earned that amount previously. However, the expenditure has also increased keeping pace with the income. Almost three fourth (75.5%) of the migrants have a household expenditure of more than BDT 8000. This is one of the underlying causes, as other studies suggest, that triggers the decision of migrating to big cities for better living opportunities.

Origin of Respondents

Throughout the study it has been found that the migrants who ended up in slums of Dhaka are from ten districts. These districts are Kurigram, Gaibandha, Jamalpur, Barishal, Shariatpur, Bagerhat, Barguna, Patuakhali, Bhola and Chandpur. The highest number of the disaster induced migrants are from Kurigram district (17.8%) while Barishal district contributes to the second highest (15.8%). The districts Kurigram, Gaibandha, Jamalpur are prone to river erosion, as the mighty Brahmaputra passes through them, that causes the total loss of livelihood in most of the cases. On the other hand, Barishal to cyclone and storm surge, river erosion, water – logging, salinity that also cause loss of livelihoods (Walsham, 2010). This might be the underlying reason for more than 30% are from these two districts.

Steps of Migration to Dhaka

It is evident from the study that, about 66.5% (266 out of 400) of the respondents migrated directly or in one step to Dhaka after the occurrence of disasters. On the other hand, 24% of the respondents end up in Dhaka following two steps which means that they tried to stay in another place before coming to Dhaka. The remaining respondents (9.5%) followed three or more steps before migrating. The data represents that majority of the disaster induced migrants were compelled to migrate immediately or within a short period of time after the disaster occurred (Table 1).
It is also evident from the data that more than one fourth (27.25%) of the respondents migrated directly to Dhaka due to river erosion while the 16.75% migrated directly due to cyclone and storm surge (Table 1). River erosion causes complete destruction of assets such as homestead, agricultural land etc. That is why people are left with no choice than to migrate as they lose both their homestead and the sources of income. It

has been found that the respondents tried to move further back from the riverbank at the time when the first erosion occurred. However, they could not continue after the second erosion took place. Some of the respondents reported that they kept going further back from the riverbank or other side of the river until they were compelled to migrate as they had to face total loss of livelihoods two or three times.

Table 1. Distribution of respondents by encountered disaster and migration steps

Migration Steps	Encountered Disaster					Total
	Cyclone and Storm Surge	Flood	River Erosion	Salinity	Water Logging	
One step	67 (16.75%)	39 (9.75%)	109 (27.25%)	21 (5.25%)	30 (7.5%)	266 (66.5%)
Two steps	15 (3.75%)	16 (4%)	55 (13.75%)	4 (1%)	6 (1.5%)	96 (24%)
Multiple steps	4 (1%)	0 (0%)	31 (7.75%)	2 (0.5%)	1 (0.25%)	38 (9.5%)
Total	86 (21.5%)	55 (13.8%)	195 (48.8%)	27 (6.8%)	37 (9.2%)	400 (100%)

However, when the origin of the respondents is analyzed with the steps of migration the highest number of respondents who migrated directly to Dhaka are from Barishal district (11.75%) followed by Kurigram district (10.75%) (Table 2). River erosion, cyclone and storm surge, flood, waterlogging are most common form of disasters that occur in regions like Barishal, Bhola, Kurigram. These disasters take a heavy toll of lives especially river erosion, and cyclone and storm surge. Table 2 also shows that all of the respondents of Barguna district migrated directly to Dhaka. Migration through three or more steps has been found most common in Gaibandha and Kurigram.

Table 2. Distribution of respondents by migration steps and origin of respondents

Migration Steps	Origin of Respondents										Total
	Bagerhat	Barguna	Barishal	Bhola	Chandpur	Gaibandha	Jamalpur	Kurigram	Patuakhali	Shariatpur	
	Percentage (%)										
One step	5.25	6.25	11.75	8.25	6.25	3.00	5.00	10.75	6.25	3.75	66.50
Two steps	1.25	0	3.25	2.50	2.25	4.00	3.25	3.75	.75	3	24
Multiple steps	.50	0	.75	.50	.50	4.00	0	3.25	0	0	9.5
Total	7.00	6.25	15.75	11.25	9.00	11.00	8.25	17.75	7.00	6.75	100

Year of Migration

While analyzing the first migration of the respondents, almost one fourth of the respondents (23.25%) migrated to another location or ended up in Dhaka in the year 2008, most of them are from Kurigram district (8.5%). River erosion is the primary reason for that. The percentage for first migration of the respondents is almost same (21%) in the year 2009. The coastal region of Bangladesh was hit by cyclone AILA (May, 2009) is the prominent reason for that. About 12% of the respondents has been found from Barishal, Bhola, Patuakhali, Bagerhat, and Barguna which were severely hit by a cyclone mentioned earlier. However, not all of them end up in Dhaka that year (Appendix B). In the year 2012 no one migrated from Bagerhat, Barguna, Kurigram, and Patuakhali while a mere percentage migrated from all other districts signifying the absence of major disasters in that year. None of the respondents migrated in 2014 from Chandpur and Kurigram while in 2015 less than 1% of the respondents from all regions except for Bhola has been found to have their first migration.

Mapping the Process

Considering all of the migration steps, the migration map of the respondents has been produced (Figure 1). It shows the direction of migration of the respondents from their place of origin to Dhaka. While producing the map the different movements from a particular district have been considered. For example, all of the respondents from Barguna district migrated directly to Dhaka. In this case only one line has been shown in the map directing the movement rather than lines for all of the respondents. This has been done to make the map visually pleasing. A larger map has been provided in Appendix C.

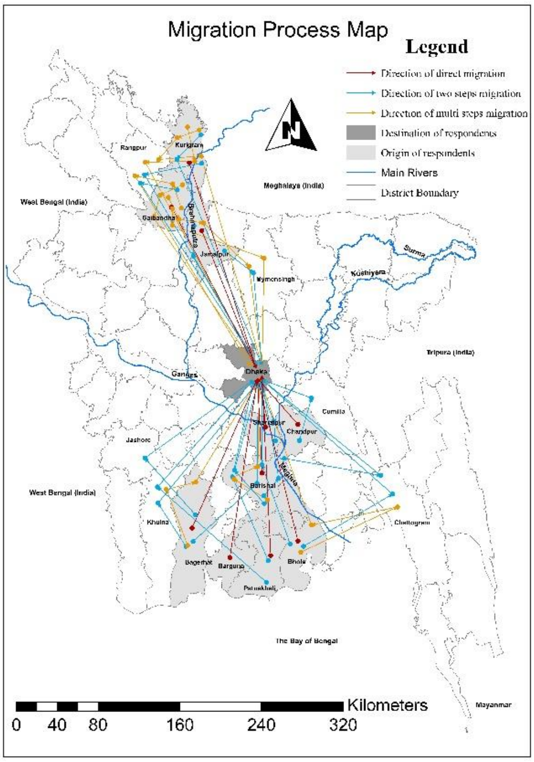


Figure 1. Map showing the process of migration.

The respondents who migrated directly from the coastal regions i.e. Barisal, Bhola, Barguna, Bagerhat to Dhaka faced disasters such as cyclone and storm surge, water logging, salinity most. However, some of the migrants in those districts tried to stay there as long as possible. Some of them migrated to Chittagong to find better opportunities. The respondents of Kurigram, Gaibandha and Jamalpur faced river erosion and flood most. The river Brahmaputra passes through these districts which is known for its frequent erosions. However, some of the respondents of these districts who faced river erosion changed their location of household to other side of the bank of the river. Some other from Kurigram and Gaibandha district migrated to the nearby divisional district Rangpur initially while the respondents of Jamalpur district migrated to Mymensingh before ending up in slums of DCC area. Some migrants of Kurigram also migrated within the district. Barguna district has no such pattern as all of the migrants of this district went directly to Dhaka after migration. However, it has been found that respondents tended to stay as long as possible in the nearby districts than to move to Dhaka.

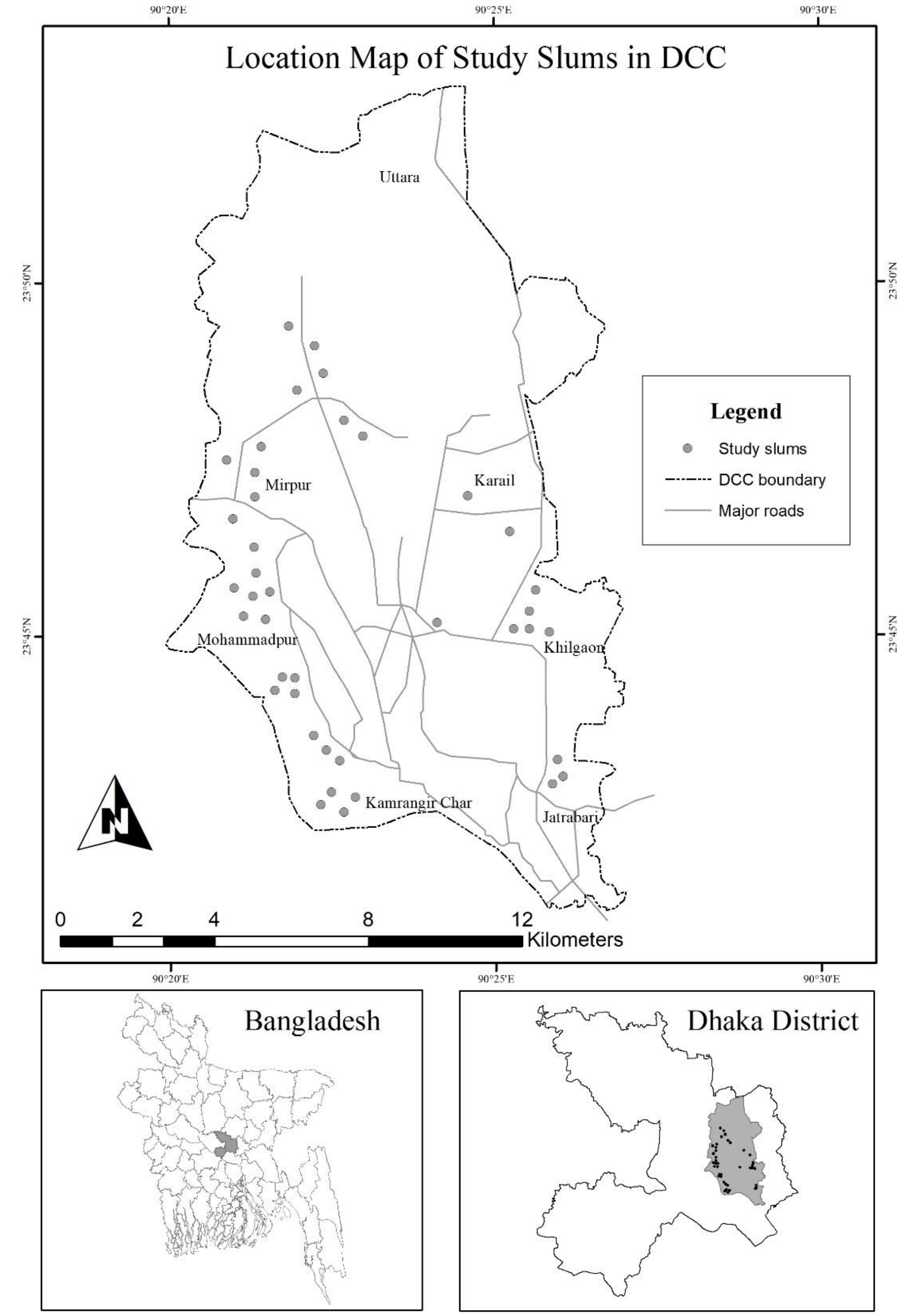
Conclusion

This research provides the overall portrait of the migration process of disaster induced migrants to the DCC area. Throughout the study it has been found that the respondents were reluctant to migrate from their place of origin to other area unless they were compelled. It shows the importance of developing infrastructure and financial supports in the affected regions and also in nearby districts. Thus it shows the need for a comprehensive regional plan of our country. Adaptation programs such as rehabilitation of the affected people, provision of necessary financial and health supports from government and non-government organizations during and post disaster period in the affected regions, employment opportunities in nearby districts, regulation of the migration process within national framework through incentive measures are some the policy recommendations suggested to minimize the effects of disasters to reduce the influx in big cities.

Acknowledgments

We would like to thank the corresponding author, Dr. Ishrat Islam, for her systematic, valuable and proper guidance for the successful completion of our research. We are thankful to the respondents of our primary questionnaire survey who gave their valuable time to and cooperated with the research.

Appendix A



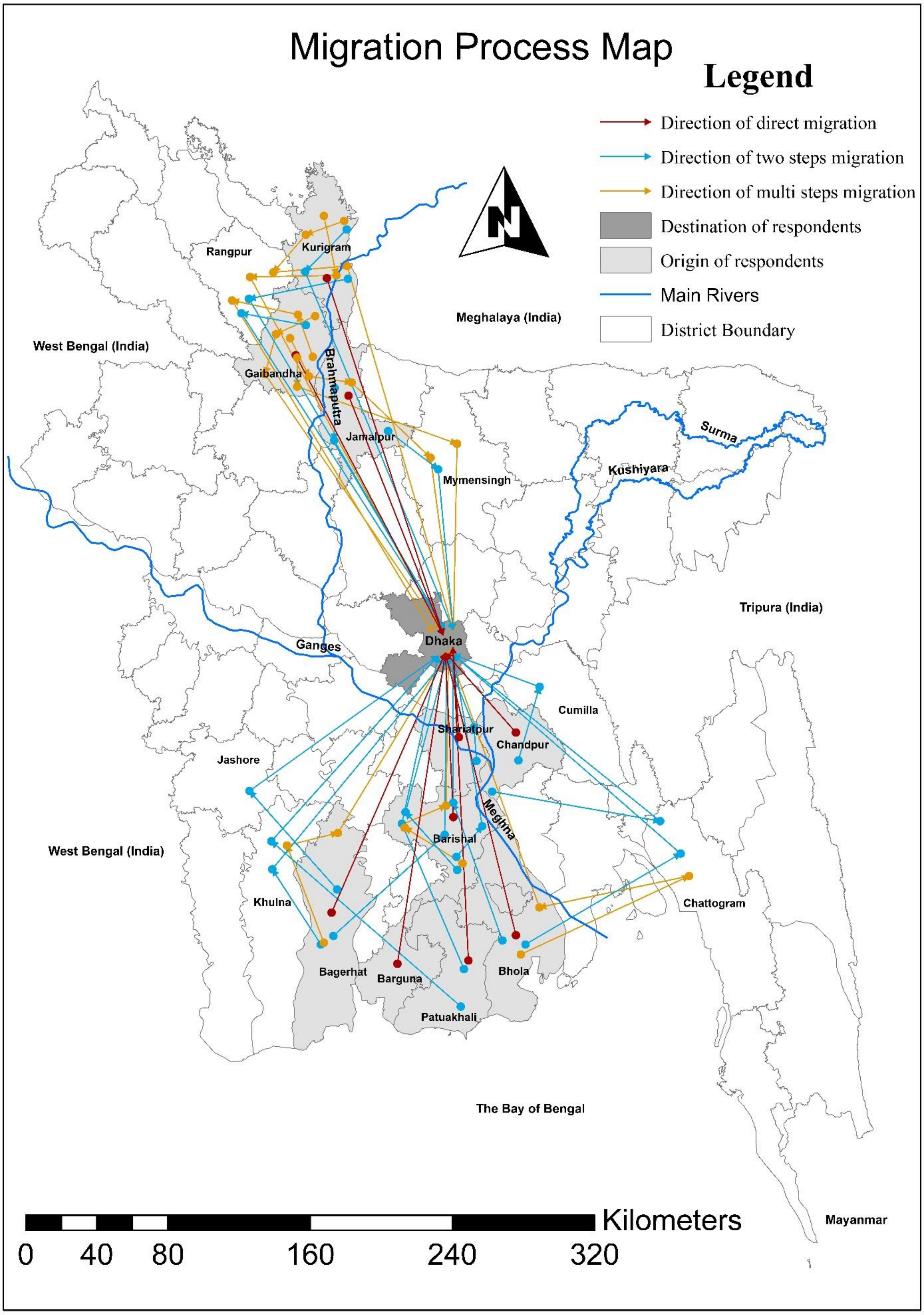
Appendix B

Table: Distribution of respondents' first migration by year and origin of the respondents

Year of Migration	Origin of respondents	Total

	Bagerhat	Barguna	Barisal	Bhola	Chandpur	Gaibandha	Jamalpur	Kurigram	Patuakhali	Shariatpur	
	Percentage (%)										
2008	.50	.50	4.00	0	1.00	5.50	1.25	8.50	.75	1.25	23.25
2009	3.25	.75	2.75	3.50	.50	1.00	1.00	4.50	2.00	1.75	21.00
2010	0	1.25	3.50	1.50	2.25	.50	.50	2.00	2.00	.25	13.75
2011	.50	.50	.50	1.50	1.00	1.50	.25	1.00	1.50	1.00	9.25
2012	0	0	.25	.25	.25	1.00	1.50	0	0	1.00	4.25
2013	.75	2.75	4.00	2.75	4.00	.50	2.50	1.25	.50	1.25	20.25
2014	1.50	.50	.50	.50	0	.50	1.00	0	.25	.25	5.00
2015	.50	0	.25	1.25	0	.50	.25	.50	0	0	3.25
Total	7.00	6.25	15.75	11.25	9.00	11.00	8.25	17.75	7.00	6.75	100.0

Appendix C


Migration Process Map
Legend
Direction of direct migration
Direction of two steps migration
Direction of multi steps migration
Destination of respondents
Origin of respondents
Main Rivers
District Boundary
Rangpur
Kurigram
Meghalaya (India)
West Bengal (India)
Gaibandha
Brahmaputra
Jamalpur
Mymensingh
Surma
Kushiyara
Tripura (India)
Dhaka
Ganges
Cumilla
Shariatpur
Chandpur
Jashore
Meghna
Barishal
West Bengal (India)
Khulna
Chattogram
Bagerhat
Barguna
Bhola
Patuakhali
The Bay of Bengal
Kilometers
0
40
80
160
240
320
Mayanmar

References

Ahmed, A. U., & Neelormi, S. (2008). *Climate change, loss of livelihoods and forced displacements in Bangladesh.* Dhaka: Centre for Global Change (CGC).

Ahmed, B., Hassan-Firoz-ul, A., & Islam, T. M. (2014). Disaster induced migration and social conflict in Bangladesh: Study on cyclone Sidr. *International Journal of Interdisciplinary and Multidisciplinary Studies (IJIMS), 1*(4), 11-16.

Akter, T. (2009). *Climate change and flow of environmental displacement in Bangladesh.* Dhaka: Unnayan Onneshan. Retrieved December 14, 2016, from http://unnayan.org/documents/Climatechange/climate_change_flow_environmental_displacement.pdf

BBS. (2015). *Census of slum areas and floating population 2014.* Dhaka: Author.

Displacement Solutions. (2012). *Climate displacement in Bangladesh: The need for urgent housing, land and property (HLP) rights solutions.* Geneva: Author.

DMB. (2010). *National plan for disaster management: 2010-2015.* Dhaka: Author.

Garschagen, M., Hagenlocher, M., Kloos, J., Pardoe, J., Lanzendörfer, M., Mucke, P., . . . Birkmann, J. (2016). *World risk report 2016.* Berlin: Bündnis Entwicklung Hilft and UNU-EHS.

IIFC. (2010). *Shelter projects 2009.* Retrieved December 12, 2016, from http://www.ifrc.org/PageFiles/95888/E.01.04.%20Shelter%20Projects%202009%20(IFRC,%20UN-Habitat).pdf

Khanom, & Tanzinia. (2016). Effect of salinity on food security in the context of interior coast of Bangladesh. *Ocean & Coastal Management, 130,* 205-212. doi:https://doi.org/10.1016/j.ocecoaman.2016.06.013

Khatun, M. (2013). Climate change and migration in Bangladesh: Golden bengal to land of disasters. *Bangladesh e-Journal of Sociology*, 64-79.

MoEF. (2005). *National adaptation programme of action (NAPA).* Dhaka: Author.

MoEF. (2009). *Bangladesh climate change strategy and action plan 2009.* Dhaka: Ministry of Environment and Forests, Government of Peoples Republic Bangladesh.

Shamsuddoha, M., Khan, S. M., Raihan, S., & Hossain, T. (2012). *Displacement and migration from climate hot-spots in Bangladesh: Causes and consequences.* Dhaka: Action Aid Bangladesh.

UNISDR. (2009). Terminology on DRR. Author. Retrieved December 17, 2016, from http://www.unisdr.org/we/inform/terminology

Walsham, M. (2010). *Assessing the evidence: Environment, climate change and migration in Bangladesh.* Dhaka: International Organization for Migration.

CULTURAL CONSIDERATION IN REBUILDING IN NEPAL

Umesh Prasad Pokharel[1]

ABSTRACT

Data from National Reconstruction Authority (NRA) of Nepal, an authority mandated of rebuilding following the Nepal earthquake 2015 shows that a total of 24, 2018 private- houses have completed reconstruction till November 24, 2018 which is 38.97 percentages of the total shelter- support beneficiaries. The houses which completed construction are neither looks likes the traditional houses nor includes cultural elements.

On the backdrop, the paper analyses Nepal Government's post-earthquake reconstruction policies and identified due to the lack of emphasis of rebuilding policies on cultural consideration coupled with discouragement of the NRA engineers and pressure of deadline has resulted in lack of cultural consideration in rebuilding. Further, it identified that pressure of deadline to complete the reconstruction and discouragement of the engineers from National Reconstruction Authority (NRA) to apply the cultural elements into reconstruction are other major reasons.

A lesson that international community could learn from Nepal's experience is about emphasizing policy provisions for incorporation of cultural elements in rebuilding following the earthquake.

Key Words: Traditional Architecture, Rebuilding, Private House, Nepal.

Introduction

The devastating earthquake measuring 7.8 and 7.3 Richter scale that struck Nepal in April and May 2015 caused 8,891 casualties and 22,302 injuries. Similarly, 608,155 residential buildings were completely destroyed while 298,998 houses were partially damaged. Furthermore, 2,687 government buildings (including schools and health posts) collapsed completely while 3,776 were partially destroyed. Likewise, 743 historical and archaeologically invaluable heritage sites and monuments were affected, causing 133 to fully collapse, 95 to partially collapse and 515 to be partly damaged. Out of 35 districts affected by the earthquake, 14 were severely affected (Post Disaster Need Assessment, 2015) .

The collapse of the private houses and government building not only destroyed the physical structure but also ruined the overall architecture, art and craft including wood carving, roof- art, wall painting, stone art among others. Furthermore, number of settlements which were the center of attraction for its unique cultural and social significance, lost their true identity (Bothara, Jitendra K.Dhakal, Rajesh P,Ingham, Jason M.Dizhor, Dimytro, 2015).

Background of the Reconstruction and its Progress

Although Post Disaster Need Assessment report suggested Nepal government to facilitate the reconstruction of private houses right after the earthquake, Nepal Government took 9 months to pass the reconstruction bill. Then National Reconstruction Authority (NRA) was formed in December 25, 2015 with a mandate to implement and monitor the reconstruction including reconstruction of private houses (Post Disaster Recovery Framework, 2016). Only then, an avenue for rebuilding has been opened.

As per policy and guidelines developed based on the reconstruction act, 2015, Nepal government initially decided to offer Nrs.20, 000(approx. 2000 dollar) as a house- reconstruction grant to those who lost their homes in the earthquake (Nepal Government Distribution of Earthquake Reconstruction Cash Grants for Private Houses:2016). Later on, the grant was increased to Nrs 300,000 (approx. 3000 dollar) and was disbursed on three tranches.

As of November 24 2018, a total of 316,551 houses have been completed construction. This is 38.97 percentages of the total shelter grant beneficiaries. Similarly, 319,384 houses have received third tranche (which is the last tranche) of the housing grant which means 40 percentage of the shelter grantee are about to complete construction of their houses.

Research Methodology

The paper primarily focused on the use of traditional architecture in rebuilding. It has analyzed the degree of

---

[1] *PhD scholar, Department of Journalism and Mass Communications, Tribhuwan University, Kathmandu, Nepal*

use of traditional art and craft including wood craving, stone – art, stone carving, wall painting while rebuilding the houses in Nepal.

In order to find the answer to above mentioned research objectives, a Focus Group Discussion (FGD) was conducted with a shelter grant beneficiaries in Malu village of Tamakoshi Rural Municipality in Dolakha district of Nepal. Similarly, Gatlang, popularly known as black village of Nepal and one of the touristic destinations in Parbatikunda Rural Municipality in Rasuwa district was selected for case study while Key Informants Interview (KII) with the shelter beneficiaries in Sindhupalchok district provided important insights to the research paper.

Ethical considerations

Informed consent was obtained through explaining the aim and process of the research orally and in writing. The participants then signed informed consent or gave a verbal consent to participating in the study.

Findings Regarding Cultural Consideration in Rebuilding of Private Houses

Newly- built houses no longer have traditional outlook

A ground floor kitchen, upper story bedrooms, and an attic storage room known as ***Buigal*** is the true identity of traditional Nepali houses in hill districts in Nepal**.** Also, an ideal Nepali home includes spacious courtyard, veranda and clean sheds for their livestock. The houses used to have beautiful wooden art and craft. Further painting of different icons made of clay on the inside- wall was another feature of the traditional Nepali houses. However, most of the newly constructed houses at present neither look like the traditional Nepali houses nor include the components that traditional Nepali houses used to have. People have been using ready-made door and windows in place of craved and decorated wooden door and windows. Similarly, the ceiling art and craft have not revived. Earlier, ceiling of rural Nepali houses were seen craved with traditional art such as *Diyo Ghar* (light – stand), pictures of goddess, snakes (as a symbol of ***Naga*** God) among others. This has not been prioritized in rebuilding. Further courtyard is one of the important parts of the traditional Nepali houses from centuries. But many of the houses constructed after the earthquake don't have wide courtyard. It has affected the overall outlook of the house. The courtyard was emerged as one of the important components of the building design since around 6500-6000 BC in the era of the Indus Valley Civilization and a numerous mythology are associated with it.

Lack of space in newly- built house affects ritual

Most of the houses built after the earthquake with the Nepal government's grant support are made of two rooms Also, there are many newly built houses having one- room. It has created a problem for accommodation. Also, lack of enough room and space in houses has negative consequences on their ritual. Earlier, people used to allocate a separate room or space to worship and prayer both in Hindu and Buddhist communities in Nepal. Those who believed on *Tantrism* and practices *Kul*, *Bayu* and other sorts of prayer as part of their rituals used to allocate separate room for such the rituals. This apart, Brahmin, a so-called upper caste in Nepal used to have separate room for performing their daily prayers and worship. Also, ***Lama***s, religious leaders in Buddhist community used to allocate separate space for the religious performance. However, the space is compromised at present. Such the compromise affects the quality and true spirit of the rituals. Key informants in Sindhupalchok district opined that true quality of the worship and prayer can't be achieved when you can't concentrate. Those who practice the *Tantrism* opined that they need to have separate spaces which are to be remained untouched by other people to be able to fully practice it.

Also, space limitation has affected hierarchical system in terms of dining seat arrangement within ***Brahmins's*** society. In ***Brahmins*** households, dining seat arrangement used to be made in a culturally prescribed order. ***Purohits*** and males having ***Bratabanda*** are to be seated near to oven while married women's seat was a bit farther from formers. Similarly, children's seat is allocated farther than the women's seat. Such the cultural practices have been dismissed following Nepal earthquake.

Emphasizing on use of non- traditional construction materials likely to affect traditional construction knowledge

Materials used in reconstruction following the earthquake are different than the materials used before the earthquake. Such the practice is likely to affect transmission of the traditional construction-knowledge to future-generations. Mud- mortar masonry was the true identity of rural Nepali houses. The houses used to be erected till attic level (***Buigal***). However, due to the Government of Nepal (GoN) not allowed to erect houses having mud – mortar masonry beyond ground floor stating such houses don't have earthquake resilience, most of the rural houses are seen using mud mortar masonry till lintel level. Those who wished to raise the house to first floor and above have opted Reinforced Cement Concrete (RCC) structure. Hence, use of wooden art, stone art, roofing-art and traditional paintings have been compromised.

People concern for the loss of cultural knowledge and value- system related to construction

A case study of Gatlang Village of Nainikunda Rural Municipality in Rasuwa District

Gatlang, situated at an altitude of 2,400 meters in Rasuwa, a mountainous district of Nepal is known as the black village for the fact that it used to have a black roofed houses made of wood. This village in northern Rasuwa district was adorned with joined three stories houses made of dry stone walls, black wooden roofs and a mix of ***Hindu*** and ***Tibetian*** art and craft craved in wood- structures. Before the earthquake, the houses' stone walls were framed by wooden pillars intricately engraved with traditional symbols and flags. Most of the houses had engravings of the Buddha and lotuses or Tibetan mantras in its ceiling. Also, a prayer flag in most of the houses used to give the black village a unique identity. This is the reason why a large number of tourists used to visit the place. However, Nepal earthquake 2015 destroyed not only the physical structures in the village; it destroyed traditional art and craft, architecture as well.

Like it is the case in other earthquake affected areas in Nepal, people have started rebuilding in Gatlang now. They want to rebuild their house keeping the black- roof, wooden art and craft and wall paining traditions alive which has a history of more than eight centuries. However, due to no emphasis and consideration on applying cultural/ traditional elements in rebuilding from the side of government coupled with the local people's inability to invest more money to rebuild their houses, no availability of the wood along with the pressure of deadline, people are not in situation to rebuilt the houses reviving the cultural elements despite their interest to preserve it.

Earlier, Gatlang locals had demanded Government of Nepal to bring in a special package of reconstruction in their village keeping its sociological and cultural value in view. They went to the extent that many households refused green- CGI sheet support by NGOs during relief phase. Also, they carried out a numerous advocacy activities, visited government offices and submitted petitions requesting to manage necessary arrangement to restore the village as it was before. Locals say that assurance was given, but no concrete support was provided.

Despite communities' best interest to preserve the traditional outlook, traditional art and craft in rebuilding, NRA's imposition of deadline made them to accept the grant support and therefore they are going to end - up constructing one or two room structure.

Reasons for house owners not opting the traditional way of reconstruction

Reconstruction policies not prioritized cultural consideration

Government of Nepal introduced more than a dozen guidelines and Standard Operating Procedure (SOP) in line with the act relating to reconstruction of earthquake affected structure 2015 and Post-Earthquake Recovery and Reconstruction Policy 2015.However, none of the policy documents have emphasized the cultural consideration in rebuilding. Since no policy document instructs the integration of cultural elements in reconstruction, it has been ignored by construction workers, supervising engineers and shelter beneficiaries who are pressurized by the imposition of deadline by the NRA.

NRA Engineer's discouragement

NRA has deployed engineers in the field to facilitate the reconstruction process. However, instead of becoming facilitator, they didn't respond positively to the queries from the grant beneficiaries who were interested on rebuilding using the traditional style and architecture. FGD participants shared that when local tried to incorporate cultural elements in their construction, engineers bluntly rejected their idea terming such the practice is against the standardized norms set by NRA. It is important to note that the NRA engineers delayed to recommend second or third tranche of the shelter grant to those who tried to apply cultural components in rebuilding.

Financial Factor

One of the major reasons why most of the houses are constructed of one or two room is because of the financial factors. There is a common tendency among house- owners not to invest more money. Lack of money and dependency syndrome has contributed to it. We can find a number of cases where house – owner has built one –room building and saved Nrs 50,000 from the shelter grant amount provided by the government. Those who constructed two-room structure had to invest additional Nrs 200,000.

Pressure of Deadline

NRA and NGOs working in reconstruction in Nepal have adopted a strategy to impose deadline so as to expedite the reconstruction. However, such the deadline- imposition made shelter beneficiaries panic. Also, the pressure made earthquake survivors to ask for debt to rebuild, pay high for construction workers and construction materials. FGD respondents and Key Informants shared that they gave up their interest to include cultural elements into rebuilding due to the pressure of the deadline. There are many cases where earthquake survivors sold their cattle, jewelries to manage the additional money required for constructing the house. Those who couldn't manage the money ended up constructing one- room shed where incorporation of cultural element is almost impossible. The observation is corroborated by the latest Community perception report by the UK-funded Common Feedback Project in May 2018. It shows that over one-third of earthquake-affected families rebuilt houses to meet the NRA's July, 2018 deadline (COMMUNITY PERCEPTION REPORT:2018). Half of these are one-room houses that are just sheds.

Lack of availability of the skilled reconstruction crafts-person

Since rebuilding is taking momentum in all 14 earthquake- worst affected districts of Nepal, there is scarce of skilled human resources who have ability to apply cultural element in reconstruction while meeting the technical requirements of the earthquake resilience building. Government of Nepal and NGOs trained additional human resources on masonry and carpentry. However, no cultural consideration was taught during the training sessions. This apart, applying the cultural elements such as wooden art and craft, ceiling art, roof-art they found is time consuming which is not a desired task for already busy craftsmen who have taken business from many clients.

Conclusions

Nepal's rebuilding after the Gorkha earthquake has not been able to incorporate cultural elements mainly due to lack of emphasis of cultural consideration in reconstruction act and policies. Further, discouragement of the NRA engineers, pressure of deadline, financial resource crunch, lack of availability of woods and other raw materials, unavailability of skilled craftsmen has adversely affected the interest of the shelter grant beneficiaries to incorporate cultural elements in rebuilding their houses.

A lesson that international community can learn from Nepal's experience is about emphasizing cultural consideration in policy provisions in order to ensure that reconstruction not only meets the technicalities of earthquake resilience building, but also recognizes, respects and adheres the traditional art and craft, building construction knowledge, societal code and people's sentiment as a whole.

Acknowledgement

I would like to acknowledge support from Bhuwan KC, head of communications in National Reconstruction Authority (NRA) for his mentorship, Haribabu Pokharel for providing guidance to refine my paper. Also, my sincere thanks go to Focus Group Discussion (FGD) participants in Malu village of Tamakoshi Rural Municipality, Key Informants Interview participants of Baramchi village in Sindhupalchok district and respondents from Gatlang Village of Parbatikunda Rural Municipality in Rasuwa district in Nepal.

References

Bothara, J. K., Dhakal, R. P., Ingham, J. M., & Dizhor, D. (2015). The Challenges of Housing Reconstruction after the April 2015 Gorkha, Nepal Earthquake. *Technical Journal*, (January), 121–131.

National Reconstruction Authority. (2016). Post Disaster Recovery Framework. *Government of Nepal*.

Peacock, W. G., Dash, N., & Y., Z. (2007). Sheltering and Housing recovery following disaster. In H. Rodriguez, E. L. Quarantelli & R. R. Dynes (Eds.), *Handbook of Disaster Research* (pp. 258-274). New York, NY: Springer.

Post Disaster Needs Assessment (PDNA). 2015. Nepal earthquake 2015: post disaster needs assessment. Government of Nepal, available at: http://npc.gov.np/en.

Public, Ministry of Home Affairs (MoHA). 1982. Natural Disaster Relief Act. Kathmandu: His Majesty's Government, Ministry of Home Affairs (MoHA) (in Nepal Language).

Security, F. (2018). COMMUNITY PERCEPTION REPORT, (May).

Sharma K, Apil KC, Mandip Subedi & Bigul Pokharel (2018) Challenges for reconstruction after Mw7.8 Gorkha earthquake: a study on a devastated area of Nepal,*Geomatics, Natural Hazards and Risk*, 9(1). 760-790

TAF. (2016). Nepal Government Distribution of Earthquake Reconstruction Cash Grants for Private Houses, (September), 1–33. Retrieved from https://asiafoundation.org/wp-content/uploads/2016/12/Nepal-Govt-Distribution-of-Earthquake-Reconstruction-Cash-Grants-for-Private-Houses.pdf

SOCIO-ECONOMIC RECOVERY AND REHABILITATION OF PEOPLE WITH DISABILITIES AND THEIR FAMILIES FOLLOWING RANA PLAZA COLLAPSE

Ripon Chakraborty[1]

ABSTRACT

The collapse of an eight-story commercial building named Rana Plaza in Savar, Bangladesh, on 24th April 2013, killed 1134 people, with approximately 2500 people injured. The injured people received immediate medical treatment from hospitals in Savar, Uttara and Dhaka. Around 500 of those injured people sustained disabilities, some of whom received support from rehabilitation service providers. However, not all those injured people had access to rehabilitation and livelihood facilities, as many returned to their villages and were no longer living in Savar.

Handicap International (HI) implemented a 2-year project during April 2014 – March 2016, aimed to support people with disabilities and their families to contribute to the sustained socio-economic recovery and rehabilitation by increasing access to rehabilitation services, providing access to employment opportunities, and improving the inclusiveness of the labour environment. The project produced significant achievements and lessons that may be interesting and useful for others to learn and apply.

Keywords: Rana Plaza Collapse, Socio-economic Rehabilitation, People with Disabilities, Bangladesh.

Methodology

To link 100 people with disabilities with the different service providers at the district and sub-district levels, and to provide regular follow-up and support, Handicap International – Humanity & Inclusion (HI) selected five local non-government organizations (NGOs) and one Disabled Peoples' Organization (DPO) located in the seven target districts and their capacity has been built on 1) organizational assessment and capacity development plan, 2) evidence-based advocacy.

Personalized Social Support (PSS) - One hundred people with disabilities and their families were the active part in assessment, design, implementation and decision-making process. HI provided home based rehabilitation support to people with disabilities. The local partner agencies carried out follow-up visits, assisted in mapping service providers, linked beneficiaries with service providers and employment opportunities.

Mainstreaming disability in employment - To foster overall inclusion of people with disabilities in the labor environment, the service providers and employers were sensitized on:

1) Reasonable accommodations, accessibility, and modified equipment which physically adapt and permits people with disabilities to productively contribute in the workplace;

2) Inclusive practices in the work environment such as recruiting people with disabilities, adapting human resource policies, flexible work schedules, suitable/adapted work for people with disabilities.

Making it Work (MiW) - The local partner agencies with the support of existing MiW advisory committees identified, documented and used good practices for advocating the local service providers, employers and policy makers.

Results

Increased access to medical care and rehabilitation services - 100 people with disabilities received rehabilitation services, including an average of 14 sessions per beneficiary by government rehabilitation centers and HI professionals and 9 follow-up sessions by each of the partners. The same number of beneficiaries also received medical treatment from medical practitioners in their locality for different health

[1] *Technical Advisor- Inclusion, Handicap International – Humanity & Inclusion, Bangladesh.*

complications. 99 beneficiaries got significant physical improvement.

Increased access to employment opportunities - 99 people with disabilities received livelihood trainings including sewing, livestock, computer skills, garments, and electronics. After the trainings, people with disabilities explored small loan options from banks, the Department of Youth Development and NGOs. At project closure, beneficiaries were engaged in the following income generating activities: 23% in small shop/grocery, 12% in tailoring, 2% in garments, 1% in commercial driving, and the rest 57% in other activities, such as livestock rearing, cultivation etc. 5% of people with disabilities had yet to start livelihood activities due to a long rehabilitation process, however, action plans have been created for them too, with the support of local DPOs and NGOs, in order to ensure the effective development of livelihood activities.

Improved understanding of inclusive labor environment by business and national authorities - A national level workshop was organized with the representatives from 20 labor organizations and garment companies on improved inclusive labor environment for people with disabilities. Following the event, participants stated being more aware about disability inclusion and concrete ways to include people with disabilities in employment. Also, through an email campaign 4 companies responded with interest to employ people with disabilities and learn more about disability inclusive approaches at workplace.

Stronger and more sustainable access to relevant service providers (health, rehabilitation and livelihood) -

1) HI organized 6 workshops at the district level with the service providers to create awareness on disability inclusion and increase access to services for people with disabilities. A total of 279 participants attended the workshops including service providers and beneficiaries. Through those workshops various stakeholders committed to support people with disabilities and their families: rehabilitation service providers offered therapy services on a priority basis, social service offices and Department of Women Affair's committed to include the beneficiaries in their current safety net program, the Department of Youth Development committed to include the beneficiaries in their skills development training, NGOs committed to incorporate the beneficiaries into their existing program (BRAC, Bangladesh Bekaritto Durikoron Sangstha (BBDS) - income generating activities, financial services, rehabilitation, skill development).
2) Through two national level workshops, various national level stakeholders committed to continue supporting beneficiaries of the project after its completion and also to support an inclusive labor environment. Those included Bangladesh Garments Manufacturers and Exporters Association (BGMEA), garments companies, ministries, Jatiyo Protibondhi Unnayan Foundation - JPUF, Ministry of Social Welfare, national and international NGOs, researchers, and policy makers.
3) At the end of the project, HI organized an exit workshop with all the beneficiaries and local partner agencies. Participants developed a follow-up plan on the commitment made by different stakeholders during the district level workshops for each beneficiary.

Improved capacity of local NGOs and DPO- Along with 5 partner NGOs and one DPO working in the 7 target districts, HI also identified 5 additional DPOs working in the target districts. Due to the challenge met by current partners to reach some beneficiaries located far from their base, HI and partner organizations started a capacity building initiative with those additional DPOs located in areas of unmet needs. The process was based on the organizational capacity assessment and a capacity development plan. Following those, HI organized training for the DPOs on project development and advocacy in order for them to support linkages of the project beneficiaries with the service providers.

Challenges and Lessons learnt

Selection of the beneficiaries took more than 4 months as the initial list of affected people were incomplete

- 3 months political unrest, restrict movement of the project staff to the areas of intervention
- Beneficiaries prefer self-employment at their locality rather than wage employment outside
- Scope of wage employment at the locality was very low
- Some beneficiaries needed more time to get medically and psycho-socially stable to engage in activities
- The beneficiaries received compensation from the Government of Bangladesh (GoB)/BGMEA/Buyers which was kept as fixed deposit, struggling to manage startup capital

Conclusion

The project supported 100 people with disabilities through the provision of rehabilitation support from existing rehabilitation and health service providers. After improvement in their physical condition, the project facilitated access to livelihood training for 99 people with disabilities from local service providers. As a result of the trainings 38 people with disabilities started up activities in grocery/small stores, tailoring, driving and wage employment, while 57 people with disabilities undertook cattle rearing and cultivation. The next step for HI efforts for the Rana Plaza victims might be considering how to better link local and national actors to create more awareness and synergies and to transform the rights of people with disabilities into practice. In addition, as the project had some exposure to the garment companies, HI will look at building on the interest of garment company owners to sensitize them more on inclusiveness and address the barriers of people with disabilities at working environment.

REMEDIATION OF CONTAMINATED BROWNFIELD THROUGH URBAN REDEVELOPMENT OR REGENERATION: A CASE STUDY ON HAZARIBAGH TANNERY AREA

Md. A. Islam[1], Md. M. Mamun[2], Kazi N. Kowser[3]

ABSTRACT

Hazaribagh area was started to grow as a potential industrial estate for the tannery. The effluents from industries with the wastewater were discharged to Buriganga river. Topsoil of the area and water of the Buriganga river are highly contaminated with Chromium (23148 mg/kg). Tannery has already relocated in Hemayetpur, Savar Upazila, Dhaka. Hazaribagh tannery area has the scope to have planned development for its high demand for commercial office and residential development due to adjacent to Dhanmondi Residential area. Making resilient city in Hazaribagh with self-sustaining emergency management and recovery system through the introduction of Urban Redevelopment or Regeneration. The process of regeneration includes PRA session with tannery owners, interviewing experts, consultation with local people, and professionals in every step and following existing guidelines in Detailed Area Plan (DAP). The soil must be excavated minimum 8 feet before using the area. 65% of the landowners are agreed on redevelopment in Hazaribagh. Redevelopment or regeneration is a solution to build disaster resilient community with mixed-use development construction and fire safety. Creation of public space through parks and open spaces can be used as an emergency shelter/space after any disaster. Landowners can be motivated by attracting FAR incentive and low rate finance from local or international investors. If the Government of Bangladesh (GoB) involves in this project, tannery owners, government and the Dhaka city will be benefited and that will make a resilient community.

Keywords: Disaster, Resilient, Emergency Management, Hazaribagh, Redevelopment, Regeneration.

Introduction

Hazaribagh area started to grow as a potential industrial estate for tannery from 1947. The effluents from industries with the wastewater were discharged into Buriganga River. Tannery has already been relocated to Hemayetpur, Savar Upazila, Dhaka leaving this area as a brownfield. Topsoil of this area and water of Buriganga River are highly contaminated with different heavy metals. This study illustrates obstacles of the development in Hazaribagh, gives the ways to eradicate the obstacles and finds out the design considerations.

Objective

The study has been carried out with the following objectives:

- To find out the process of the brownfield treatment in Hazaribagh.
- To find out the best possible use and development of the land in Hazaribagh tannery area.
- To create public space during emergency situation through urban redevelopment for earthquake and build a resilient community.

Literature Review and Definitions

Various agencies and scholars defined brownfield in different ways. The US Environmental Protection Agency (USEPA) and Department of Housing and Urban Development (HUD) defined brownfield as “abandoned, idled, or underutilized industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived contamination” (USEPA, 1997). The status quo of urban land use in China defined in the way that “the industrial and commercial lands, sites and facilities in urban areas, which are abandoned, idled or underused due to real or perceived environmental threats and other developing obstacles, and cannot be immediately put into use without treatment.” As our study area is a tannery area and tanneries

[1] Town Planner and Project Director, Detailed Area Plan (DAP), Rajdhani Unnayan Kartripakkha (RAJUK), Dhaka, Bangladesh.
2 Research Assistant, Detailed Area Plan (DAP), Rajdhani Unnayan Kartripakkha (RAJUK), Dhaka, Bangladesh.
3 Research Assistant, Detailed Area Plan (DAP), Rajdhani Unnayan Kartripakkha (RAJUK), Dhaka, Bangladesh.

had been relocated to Hemayetpur, Savar leaving Hazaribagh Tannery Industry as abandoned; this study considers the area as a brownfield.

A previous study revealed that most severe soil pollution up to a depth of 10-20 ft (3.048-6.096 m) is a serious threat to the environment and human health (Karim et al., 2013). Another study showed that the concentration of heavy metal in the samples crossed the maximum allowable concentration in both wet and dry season. The highest concentration of Cr (172792 ppm) was found at the main disposal point in the soil sample (Mondol and Asia, 2017). The author also stated that a high concentration of heavy metal in plant samples consequently affect the food chain, which is a major environmental concern. Another study gave an overview of Cr (Chromium) toxicity in the environment, particularly in water and soil (Oliveira, 2012). In this research, the diverse impacts of Cr (III) and Cr (VI) on plants were identified such as decrease of seed germination, reduction of growth, a decrease of yield, inhibition of enzymatic activity, nutrient and oxidative imbalances. Another study showed different health problems such as skin diseases, itch, rash, cough, fever, diarrhea, headache, asthma, dizziness etc. due to unplanned tannery waste disposal. This study also identified that tannery waste was the reason for the death of livestock and poultry indicated by 59% respondents. The study also derived outcome of 48% low livestock and fish production (Tinni et al., 2014).

Methodology

Study area selection

Hazaribagh tannery area has a high demand for commercial office and residential development because it is very adjacent to Dhanmondi residential area. Because of the demand, any illegal building construction can be started without taking land use clearance from RAJUK. As Hazaribagh Tannery Area is vulnerable to human health, any type of construction must be prohibited without proper treatment of contaminated soil. For these reasons, this site is taken as the study area of this study.

Data Collection

Primary data collection was carried out for the study. A questionnaire survey of local people, Participatory Rural Appraisal (PRA) of landowners and Key Informant Interviews (KII) of experts were included in primary data collection. Simple Random Sampling was used to select the sample size of the local people. Hazaribagh Thana has 185639 population according to the District Statistics 2011. So, with 95% confidence level and 10% confidence interval the sample size is 96 respondents from 185639 population. One PRA session was conducted to know the views and requirements of landowners. Ten KII were conducted for suggestions on the development of the land. In this study, Key Informant Interviews were functioned to get the best considerations for the treatment of contaminated soil and creating a resilient community in Hazaribagh Tannery area.

Findings and Discussions

Findings and discussions are based on the analysis of the survey data.

Findings and Discussions

Pollution in Hazaribagh Tannery Area

Soil

In Bangladesh, there are no standard regulations for soil contamination. So, the concentration of heavy metal in the sample of soil has been compared with the European standard. The maximum permissible limit of Cr concentration is 150 mg/kg in EU standard. Where a high amount of Chromium ranging from 34.85 to 23148 mg/kg was found in the samples of the tannery area. (Juel et al., 2016). Previous studies (Karim et al., 2012; Shams et al., 2009; Zahid et al., 2006) also reported that topsoil of Hazaribagh area is containing a higher concentration of chromium ranging from 1000 to 30000 mg/kg. Where most of the Chromium accumulated in the soil has been found as Cr(III) (Saha and Ali, 2001) and very low amount (maximum 1 mg/kg) of Cr has been found as Cr(VI) (Shams et al., 2009). Another study revealed that 10-20 ft depth of soil of Hazaribagh tannery area is highly contaminated with heavy metals (Karim et al., 2013).

Water

Different chemicals and effluents are discharged from Hazaribagh Tanneries in the nearest channel and rivers through drains. This waste in form of liquid are discharged in Burigannga and eventually, it pollutes the water and harms fishes and other species in the water. Moreover, the toxic materials in the waste sip into the cropland and surrounding groundwater (Ahmed, 2013). As a result, the tannery waste is poisoning the soil, water, and air round the clock. Tannery wastes also cause harm to the health, houses, and utensils of those situated around the area (Bhowmik and Samiul, 2009).

Effects and removal of Chromium

The concentration of Cr(VI) in the soil of Hazaribagh is very low and so the soil of Hazaribagh is less hazardous for Human health. Cr(III) is less toxic than Cr(VI) for both acute and chronic exposures. (EPA, 2000) But high level of Cr(III) and Cr(VI) by inhalation or oral exposure effects liver, kidney, gastrointestinal and immune systems, and possibly the blood. Chromium (VI) is considered as a human carcinogen. (Sun et al., 2016) Chromium is easily soluble in water, so the groundwater in the tannery may contain a high concentration of Chromium. So, drinking or using this water for daily use is not safe. This groundwater cannot be used without a minimum level of filtration or removal of chromium.

Treatment of Brownfield

If the soil contains Cr(VI) at a higher level then a huge reduction will be required but if it is Cr(III) then it will be very easy to bring it down to the tolerance level. One way is that Cr(VI) can be converted to Cr(III) by some chemical reactions. The process of decreasing Cr(VI) to Cr(III) consists of using Ferrous Sulfate followed by coagulation and filtration. This removal system is now at the laboratory level and may not be suitable for a mass level project (Gang et al., 2005). Second way of removing toxic Cr(VI) from the contaminated environment is the process of bacterial isolation from the soil. It can be done by one bacterial isolate (Bacillus sp. ES 29) which is capable of reducing 90% of Cr(VI) aerobically in six hours (Camargo et al., 2003). Another way to reduce the direct contact with the Cr(VI) soil is to excavate the contaminated soil and a case study shows that excavating up to 35 feet depth and filled up with uncontaminated soil had removed the vulnerability of heavy metals in soil (EPA, 2012). But according to Karim et al., a depth of up to 10-20 feet of Hazaribagh tannery area is contaminated. Considering these points, Detailed Area Plan (DAP), Dhaka Metropolitan Development Plan (DMDP) 1995-2015 suggests to excavate the topsoil of eight feet of the study area can be a solution. Using Bacillus sp. ES 29 will help to reduce Cr(VI). This new layer of soil will keep away from direct human contact. But according to experts, in the case of plantation, any type of vegetable or fruit plantation must be prohibited because these trees will intake Cr from the groundwater.

Land Owners' View on Redevelopment

There are around 187 Tannery industries in Hazaribagh. (RAJUK, 2010) The landowners of those Tanneries were invited in a PRA session. In the PRA session, 40% of total landowners attended. Where 65% of the attendee landowners were agreed about redevelopment in Hazaribagh Tannery Area. Finance from GoB, local or international investors will be welcomed by the landowners and these investments will help to undertake and implement a redevelopment project in Hazaribagh in a more smooth way.

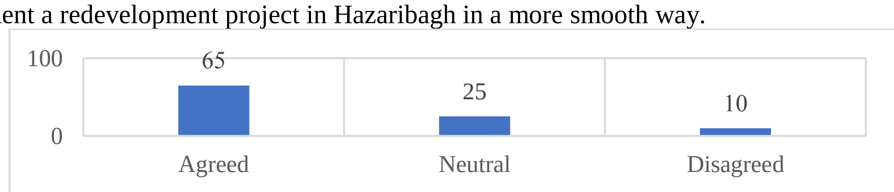


Figure 1. Landowners' Opinion on Redevelopment

Need Assessment of Local People

Need assessment is based on a questionnaire survey of local people.

Employment Facilities

Because of shifting the tannery industry many people become unemployed. Some of the labors of tanneries have also shifted in Savar with industry but a big number of people are still living in Hazaribagh being jobless. To remove the scarce job opportunities, the local people want some commercial activities in this area which may create a scope of employment for them.

Park and Open Space

Compared to other areas of Dhaka city, Hazaribagh tannery area and its surrounding area do not have enough open space. Nearest park or lake is Dhanmondi Lake which is not within the walking distance from that community. As a result, the tannery area can be redesigned and redeveloped for creating large open space and playground.

Health Care Center

Hazaribagh was a tannery industry with very poor health security for the workers. The workers worked in those industries suffered from many diseases. A study discovered that 25.3% of the workers from the sample were facing skin problems. Other diseases like gastrointestinal problems (8.5%) and chronic headache (8.2%) have been confronted by the tannery workers. The environmental condition of the working place was not significant enough for maintaining good health of the tannery workers. There is no specialized hospital or health center near to this area. So local people living in that area need a hospital in the tannery area (Islam et al., 2017).

Transportation Network and Accessibility

Connecting roads to Hazaribagh tannery area are very narrow and drainage, electricity, the gas network are poorly circulated. Some existing roads are less than eight feet in width. In emergency situations, ambulance and fire service cannot go through them. A well-designed road network must be constructed in the tannery and residing area. New road network must include spacious walkways as community people want non-motorized transport and pedestrian facilities in the new community.

Future Best Use of the Land

In the DAP (2016-2035) proposal, Hazaribagh Tannery Area's proposed land use is open space or green space. So, the tannery owners cannot construct any kind of infrastructure in this area. In this situation, considering the need assessment and DAP proposal, RAJUK is trying to develop this area with new kind of city development approach. RAJUK is trying to apply Urban Redevelopment in Hazaribagh Tannery area. In redevelopment approach, an existing buildup area can be reconstructed with open spaces, lakes, better housing and commercial facilities, service, and community facilities and well-designed transportation and accessibility. The main reason for adopting redevelopment for Hazaribagh area is to preserve green space to a large extent which is very similar to the DAP (2016-2035) proposal.

Design Considerations for Building Hazaribagh as a Resilient Community

Before preparing the plan it requires to consult with experts from different fields related to this project. A detail design consideration was prepared by consulting with university professors and professional according to their expertise. They gave their expert opinion on soil treatment and the best way to heal soil and water through the plantation. Most of the experts suggested a green network within the community with water body and restricted forest land for creating its own biodiversity.

Land and Infrastructure

- Any type of contaminated land can be usable after 15-20 years of plantation. Banyan tree for greater ecosystem also small size restricted forest should design for greater recovery of soil and environment. Conifer or Christmas tree is very effective to reduce air pollution.
- Topsoil of the whole area must be excavated for a certain layer. According to the Dhaka Metropolitan Development Plan 1995-2015, first 8 feet top soil of this area should be removed before the construction.
- Other chemicals like Cr may be treated by the give solutions above or through further research with the help of experts.
- Because of scarce land, plot allotment cannot be permitted and the ground coverage of buildup area should remain as low as possible.
- Rainwater harvesting and using renewable energy technology must be installed.
- The area will be designed as mixed use zone incorporating height zoning.

- High rise buildings will be built adjacent to wider roads and low rise buildings will be built at the inner side of the community so that the neighborhood has less car pressure. No parking facilities will be provided in the residential buildings. At the entrance of the neighborhood, a multi-storied building is highly recommended which helps to create an NMT based community and walking friendly environment in the community.
- A modern, environment-friendly and residential neighborhood can be created by low Job-house mismatch as employment opportunities can be created in the community.
- Cr(VI) is soluble in the water and it is harmful to human health. So, water supply from the neighboring community or water supply from WASA from outside of Tannery area may be a solution to drinking water.

Environment

- If the major road is designed to make underground then there will be an opportunity to create a car-free community.
- It will be possible to create a livable environment with open space, lakes, and playgrounds.
- The project design should ensure maximum Social welfare.
- Major features of the area will be creating Green Development, Waterbody Creation, Pedestrian Friendly Community, Separate Parking Facility, and Car-free Community.
- Old or encroached canals need to reconstruct in its old path.

Social benefit and Recreational facilities

- Provision of School, college, community clinic and consultancy, Tannery Museum, Amphitheatre, Library, Cultural belt in the redeveloped area will enrich the area as a self-sustained community.
- The new lakes will be excavated and no human access to these lakes.
- Walkways and cycle lanes will be designed for creating a public space.
- A multipurpose building complex can be built with all social and citizens facilities. This building may have ward councilor’s office, community clinic, community center, swimming pool, day care center, women's club, gym etc. This building complex will be disable friendly. Open space should be reserved in front of this building. This is a place where the elected representatives can affiliate with the local people.
- Secondary Transfer Stations (STS) for Solid Waste Management must be built. Reduction of waste production can be achieved through reuse, recycle and practice of reducing wastes in the community.
- The design should be consistent with the affordability and accessibility of low-income people.
- Provision of field may not be possible in every school but community open spaces can be used as playgrounds.

Disaster Management

- During Earthquake Emergency, open spaces and playfields will serve as Emergency Shelter or Evacuation area.
- Decreased amount of paved area and increased amount of unpaved area with vegetation, plantation and water bodies will reduce the urban heat island effect.
- Water bodies can be used during fire extinguishing.
- Ladders or Steers must be included in each building for emergency evacuation.

Economic

- Mixed use development will create more job opportunities also discourse mono-functional land use.
- Limited informal activity should be allowed and for this, temporary structure may allowable.

Transportation

- Inner transportation network of the community should be walking friendly.

- Encouraging pedestrian and NMT (non-motorized transport) within the community will help to reduce the need of motorized vehicles. Extension of Sher-E-Bangla road will ensure better accessibility with the community.
- To avoid through traffic, ring road or underground major road is essential.
- Community Based Transportation (CoTI) can be introduced providing necessary stoppage, garage, and parking area. This garage may be located in the multi-purpose building complex.

Creating Public Space for Building Disaster Resilient Community as an Outcome

After the completion of Redevelopment in Hazaribagh, the newly developed community will work as a disaster resilient community because of the following design considerations. Firstly, large open space for the shelter of evacuation during an earthquake or other disasters. Secondly, emergency exit facility with ladders and steers and built-in fire extinguishing system. Thirdly, the large green community with a variety of vegetation and plantation. Fourthly, a wider road with Non-Motorized Transport (NMT).

Conclusion

The main obstacle of development on a brownfield is to treat the soil. Without making the soil uncontaminated, any type of land use can be harmful to human health. Being a brownfield, Hazaribagh Tannery area needs proper treatment to the heavy metals especially hexavalent chromium (VI) as it is most harmful to human health. For development, urban redevelopment process can be used to meet the demand of local people, and the city dwellers. Public spaces, sufficient open spaces, encouraged community-based non-motorized transport network can be introduced in the urban redevelopment in Hazaribagh Tannery area. Open spaces, lakes, canals and natural environment will increase the disaster resiliency of the community.

References

Azom, M. R., Yahya, S. M., Sontu, A., & Himon, S. (2012). Environmental Impact Assessment of Tanneries: A Case Study of Hazaribag in Bangladesh. *International Journal of Environmental Science and Development*.

Bhowmik, A., & Samiul, M. I. (2009). Environmental concerns regarding Hazaribagh tannery area and present relocation scenario. *Nagar Shoilee*, 33-41.

Brugmann, J. (2013). *Building Resilient Cities from Risk Assessment to Redevelopment.* Ceres, The Next Practice, and the University of Cambridge Programme for Sustainability Leadership.

Camargo, F., Bento, F., Okeke, B., & Frankenberger, W. (2003). Chromate reduction by chromium-resistant bacteria isolated from soils contaminated with dichromate. *Journal of Environmental Quality*.

Chakraborty, C., Ahmed, S., Huq, M. M., Zohra, F. T., Tabassum, T., & Siddiqui, A. A. (2013). Assessment Of Level Of Water Pollution Dis-charged From Hazaribagh: A Critical study. *International Journal of Scientific and Engineering Research*.

EPA. (2000). *Chromium Compounds.* United States Environmental Protection Agency.

EPA. (2012). *A Citizen's Guide to Excavation of Contaminated Soil.* United States Environmental Protection Agency.

Gang, Q., Michael, J. M., Nicole, K. B., Chad Seidel, †., & Leighton, F. (2005). Hexavalent Chromium Removal by Reduction with Ferrous Sulfate, Coagulation, and Filtration: A Pilot-Scale Study. *Environmental Science & Technology*.

Hashem, M. A., Arefin, M. S., & Jor, A. (2015). Gaseous Air Pollutants and its Environmental Effect- Emitted from the Tanning Industry at Hazaribagh, Bangladesh. *American Journal of Engineering Research (AJER)*, 138-144.

Islam, R., Hossain, M. S., & Siddique, M. A. (2017). Occupational health hazards and safety practices among the workers of tannery industry in Bangladesh. *Jahangirnagar University Journal of Biological Sciences*, 13-22.

Juel, M. A., Chowdhury, Z. U., Mizan, A., & Alam, M. S. (2016). TOXICITY AND ENVIRONMENTAL IMPACT ASSESSMENT OF HEAVY METALS CONTAMINATED SOIL OF HAZARIBAGH TANNERY AREA. *Proceedings of 3rd International Conference on Advances in Civil Engineering.* Chittagong: CUET.

Kang, C., & Hua, G. (2007). Brownfield Redevelopment Toward Sustainable Urban Land Use in China. *Chinese Geographical Science*.

Karim, M. R., Manshoven, S., Islam, M. R., Gascon, J. A., Ibarra, M., Diels, L., & Rahman, M. M. (2013). Assessment of an Urban Contaminated Site from Tannery Industries in Dhaka City, Bangladesh.

Journal of Hazardous, Toxic, and Radioactive Waste, 52-61.

Khan, N. M. (2017). *SCP in Bangladesh: The Brown Hope of Hazaribagh and the Golden Fibre of Bangladesh.* World Scientific Publishing Company.

Mengel, K. e. (2001). *Principles of Plant Nutrition.* Kluwer Academic Publishers.

Mondol, M. N., & Asia, A. C. (2017). CONTAMINATION OF SOIL AND PLANT BY THE HAZARIBAGH TANNERY INDUSTRIES. *Journal of the Asiatic Society of Bangladesh, Science*.

Oliveira, H. (2012). Chromium as an Environmental Pollutant: Insights on Induced Plant Toxicity. *Journal of Botany*.

RAJUK. (2010). *Dhaka Metropolitan Development Plan (DMDP) 1995-2015, DAP Part - III.* Dhaka: RAJDHANI UNNAYAN KARTRIPAKKHA (RAJUK).

Rida, B., Yrjälä, K., & Hasnain, S. (2012). Hexavalent Chromium Reduction by Bacteria from Tannery Effluent. *Journal of Microbiology and Biotechnology*.

Siddiqee, M. H., Islam, M. S., & Rahman, M. M. (2012). Assessment of pollution caused by tannery-waste and its impact on aquatic bacterial community in Hajaribag, Dhaka. *Stamford Journal of Microbiology*.

Sun, H., Brocato, J., & Costa, M. (2016). Oral Chromium Exposure and Toxicity. *Current Environmental Health Reports*.

Tinni, S. H., Islam, M. A., Fatima, K., & Ali, M. A. (2014). Impact of Tanneries Waste Disposal on Environment in Some Selected Areas of Dhaka City Corporation. *Journal of Environmental Science and Natural Resources*, 149-156.

USEPA (US Environmental Protection Agency). (1997). *Brownfield Economic Redevelopment Initiative.* Washington DC: US Environmental Protection Agency.

INTER-ORGANIZATIONAL RESPONSE TO CYCLONE SIDR (2007): A NETWORK BASED APPROACH

T.T. Isaba[1], A.M. Riyadh[2] and M. A. Ansary[3]

ABSTRACT

This paper examines the response system that emerged in Bangladesh following the 2007 cyclone Sidr. The analysis is based on content analysis of news reports that has documented the actions taken in response to this major cyclone. From the news reports, the paper has identified 203 organizations that participated in the response system. These data are analyzed using ORA software across the first three weeks following the cyclone. The authors have attempted to find out the most influential actors in the response network. Important and effective players during the cyclone are found to be national, public organizations (government of Bangladesh, Armed Forces Division) and mostly international organizations (government of Japan, International Federation of Red Cross) etc. This research has argued that an effective mechanism is required to improve and increase the participation of local organizations in emergency response of Bangladesh. Results obtained from the study have documented the breakdown of inter-organizational response which will support efforts to improve the future response activities after a disaster.

Keywords: Cyclone Sidr, Inter-organizational network, Disaster response system, Network analysis, Bangladesh.

Introduction

Bangladesh is one of the most disaster-prone countries in the world due to its geographical location, soil characteristics, diversity of rivers and monsoon climate. With Bay of Bengal at its southern border, Bangladesh is particularly vulnerable to tropical cyclones and from 1584 to 1991, about 53% of the world deaths from these cyclones have taken place in Bangladesh (Ali, 1999). Cyclone Sidr (a category IV storm on the Saffir-Simpson hurricane scale of I to V) is one of the most devastating cyclones in the history of Bangladesh. Being originated from a depression in Bay of Bengal, the cyclone has swept through the southwestern coast of Bangladesh on 15 November, 2007 with a diameter of nearly 1000 km and sustained winds of up to 240 km per hour. According to official reports, about 27 million people from 30 districts have been affected by the cyclone with a death toll of 3,406 and estimated loss of $1.3 billion. Storm surge with a maximum height of 20 feet in certain areas has caused immense physical destruction, damage of crops, livestock and flooding of low-lying areas. Mainly the poverty-prone districts of the country have been affected by the cyclone (Paul, 2009; Dhar and Ansary, 2012; Haque, 2016). Although the death toll is significantly less compared to previous cyclones that hit Bangladesh, Sidr has caused extensive damage to properties. The scale and devastation of the cyclone have created dynamics that are impossible to be addressed by any single organization or jurisdiction area. In addition to national assistance directed towards the affected people, the cyclone has resulted in a global response with supports from various international donors and development partners (GoB, 2008).

The term “network” is defined as- “group of individuals or organizations who, on a voluntary basis, exchange information and undertake joint activities and organize themselves in such a way that their individual autonomy remains intact”. The term is used to describe the multiple organizations engaged in interactions involving multiple nodes (Kapucu, 2005). After catastrophic events the formal structure of operation, including the functioning of existing support networks, communication networks and other infrastructures are often disrupted as seen from previous incidents of South-Asia Tsunami (2004), Hurricane Katrina (2005), the Great Japan Earthquake (2011) etc. (Almquist *et.al*., 2017). At times of emergencies, a collective action is required among public, private and non-profit organizations towards mitigating the adverse consequences (Waugh, 2004; Wang, 2012). Emergency management organizations, both governmental and non-governmental, look to one another for topical information and practical guidance (Comfort *et.al*., 2004; Drabek and McEntire, 2002). Inter-organizational networks in emergencies play a vital role in facilitating the

[1]*Lecturer, BUET-JIDPUS, BUET, Dhaka-1000, Bangladesh*
[2]*Graduate Student, Dept. of Urban and Regional Planning, BUET, Dhaka-1000, Bangladesh*
[3]*Professor, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh*
Email of Corresponding Author – isaba.buet@gmail.com

flow of information across organizational boundaries (Kapucu, 2005). Therefore, network analysis can be conducted to determine the pattern of relationship among different organizations that interacted within a disaster response system. Social network analysis is a well-developed area of organizational sociology which provides tools and concepts for analyzing organizations as networks. The basic idea is to consider the organizations as “nodes” and the relationship between them as “ties”, forming a network-like structure (Wasserman and Faust, 1994; Zhao, 2013). Considering the vulnerability of Bangladesh to tropical cyclones and the future probability of cyclones in the country, the inter-organizational relationships that emerge in response to cyclones must be thought with great importance.

Organizational Response to Cyclone Sidr (2007)

The performance of any disaster risk reduction plan can be verified when an actual incident of disaster occurs. Cyclone Sidr provided major test of Standing Order of Disasters (1999) and the international commitment of HFA (2005) and SAARC framework (2006).

The organizational response system that emerged following cyclone Sidr has been observed through content analysis. From the news articles reported in *The Daily Star* newspaper, all the organizations that participated in the response system through provision of search and rescue services, medical care, relief distribution, donation, shelter and other types of assistance for the affected persons have been identified. Content analysis has been conducted for a period of three weeks, starting from 15 November, 2007 to 7 December, 2007. Content analysis of news reports has identified 203 organizations that responded to cyclone Sidr and it does not claim to represent the entire response network. Table 1 shows the composition of the response system as found from the analysis. Here city-based organizations denote those organizations that are mainly based on capital Dhaka or other major cities. Local based organizations have been identified as organizations that are located at 30 districts that have been directly affected by the cyclone. Organizations that operate worldwide or outside the territory of Bangladesh have been mentioned as international.

Table 1. Frequency Distribution of Organizational Response System by Jurisdiction and Source of Funding, Cyclone Sidr, November 15–December 07, 2007

	Public		**Private**		**Non-profit**		**Special interest**		**Total**	
	N	%	N	%	N	%	N	%	**N**	**%**
International	43	21.18	11	5.41	38	18.71	0	0	92	45.32
National	33	16.25	15	7.38	6	2.95	7	3.44	61	30.05
City	9	4.43	7	3.44	11	5.41	0	0	27	13.30
Local	12	5.91	1	0.49	10	4.92	0	0	23	11.33
Total	97	47.78	34	16.74	65	32.01	7	3.44	203	100

(Source: Content analysis of news reports regarding cyclone Sidr from *The Daily Star*)

Table 1 documents 203 organizations in the response system, with the largest number, 97 organizations (47.78%) are identified as public organizations. The breakdown by jurisdictions shows that the largest number of public organizations are from international level (43, or 21.18% of total organizations). National and international organizations have made up 34.02 % and 44.33% of the public organizations respectively. In case of private sector, national organizations (44.12%) have dominated over international organizations (32.35%). The non-profit organizations have made up the second highest group of organizations (32.01% of total), with more than half (38, or 58.46%) belonging to international organizations. It is noteworthy from the analysis that nearly half of the total organizations (45.32%) are from international level. Local organizations constitute the smallest segment (11.33%) and majority of the local organizations are public (15.38%). The special interest group has been identified as groups having political interest that didn’t fit any of the other three categories.

Results from content analysis doesn’t fully correspond to the SOD (1999) as only 34.02% of the public organizations are from national level. In contrast to the national policies which have designated major responsibilities towards the public organizations, nearly half of total organizations (48.75%) has been represented by private and non-profit organizations. Undoubtedly national and public organizations required the support from international public, private and non-profit organizations. The significant participation of international aid organizations in the response network denotes the country’s dependency on international

assistance. The lowest participation made by local organizations signifies the lack of power and resources at the local level despite their importance being mentioned in SOD and other national policies.
The performance of the organizations can be more clearly defined by identifying the time at which organizations from different jurisdiction and sector entered into the response system. Figure 1 and 2 show the date of entry of organizations into the response system by jurisdiction and source of funding respectively.

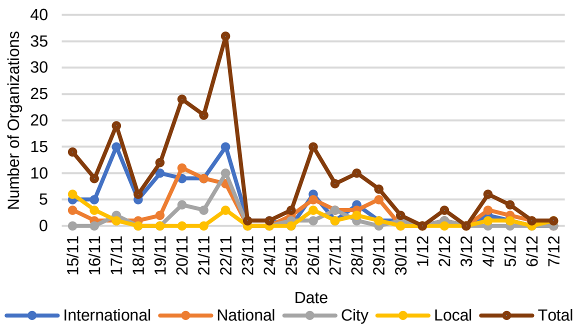


Figure 1. Entry of new organizations into the response system by jurisdiction and date (Source: Data from The Daily Star)

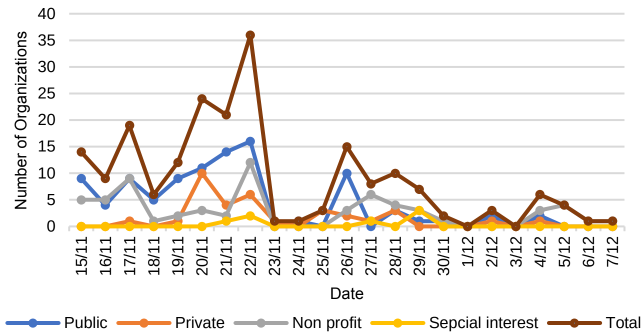


Figure 2. Entry of new organizations into the response system by funding source and date (Source: Data from The Daily Star)

At the day of landfall (15 November, 2007) the local organizations have responded quickly, followed by international and national organizations. District and upazila administration, law enforcement agencies and local NGOs have quickly entered into the response system as per requisition of upper levels of administration. Among the national organizations, central government and ministries have responded rapidly through an emergency meeting of National Disaster Management Council and directed the district administrations. Significant international assistance came in 17 November, two days after the cyclone made landfall. Seven days after the storm, city-based organizations had their peak on 22 November, 2007. The entrance of new organizations into the response system has been increasing for the first week after landfall and decreased after 22 November, 2007. When the rate of entry is analyzed by source of funding, results show the early and intense response by public and non-profit organizations, which has been continued throughout the first three weeks after landfall. Organizations from private sector have only entered into the response system on 20 November, five days after the cyclone hit.

Network Analysis

After identification of organizations, a matrix has been prepared depicting the interactions among them for network analysis. The data has been entered into ORA, a network analysis software developed by Center for Computational Analysis of Social and Organizational Systems (CASOS), Carnegie Mellon University. Figure 3 shows the visual representation of interaction among 203 organizations responding to cyclone Sidr as prepared by ORA. Sources of funding are represented by colors of the node and jurisdiction areas are shown

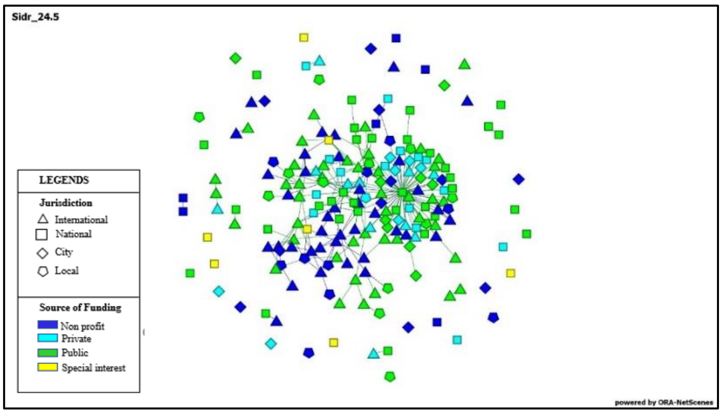


Figure 3. Network diagram of the cyclone Sidr (2007) response system (Source: Data from The Daily Star and analysis from ORA)

by node shapes. The network map depicts the presence of a large cluster located at the center of the response network. Many of the international, national and city-based organizations from public, private and non-profit sectors have channeled their assistance through central government which can be seen from the diagram. Organizations with special political interest remained as isolates and didn't take part into the central network. Findings from the network analysis can be validated from the review of news reports. Immediately after the cyclone, the Chief Advisor of contemporary Care Taker government has established emergency relief fund which collected donations from the donor agencies, from both national and international level. Therefore, maximum amount of donation has to be channelized through central government in order to reach the affected people. However, some international/ public agencies have disbursed their assistance through international NGOs. For example- German Red Cross in association with CARITAS, an international NGO, distributed the amount granted by German government.

One key information that can be derived from the network map is the large number of isolates. 33 out of 203 organizations (16.26%) don't have any interaction with other organizations, and are isolated from the central network. Major portion of the isolated organizations are national and public (6 or 18.2%) organizations. Isolates are quite common in network structures, but such large number of isolated organizations in response to a major disaster of the country is not typical. An organization that is disconnected from others will find it difficult to manage by itself as the lack of connections will weaken its ability to learn from others' actions (Scheinert and Konstantinova, 2011). Especially for public organizations who have prime responsibility in emergency management, this lack of interaction denotes a major discrepancy from the stated national policies. The study has identified ten key organizations in the response system calculated by ORA, as shown in Figure 4. Key entities are those organizations which have the most ability to monitor information flow and reach out to other organizations (Comfort *et.al.*, 2013).

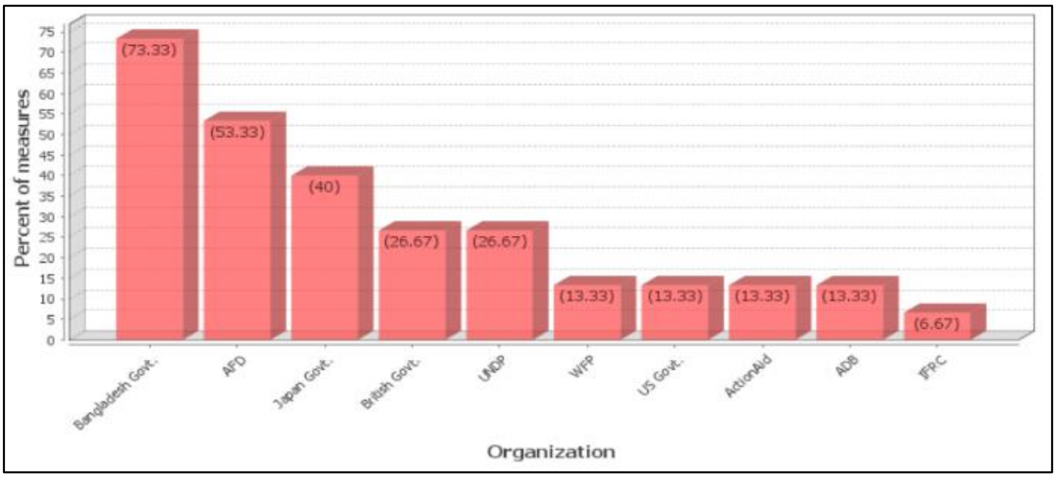


Figure 4. Key agents in the overall disaster response system (Source: Data from The Daily Star and analysis from ORA)

Centrality Measures

In this section, the nodes are analyzed based on their centrality. An analysis of network centrality measures helps to identify the actors that shape the performance of the response network. Centrality scores are assigned to nodes based on the principle that connections to high-score nodes contribute more to the score of the particular node than connections to low-score nodes (Cheong and Cheong, 2011). Table 3 shows the top five organizations in the main component of cyclone Sidr ranked by order of importance on their centrality values named as – degree, betweenness, closeness, and eigenvector centrality.

Degree centrality is the measure that evaluates actors in the network by the number of ties actors possess (Wasserman and Faust, 1994). An analysis of degree centrality shows the organizations that most frequently interacted with other organizations in the network. Total degree centrality calculated by ORA shows that government of Bangladesh has the highest degree centrality, and can be regarded as the most influential in the response network.

Out-degree centrality represents the number of links or connections emanating from a node. Organizations with high out degree centrality scores include government of Bangladesh, Japan, Britain, US, and Australia. Bangladesh government has communicated with local administration, MoFDM, local NGOs as well as with multiple international organizations such as UN to coordinate the relief efforts.

In-degree centrality depicts the number of links directed to a node, or the number of connections the node of interest receives from other nodes. The top organizations in terms of in degree centrality include government of Bangladesh, AFD and IFRC. Government and AFD both have received significant response from national and international donors through the emergency fund. IFRC has received information from BDRCS and coordinated relief from international donors. Local NGOs and local administration (UNO) have ranked fifth and eighth among 203 nodes respectively, which denotes that the local organizations have received substantial assistance from other nodes in the form of order of evacuation, donations, relief materials etc. Therefore, strengthening local government can leverage this effect and have a greater impact on overall emergency management.

Table 2. Top five organizations under different centrality measures in response to Sidr (2007)

Total degree centrality	**Out-Degree centrality**
1. Bangladesh government	1. Bangladesh government
2. AFD	2. Japan government
3. Japan government	3. British government
4. British government	4. US government
5. US government	5. Australia government
In-degree centrality	**Betweenness Centrality**
1. Bangladesh government	1. Bangladesh government
2. AFD	2. AFD
3. IFRC	3. UNDP
4. WPB	4. WFP
5. NGO	5.German government
Closeness centrality	**Eigenvector Centrality**
1. British government	1. Bangladesh government
2. Japan government	2. WFP
3. US government	3. AFD
4. Australia government	4. US government
5. Denmark government	5. Japan government

(Source: Data from *The Daily Star* and analysis from ORA)

Betweenness centrality is another centrality measure which measures the extent to which a particular node lies between the various other nodes of the network (Freeman, 1979). Greater betweenness centrality of an actor also depicts that more actors are dependent on that actor to communicate with other actors (Kapucu *et.al*., 2010). In regards to betweenness centrality, the top organizations are- government of Bangladesh, AFD, UNDP, WFP etc. Many of the donor countries have coordinated with Bangladesh government and disbursed their assistances through international organizations like WFP and UNDP. Being the shortest path between other nodes, these organizations have served as gatekeepers between organizations and controlled the flow of response network.

Closeness centrality measures how close an actor is to other actors of the network (Wasserman and Faust, 1994). Nodes with high values of closeness centrality are likely to receive information more quickly than others, as there are less numbers of intermediaries to reach them (Cheong and Cheong, 2011). The top organizations in terms of closeness centrality include government of Britain, US, Japan etc. Government of US has coordinated the efforts of USAID, US State Department, US Army, US Mission, as well as maintained connection with the central government of Bangladesh. Thus, it is considered as the leader in terms of closeness centrality.

Lastly, organizations that are connected to groups that have many connections themselves can be identified using **Eigenvector centrality**. Organizations that are connected to isolated nodes will have a lower score compared to those organizations that are connected to well-connected nodes (Bonacich, 1972). Government of Bangladesh is the leading organization according to this criterion. This means that it is connected to many other organizations who are well connected and thus is most likely to receive new information. In response to cyclone Sidr (2007), the degree of connectedness among the nodes is calculated as 0.531. A connectedness score of 1 suggests that all actors are reachable to each other and deviation from 1 indicates the fragmentation of network (Comfort *et.al*., 2013). The overall degree of centralization is 10.3%. The percentage of isolated nodes discussed before and the degree of centralization value indicate that a large number of organizations were not in communication with other organizations.

Another interesting finding from the response network is the identification of cliques. Cliques are subset of organizations, often consisting of three or more organizations, that develops recurring pattern of interaction in conduct of disaster operations (Scott, 2000). Using ORA, 19 cliques were identified from the larger network as shown in Table 3.

Table 3. Cliques identified in disaster response network of cyclone Sidr: 15 November- 7 December, 2007

Clique	Members
1	AFD, Bangladesh government, WFP, MoFDM, UNDP
2	AFD, Bangladesh government, UNICEF, MoFDM
3	AFD, Bangladesh government, NGO, UNICEF
4	AFD, Bangladesh government, NGO, WFP
5	Bangladesh government, UN, MoFDM
6	Bangladesh government, MoFDM, Japan government
7	Bangladesh government, NGO, European Commission
8	Bangladesh government, NGO, Grameen Phone
9	Bangladesh government, US Embassy in Dhaka, UNFPA
10	Bangladesh government, WFP, US government
11	Bangladesh government, Japan Govt., Japanese Embassy
12	Bangladesh government, Denmark, GFDRR
13	Bangladesh government, Youngone Corporation Korea, GFDRR
14	CARITAS, World Vision, Tree Das Homes
15	CARITAS, World Vision, Samajtantrik Chhatra Front
16	CARITAS, World Vision, Shiblee's Children Debate Center
17	CARITAS, German government, German Red Cross
18	British government, CARE, German government
19	NGO, Agriculture ministry, Bangladesh Bank

(Source: Data from *The Daily Star* and analysis from ORA)

Among the 19 identified cliques, 13 or 68.4% include Bangladesh government. The next largest subset includes 12 or 63.2% of cliques with interactions among national and international organizations. Only 5 or 26.3% of cliques has represented interactions among national and local level organizations, a finding that confirms the gap between disaster management plans and practice. Two cliques have involved only non-profit agencies, working at the international and local level

Conclusion and Future Work

The country experienced other cyclones including cyclone Aila (2009), cyclone Roanu (2016), cyclone Mora (2017) which have showed a lot of mismanagement in their emergency response activities. For example- findings from cyclone Aila have revealed that there was negligence in the provision of services as well as bribery and misuse of resources in the post-disaster interventions (Mahmud and Prowse, 2012). The inter-organizational connectedness or degree of centralization which have been achieved through the leadership of the Care Taker government in case of cyclone Sidr (2007), may differ significantly for other disaster events due to variation in political situation under the leadership of a typical democratic government. Therefore, further network analysis can be conducted for other disaster events to generate a comparative analysis of inter-organizations network. Due to the increasing frequency of cyclones in the recent years in Bangladesh, effective interorganizational network at all levels of governance should receive due attention from the policy makers. Inability to do so will adversely affect the emergency management process resulting in increased causalities and destruction of properties after disastrous events.

References

Ali, A. (1999). Climate change impacts and adaptation assessment in Bangladesh. *Climate research*, 12(2-3): 109-116.

Almquist, Z.W., Spiro, E.S., & Butts, C.T. (2017). Shifting Attention: Modeling Follower Relationship Dynamics Among US Emergency Management-Related Organizations During a Colorado Wildfire. In *Social Network Analysis of Disaster Response, Recovery, and Adaptation*, ed. Jones, E.C. & Faas, A.J., 93-112. United States: Elsevier.

Bonacich, P. (1972). Factoring and weighting approaches to status scores and clique identification. *Journal of Mathematical Sociology* ,2(1): 113–120.

Cheong, F., & Cheong, C. (2011). Social media data mining: A social network analysis of tweets during the Australian 2010-2011 floods. In *15th Pacific Asia Conference on Information Systems (PACIS)* (pp. 1-16). Queensland University of Technology.

Comfort, L. K., Okada, A., & Ertan, G. (2013). Networks of Action in Catastrophic Events: The 11 March 2011 Tohoku-Oki Disasters. *Earthquake Spectra*, 29(1): 387-402.

Comfort, L.K., Dunn, M., Johnson, D., Skertich, R.& Zagorecki, A. (2004). Coordination in complex systems: increasing efficiency in disaster mitigation and response. *International Journal Emergency Management*, 2(1–2): 62–80.

Dhar, A.S., & Ansary M.A. (2012). Community-based evaluation for the development of a sustainable disaster early warning system. *Journal of Emergency Management*, 10(3).

Drabek, T. E., & McEntire, D. A. (2002). Emergent phenomena and multiorganizational coordination in disasters: Lessons from the research literature. *International Journal of Mass Emergencies and Disasters*, 20(2): 197-224.

Freeman, L. C. (1979). Centrality in social networks: Conceptual clarification. *Social Networks,* 1(3):223-258.

GoB (Government of the People's Republic of Bangladesh). (2008). *Cyclone Sidr in Bangladesh: Damage, loss, and needs assessment for disaster recovery and reconstruction*. Dhaka: GoB

Haque, A., & Jahan, S. (2016). Regional Impact of Cyclone Sidr in Bangladesh: A Multi-Sector Analysis. *International Journal of Disaster Risk Science*, 7(3): 312-327.

Kapucu, N. (2005). Interorganizational coordination in dynamic context: Networks in emergency response management. Connections, 26(2): 33-48.

Kapucu, N., Arslan, T., & Collins, M. L. (2010). Examining intergovernmental and interorganizational response to catastrophic disasters: Toward a network-centered approach. *Administration & Society*, 42(2): 222-247.

Mahmud, T., & Prowse, M. (2012). Corruption in cyclone preparedness and relief efforts in coastal Bangladesh: Lessons for climate adaptation. *Global Environmental Change*, 22(4): 933-943.

Paul, B. K. (2009). Hazard warnings and compliance with evacuation orders: the case of Bangladesh's Cyclone Sidr. *The Natural Hazards Center*, University of Colorado at Boulder. Quick Response Rep (forthcoming).

Scheinert, S., & Konstantinova, R. (2011). Attempting a Knowledge Commons in the Field: The Response to the January 12th, 2010 Haitian Earthquake. Working Paper No. 1104. Centre for Disaster Management: University of Pittsburgh

The Daily Star. (2011). Various news reports published between 16 November 2007 and 8 December 2007, Dhaka, Bangladesh

Wang, W. J. (2012). The Formation of Interorganizational Networks in Extreme Events: A Comparative Study of the 1999 ChiChi Earthquake and the 2009 Typhoon Morakot (Doctoral dissertation, University of Pittsburgh).

Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications (Vol 8*). Cambridge, UK: Cambridge University Press.

Waugh Jr, W. L. (2004). Leveraging networks to meet national goals: FEMA and the state construction

networks. *Collaboration: Using Partnerships and Networks*: 273-320.
Zhao, Y. (2013). Social networks and reduction of risk in disasters: an example of the Wenchuan Earthquake. In *Economic Stress, Human Capital, and Families in Asia*, 171-182. Netherlands: Springer.

COMMUNITY PARTICIPATION IN EARTHQUAKE CONTINGENCY PLANNING: AN EXPERIENCE FROM WARD NO. 14, MYMENSINGH MUNICIPALITY, BANGLADESH

Uttama Barua[1], Tamanna Akter[2], Md. Aminul Islam[3], Dr. Mohammad Shakil Akther[4], Dr. Ishrat Islam[5], Dr. Raquib Ahsan[6], Dr. Mehedi Ahmed Ansary[7]

ABSTRACT

Contingency planning for an earthquake is the decision-making process in advance about the management, coordination and communication procedures to ensure a timely and effective response. During or after a disaster, community people face the immediate impact of damage or loss, and also act as first respondents. They also possess better knowledge about their community. Due to these facts, the integration of community people in the contingency planning process is very important. In this background, this research aims to prepare an earthquake contingency plan through participatory approach, considering planning for temporary shelter, emergency health facility, command center, and evacuation route. Bangladesh is highly vulnerable to earthquake, where Mymensingh municipality is located in earthquake hazard-prone zone. So Ward no. 14 of Mymensingh municipality has been considered as the study area in this research. For this purpose, firstly draft conceptual contingency plans were prepared based on widely practiced planning standards which were then verified by the local people to ensure acceptability. After that, the conceptual plans were modified and finalized by the community people through focus group discussion sessions. This research can be used as a guideline to prepare a contingency plan in other areas of Bangladesh as well as in other countries with proper modification considering local context.

Keywords: Earthquake, Contingency Planning, Evacuation Route, Accessibility.

Introduction

Earthquake is one of the deadliest natural calamities which causes massive destruction and damage to physical and human environment (Choudhury *et al,* 2016). Bangladesh lies in a moderately seismic-prone region signifying vulnerability to earthquake. Rapid urbanization, population growth, migration and development of economic activities have also prompted high vulnerability (CDMP, 2014). A severe earthquake will cause human casualty, damages of infrastructures, social loss etc. (Alam *et al,* 2008). Although it is not possible to prevent the occurrence of a natural disaster like earthquake, appropriate risk reduction measures can minimize the potential loss of it (Amri, *et al,* 2016). Contingency planning is a disaster management tool that aims to establish a standing capacity to withstand the risk of a specific event or disturbance. Such planning helps to minimize the destructive effects of a disaster like an earthquake with risk assessment and mapping, capacity building, effective management of human and financial resources, emergency supplies, and humanitarian aid to the affected people (Swanson, 2011). Preparation of emergency plan must incorporate the participation of local community (Perry *et al,* 2003).

At the occurrence of disaster, the local community would suffer most, they would be in the frontline to respond this disastrous condition. They must know the coping and survival strategies to face or respond long before the appearance of additional help (Habiba *et al,* 2013). So the significance of public participation collaborating local and central Government in emergency planning is recognized globally (Van *et al,* 2017). The prime objective of this research is to prepare earthquake contingency plan to reduce seismic vulnerability in Ward no. 14, Mymensingh, Bangladesh. It also aimed to prepare guidelines for the successful functioning of emergency planning components for risk reduction with collaborating the local community of the study area.

[1]*Lecturer, Department of Urban and Regional Planning, BUET, Dhaka-1000, Bangladesh.*
[2]*Graduate Student, Department of Urban and Regional Planning, BUET, Dhaka-1000, Bangladesh.*
[3]*Lecturer, BUET Japan Institution of Disaster Prevention and Urban Safety, Dhaka-1000, Bangladesh.*
[4,5]*Professor, Department of Urban and Regional Planning, BUET, Dhaka-1000, Bangladesh.*
[6,7]*Professor, Department of Civil Engineering, BUET, Dhaka-1000, Bangladesh.*
Email of Corresponding Author – sorna.urpbuet@gmail.com

Methodology of the Research

Study Area Selection

Mymensingh Municipality is situated in Mymensingh district of Dhaka division on the west bank of Old Brahmaputra River which lies in one of the earthquake-prone zones of Bangladesh (Draft BNBC, 2018). There are 21 wards among which Ward no. 14 has been selected as study area for this research. It covers an area of 0.54 sq. km. with 12,142 population. The total number of households is 2,194 and average family size is 4.5 (BBS, 2015). There are 1,611 buildings consisting of 535 RCC buildings, 208 URM buildings and rest semi-pucca and others.

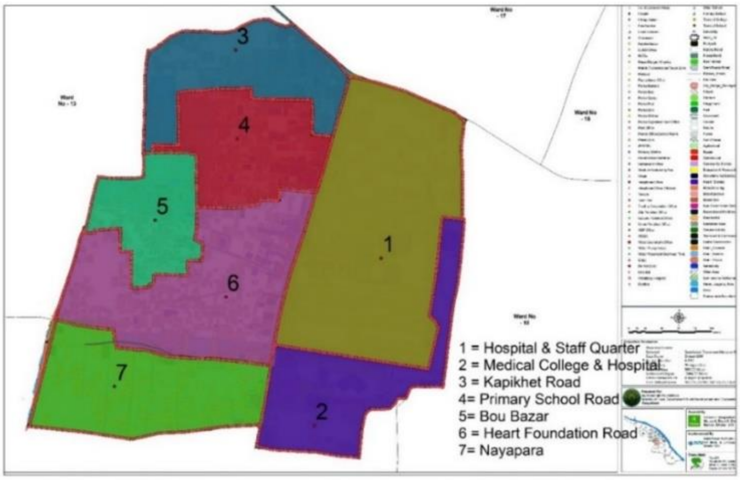


Figure 1. Clusters of the study area

The study area was delineated in seven clusters (Figure 1). Mymensingh Medical College Hospital (MMCH) is located in this area. It was expected that MMCH would serve as a regional center so excluded from the research.

Data Collection

For this study, the GIS database of Ward No. 14 of Mymensingh Municipality was collected from Urban Development Directorate (UDD and then data was updated through a reconnaissance survey. From Community Series, 2011, population data of the study area was collected (BBS, 2015). In this research, geological assessment was done by borehole test at twelve locations and micro-tremor test at eight locations. Rapid Visual Screening (RVS) Method was used to assess the vulnerability of 735 buildings. Socio-economic data were collected by a questionnaire survey of 700 households. Based on these data, risk profile of the study area was prepared.

Selection of Components of Earthquake Contingency Planning

In this research, four components were considered for earthquake contingency planning. They are:

i. **Temporary shelter:** After an earthquake, buildings may collapse or get damaged making a number of people homeless. Experience in Nepal shows that people may not return to their buildings irrespective of the building condition after earthquake (Burke and Rauniyar, 2015).
ii. **Emergency health facility:** Provision for initial emergency treatment by local medical services is important before the arrival of external medical assistance to the disaster site (CDMP, 2009b).
iii. **Ward Co-ordination Center:** One of the very important tasks during and after any disaster is to co-ordinate the different activities of management (Haque *et al*, 2011).
iv. **Evacuation route:** Safe routes in an area for immediate transfer of victims to safer places and shelters, take injured to health facilities and transfer relief to the shelters and health facilities after an earthquake.

Earthquake Contingency Planning

Temporary Shelter Planning

In this research, temporary shelter planning included three steps: need assessment, space availability assessment, and estimation of facilities in temporary shelter.

a) Need Assessment:

After an earthquake, some people in an area may become homeless due to building collapse or damage. Additionally, as a result of aftershocks people may not prefer to return to their buildings which are not damaged.

Demand Scenario 1: The residents of buildings which will be damaged or collapsed would need shelter. To calculate the demand for temporary shelter in this scenario, the following assumptions were considered:

- The vulnerable buildings are susceptible to collapse or damage after an earthquake. Thus people residing in these vulnerable buildings in the study area would require temporary shelter after an earthquake;
- In one floor, only one household is residing. Here the household size is considered as 4.5
- 50% affected population will find shelter; rest would need an arrangement for temporary shelter.

Demand Scenario 2: All of the residents in the study area will require temporary shelter.

b) Space Availability Assessment:

In Japan, large-park, playground and open space, and religious, and public buildings are considered to provide shelter in aftermath of an earthquake. So park, playground and open space and religious, public buildings were considered for temporary shelter also preferring the local people's choice.
Based on their preferences all the possible temporary shelters in the study area were identified and capacity of each of the shelters was calculated following two assumptions:

- About 80% of total area of identified shelter area (i.e. floor area for buildings, area for open space) was considered to be available for shelter. Rest would be used for amenities: toilet, circulation etc.
- A person would need 1.8m^2 space in the temporary shelter (Xu, Okada, Hatayama, & He, 2006).

During the workshop, the participants identified some of the open spaces which remain inundated during the rainy season. So, in estimating available space for temporary shelter, two different scenarios were considered:

- **Supply Scenario 1:** Available Space for temporary shelter identified for dry season
- **Supply Scenario 2:** Available Space for temporary shelter identified for wet season

Emergency Health Facility Planning

In this research, emergency health facility planning included three steps: need assessment, space availability assessment, and estimation of facilities in emergency health facilities.

a) Need Estimation

According to CDMP (2009b), there would be a casualty with four different levels of severity after an earthquake. Table 1 shows different severity levels as well as an assumption about the proportion of injuries in total population and treatment provisions required accordingly.

Table 1. Different severity levels and assumptions for estimating demand for emergency health facility

Injury Severity Level	Treatment level required	% of injuries in total population	Treatment provision
Severity 1	First aid, e.g. bandages or observation.	**4.6%**	First aid treatment at temporary shelters
Severity 2	A greater degree of medical care and use of medical technology such as x-rays or surgery, but not progress to a life-threatening status.	**0.8%**	Treatment at a health facility in the study area
Severity 3	Pose an immediately life-threatening condition if not treated adequately and	**0.2%**	

	expeditiously.		
Severity 4	Instantaneously killed or mortally injured	**3.6%**	Treatment at local health facilities and then transfer regional medical hospital
Total		**9.2%**	

(Source: CDMP, 2009b)

b) Availability of Emergency Health Facility

Existing hospitals, clinics, and diagnostic centers were considered as medical facility after the earthquake. The structurally safe facilities were identified as a possible emergency health facility based on following assumptions:

- About 80% of total floor area of emergency health facilities would to be available for the treatment.
- About 50% of the usable space would be occupied by patients who were admitted before the earthquake.
- A person would need $2m^2$ space in an emergency health facility (Xu, Okada, Hatayama, & He, 2006).

Ward Co-ordination Center Planning

In identifying Ward Co-ordination Center, Government building should be identified which is structurally safe, centrally located and easily accessible.

Evacuation Route Planning

For evacuation route planning, vulnerable buildings were identified and considered to be susceptible to collapse or damage after an earthquake. Blockage of roads due to collapse or damage of vulnerable buildings were assumed considering the conditions described below.

- ***No block condition:***
  - Vulnerable URM and RCC building below three stories will not collapse due to an earthquake. If does, then it would collapse on the site and will not block the adjoining roads.

- ***Partial block condition:***
  - If the building height is at least one feet less than the sum of width of front road and setback space, then the road would be partially blocked. Because there will be at least one feet space for movement of people.
  - If building height is at least one feet less than the sum of width of front road and setback space, then it was considered to block road partially. As there will be at least one feet space for movement of people.
  - Secondly, if building height is greater than sum of width of front road and setback space, safe building with more than one storey on opposite side of road, then the building will stuck on opposite building leaving some space for movement of people underneath.

- ***Full block condition:***
  - If the building height is greater than or equal to the sum of width of front road and setback space, then it will fully block the road in front of it.
  - If building height is greater than or equal to the sum of front road and setback space, opposite building is multi storied vulnerable building or no building at all, then it will fully block the road in front of it.

a) Accessibility of the Open Roads

Once the blocked roads were identified, the rest of the open roads were considered based on their accessibility considering road width. The routes were classified into four groups:

- Pedestrian movement i.e. road width, is equal or less than 2 feet;
- Movement of pedestrian, cycle or one-way non-motorized traffic (rickshaw or van) i.e. road width, 2 to 6 feet
- Movement of two-way non-motorized traffic or one-way motorized traffic i.e. road width, is 6 to 12 feet;
- Movement of two-way motorized vehicle i.e. road width more than 12 feet.

b) Identifying Evacuation Route

Based on road blockage and accessibility, the evacuation route map was prepared. This route will be usable for the evacuees to move to the temporary shelters, to take the injured people to the emergency health facilities and to connect the temporary shelters and the emergency health facilities with the Ward Co-ordination Center.

Results and discussion

Risk profile of the study area

The study area is highly prone to earthquake but the result of borehole test pointed that the area is not susceptible to liquefaction. Although the area is newly developed, about 37% of the buildings are vulnerable to earthquake. Again, though road network covers 21.8% of total land area, accessibility condition is very poor. Community awareness level and participation in disaster management programs are merely symbolic.

Temporary shelters in the study area

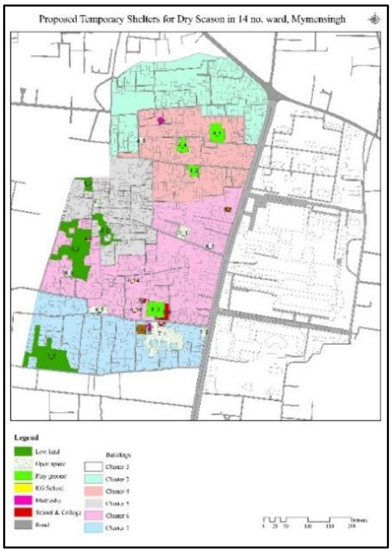
Based on the assumptions, firstly the need for temporary shelter in demand scenarios was determined. For the identification of sites for temporary shelter, the preferences of the local respondents are shown in Table 2. It can be concluded that most preferred spaces for the purpose are open space, playfield and government buildings.

Table 2. Ranked preference for temporary shelter types by the respondents

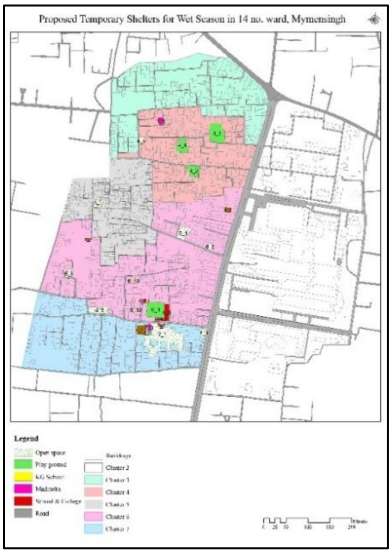
Temporary shelter	1st preference	2nd preference	3rd preference	4th preference	5th preference	Total
Open space	233	52	20	21	25	**351**
Play ground	103	93	45	35	34	**310**
Educational Institution	102	99	94	27	27	**349**
Religious Institution	64	104	69	44	13	**294**
Government Institution	114	104	68	35	38	**359**

(Source: Field survey, 2017)

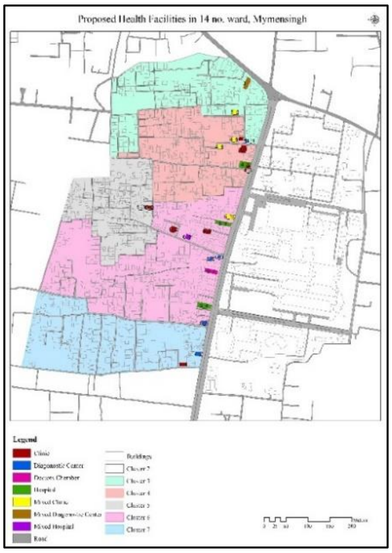
According to the assumptions of methodology and preferences of local people, potential sites for temporary shelters of the study area were selected. After evacuation route preparation, some temporary shelters seemed to lose accessibility due to road blockage. Considering road accessibility temporary shelters were identified (Map 1 and Map 2). Once space for temporary shelter was identified, the capacity of each of the shelter was calculated based on the assumptions. Table 3 and Table 4 shows cluster-wise comparison of need in demand scenarios and availability of temporary shelter in the study area for Supply Scenario 1 (dry season) and Supply Scenario 2 (wet season) respectively. Temporary shelters could accommodate the population under Supply Scenario-1, for Supply Scenario-2, people would be needed to be accommodated in other wards of the Municipality.



Map 1. Cluster wise location of proposed spaces for temporary shelter in dry season



Map 2. Cluster wise location of proposed spaces for temporary shelter in wet season



Map 3. Cluster wise proposed health facilities in the study area

Table 3. Cluster wise need –availability scenario of temporary shelter in the study area in Supply Scenario 1: Dry Season (in persons)

Cluster	Persons could be accommodated in the available Space	Persons need Shelter		Surplus/Deficit	
		Demand Scenario 1	Demand Scenario 2	Demand Scenario 1	Demand Scenario 2
3	-	392	2,071	-392	-2,071
4	1,449	468	1,996	871	-657
5	1,063	185	1,466	878	-403
6	4,377	792	3,502	3555	845
7	4,388	437	2,308	3952	2,081
Total	**11,277**	**2,273**	**11,343**	**8865**	**-205**

(Source: Field Survey, 2017)

Table 4. Cluster wise need –availability scenario of temporary shelter in the study area in Supply Scenario 2: Wet Season (in persons)

Cluster	Person could be accommodated in the available Space	Persons need Shelter		Surplus/Deficit	
		Demand Scenario 1	Demand Scenario 2	Demand Scenario 1	Demand Scenario 2
3	-	392	2,071	-392	-2,071
4	1,339	468	1,996	871	-657
5	113	185	1,466	-72	-1,353
6	1,627	792	3,502	835	-1,875
7	2,130	437	2,308	1693	-178
Total	**5,209**	**2,273**	**11,343**	**2,936**	**-6,134**

(Source: Field Survey, 2017)

Emergency Health Facilitates in the Study Area

About 522 injured people (Severity 2, 3 and 4) are assumed to get admitted in the health facilities. A considerable number of privately owned health facilities (hospital, clinic, diagnostic center) are operating around MMCH. The emergency health facilities were identified considering structural safety and accessibility and verified by the focus group discussants (Map 3). Cluster-wise comparison of need and availability of emergency health facilities are done (Table 5). Available facilities within the study area are observed to be adequate to treat the estimated injured persons. Cluster 5 has deficit, whereas in Cluster 3, 4, 6 and 7 there is surplus. From the focus group discussion, the participants suggested to allocate the deficit of Cluster 5 in nearest Cluster 6.

Table 5. Cluster wise demand-supply comparison of health facilities in the study area

Cluster	Person needed to be Treated	Person can be Treated	Surplus/Deficit
3	95	153	58
4	92	372	280
5	67	20	-47
6	161	969	808
7	106	147	41
Total	**522**	**1661**	**1140**

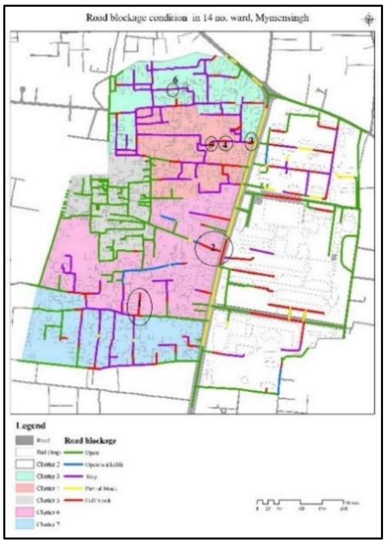
(Source: Field Survey, 2017)

Ward Co-ordination Center (WCC)

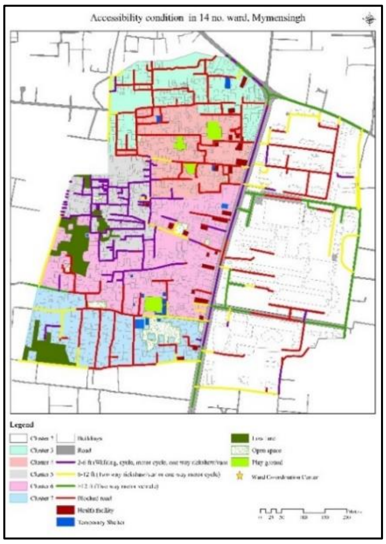
Charpara Primary School was the only government building in the Ward but it is structurally vulnerable. However, Matiur Rahman Academy School and College was chosen as Ward Co-ordination Center by local representatives in spite of private ownership. The facility is one storied and considered to be structurally safe and accessible from other clusters and Dhaka-Mymensingh highway, most temporary shelters and health facilities.

Evacuation Route Plan

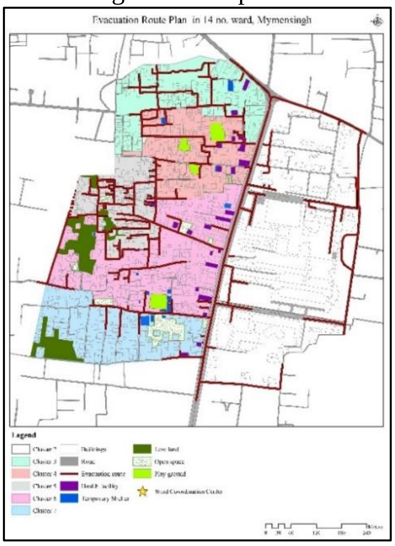
In this research, potential road blockage (Map 4) at the event of an earthquake is identified. Also, accessible roads (Map 5) for rescue and rehabilitation is recognized considering road width and road blockage condition. It is evident that most of the roads are only accessible through walking, cycle, motorcycle or one-way rickshaw/van. Non-motorized vehicles can be customized to fit the narrow roads during a rescue operation.



Map 4. Road blockage condition in the study area



Map 5. Accessibility condition considering road blockage



Map 6. Evacuation route plan

Conclusion

It should be bear in mind that contingency plan is neither a stand-alone document nor a static document. It should be an ongoing process integrated and coordinated with activities suggested by other documents. It is well understood that earthquake would cause damaged at regional scale. So contingency plan at regional scale should be prepared. Though CDMP (2014) prepared a contingency plan for Mymensingh Municipality, it focused on institutional activities. The plan did not take into account the effect of an earthquake on spatial dimension at micro level. This research looks at the issue at local level. However, for successful implementation of contingency plan, integrated approach should be taken for all wards of the Municipality.

Acknowledgement

Authors are thankful to United Nations Development Programme (UNDP) and Mymensingh Municipality for their support and assistance in successfully completing the research.

References

Alam, M. J. B., Ansary, M. A., & Chowdhuary, R. A. (2008). Evaluation of building's vulnerability to earthquake in Old Part of Sylhet and construction safety rules. IUST International Journal of Engineering Science, 19*(3).*

Amri, A., Bird, D. K., Ronan, K., Haynes, K., & Towers, B. (2016). Disaster risk reduction education in Indonesia: challenges and recommendations for scaling up. Natural Hazards and Earth System Sciences, 2016*, 1-1.*

Bangladesh Bureau of Statistics. (May, 2015). Bangladesh Population and Housing Census 2011. Community Report, Zila: Mymensingh. *Retrieved 4th April, 2017 from: http://203.112.218.65/WebTestApplication/userfiles/Image/PopCen2011/Com_Mymensingh.pdf*

Burke, J. and Rauniyar, I. (May 2015) Most buildings in Kathmandu deemed uninhabitable or unsafe following quake. Retrieved 28 May, 2017, from https://www.theguardian.com/world/2015/may/03/most-buildings-in-kathmandu-deemed-uninhabitable-following-quake.

CDMP. (2009b). Earthquake Contingency Plan for Dhaka City. *Dhaka: Comprehensive Disaster Management Programme (CDMP), Ministry of Food and Disaster Management, Government of the People's Republic of Bangladesh, Phase 1.*

CDMP. (2014). Scenario Based Earthquake Contingency Plan of Mymensingh Municipality Area. Comprehensive Disaster Management Programme (CDMP), Ministry of Food and Disaster Management, Government of the People's Republic of Bangladesh.

Choudhury, M., Verma, S., & Saha, P. (2016). EFFECTS OF EARTHQUAKE ON THE SURROUNDING ENVIRONMENT: AN OVERVIEW.

Habiba, U., Shaw, R., & Abedin, M. A. (2013). Community-based disaster risk reduction approaches in Bangladesh. In Disaster Risk Reduction Approaches in Bangladesh *(pp. 259-279). Springer, Tokyo.*

Haque, A., Maksud Kamal, D. A., & Kamrul Hassan, S. M. (2017). Partnership, Coordination, and Accountability in Urban Disaster Management: A Review of Policies in Bangladesh.

Jimee, G. K., Upadhyay, B., & Shrestha, S. N. (2012). Earthquake awareness programs as a key for earthquake preparedness and risk reduction: lessons from Nepal. In The 14th World Conference on Earthquake Engineering

Perry, R. W., & Lindell, M. K. (2003). Preparedness for emergency response: guidelines for the emergency planning process. Disasters, 27*(4), 336-350.*

Swanson, M. (2011). Contingency planning guide for federal information systems *(Vol. 800). DIANE Publishing.*

Van Krieken, T., Kulatunga, U., & Pathirage, C. (2017, September). Importance of community participation in disaster recovery. In 13th IPGRC 2017 Full Conference Proceedings *(pp. 860-869). University of Salford.*

Xu, W., Okada, N., Hatayama, M., & He, C. (2006). Conceptual Model of Shelter Planning Based on the Vitae System. Annuals of Disaster Prevention Research Institute (DPRI)*, Kyoto University, 49 (B), pp 181-189.*

THE SOCIAL CAPITAL AND LIVELIHOOD RECOVERY NEXUS AFTER CYCLONE *AILA*: A STUDY IN THE SOUTHWESTERN COASTAL BANGLADESH

Md. Nasif Ahsan[1]*, Saifullah[1], Md. Sariful Islam[1]

ABSTRACT

In contemporary natural hazard-led disaster risk management literature, there is an increasing usage of the concept of social capital, livelihood, response and recovery. However, only limited empirical studies considered people at risk's perception on the nexus between social capital and livelihood recovery in the post hazard circumstances. This study presents results from an empirical investigation on the nexus between social capital and livelihood-recovery of the households at risk who were the victims of tropical cyclone *Aila*. This study used primary data collected through face to face interview from 160 households from four villages of Koyra Union of Khulna district. Empirical results obtained from factor analysis and regression models reveal several aspects of social capital - community participation, perceived neighboring and community trust, and social cohesion and inclusion have statistically significant influence on livelihood-recovery of the hazard affected households. We also found social cohesion and inclusion is the most determining factor of livelihood recovery process. Henceforth, social capital is found to have significant contribution in rebuilding the livelihoods of the cyclone *Aila* affected households. This study recommends strengthening social cohesion and inclusion with a view to accelerating recovery of livelihood damages from hazards.

Keywords: Cyclone Aila; Social Capital; Livelihood Recovery; Households at Risk

Introduction

Bangladesh is one of the most hazard prone countries in the world as it is located in the worlds' most cyclone prone zone with- flat topography, a number of large rivers and impacts of climate change (Dasgupta et al., 2014; Mahmud and Prowse, 2012). Cyclone *Aila* hit the south-western region of Bangladesh in 2009 and damaged lives and assets, especially the livelihood options of the inhabitants (Aid, 2009). Islam and Walkerden (2015) stated that social capital - interpersonal relationships among the local people, trust and community participation, which satisfy a common goal and network with community-based organizations (CBOs) play an important role to accelerate community level development in the recovery stage aftermath cyclone *Aila*.

Considering this viewpoint, this study attempts to explore the impact of social capital (SC) on livelihood recovery after cyclone *Aila* since it affected livelihood assets at a greater extent. There are a number of studies on Bangladesh which have dealt with social capital with its various dimensions. However, the impact of social capital on livelihood recovery after any post-disaster period has yet to be assessed quantitatively in the literature. Therefore, this study contributes to literature by quantitative exploring how social capital accelerates livelihood recovery after the cyclone *Aila*.

As it is difficult to measure various aspects of social capital considering people's code of conduct, values, confidences and networks, we followed World Bank's procedure "Social Capital Initiative" that has four aspects of social capital namely micro, macro, cognitive and structural (Grootaert and van Bastelaer, 2002). This study presents the impact of micro social capital on *Aila* affected households' livelihood recovery process. It investigates how the various dimensions of micro social capital - community participation, perceived neighboring and community trust, collective action and co-operation, and social cohesion and inclusion contribute to the recovery of households' perceived food security, well-being and economic conditions. Hence, in this study, we attempted to explore which dimensions of social capital explain livelihood recovery significantly in the *Aila* affected regions. This study presents some important insights to policy makers for strengthening social capital in order to develop disaster resilient livelihood options.

* *Corresponding author*
[1] *Economics Discipline, Khulna University-9208, Bangladesh*
E-mail of corresponding author: nasif.ahsan@econ.ku.ac.bd

Methodology

Study area and sampling strategy

Koyra, a sub-district (upazila) of Khulna district in Bangladesh was selected for assessing the impact of social capital on livelihood recovery in the aftermath of cyclone *Aila* as this area was severely affected by two successive devastating cyclones Sidr and Aila in 2007 and 2009, respectively. These cyclones severely destroyed livelihood options. This study followed two stage sampling procedures. Firstly, Dakshin Bedkashi and Uttar Bedkashi, two unions under Koyra upazila were purposively selected followed by random selection of two villages from each union. Therefore, these surveyed four villages have constituted the primary sampling units (PSUs) of this study. We surveyed a total of 160 households from these four PSUs, taking 40 from each village using the random sampling method. We assessed people's perception toward various dimensions of social capital by using structured questionnaire. It focused households' socio-demographic and socio-economic aspects of social capital proposed by World Bank and aspects of livelihood recovery that damaged by cyclone *Aila*.

This study collected data on four dimensions of social capital modified to local socio-economic context considering Social Capital Assessment Tool (SOCAT) of World Bank as base namely, i) community participation, ii) perceived neighboring and community trust, iii) collective action and cooperation, and iv) social cohesion and inclusion. Each dimension incorporated several statements measured in Likert Scale to elicit the perception of the household. On the other hand, data on three indicators of livelihood recovery has also been collected - i) perceived household economic condition change, ii) households' perceived food security and iii) perceived well-being. Each indicator incorporated several statements and labeled five-point Likert scale to elicit the perception of the household.

Analytical Framework

Since the study objective is to explore quantification in terms of statistical association between different dimensions of social capital and livelihood recovery after cyclone *Aila*, we constructed an index - Livelihood Recovery Index (LRI) using confirmatory factor analysis and thus, LRI was regressed by four specific dimensions of social capital. Alpha tests, Kaiser-Meyer-Olkin (KMO) tests and average inter-item correlation range (R) were used to check consistency and validity of the selected factors to construct LRI. The LRI is a weighted index of households' perceived change in economic condition, perceived change in food security and perceived change well-being.

Finally, we have used multiple linear regression model to analyze the impact of social capital on household's overall perception of livelihood recovery. In this regard, two econometric models were instrumented. The first model is the base model in which the LRI is regressed by only various dimensions of social capital - community participation, perceived neighboring and community trust, collective action and cooperation, and social cohesion and inclusion. The second model, an extended version of base model includes households' socio-economic characteristics – age and education of household head, household size, number of earning members, household income sources, housing and latrine condition in order to compute precise estimates of social capital after controlling other factors. The details of variables are reported in appendix A1.

Results and Discussion

At first index values for each of the four dimensions of social capital together with livelihood recovery were computed. After computing these indices, this study attempted to assess the impact of each of the four dimensions of social capital on household level livelihood recovery perception in the *Aila* affected households through multiple regression model. The results are presented in Table 1. Model 1 shows that community participation, perceived neighboring and trust, and social cohesion and inclusion have positive effects on households' livelihood recovery perception at one percent significance level. In contrast, collective action and co-operation does not have statistically significant effect on households' recovery of livelihoods in cyclone *Aila* affected region. Both collective participation, and neighboring and community trust played almost equal contribution to the livelihood recovery process. One percent increase in both indices accelerates livelihood recovery by 0.24 percent. However, social cohesion is found the most influential factors among all dimensions of social capital on households' livelihood recovery process in the *Aila* affected region. The impact of this dimension is double compared to other two significant dimensions of social capital. More specifically, 0.44 percent improvement in livelihood recovery is associated with one percent increase in the social cohesion index. We note that this base model is well fit to our dataset since the goodness of fit statistic R^2=0.59 implying that variation in the all dimensions of social capital explained the variation of livelihood recovery index by around 59 percent.

The major limitation of the base model is that it did not control household specific characteristics, which might have influences on livelihood recovery process. In order to address this issue, we extended our base model by including household characteristics, reported in Model 2 column of Table 1. This extension improves the goodness of fit of Model 2 from 0.59 to 0.71. This implies 71 percent variation of livelihood recovery index is explained by the variation all explanatory variables. We found age of the household head, numbers of earning members and physical infrastructure – house condition, and latrine condition have positive and statistically significant impact on livelihood recovery after cyclone *Aila*. After controlling these factors, the effect of dimensions of social capital is differed much compared to the effect of dimensions when we do not control these household characteristics. The impact of community participation is reduced from 0.24 percent in Model 1 to 0.13 percent in Model 2. Therefore, livelihood recovery is improved by 0.13 percent is associated with 1 percent increase in community participation index. The effect of community trust tends to be statistically insignificant while explaining livelihood recovery process. However, the effect of social cohesion and inclusion does not change even after controlling household characteristics. Therefore, social cohesion and inclusion is the most determining factor of livelihood recovery in cyclone *Aila* affected region.

Table 1. Multiple Regression on Livelihood Recovery and Social Capital

Variable Description	**Model 1 (Base model)**	**Model 2 (Extended model)**
Community Participation (Likert scale)	0.242*** (0.0609)	0.129** (0.0572)
Perceived Neighboring and Community Trust (Likert scale)	0.238*** (0.0844)	0.0709 (0.0789)
Collective Action and Cooperation (Likert scale)	-0.0683 (0.0552)	-0.0537 (0.0491)
Social Cohesion and Inclusion (Likert scale)	0.437*** (0.0998)	0.443*** (0.0901)
Age		0.00207* (0.00116)
Household Size		0.00461 (0.00897)
Education		0.00133 (0.00298)
Earning Member		0.0718*** (0.0237)
Household's Income Source		0.0299 (0.0223)
House Condition		0.0672** (0.0271)
Latrine Condition		0.0722*** (0.0262)
Constant	-0.157** (0.0620)	-0.344*** (0.0807)
N	160	160
R^2	0.590	0.705

N.B.: Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Findings of the Study

Social capital indeed affects household livelihood recovery. This proposition is supported by the analysis carried out in this study. Empirical results suggest that three dimensions of social capital that significantly and positively have contributed in recovering households' livelihood after cyclone *Aila*. Households with higher degree of community participation, quality neighboring and strong cohesion within society showed better recovery compared to those having lower degree of aforesaid three dimensions of social capital. Results suggest that the importance of social capital variables remain unchanged when other socio-economic covariates are present to explain livelihood recovery of the households. Specially, the role of social cohesion and inclusion is significant and positively associated with the livelihood recovery perception.

Policy Recommendation

This study entails livelihood recovery effort of cyclone Aila affected households and demonstrates the contribution of social capital assets to their livelihood outcomes. The analysis indicates that the ability of the affected households to reestablish their livelihoods is strongly attached to their social capital assets. Therefore, enhancing ties with family, friends, neighbors, local organizations and community as a whole is crucial to achieve success in households' economic and social development strategies. From the empirical analysis, we have found three dimensions of social capital; community participation, social cohesion and quality neighboring of the household impact significantly and positively on the livelihood recovery perception. Household with higher levels of community participation, more quality neighboring and stronger social cohesion were more likely to report higher levels of livelihood recovery than their counterparts. Different NGOs have been working to create group like women club, youth club, and village development community to build SC in these affected regions. This study suggests enlarging these initiatives.

Conclusion

This study has attempted to explore the dimensions of social capital affecting the livelihood recovery perception of households affected by cyclone Aila. Empirical findings suggest three dimensions of social capital namely- community participation, social cohesion and quality neighboring of the households significantly and positively affected the livelihood recovery perception. It implies that households with higher levels of community participation, more quality neighboring and stronger social cohesion were more likely to report higher levels of livelihood recovery than their counterparts. Different NGOs have been working to create groups like women club, youth club, and village development community to build SC in these affected regions. This study recommends for enhancing the aforesaid initiatives.

Appendix

Table1 A1. List of Variables

Variable name	Description	Unit of measurement
Dependent Variable: Livelihood Recovery		
Perceived Household Economic Change	Overall economic condition change perception compared to pre cyclone Aila period	5 level scale 1= significantly worse, 5= significantly improved
Perceived Food Security	Five food insecurity questions	4 level scale 1 = Often happen, 4 = Never happen
Perceived Well-being	Four compatibility and comfort related statements	5 level scale 1= Strongly disagree, 5= Strongly agree
Independent Variable: Social Capital		
Community Participation	Five statements related to participation in groups and networks	5 level scale 1= Strongly disagree, 5= Strongly agree
Perceived Neighboring and Community Trust	Nine issues related to trust and solidarity	5 level scale 1= Strongly disagree, 5= Strongly agree
Collective Action and Cooperation	Four issues related to do good for others	5 level scale 1= very unlikely, 5= very likely
Social Cohesion and Inclusion	Five items related to individual power and rights	Five level scale 1= strongly disagree, 5= strongly agree
Independent Variable: Socio-economic Characteristics		
Socio-economic Covariates	Age, Household Size, Education, Earning Member, Sources of Income,	Continuous
	House Condition, Latrine Condition	Categorical, Dummy

Source: Authors' Compilation

CENTRALIZED WAREHOUSE TO SYNERGIZE SPORADIC DATA SOURCES FOR EFFICIENT EMERGENCY RESPONSE

[1]Suresh Manandhar, [2]Suman Baral, [3]Janak Parajuli

ABSTRACT

Natural Disaster is a natural phenomenon that may occur anytime or anywhere causing destruction of lives and properties further demanding the needs for immediate response. A timely effort is obligatory regarding the rescue and relief operations including resource management. Information and data from various sources begin to fly in the sky whose harmonized storage comes to be indispensable. Judicious extraction of information figuring out the patterns from the crude datasets ought to be done to facilitate sensible decision making by the process called data mining.

This paper is intended at conferring data warehouse as an effective means of emergency response. Data in a warehouse is acquired from diverse sources like social media (facebook and twitter hashtags, mostly), android applications, crowdsourcing, government bodies, relief providing organizations and so on. The collected data are then stockpiled in a central data warehouse using different schemes for database management system. Besides, data mining is also facilitated by data warehousing. These lumped data are analyzed using various approaches of pattern recognition and predictive modelling. In general, primarily scrutinized data involves finding the attribute and spatial figures of injured, casualties and missing ones. In addition, other analyses are done to figure out the suitable location for IDP camps, food and relief materials. The data then can be used by the stakeholders (government agencies, NGOs, INGOs and so on) as per their necessities.

To conclude, here we can perceive that emergency response and management is a synchronized approach involving different stakeholders. A proficient mining of centralized warehouse datasets acquired from various sources can be a milestone for the speedy disaster management.

Keywords: Emergency, Warehouse, social media, pattern recognition, data mining, IDP camps.

Introduction

Natural disaster is the phenomenon that may occur anytime or anywhere causing destruction of lives and properties while demanding the needs for immediate response. According to Ministry of Home Affairs, more than 12000 people have lost their life due to natural disasters in the last seven years in Nepal[4]. Understanding and tracing the advancement of disaster and crisis situations are extremely difficult due to their complexity. Disaster management is not only related to prediction of consequences of disasters but also principally directed at minimalizing the undesired results from disasters in short time. Nowadays, modern technologies have evolved to support people to make apt decisions to confront disaster scenario. So disaster management is no exception, however, it has its own challenges and defies because of the unprecedented volume of data (*A.T. Zagorecki et al., 2013, pp. 353*). The disaster management or the emergency management is the process which assimilates different available resources to administer emergency analyzing its root, growth and results (Ji, L. and Chi, H. 2006).

In order to make timely rescue operations and proper resource management, systematic analysis of acquired information must be done which can be achieved by the process called data mining (Goswami et al., 2018 pp. 367). Discovering interesting and useful patterns from large datasets and extracting the hidden information from them using set of rules is data mining. Other terms used for data mining are knowledge discovery (mining) in databases (KDD), knowledge extraction, data/pattern analysis, data archeology, data dredging and information harvesting (Jiawei, H. et al, 2011)(Fayyad, U. et. al.; 1996)(Tan, P. et. al., 2005). This data mining process is carried out to build an effectual predictive or descriptive model of a large amount of data that not only best fits or explains it, but is also able to generalize to new data (Mukhopadhyay, A., 2014, pp. 6). Additionally, in data mining we discover interesting knowledge from large amounts of data stored in either

---

[1] *Survey Officer, Survey Department, Nepal*
[2] *GIS-Database Expert, Habitat for Humanity, Nepal*
[3] *Survey Officer, Survey Department, Kathmandu 44600, Nepal*
Email of Corresponding Author- janak.parajuli1@gmail.com

4 http://www.neoc .gov.np/uploads/news/file/Seven%20year%20data_20180427010733.pdf, retrieved on 25th Jan, 2018.

databases, data warehouses, or other information repositories through some kind of algorithms (Chen, F. et. al., 2015).

Background

This research is oriented towards conferring centralized warehouse and data mining techniques as efficient approach of emergency response. Warehouse accumulates the data from various sources like social media (facebook, twitter), remote sensing imageries, crowdsourcing, android application, relief organizations (like Red Cross) etc. In today's scenario, mining planned and anticipated data from social media feeds have become more successful in providing valuable intuitions and situational awareness to the first responders of the disaster (Vieweg, S., 2012. These data are then scrutinized using various approaches of pattern recognition and predictive modelling with preference to four priorities and seven targets of Sendai Framework. Based on data mining techniques for predictive and situational models, we can plan for rescue, recovery, evacuation camps, food and shelter. There are several major data mining techniques developed and used: association, classification, clustering, prediction, sequential patterns and decision tree. We often combine two or more of those data mining techniques together to form an appropriate process that meets the humanitarian needs[1]. The analyzed data then can be disseminated with preference to the four primary Sphere indicators.

ICTs in Disaster Response

Parajuli, J. and Baral, S., 2018 in page number 2-4 have talked about wide scope mobilization of ICTs in disaster (flood, landslide, forest fire, earthquake etc.) response and management throughout the world. The main advantage of ICTs is they play prominent role in difficult situations where human involvement for rescue purpose is perilous. It is obvious that ICTs can't replace the need for food, water, shelter etc. in times of disaster but we can't deny the fact that it has become the middleware for worldwide collaboration[2]. ICTs help to reach large number of victims in lesser time more efficiently and help the communities to be more pliable and prepared for the anticipated disasters in future. Besides, smartphones and mobile applications have risen to be the efficacious and fastest means of communication during disaster period. They have defied all the hurdles to empower incessant connectivity during the times when we need them most providing a new effectual way of communication in order to save more lives.

A Standard Approach to Emergency Response

The main focus of this research is to recommend the Consolidated Data Warehouse as the efficient emergency response scheme. Data collection is done from varying sources including Remote Sensing imageries, UAVs, Mobile SMS and android applications etc. to develop a consolidated data warehouse. At present, there is this growing trend of mining social media data also, for response and relief purpose from the research proficient (Imran, M. et. al., 2013). The rudimentary idea is to cluster these data in a warehouse, analyze them and distribute to the stakeholders including government and humanitarian organizations to save lives, livestock and properties.

Data Warehouse characteristics

Unlike database system, data warehouse is only for storage, query and analysis of the data stored from single or multiple sources (including databases also) in a cyclic manner and not frequently. Databases are concurrent storehouses of information and usually they are collected for particular purposes. According to B*usiness Management Ideas*, a warehouse generally functions in three steps. In the first step, raw data are stored for use by developers called as **staging**. The next is data **integration** step in which obtained data are assimilated to build up a general concept by users. In the third step, data are then cleaned, transformed and categorized and made accessible to the users in this last step called **access**[3]. Commonly the characteristics of data warehouse can be listed in following four points:

i. **Subject-oriented**: Data in a warehouse are obtained from various sources and they should be cleaned and transformed into a uniform format abiding by naming conventions, formats and encoding.
ii. **Integrated**: In a warehouse, data from several sources are integrated.
iii. **Non-volatile**: The data are for read only purpose without supporting CRUD operations and even old data are not erased while adding newer which helps to find out the historical trends of data.

[1] *http://www.zentut.com/data-mining/data-mining-techniques/ retrieved on 25th Jan, 2018*
[2] *https://www.forbes.com/sites/trevornace/2017/12/15/how-technology-is-advancing-emergency-response-and-survival-during-natural-disasters/#2560d3dd9cc8 retrieved on 15th Dec, 2017, 01:31 pm*
[3] http://www.businessmanagementideas.com/crm/customer-database/data-warehouse-meaning-characteristics-and-benefits/3608 retrieved on 25th Dec, 2017

iv. **Time variant**: Principally, the data in a warehouse are kept concerning the historical point of view which helps to study trends and changes.

When we talk about disaster risk reduction and response, basically we need to emphasize on two popularly accepted approaches by United Nations: Sendai framework and Sphere standards.

i. Se**ndai Framework:** This is the foremost major covenant endorsed by UN General Assembly for the 15 year period during 2015-2030 aimed at disaster risk reduction[1]. It adopts four priorities and seven targets for substantial minimization of disaster menace. It emphasizes on understanding all the dimensions (vulnerability, exposure to hazards etc.) of the disaster risk, strengthening the governance in disaster risk and its management, encouraging investments in disaster risk reduction for pliability and finally enhancing disaster vigilance for efficacious response with 3B (Build Back Better) approach in recovery, rehabilitation and reconstruction (Twigg J., 2015, pp. 329).

ii. **The Sphere Standard**: According to Sphere Handbook-2018, the Sphere Standards were created by a Red Cross and Red Crescent movement in collaboration with a group of altruistic people working in non-governmental organizations. It also claims that the philosophy of Sphere resides on two main beliefs:

- Every people who are affected by disaster have right to life and assistance with self-respect.
- Necessary precautions and steps ought to be taken to lessen human suffering due to disaster.

Further, it has set minimum standards in four vital response areas which are Health, Food Security and Nutrition, Shelter and Settlement and lastly the Water Supply, Sanitation and Hygiene Promotion (WASH).

This research is concentrated on proposing the emergency response model within the scope of these two approaches accepted by United Nations and humanitarian organizations.

Proposed Disaster Response Model

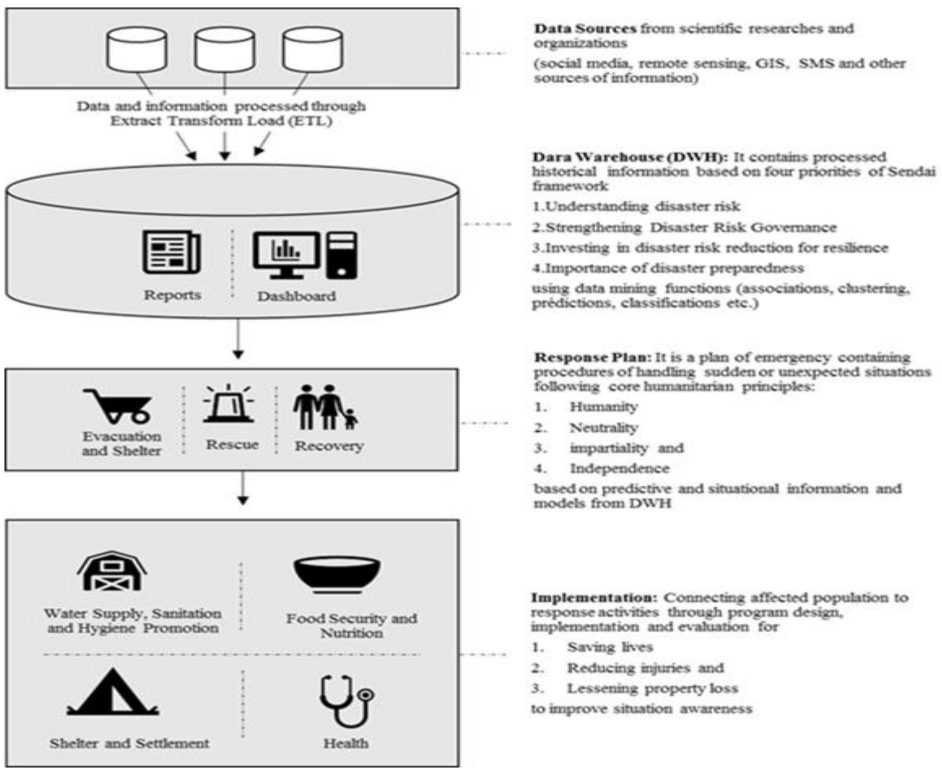


Figure 1 A proposed framework for efficient disaster response

Our proposed model to efficiently respond emergency can be summarized in following four components: data sources, warehouse, response plan and implementation.

i. **Data Sources**: There are various contributors for data including scientific community, researchers, humanitarian organizations, social media (facebook, twitter etc.), remote sensing imageries, SMS and mobile applications etc. The question is how these data can be managed properly in order to utilize them for the betterment of mankind during disasters. Disaster time is crucial in the sense that response time is very less and in that time saving time effectively is saving lives. In this sense we can claim that time is inversely proportional to number of lives. According to world economic forum, during 2005-2014 more than 7,00,000

[1] https://www.unisdr.org/we/coordinate/sendai-framework, retrieved on 20th Dec, 2017

lost their lives by disaster and obviously it could have been minimized, had some precautions been taken[1]. So, basically there is this requisite of harmonized storage of those data. The next thing we need to be aware is those data from various data are inconsistent and varies in terms of format and so they can't be used as such. To make it usable, we need to bring consistency in data formats and information products.

ii. **Data Warehouse**: So as to address aforesaid issues, we have come up with the notion of data warehouse which can play vital role not only in efficient disaster response but also in mitigating the disaster risk for future purposes. The collected data are then processed through a method called **Extract Transform Load (ETL)**. The extract, transform and load are three database functions integrated into single means to excerpt data out from one database into another database. During extraction, the data are read from different sources and collected in a vessel. The data obtained from various sources are not uniform so the next step is to standardize those using predefined norms and rules or lookup tables. Lastly, the unified data are then loaded into the target database. All these process are done using different data mining functions like associations, clustering, predictions, classifications, modelling etc. The data can be visualized in dashboard in terms of bar graphs, charts, reports, tables and other statistical representations. Users can query the database dynamically and can access data as per their requirements, however, since the data are read only, they can't run CRUD operations which is outside the notion of data warehouse.

iii. **Response plan**: Using the data from the warehouse, stakeholders including government, humanitarian organizations like Red Cross, Scout etc., media and general public can make either a timely escape plan or plan to tackle the disaster. Basically the rescue operations are carried out following the four humanitarian principles: humanity, neutrality, impartiality and independence[23]. Also, these data can be analyzed using various approaches of pattern recognition and predictive modelling to find out the figures of injured, casualties and missing ones. Similarly, the number of internally displaced people (IDP) can be determined to calculate the required count and apposite location of evacuation camps and shelter. Besides, it will be very easy to supply food, medicine and relief materials also. Not only this, the mobilization of warehouse data can be protracted for recovery and rehabilitation approaches as well.

iv. **Implementation**: In the implementation phase, affected people can be connected to response activities and encouraged them for saving lives, reducing injuries and minimizing the property loss to enhance situation awareness. Within the scope of sphere standards, programs can be launched in order to improvise the condition of: a. water supply, sanitation and hygiene promotion, b. food security and nutrition, c. shelter and settlement and d. Health through coordination and collaboration between organizations.

Data and information in the warehouse

Data warehouse is the storage location of both historical and current data sources and processed information as insights. According to *infogineering*, although data and information seem to be used interchangeably, their major difference is that data is raw material that is to be processed to acquire anticipated information i.e. data is used as input for the model, algorithms and processes while information is the output of data[4]. As been discussed already, the data comes from various sectoral data sources as remote sensing and UAV, social media, GIS databases, research and academia reports, multimedia, micro-mapping etc. These technologies often reach and inform about the situation where communication, location and rescue is risky or even impossible. To give a clear sense of how these all fit into disaster response, here we have considered a use case for flood which is one of the supreme taking place disaster and most often pertinent in most part of world.

The list of anticipated data and information is as follow:-

Data: It is the input for the model, fitted as values for variables. In this case we may need the following but not limiting to these only, data from various sources clustered in a warehouse:

a. Hydrological and meteorological records
b. Population and infrastructure
c. Vulnerabilities, capacities and exposed hazards
d. Local clubs, Organizations, Community based Organizations (CBO) including first responders as set by government and non-government organizations

[1] *https://www.weforum.org/agenda/2018/01/4-ways-technology-can-play-a-critical-role-in-disaster-response/ retrieved on 26th Jan, 2018*

[2] (The Sphere Handbook- 2018)

[3] https://www.unocha.org/sites/dms/Documents/OOM-humanitarianprinciples_eng_June12.pdf retrieved on 27th Jan, 2018

[4] http://www.infogineering.net/data-information-knowledge.htm retrieved on 26th Jan, 2018

e. Education institutions, government and non-government organizations disaggregated by working sector and area
f. Early warning data containing flood level, location of flood
g. Social media reporting standards - hashtags, safety checks, tags etc.
h. Real time cellular locations
i. Sewage and drainage channel
j. Network of micro-mappers

Information and process: Most of the information during the process is automatic rather than manual i.e. aforesaid data are processed using various algorithms and models to acquire desired information. The said data can be processed to get following, and again not limiting to these only, information:
a. Weather forecast as per hydrological and meteorological records from stations
b. Early warning dissemination channels to reach people to be affected with time limit of flood to reach from one early warning station to another that disseminated the level and extent of flood
c. Communication of safety measures through radio, television and faster popular means. This may also include notification of individuals through social media.
d. Appropriate location identification for internally displaced people (IDP) using GPS, GIS and remote sensing technology
e. Deploying first responders in the field based on information from micro-mappers including response channel, evacuation routes and its classification
f. Mathematical model for loss estimation. The loss primarilyy includes human, property and livestock loss calculated based on previously available data in the warehouse.
g. Dissemination of disaggregated data developed based on previously fetched information that indicates organization roles, working area, sector and indicator as per Sphere standards.

Advantages/limitations of Warehouse

It is an intricate job to examine and evaluate the efficaciousness of a disaster response system in a quantitative manner since at present there are no any protocols to quantity it (Chapman, C., and Ciravegna, F., pp.7). However we can weigh the system in terms of its pros over cons.
While talking about its pros, data warehouses do have uniform data quality with quicker and easier data access and thus assist in better decision making[1]. Other pros are, data history are maintained to study chronological trends, and the data integrity is maintained with standard norms, codes and rules. Thus, the large volume of data are cleaned by removing inconsistent errors and improves the data quality of metadata. Indexing is done to deal with large volumes of data so as to increase data accessing speed. Irrespective of the data sources, there is a common data model for all sorts of data. Data are reorganized as per requirements making easy for complex analytic queries and during all these also, operational systems are intact. Additionally, unauthorized access are checked with data security policies and users can only access data through various pre-defined modules[2].
As it is palpable that, every coin has two sides. Though, there are many advantages of data warehousing, there are some drawbacks as well. Data are obtained from various sources due to which the major drawback regarding the ownership, privacy and secured results occurs at this point. Besides, all those data may not be compatible each time and the technicians may have to go through the specific cases of data resulting in consumption a significant amount of time. Normally, an organization runs warehouse data at the risk of mapping in with same schema and filters which diminishes the pliability of data. It is difficult job to maintain such a tremendous volume of data online.

Conclusion

In summary, here we discussed the potential and challenges of data warehouse as an efficient emergency response schema and this paper is oriented towards conferring it as an efficient approach. Data warehouse is the suitable answer to handling large volume of data as it cleans and standardizes them to aid responders form a quick action plan at the time of emergency. The data are analyzed within the scope of four priorities and seven targets of Sendai framework, a commonly endorsed covenant by the UN using pattern recognition and predictive modelling techniques. In addition, using these techniques we can derive apt plan for timely response for rescue and relief operations along with "Build Back Better" approach in recovery, rehabilitation and reconstruction. The derived information acquired after processing the available data in the warehouse,

[1] https://dzone.com/articles/data-warehouse-characteristics-and-benefits retrieved on 25th Dec, 2017
[2] https://content.wisestep.com/data-warehousing-characteristics-functions-pros-cons/ retrieved on 25th Dec, 2017

can be disseminated sector wise so that the emergency responders can use it as per their requirement. While responding, normally they endure within the scope of standards set by Sphere Standards, another commonly endorsed covenant by the UN. Establishing the two main beliefs regarding people's right to life and precautions to be taken to lessen human suffering during disaster, the sphere standard has also set protocols in four vital areas which are Health, Food Security and Nutrition, Shelter and Settlement and lastly the Water Supply, Sanitation and Hygiene Promotion (WASH).

References

Chapman, S. and Ciravegna, F., "*Focused Data Mining for decision support in Emergency Response Scenarios*" funded by Advanced Knowledge Technologies (AKT) Interdisciplinary Research Collaboration (IRC) sponsored by EPSRC, grant number GR/N15764/01, pp. 1-9

Chen, F.; Deng, P.; Wan, J.; Zhang, D.; Vasilakos,A.V.; and Rong, X.; (2015) '*Data Mining for the Internet of Things: Literature Review and Challenges*', Hindawi Publishing Corporation International Journal of Distributed Sensor Networks Volume 2015, Article ID 431047, 14 pages http://dx.doi.org/10.1155/2015/431047

Fayyad, U.; Piatetesky-Shaoiro, G.; and Smyth, P. (1996) "*From data mining to knowledge discovery in databases*," *AI Magazine* Vol. 17, No.3, 1996.

Goswamia S., Chakrabortya S., Ghosha S., Chakrabarti A., Chakraborty B., (2018) '*A review on application of data mining techniques to combat natural disasters'*, Ain Shams Engineering Journal, ISSN: 2090-4479, Vol: 9, Issue: 3, Page: 365-378

Imran, M.; Elbassuoni, S.; Castillo, C.; Diaz, F.; Meier, P. (2013) "*Practical extraction of disaster-relevant information from social media*", In Proceedings of the 22nd International Conference on World Wide Web Companion, Rio de Janeiro, Brazil.

Ji, L. and Chi, H. (2006). "*Emergency Management*", High Education Press.

Jiawei, H.; Kamber, M. and Pei, J. (2011) 'Data Mining: Concepts and Techniques 2011' Morgan Kaufmann Publishers Third edition.

Mukhopadhyay A., Maulik U., Bandyopadhyay S. and Coello C. A. C, (2014) "*A Survey of Multiobjective Evolutionary Algorithms for Data Mining: Part I*", in *IEEE Transactions on Evolutionary Computation,* vol. 18, no. 1, pp. 4-19, doi: 10.1109/TEVC.2013.2290086

Parajuli, J.; Baral, S. (2018) "*Remote Sensing Schemes Mingled with Information and Communication Technologies (ICTS) for Flood Disaster Management",* i-manager's Journal on Pattern Recognition; Nagercoil Vol. 4, Iss. 4, (Dec 2017-Feb 2018): 1-9.DOI:10.26634/jpr.4.4.14128

Tan, P.-N., Steinbach, M., & Kumar, V**. (2005)"***Introduction to Data Mining*", Addison Wesley,

Twigg, J. (2015), "Disaster Risk Reduction", Overseas Development Institute, 203 Blackfriars Road London SE1 8NJ United Kingdom, new edition, pp.1-382

Vieweg, S. (2012) "*Situational Awareness in Mass Emergency: A Behavioral and Linguistic Analysis of Microblogged Communications*". Ph.D. Thesis, University of Colorado at Boulder, Boulder, CO, USA.

Zagorecki, A.T., Johnson, D.E.A. and Ristvej, J. (2013) '*Data mining and machine learning in the context of disaster and crisis management*', Int. J. Emergency Management, Vol. 9, No. 4, pp.351–365.

RETHINKING DESIGN AND POLICY GUIDELINES FOR DISASTER MIGRANT REHABILITATION PROJECTS IN BANGLADESH: A STUDY OF THREE ASHRAYAN PROJECTS IN PAIKGACHHA, KHULNA

Puja Mallick[1], Muhaiminul Islam[2] and Mahmud Hasan Reaz[3]

ABSTRACT

Bangladesh is one of the most vulnerable countries in the world because of various types of frequent disasters driven by climate change. Disaster migration has become a burning issue here. It has been assumed that about 78 million people will be displaced by 2020 due to climate change in Bangladesh (Khatun, 2013). GoB has developed a housing rehabilitation scheme called "Project Ashrayan" to accommodate mainly the landless and homeless population. Disaster migrants are one of the main target groups of this project. Though being a noble humanitarian instigation towards the displaced humanity, some Ashrayan projects are now gone under water, have been left abandoned or gone in wrong hands who are actually not homeless at all. While government is committed to obliterate the landless problems from the country by these types of projects and trying to support the pro-poor, landless people, some decision-making errors are turning these attempts into failure. This study tries to identify the flaws in this post disaster housing rehabilitation project by investigating three Ashrayan project cases in Paikgachha Upazilla of Khulna District. The study reveals the proximity of selected site for housing reconstruction projects with rural market or growth centre is highly influential for success of Ashrayan projects. Besides, this study suggests, the participation of users can also play vital role in building the belongingness of the users with the projects. Absence of spatial consideration of future generations of the current users was also identified as a barrier against belonging the provided houses. Based on comparison between the three cases, a number of recommendations for post disaster long term housing rehabilitation have been derived.

Introduction

Increase of disaster migrant is becoming a severe issue for Government of Bangladesh. Providing shelter to these homeless people is a tough challenge. Because of climate change the number of disaster migrants are increasing in a continuous basis. According to Govt. statistics, nearly 46% people temporarily displaced and 12% people permanently displaced due to different hazards in four climate hotspots of Bangladesh (CDMP II Report, 2014). However, project Ashrayan is initiated by government to rehabilitate the homeless, rootless and disaster migrant people in Bangladesh. This project, started in the coastal areas of Bangladesh in 1996, included the construction of basic housing in a barrack style (Rahman, 2017). This project is controlled by prime minister's office of GoB and implemented by Bangladesh Army. Such proactive initiative is appreciable in case of post disaster rehabilitation projects because the situations are severe in those moments and a shelter is the most urgent need of that time. But after construction of many projects it has been found that a good number of Ashrayan projects are struggling for becoming a successful rehabilitation project. Surely many projects have become successful examples. But the reasons behind the success and failure of the Ashrayan projects are yet to explore. Among the three cases investigated by this study, *Chadkhali* Ashrayan has been found economically and socially more sustainable than the *Betbunia* and *Goraikhali* Ashrayan projects. The comparison among them has identified three central factors behind the success and failure of Ashrayan projects.

Methodology

The three Ashrayan projects surveyed in Paikgachha Upazilla were *Betbunia* Ashrayan, *Goraikhali* Ashrayan and *Chadkhali* Ashrayan. Paikgachha was selected because of availability of Ashrayan projects in same region. In Paikgachha the Ashrayan projects were mainly inhabited by the migrants who lost their homes in Cyclone *Aila* in 2011 in nearby villages. Among three Ashrayan projects, the household units and Barracks

[1] *Architect and Post Graduate Independent Researcher, Khulna-9100, Bangladesh*
[2] *Lecturer, Dept. of Architecture, Northern University of Business and Technology Khulna, Khulna-9100, Bangladesh*
[3] *Architect, Nirnoy Upodesta, Dhaka-1207, Bangladesh*
Email of Corresponding Author – mrahi9213@gmail.com

were surveyed in a random basis. Empirical data were collected mainly from on-site observation through sketches, still photographs, focused group discussions and questioner survey. From the surveyed data the focusing issues were sorted out in a qualitative manner. S.W.O.T. analysis method was used for qualitative data analysis to concise the strengths, weaknesses, opportunities and threats of the surveyed Ashrayan Projects. The findings from the S.W.O.T. analysis was filtered and three focusing issues and underlying sub-issues were then derived. The design and policy guidelines were proposed for Ashrayan projects based on those three main issues.

Findings from Paikgachha Ashrayan projects

From the comparison of three Ashrayan projects in Paikgachha Upazilla the *Chadkhali* Ashrayan Project was found in a far better condition in terms of social and economic sustainability. On the other hand *Goraikhali* and *Betbunia* Ashrayan projects were lagging far behind. Existence of fake beneficiaries from nearby settlements who were actually not disaster migrant was a highlighting indicator of projects' unsuccessfulness. Another indicator is the number of vacant units. Belongingness of users with their project was identified by the rate of extension and modification of the households by the user themselves.

Table 1. Comparison of different variables among three different Ashrayan projects in Paikgachha

Indicators	***Betbunia* Ashrayan**	***Chadkhali* Ashrayan**	***Goraikhali* Ashrayan**
Vacant Households	18%	0%	9%
Households owned by improper beneficiaries'	31%	3%	6%
Households going through extensions and modifications	23%	99%	37%

The findings from table 1 above revealed that Ashrayan in *Chadkhali* was more belonged by the community. The extensions and modifications are the evidence of economic investment of the users' themselves which also indicate the economic growth of them. Here the existence of inappropriate beneficiaries is also almost zero. The Ashrayan of *Betbunia* and *Goraikhali* was in an opposite condition. There was existence of inappropriate beneficiaries who already had a household in a nearby area. They used the household of Ashrayan project as an extra property. Most of the time they were away living the household locked. As a result it can be assumed that the level of belonging is lower in *Goraikhali* and *Betbunia* Ashrayan projects. The rate of user driven extensions are also lower in these cases.

However, the study of three different cases, of which one was comparatively more successful and on the other two was less successful, gave an opportunity to explore the issues which were responsible for failure of many other Ashrayan projects. Analysing the strengths, weaknesses, opportunities and threats of each case three major issues were found.

i. *Improper site selection*
ii. *Lack of user end participation*
iii. *Lack of space for future generation*

Improper Site Selection

In many Ashrayan projects, site is selected in a remote area to get land in lower price. Both *Goraikhali* and *Betbunia* Ashrayan is located away from nearby settlements in a position near the *Shibshah* River from where any livelihood service is quite unreachable. Because of being away from economically active zones there was lack of job opportunity among the users. Most families in the two less successful cases have to find seasonal jobs and leave home for 5/6 months. Usually they go to Khulna and Jessore to work in the brick fields for those months. The figure bellow shows the site of Betbunia Ashrayan which is two kilometres away from nearby rural settlements and surrounded by low watery lands and *ghers* in local terms.
On the other hand *Chadkhali* Ashrayan is located adjacent to existing rural settlements near a rural market. As a result the users of *Chadkhali* Ashrayan got chance to get employed in the economic activities of the area and were able to grow their economic condition. The extended cooking and living spaces, cattle houses, small shops etc. are the evidence of their economic growth.

Legends:
1. Betbunia Ashrayan
2. Rural Settlements

Figure 1. Distant location of Betbunia Ashrayan from nearby rural settlements

Lack of User end Participation

From the secondary data it was clear that participation of users in the various phases of rehabilitation of post disaster reconstruction process play vital role in creating the belongingness of the users with their new homes (Shafique & Warren 2018). But in Ashrayan project there is no scope of user end participation in any phase of the project. Though it is a high emergency project which may consider user end participation may delay the implementation process. As a result the responsibility of project implementation is handed over to Bangladesh Army who construct the project in an army Barrack configuration which is totally contrasting with the homely environment of the users. In many cases like *Betbunia* and *Goraikhali* Ashrayan projects' many users leave the provided houses because they cannot belong with the environment and the whole process. The mental image of a shelter or home of the user does not match with the provided housing scheme.

Figure 2: Mapping of mental image of "Dream Home" by children of Ashrayan

The images above in figure 2 show how the mental image of "dream home" were collected from the children of Ashrayan projects. The drawings provided by the children contain some common features for example individual house, shared space, space for vegetation, connection with road, poultry farm, playground, school etc. However lack of participation of users in the design development and construction phases were responsible for lack of consideration of the needs of the users. As government has totally constructed the projects and then handed over to the users, they think it is government's responsibility to maintain the projects too. They seldom get involved in any further investment for maintaining the houses.
Also a lack of confidence was found from *Goraikhali* and *Betbunia* cases. The users there feel uncomfortable with their identity of their address. They try to hide that they live in Ashrayan project as the neighbourhood do not appreciate them. Neighbourhood perceives that they are getting facilities from govt. without any effort. If they get involved in design development and construction process from the beginning, they would be able to belong with the houses. And this can also minimize the arrival of fake beneficiaries in the project.

Lack of Consideration for Future Generation

In current scheme of Ashrayan project there is no consideration of next generation from spatial perspective. As a result the parents have to live in the veranda after expansion of the family or when their son or daughter get married. This is a sever sense of insecurity which brings depression among the users as they do not find any future in the projects. As they see no future of their next generation, they do not feel interested in investing in their households. Lack of tenure security is also responsible for this insecurity.

Recommendations and Conclusion

From the above issues it is clear that, site selection, user end participation and consideration for future generation are highly sensitive issues in post disaster rehabilitation projects. Better thoughts are necessary in these three spectrums. In light of the above specific issues several design and policy guidelines can be suggested. The guidelines are stated bellow grouped in several sections.

Site selection guidelines

- Site should be selected near any existing settlement or a growth centre
- Site should not be detached from existing settlement
- If government land is not available near market or growth centre then government should try to go for private land acquisition near growth centre

Market related guidelines

- If site is adjacent to market 15 to 30 shatak of land should be provided for extension of market
- The markets inside the site should be rent by both community people and other people outside community
- Rent fee of market per square feet should be decided by the community development committee
- The rent fee of community market for community people should be in 15% to 30% discount
- The rent fee collected from community market should be collected in community development found

Community centre related guidelines

- If site is adjacent to market the community centre of that site should be multi-storeyed and ground floor should be used as market space
- Community centre should be used as informal school in morning, as vocational training centre at afternoon and as community meeting space in the evening

Beneficiary's involvement related guidelines

- To involve beneficiaries with design and implementation process families should be selected at first
- After selection families should be given training on forming co-operative and training on disaster resistant local construction techniques
- After training families should form co-operatives among them
- Communities should be involved in design process with experts by giving their opinion
- Some design schemes should be prepared by the community people through community design workshop by community architects
- Experts and people through workshop should decide the scheme of unit detail and plot distribution
- After design decisions community should be involved in construction process
- Government should provide funding for plinth, structural members and roof materials. Walls might be provided by families themselves

Future extension and tenure related guidelines

- Each family should get a piece of open land for their vegetation, and kitchen as extension
- It should be tried to provide a large veranda for multipurpose use which will be in future used as a room when family size will increase
- Families should be given training for multi-storeyed construction with local materials
- Families should be provided tenure security of their land by giving lease for 30 years.
- After 30 years they should be allowed to by their land from government if they can return 20% to 10% of their current land value in instalment basis

This can be concluded that, many of the Ashrayan projects are not achieving their deserving success for improper site selection, lack of involvement of users in design development and construction process and having no vision for accommodating future generation of the users in design of these projects. The provided guidelines according to those issues should be helpful to enhance the success rate of Ashrayan projects. However, further thoughts are also necessary on these guidelines to implement them more accurately.

Acknowledgements

This paper is based on works of Ashrayan study report of Group-4 which is an outcome of a project of Design Studio VIII-2015 called “Reconstructing Ashrayan: Designer as A Role-player” of B.Arch. program under the Architecture discipline of Khulna University. Authors would like to solely thank the teachers of Design Studio VIII-2015, Professor Dr. Sheikh Serajul Hakim, Dr. Hafizur Rahaman, and Auditi Bridget Biswas. They not only coordinated the design studio, rather envisioned and encouraged to uphold this studio work to a broader arena. Also we would love to thank all our group members: Mahmud Hasan Reaz, Puja Mallick, Muhaiminul Islam Rahi, Sk. Mahfuz Alam and Imran Mahmud Shimul Vai. Undoubtedly without the help of all our studio-mates, this work would not have been possible. Finally authors are grateful to the informants of *Ashrayan* Project for their keen participation and all the information they provided.

References

Khatun, M. (2013). Climate Change and Migration in Bangladesh: Golden Bengal to Land of Disasters. *Bangladesh e-journal of Sociology*, *10*(2).

Rahman, M. (2017). Resettlement of Climate Induced Displaced People in Bangladesh: Governance Perspective. *IOSR Journal Of Humanities And Social Science 22(10), 07-17.*

Shafique, K., & Warren, C. M. (2018, January). Empowerment and legitimization of effected communities in post-disaster reconstruction. In *Procedia engineering* (Vol. 212, pp. 1171-1178). Elsevier Ltd.

CDMP II (Comprehensive Disaster Management Programme), Trend and Impact Analysis of Internal Displacement due to the Impacts of Disaster and Climate Change, Ministry of Disaster Management and Relief, Dhaka, Bangladesh, 2014.

FLOOD DISASTER MANAGEMENT: A CASE STUDY OF MODEL VILLAGES IN SOUTH PUNJAB

Muhammad Salman[1*], Dr. Fariha Tariq[2]

ABSTRACT

Pakistan has faced numerous devastating floods since its creation. Floods in 2010 affected hundreds of villages in Punjab, which resulted in 0.5 Million destroyed houses in South Punjab only. In response to these floods, Model Villages were set up in affected Southern Districts and devastated communities were given shelter in these villages. This research aims to study the deliverance mechanism of these shelter units, the impacts of providing these units on the lifestyle of inhabitants and if Model Villages are truly contributing towards disaster risk mitigation or not. This research also addresses aspects of community participation, community empowerment and liberty given to end users, in designing and building their own houses. Data from both primary and secondary sources, available statistics, case studies, field surveys and interviews, has been used to carry out the research. Eventually, based on the performance of these model villages, the paper lists out the flaws present in this rehabilitation model and puts forward recommendation to govern the disaster risk and to boost the role of community in disaster preparedness and post disaster recovery.

Introduction

Natural disasters cause deterioration of environment and infrastructure and the occurrence of these natural hazards has augmented all over the world, during 1990 to 2000, the frequency of these disasters and affected people have increased to double (UN-ESCAP, 2006). Owning to its geo-climatic conditions, distinctive in nature, Pakistan is assumed to be a country prone to the natural disasters that has caused massive destruction all over the country in recent years. Among these disasters, earthquakes, floods, land sliding and droughts are notable. As per the studies, almost 40% land area in Pakistan is located on seismic fault lines, 60% area is vulnerable to floods and 25% of the Barani Land being cultivated is prone to drought (Qaddafi, 2018).

In Pakistan, floods, usually, are caused by the storm systems which originate from the Bengal Bay and enter Pakistan passing over the Central India during the monsoon period, July to September, and continue towards North. These floods leave Pakistan among the countries, having highest average of people vulnerable to floods annually (Sayeeda Amber Sayed, 2014). The glaciers in Himalayas and Karakorum feed six main rivers and almost 50 small rivers (Attaur Rahman, 2015). During summers, this inflow reaches its maximum and monsoon also causes increase in water level of rivers, Indus, Jhelum, Chenab, Swat and Kabul, which cause most of the flooding almost every year. In River Ravi and Sutlej, water discharged from the Indian side gives rise to floods in Pakistan. Dams, barrages and link canals can help in managing these floods to an extent only and when these floods surpass the normal level, the hazard turns catastrophic and causes extensive deaths as well as loss to economy (Iqbal, 2011). In addition to the said factors, increased temperature caused by the climate change results in supplementary melting of snow and glaciers in mountain ranges in North; Karakorum and Himalaya, increasing the water inflow into the rivers and later on resulting in catastrophic floods (Gronewold, 2010). Climate related disasters accounted for almost 76% of all the natural disasters recorded in last four decades. During these four decades, among the total affected population, 85% was affected by just the floods, and out of this proportion, 74% were affected by the riverine floods (Ole Larsen, 2014). In case of Punjab, most floods are caused by River Ravi, Sutlej and Chenab, but weather is not the only factor which gives rise to these floods, there are some other factors including human, political and administrative, which also cause floods at some level. Some of the reasons are discussed below.

Inefficient disaster management bodies and plans are also responsible for floods in history. Infrastructure built to control or mitigate the effect of floods was not properly maintained over time, which, eventually, failed to stop the flood. The financing provided for maintenance of dams, canals and barrages was not brought to use effectively and the said structures could not withstand even the low intensity floods (Memon, Root causes of floods, 2011).

Human actions affecting the environment are also responsible for the flooding in country. As a result of Criminal deforestation carried out by the communities, every year 5600 acres of riverine forest is lost, which has resulted in removal of natural setback formed by the trees and settlements have become vulnerable to the

[1] *MS Student, Department of City & Regional Planning, University of Management & Technology, Lahore.*
[2] *Chairperson, Department of City & Regional Planning, University of Management & Technology, Lahore.*
[*] *Corresponding Author: Muhammad Salman,* msalman703@gmail.com

high water tides (Jamshed, 2015). Moreover illegal constructions by the local people along the river to protect their crops cultivated in flood plains have also disturbed the natural flow of rivers.

Rural and political elites own major share of land in the rural areas It was witnessed in past years that during the flood events this elite channeled the flood away from their agricultural land by destroying the structures built to protect the area from floods. As a result small settlements, earlier safe from the floods, were hit by the floods and heavy loss was recorded.

Since independence, floods have caused loss of $12.46 Billion to economy and taken nearly 15000 lives (Report, 2011). Frequent floods, in 1950, 1977 and 1992 have caused deaths of thousands of human beings and ruined thousands of villages. From1960 to 2011, these floods caused, on average an annual damage of 1% of the Gross Domestic Product (GDP) (Memon, Malevolent Floods of Pakistan 2010-2012, 2013). The loss of livestock heads and agricultural land is also notable. Right after partition, in 1950, Pakistan witnessed first severe flood disaster which affected almost 10,000 villages and took lives of over 3000 humans (A Review of Disaster Management Policies and Systems in Pakistan, 2005). As per the official statistics, flood events during the time period of 1991-2001 caused damage of up to 78,000 million rupees to property (SAARC-SAKDN, 2009).

Disaster Risk Management in Pakistan:

Pakistan has been facing catastrophic events since its creation. Severe flooding of 1950 is worth mentioning here which claimed around 3000 lives, but the governments could not succeed in devising an effective disaster management authority. However, in 1960s, the administrative institutions realized need for a flood management program to control the floods occurring at intervals in East Pakistan, as a result a program was included into Fourth Five-Year Plan (1970-75). Prepared with a vision to cope with disasters and their management, unfortunately, this draft was never concluded and implemented.

In later decades the governments formulated multiple acts and legislations to manage and control the disasters, National Calamity Act (1958), Local Government Ordinance (2001) and Emergency Services Ordinance (2002) are few to be named, but these programs were not much effective in mitigating the disaster risks. In 2005 worst earthquake highlighted the extent of threat that natural disasters can pose not only to the human lives but also to the infrastructure and economy. Thus an ordinance named National Disaster Management Ordinance was agreed in 2006 which called for establishment of disaster management bodies at national, provincial and regional level (NDMA, 2012).

This ordinance was valid and in practice until Pakistan faced floods in 2010 which caused devastation all over the country. At that point, it was realized that ordinance passed in 2006 or earlier ones mainly focused on controlling hazards, rescue and rehabilitation aspects while the characteristic of preparedness was missing in all these legislations. Thus, to fill these loopholes, a new management act named National Disaster Management Act was approved in 2010 by the political institutions which was very comprehensive in nature and discussed not only the recovery and reconstruction practices but also focused on preparedness. This ordinance also laid importance on establishment of National and regional disaster management authorities and defined their respective roles, authorities and duties. Hence, National Disaster Management Authority (NDMA), Provincial Disaster Management Authorities (PDMA) and District Disaster Management Authorities are working simultaneously, at national, provincial and district level respectively, to manage the disasters and to reduce the vulnerabilities of disaster prone communities. PDMA Punjab is responsible for carrying out necessary and inevitable actions to meet the above mentioned needs in province of Punjab (Senate Secretariat, 2010).

Case of Model Villages

After the flooding in 2010, there was a dire need to work out an effective post-disaster rehabilitation strategy which would not only facilitate the displaced households whose houses have been destructed but would also aim to reduce the vulnerability of this population to the floods. Thus, in response to 2010 floods, Government of Punjab with the collaboration of NDMA and PDMA formulated an action plan to develop planned resilient rural neighborhoods having all the amenities in harshly affected districts of Punjab. The main idea was to alleviate the living standards of this flood prone population by providing modern facilities and to reduce their vulnerability. As per this program, Government of Punjab planned to develop total of 22 model villages, comprising of almost 1900 housing units, in seven different flood affected districts of South Punjab. Furthermore, these villages not only provided shelter, but all other social amenities, such as, educational institutes, health facilities, community centers and Technical Education & Vocational Training Authority (TEVTA) centers were also part of these developments. Stable supply of Power and Fuel Energy is guaranteed by means of fitting the utmost cutting edge equipment like Bio Gas Plant and Solar Panel. Below are the details of all the model villages in Punjab.

Materials and Methods

This research focuses on district of Muzaffargarh with the aims to study the life before and after disastrous floods as well as focuses on the impacts of providing model villages on the lifestyle of inhabitants. Following are the detailed objectives achieved through this research study;

- The deliverance mechanism of these shelter units was studied in order to find out if Model Villages are truly contributing towards disaster risk mitigation or not.
- The performance of these model villages during the catastrophic events in flood prone areas since their establishment was quantified.
- The aspects of community participation, community empowerment and liberty given to end users, in designing and building their own houses were addressed, as these approaches ensure post disaster psychological recovery, reduced vulnerability towards disasters and reflect cultural and traditional character in final product.
- Eventually, the paper lists out the flaws present in these provided shelter units and puts forward recommendation to govern the disaster risk, to enhance the performance of post disaster infrastructure in disaster prone areas and to boost the role of community in post disaster recovery.

For carrying out the research, focus has been laid on the model villages developed in the district of Muzaffargarh, total 6 in number. These 6 villages comprises of total 499 housing units which form almost 26.5% of the total houses built in this program. Units were handed over to the qualified households in 2011 and the households moved into these houses soon after they got the possession.

Data from both primary and secondary sources has been acquired. Available statistics, field surveys and interviews helped in conducting the research. 30 individuals belonging to different households were contacted and their responses regarding Allotment policy, Community participation and disaster Reduction were recorded. Officials from PDMA Punjab and Project Implementation Unit (PIU) PDMA and DDMA Muzaffargarh were interviewed which helped in understanding the policy decisions taken during the execution of project. Data collected contains statistics of damage caused by floods before provision of model villages, the differences recorded after provision of model villages and role of communities in disaster mitigation. Based on the performance of these model villages, over the years, along with the parameters of community participation and community empowerment, paper includes recommendations which can rectify the performance of these model villages.

Results and Discussions

Below section gives insight to the aspects which were focused during the phase of data collection and surveys and describes the results which are based on the analysis of the collected data.

Land selection criteria

For selection of land, focus was on to reduce the vulnerability of affected population towards disasters, so it was principally thought to select those sites which were not prone to flooding or other disasters and preference was given to those areas where state land, mostly barren, was present. During the field survey, 60% of the residents expressed dissatisfaction regarding the site selected for development of villages (Table 1).

Table 1: Satisfaction with the selection of land for development of Model Villages.

Response	Frequency	Percentage
Strongly Agree	3	10%
Agree	4	13.33%
Neutral	5	16.66%
Disagree	7	23.33%
Strongly Disagree	11	36.66%
	30	100%

They were of the view that sites chosen were far away from their old neighborhoods and had no suitable work opportunities in surrounding areas. Moreover, in some cases, it was observed and expressed by the residents and local community that political individuals manipulated the process of land selection for their own benefits which impacted the sustainability of the these villages.

Adopted allotment Policy

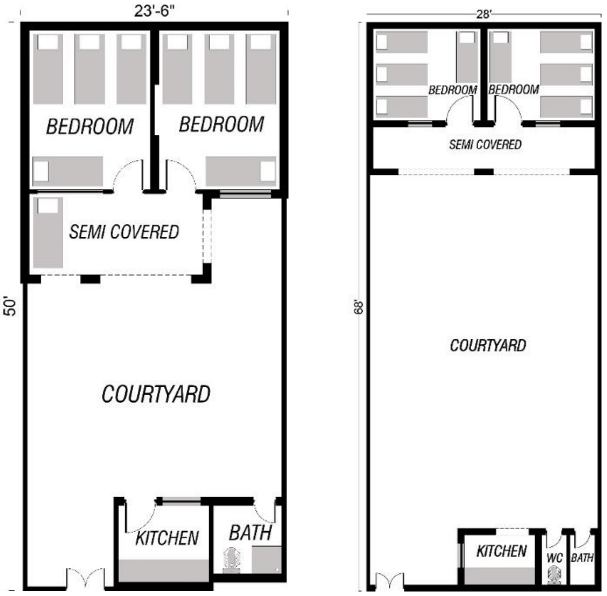
For allotment of these newly built units, households having completely damaged houses were eligible and every household was entitled to get only one unit in replacement of their destroyed housing unit. This was verified by a Household Survey carried out by the PDMA in collaboration with the regional DCOs. For every single damaged house, a new model village dwelling was assigned to an eligible household. In this process of household verification, only those villages were considered where more than 75% of houses have been damaged and it was recommended to relocate an entire neighborhood into single new village, instead of relocating individuals into different model villages (PDMA Punjab, 2011). By the year 2011, the development work of these model villages was underway and it was completed in a record history time. Majority of residents, nearly 45%, agreed to fact that the process of allotment and delivery was transparent and no malfunctions were witnessed (Table 2).

Table 2. Process of Allotment and Delivery was transparent.

Response	Frequency	Percentage
Strongly Agree	5	16.66%
Agree	9	30%
Neutral	10	33.33%
Disagree	4	13.33%
Strongly Disagree	2	6.66%
	30	100%

Inclusion of community participation

During the survey, 90% residents expressed that they were not embraced as stakeholders in designing phase of the villages and, unfortunately, Top-down approach was used. All the decision were made by the higher authority, be it land selection, architectural or urban design, material selection or other, the residents were not given any importance and their opinions were not taken into considerations (Table 3). However, after the households moved in, Village Organizations were proposed to be established in all villages consisting of members of society. Below are the architectural plans of the dwelling units constructed in the model villages (Figure 1).



Total Area: 1160 sq. ft. Total Area: 1900 sq. ft.

Figure 1. Architectural plans of housing units

Table 3. Community was involved in decision making process.

Response	Frequency	Percentage
Strongly Agree	3	10%
Agree	4	13.33%
Neutral	5	16.66%
Disagree	7	23.33%
Strongly Disagree	11	36.66%
	30	100%

Disaster Reduction

As far as the disaster risk reduction is concerned these model villages have performed really well, the population which was prone to disasters earlier on is now living in these units built by the Punjab Government and in coming years they were affected by the floods. 70% of the residents also endorsed the opinion that these model villages have helped in disaster reduction (Table 4). Moreover, these settlements were not affected by the flood hazards which took place in years of 2012 and onwards which also leads us to the result that these units have contributed towards disaster risk reduction. Moreover the provision of community amenities, schools, dispensaries and allied facilities have also contributed in improving living standards of the residents.

Table 4. These villages helped in disaster reduction

Response	Frequency	Percentage
Strongly Agree	13	43.33%
Agree	8	26.66%
Neutral	4	13.33%
Disagree	3	10%
Strongly Disagree	2	6.66%
	30	100%

Current Status of Model Villages

During the visit of these model village, it was witnessed that a number of allotees had sold the housing units and shifted to their native places owing to non-existence of livelihood opportunities. Currently 15% of housing units are possessed by illegal residents and nearly 17% housing units are vacant or locked (Table 5).

Table 5. Current status of Model Villages.

Village Name	Status			
	Houses	Occupied By original Allottee	Occupied by illegal Allottee	Locked
Basti Meeran Mullah	106	102	0	4
Basti Khara Niazi	83	43	0	40
Khara Nawa	30	30	0	0
Rakh Jalwala	136	98	0	38
Bhulla, Mouza Aalo Rid	78	69	9	0
Rakh Ehsanpur	66	5	61	0
Total	499	347	70	82

Moreover, although, these model villages had positive influence on homeless flood affected population through providing them with proper housing units along with the ownership rights. However, the facilities which were proposed or promised are not there. Below is a summary that describes the current status of facilities or amenities in the Model Villages, facilities either not available or non-functional are highlighted (Table 6 and 7).

Table 6. Current status of Model Villages.

Village Name	Status					
	School	**Functional**	**Dispensaries**	**Functional**	**Tevta Centres**	**Functional**
Basti Meeran Mullah	Yes	Yes	Yes	Yes	Yes	Yes
Basti Khara Niazi	Nil	-	Yes	Yes	Nil	-
Khara Nawa	Nil	-	Nil	-	Nil	-
Rakh Jalwala	Yes	Yes	Yes	Yes	Nil	-
Bhulla, Mouza Aalo Rid	Nil	-	Yes	-	Yes	No
Rakh Ehsanpur	Nil	-	Yes	Yes	Yes	No

Table 7. Current status of Model Villages.

Village Name	Status					
	Vet Dispensary	**Functional**	**Park**	**Functional**	**Community Centre**	**Functional**
Basti Meeran Mullah	Yes	Yes	Yes	No	Nil	-
Basti Khara Niazi	Yes	Yes	Yes	No	Yes	No
Khara Nawa	Nil	-	Nil	-	Nil	-
Rakh Jalwala	Yes	Yes	Yes	No	Yes	Yes
Bhulla, Mouza Aalo Rid	Nil	-	Yes	No	Yes	No
Rakh Ehsanpur	Yes	Yes	Yes	No	Yes	No

Conclusions

Results show that majority of the population expressed satisfaction regarding the performance of these Model Villages and they agreed to the fact that these villages have really protected them from flood hazards and improved their living standards. They also expressed satisfaction towards the allotment policy ad deliverance mechanism.

Yet, majority of residents were of the view that community participation was not ensured and decisions relating to the selection of land and designing of housing units were taken at higher levels and implemented without seeking the opinions of recipients. Which is also endorsed by the current status of these model villages in the form of a number of vacant and illegally owned housing units. Either non availability or non-functionality of proposed facilities is also the probable cause of the outward migration of families.

This model of disaster rehabilitation helped in disaster reduction, however results point out some of the malpractices in this approach recorded during the data collection and field survey. First of all the selection of land must be done on the defined parameters and in a transparent way regardless of the external pressure.

Secondly, and most importantly, the community participation must be ensured. Local Community must be embraced as a stakeholder and their active participation in decision making process must be ensured. The outcome of such participation will be more sustainable as it will be according to the need, lifestyle and desires of the community and they will own it as their own, which will help in reducing outward migration. In addition to the aforementioned measure, if the proposed infrastructure and amenities are also provided in a timely manner, it will also help the community to fight better against the disasters and will improve the living standards of the community even more.

Acknowledgments

We thank the office bearers of PDMA and PIU, Rana Sohail and Ms Hania, in cooperating and providing the apt information needed for the research. We also thank Mr. Irfan Sial, DDMA Muzaffargarh, for providing credible statistics and documents to conduct this work.

References

A Review of Disaster Management Policies and Systems in Pakistan. (2005).

Attaur Rahman, R. S. (2015). Introduction and Approaches of Disaster Risk Reduction in Pakistan. In A. n. Atta Ur Rahman, Disaster Risk Reduction Approaches in Pakistan (pp. 3-29).

Gronewold, N. (2010). What Caused the Massive Flooding in Pakistan? Retrieved from www.scientificamerican.com: https://www.scientificamerican.com/article/what-caused-the-massive-flooding-in-pakistan/

Iqbal, A. R. (2011). Flood Management in Pakistan – A Case Study of Flood 2010. ISSRA Papers, 55-66.

Jamshed, A. (2015). Assessing Vulnerability and Capacity of Flood Affected Communities in Punjab, Pakistan. Case Study: District Jhang and Muzaffargarh.

Memon, N. (2011). Root causes of floods. Retrieved from http://pnc.iucnp.org: http://pnc.iucnp.org/wp/?p=270

Memon, N. (2013). Malevolent Floods of Pakistan 2010-2012. Strengthening Participatory Organization.

NDMA. (2012). National Disaster Management Plan, Main Volume. Ministry of Climate Change. Retrieved 06 12, 2018

Ole Larsen, J. O. (2014). Developing a disaster risk insurance framework for vulnerable communities in pakistan: Pakistan disaster risk profile. United Nations University Institute for Environment and Human Security (UNU-EHS).

PDMA Punjab. (2011). Allotment Policy. Government of Punjab. Retrieved 05 20, 2018, from https://modelvillages.punjab.gov.pk/AllotmentPolicy

Qaddafi, S. M. (2018). Flood Mitigation Strategy, Plan and Measures for Pakistan. Retrieved from http://reporter.aaj.tv/u/qaddy/

Report, I. R. (2011). Flooded and forgotten, The ongoing crisis threatening lives and livelihoods in Pakistan.

SAARC-SAKDN. (2009). Pakistan Disaster Knowledge Network: Pakistan Hazard Profile. Retrieved from http://www.saarc-sadkn.org/countries/pakistan/hazard_profil

Sayeeda Amber Sayed, P. A. (2014). Flood disaster profile of Pakistan: A review. Science Journal of Public Health, 144-149.

Senate Secretariat. (2010). The Gazette of pakistan. Islamabad. Retrieved 04 21, 2018

Sohail, R. (2018, 05 14). Chair, Project Implementation Unit (PIU). (M. Salman, Interviewer)

UN-ESCAP. (2006). Enhancing regional cooperation in infrastructure development including that related to disaster management. New York. Retrieved April 18, 2018, from http://www.unescap.org/resources/enhancing-regional-cooperation-infrastructure-development-including-related-disaster

LANDSLIDE SUSCEPTIBILITY MAPPING USING XGBOOST MODEL IN CHITTAGONG DISTRICT, BANGLADESH

Torit Chakraborty[1], Md Didarul Islam[2] and Md Shaharier alam[3]

ABSTRACT

Landslide is one of the most destructive geological hazards in the hilly areas of Bangladesh due to heavy monsoon rainfall within short period. Chittagong District area was selected as study area which experiences several landslides each year causing casualties and economic loss. In this study, two machine learning models including XGBoost and support vector machine, are applied for landslide susceptibility mapping based on eight distinct causative factors in GIS platform. The landslide location data are randomly divided into two groups: 70% for training and 30% for validation. The accuracy of the aforementioned models are compared among themselves to find out the most accurate model for landslide susceptibility mapping. The validation result shows that XGBoost model gains highest 93.63% kappa score, 88.23% AUC score and 94.53% accuracy score whereas SVM gains 89.77% kappa score, 84.38% AUC score and 91.02% accuracy score. As XGBoost model has relatively higher accuracy, it is used to generate the final landslide susceptibility mapping of the study area where the result shows that 32.47% areas are highly susceptible, 19.75% are moderately susceptible and 47.75% areas are low susceptible. This study is expected to be helpful in developing effective risk prevention and mitigation strategies.

Keyword: Landslide susceptibility mapping, XGBoost, Support Vector Machine (SVM), GIS

Introduction

Landslides are among the natural disasters that are often experienced in Bangladesh specially in Chittagong district due to its geological, geographical structure and short period torrential rain which are always resulting this hazard sometimes in a very destructive way causing severe economic loss. For that reason, it's very necessary to analysis the landslide risky zone to take effective planning intervention to minimize the loss.All the recent study shows that due to heavy rainfall for a short period of time, Chittagong district has experienced landslides every year so that landslide susceptibility mapping is very important to identify the risky zone.

Landslide susceptibility mapping can be done using both qualitative and quantitative approach. But in recent decades the use of quantitative approach has become very popular due to new development of geospatial technology and geo-computing methods which provide better accurate results. In this research, two very popular machine learning model(XGBoost and SVM) has used to perform the landslide susceptibility mapping. Different researcher had used different model to produce landslide susceptibility map such as logistic regression, multi linear regression (ahmed,2015),in cox's bazar, Bangladesh, SVM (huang,2018) in china, artificial neural network, SVM(zhuo,2018) in china. But in this paper, another machine learning model is used named XGBoost to produce the landslide susceptibility mapping in comparison to the frequently used SVM model. XGboost had been used by researchers(Dong,2018),(Georganos,2018) for land use/land cover (LULC) image classification. But here this model is used to produce the landslide susceptibility map. For both model, 8 causative factors are chosen such as elevation, soil type, rainfall, NDVI (normalized difference vegetation index), distance from river, land cover, flow accumulation, slope to find spatial correlation with the landslide location to produce the susceptibility map and both model performance are evaluated by Accuracy score, Kappa score and AUC. The final output of landslide susceptibility map will show the susceptibility level in three categories like high, medium and low.

[1]*Graduted, Urban and Rural Planning Discipline, Khulna University, Khulna, Bangladesh, Email: toritchakraborty@gmail.com*
[2]*Graduted, Urban and Rural Planning Discipline, Khulna University, Khulna, Bangladesh, Email: didarul.kuu.14@gmail.com*
[3]*Graduted, Urban and Rural Planning Discipline, Khulna University, Khulna, Bangladesh, Email:sharier3@gmail.com*
Email of Corresponding Author – toritchakraborty@gmail.com

Study Area

Chittagong district is located in the south-eastern region of Bangladesh is selected as the study area which has the second largest and only port city inside it.The coordinate of the district is 22.3375°N 91.8389°E.The total area is 5282.92km^2 .As the Chittagong district has high elevation places with the most hilly areas, landslides occur mostly in this district. So that the study area is selected to identify the high, moderate and low risk zone.

Methodology

Data collection , preparation and Causative factors

In this research, eight causative factors were used for landslide susceptibility mapping. These factors were selected from the literature review and considering available data. All the factor data were collected from multiple sources and processed using GIS and RS techniques . Landset-8 Satellite image was used to prepare land use, NDVI, and distance from river map . SRTM DEM 30m data was used to prepare elevation ,slope, flow accumulation map. Soil type and rainfall data are collected from geological survey of Bangladesh and Bangladesh meteorological department. All the factor maps were prepared in GIS environment.
For training and validation of model, 60 landslide locations(Ahmed,2014),(Rahman,2016) were used, which randomly divided into two groups:70% for training and 30% for validation. Later, the training data sets were used to build a spatial relationship between the factors and landslide locations. Then the model used on validation datasets to justify models actual performance in real-world scenario.The factors maps are shown below (Figure-1).

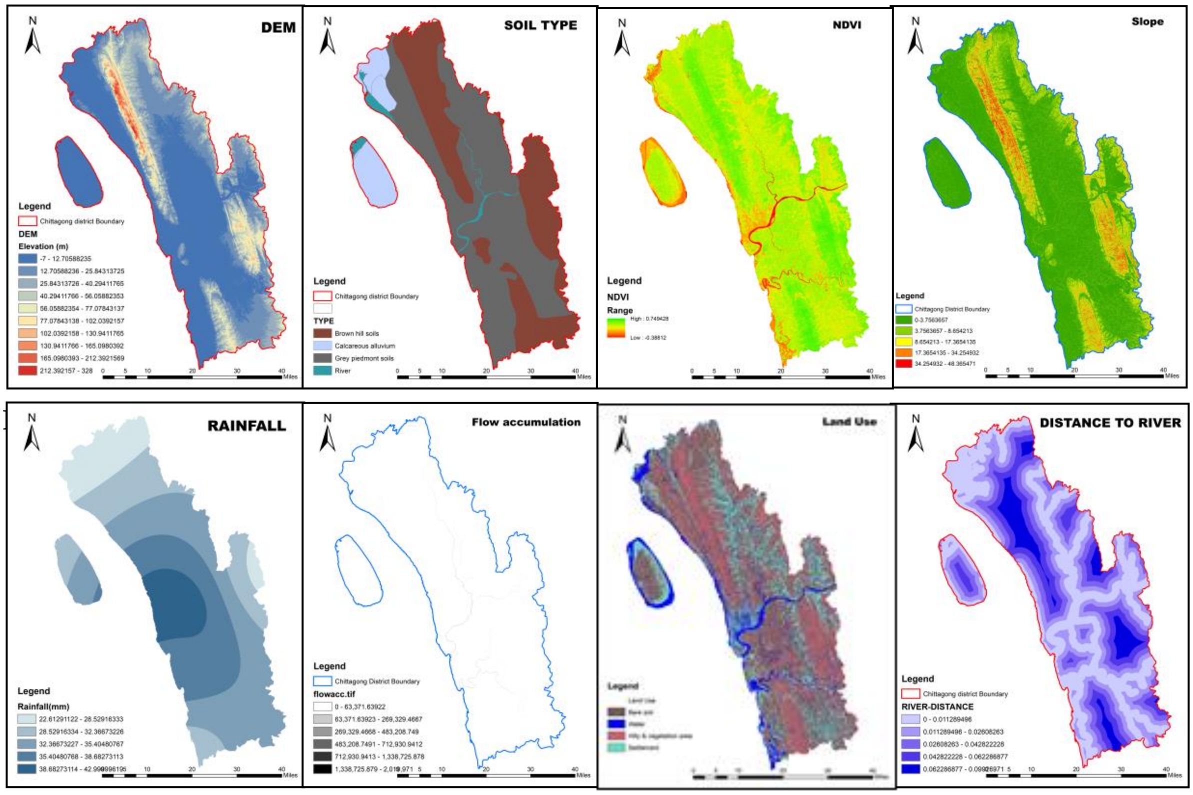


Figure 1. Causative factor maps for Landslide Susceptibility Map

The factors maps show the range and spatial variation of values for the study area. Elevation range is -7 to 328 m where highest elevation found in most of the place. Three types of soil found in the study area where Grey piedmont soil found most frequently then brown hill soil in the hill area but very little of calcareous alluvium soil. NDVI shows the vegetation index range from -0.38 to 0.74 where negative values indicate water and positive values indicate to different vegetation and built up area. The slope map shows the degree range from 0 to 48 degree where most of the place is below 4 degree but a significant hilly portion has high slope value more than 30 to 48. Flow accumulation map shows the value distribution of water based on surrounding elevation cells which is calculated in ESRI ArcGIS. Rainfall map shows the rainfall distribution of the study area based on the multiple rainfall station data where lowest rainfall rate is 2200 mm and highest 4200 mm. The heavy rainfall pattern found at most of the landslide location. The distance from river map is produced by calculating Euclidean distance of each cells from the river. The land use map shows the land-use distribution in major classes including built-up area, water body, hilly and green area.

Data Analysis

The whole process of data modelling using Xgboost and SVM are performed in the Anaconda platform of python programming language. All the causative factors map and background spatial statistics are made and calculated by ESRI ArcGIS 10.4. The Landsat image layer stacking, NDVI calculation, Land use image classification are done by the Erdas Imagine.
The process of producing landslide susceptibility mapping:

- At the very first stage all the causative factors data are converted to raster format mainly in .TIFF file in ArcGIS.
- After that, all the 60 landslide location data are applied on all the eight causative factor raster map to extract the feature attribute of the corresponding raster cells to prepare training data for the model.
- Then the raster maps are converted into .CSV file (Excel file) to analyze and model the data in Anaconda platform of python programming language.
- Then the training datasets are divided randomly into two groups:70% as training data and 30% as validation data using random split function.
- After training the datasets, both modelling algorithms are applied on validation datasets.
- The validation data are used to check the performance of both model by using Accuracy score, Kappa score and Area under curve score statistics.
- Finally, the model applied to whole dataset to classify the study area into three landslide susceptible categories: low susceptible, medium susceptible and high susceptible.

The work flow of the modeling process is shown in figure-2.

Figure 2. Working process flow of Landslide Susceptibility Mapping

Result and Discussion

Figure-3 shows the relative importance of each factors in constructing model. The graph shows soil type and rainfall is the most influential factors for landslide whereas flow accumulation is less influential. After the training, both models are evaluated by Accuracy score, Kappa score and Area Under Curve(AUC) to assess the performance. The performance of both models are given below:

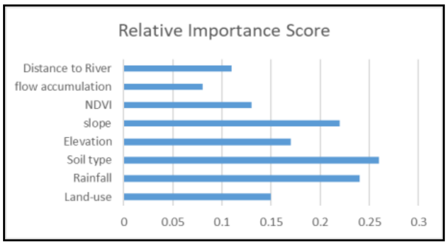


Figure 3: Relative Importance of Each Factors in Landslide Susceptible modeling

Table 1: Validation Performance of two model

Model	**Accuracy Score**	**Kappa**	**AUC**
XGBoost	94.53%	93.63%	88.23%
SVM	91.02%	89.77%	84.38%

According to the table-1, the XGBoost model performs better than SVM model in-terms of validation datasets. The XGBoost model gain 93.63 % kappa score and 94.53 % accuracy score respectively whereas

SVM model gain 89.77% kappa score and 91.02% accuracy score. In terms of AUC, XGBoost model also gain higher accuracy than SVM model. So, based on the performance, it can be concluded that the XGBoost model is more suitable than traditional SVM model for mapping landslide susceptibility. Finally, the XGBoost model was applied on the study area to map the landslide susceptible area (Figure-4). After area calculation of each category of landslide susceptibility, we found that 32.47% of the study area is highly susceptible, 19.75% area is moderately susceptible and 47.75% area is low susceptible.

Conclusion

As landslide is a regular phenomenon is the study area which cause casualties and damage of live and wealth, mapping landslide susceptible area can be an effective alternative measure to reduce causalities. But modeling the landslide susceptible area is a complex process which require well understanding of the study area and the factors responsible for landslide. Besides, selection of landslide modeling techniques also an important criterion for effectively mapping the most susceptible landslide area. One of the main objective of this study is to identify the most responsible factors for landslide and selection of suitable modeling techniques. Based on the above analysis, we found that the soil type and rainfall are the most influential factors for landslide. Besides, we also found that the recently developed machine learning algorithm XGBoost perform better than traditional SVM model for mapping the landslide susceptible area.

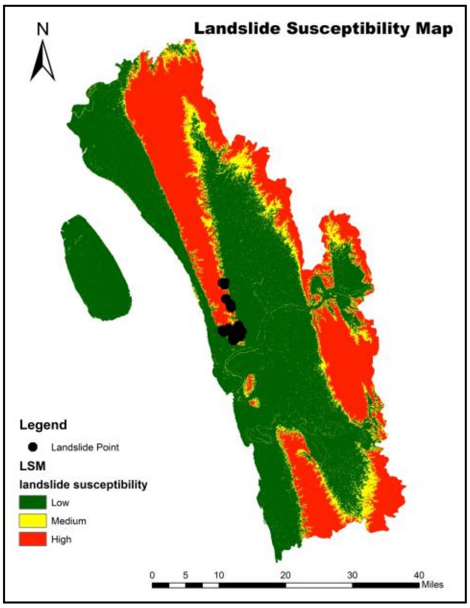


***Figure 4**. Landslide susceptible map using XGBoost model*

References

Ahmed, B. (2015). Landslide susceptibility modelling applying user-defined weighting and data-driven statistical techniques in Cox's Bazar Municipality, Bangladesh. *Natural Hazards*, *79*(3), 1707-1737. doi: 10.1007/s11069-015-1922-4

Dong, H., Xu, x., Wang, L., & Pu, F. (2018). Gaofen-3 PolSAR Image Classification via XGBoost and Polarimetric Spatial Information. Sensors, 18(2), 611. doi: 10.3390/s18020611

Georganos, S., Grippa, T., Vanhuysse, S., Lennert, M., Shimoni, M., & Wolff, E. (2018). Very High Resolution Object-Based Land Use–Land Cover Urban Classification Using Extreme Gradient Boosting. IEEE Geoscience And Remote Sensing Letters, 15(4), 607-611. doi: 10.1109/lgrs.2018.2803259

Huang, Y., & Zhao, L. (2018). Review on landslide susceptibility mapping using support vector machines. CATENA, 165, 520-529. doi: 10.1016/j.catena.2018.03.003

Rahman, M.S.; Ahmed, B.; Huq, F.F.; Rahman, S.; Al-Hussaini, T.M. (2016). Landslide Inventory in an Urban Setting in the Context of Chittagong Metropolitan Area, Bangladesh. Paper Id: 36 (pp. 170–178), 3rd International Conference on Advances in Civil Engineering 2016 (ICACE 2016), 21–23 December 2016, Chittagong University of Engineering and Technology (CUET), Chittagong, Bangladesh.

Zhou, C., Yin, K., Cao, Y., Ahmed, B., Li, Y., Catani, F., & Pourghasemi, H. (2018). Landslide susceptibility modeling applying machine learning methods: A case study from Longju in the Three Gorges Reservoir area, China. Computers & Geosciences, 112, 23-37. doi: 10.1016/j.cageo.2017.11.019

A STUDY OF THE RECENT LANDSLIDE IN RANGAMATI REGION: CAUSES, IMPACTS AND EXISTING SLOPE PROTECTION MEASURES

Alam T. A.[1], Barua G. [1],Mahsin M.[1], Abid Kamal[2], Mazumder M.H.[3] and Omi F.R.[3*]

ABSTRACT

Recent landslide in Rangamati has sparked discussions whether natural or anthropogenic causes or both were responsible for triggering devastating landslides in the hill tracts region of Bangladesh. The geological formation of hills in those areas, although not very young, is still in the process of degradation and reformation through weathering or other natural processes. Destabilization of hill slope may happen due to increased gravity load due to rainfall, other natural or anthropogenic actions on hill slope. In this backdrop, this paper aims at discussing observations of a survey done at selected locations of Rangamati where recent devastating landslides have caused immense loss of lives and properties. In this paper, Rangamati is chosen as the study area and information are obtained through a field visit survey on landslide affected areas. The study has found that the types of soil play a significant role while heavy rainfall, hill cutting, deforestation, unauthorized human settlements and faulty infrastructure construction act as a catalyst behind the landslide. This paper discusses some causes that induced the landslide in Rangamati region as well as to present an overview of the existing protection measures and the feasibility of these infrastructures to prevent landslide.

Keywords: Landslide, Damage, Cause, Protection measures

Introduction

Bangladesh is one of the most disaster prone countries in the world (Khan, 2008). Due to the deforestation and unplanned urbanization, manmade disaster has now become one of the burning questions. Landslide is occurring frequently in the hilly regions of the country (Alam et al, 2005) especially in Chattagram region, a south-eastern part of Bangladesh (Ahmed et al., 2014). Rapid urbanization and human development activities such as, building and road construction through deforestation and excavation of hill slopes have increased landslide in densely populated cities located in mountainous areas (Galli and Guzzeti, 2007; Schuster and Highland, 2007).On June 12, 2017 heavy monsoon rain triggered a series of landslides in Rangamati, Chattagram and Bandarban - three hilly districts of Bangladesh - and killed at least 152 people (The financial express,2017). The worst-hit district was Rangamati, where landslides buried hillside houses while people were asleep (BBC NEWS, 2017). At least 20 separate landslides hit the district (The financial express,2017) and up to 105 deaths were reported as of 15 June (The Daily Star, 2017); 5000 homes were damaged(The Weather Channel, 2017). Roads in Rangamati remained inaccessible till 15 June (BDnews24.com, 2017) and district's power grid was also faced severe damage. Many roads in the district were washed away, leaving craters up to 15 meters (50 feet) deep, or heaped with debris (The Daily Star, 2017).

Methodology

The primary information has been collected by conducting field survey in Rangamati. The road side interview has been made during the survey while the hotspots of the June landslide were identified by using GPS and ArcGIS was used for data analysis. The different types of data have been used in this study such as rainfall data, land use patterns, Digital Elevation Model (DEM 30m) and soil data. Rainfall data has been collected from Bangladesh Metrological Department (BMD) and NOAA 3 hourly real time data. Thematic Map (TM-4) has been collected from earth explorer while the soil data has been collected from Soil Resource Development Institute (SRDI). The different types of soil map are shown in this study such as soil permeability, texture and soil nutrients etc. The DEM 30 m data was collected from Global Visualization Viewer (GloVis) and the DEM is used to derive the slope angle and the elevation of the area. The DEM is also used for hydrological analysis. To detect the vegetation level of this area land use pattern was used and the Normalized Difference Vegetation Index (NDVI) is used to detect the vegetation level. ArcGIS-10.2 software is used to analyze the reason of landslide of Rangamati.

[1] *MSc. Student, Dept. of Disaster & Environmental Engineering, CUET, Chittagong-4349, Bangladesh*
[2] *Research Assistant, Asian Development Bank, Bangladesh*
[3] *Assistant Professor,Dept. of Disaster & Environmental Engineering, CUET, Chittagong-4349, Bangladesh*
** Email of Corresponding Author: farahomi@gmail.com*

Result

Infrastructural developments on relatively unstable hills in risky areas were identified which was undesirable at least concerning development of national road networks or important government establishments (Fig.1 and Fig.2). By using GPS the locations of the landslide affected areas were spotted in Fig 3.Based on the information obtained from the landslide affected areas, this study identified this cause-effect relationship for each of the following clauses:

Unplanned and Non-engineering construction: The green hills of Rangamati have been clawed all over and the trees, that grip the soil together, cleared to make pieces of flat land for building houses. The unplanned and non-engineering construction is another cause of landslide of Rangamati.

Figure 1. Unplanned Hill top Construction

Figure 2. Important Govt. Building at risk

Hill cutting: Most of the landslide occurred in Chittagong region due to indiscriminate hill cutting. About 36% respondents reported that the major cause of landslide occurred due to hill cutting.

Land use cover: Deforested areas of hills are easily exposed and top soils are eroded by surface run-off or by wind erosion. Forest covered areas are less vulnerable to landslide than deforested area and debris stored areas are more in deforested area than a forest covered area. Vegetation protect earth surface from exposure and roots of a tree stabilize the strength of soil compaction acting as cementing material and reducing soil erosion.

Normalized difference vegetation index map: The Normalized Difference Vegetation Index (NDVI) is a standardized index that allows generating an image displaying greenness (relative biomass). The NDVI equation is as follows (ArcGIS® 10 Help 2012): NDVI = (IR − R / IR +R) where IR=pixel values from the infrared band (band 4) and R=pixel values from the red band (band 3). This index output varies between −1.0 and 1.0, mostly representing greenness, where any negative values are mainly generated from clouds, water, and snow, and values near zero are mainly generated from rock and bare soil. Very low values of NDVI (0.1 and below) correspond to barren areas of rock or sand. Moderate values (0.2 to 0.3) represent shrub and grassland, while high values (0.6 to 0.8) indicate temperate and tropical rainforests (Ahmed et al. 2013). In this research, the Landsat 4–5 TM images from the same season (dry and summer) were acquired from the official website of the USGS. Finally, the NDVI map of Rangamati was prepared by analyzing band 3 and band 4. The two different maps (Fig. 4 and Fig. 5) show vegetation cover of Rangamati hill track. In 1978, green vegetation was 65000 ha but in 2017, the number of pixel has been decreased and which is about 62123ha. The NDVI analysis shows the land cover of hilly area of Rangamati has been transformed from vegetation to other uses which are other reasons for landslide in Rangamati.

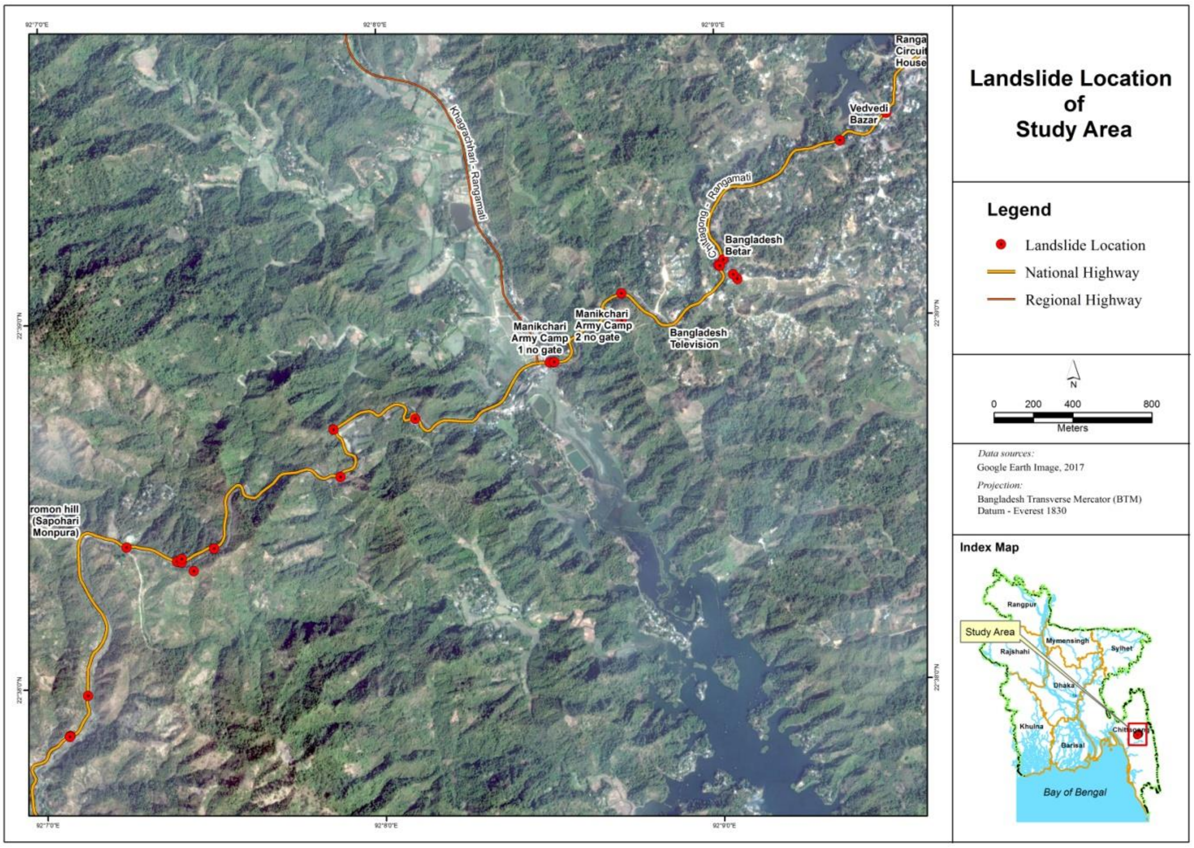


Figure 3. Landslide Location of study area which occurred in June 2017

Soil texture: The soils of the city are sandy which makes them easily saturated during heavy rainfall and susceptible to massive soil erosion through formation of unstable and steep hill slopes (Khan, 2008). The usual type of soil at the hill slope is silty clay. At most areas, the soil consists of different layers of sand and clay/shale. Shear strength of silty clay type soil is much lower than regular sand or clay soils. Again, excessive rainfall had saturated the soil resulting in increase of soil mass. The bedding of the soil formation is almost horizontal. Alternate layer of sand and very thin film of cementing clay/shale layer, Rainwater seeps through the layers and creep effect reduces the bond between the sand and clay/shale layers. The soil texture map of Rangamati is shown in fig 6.

Soil permeability: Soils of open hill surface absorb rain water quickly that dissolve soil nutrient losing its compaction and adding heavy weight to the basement of the hill. Slope instability influenced by decreased base area, and loose muddy soil because of rainwater absorption cannot hold the extra weight added by rain water, resulting downward soil movement or landslide. The soil permeability of this area is high shown in Fig 7.

Rainfall Analysis: A study by Yalcin (2007) concluded that an intense rainfall of 70mm per hour or greater will create landslide favorable condition. From June 12 to 14, 2017 heaviest rainfall accumulation estimates (purple) by IMERG were located over southeastern Bangladesh. IMERG estimates indicated that landslide inducing rainfall totals there were greater than 510 mm (20 inches). The consecutive rainfall in more than 7 days influenced the soil liquefaction. In 6 to 15 June 2017, the study area got the high intensity rainfall (Fig. 8). Due to 5 days consecutive rainfall the water table of this area was filled and soil become loosely.

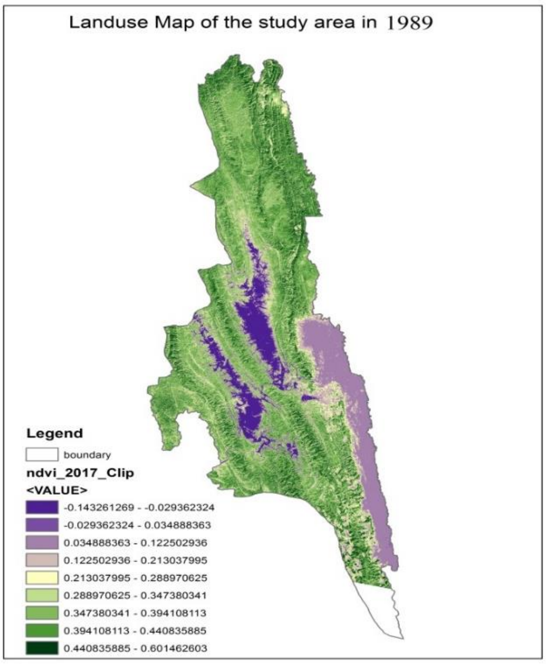


Figure 4. Vegetation Index map in 1989

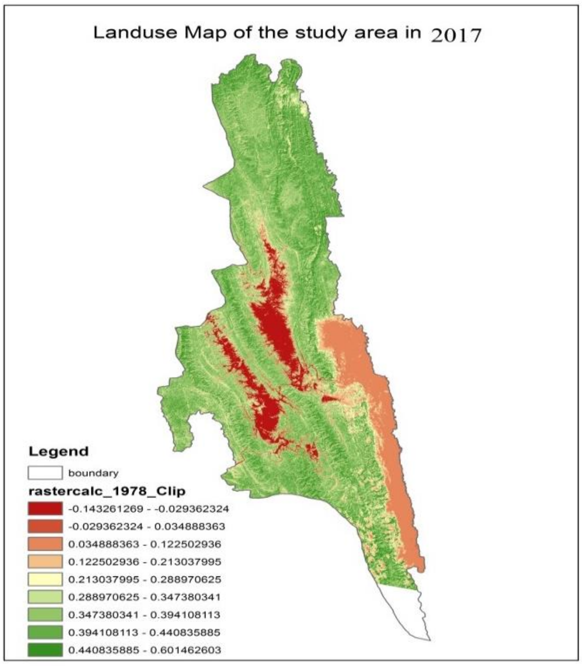


Figure 5. Vegetation Index map in 2017

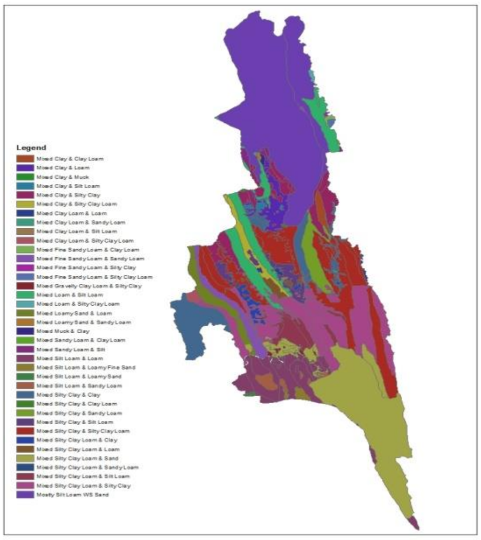


Figure 6. Soil texture map

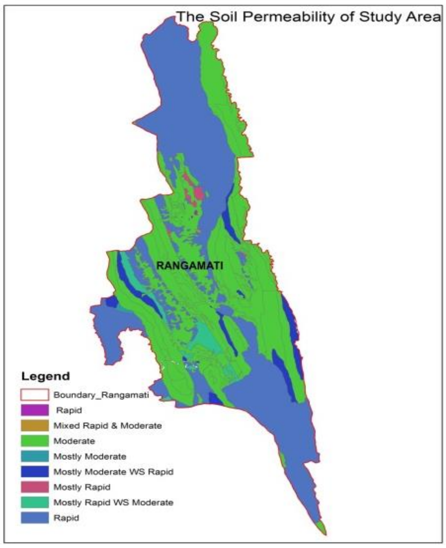


Figure 7. Soil permeability map

Existing protection measures: After landslide in Rangamati some protective constructions has also been made by local government with the help of local people. Retaining wells have been built with local materials such as

wood and bamboo which help to retain from further slides along the unstable slopes. In Rangamati, important structures including government offices such as Regional Passport office on the apex of the hill have exposed in jeopardy. Those unstable slopes have been protected using Sandbags and wood scrap filled sacks tied with rope. Some interesting features have also been noticed like diverting the direct precipitation in road rather in soil by using tin roof structures at the hill top in an inclined manner (Fig. 9).

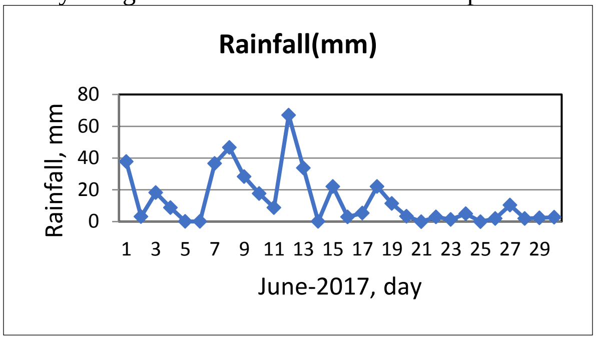


Figure 8. Rainfall data of Rangamati (June, 2017)

Fig. 9: Typical protection measures on slopes

Conclusion

Landslide vulnerability is an important issue for people living in the hilly areas of Rangamati. The major impacts of landslide on the local communities were destruction of settlement, economic loss, loss of lives and environmental problems. Without proper survey and engineering concept, these temporary protection measures were taken without proper survey or engineering design which might not provide protection against moderate thrust of landslide. This paper shortlisted the present scenario regarding the changes in Rangamati after frequent landslides in recent years. For further investigation, detailed soil stability check can help to identify identifying locations vulnerable to landslides which will contribute to landslide forecasting relative to rainfall intensity.

Acknowledgments

At first, the authors express the heartiest thanks and gratefulness to “Almighty Allah” for His divine blessings. The authors would like to acknowledge their profound indebtedness to the Disaster & Environmental Engineering Department, Chittagong University of Engineering & Technology

References

Khan, I.S. 2008.Hill cutting in Chittagong City Corporation area: its causes and the consequences. PhD Dissertation. Khulna University, Bangladesh

Alam, E. M., Chowdhury, M.A.T., and Akbar, M.T. 2005. Aspects of social environmental problems resulting from hill cutting in the city of Chittagong, Bangladesh: local people’s perspectives. Pakistan Journal of Social Sciences. Vol. 3 (8), pp. 1048-1052

Ahmed, B.; Rahman, M. S.; Rahman, S.; Huq, F. F. and Ara, S. 2014. Landslide Inventory Report of Chittagong Metropolitan Area, Bangladesh. BUETJapan Institute of Disaster Prevention and Urban Safety (BUET-JIDPUS). Dhaka-1000, Bangladesh. 125p

Galli, M. and Guzzetti, F. 2007. Landslide vulnerability criteria: A case study from Umbria, central Italy. Environmental management, 40: 649-664

The Financial Express. 14 June 2017. Bangladesh landslide toll reaches 152. (Bangladesh). Dhaka.

"Bangladesh: Rain triggers landslides and leaves 107 dead". BBC News. 13 June 2017

Associated Press. 14 June 2017. Death Toll Raises to 140 in Wake of Massive Bangladesh Landslides

Bdnews24.com. 15 June 2017. Three more bodies found in Rangamati after landslides. Rangamati. Retrieved 15 June 2017

The Daily Star (Bangladesh). 15 June 2017, Rangamati in food, power, fuel crisis. Dhaka

Khan, Y.A.; Chang C. 2008. Landslide hazard mapping of Chittagong City Area, Bangladesh. Jour. Engg. Geo. Volume XXXV, Nos. 1-4

Yalcin, A., 2007.The Effects of Clay on Landslides: A Case Study. Applied Clay Science, 38, 1-2, 77-85

LANDSLIDES: AN INVENTORY ANALYSIS OF CHATTOGRAM CITY

Md. Mehedi Hasan Khan[1], and Showmitra Kumar Sarkar[2]

ABSTRACT

Landslides, the most occurring geological hazards causing injuries, losses of life and economy, damages to properties as well as infrastructures and affect a number of resources. Every year during monsoon, landslides damage a number of structures with numerous loss of life in Chattogram City of Bangladesh. The objective of the study was to prepare a landslide inventory of Chattogram City. 38 previous landslides location and their characteristics were collected through field survey and other required data (Precipitation and other spatial data of chottrogram) were collected by literature review and satellite image interpretation. For inventory analysis, spatial distribution of five casual factors of landslide (i.e. Landcover, Precipitation, DEM, Soil types, and NDVI) was analyzed through R, ArcGIS and ERDAS imagine. Landsat 7 ETM+ images were used for DEM, Landcover and NDVI analysis. Results indicate that most of the landslide occurs at 20-40-meter elevation on silty sand and in vegetation cover. The findings of the study would help the development authorities in decision making process to managing and monitoring landslide risk in Chattogram City.

Keywords: Landslide, Inventory Analysis, GIS, DEM, NDVI

Introduction

Chittagong Metropolitan Area (CMA) is a highly urbanized area with 10% of hilly land which was developed in tertiary age and that makes the city more vulnerable to landslide hazard (Ahmed, Rahman, Rahman, Huq, & Ara, 2014). Since 1997, nearly 235 peoples who lived in various informal settlements within the Chittagong City Corporation (CCC) area and adjacent urban centers were death caused by landslides (Technical Report, 2008). In June 11, 2007, a landslide hazard occurs in city corporation area which results more than 128 people deaths and 150 people injures (SDMC, 2007). Again, in 21 July, 2017 six people were killed by landslide in Sitakunda (The independent, 2017). Though in recent year, devastating landslides hit Chattogram repeatedly but there is no proper plan (i.e. risk reduction plan, development plan or action plan) to minimize the landslide event or minimize the losses due to landslide hazard. The aim of this paper is to prepare a landslide inventory that a can help the decision makers to prepare proper development plans.

Methodology

Base on the previous landslide rate, five wards of CCC (Sulakbahar (W-8), Pahartali (W-13), North Pahartali (W-9), Lalkhan Bazar (W-14), Bagmoniram (W-15)) was selected for the study purpose. To prepare the landslide inventory map extensive field survey was carried out within the study area from 26 March 2018 to 30 March 2018. 38 previous landslides were identified and analyzed (Figure 1). An android software (GPS logger) was used to identify the landslides location. For each landslide location, various information such as width and length, vegetation types etc. were collected. Digital Elevation Model (DEM) was extracted from ASTER data through ArcGIS. For preparation of precipitation map and rainfall pattern analysis past 50 years (1963-2013) was collected from Bangladesh Metrological Department. Precipitation map was prepared byusing kriging interpolation method through ArcGIS 10.4. (Figure 1(d)). And for rainfall pattern analysis 6 precipitation indices are calculated from through Rclimdex. The landcover map of study area was prepared form Landsat 7 ETM+ imagery, 2017 by using maximum likelihood supervised classification technique through ERDAS imagine 14. After the classification, kappa coefficient was calculated by usingEq. 1 to check the accuracy of classified image. According to Landis, if the kappa coefficient is greater than .6 than it agrees. Which means that the classified image can be used for further research purpose (Landis & Koch, 1977).

$$Kappa\ Coefficient(k) = \frac{Observed\ accuracy - Change\ agreement}{1 - Change\ Agreement} \quad 1$$

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad 2$$

Four NDVI at 5-year interval (2002, 2007, 2012, and 2017) was calculated by using Eq. 2 in GIS environment to understand the degrading rate of forest cover. And soil data at 5m depth data was collected from Chittagong City Corporation as shape file format.

---

[1]*Student, Masters in GIS for Environment and Development, Jahangirnagar University, Savar, Dhaka.*
[2]*Lecturer, Department of Urban and Regional Planning, Khulna University of Engineering and Technology, 9203, Khulna*

Inventory Analysis

Land cover

The landcover of study area is classified as i) Buildup area ii) Vegetation iii) Bare soil and iv) Waterbody from landsat 7 ETM+ imaginary. It is found that 47% of study area is covered by buildup area where only 3% of total area is covered by waterbody (Figure 1(a)). The kappa coefficient of classified image is found .73 which is acceptable for further analysis. By spatial joining of landcover map with previous landslide location, it is found that most of the landslide occurs in the vegetation cover (21, 55.26%). Table 1(c) shows that the percentage of pervious landslide event on different landcovers types.

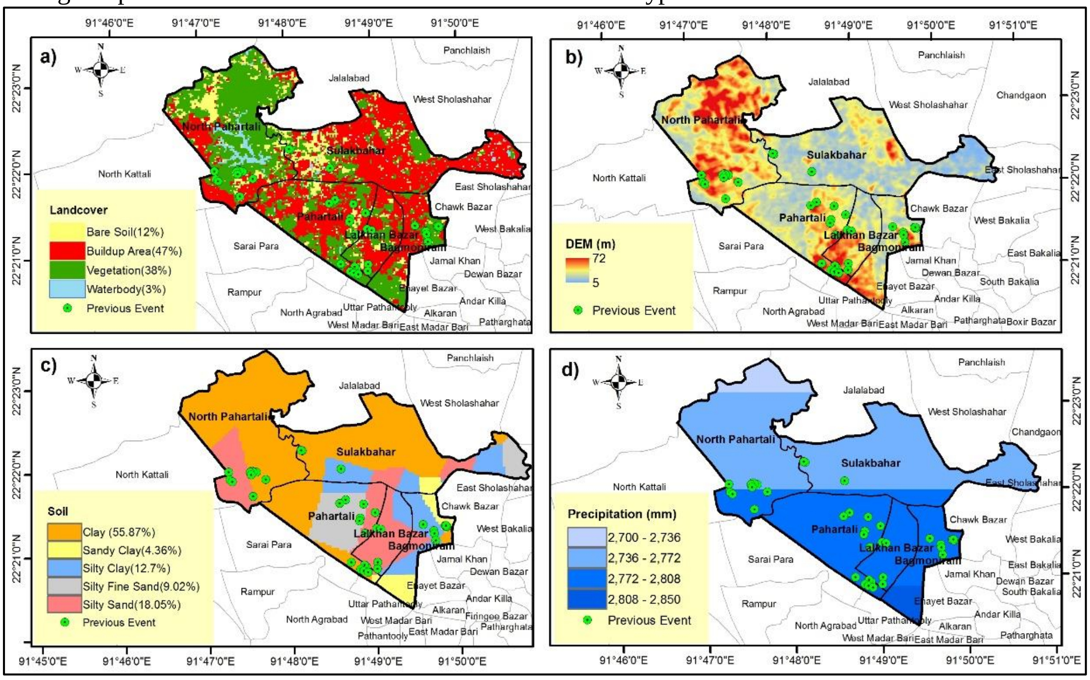


Figure 1. a) Landcover Map; b) DEM; c) Soil Map; d) Precipitation Map

Precipitation

The precipitation map of Bangladesh is prepared by using the collected daily precipitation data (1963–2013) for all 35 rainfall stations of Bangladesh. The range of annual average rainfall of Bangladesh is found 1129.21 to 4196.34 mm, and the range of annual average rainfall of study area is found 2700 to 2850 mm. By spatial joining with previous landslides, it is found that, 74% landslide occurs in 2723 to 2808 mm range. The output of rainfall pattern analysis shows that the average precipitation rate of Chattogram is increasing with 5.287% estimated slope. But maximum number of consecutive days with daily precipitation ≥1mm is decreasing with a decreasing slope rate of .053. On the other hand, Maximum number of consecutive days with daily precipitation <1mm is increasing with an increasing slope rate of 0.657. These increasing average precipitation rate and Consecutive dry days and decreasing consecutive wet days indicate that the precipitation frequency is decreasing day to day but precipitation intensity is increasing. As a result, the rate of number of days having ≥10mm, ≥20mm and ≥25mm rainfall is found with an increasing slope rate of .079, .071 and .053 respectively. So, form the indices result it can conclude that the intensity of rainfall is increasing continuously which may results in landslide as the high rate of precipitation make the soil more vulnerable as it decreases the soil strength.

NDVI

Four NDVI of study area is calculated at 5-year interval (2002, 2007, 2012 and 2017) through ERDAS IMAGINE 14 (Figure 3). After the classification of NDVI value into 3 category (i) Buildup area and water body ii) Low dense forest cover iii) High dense forest cover, it is found that buildup area has an increasing trend where high and low dense forest area has a decreasing trend (Figure 2). In 2002, buildup area was only 2.1%.Which increase to 31.4% after 15 years in 2017. On the other hand, high dense forest cover had a decreasing rate before 2012. In 2002, high dense forest cover was 33.4% of total area and in 2012 it decreases to 26.3%.But in 2017 it increases to 28.2% (Figure 2). However, in between 2012 and 2017, low dense forest cover decreases at highest rate (25%) among last 15 year. These findings indicate that the forest cover is continuously covering by buildup area.

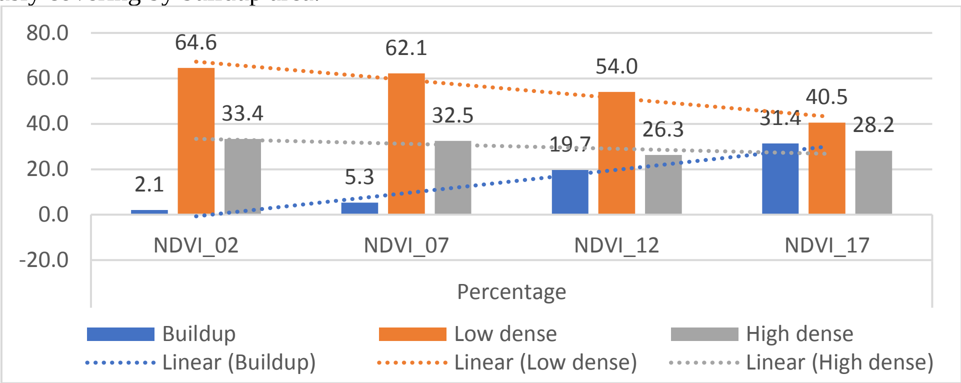


Figure 2.Percentage of various types of land at 5-year interval (2002-2017)

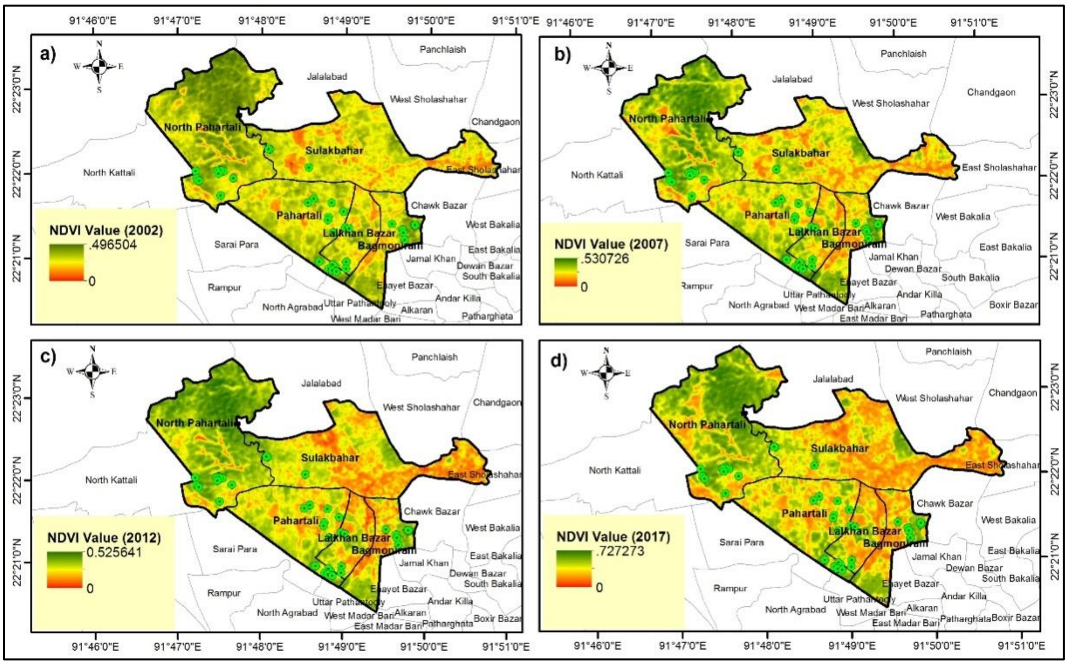


Figure 3. a) NDVI 2002; b) NDVI 2007; c) NDVI 2012; d) NDVI 2017

Digital Elevation Model (DEM)

Digital Elevation Model (DEM) is extracted from Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) data and analyzed by ArcGIS 10.4. The range of elevation of study area is found 5 m to 72m (Figure 1(b)). It is also found that North Pahartali have relatively higher elevation than others. Around 60% area of North Pahartali is covered by hills and around 26% previous landslide occurs in this ward. On the other hand, Sulakbahar have relatively low elevation. Only 7% area of this ward is covered by hills and only 9% of previous landslide occurs in here. Moreover, range between 21m and 50m is found more vulnerable to landslide hazard. Around 76% previous landslide occurs in this range of elevation.

Table 5. Inventory information of previous landslides

a. DEM (m)	%	b. Precipitation(mm)	%	c. Land Cover	%
10-20 m	7.89	2700-2736	0.00	Buildup Area	28.95
21- 30 m	28.95	2723-2808	73.68	Vegetation	55.26
31-40 m	18.42	2736-2772	23.68	Bare Soil	15.79
41-50 m	28.95	2809-2850	2.63	Water Body	0.00
Grand Total	**100.00**	**Grand Total**	**100**	**Grand Total**	**100**

d. Soil Types	**%**	**e. NDVI Value**	**%**	
Clay	28.95	0-.14	7.89	
Sandy Clay	10.53	.15-.39	36.84	
Silty Clay	13.16	.4-1	55.26	
Silty Fine Sand	34.21	–	–	
Silty Sand	13.16	–	–	
Grand Total	**100**	**Grand Total**	**100**	

Soil Types

According to CCC, the whole study area contains 6 types of soil (Figure 1(c)). After the spatial joining between previous landslide location and soil types it is found that most of the landslide occurs in silty sand soil. Though this type of soil contains only 18% of total area but around 34% landslide occurs in this area. Moreover 29% landslide occurs in clayey silt where there is no previous landslide occurs in clay soil. Which indicates that silty sand is more vulnerable to landslide hazard than others. Table 1(d) shows the percentage of previous landslide event in different type of soils.

Conclusion

Population of Chottragram city is increasing continuously and to meet the demand of increasing population, the CCC and Chittagong Development Authority (CDA) are now going to prepare their physical and infrastructure development plan. The result of the paper concludes by explaining the existing scenario and inventory information of previous landslides. The development the authority can take the study as their baseline to make a proper development plan to reduce the risk of social, economic and environment loss due to landslides. Though the development authority will have an idea on factors affects the landslides by this paper but there have some limitations. Firstly, only five factors of landslide are considered here but there are many other factors which can affects the landslide. Moreover, landslide mechanism is too much complex and factors affect the landslides can varies place to place. Further research needs to incorporate the limitations to make the result more accurate.

References

Ahmed, B., Rahman, M. S., Rahman, S., Huq, F. F., & Ara, S. (2014). *Landslide Inventory Report of Chittagong Metropolitan Area, Bangladesh.* Dhaka, Bangladesh : International Centre for Integrated Mountain Development (ICIMOD).

Landis, J., & Koch, G. (1977). The Measurement of Observer Agreement for Categorical Data. *Biometrics* , *33* (1), 159-174.

SDMC. (2007). *South Asia Disaster Report.* New Delhi, India: SAARC Disaster Managment Centre.

Technical Report. (2008). *Identification of landslide causes and recommendation for risk reduction.* Chittagong, Bangladesh.: Chittagong Divisional Office.

The independent. (2017, July 22). *Chittagong landslide*. Retrieved from The independent: http://www.theindependentbd.com/arcprint/details/105293/2017-07-22

ADDRESSING SEISMIC HAZARDS VULNERABILITY IN BANGLADESH BY RVS: A CASE STUDY OF BOGURA MUNICIPALITY

Mehnaz Sharmin[1] and S. M. Nawshad Hossain[2]

ABSTRACT

An earthquake occurs unevenly on the globe in a twinkling of eye. Tectonic framework of Bangladesh shows that it is a seismic active country. Recently many tumors have shacked the county frightened its people. This study focuses on local physical vulnerable factors such as vulnerable buildings. Bogura municipality has been selected as study area. Analysis has been done according to Rapid visual screening method to find the vulnerability of specific buildings so that further initiatives could be taken to reduce the negative impact of earthquake hazard of this area. Most of the buildings have poundings effect, heavy overhangs, parapets and irregularities and lack of setback rules. Nowadays many new constructions have been started using modern technologies but most of them are not following Buildings Codes. Many governments, non-government and international organizations are helping Bangladesh to mitigate disasters and hazards. But people need to be more aware of the risk factors. Local level participation and training are highly recommended. Besides, some structural and non-structural measures have been also recommended in this study.

Introduction

The study focused on analyzing the factors that contribute to make the area vulnerable and evaluate the probable impact of the seismic hazard. Seismic hazards are sources of potential harm or damage during earthquakes. These can be natural phenomena such as landslides or tsunamis, or they can be an element of built environment such as vulnerable building, brittle piping or loose equipment which can become hazards when exposed to earthquake shaking. This study tries to address the reason for a seismic vulnerability in terms of physical and geological aspects of the area and find out the damage factors. It will also make the discussion about the impacts of seismic hazards on the particular area.

Objective and Methodology

The aim of the study is accomplished by fulfilling some research objectives. The objectives of this research are to identify the vulnerable factors associated with seismic hazards in the study area; to assess the vulnerability of the study area based on selected factors, and to provide some recommendations to reduce the probable impacts of seismic hazards in the study area.

Rapid Visual Screening procedure by FEMA 154 has been used to identify, inventory and rank potentially seismically hazardous buildings. The RVS procedure uses a methodology based on a sidewalk survey of buildings. A data collection form is used to record the potential data. Total 105 buildings have surveyed for the study by purposive sampling method. Sample size has been selected as 25% of 420 buildings (approximately) of the study area. A checklist has been made based on the FEMA-154 data collection form for moderate earthquake zone. Data collection is carried out from both primary and secondary sources for the study. Two types of the survey have been conducted for the study. These are- Physical observation survey and key informant survey.

Conceptual Issues

Earthquake Zones of Bangladesh

A seismic zoning map of Bangladesh has been proposed in 1979 by Geological Survey of Bangladesh (GSB) dividing the country into three seismic zones which were accompanied by an outline of a code for earthquake resistant design. Later, a new updated seismic zoning map and detailed seismic design provisions have been

[1] Graduate Student, Department of Urban and Regional Planning, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh.
[2] Assistant Professor, Department of Urban and Regional Planning, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh.
E-mail of Corresponding Author- mehnaz.titly@gmail.com

incorporated in Bangladesh National Building Code (BNBC 1993). In the generalized tectonic map of Bangladesh by BNBC (1993), Bogura is located in the medium risk zone.

Description of the Study Area

Bogura is one of the populated small industrial cities in Bangladesh. Now a day rapid urbanization has occurred in the city. Unplanned urbanization may trigger the hazards. Bogura is situated in Moderate earthquake zones (BNBC, 1993). There is a fault named "Bogura Fault" which is one of the structural elements which have been activated at different times and is located in the Western Foreland Shelf. A major earthquake can devastate any populated area like Bogura. A city already threatened by floods and shifting river channels can face devastating natural calamities if hit by a big earthquake. The whole municipality is very large to cover for the research in a very short time. That is why only selected part of ward 05 has been chosen for the study. It covers Borogola with two other area named Badurtola and Namajgor in ward no 5 of Bogura municipality. The study area is located in the heart of the municipality with various economic activities.

Vulnerability Analysis of the Study Area

Rapid visual screening method has been chosen for assessing seismic vulnerability assessment as mention earlier. There are three types of form in FEMA 154. The form for moderate seismicity region has been used to carry out the research work. Basic Structural Hazard Scores based on Lateral Force Resisting System for various building types are provided on the form, and the screener circles the appropriate one. Building types have been incorporated through literature review.

The screener modifies the Basic Structural Hazard Score by identifying and circling Score Modifiers related to observed performance attributes, by adding (or subtracting) them a final Structural Score, 'S' is obtained. Basic score for different building types, plan and vertical irregularities and soil types has given in the data form. In the basic seismic zoning map of Bangladesh Bogura has been shown under Zone II with a basic seismic coefficient of 0.15 (BNBC, 2006). For this reason, the cut-off score has been selected as 1.5 for this study. Final Level 1 score has been determined by the following equation.

Equation

$$S_{L1} \geq S_{MIN} \quad (1)$$

Where S_{L1} is the Final Level 1 Score and S_{MIN} is Minimum Score.

Table 1. Basic Scores of RVS

BASIC SCORE, MODIFIERS, AND FINAL LEVEL 1 SCORE, S_{L1}

FEMA BUILDING TYPE / Do Not Know	W1	W1A	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM	MH
Basic Score	**5.1**	**4.5**	**3.8**	**2.7**	**2.6**	**3.5**	**2.5**	**2.7**	**2.1**	**2.5**	**2.0**	**2.1**	**1.9**	**2.1**	**2.1**	**1.7**	**2.9**
Severe Vertical Irregularity, V_{L1}	-1.4	-1.4	-1.4	-1.2	-1.2	-1.4	-1.1	-1.2	-1.1	-1.2	-1.0	-1.1	-1.0	-1.1	-1.1	-1.0	NA
Moderate Vertical Irregularity, V_{L1}	-0.9	-0.9	-0.9	-0.8	-0.7	-0.9	-0.7	-0.7	-0.7	-0.7	-0.6	-0.7	-0.6	-0.7	-0.7	-0.6	NA
Plan Irregularity, P_{L1}	-1.4	-1.3	-1.2	-1.0	-0.9	-1.2	-0.9	-0.9	-0.8	-1.0	-0.8	-0.9	-0.8	-0.8	-0.8	-0.7	NA
Pre-Code	-0.3	-0.5	-0.6	-0.3	-0.2	-0.2	-0.3	-0.3	-0.3	-0.4	-0.3	-0.2	-0.2	-0.2	-0.2	-0.1	-0.5
Post-Benchmark	1.4	2.0	2.5	1.5	1.5	0.8	2.1	NA	2.0	2.3	NA	2.1	2.5	2.3	2.3	NA	1.2
Soil Type A or B	0.7	1.2	1.8	1.1	1.4	0.6	1.5	1.6	1.1	1.5	1.3	1.6	1.3	1.4	1.4	1.3	1.6
Soil Type E (1-3 stories)	-1.2	-1.3	-1.4	-0.9	-0.9	-1.0	-0.9	-0.9	-0.7	-1.0	-0.7	-0.8	-0.7	-0.8	-0.8	-0.6	-0.9
Soil Type E (> 3 stories)	-1.8	-1.6	-1.3	-0.9	-0.9	NA	-0.9	-1.0	-0.8	-1.0	-0.8	NA	-0.7	-0.7	-0.8	-0.6	NA
Minimum Score, S_{MIN}	*1.6*	*1.2*	*0.9*	*0.6*	*0.6*	*0.8*	*0.6*	*0.6*	*0.3*	*0.3*	*0.3*	*0.3*	*0.2*	*0.3*	*0.3*	*0.2*	*1.5*

Source: FEMA-154 Data Form.

Basic score for C3, RM1, RM2 and URM building types are respectively 2.0, 2.1, 2.1 and 1.7. Basic score for vertical and plan irregularities also given here. For this study pre-code and post- Benchmark has been inapplicable. The soil type of the study area come under "soil type D" which is for dense soil is also remained constant. For representing the severity of the vulnerability, the result has been segmented in three parts. The minimum score should be counted for the calculation, where the final score is less than minimum score (Appendix).

Table 2. Final scores of RVS

Range	S<0.5	0.5<S<1	1.1<S<1.5
No. of Buildings	67	26	12

Source: Field Survey, 2018

Interpretation of Result

A high score means good seismic performance and a low score means potentially hazardous buildings. Score less than cut-off means detail evaluation recommended. As seen in the result, no score has been touched cut-off score according to FEMA method and all of them require further detailed analysis for vulnerability to determine the level of actual risk. A final map has been prepared based on the final result representing the severity of vulnerability using sketch up and GIS. This map will help to identify potentially hazardous buildings.

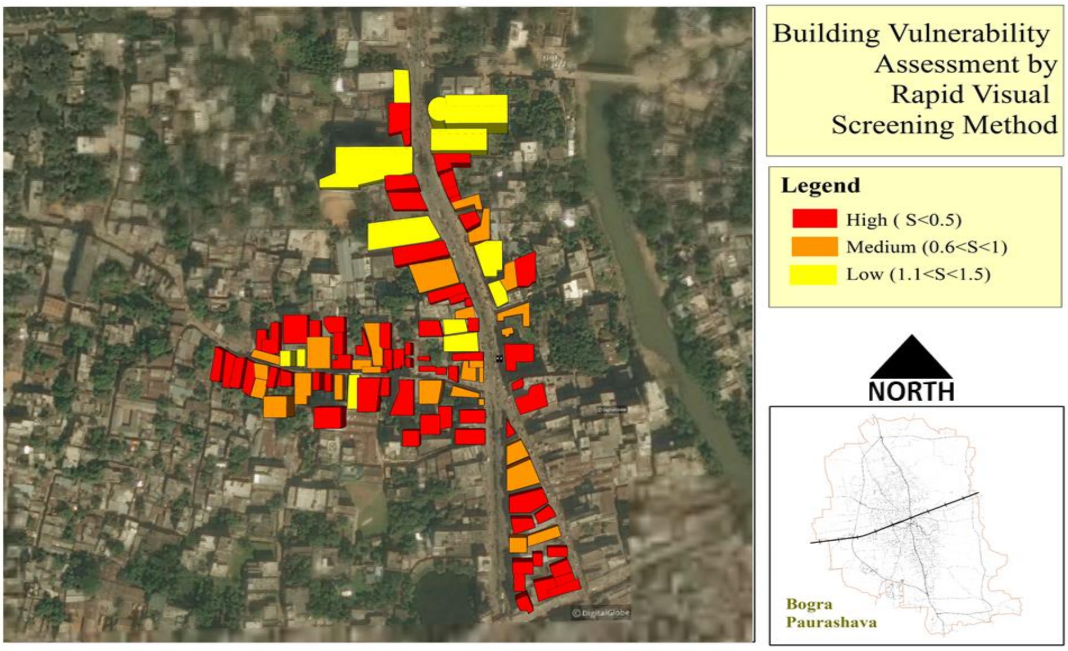


Figure 1. Vulnerability Assessment by RVS Method of Study Area

Recommendations

Some structural and non-structural measures have been suggested for both short term and long term. It includes structural measures such as widening road, Introducing new road network, applying building code and review, free from informal settlement around the roads, stitching and grouting, involvement of trained laborers in construction, ensuring segregated use of building, repair and reform of Old vulnerable buildings, Installation of vertical columns, Using rapid visual screening (enormous level) etc. The non-structural measures include obstruction free road network around possible evacuation centers and open spaces, proper education about action during and after an earthquake, raising awareness among local people by training program on earthquake hazard safety in the study area and ensuring participation of at least one member from each household, focusing regular community group discussion and meeting on earthquake hazard awareness at school, social clubs and Municipality office with the local people, introducing ward wise and community Disaster Management Committee, introducing local evacuation plan and spread it to the community etc.

Conclusions

Assessing the vulnerability of the built environment to hazards is extremely important in assessing the potential consequences of an event and for mainstreaming disaster risk reduction into the local development planning process (UNISDR, 2013). On average, a magnitude 8 quake strikes somewhere every year and some 10,000 people die in earthquakes annually (National Geographic News, 2018). This primary hazard often produces secondary hazards such as ruptured utility lines, hazardous spills, and fires. Buildings can crumble or collapse, trapping people inside and burying streets in the rubble.

In this research vulnerability assessment of buildings has been carried out in a small area of Bogura municipality. A very simplified process for building vulnerability assessment has been done which do not need much cost to carry out. Through this process, hazardous buildings have been identified. Only level 1 assessment has been done in this research. As results show that approximately all the buildings are potentially hazardous. Bogura is a growing city. Rapid urbanization has changed the whole area. Many new constructions of industrial and commercial buildings have increased by a good number. It's the high time to take a proper step towards planned urbanization, because planned urbanization not only eases the life of the community but also taking consideration the risk factor associating the specific area.

Acknowledgment

I highly appreciate the support from all the teachers of the Departments of Urban and Regional Planning and Md. Mehedi Hasan, Town Planner of Bogura Municipality, for their invaluable suggestions, generous help to carry out this research authentically.

Appendix

Example of Calculation

Building type	Basic score	Severe Vertical irregularities	Moderate Vertical irregularities	Plan irregularities	Final score	Minimum score
RM-2	2.1	-1.1		-0.8	0.2	0.3
RM-1	2.1	-1.1		-0.8	0.2	0.3
RM-2	2.1		-0.7	-0.8	0.6	0.3
URM	1.7	-1		0	0.7	0.2
RM-2	2.1		-0.7	0	1.4	0.3
C3	2		-0.6	0	1.4	0.3

References

BBS. (2011). "Bangladesh population and housing census 2011: Community report for Bogura Zilla. Bogura", Bangladesh Bureau of Statistics.

Choudhury J.R. (1993) "Seismicity in Bangladesh", Bangladesh University of Engineering and Technology (BUET), Dhaka, Bangladesh.

FEMA (2002) "Rapid Visual Screening of Buildings for Potential Seismic Hazards, A Handbook", FEMA 154, Federal Emergency Management Agency, Edition 2.

BNBC (1993) Bangladesh National Building Code

BNBC (2006) Bangladesh National Building Code

https://www.unisdr.org/files/37302_annualreport2013.pdf

https://www.nationalgeographic.com/environment/natural-disasters/earthquakes/

EPISTEMIC UNCERTAINTY ON PROBABILISTIC SEISMIC HAZARD CONSIDERING THE MAIN HIMALAYAN THRUST (MHT) IN NEPAL HIMALAYA

Deepak Chamlagain[1]* John G. Anderson[2] Steve G. Wesnousky[3]

ABSTRACT

The Main Himalayan Thrust (MHT), a plate boundary thrust fault between Indian and Eurasian plates, is the major source of seismic hazard in the Himalaya. In this contribution, we investigate the sensitivity of the estimated seismic hazard in terms of spectral acceleration (SA) at 0.01s to different input variables for a transect (MHT) that extends from beneath the high Himalaya into the Indo-Gangetic plain at the longitude of Kathmandu. The uncertainties associated with the incomplete knowledge on earthquake source and other parameters are assessed with the help of a logic-tree. The logic-tree is made of input variable branches representing the preferred, lowest and highest maximum values for several parameters. Altogether eight parameters, namely choice of Ground Motion Prediction Equation (GMPE), fault geometry, maximum magnitude (M_{max}), mean shear wave velocity in the upper 30m (Vs_{30}), slip, slip rate, Z1.0 and Z2.5 are considered. Sensitivity of SA at 0.01sto these parameters is computed for 2%probability of exceedence in 50 years. Tornado plots are developed to illustrate the uncertainty level of each parameter. The parameters that most influence the uncertainty in the hazard estimates from geological information in Kathmandu are (1) GMPEs and M_{max} for ridge forming bedrock sites, (2)Vs_{30} and GMPEs for intermontane basins (3) GMPEs, Vs_{30} and slip for the Dun valleys, and (4) GMPEs, $Vs_{30}$and M_{max} for the Indo-Gangetic plain in the footwall wall side. Continued research in these areas has the greatest potential to reduce the uncertainty in the seismic hazard calculations.

Introduction

One key advantage of probabilistic seismic hazard assessment (PSHA) is the facility to estimate uncertainties on the computed hazard level. There are basically two types of uncertainties on probabilistic seismic hazard assessment (PSHA), the epistemic and the aleatory uncertainties (Tavakoli, 2002). The epistemic uncertainty is related to earthquake source characterization, e.g. demarcation of source zone boundaries, earthquake size, location, rate and variation of ground motion characteristics with earthquake size and distance. Such uncertainty is attributed to incomplete knowledge of the physics of the earthquake or lack of required geological information. The application of the logic tree in PSHA(e.g., Kulkarni et al., 1994) provides the structural platform to identify, quantify, and evaluate the sensitivity of the hazard to the epistemic uncertainties in a logical way. For a given site, each branch of the logic tree corresponds to a plausible combination of values of parameters with epistemic uncertainty. The distribution of these curves thus reveals the uncertainties that are present in the seismic hazard and can be used to prioritize future studies that would be most valuable to reduce those uncertainties (e.g., Atkinson and Charlwood, 1983; Cramer et al., 1996). In this contribution, we use the approach to identify the epistemic factors that lead to the greatest uncertainties in our understanding seismic hazard due to the Main Himalayan Thrust (MHT) in Nepal Himalaya. The results may be used to guide what future research efforts may lead to the greatest reduction in uncertainty.

The Main Himalayan Thrust (MHT)

The crustal structure of the Himalaya has been investigated with applications of structural geology, seismology, gravimetry and magnetotelluric techniques. Hirn and Sapin (1984), using wide-angle seismic reflection records first suggested the presence of a major mid-crustal reflector at 30-40km. The reflector was subsequently imaged by the common midpoint deep seismic profiling method during the INDEPTH experiment. The mid-crustal reflector is interpreted to be the basal decollement of the MHT inferred from the balanced and restored structural sections prepared for far eastern and western Nepal Himalayas (Schelling and Arita, 1991;). The MHT is referred to as the Himalayan Frontal Thrust (HFT) at its southern limit where

[1] *Asst. Professor, Dept of Geology, Tri-Chandra M. Campus, Tribhuvan University, Kathmandu, Nepal*
[2] *Professor, Nevada Seismological Laboratory, University of Nevada, Reno, USA*
[3] *Professor, Center for Neotectonic Studies and Seismological Laboratory, University of Nevada, Reno, USA*
**Email: deepakchamlagain73@gmail.com*

it cuts the ground surface(Brown et al., 1996)(Fig. 2).

Pandey et al. (1999) have studied micro-seismicity recorded by a local seismic network of Department of Mines and Geology, Nepal and reported that intense micro-seismicityis concentrated along the mid-crustal ramp that acts as a geometrical asperity to absorb the convergence of the Indian Plate(Fig. 1).Geodetic models have inferred that the southern flat of the MHT is actually locked during the inter-seismic period. North of the mid-crustal ramp the MHT creeps aseismically at the rate of 20 mm/yr (Bilham, 1997). Most of the historical as well as instrumentally recorded moderate to great earthquakes are interpreted to be the result of slip on the currently locked portion of the MHT(Avouac et al., 2015; Wesnousky et al., 2017). The geometry and the underlying rheology of the MHT had generated many micro to great past earthquakes, e.g. earthquake of 1100, 1255, 1833, 1934 Bihar-Nepal earthquake, 2015 Gorkha earthquake (Mugnier et al., 2012). Thus, the MHT is a key thrust fault in the Himalaya to contribute major part of the seismic hazard.

Eight sites are carefully selected for estimation of uncertainties (Fig. 1). These sites are located at the particular sites of the MHT with distinct geological characteristics. Two sites (e.g. Simara and Birgunj) are selected on the footwall side of the MHT, which are characterized by ~ 5 km thick alluvial deposits composed of clay, silt, sand, gravel etc. The remaining six sites represent the hanging wall side of the MHT. Chautara is located above the mid-crustal ramp along the MHT and geologically lies on the ridge of bed rock and the remaining sites, e.g. Kathmandu, Banepa and Pokhara represent intermontane basin. Bharatpur and Hetaunda represent dun valley in the Siwalik. In this contribution, we show result for Chautara, Kathmandu, Hetaunda and Birgunj only.

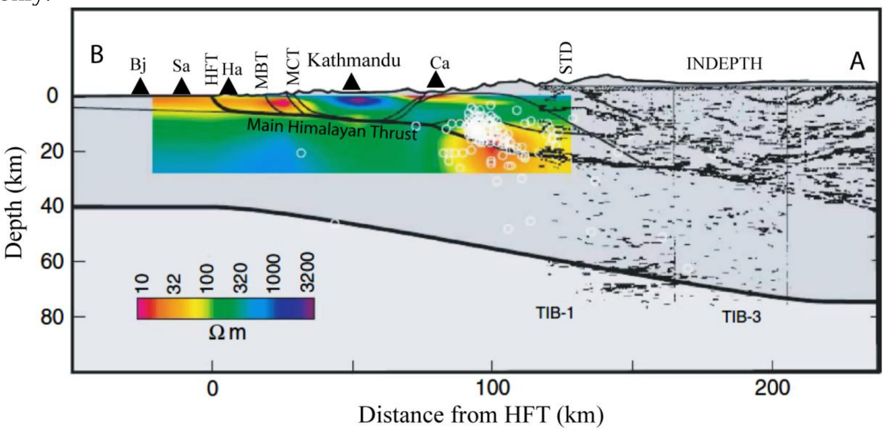


Figure 1. Geophysical observation showing the crustal structure across central Nepal (adopted from Avouac, 2007. The resistivity section across central Nepal was taken from (Lemonnier et al., 1999). Also shown is the INDEPTH seismic section ~ 300 km east of Kathmandu. The major crustal faults are inferred to merge with the sub-horizontal ductile shear zone termed as MHT. The surface expression of MHT is HFT at the frontal part of the Himalaya. The triangles show the selected sites for uncertainty analysis. Ca=Chautara, Ha=Hetauda, Bj=Birgunj.

Uncertainty Parameters

The analysis of uncertainty in seismic hazard maps is an important in estimating the seismic hazard, vulnerability and risk at a particular site. Engineering communities often need to account for uncertainties on the expected ground motion at a particular site. In case of the Himalaya, incomplete knowledge on fault geometry, earthquake history, magnitude, slip, slip rate, Vs_{30} etc all contribute to uncertainty in the hazard estimates. These all parameters are shown in logic tree with assigned weight (Fig. 2).

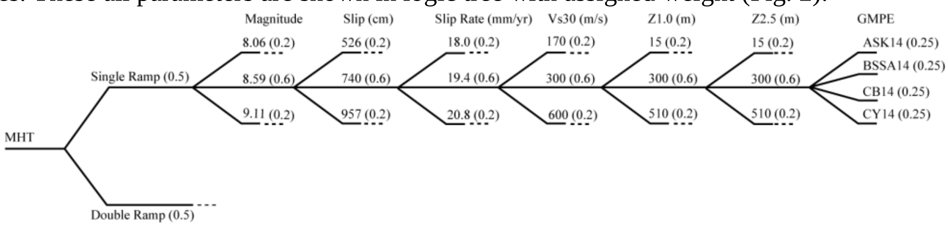


Figure 2. Logic tree adopted for seismic hazard computation. The logic tree shows eight different parameter to estimate their contribution to uncertainty analysis. The middle value is preferred value for computation purpose.

The geometry of MHT is one of controversial structures in the Himalayas. There is disagreement on its deep structure beneath the Himalaya. Recently, two works with differing ideas on the geometry of the MHT have been published. Elliot et al. (2016) base on the geodetic data, combined with geologic, geomorphological and geophysical analyses proposed a single ramp along the MHT. In contrast, Hubbard et al. (2016) proposed a structural cross section along with a three-dimensional model of the MHT with double ramps. We consider both models separately. The tectonic rupture and magnitude of the historical earthquake are another uncertain parameters. Available data are insufficient to estimate the exact limits of future earthquakes. In this study, we simply consider possible rupture lengths of 200, 400, and 800 km based on plaeoseismological studies and use Leonard's (2010 and 2014) empirical scaling laws given for the interplate dip slip earthquakes to determine the corresponding magnitudes. In case of slip and slip rate, there are non-uniform data based on the paleoseismological studies. To adopt more consistent and logical values for the hazard assessment, slip along the MHT is determined using the empirical scaling laws given by Leonard (2010 and 2014) for the interplate reverse faults. The convergence rate of 19.4±1.4 mm/yr for central Nepal (Ader et al.,2012) is used for the hazard assessment. Choice of the Ground motion prediction equation is also considered as a uncertainty parameters.. In case of the Himalaya, there are no specific GMPE yet. This study includes the NGA West2 GMPEs of Abrahamson et al. (2014), Boore et al. (2014), Campbell and Bozorgnia (2014), and Chiou and Youngs (2014). Each GMPE is given equal weight in the logic tree (Fig. 3). The other parameters considered in the logic tree are Vs_{30}, Z1.0 and Z2.5 are shown in the Fig. 3. For the Kathmandu Valley, we have taken the computed Vs_{30} from the microtremor measurements (Poovarodom et al., 2018) and for other sites except Chautara, we use the Vs_{30} values in the Kathmandu Valley. At Chautura, the calculations use Vs_{30} of 1500 m/s (1000-2000), Z1.0 of 30, and Z2.5 of 30 m (15-510 m).

Calculation of Hazard Curves

Seismic hazard curves are produced using PSHA technique considering eight uncertainty parameters shown in logic tree (Fig. 2). Seismic hazard curves for peak ground acceleration (PGA) at Kathmandu Valley are shown in Figure 3. There are 21870 branches of logic tree for each site and thus 21870 hazard curves on Figure 5. We adopted the same statistical approaches proposed by Anderson (2017) to use methods of probability theory to help to characterize this distribution.

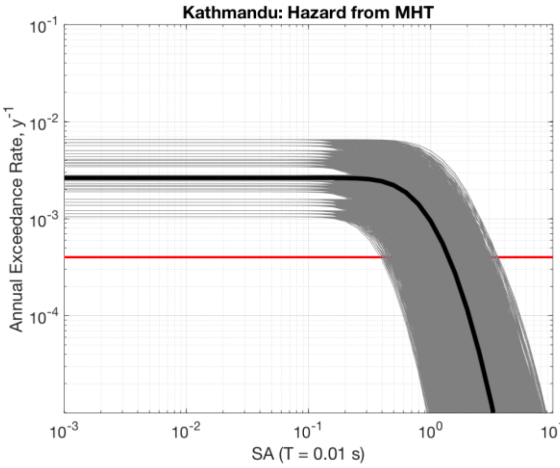


Fig. 3. Hazard curves from all branches of the MHT logic tree in Figure 2 for the hazard at Kathmandu valley. The response spectrum, SA for oscillator period T=0.01s is equal to the peak acceleration (PGA). Hazard at the annual exceedance rate of 4 x 10-4 yr-1 is represented by the heavy horizontal red line. The thick black line represents the hazard curve for preferred values for the uncertain parameters modelled in the logic tree.

In this study, to create tornado plot, a base case seismic hazard curve (thick line in Fig. 3) is used. Then each parameter in the logic-tree is varied systematically through all their values. For example, to find the effect of maximum magnitude (M_{max}), the hazards for all considered values of M_{max} are found in combination with all other parameter's base case and then the extremes are found. The ratio of these extreme to the base case are found next. The horizontal bar between the natural logarithms of these ratio represents the maximum effects of changing this parameter alone (Fig. 4). Similar method is repeated for all the uncertainty parameters. The ratios, as shown in Figure 4, are sorted by decreasing absolute impact from top to bottom. As in Figure 4, all values of SA are evaluated for the return period of $4x10^{-4}$ yr^{-1}. We note that some of these effects are coupled. Thus for instance, for different fault lengths, the range of considered magnitudes are different. Thus the "fault geometry" category that includes both down dip geometry and rupture length is coupled with the effect of varying the magnitude.

Results

The contribution of uncertainty parameters to seismic hazard is shown by the tornado plot. Results are shown for both hanging and foot walls.

MHT-Hanging wall

Intermontane Valley

The tornado plot for the Kathmandu Valley, where capital city located, is presented in Figure 4a to show the relative importance of the uncertainty parameters that are systematically varied in this study. The most to least influential parameters are Vs_{30}, GMPE, fault geometry, M_{max}, slip, slip rate, and Z1.0. This means that shear wave velocity in the upper 30m and GMPE are the most influential parameters that add substantial level of uncertainty on seismic hazard in the Kathmandu Valley. The M_{max}, slip, slip, slip rate, and Z1.0 have a less impact on hazard assessment.

Chautara

Chautara is located on the bedrock of Higher Himalaya above the mid-crustal ramp of the MHT. The tornado plots show that GMPE has the greatest influence on hazard assessment (Fig. 4b). Other parameters, e.g. M_{max}, slip, fault geometry, $Vs_{30}$and slip rate have relatively lower impact on hazard estimation.

Dun Valleys

Dun valleys are located in the Siwalik sequence. In the south, these valleys are bounded by the HFT, a southern tip of the MHT, and are considered to be in the high risk of earthquake. These valleys are composed of clastic sediments that are derived from the surrounding Siwalik hills make it potential to amplify the ground motion. Tornado plots for Hetauda (Dun valley) has shown different results to that of other sites. The GMPE and Vs_{30} are the most influential parameters for uncertainty on seismic hazard, which is followed by fault geometry, slip, M_{max} and slip rate and Z1.0 (Fig. 4c).The Z2.5 is found to be insignificant parameter for uncertainty analysis.

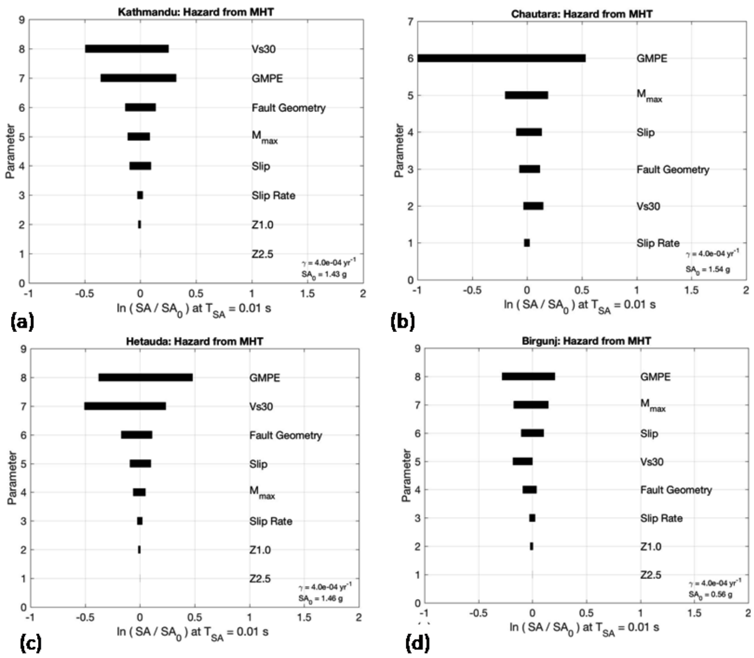


Fig. 4. Tornado plots for (a) Kathmandu (b) Chautara (a) Hetauda (b) Birgunj.

MHT-Footwall

To understand the uncertainty level of the parameters one sites, (Birgunj) on the footwall of the MHT, is considered. The tornado plots reveal that the GMPE ,M_{max} and Vs_{30}, are the most influential parameters for Birgunj (Fig. 4d).

Effect of Ramp along the MHT

In order to isolate the contribution of location and number of ramps to uncertainty, we made a separate set of calculations in which only 400 km long ruptures were considered. In these calculations, the downdip fault geometry is decoupled from effects of different magnitudes. The results found that the effect of the downdip fault geometry is always comparatively small, i.e. smaller than the effects of GMPE, M_{max}, slip, and Vs_{30}. The tornado plots have revealed no significant impacts of number of ramps along the MHT on uncertainty.

Discussion and Conclusions

We have tried to examine the uncertainty level due to different source related parameters only for an earthquake on the MHT. The study does not consider other relevant faults or a more thorough selection of GMPEs. The MHT is assumed to be the main source of seismic hazard, at least for the exceedance rate of $4x10^{-4}$ yr^{-1} considered here. We found that in the intermontane valleys (e.g. Kathmandu) Vs_{30} stood as the most important parameter that can give higher uncertainty on peak acceleration. The Kathmandu Valley is filled with thick deposit of clay, silt, sand and gravel that has profound effect on change on characteristics of the seismic-wave resulting into strong site effects as shown by Chamlagain and Gautam (2015). The seismic hazard in the ridge forming bedrock site (e.g. Chautara) is mainly controlled by GMPE followed by M_{max} and slip. Considering that the GMPE, in this study, appeared as the most influential parameter to give the highest level of uncertainty on peak acceleration and that it is not even established that these GMPE are appropriate for this region, clearly indicates that GMPE need considerable research for this region. Similarly, the impact of GMPEs in the Dun valleys (e.g. Hetauda) is also profound. After this, Vs_{30} is found be influential parameter as these valleys are deeply filled with clastic sediments from the surrounding Siwalik hills that has potential to amplify ground motion. The site located on the footwall has also indicated GMPEs are more influential followed by Vs_{30} and slip. However, consideration of single or double ramp geometry did not give any difference on uncertainty on peak acceleration, means less impact on hazard estimation.

Based on above findings, it can be concluded that continued research in five areas of investigation should provide the most benefit for reducing the uncertainty in the seismic hazard calculations particularly for Nepal and the Himalaya in general. These areas are (1) determination of Vs_{30} in the intermontane basin, Dun valley and Indo-Gangetic plain to characterize the site by earthquake geotechnical point of view (2) continued earthquake monitoring through dense network and development of the GMPEs for the Himalayan region to improve the prediction of ground motion (3) paleoseismological studies to estimate fault rupture length, earthquake magnitude, and recurrence interval of the large earthquakes, (4) detail studies of strong-ground motions, and (5) delineation of detail geometry of MHT in the Himalaya through integrated studies.

Acknowledgments

DC is thankful to the Fulbright Commission, USA for providing a fellowship to carry out this research at the University of Nevada, USA under the Fulbright Visiting Scholar Program.

References

Abrahamson, N.A., Silva, W.J. and Kamai, R. (2014) "Summary of the ASK14 ground motion relation for active crustal regions", *Earthquake Spectra* 30, no. 3, 1025–1055.

Ader, T., et al. (2012) "Convergence rate across the Nepal Himalaya and interseismic coupling on the Main Himalayan Thrust: Implications for seismic hazard", *J. Geophys. Res.* 117, B04403, doi:10.1029/2011JB009071.

Anderson, J.G. (2018) "Quantifying the Epistemic Uncertainty in the Probabilistic Seismic Hazard from Two Major Faults in Western Nevada" *Earthquake Spectra*. https://doi.org/10.1193/080717EQS156M.

Atkinson, G.M. and Charlwood, R.G(1983) "Uncertainties in probabilistic seismic hazard assessment as a function of probability level: a case history for Vancouver, British Columbia" *Bull. Seism. Soc. Am*. 73, 1225–1241.

Avouac, J.-P., Meng, L., Wei, S. Wang, T. and Ampuero J.-P. (2015) " Lower edge of locked Main Himalayan

Thrust unzipped by the 2015 Gorkha earthquake" *Nat. Geosci*. 8, 708–711.

Avouac, J.P. (2007) " Dynamic Processes in Extensional and Compressional Settings – Mountain Building: From Earthquakes to Geological Deformation". *Treatise on Geophysics,* vol. 6, pp. 377-439.

Bilham R., Larson, K., Freymueller J. and Idylhim members (1997) "GPS measurements of present-day convergence across the Nepal Himalayas" Nature, 386, 1-94.

Boore, D. M., Stewart, J. P., Seyhan, E., and Atkinson, G. M. (2014) "NGA-West2 equations for predicting PGA, PGV, and 5% damped PSA for shallow crustal earthquakes" *Earthquake Spectra* 30, no. 3, 1057–1085.

Brown L.D. et al. (1996) "Bright spots, structure, and magmatism in southern Tibet from INDEPTH seismic reflection profiling" *Science* 274, 1688–1690.

Campbell, K.W. and Bozorgnia, Y. (2014) "NGA-West2 ground motion model for the average horizontal components of PGA, PGV, and 5% damped linear acceleration response spectra" *Earthquake Spectra* 30, no. 3, 1087–1115.

Chamlagain, D., Gautam, D.(2015) "Seismic Hazard in the Himalayan Intermontane Basins: An Example from Kathmandu Valley, Nepal" In Mountain Hazards and Disaster Risk Reduction; R. Shaw, H.K. Nibanupudi (eds.), Springer Japan DOI 10.1007/978-4-431-55242-0

Chiou, B. S.-J. and Youngs, R. R. (2014) "Update of the Chiou and Youngs NGA model for the average horizontal component of peak ground motion and response spectra" *Earthquake Spectr*a 30, no. 3, 1117–1153.

Cramer, C.H., Petersen, M.D. and Reichle, M.S. (1996) " A Monte Carlo approach in estimating uncertainty for a seismic hazard assessment of Los Angeles, Ventura and Orange counties, California" *Bull. Seism. Soc. Am.* 86, 1681–1691.

Elliott, J.R., Jolivet, R., Gonzalez, P. J., Avouac, J. P., Hollingsworth, J., Searle, M. P., Stevens, V. L. (2016) "Himalayan megathrust geometry and relation to topography revealed by the Gorkha earthquake" *Nat. Geosci.* 9, 174-180.

Hirn, A. and Sapin M. (1984) "The Himalayan zone of crustal interaction: suggestions from explosion seismology (Tibet)" *Annal. Geophys.* 30, 205-249.

Hubbard, J., Almeida, R. V. Foster, A. E. Sapkota, S. N. Burgi, P. Tapponnier, P. (2016) "Structural segmentation controlled the 2015 Mw 7.8 Gorkha earthquake rupture in Nepal" *Geology*. doi:10.1130/G38077.1

Kulkarni, R.B., Youngs, R.R. and Coppersmith, K.J. (1984) Assessment of Confidence Intervals for Results of Seismic Hazard Analysis,Proc.8th world Conf. on Eq. Engr. I, pp. 263–270.

Lemmonier, C., Marquis, G., Perrier F. et al. (1999) "Electrical structure of the Himalaya of central Nepal: High conductivity around the mid-crustal ramp along the MHT" *Geophys. Res. Lett.* 26, 3261–3264.

Leonard, M. (2010) "Earthquake fault scaling: Self-consistent relating of rupture length, width, average displacement, and moment release" *Bull. Seism. Soc. Am.* 100, 1971–1988.

Leonard, M. (2014) "Self-consistent earthquake fault-scaling relations: Update and extension to stable continental strike-slip faults" *Bull. Seism. Soc. Am.* 104, 2953–2965.

Pandey, M., Tankudar, R., Avouac, J.-P. Vergne, J., Héritier, T. (1999) "Seismotectonics of the Nepal Himalaya from a local seismic network" *J. Asian Earth Sci.* 17, 703–712.

Poovarodom, N., Chamlagain, D., Jirasakjamroonsri, A., and Warnitchai, P. (2017) "Site Characteristics of Kathmandu Valley from Array Microtremor Observations" *Earthquake Spectra* 33, No. S1, S85–S93.

Schelling, D., and Arita, K. (1991) "Thrust tectonics, crustal shortening, and the structure of the far-eastern Nepal Himalaya" *Tectonics* 10 no. 5, 851–862.

Tavakoli, B. (2002) "Sensitivity of seismic hazard evaluations to uncertainties determined from seismic source characterization" *J. Seism.* 6, 525-545.

Wesnousky, S. G., Kumahara, Y., Chamlagain, D., Pierce, I. K., Karki, A., and Gautam, D. (2017) "Geological observations on large earthquakes along the Himalayan frontal fault near Kathmandu, Nepal" *Earth Planet. Sci. Lett.* 457, 366-375.

APPLICATION OF ARTIFICIAL HIERARCHY PROCESS FOR LANDSLIDE SUSCEPTIBILITY MODELLING IN RANGAMATI MUNICIPALITY AREA, BANGLADESH

Abdulla - Al Kafy[1, 2*], Mahmudul Hasan[1], Lamia Ferdous[3], Md. Rahamat Ali[4] & Md. Salah Uddin[5]

ABSTRACT

Landslide hazards are a common threat for the community people living in the risky hill slopes in Rangamati Municipality Area (RMA) in Bangladesh. Extensive hill cutting for urban settlements and heavy rain in a short period of time are responsible for triggering frequent landslide disasters in RMA. Every year, landslides cause economic losses, human casualties, and damage. Therefore, the principal objective of this research is to develop the Landslide Susceptibility Maps (LSM) for RMA so that suitable landslide disaster risk reduction approaches can be developed in near future. In this research, Artificial Hierarchy Process (AHP) has been applied for assessing the landslide susceptible areas in RMA which is a Geographic Information System (GIS) and remote sensing-based technique. LSM has been prepared on the basis of eleven (11) relevant factor (i.e. Geology, slope, elevation, topography, distance from road and structure, land cover, NDVI, stream, and faults–lineaments). A landslide inventory map has been prepared using field surveying data of 48 historical landslide locations. Finally, the area under the relative operating characteristics curves (AUC) has been used to validate the AHP modelling result and AUC values of AHP 76.3%. According to the results of the AUC evaluation, the produced map has exhibited good performance. This study would support decision making by relevant departments for formulating policies and planning associated with landslide disaster risk reduction in Bangladesh.

Keywords: Landslides, Landslide Susceptibility Mapping, Artificial Hierarchy Process, ROC curve.

Introduction

Landslides are most hazardous incident in the history of the world and third category of natural hazard for its worldwide position (Ahmed & Dewan, 2017; Rahman, Ahmed, & Di, 2017). Bangladesh is also affected by landslides during the monsoon period (June–September), which hit Chittagong Hill Track (CHT), almost every year (Rahman et al., 2017). Vulnerability level of landslide hazard to CHT is very high with a cumulative trend of frequency and harm (Ahmed, 2015). High rainfall, rapid urbanization, increased population density, inappropriate land use, hill cutting, deforestation, and agricultural practices are provoking the landslide susceptibility in CHT (Ahmed, 2015; Khan, Lateh, Baten, & Kamil, 2012). Recently, overwhelming landslides have frequently hit Rangamati Metropolitan Area (RMA) and caused injured person, compensations and loss. According to the district administration's report at least 15,000 people from 3,378 families are living at risk from landslides in the hilly areas and 120 people killed in last year's landslides in RMA. The huge amount of natural, social and economic losses due to landslides indicate its vulnerability (Ferdous, Kafy, Roy, & Chakma, 2017)and in last few years geographic information system (GIS), remote sensing (RS) and spatial statistical techniques and tools are applied in LSM studies frequently to identify the landslide locations, condition and predictability(Ahmed & Dewan, 2017; Chousianitis et al., 2016; Scaioni, Longoni, Melillo, & Papini, 2014).

Nowadays, different landslide susceptibility calculation methods are used, i.e., analytical hierarchy process (AHP), Weighted linear combination, ordered weighted averaging, decision tree methods etc. (Nefeslioglu, Gokceoglu, & Sonmez, 2008; Pourghasemi, Mohammady, & Pradhan, 2012; Pourghasemi, Pradhan, Gokceoglu, Mohammadi, & Moradi, 2013). The analytical hierarchy process (AHP) is known to analyze landslide condition for landslide susceptibility mapping and its combinations which are multi-criteria evaluation (MCE), multi-criteria decision analysis (MCDA), spatial multi-criteria evaluation (SMCE) is used in different related researches (Demir, Aytekin, Akgün, Ikizler, & Tatar, 2013; Pourghasemi et al., 2013; Yalcin, 2008). Landslides in CHT are a complex and multi-faced problem but despite a high degree of landslide hazard and vulnerability in RMA, only a few studies have been carried out to in Chittagong, Cox's Bazar area expect Rangamati area. The paper basically tries to develop the Landslide Susceptibility Maps (LSMs) using publicly available data with the assistance of AHP approach so that suitable landslide disaster risk reduction approaches can be developed in near future for RMA.

Methodology

Rangamati municipality is located at the South-eastern side of Bangladesh and it lies between 22º27´ and 23 º 44´ north latitudes and 91º56´ and 92º33´ east longitudes. The total area of the RMA is 546.49 sq. km. of which 210.32 sq. km. is under forest and is one of the most landslide prone areas in Bangladesh (Bangladesh Bureau of Statistics, 2013). Based on the data from the Bangladesh Meteorological Department, the annual average temperature of this district varies from maximum 36.5°C to minimum 12.5°C and annual rainfall is 2673 mm.

The first step of LSM is identifying the contributing factors of landslide hazards and then generating the relevant factors maps. For this research purpose, eleven relative factor maps and a landslide inventory map was produced. All the raster images (30 m×30 m) were projected to 'Bangladesh Transverse Mercator (BTM)' using 'Everest Bangladesh' datum. Landsat 8 operational land imager (OLI) satellite images were used for the land cover mapping (2017) of RMA. The images dated 21 November 2015 with row (44), path (136) were downloaded from the global visualization viewer of the United States Geological Survey (USGS) for land cover mapping. Science October and November are cloud-free seasons and trees are not in leaf-off condition image collected from those two periods (Kafy, Rahman, & Ferdous, 2017; Rahman et al., 2017). A supervised image classification technique has been performed to prepare decadal land cover maps of the CHT (Ahmed & Rubel, 2013; Kafy et al., 2017). Five broad land cover types (Built-up area, Hill forest, water body, crop and shrubland, and bare soil) were identified (Fig.1-a).

The digital elevation model (DEM) image, dated on 2011, was acquired from the advanced spaceborne thermal emission and reflection radiometer (ASTER) global digital elevation model web-portal and DEM were used for the preparation of Elevation and slope maps (Fig. 1-b). The Normalized Difference Vegetation Index (NDVI) is a standardized index that allows generating an image displaying greenness (relative biomass). In this research, the Landsat-8 OLI images from the same season (dry and summer) were acquired from the official website of the USGS. Finally, the NDVI map of RMA was prepared by analyzing band 3 and band 4 in Erdas Imagine 15 software.

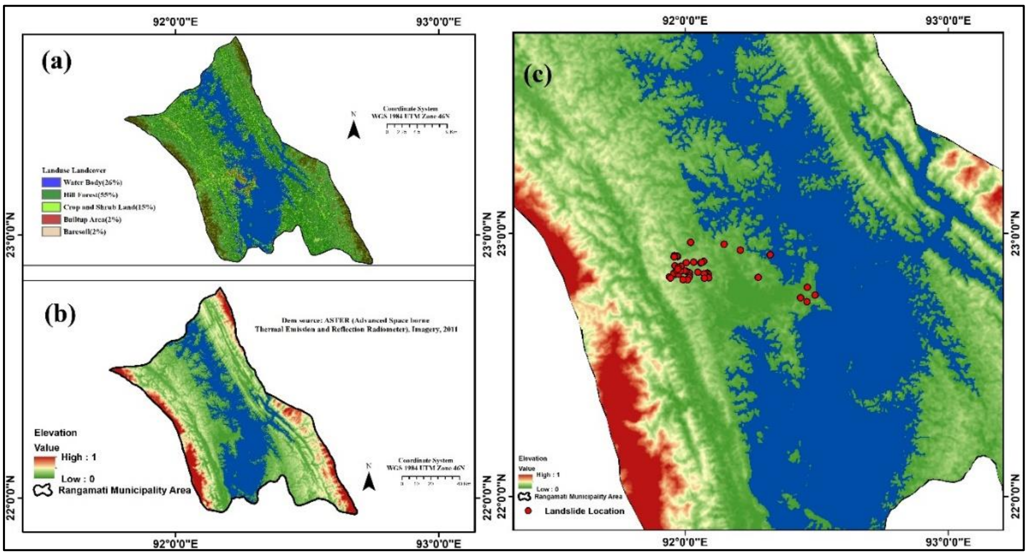


Figure 1. Rangamati Municipality Area (RMA) a) Land use of RMA, 2015 b) Elevation map of RMA c) Landslide inventory map of RMA

The effect of topography on the location and size of saturated source areas of runoff generation have been described using the topographic wetness index (TWI). Moore described the calculation of TWI under the assumption of steady-state conditions and uniform soil properties in Eq.1 (Moore, Grayson, & Ladson, 1991).

$$TWI = \ln (A_s - \tan \beta) \quad (1)$$

The stream power index (SPI) is a measure of the power of water flow based on the assumption that discharge (q) is proportional to specific catchment area (A_s) (Eq. 2)(Moore et al., 1991).

$$SPI = (A_s \times \tan \beta) \quad (2)$$

where A_S is the specific catchment's area (m^2/m), and β is slope gradient (in degrees).

The road, drainage network, and existing structure layers were collected from secondary sources and various government office. The geological, geomorphological and fault–lineaments layers were collected from the Geological Survey of Bangladesh. Euclidean distance technique was executed to generate the distance images which calculates the distance from each raster cell to its nearest source (ArcGIS 10.2 Help, 2014).

The existing landslide inventory map is very essential for identifying the relationship between landslide distribution and the conditioning factors. To produce a comprehensive and reliable landslide inventory map, extensive field surveys and observations were performed in the study area. A total of 48 historical landslides were identified and mapped in the study area (Fig. 1-c). For each landslide hazard location, information on the soil characteristics, landslide width and length, slope angle, vegetation type, number of houses and population, and occurrence of landslide history were collected.

Satty develops AHP method in 1977 which is used to identify the weights related with the suitability of map layers and combined the attributes of map layers. AHP is an effective tool in decision making and helps to check the consistency of attributes suggested by the decisions makers. AHP builds a hierarchy of decision criteria through pairwise comparison of the factor maps (Saaty, 1977). The weight in AHP rating monitors a 9-point continuous scale: (1/9, 1/8, 1/7, 1/6, 1/5, 1/4, 1/3, 1/2, 1, 2, 3, 4, 5, 6, 7, 8, 9). Here, the factor weight values greater than 1 represent more importance, less than 1 represent less importance, and 1 represents equal importance in relation to another factor (Ahmed, 2015; Eastman, 2012). The weights also undertake eigenvalues and eigenvectors calculations. If one factor has a preference, then its eigenvector component is larger than that of the other. The eigenvector values sum to unity (Reis et al., 2012). In AHP, an index of consistency have been used to determine the degree of consistency, designated as the Consistency Ration (CR), expressed in Eq.4 (Reis et al., 2012). The consistency index (CI) of a matrix of comparisons is as Eq.3

$$CI= (\mu_{max} - n)/ (n-1) \quad (3)$$

Where μ_{max} is the largest or principal eigenvalue of the matrix, and n is the order of the matrix (Saaty, 1977). It is stated that CR ratings greater than 0.10 should be re-evaluated (Saaty, 1977).

$$CR= CI/RI \quad (4)$$

Where RI is the average of the resulting CI depending on the order of the matrix given by (Saaty, 1977).

The weighting value of this method was given by calculation process of analytical hierarchy process (AHP). The values were extracted based on the level of influences. Expert opinion is an important part of the AHP method because it depends on the observed physical characteristic of landslides which helps to determine the levels of the influencing factors in the hazardous area.

Result and Discussion

As previously discussed pairwise comparison matrix for all the factors were constructed in the first step of AHP method and the factor weights were assigned based on the knowledge gathered from fieldwork and expert opinion surveying in RMA area. All factors were classified into a few groups.

Table 1. Pairwise comparison matrix for AHP

Criteria	Pairwise Comparison 9 Point Continuous Rating Scale											Eigen Value
	SP	LC	NV	GU	EV	DS	DR	DST	SPI	TWI	PC	PRC	
SP	1	3	4	5	8	4	5	7	6	7	8	9	0.267005
LC	0.333	1	3	4	8	4	5	6	6	5	8	8	0.202036
NV	0.25	0.333	1	3	7	3	5	5	5	6	7	8	0.149356
GU	0.2	0.25	0.333	1	5	0.333	1	4	3	4	5	6	0.072
EV	0.125	0.125	0.143	0.2	1	0.2	3	3	4	1	3	4	0.047428
DS	0.25	0.25	0.333	3	5	1	2	4	4	5	6	7	0.098754
DR	0.2	0.2	0.2	1	0.333	0.5	1	4	4	5	5	6	0.058815
DST	0.143	0.167	0.2	0.25	0.333	0.25	0.25	1	0.333	1	2	3	0.021889
SPI	0.167	0.167	0.2	0.333	0.25	0.25	0.25	3	1	2	3	4	0.031025
TWI	0.143	0.2	0.167	0.25	1	0.2	0.2	1	0.5	1	2	3	0.024139
PC	0.125	0.125	0.143	0.2	0.333	0.167	0.2	0.5	0.333	0.5	1	2	0.015504
PRC	0.111	0.125	0.125	0.167	0.25	0.143	0.167	0.333	0.25	0.333	0.5	1	0.012049

Consistency Ratio = 0.09 (Accepted)

SP= Slop, LC=Land Cover type, NV = NDVI, GU = geological unit, EV = Elevation, DS= Distance to Structure, DR= Distance to Road, DST= Distance to Stream, SPI= Stream Power Index, TWI= Topographic Wetness Index, PC = Plan Curvature, PRC = Profile Curvature

The first group consists of slope, elevation, plan curvature and profile curvature parameters; the second one includes distance from faults parameters which were extracted from the geological map. The next groups presenting the hydrological condition contains of distance from streams, topographical wetness index (TWI), stream power index (SPI). The final group consists of land use and distance from roads parameters because

both of these were induced by human activities. The level of influence for groups and parameters were estimated by the range of weighting and were determined by the range of weighting values between spectrums from minimum to maximum. It was found that the highest weight was assigned to slop. Land cover, NDVI and distance to structure factors were also found effective. The other layers (i.e., distance to road, stream, TWI, SPI) were identified as less important (Table 1).
The final weight values were automatically calculated by means of spatial multi-criteria evaluation in IDRISI Selva software. Based on weighting values in AHP, the levels of the influence of parameters were generated. The CR of the AHP method was found <0.1 that can be considered as acceptable (Saaty, 1977). Based on total weight value, the Landslide susceptibility map for Hazard watershed was constructed in Fig. 2.

Validation of the Landslide Susceptibility Map

To develop LSM and determination of its prediction ability Validation is an essential step. The area under the ROC curve (AUC) is a very effective approach to measure the validity of a susceptibility mapping. This method has been widely used as a measure of performance of a predictive rule (Chuvieco et al., 2010; Yesilnacar & Topal, 2005). AUC values ≤0.5 indicate no improvement, between 0.7 and 0.9 indicate reasonable agreement, and AUC ≥0.9 represents an ideal situation(Eastman, 2012). Figure 3 shows the ROC curve of the spatial multi-criteria evaluation model for the training sample. The AUC value is 0.763, indicate the good ability of a function to correctly discriminate between failed and un-failed groups in the sample used to develop the susceptibility model.

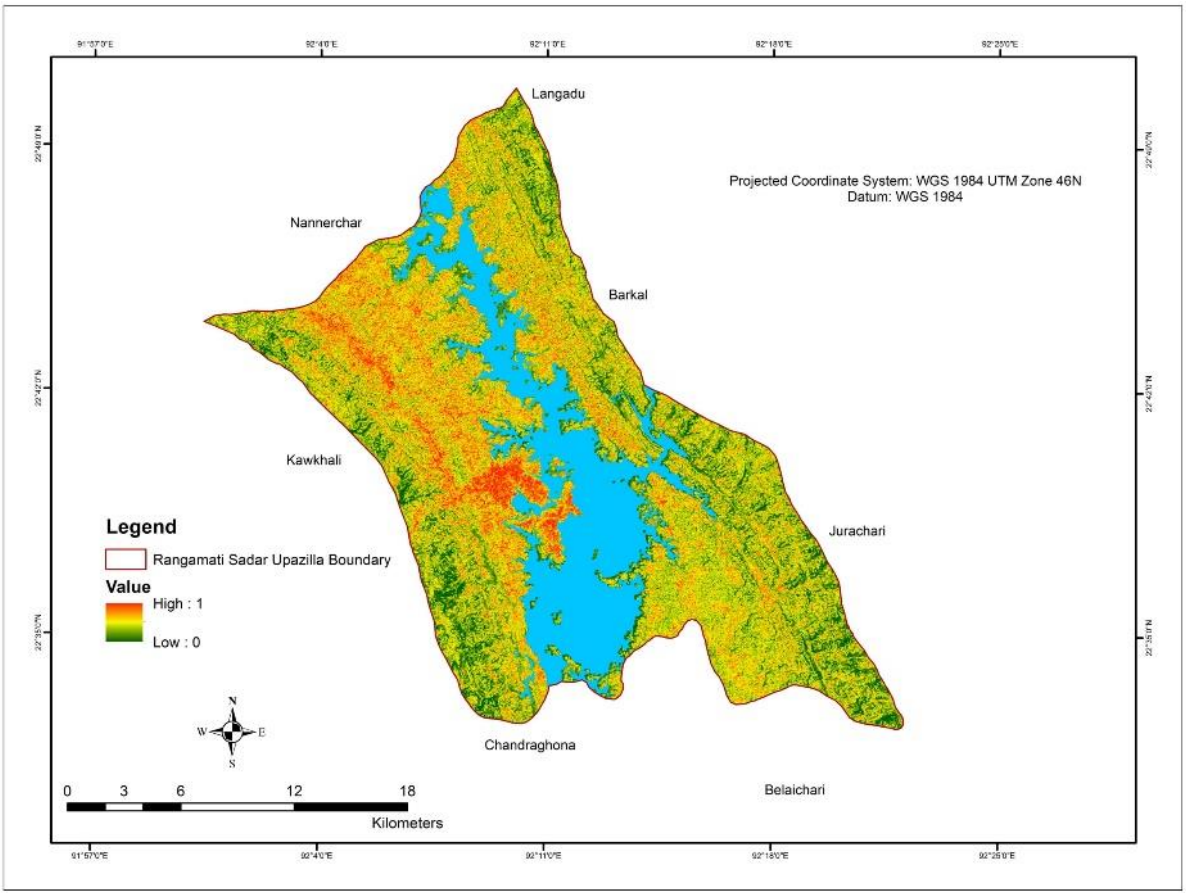


Figure 2. Landslide susceptibility map using AHP method

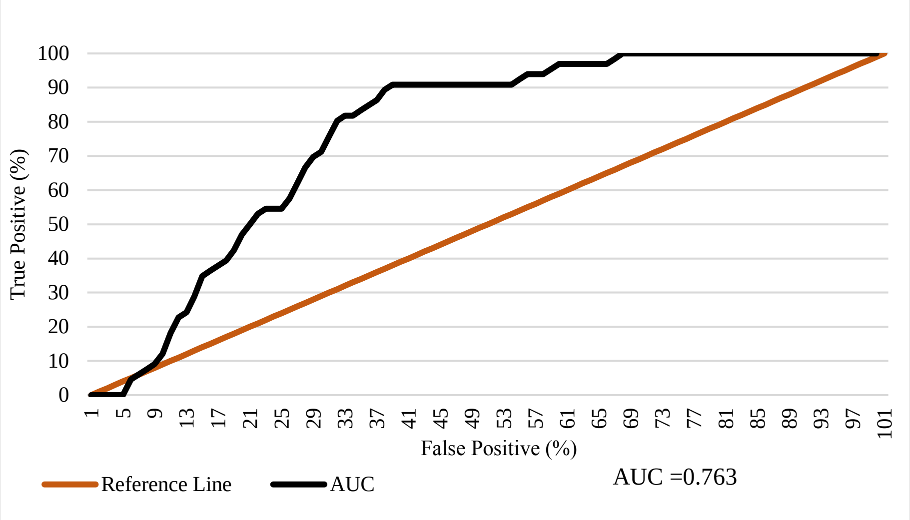


Figure 3. Assessment of the model performances based on the ROC curves

Conclusion

Landslides are devastating phenomena causing serious casualties, economic and property loss. This situation is increased in recent year due to the manipulation of the natural formation of the hills to accommodate the living of people in the dangerous foothills region. Majority of human fatalities and costs related to landslide hazard occur in economically least-developed countries and this scenario is highly noticed for urbanized hilly areas of RMA. The aim of this article is to produce statistically valid and rational landslide susceptibility maps, using GIS- and RS based modelling techniques and freely available data sets, for the people living in the hazardous hilly gradients in RMA. The landslide susceptibility map prepared using weight-based approach (i.e. AHP) in the current study is the outcome of a combination of various factors responsible for landslide susceptibility, in which each factor has relative significance to probable landslide activity. In this study, eleven landslide-controlling parameters, namely slope, elevation, geology, plan and profile curvature, land use, NDVI, distance from streams, distance from roads, distance from structure, topographic wetness index, stream power index, were considered. The landslide inventory map of 48 observed landslides in RMA was then compared with the LSMs produced with the help of the AHP method. For the purpose of model verification, ROC curves have been produced. The AUC values for AHP was calculated as 0.763 which describe the statistically significant of the model and the produced map has exhibited promising results. The availability of higher-resolution satellite images, better base maps, and up to date data sets can help to produce better accuracies and validation results in LSMs. The research outcome will help the threaten the local community, urban planner and engineers to reduce the fatalities caused by existing and upcoming landslides by means of prevention and mitigation strategies adaptation in the hilly and vulnerable landslides occurrence regions of Bangladesh. The results will be an effective approach for explaining the driving factors of the known historical landslides, for preparing necessary emergency and risk-sensitive land use plans and for supporting activities to mitigate the future landslide hazards in RMA, Bangladesh.

Acknowledgement

We are grateful to the Rangamati Hill District Council, Chittagong Development Authority, Geological Survey of Bangladesh, Chittagong City Corporation, Bangladesh Meteorological Department, Survey of Bangladesh, Bangladesh Agricultural Research Council, U.S. Geological Survey, and the National Aeronautics and Space Administration for providing the necessary datasets.

References

Ahmed, B. (2015). Landslide susceptibility mapping using multi-criteria evaluation techniques in Chittagong Metropolitan Area, Bangladesh. *Landslides, 12*(6), 1077-1095.

Ahmed, B., & Dewan, A. (2017). Application of bivariate and multivariate statistical techniques in landslide susceptibility modeling in chittagong city corporation, bangladesh. *Remote Sensing, 9*(4), 304.

Ahmed, B., & Rubel, Y. (2013). Understanding the issues involved in urban landslide vulnerability in Chittagong metropolitan area, Bangladesh.

ArcGIS 10.2 Help. (2014). Environmental systems research institute (ESRI). Redlands, CA, USA. http://resources.arcgis.com/en/help/main/10.2/.Accessed 12 February 2015.

Bangladesh Bureau of Statistics, B. (2013). District Statistics 2011, Rangamati (M. o. P. G. o. T. P. s. R. o. B. Statistics and Informatics Division (SID), Trans.) (pp. 1-137). www.bbs.gov.bd.

Chousianitis, K., Del Gaudio, V., Sabatakakis, N., Kavoura, K., Drakatos, G., Bathrellos, G. D., & Skilodimou, H. D. (2016). Assessment of Earthquake-Induced Landslide Hazard in Greece: From Arias Intensity to Spatial Distribution of Slope Resistance DemandAssessment of Earthquake-Induced Landslide Hazard in Greece. *Bulletin of the Seismological Society of America, 106*(1), 174-188.

Chuvieco, E., Aguado, I., Yebra, M., Nieto, H., Salas, J., Martín, M. P., . . . Ibarra, P. (2010). Development of a framework for fire risk assessment using remote sensing and geographic information system technologies. *Ecological Modelling, 221*(1), 46-58.

Demir, G., Aytekin, M., Akgün, A., Ikizler, S. B., & Tatar, O. (2013). A comparison of landslide susceptibility mapping of the eastern part of the North Anatolian Fault Zone (Turkey) by likelihood-frequency ratio and analytic hierarchy process methods. *Natural hazards, 65*(3), 1481-1506.

Eastman, J. (2012). IDRISI Selva help system. *Clark Labs, Clark University, Worcester*.

Ferdous, L., Kafy, A.-A., Roy, S., & Chakma, R. (2017). *An analysis of Causes, Impacts and Vulnerability Assessment for Landslides Risk in Rangamati District, Bangladesh*. Paper presented at the International Conference on Disaster Risk Mitigation., Dhaka, Bangladesh.

Kafy, A.-A., Rahman, M. S., & Ferdous, L. (2017). *Exploring The Association of Land Cover Change and Landslides In The Chittagong Hill Tracts (CHT): A Remote Sensing Perspective.* Paper presented at the International Conference on Disaster Risk Management Dhaka, Bangladesh.

Khan, Y. A., Lateh, H., Baten, M. A., & Kamil, A. A. (2012). Critical antecedent rainfall conditions for shallow landslides in Chittagong City of Bangladesh. *Environmental Earth Sciences, 67*(1), 97-106.

Moore, I. D., Grayson, R., & Ladson, A. (1991). Digital terrain modelling: a review of hydrological, geomorphological, and biological applications. *Hydrological processes, 5*(1), 3-30.

Nefeslioglu, H. A., Gokceoglu, C., & Sonmez, H. (2008). An assessment on the use of logistic regression and artificial neural networks with different sampling strategies for the preparation of landslide susceptibility maps. *Engineering Geology, 97*(3-4), 171-191.

Pourghasemi, H. R., Mohammady, M., & Pradhan, B. (2012). Landslide susceptibility mapping using index of entropy and conditional probability models in GIS: Safarood Basin, Iran. *Catena, 97*, 71-84.

Pourghasemi, H. R., Pradhan, B., Gokceoglu, C., Mohammadi, M., & Moradi, H. R. (2013). Application of weights-of-evidence and certainty factor models and their comparison in landslide susceptibility mapping at Haraz watershed, Iran. *Arabian Journal of Geosciences, 6*(7), 2351-2365.

Rahman, M. S., Ahmed, B., & Di, L. (2017). Landslide initiation and runout susceptibility modeling in the context of hill cutting and rapid urbanization: a combined approach of weights of evidence and spatial multi-criteria. *Journal of Mountain Science, 14*(10), 1919-1937.

Reis, S., Yalcin, A., Atasoy, M., Nisanci, R., Bayrak, T., Erduran, M., . . . Ekercin, S. (2012). Remote sensing and GIS-based landslide susceptibility mapping using frequency ratio and analytical hierarchy methods in Rize province (NE Turkey). *Environmental Earth Sciences, 66*(7), 2063-2073.

Saaty, T. L. (1977). A scaling method for priorities in hierarchical structures. *Journal of mathematical psychology, 15*(3), 234-281.

Scaioni, M., Longoni, L., Melillo, V., & Papini, M. (2014). Remote sensing for landslide investigations: An overview of recent achievements and perspectives. *Remote Sensing, 6*(10), 9600-9652.

Yalcin, A. (2008). GIS-based landslide susceptibility mapping using analytical hierarchy process and bivariate statistics in Ardesen (Turkey): comparisons of results and confirmations. *Catena, 72*(1), 1-12.

Yesilnacar, E., & Topal, T. (2005). Landslide susceptibility mapping: a comparison of logistic regression and neural networks methods in a medium scale study, Hendek region (Turkey). *Engineering Geology, 79*(3-4), 251-266.

Proceedings on International Conference on Disaster Risk Management, Dhaka, Bangladesh, January 12-14, 2019

LANDSLIDE VULNERABILITY ANALYSIS OF CHITTAGONG CITY CORPORATION AREA USING GEOGRAPHIC INFORMATION SYSTEM

M. R. H. Kauser[1] and M. N. Neema[2]

ABSTRACT

At present more than half of world population living in urban areas and it will be two-thirds in the year 2050. Chittagong city is the port city, due to its geographical location; city suffers from numerous natural disasters like landslide, water logging, cyclone, flood etc. Recently approximate 90 people were killed and 15000 people stranded in a landslide occurrence in 2012. For these reason landslides is the most burning issues for this city. So, it is necessary to prepare vulnerability map of landslide for CCC area so that proper mitigation measure and strategies can be developed to make this city sustainable and inclusive. To analyze vulnerability of landslide, GIS (Geographic information system) based AHP (Analytical Hierarchy Process) model is used in this research. The major findings of the research are 27% of total CCC area is vulnerable to landslide hazard where 6.5 sq.km areas are very highly vulnerable. The findings of the research will help to prepare GIS base early warning system, implementation of existing master plan, creating awareness among the local people.

Introduction

At present more than half of people of the world living in urban areas and it will be two-thirds in the year 2050. Without managing and significantly transforming the urban area sustainable cities and communities cannot be achieved (UNDP, 2017). Natural hazard is one of the burning issues that 75% of the world's population lives in areas affected at least once by earthquake, tropical cyclone, flood, drought, landslide or water logging between 1980 and 2000 (UNDP, 2017). Chittagong is the second largest urban area as well as coastal area of Bangladesh surrounded by hill tracts (Ashraf, 2011). For the reason of its geographical location, Chittagong city suffers from numerous natural disasters like landslide, water logging, cyclone, flood etc. But at present landslides is the most burning issues in respect of Chittagong city area. This condition is decreasing day by day and becoming one of the main problems of city life. Recently approximate 90 people were killed and 15000 people stranded in a landslide occurrence in 2012 (BBC news, 2012). "Most of the landslides in Chittagong happened during and after incessant torrential rainfall. It has been stated that the rainfall intensity and duration play very important role in producing these shallow landslides in Chittagong because of climate change (Khan et al., 2012)". "Moreover, improper land use, alterations in the hilly regions by illegally cutting the hills, indiscriminate deforestation and agricultural practices are aggravating the landslide vulnerability in Chittagong (Mahmud et al., 2014)". Landslide vulnerability models are the most powerful diagnostic and analytical tool for decision makers and geomorphologists to predict the spatial and temporal occurrence of mass movement. "Early attempts had defined susceptibility classes by qualitative overlaying of geological and morphological slope-attributes to landslide inventory (Nielsen et al., 1979)". There are some qualitative approaches, incorporate the idea of ranking and weighting which may evolve to be semi-quantitative in nature. However, more sophisticated assessments involved techniques such as AHP, bivariate, multivariate, logistics regression, fuzzy logic, or artificial neural network (ANN) have been reported in recent years (Lee & Pradhan, 2006). The application of the analytical hierarchy process (AHP) method, developed by Saaty (1980), was widely used in landslide vulnerability mapping (Ayalew et al., 2004). AHP (Analytical Hierarchy Process) is a semi-qualitative method, which involves pair-wise matrix-based comparison of the contribution of different factors for landslides (Saaty, 1977 and Saaty & Vargas, 2001). "The increase of computer-based tools has been found to be useful in the hazard mapping of landslides. One of such significant tools is geographic information systems (GIS) (Burrough & McDonnel, 1998)". A GIS is commonly defined as a powerful set of tools for collecting, storing, retrieving at will, displaying, and transforming spatial data (Burrough & McDonnel, 1998). So, main objective of the study is to prepare a landslide vulnerability map for Chittagong City Corporation (CCC) area. Landslide should be considered as

[1]*Postgraduate Student, Dept. of Urban and Regional Planning (URP), Bangladesh University of Engineering and Technology (BUET), Dhaka-1000, Bangladesh.*
[2]*Professor, Dept. of Urban and Regional Planning (URP), Bangladesh University of Engineering and Technology (BUET), Dhaka-1000, Bangladesh.*
Email of Corresponding Author – rhkauser@gmail.com

cautionary signal and it is essential to think about sustainable land management in Chittagong city to reduce the risk ensure sustainable cities and communities.

Study Area

Chittagong City lies 22° 14′ North to 22° 24′30’’ north latitude and 91° 46′ east to 92° 14′east longitude and extend north bank of the Karnafuli River to west bank of the Halda River. The city, under the jurisdiction of City Corporation, has a population of about 2.5 million and is constantly growing (CDA, 2018).

Figure 1. Location of study area (Chittagong city Corporation) (Source: Prepared by author).

Chittagong city is highly vulnerable to landslide hazard (Khan & Rahman, 2007). Over the last few decades landslides have become an increasingly serious hazard (Ahmad & Ahmed, 2003). The formation of informal settlements (generally termed “slums”) on hill slopes with unplanned hill-cutting is the main cause of vulnerability to landslides (Ahmad & Ahmed, 2003). So landslide has become the prominent disaster in Chittagong where death toll due to landslides is getting higher in number for the last several years. Fig 02 shows the landslide in unplanned slum at the foot of hill in Chittagong.

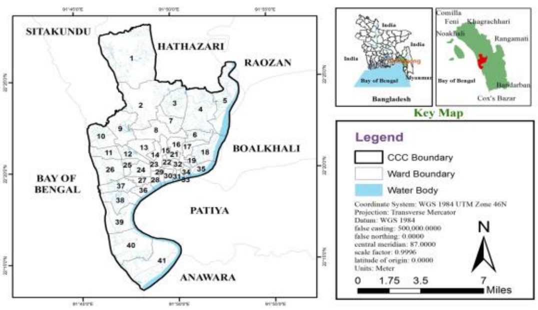


Figure 2. Landslide in unplanned slum at the foot of hill in Chittagong (Source: The Daily Star, 2012)

Method

Mainly secondary data has been used for preparing this research. Primary data has been collected through open discussion with experts for determining landslide vulnerability factors. The secondary data such as demographic data, satellite image (DEM), Geology and Geomorphology data and different types of GIS data base on CCC are collected for conducting this study. The DEM is acquired from using the Global visualization viewer (GLOVIS) of United States Geological survey (USGS). Geology data from Geological Survey of Bangladesh (GSB) and demographic data on CCC area collected from Bangladesh Bureau of Statistics (BBS). GIS data base for CCC area has been collected from Chittagong Development Authority (CDA). Many papers and documents such as journals, reports, and conference papers have also been collected from the internet.

Thematic data layers are prepared for landslide vulnerability mapping process. Elevation, slope and aspect can be produced from the raster DEM obtained from USGS website by using spatial analyst tool. “The analyst tool identifies the slope (gradient, or rate of maximum change in z-value) from each cell of a raster surface (ArcGIS 10.1, 2018)”. The aspects can be derived from a raster surface which identifies the downslope direction of the maximum rate of change in value from each cell to its neighbors. The values of the output raster will be the compass direction of the aspect (ArcGIS 10.1, 2018). The elevation map can also be prepared from the DEM layer where the relative height of the layer is considered. Geomorphology and Geology data are collected from GSB (Geological Survey of Bangladesh). Soil type data has been collected from the secondary sources. Latitude and longitude values 20 landslide locations are collected from Sourab et. all 2016. This has been used for compering the final vulnerability map. To prepare numeric data layers, Analytical Hierarchy Process (AHP) is used. The weightage values of each class are calculated through mathematical equations. The factors are also given weightage values generated from the AHP process. The numeric layers are overlaid using Weighted Sum of Spatial Analyst tool. Weighted sum overlays several raster’s, multiplying each by their given weight and summing those together (ArcGIS 10.1, 2018). The class weightage and the factor weightage are multiplied each other to produce a combined weightage map of landslide vulnerability. The landslide vulnerability weightage maps are classified into five (5) classes using Natural breaks (Jenks) classification method. The classified five classes are characterized by Very High, High, Medium, Low, very low vulnerability and the final landslide vulnerability map is prepared.

Data Analysis

Landslide vulnerability mapping

Slope is one of the major factors related to landslide occurrences and divided into 5 classes which are (0-2), (2-10), (10-15), (15-30), (30-37). Most of the landslides were found a slope range from 15-45 degree in the CCC area. The elevation classes are (0 – 12), (12 – 22), (22 – 40), (40 – 60), (60 – 88). In CCC area, most of the landslide occurred between the ranges of (40-60) m. The geology data are classified into five classes which are Fluvio tidal deposit, Hilly deposit, Others, Slope& valley deposit, Tidal deposit. Geomorphologic data are also classified into four classes which are fluvial, tidal, hill and others. The hilly/denudational landforms are located at the north western side of the CCC area also highly vulnerable to landslide. The fluvio tidal reforms and others have no possibility landslide occurrences because of plain characteristics and given less weightage value in vulnerability mapping. The soil type data are classified into nine classes which are Clay, Clayey Sand, Clayey Silt, Sandy Clay, Silty Clay, Sandy Silt, Silty Sand, Silty Fine sand and Sand. The landslide response of soil depends on its water content of soil mainly sand type of soil is more vulnerable than clay type of soil. The aspects values derived from the slope are Flat (-1), North (0 - 22.5), Northeast (22.50 - 67.5), East (67.50 - 112.5), Southeast (112.50 - 157.5), South (157.50 - 202.5), Southwest (202.501 - 247.5), West (247.50 - 292.5), Northwest (292.50 - 337.5) North (337.50 - 360).

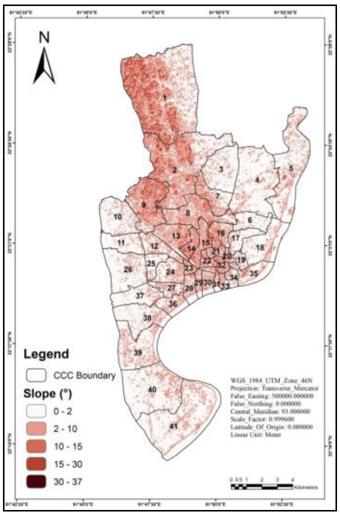


Figure 3. Slope map of CCC area

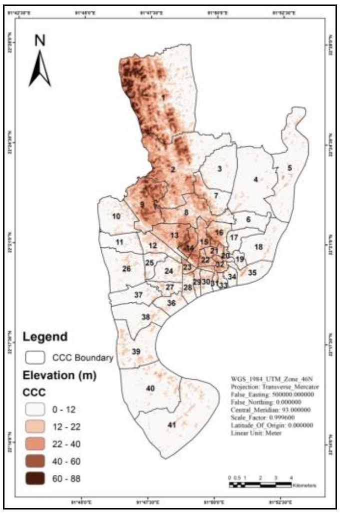


Figure 4. Elevation map of CCC area

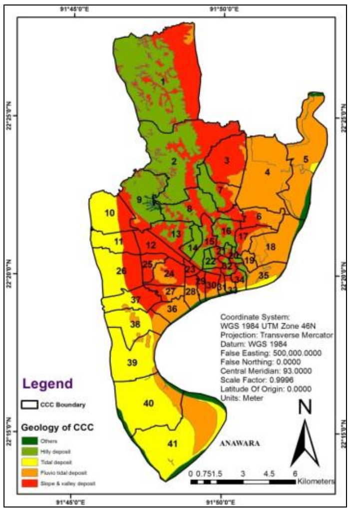


Figure 5. Geology map of CCC area

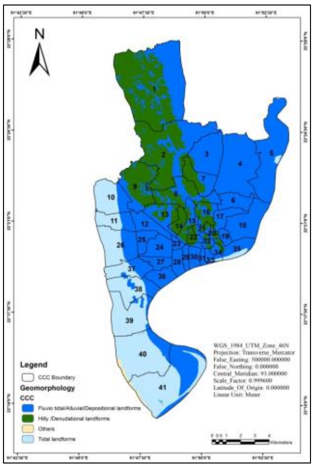


Figure 6. Geomorphology map of CCC area

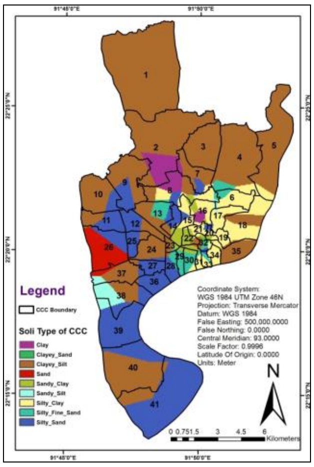


Figure 7. Soil type map of CCC area

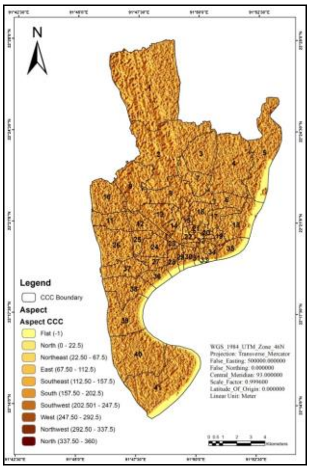


Figure 8. Aspect map of CCC area

Landslide vulnerability weightage and results

Calculating factors weights has a crucial role in the production of landslide vulnerability mapping (Kavjoglu et al., 2013). To prepare weightage of each factor using AHP method, first it is necessary to construct a pairwise matrix. Then both the weight values of sub-criteria of the criterions and the datasets/factors were calculated (Table no 01). The models with a CR greater than 0.1 were automatically rejected, while a CR less than 0.1 were often acceptable. This CR was calculated in order to determine whether the pairwise comparisons were consistent or not. It means the relative weights are appropriate and the comparisons are consistent (Saaty, 1977). The class rating within each factor was based on the relative importance of each class and some assumptions were undertaken for the factors on the basis of relevant literature.

Table 1. Pair wise comparison matrix, factor weights and consistency ration of the data layers

Factors	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**Eigen values**
Slope (1)	1						0.25
Geology (2)	1/2	1					0.2
Geomorphology (3)	1/2	1/5	1				0.1
Soil Type (4)	2	2	1	1			0.15
Elevation (5)	2	1/3	3	1/4	1		0.21
Aspect (6)	1/5	1/8	1/3	1/9	1/4	1	0.09
Consistency ratio (CR) : 0.03							

Source: Prepared by author.

Table 2. Allocation of the reference landslide points within the defined landslide Vulnerability classes and the associated frequency ratio (FR) of each class

Vulnerability classes	Vulnerability index values	Vulnerable area (km)	% of Area	Number of landslide points	Frequency ratio (FR)
Very low vulnerability (VLV)	0.053 - 0.130	57.11	33	0 (0%)	0.000
Low vulnerability (LV)	0.130 - 0.189	67.58	39	0 (0%)	0.000
Moderate vulnerability (MV)	0.189 - 0.233	30.29	18	4 (20%)	1.142
High vulnerability (HV)	0.233 - 0.316	11.45	7	7 (35%)	5.289
Very high vulnerability (VHV)	0.316 - 0.454	6.58	4	9 (45%)	11.832

Source: Prepared by author.

From Table 2, it is found that the LV had a minimum value of 0.053, and a maximum value of 0.454, with an average value of 0.162 and a standard deviation of 0.061. The LV represents the relative vulnerability of a landslide occurrence. These LV values are then divided into five classes based on the natural breaks range, which represent five different zones in the landslide vulnerability Map. These are very high (VHV), high (HV), moderate (MV), low (LV) and very low (VLV) vulnerability zones (Figure 9).

The percentage covering areas of each vulnerability class are shown in Table 2, along with number of reference landslide points occurred. From data it is obvious that only 11% of the total areas are classified as being in the VHV (4%) or HV (7%) landslide vulnerability zones but they have accommodated about 80% of the landslide reference points. Other areas are located in the MV (18%), LV (39%), and VLV (33%) vulnerability zones and only 4 landslide incidence (out of 20) being observed in the MS zones. The frequency ratio (FR) values for each identified class are also given in Table 2. These values are computed from ratio of the percentage landslide occurrences and the percentage area coverage (for each individual class to the whole study area). The FR values of 11.832 for the VHV zone and 5.289 for the HV zone indicate the notably higher chance of having landslide activities in these areas when compared to those of the MV (1.142) and LV (0). These results emphasize the applicability of the vulnerability mapping that is constructed based on the AHP method and being depicted in Figure 09. Since landslide occurrences only recorded in the very high and highly vulnerable areas in CCC, the very high, high and moderate vulnerable areas are taken in this research for vulnerability analysis process.

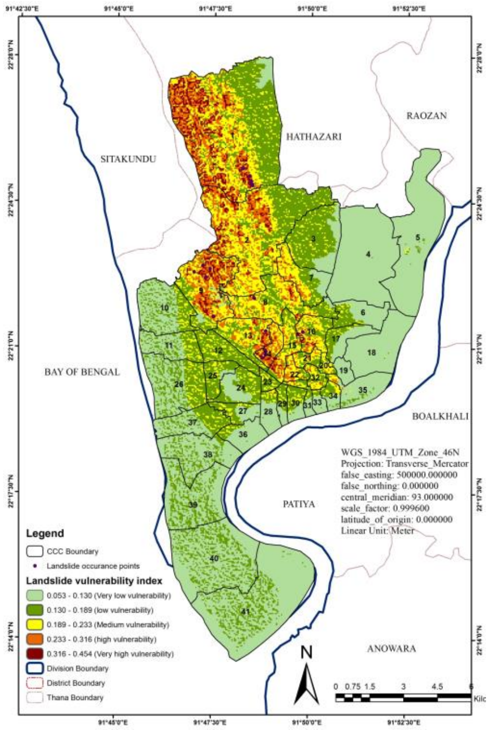


Figure 9. Landslide vulnerability map of CCC area (Source: Prepared by author)

Very high vulnerable (landslide) locations in CCC area

Kushumbag Residential Area: Kushumbag residential area is located near the Chittagong Metropolitan Police line. Badsha mia road in this area is high vulnerable to landslide. This is a middle class residential area.

Lebubagan Area: This Lebubagan area is situated near Chittagong Cantonment in Hathazari Thana. Maximum inhabitants of Lebubagan are poor labor/workers and live in foothill slum. They migrated from plain land and coastal area because of poverty and riverbank erosion.

Batali Hill Area: This area is highly vulnerable as the hill is surrounded by foothill slums and settlements. Most of the inhabitants are poor factory workers. Any large scale landslide can cause massive destruction to slums and cause death of many people.

Motijharna Area: Motijharna is located at Lalkhanbazar area near Tigerpass. This area is also heavily populated and occupied by lower income groups. Motijoran area is considered as the most vulnerable location in CCC area.

Foy's Lake Area: A few housing areas are being developed behind the hills of Foy's lake. A massive hill cutting process is in progress. However, this area is not very populous and in some places, houses are yet to be built. Some landslide occurrences are also documented and the area is considered as highly landslide prone.

Khulshi Area: This is a posh residential area located in the north and south of Khulshi hill. Mukul adarsha primary school in this area is high vulnerable to landslide.

Nasirabad Area: Nasirabad Residential area is a posh residential area in Chittagong City. Finlay state, kanandhara abasik prokolpo are highly vulnerable to landslide. Most of the constructions are completed. There are few hills surrounding this area. Inhabitants of Nasirabad protected their houses by constructing concrete wall (retaining wall). For this reason, vulnerability of this area is less than other hilly areas of Chittagong city.

Conclusion

This study has assessed the vulnerability of landslide hazard for CCC area. The main objective of this study is to prepare landslide vulnerability of CCC area. As CCC belongs to coastal area and north-south hill range crosses the city area. So, the landslide phenomena are quite very severe than any other location of Bangladesh. Also, many settlements and slums have been developed in the foothills and lower income people are living in these areas in a risky situation. Therefore, every year number of people dies to landslide event. In these circumstances it would be rational to identify vulnerable locations due to landslide hazard into city area which can provide supportive actions for preparing disaster management plan. Finally, on the basis of the study it can be concluded that if the government and other concerned authorities take necessary steps, vulnerability of landslide hazards can be reduced to an extent tolerable to the city people.

Acknowledgments

We would like to thank United State Geological survey (USGS) and Geological Survey of Bangladesh for providing data. We would also like to thank Chittagong development authority to providing GIS data. We are grateful to Sourab Das, Lecturer, Department of Urban and Regional Planning, Chittagong University of Engineering and Technology for providing GIS location of landslide occurrence.

References

Ahmad, Q. K., & Ahmed, A. U. (2003). Regional cooperation in flood management in the Ganges-Brahmaputra-Meghna region: Bangladesh perspective. *Natural Hazards*, 28, 181-198.

ArcGIS10.1 (2018). *Environmental systems Research Institute.* Retrieved from http://help.arcgis.com/en/arcdesktop/10.1/help/

Ashraf, M. A. (2011). *Landslide in Chittagong problems, issues and measures for mitigation*. Dhaka-1208: Media New Age Ltd.

Ayalew, L., Yamagishi, H., & Ugawa, N. (2004). *Landslide susceptibility mapping using GIS-based weighted linear combination, the case in Tsugawa area of Agano River*, Niigata Prefecture, Japan. Landslides, 1:73–81.

BBC news. (2012, June 27). *Heavy rains and landslides in Bangladesh kill 90. Chittagong*: BBC.

BBS. (2011). *Bangladesh Population and Housing Census, Community report, Zilla: Chittttagong*. Dhaka: Vol. 3, Bangladesh Bureau of Statistics.

CDA. (2018). *Chittagong Development Authority Website*. Retrieved from Chittagong Development Authority: http://portal.cda.gov.bd/

Khan, Y. A., Habibah, M. L., Baten, M. A., & Kamil, A. A. (2012). Critical antecedent rainfall conditions for shallow landslides in Chittagong City of Bangladesh. *Environmental Earth Sciences*, Volume 67, Issue 1, pp 97-106.

Kusky, T. (2008). *landslide: Mass wasting soil and Mineral hazards*. Fact on file Inc. Newyork, 145.

Lee, S., & Pradhan, B. (2006). Landslide hazard assessment at Cameron Highland Malaysia using frequency ratio and logistic regression models. *Geophy Res Abstracts*, 8: SRef-ID:1607–7962/gra/ EGU06-A-03241.

Mahmud, S. H., Hossen, M. B., Islam, M. M., & Ali, S. (2014). Coastal Hazards and Community-Coping Methods In South-West Coastal Region Of Bangladesh. In Q. S. Hossain, K. S. Islam, M. H. Rashid, K. M. Hasan, M. S. Ali, M. Rokonuzzaman, & A. Z. Morshed (Ed.), *2nd International Conference on Civil Engineering for Sustainable Development* (p. 650). Khulna: Khulna University of Engineering and Technology.

Nielsen, T., Wrigth, P., Vlasic, T. C., & Spangle, W. E. (1979). Relative slope stability and land-use planning in the San Francisco Bay region, California. *US Geological Survey Professional*, p. 944.

Saaty, T. (1977). A scaling method for priorities in hierarchical structures. *Math Psychol.* 15:231–281.

Saaty, T., & Vargas, L. (2001). *Models, Methods, Concepts, and Applications of the Analytic Hierarchy Process*. Boston: 1st ed. Kluwer Academic 333p.

The Daily Star. (2012, June 25). *Rain causes water logging in chittagong city. Chittagong*.

UNDP. (2012). *Reducing Disaster Risk: A Challenge for Development*. Bureau for Crisis Prevention and Recovery. Washington, DC: United Nations Development Programme.

USGS. (2017). USGS: science for a changing world. Retrieved from USGS: http://search.usa.gov/search?affiliate=usgs&query=landslide+definition.

SEISMIC VULNERABILITY ASSESSMENT OF STRUCTURES IN MOUNTAINOUS REGIONS OF CENTRAL ASIA

Md Nurul Alam [1], Hasibullah Ziar [2], Amit Kumar[1] and Sulaymon Sulaymonov[1]

ABSTRACT

In view of development and infrastructure operations in Central Asia, Aga Khan Development Network has developed a comprehensive seismic vulnerability assessment methodology consisting of three-step approach to assess the prevailing vulnerabilities of structures. Following the set validated methodology, several hundreds of simple to complex structures (education, health, and community structures) having various building typologies were considered for Level 0 and Level 1 assessment. The paper discusses the process, data features, assessment criteria, structural/ non-structural indices, and relevant mitigation recommendation for the surveyed structures. Further, it discusses the outcome, lessons learnt and the way forward (detailed assessment, retrofitting etc.) of this assessment. The paper suggests the skill development for vulnerability assessment can enable the large scale seismic vulnerability assessment in the region. Finally, it discusses the challenges and opportunity for rapid seismic vulnerability assessment in the region.

Introduction

Central Asia, particularly the Badakhshan territories of Afghanistan and Tajikistan is one of the most seismically active regions in the world (GSHAP, 2017). In the past, the Gorno-Badakhshan Autonomous Region (GBAO) of Tajikistan was affected by large and destructive earthquakes killing thousands of people (Tyagunov, 2012). Large earthquakes in the region are inevitable, however associated losses can be minimized with timely action for structural safety. (World Bank, 2017).

The global framework for disaster risk reduction has provided a wide range of pro-active measures to reduce disaster risk and vulnerability in the Central Asian region. In 2010, the Government of the Republic of Tajikistan endorsed a National Disaster Risk Management Strategy (NDRMS) - 2010-2015 in line with the Hyogo Framework for Action (HFA) for 2005- 2015 (UNISDR ,2017). This is a key strategic country disaster risk management document in Tajikistan. The priorities set by NDRMS include: reducing disaster losses in livelihoods, social, economic, and environmental assets of communities and countries. Further, the 'Dushanbe Declaration on Disaster Risk Reduction for Resilience Building' acknowledged the importance of disaster risk management and risk resilient development, which suggests the need for safer and resilient housing in the region (UNISDR, 2017).

This paper discusses the process, data features, assessment criteria, structural/ non-structural indices, and relevant mitigation recommendation for the surveyed structures in Badakhshan territories of Afghanistan & Tajikistan and shares experiences of the AKDN Disaster Risk Management Initiative (DRMI)-now part of Aga Khan Agency for Habitat (AKDN, 2013). The paper entails the process, data features, assessment criteria, structural/ non-structural indices, and relevant mitigation recommendation for the surveyed structures. Further, it discusses the outcome, lessons learnt and the way forward (detailed assessment, retrofitting etc.) of this assessment.

Seismic Vulnerability Assessment Approach

In view of recent Kashmir earthquake, AKDN put impetus on its operations' safety, resiliency, and continuity. Most of its community, health, and education operations are located in the very high seismic risk zone, which needed thorough scientific assessment of all structures safety. There are more than 500 structures (AKDN, 2013) across the mountainous region of Central Asia (Badakhshan territories of Afghanistan and GBAO (Gorno Badakshan Autonomous Oblast) of Tajikistan) which are owned, operated or eased by its agencies. Disaster Risk Management Initiative of AKDN (now part of Aga Khan Agency for Habitat) attempted to establish a systematic approach for seismic vulnerability assessment and mitigation. The works started in 2011 and continued thereafter as a major programme with Aga Khan Agency for Habitat. Figure-1 explains the incremental approach stating Level 0 (Inventorisation), Level 1 (Rapid Visual Screening), Level 2

[1] *Aga Khan Agency for Habitat, Tajikistan*
[2] *Aga Khan Agency for Habitat, Afghanistan*
e-mails: nurul.alam@akdn.org *(corresponding author),* hasibullah.ziar@akdn.org, amit.kumar@akdn.org, sulaymon.sulaymonov@akdn.org

(Performance-based analysis for simpler structures) and level 3 (Performance-based analysis for complex critical structures).

Level 0 Survey – this compiles the facility information which is used to understand the regional distribution of structural vulnerability of personnel, physical assets, and activities. That basic understanding also is used to develop short- and long-term disaster risk reduction strategies. The data includes agency name, their facility name, geographical location with latitude and longitude, purpose and building basic information (number of structures, building age, capacity (Maximum and Average), stories, tenure, and condition. The information is mapped using the GIS tools to understand their distribution. The Level 0 survey data is followed by the level 1 survey to collect further critical structural and non-structural information.

Level 1 Survey -Rapid Visual Screening Survey (RVSS) – This level of survey requires basic information, mainly relying on existing data with very few integrations which must be collected on site by rapid visual screening. Based on the recommendations of Level 1 survey, a mitigation guideline has been prepared which aims to help agencies in allocating adequate resources for detailed vulnerability assessment and risk reduction. The identified structures have been evaluated in terms of structural & non-structural vulnerabilities (SVI & SNVI) and risk potentials, which provide necessary understanding to the relevant agencies in mobilizing necessary resources and skills to achieve the target safety. The SVI and NSVI are they are mutually independent and different with respect to calculation and importance. Among the identified structures, the vulnerability scoring and prioritization studies have identified those structures, which require further investigation to be assessed under L2 and L3.

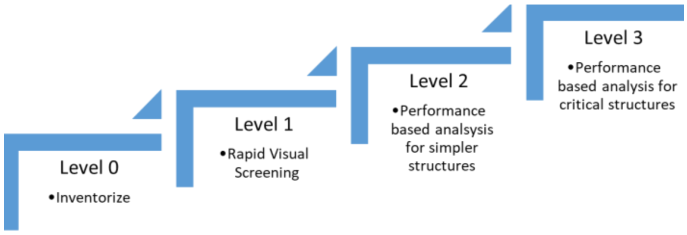


Figure 1. Systematic Seismic Vulnerability Assessment (AKDN, 2014).

Level 2 Survey – Level 2 Survey is designed for the simpler load bearing structure with the most prevalent building typologies (low rise). Level 2 audit collects structural and architectural drawings, characteristics of structural and non-structural components and structure conditions which results in structural and non-structural retrofitting of simple or basic structures. It follows the AKDN methodology for structural audit, which is based on performance-based seismic analysis of the existing facilities (ASCE-41). The main components of the assessment are: a) Data Collection, b) Surveying and foundation analysis, c) Economic cost effectiveness or cost-benefit analysis d) Feasibility and appropriateness for retrofitting measures, and long-term sector plans e) Assessment and Analysis method for verification of actual status of the structure, f) Preliminary analysis for retrofitting and rehabilitation of the structure, g) Retrofitting schemes, h) Conventional and innovative techniques, f) Non-structural components, etc. Major features for Level 2 audit are:

1. Implies for simple and basic structures
2. Collects structural and architectural drawings, characteristics of structural and non-structural components and structure conditions
3. Requires limited engineering analysis based on information from visual observations and structural drawings or on-site measurements.

Level 3 Survey - Level 3 audit is recommended for all critical (important and lifeline) structures. The Level 3 audit is case specific and will only be carried out for complex and large structures. The procedures in Level 3 employ linear or nonlinear analyses of the building under consideration and require the as-built dimensions and the reinforcement details of all structural elements. In this evaluation stage, buildings that cannot be classified in the first two stages are considered. This phase of the evaluation usually requires laborious strength and displacement calculations and takes a much longer time that the first two evaluation stages. Therefore, it is preferred to have a small number of buildings to be assessed in this stage. The survey process comprises of structural data collection, analytical and experimental studies, destructive and non-destructive testing etc., geological and geotechnical studies, complete linear/non-linear analysis, cost-benefit analysis, tender documents for structures feasible for retrofitting, complete retrofitting designs, etc.

Level 0 & Level 1 Survey: Data Collection Process, Methodology and Assessment Outcome

Rapid Visual Screening Survey (RVSS) is developed for decision makers, building officials, owners, and engineers to identify, inventory, and rank buildings that are potentially seismically hazardous. The basic purpose of RVSS is to identify older buildings designed and constructed before the adoption of adequate seismic design and detailing requirements, building on soft or poor soil and buildings having adverse seismic performance. Once identified as potentially hazardous, such buildings should be further evaluated by a professional experienced in seismic design to determine, whether they are seismically hazardous. Objectives of the RVSS are to validate facility survey data and finalize the database, screen buildings & facilities and define the vulnerability status, define mitigation strategy based on RVSS outcomes, optimize the mitigation levels i.e., Structural and non-structural mitigation and to assess human life at risk

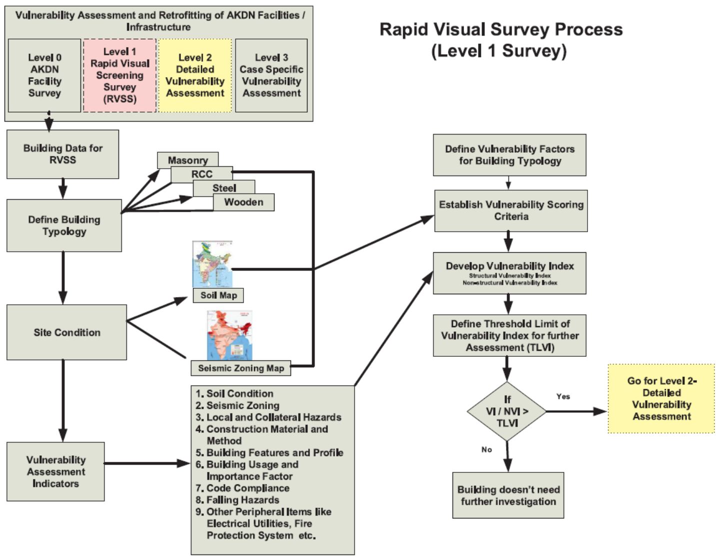
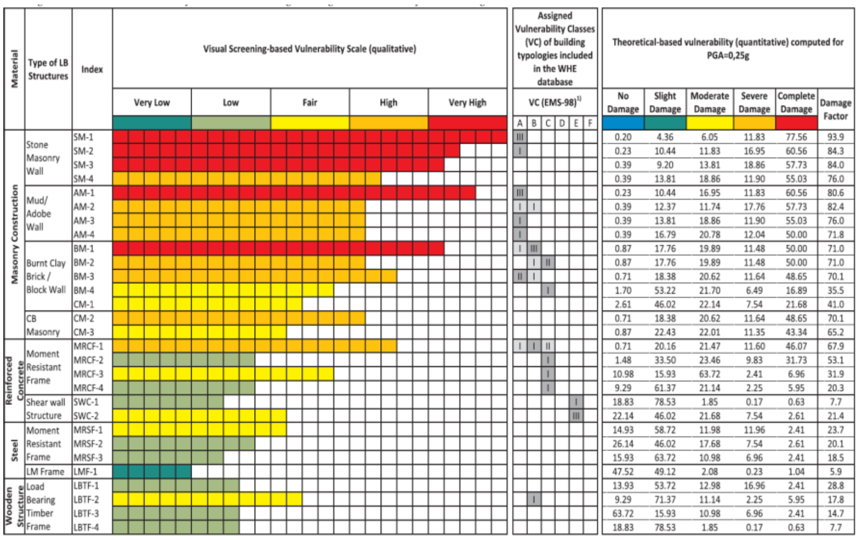


Figure 3. Level 1 RVSS procedure (AKDN, 2013)

The RVSS follows scientific and management process to assess vulnerability condition of structures, which largely encompasses defining building typology and their fragility (Vulnerability) functions, defining indicators for RVSS, developing vulnerability scoring and ranking and formulating approach for field survey and management. The approach for RVSS is shown in flowchart, Figure 2.

Survey Form Development and Field Testing: The Survey form has been developed based on established survey methods (i.e. ATC-41, FEMA-154, ASCE-31/41, NORSAR, IS Code 13935:2009). The survey form consists the information such as sketch of the building plan with approximate dimension; Isometric picture of the building; Soil, seismic zones, local and collateral hazards; physical status, age, structural features; material used and construction type; structural vulnerability indicators such as plan & elevation irregularities, configuration, alterations, etc.; code compliance; non-structural vulnerability indicators such as: falling hazards and other building utilities like electrical network and appliance, fire protection, escape route, appendage, movable equipment etc. Field testing has been carried out to validate the scoring and ranking system.



Material	Type of LB Structures	Index	VC A	VC B	VC C	VC D	VC E	VC F	No Damage	Slight Damage	Moderate Damage	Severe Damage	Complete Damage	Damage Factor
Masonry Construction	Stone Masonry Wall	SM-1	III						0.20	4.36	6.05	11.83	77.56	93.9
		SM-2	I						0.23	10.44	11.83	16.95	60.56	84.3
		SM-3							0.39	9.20	13.81	18.86	57.73	84.0
		SM-4							0.39	13.81	18.86	11.90	55.03	76.0
	Mud/ Adobe Wall	AM-1	III						0.23	10.44	16.95	11.83	60.56	80.6
		AM-2	I	I					0.39	12.37	11.74	17.76	57.73	82.4
		AM-3	I						0.39	13.81	18.86	11.90	55.03	76.0
		AM-4	I						0.39	16.79	20.78	12.04	50.00	71.8
	Burnt Clay Brick / Block Wall	BM-1	I	III					0.87	17.76	19.89	11.48	50.00	71.0
		BM-2		I	II				0.87	17.76	19.89	11.48	50.00	71.0
		BM-3	II	I					0.71	18.38	20.62	11.64	48.65	70.1
		BM-4			I				1.70	53.22	21.70	6.49	16.89	35.5
		CM-1							2.61	46.02	22.14	7.54	21.68	41.0
	CB Masonry	CM-2							0.71	18.38	20.62	11.64	48.65	70.1
		CM-3							0.87	22.43	22.01	11.35	43.34	65.2
Reinforced Concrete	Moment Resistant Frame	MRCF-1	I	I	II				0.71	20.16	21.47	11.60	46.07	67.9
		MRCF-2			I				1.48	33.50	23.46	9.83	31.73	53.1
		MRCF-3			I				10.98	15.93	63.72	2.41	6.96	31.9
		MRCF-4			I				9.29	61.37	21.14	2.25	5.95	20.3
	Shear wall Structure	SWC-1					I		18.83	78.53	1.85	0.17	0.63	7.7
		SWC-2					III		22.14	46.02	21.68	7.54	2.61	21.4
Steel	Moment Resistant Frame	MRSF-1							14.93	58.72	11.98	11.96	2.41	23.7
		MRSF-2							26.14	46.02	17.68	7.54	2.61	20.1
		MRSF-3							15.93	63.72	10.98	6.96	2.41	18.5
	LM Frame	LMF-1							47.52	49.12	2.08	0.23	1.04	5.9
Wooden Structure	Load Bearing Timber Frame	LBTF-1							13.93	53.72	12.98	16.96	2.41	28.8
		LBTF-2		I					9.29	71.37	11.14	2.25	5.95	17.8
		LBTF-3							63.72	15.93	10.98	6.96	2.41	14.7
		LBTF-4							18.83	78.53	1.85	0.17	0.63	7.7

[1] bars indicate the number of individual reports included in the World Housing Encyclopedia addressing the respective building typology; gray shading indicates the most likely vulnerability class.

Figure 3. Major building types and vulnerability scales (Lang et al., 2018)

Field Survey and Management: The number of facilities and structure were retrieved from the agencies' facility inventory survey (Level 0) database. Further, the RVSS has been conducted by civil engineers /architects through visiting each facility and structure. For effective RVSS, the survey coordination office has developed instruction manual and conduct training for surveyors. The national implementation team constituted team of technical surveyors and supervisors. The surveyors carried out the survey for national wide institutional facilities and structures. The national implementation team focal point in each country performed field checking for authenticity of data collected. Once collected, survey coordination office validated the consistency of data and carry out vulnerability ranking of each structure. The cut-off points for SVI and NSVI were calibrated to define safety of buildings. Finally, the reports were submitted to concerned agencies for necessary further assessment and mitigation planning.

Building Typology and Fragility Function: The building typology for each target country have been identified, which largely falls under Masonry, RCC, Steel, and Timber with large structural and architectural variation. For each building typology, the fragility functions have been defined, that characterized performance of typology at various intensity/magnitude of the earthquake. The typology distribution of collected structures are provided in Table 1:

Table 1. Structural Typology Distribution of the AKDN Institutional Structures (AKDN, 2013)

Structural Type	Afghanistan	Tajikistan	Grand Total
Adobe Mud	121	2	123
Burnt Clay Brick	49	0	49
Concrete Block Masonry	5	33	38
Light Metal Steel Frame	0	7	7
Load Bearing Timber	1	12	13
Moment Resistant Concrete Frame	7	22	29
Moment Resistant Steel	1	1	2
Shear Wall	0	2	2
Stone Masonry	272	57	329
Total	456	136	592

From the above Table, it is evident that the majority of the structures (more than 80% in Afghanistan and more than 40% in Tajikistan) are adobe and stone masonry structures. Based on the vulnerability functions developed for major building types (Figure 3), these structural typologies have higher damage potentials, resulting more vulnerabilities in the assessment.

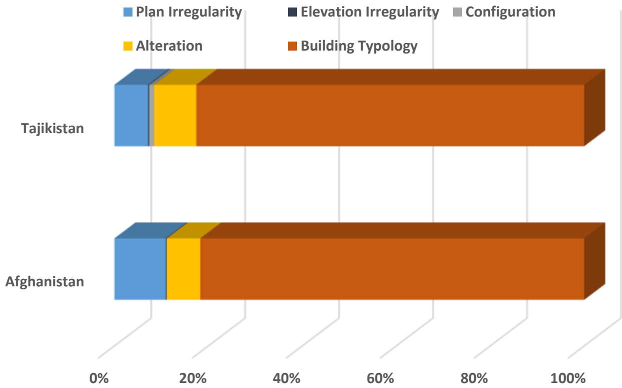


Figure 4. Contribution of structural vulnerability indicators

Establish RVSS Indicators: The appropriate indicators for RVSS are essential component for ranking the vulnerability of structures. The indicators include soil profile, seismic zoning, site-specific and collateral hazards, physical condition of structure, construction material and methods, building features, usage & importance factor, code compliance, falling hazards and other building utilities like electrical connection, Fire protection system, water drainage, etc. The contribution of vulnerability indicators for each of the country are provided in Figure 4. It is evident that building typology is the major indicator contributing to the overall seismic vulnerability. Other than the building typology, Afghanistan plan irregularities for 11% structures and building alteration for 7% structures. Whereas in Tajikistan, plan irregularities contribute 7% to the vulnerability, configuration irregularities contribute 1% and alterations contribute 9% to the overall vulnerabilities. Figure 5 shows the distribution of contributing indicators for non-structural vulnerabilities in both countries. From the figure, it is evident that for Afghanistan, blocked escape routes (54%) and fire hazards (28%) contribute the major portion for the non-structural hazard. Whereas, if Tajikistan, escape routes (37%), fire hazard (31%) and electrical hazards (18%) are the major contributors for the non-structural vulnerability.

Vulnerability Scoring and Ranking: Based on building typology, their fragility functions, and RVSS indicators, the scoring system has been developed, which followed the statistical tools/ functions. The RVSS resulted in two indicators i.e. structural vulnerability index (SVI) and non-structural vulnerability index (NSVI). SVI provides an overall understanding of structural weakness and NSVI provides profile of non-structural elements and their potential to be hazardous. SVI and NSVI reflect overall vulnerability status of structure. This helps decision-makers and engineers to prioritize mitigation measures based on available resources.

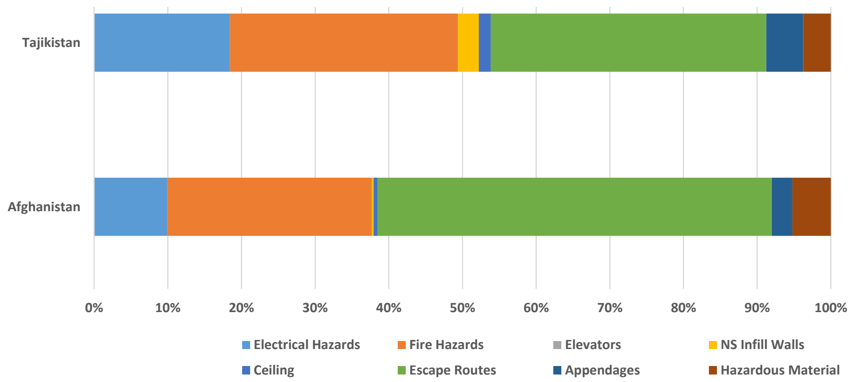


Figure 5. Contribution of non-structural vulnerability indicators

The methodology suggested 5 grades of SVI and NSVI which are Very Low, Low, Moderate, High and Very High. From the study, it is found that the majority of the structures (82%) are stone masonries (SM) and adobe masonries (AM) in Afghanistan and 91% of them are moderate to highly vulnerable, which requires detailed assessment. Whereas, in Tajikistan, majority of the structures are stone masonries (SM, 42%), concrete block masonries (CM, 24%) and moment resistant frame (MRCF, 17%). Majority of the stone masonries (98%) fall in moderate to high SVI, which require detailed assessment. Further, from the study, it was found that 23% of the surveyed structures in Afghanistan and 27% of the surveyed structures in Tajikistan require non-structural hazard mitigation, which will reduce the impact of an earthquake on the life, properties, and functionality of the structure in an affordable way.

Mitigation Measures

Further to the SVI and NSVI, Mitigation Guidelines were developed for each of the structure that discusses the programs and goals for disaster risk reduction. The comprehensive mitigation guidelines initiate the overall procedure for prioritization and economic assessment of the AKDN facilities. Further, it is supplemented by the recommendations for mitigation strategy, mitigation planning, mitigation, and mitigation priority. These set forth a database for the development of the defined reporting. The report helps the relevant agencies to allocate necessary resources for disaster risk reduction. Mitigation framework presents on what context the structures are prioritized, the strategy behind mitigation, how mitigation is planned both in terms of budgetary and implementation-wise issues. Further, it discusses on how the risk is reduced, controlled and transferred; organizational, financial, reporting, monitoring, and sustainability issues. Finally, it focuses on “Priority actions for implementation” including mitigation investments and actions, leadership, roles and responsibilities of the entities. Based on the Level 1 survey results, about 40 structures from Afghanistan and 23 structures from Tajikistan have gone through the performance-based detailed structural assessment viz. Level 2 & Level 3 structural audit (ASCE 41). The structures were selected based on the SVI grade (having moderate to high SVI) and their importance. Few of the structures have been assessed as safe, some are not feasible to retrofit and the rest were recommended for seismic retrofitting. Based on the recommendation, about 15 structures have been retrofitted in this region.

Challenges and Opportunities

The data collection planning and implementation are impacted by the unavailability of information, weather, remoteness, prevailing safety and security of the region. Logistic support is complicated, and the coordination among the agencies are difficult. It will be smoother if a buy-in process is established among the relevant agencies to conduct a coordinated survey. The ground support for the implementation of developed technology is minimum and need expedited efforts to meet the potential demand. Due to ignorance and limited awareness, stakeholders are working in silos ignoring the sensitivity of others. This leads to coordination complexities and more efforts are required to resolve the impediments. Unless the initiative outcomes and benefits are not tangible, the demand for such interventions will be relatively low. The mitigation options and strategies are proposed for the institutions. The options are evolved based on the needs and priorities, thus no additional efforts are required for stakeholder buy-in and ensure risk reduction. The options are cost-effective and through cooperative societies, the cost can be further optimized to the larger extent. Although the methodology has been developed for the institutional buildings, it can be calibrated and applied to the mass housing for rapid seismic risk assessment and prioritization in the region. Awareness programmes can be developed to capacitate the relevant local Government.

Conclusion and Recommendations

RVSS is one of the important processes to assess the buildings to identify major seismic hazard factors and their quantified vulnerability scores and their ranks. Scientific and engineering tools and applications were used to develop the tool. The tool is quick and simple for the users. This helps in prioritizing the facilities for necessary mitigation measures. It has to be noted that, this rapid assessment can only be utilized for screening and prioritizing of the structures. Further detailed structural assessment is required for confirmation and mitigation of the identified structures. The assessment procedure may also include existing natural hazards addition to seismic hazard in future. There are some challenges in resources availability and skill to maximize the usage. However, the future envision includes plenty of opportunities to create a market for the services and capacity building, which will ultimately contribute to the safer and resilient settlement. Finally, a policy is essential to be developed to scale up the work for all facilities inherited or constructed for AKAH operations.

Acknowledgments

The paper acknowledges the contribution of Aga Khan Development Network (AKDN) Disaster Risk Management Initiative (now part of Aga Khan Agency for Habitat-AKAH) and other relevant AKDN agencies. The authors acknowledge support of AKF Afghanistan & Tajikistan for necessary technical support in conducting training and survey implementation.

References

AKDN. (2013) "AKDN Facility Database", Aga Khan Development Network- Disaster Risk Management Initiatives, Tajikistan 2013.

AKDN. (2014) "AKDN Structural Audit Methodology", Aga Khan Development Network- Disaster Risk Management Initiatives, Tajikistan 2014.

GSHAP. (2017) "http://www.seismo.ethz.ch/static/gshap", accessed on March 6, 2017.

Lang et al. (2018) "Building typology classification and earthquake vulnerability scale of Central and South Asian building stock", Journal of Building Engineering, Volume 15, January 2018, Pages 261-277.

Tyagunov, S. et al. (2012) "Seismic Risk Assessment in the Countries of Central Asia", DOI: 10.13140/2.1.2443.5207 · Conference: Seismic risk assessment in the countries of Central Asia, International conference on 'Complexity in earthquake dynamics: From nonlinearity to earthquake prediction and seismic stability' (Tashkent, Uzbekistan 2012).

UNISDR. (2017) "Dushanbe Declaration on Disaster Risk Reduction for Resilience Building", http://www.unisdr.org/files/51203_dushanbedeclarationeng.pdf accessed on March 6, 2017.

World Bank. (2017)"Central Asia Earthquake Risk Reduction Forum", http://www.worldbank.org/en/events/2015/09/23/central-asia-earthquake-risk-reduction-forum

VULNERABILITY ASSESSMENT FOR EARTHQUAKE IN DHAKA: A CASE STUDY OF WARD 37

Fariba Siddiq[1], Saurav Dutta[2],Tasliha Mowla[3], Tazrina Habib[4]

ABSTRACT

Dhaka city, for its geo-tectonic setup, is at high risk of the earthquake which has been exacerbated by the haphazard city development and poor construction of structures. In case of a moderate to the strong level earthquake, the incurrence of damage might be immensely severe and widespread. This study assesses the earthquake vulnerability of Ward no. 37 in Dhaka South City Corporation which is an area in the old part of the city and considered as a high-risk area for any earthquake event. A GIS-based spatial multi-criteria approach has been used for vulnerability assessment of the buildings and associated dwellers. Structural form, the gap between adjacent buildings, distance from emergency shelter, the width of the road in front of buildings and population concentration are the factors considered for assessing the vulnerability. Most of the buildings of this ward are in a medium to highly vulnerable state in terms of building form, the gap between adjacent buildings and the width of road fronting the building. In terms of distance to disaster shelter, the buildings are in a relatively better condition as most of the buildings are within 0.5 km from a potential emergency shelter.

Introduction

Bangladesh lies in between two active tectonic plates: the Indian plate in the west and the Eurasian plate in the east and north (Dhaka City Corporation (DCC), 2009). The geographic location in the seismically active zones has made the country vulnerable to earthquake (Bhuiyan, 2010). In the case of a moderate to heavy tremor, unprecedented loss of human lives may occur. The historical evidence of earthquakes in this region shows that the frequency of earthquake has increased thirty times here which indicates the increase in tectonic activities (Debnath, 2013). Repeated mild earthquakes have been experienced by the people of this region in recent years (Bhuiyan, 2010). Dhaka, the capital city of Bangladesh, is one of the riskiest cities in the world for earthquake because of the poor construction and development practice. Due to an earthquake of 7 to 7.5 magnitude, there may be loss of lives, damages of buildings, collateral hazard like economic loss, fire following earthquake and debris generation (DCC, 2009). The risk is higher in the old part of the capital which is the historic core of Dhaka city. In old Dhaka, dense unplanned development and high population density escalate the risk. Old Dhaka has been developed within a process of spontaneous growth. It represents high degree of physical earthquake vulnerabilities because of high population density, informal or unplanned settlements, non-engineered buildings and shelters, large number of poorly built buildings, contiguous building pattern and lack of open spaces etc. The gaps of buildings are less than 5 feet which are actually a violation of building code (Housing and Building Research Institute (HBRI), 2006). All these have caused difficulty of movement at the building block and street level, which is likely to make any post-disaster management even worse. Moreover, there are chemical storages and several types of hazardous factories situated in a number of houses in this area which will trigger the risk of collateral disasters like fire break out due to the combustible materials being stored in almost every house.

There are a number of researches and studies on the risk assessment and vulnerability analysis on whole Dhaka city, larger areas of Dhaka South City Corporation (DSCC) and Dhaka North City Corporation (DNCC) and the whole part of the old Dhaka. But concentration is needed at micro level with detailed analysis

[1] *Corresponding author*
Lecturer, Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology (BUET);
email: faribasiddiq@gmail.com*; phone: 435-554-6331*
[2] *Masters student, Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology(BUET)*
[3] *Masters student, Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology(BUET)*
[4] *Part-time Lecturer, Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology (BUET)*

of risk for a moderate to heavy tremor. Considering this issue, this study attempts to investigate the earthquake vulnerability of a ward (ward no 37) with detailed physical and social attributes of the locality. This study would be helpful to formulate specific measures and preparedness to minimize the disastrous effect.

Methodology of the study

Study Area

The study area for the research is Ward no. 37 (old ward no 73), located within the jurisdiction of DSCC. Islampur, Patuatuli, Shimson Road, Kumartuli Lane, G.L Shaha Lane, Kobiraj Lane, Ahsanullah Road, Liakat Avenue, Waise Ghat, Ramakanta nandi lane, Loyal Street, Bangla Bazar, Chittaranjan Avenue are located in Ward 37.

There are a number of historical and other important buildings and sites in this ward. Some sites are considered as heritage sites. Some mentionable sites are- Gol Talab, Ahsan Manzil, Pogose School, Jagannath University, Rammohan Roy Library, Brahma Samaj, Bahadur Shah Park, Sadar Ghat, Bulbul Academy of Fine Arts (BAFA) etc. Plot demarcations are arbitrary in this ward like other areas of old Dhaka. Roads are narrow, the width varying from 8’ to 15’. Most of the buildings are of mixed used. There are chemical storages in many buildings.

Data Processing and Analysis

The study has been conducted using some sequential steps. The steps are shown in figure 01.

For assessing earthquake vulnerability, five parameters have been chosen: 1) Building form, 2) Gap between adjacent buildings, 3) Distance of buildings from disaster shelter, 4) Width of road fronting the building (required for emergency vehicles’ access) and 5) Population concentration. These parameters have been chosen based on national and international studies and standards for building safety in order to minimize earthquake vulnerability. The GIS data base for wards of DSCC has been collected from DSCC. The data base contained layers named buildings, roads, educational institutes, and population density.

According to Bangladesh National Building Code (BNBC) (Gazette Amendment, 2008), ideal width of access road for the building needs to be 12 feet or above for giving access to emergency vehicles and safe movement. BNBC prefers any access road to be minimum 6 meters wide for any upcoming development for Dhaka. But in concerning study area, as the generic development of the structures left little space for vehicular access, this study considers extreme scenario of a disaster and considers if a single line of emergency vehicles can access the buildings in the study area. Form and shape of building is another important parameter for assessing vulnerability and irregular shaped buildings are more susceptible to earthquake risk (Murty, Goswami, Vijayanarayanan, & Mehta, 2012). Population concentration is significant in disaster vulnerability assessment (Pelling & Uitto, 2001). Building to building distance is another issue which is to be maintained between adjacent buildings to avoid pounding effect (Lin, 1997). Schools and educational institutes are widely used as post-disaster shelter worldwide and hence distance from these shelters is of paramount importance (Governor's Office of Emergency Services, 1995). For these parameters, category as high and low vulnerability have been assessed for buildings.

ArcGIS has been used for data processing and analysis regarding earthquake vulnerability using these parameters. For primary processing of data, Measure tool, Select by Location Tool have been used mainly. After primary processing and extracting data for ward 37, buildings have been reclassified having as 1) High vulnerability and 2) Low vulnerability based on the values assigned for each parameter as shown in Table 01. For each parameter, individual maps have been generated showing low and highly vulnerable buildings.

Table 1. Classification of the parameter for earthquake vulnerability of buildings

Parameters	Types	Vulnerability	Rank
Building form	Irregular	High	1
	Regular	Low	2
Gap between adjacent buildings	Less than 5 ft	High	1
	5 feet or above	Low	2

Distance of buildings from disaster shelter	0.5 km or above	High	1
	Within 0.5 km	Low	2
Width of road fronting the building (required for emergency vehicles' access)	Less than 12 ft	High	1
	12 ft or above	Low	2
Population concentration	Above 100	High	1
	Up to 100	Low	2

Then the linear combination method (Eq. 1) has been used to identify the vulnerability level of the buildings using all the parameters in GIS. All parameters have been assigned equal influence for the arithmetic overlay.
LC = $\sum_{n=1}^{5}(V_n)$……………………………………………………………………………………Eq. 1
LC = Linear combination
V_n= Value for n^{th} parameter
n = Number of parameters
The map was further scaled into qualitative information (using equal interval method) as vulnerability level of high, medium and low.

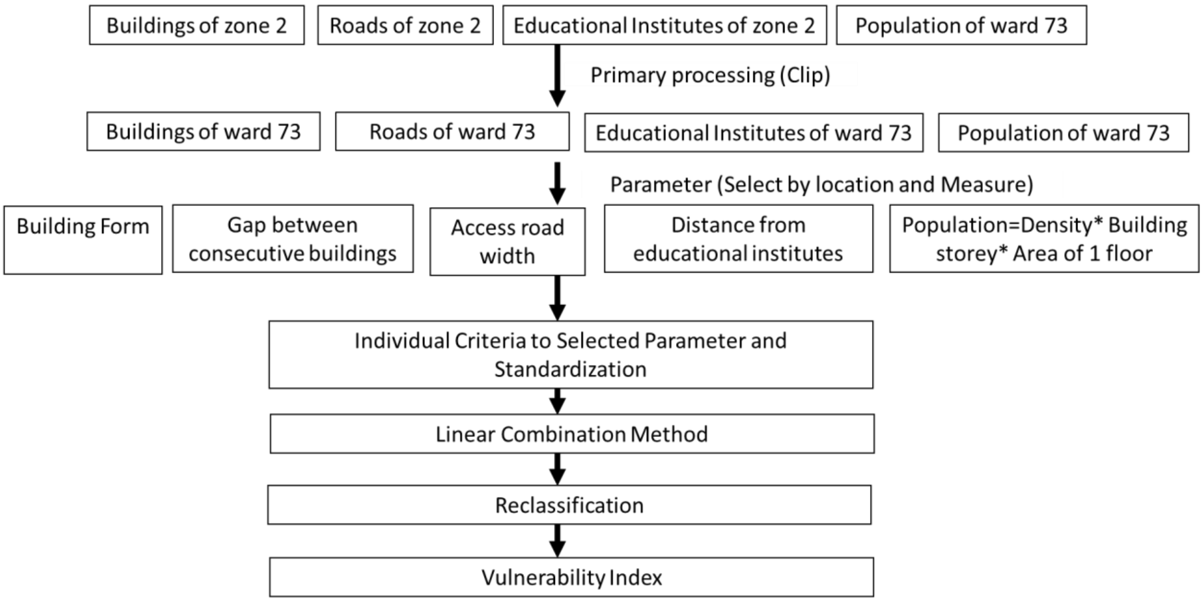


Figure 1. The GIS-based approach for assessing vulnerability assessment of buildings of Ward 37.

Result and Discussion

The result of the study shows a relatively small number of highly vulnerable buildings in the study area and an alarmingly large number of medium vulnerable buildings. This medium vulnerability of buildings indicates these buildings are susceptible to risk in numbers of risk factors, which can escalate the magnitude of a potential disaster in property and human loss. Individual risk factors are analyzed based upon five parameters that are set at first, and individual vulnerability maps according to respective parameter are generated. Finally, all these parameters are combined, and a vulnerability map is prepared for the Ward 37.

Figure 2. Vulnerability according to building form

Figure 3.Vulnerability according to distance from building.

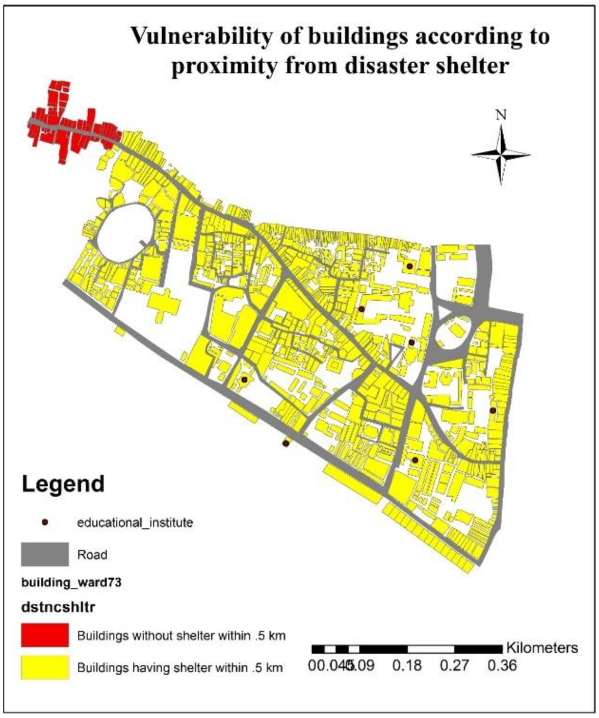


Figure 4. Vulnerability of buildings according to proximity from shelter.

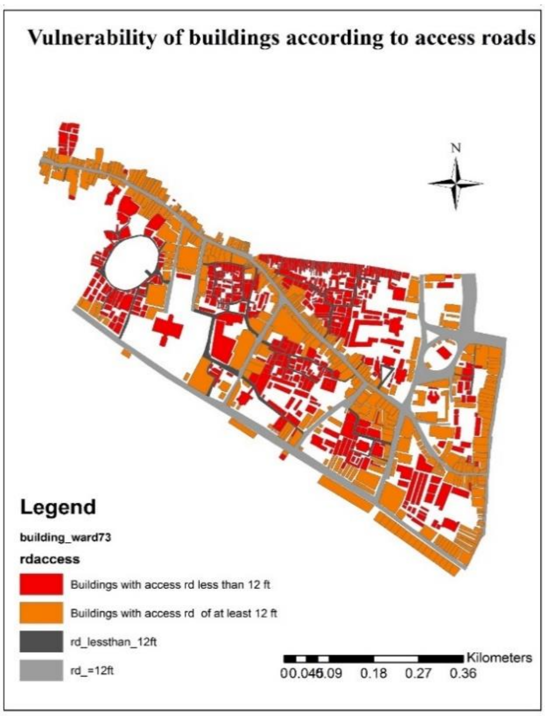
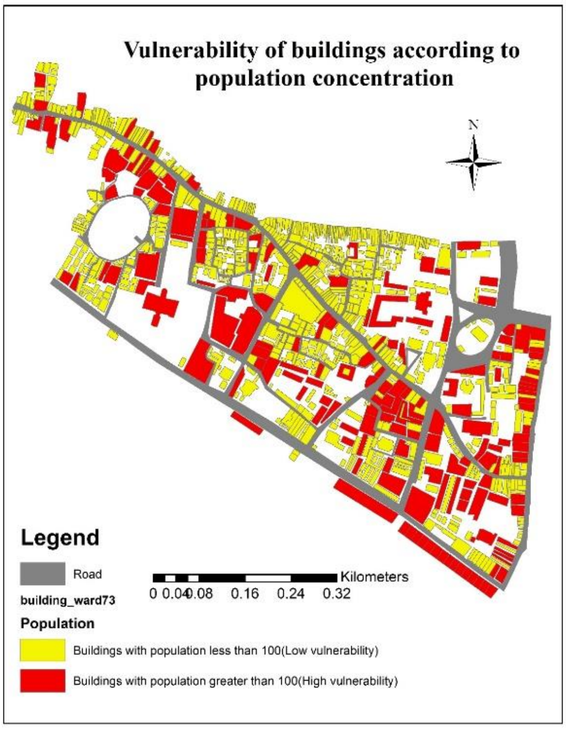


Figure 5. Vulnerability of buildings according to width of access roads.



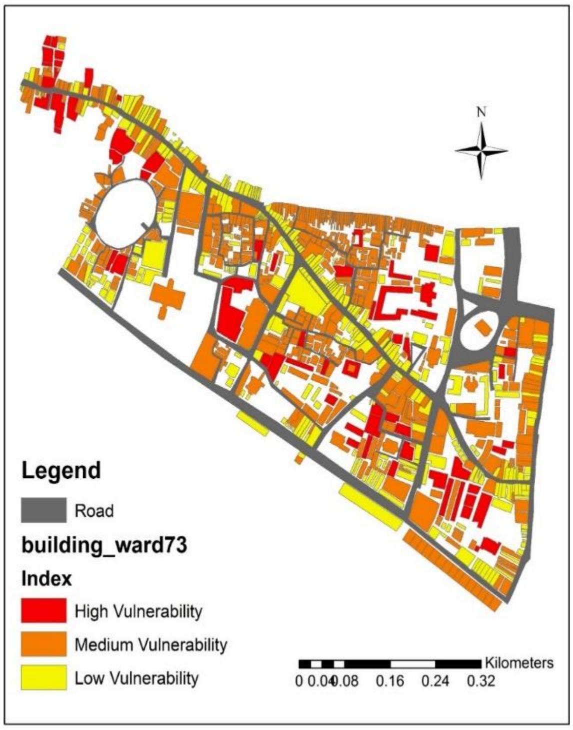


Figure 6. Vulnerability of buildings according to population concertation

Figure 7. Vulnerability of buildings

Figure 7 shows the vulnerability map encompassing all the parameters. Figure 2,3,4,5,6 show the vulnerability map based on building form, distance between adjacent buildings, proximity from access shelters, width of access road and population concentration respectively.

Irregular form of buildings is susceptible to increased risk. Analyzing this parameter, approximately 57% buildings are in irregular shape in the study area and around 43% are in regular shape. Building to building distance standard was considered to be 5 feet, according to the preferred setback in maximum cases, regulated by BNBC and Dhaka Metropolitan Building Code, which is officially referred as DMINB- Dhaka Mahanagar Imarat Nirman Bidhimala (Ministry of Housing and Public Works(MoHPW), 2008). In the study, the percentage of buildings having less than 5 feet in between them is 91.35%, while buildings having more than 5 feet in between are 8.71%. It is evident that most of the buildings are highly congested in this area and poses a serious threat to the users in case of emergency. Only 6.23% buildings are situated without having any shelter within the distance of 0.5 km. Percentage of buildings having shelter within 0.5 km is 93.83%. Regarding this parameter, most of the users in this area can find disaster shelters near to them. The study has considered minimum 12 feet width for the access road of buildings to be minimally taken as less vulnerable, as emergency vehicles may merely access the building as single line. Buildings having access roads less than 12 feet in width are 54.1% and buildings having at least 12 feet wide access road are 45.9%. Again, majority of the buildings in the study area will not be able to be accessed by the emergency response vehicles and the victims would experience increased level of vulnerability. The fifth parameter considered is the number of users per building. 81.72% buildings are with population less than 100, and 18.27% buildings are with population more than 100. In this case, fewer buildings are considered to have increased vulnerability.

Recommendation and Conclusion

In 2004, Rajdhani Unnayan Kartripakkha (RAJUK) identified 321 buildings in the capital as riskiest (Observer, 2015). RAJUK also mentioned that at least 72000 buildings that are built violating the BNBC regulations are at grave risk of earthquake collapse (Observer, 2015). The concerned authorities are yet to take any steps for their preservation, removal, and repair. In this situation, devastating aftermath might follow any disaster in old Dhaka. There is an Earthquake Contingency Plan of City Corporation. But no policy or plan will work if numbers of core problems remain, like- violating building acts and regulations, absence of proper accessibility at roads and streets, or residential buildings being used for storing hazardous chemicals, etc. Department of Disaster Management (DDM) mentions unplanned urban development as one of the major causes of increased vulnerabilities in Bangladesh (DDM, 2015). It emphasizes on determining the level of risk and vulnerability in urban setting, as well as ensuring the establishment of the BNBC in building practices in order to mitigate risk factors (DDM, 2015). This study shows a comprehensive way to determine vulnerability in a small unit of the city, that can be recreated for the rest. This would help to develop a central vulnerability scenario that can eventually help identify the prioritized issues, fields and areas to be addressed. Retrofitting and redevelopment can be adopted in the areas where development has already taken place. In case of new developments, Building Code and Act should be followed to minimize the vulnerability. As this recommendation is already present in several govt. regulations, in order to make it into reality, temporally defined action plans should be developed and put in operation on different levels of administrative authorities and boundaries. As seen from experience in Bangladesh, bureaucratic indisposition and sloth, administrative reluctance and official tendency of evaluation with only budgetary numbers, may lead to ineffective results of authoritative action plans (Benson & Clay, 2002). Research work might be incorporated within various levels of such implementation of actions plans, in order to ensure positive impact in disaster vulnerability mitigation. In such action plans, proper planning and due implementation as well as multidisciplinary technical solutions should be adapted to minimize existing risk and to ensure a safer scenario in future. Minimum road width should be ensured for all future developments strictly in accordance with the regulations of BNBC, in order to ensure access of emergency response team, vehicles etc. In case of already existing developments, alternative measures should be taken for emergency response, such as provision for emergency response equipment, volunteer teams from local population trained to use such equipment etc. Accessibility to disaster shelters needs to be ensured for all. Buildings of public functions might be used as emergency shelters. Such disaster shelter accessibility schemes should include consideration of zone-wise population density, and reach-out programs for the mass to ensure awareness. Regular assessment of disaster resilience of the social entities and participatory programs for its development should be ensured within the framework of zone-wise action plans and implementation.

The findings of this study could benefit the concerned authorities giving a perspective about earthquake vulnerability at micro level and formulate strategies for mitigating earthquake vulnerability. However, the study has its limitations. Detailed research should include data on floor heights of all buildings to check the floor height level variations in between adjacent buildings. Weightage of parameters have been considered equal in the study which can vary based on the context. Building wise population concentration was unavailable. Building specific population data can help depict a precise scenario. Data for floor levels of buildings was unavailable in case of some buildings.

References

Benson, C., & Clay, E. (2002). Bangladesh, Disaster and Public Finance, Disaster Risk Management - Working Paper Series no. 6. Washington, D.C.: The World Bank.

Bhuiyan, B. K. (2010). Urban earthquake hazard: perceived seismic risk and preparedness in Dhaka city, Bangladesh. *Journal compilation © Overseas Development Institute*,, 337-359.

DCC. (2009). Earthquake Contingency Plan for Dhaka City Corporation (DCC). Dhaka: DCC.

DDM. (2015). Ministry of disaster management and relief: Disaster Management Program-2. Dhaka: Department of Disaster Management.

Debnath, R. (2013). An assessment of spatio-temporal pattern of urban earthquake vulnerability using GIS: a study. *Annals of GIS*, 63-78.

Governor's Office of Emergency Services. (1995). *Schools as Post Disaster Shelters.* California: Governor's Office of Emergency Services, State of California, USA.

HBRI. (2006). Bangladesh National Building Code. Dhaka.

Lin, J.-H. (1997). Separation Distance to Avoid Seismic Pounding of Adjacent Buildings. *Earthquake Engineering & Structural Dynamics*, 395-403.

MoHPW, G. (2008). Dhaka Mahanagar Imarat Nirman Bidhimala. In G. Ministry of Housing & Public Works, *Bangladesh National Building Code* (p. 3031). Dhaka.

Murty, Goswami, Vijayanarayanan, & Mehta. (2012). *Some Concepts in Earthquake Behavior of Buildings.* Gujarat: Gujarat State Disaster Management Authority.

Observer, M. K.-T. (2015, May 4). *http://www.observerbd.com/2015/05/04/86910.php*. Retrieved from http://www.observerbd.com: http://www.observerbd.com/2015/05/04/86910.php

Pelling, M., & Uitto, J. I. (2001). Small island developing states: natural disaster vulnerability and global change. *Environmental Hazards*, 49-62.

PUBLIC PERCEPTION OF LIGHTNING RISK IN MOULVIBAZAR DISTRICT OF BANGLADESH

Md. Masud Rana[1]

ABSTRACT

Bangladesh is one of the major lightning prone countries in the Indian subcontinent with the maximum flash rate density of 72 flashes km-2 year-1 that constituting more than 25% of total causalities in Bangladesh. The objective of the study is to explore the public knowledge, cognition and responsive behavior in the lightning hazard. This study used qualitative methods and the primary data were collected through face-to-face interviews from respondents by using a questionnaire applying the random sampling method. Public understanding, cognition, and response to the lightning hazard are not good enough to mitigate the impact of lightning and must be improved in Moulvibazar district of Bangladesh. Low literacy rate, lack of adequate knowledge, religious orthodoxy, taking lightning as a normal phenomenon are the main reason behind that low level of knowledge. Taking incorrect measures during the lightning, poor knowledge about first aid treatment, unsafe building structures, unavailability of training and workshop also increase the deaths and injuries rate more. This study can avail in formulating public policies on lightning hazard and public safety to deal with lightning.

Introduction

Lightning is a large electrical discharge develops because of the collisions between tiny ice particles within thunderclouds that flows between clouds, from cloud to air or from cloud to the ground (Lightning, 2018). About 90% lightning strikes occur from cloud to cloud where 10-30% of lightning can be cloud to ground (Hasan et al. 2017) that cause damages of properties and losses of lives. More than 100 lightning strikes the earth every second that is about 8 million per day and 3 billion each year (Biswas et al. 2016). Romps et al. (2014) estimate that lightning strikes relatively increase about 1% in every 2 years due to global warming. Increasing the number of huge populations and deforestation also triggering factors of increasing lightning frequency. Various studies estimate that the global annual lightning fatalities range from 6,000 to 24,000 per year where maximum death tolls reported in developing countries (Dewan, et al., 2017, cited in Cardoso et al. 2014; Gomes and Ab Kadir 2011). The Indian subcontinent is the most lightning rich area on earth where on average 64,566,091 strokes per year reported by GLD360 (Nag et al. 2017). Bangladesh is one of the major lightning-prone regions in the Indian subcontinent because of its orography and local meteorological factors (Siingh, et al. 2014). The maximum flash rate density of Bangladesh is 72 flash km-2 year-1 (Dewan, et al., 2017). Different studies show that industrialization, rapid urban growth, deforestation, and population growth are leading to increasing lightning flashes (Siingh, et al. 2014; Dewan, et al., 2017). Increase in the population of Bangladesh from 107 million in 1990 to 163 million in 2016, at a growth rate of 2% per year with the 52% change, resulted in many people are exposed to the lightning threat (Holle, et al. 2018). Trees are electricity resistant and they can absorb lightning strikes. But voluminous deforestation is increasing the lightning strikes as Bangladesh losses 0.18% of its forests annually (Dhaka Tribune, 2016). Dewan et al. (2017) showed that, increase in cellular phone subscribers from 87 million in January 2012 to 128 million in July 2016 with a growth of 10% per year and 47% in less than five years in the country reporting lightning casualties. Mashreky et al. (2012) assume that more than 25% of total causality in Bangladesh constituted by lightning. Bangladesh government declared lightning as a natural disaster considering massive death tolls in 12^{th} and 13^{th} July of 2016 (Dewan, et al., 2017). Considering from 2010 to 2017, Holle, et al (2018) estimated that, 260 fatalities and 211 injuries per year while fatality rate of 2.08 per million people per year and injury rate of 1.7 in Bangladesh.

Risk perception refers to people's judgments and evaluations of hazards they are exposed to and that governs the decisions about the acceptability of risk and influence on behaviors before, during and after a disaster (Rohrmann, 2008). It is necessary to understand how people living in places at risk perceive hazard, risk and their knowledge about the hazard in order to mitigate the impacts of it. (Alam E., 2016). As there is no such study has been conducted on public perception on lightning risk, this study aims to explore the people's understanding, cognition and response to lightning risk and tries to assess the indigenous measures adopted

[1]Undergrad Student, Department of Disaster and Human Security Management, Bangladesh University of Professionals, Mirpur Cantonment, Dhaka-1216, Bangladesh.
E-mail: masudrana1076.mr@gmail.com

by the respondents in against of lightning.

Methodology

The study has used both secondary and primary sources of data and information for the analysis of lightning risk perception. Secondary sources of data were collected to understand the overall picture of lightning risk from articles, reports, online databases, and statistical records. To gain a deeper understanding regarding the lightning risk of Moulvibazar district, only qualitative methods were used in this study. The primary data were collected through face-to-face interviews from respondents by a questionnaire based on several questions related to lightning risk (including demography, the perception of lightning risk, adapting response and way forward). The questionnaire was carried out by interview of residents of Moulvibazar district to assess the public's knowledge, cognition and response to the lightning hazard. The sample size was 50 and randomly composed including samples from different occupations.

Study Area

Moulvibazar district is situated between 24.10-degree to 24.35-degree N latitudes and 90.35-degree to 91.20-degree E longitudes. The total area of Moulvibazar district is 2799 km2 and the population density is 690/km2 (BBS, 2011). The topography is portrayed by a unique combination of the hill, plain land, forest, and haors. The fatality rate of lightning is the highest in Moulvibazar district and that is 4.47 per million people per year along with highest injury rates in Bangladesh (Holle, et al. 2018) that desperately influence to select this as the study area.
Demographic Profiles
The male respondents of the interview were about doubled (64%) than female respondents (36%) where 66% of the respondents were married and 34% were unmarried. The average household size of the respondents was 7.

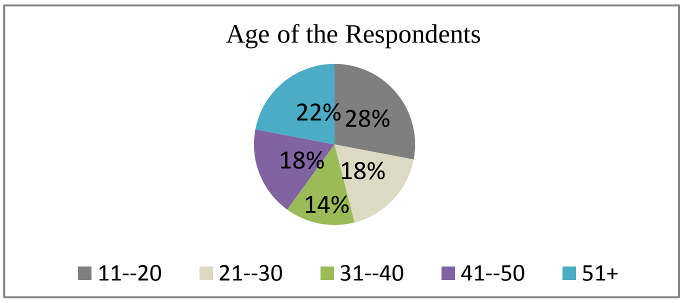


Chart 1: Age of the Respondents

Chart 1 shows the respondents were categorized based on their age groups. Five age groups were made which include 11-20, 21-30, 31-40, 41-50 and above 50 years. About 29% within 11-20, 14% within 21-30, 19% within 31-40, 15% within 41-50 and other 23% are above 51 years old. The average age of the respondents was 36 where aging 10 and 39 have the maximum death and males are reported highest fatalities (Dewan et al., 2017).

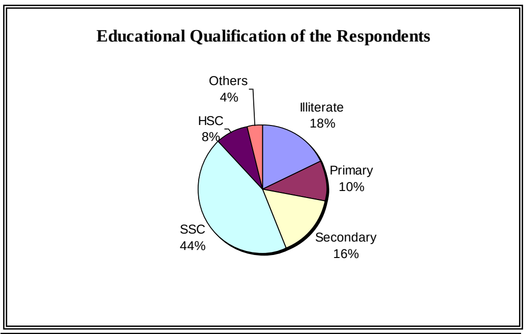


Chart 2: Educational Qualification of the Respondents

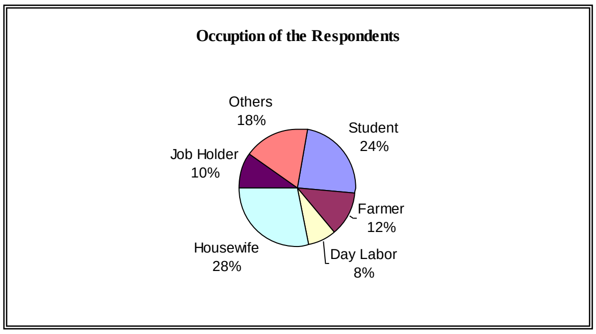


Chart 3: Occupation of the Respondents

According to chart 2, almost half of the respondents (44%) were SSC passed where illiterate was 18%. 16% were secondary level, 10% were primary level, HSC passed 8% and others were 4%.
Chart 3 represents that, 28% of respondents were the housewife while 24% were students, 12% farmers, 10% job holders, 8%-day labors and 18% others.

Results and Discussions

There are limited understanding and misunderstanding about the knowledge of lightning among the respondents. With regard to lightning hazard, 22% respondents replied lightning is "Oppression of God", 16% said "collision of cloud", "dangerous phenomenon" (12%), "flow of electric charge" (10%) (Jayaratne and Gomes, 2012), "awful loud sound" (10%), "rain" (8%), "others" (8%) and 14% respondents "don't know" what is the lightning. Lack of adequate knowledge, low literacy rate, religious orthodoxy etc. are the main reasons behind limited knowledge about the lightning. About 24% respondents believe that the study area is very high risk in terms of lightning hazard where 16% reported it as high risk, 30% reported as moderate risk, 24% indicated as low risky and 6% reported as a very low-risk area about the lightning hazard. Though the death rate is very high in the study area, predominant misconception about lightning makes them feel as normal phenomenon.
In the response to what causes lightning, respondents replied with one or more feedbacks. A large portion of the respondents (34%) believe that lightning is the act of God and occurs due to bad deeds of people (Jayaratne and Gomes, 2012). 12% of respondents reported lightning caused by "Uproot of British poles". The combination of metal magnets of Mouja Border pillars installed by British rulers with brass, copper, iron, titanium produces the electric conductor during the thunderstorm and it absorbs lightning by the pillars directly and works of earthing. The disappearance of that Mouja Border pillars recently increased the rate of lightning intensities and casualties (Siddiqui, 2018). Respondents also reported "Collision of cloud" (10%), "Deforestation" (10%), (Chowdhury, et al. 2017) "Climate change" (8%), "Rise of Temperature" (8%) (Romps et al. 2014) "Others" (16%) and 16% claimed that they don't know the reasons for lightning.
In the question about the lightning effects, most of the respondents replied with multiple feedbacks. 62% replied lightning cause "cattle death and injury", 58% replied it cause "human death", "damage trees" (56%), "human injury" 40%, "damage households" 26%, "damage crops" 16% and others effect of lightning mentioned by 16% respondents. Labor-intensive agriculture, lack of readily available fully enclosed metal-topped vehicles, unsafe dwellings, unavailability of lightning arrestors in the rural area, work in lightning unsafe structures, low literacy rate, inadequate understanding of lightning and poor knowledge of fundamental first-aid principles are the main contributing factors to lightning death and injuries. (Gomes, et al. 2006; Holle, R.L., 2016; Chowdhury, et al. 2017; Holle, et al. 2018; cited in Gomes and Ab Kadir, 2011; Raga et al., 2014). Reluctant to stop activities in firm land and ignorance of lightning guidelines are also responsible for causing lightning injuries and deaths (Jayaratne and Gomes, 2012).
Emergency responses behaviors of interviewees are explored when they stay indoors and outdoors during the lightning.

Table 1. When you were outside during lightning, what measures did you take?

Measures	Number of Mentions	Percentages of Mentions (%)
Go inside any strong enclosed building	9	18
Go Inside House	14	28
Don't do anything	7	14
Make prayer	11	22
Avoid high place	5	10
Go under trees	4	8
Avoid Water	5	10
Stay low	10	20

Table 1 shows that respondents take both correct and incorrect measures during the lightning when they stay outside. Go inside house (28%), stay low (20%), go inside substantially built enclosed building (18%), avoid high place (10%) and avoid water (10%) are the correct measures where make prayer (22%), don't do anything (14%) and go under trees (8%) are the incorrect measures taken by the respondents.

Table 2. When you were inside during lightning, what measures did you take?

Measures	Number of Mentions	Percentages of Mentions (%)
Make Prayer	9	18

Nothing	19	38
Shut down doors and windows	5	10
Switch off the electric stuff	7	14
Maintain gap	5	10
Go under bed or table	12	24
Go outside	2	4
Avoid phone	3	6
Avoid metal equipment	1	2

Table 2 shows that, a significant number of respondents (38%) don't take any measures when they stay inside during the lightning, make prayer (18%), and go outside (4%) are also the incorrect measures where shut down doors and windows (10%), switch off the electric stuff (14%), go under bed or table (24%), maintain gap (10%), avoid the phone (6%) and avoid metal equipment (2%) are the correct measures taken by the respondents.

In terms of emergency response to the lightning; fear of the loud sound of thunder, past news of deaths and injuries encourage respondents to take shelter in a relatively safe place where unavailability of adequate substantially built structure in the fields, lack of proper knowledge and taking lightning as a normal phenomenon make them reluctant to take any measures. When they are inside, they feel they are safe enough though there are very high chances of causing serious injuries even deaths as well because of most of the housing structures vulnerable to the lightning hazard.

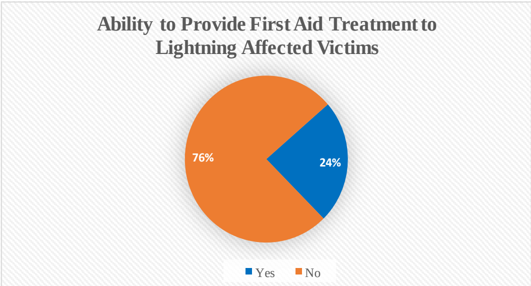


Chart 4: Respondent's Ability to Provide First Aid Treatment to Lightning Affected

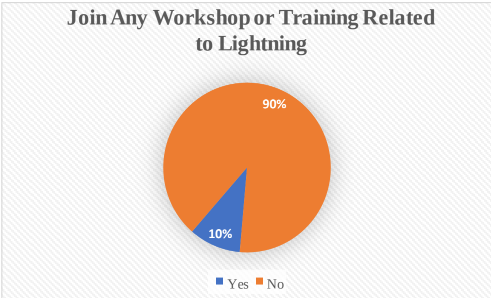


Chart 5: Respondents Joining Status in Training or Workshop

Chart 4 shows that a significant portion of respondents (76%) can't provide the first aid treatment for lightning affected victims. There are 24% respondents claims that, they can provide the first aid treatment of the lightning affected victims but most of them (67%) use the traditional method of treatment that can cause harm to the victims in most of the cases like use of herbal oils on the wounds and message it to the bodies for blood circulation, use of cold water, egg, onion juice on wounds. Only 33% of respondents can provide the proper treatment including hands-only Cardiopulmonary Resuscitation (CPR). Low literacy rate, minimum government engagement to prepare the people for lightning hazard and communication gaps are the main reason behind that inability of people to provide first aid treatment.

Chart 5 displays that, 90% of respondents didn't attend any training or workshop related to lightning safety in their lifetime because of unavailability of those opportunities where only 10% of respondents attended the training or workshop. Because 78% of respondents don't know either any organizations, agencies working or not about the lightning safety in their area while 12% replied working and another 10% replied no.

Also, 90% respondent's house doesn't have any protection system to resist the lightning where only 10% have that system. And among that 10%, only 10% have the lightning resistant building and 90% use the earthing protection system to allow to pass the electric current to the ground.

When the respondents asked to recommend for lightning safety, 54% respondents replied they don't have any idea about lightning safety and can't provide any recommendations. 28% respondents recommend to aware the mass people, 14% recommend building lightning resistant buildings, 10% suggest providing training or workshop, 8% point out about the inclusion lightning in the textbooks and 4% aims to early warning for the lightning hazard.

Misunderstanding about the lightning basic, religious orthodoxy, unawareness about the causes of lightning, misconception about the effects, unavailability of adequate substantially-built enclosed structures, improper measures during lightning, very poor knowledge of first aid treatment to lightning affected victims, unavailability of adequate training or workshop, unsafe building structures create the lightning hazard more dangerous in the study area and increase the vulnerability of lightning-related deaths and injuries.

Conclusions

The public knowledge, cognition and responsive behavior on the lightning hazard are not up to the mark and their knowledge on basic and emergency response must be improved as labor-intensive agriculture, lack of proper knowledge, lack of safe structures, poor knowledge about first-aid treatment cause more deaths and injuries. Though floods and cyclones cause extensive damage but natural hazards like lightning receive inconsiderable attention (Dewan et al. 2017; cited in Ono and Schmidlin 2011). This study can be one of the important contributors to formulating public policies on lightning hazard and public safety to deal with lightning. Policymakers should come forward to take necessary steps about this newly introduced disaster in Bangladesh and to increase the awareness level of people to respond properly in against of lightning to mitigate the impact of it. Raising awareness, arranges adequate training and workshop for basic knowledge to protect lives and properties along with various structural measures like build lightning resistant buildings and insurance allowance for that can bring a significant change in the study area to mitigate the impact of the lightning hazard. This study also recommends further broad research considering the whole country about to explore the public perception of lightning risk.

Acknowledgments

I would like to acknowledge with gratitude to Md. Rifat Hossain, Lecturer, and Jahedul Huq, Assistant Professor, Department of Disaster and Human Security Management, Bangladesh University of professionals for their worthy support to conduct this study.

References

Alam, E., (2016). Earthquake and tsunami knowledge, risk perception and preparedness in the SE Bangladesh. Journal of Geography and Natural Disasters, 6(154), pp.2167-0587.

BBS, (2011). *District Statistics 2011 Moulvibazar*. Viewed on 22 October 2018, http://203.112.218.65:8008/WebTestApplication/userfiles/Image/District%20Statistics/Moulvibazar.pdf.

Biswas, A., Dalal, K., Hossain, J., Baset, K.U., Rahman, F., and Mashreky, S.R., (2016*). Lightning Injury is a disaster in Bangladesh?-Exploring its magnitude and public health needs.* F1000Research, 5.

Chowdhury, M.J., Chowdhury, S.R. and Mahmood, J., (2017). *Design of Lightning Arresters for Country Boats and Rural Houses in Bangladesh.* International Journal of Science and Engineering Investigations, 6(61), pp. 167-171.

Dewan, A., Hossain, M.F., Rahman, M.M., Yamane, Y. and Holle, R.L., (2017). *Recent lightning-related fatalities and injuries in Bangladesh.* Weather, climate, and society, 9(3), pp.575-589.

Dewan, A., Ongee, E.T., Rahman, M.M., Mahmood, R., and Yamane, Y., (2017). *Spatial and temporal analysis of a 17-year lightning climatology over Bangladesh with LIS data.* Theoretical and Applied Climatology, 134(1-2), pp.347-362.

Dhaka Tribune, (2016) *Bangladesh's deforestation rate at 0.18%*, viewed on 19 October 2018, < https://www.dhakatribune.com/uncategorized/2016/02/22/bangladeshs-deforestation-rate-at-0-18-2>

Gomes, C., Ahmed, M., Abeysinghe, K.R. and Hussain, F., (2006). *Lightning accidents and awareness in South Asia: experience in Sri Lanka and Bangladesh.* In Proceedings of the 28th International Conference on Lightning Protection (ICLP), Kanasawa, Japan.

Hasan, R., Islam, M.M., Nooruzzaman, A.R.M., Ahmed, M., Halim, M.R., Bhuiyan, M.M.R., Rahman, M.M., Ahmed, K.N. and Roy, T.C., (2017). *Lightning Injury*. Bangladesh Critical Care Journal, 5(2), pp.132-134.

Holle, R.L., (2016). *Lightning-caused deaths and injuries related to agriculture*. In Preprints of the 33rd international conference on lightning protection, Estoril (pp. 25-30).

Holle, R.L., Dewan, A., Mohammad, S., Karim, M.R. and Hosain, M.F., (2018). *Lightning Fatalities and Injuries in Bangladesh from 1990 through 2017.*

Jayaratne, K.C. and Gomes, C., (2012). *Public perceptions and lightning safety education in Sri Lanka.* In Lightning Protection (ICLP), 2012 International Conference on (pp. 1-7). IEEE.

Lightning (2018). viewed on 15 October 2018, <https://www.metoffice.gov.uk/learning/storms/thunder-and-lightning/lightning>

Mashreky, S.R., Hossain, M.J., Rahman, A., Biswas, A., Khan, T.F. and Rahman, F., (2012). *Epidemiology of electrical injury: Findings from a community based national survey in Bangladesh*. Injury, 43(1), pp.113-116.

Nag, A., Holle, R.L. and Murphy, M.J., (2017). *Cloud-to-ground lightning over the Indian subcontinent*. In Postprints of the 8th conference on the meteorological applications of lightning data. American Meteorological Society, Seattle/Washington (pp. 22-26).

Rohrmann, B., (2008). *Risk perception, risk attitude, risk communication, risk management: A conceptual appraisal*. In Conferencia presentada en la Sociedad Internacional de Gerenciamiento de Emergencias.

Romps, D.M., Seeley, J.T., Vollaro, D. and Molinari, J., (2014). *Projected increase in lightning strikes in the United States due to global warming.* Science, 346(6211), pp.851-854.

Siddiqui, M S (2018). *Why deaths from lightning increasing,* Daily Asian Age, viewed on 22 October 2018, <https://dailyasianage.com/news/119977/why-deaths-from-lightning-increasing>.

Siingh, D., Buchunde, P.S., Singh, R.P., Nath, A., Kumar, S. and Ghodpage, R.N., (2014). Lightning and convective rain study in different parts of India. Atmospheric research, 137, pp.35-48.

ASSESSMENT OF FLOOD RISK OF SECONDARY TOWN IN BANGLADESH: A CASE STUDY OF CHHATAK POURASHAVA

Farzana Afroz[1] and Mohammad Atikul Islam[2]

ABSTRACT

The impact of the seasonal flood is very severe at many secondary towns in Bangladesh. Considering that, the principle goal of this study is to assess the flood Risk of secondary town in Bangladesh. Chhatak Pourashava has been taken as a case study which is located in Sunamganj district, one of the main flash flood-prone areas. To achieve this goal, at first identify the existing land use and flood risk based on the GIS contour data. Then the area has been broadly classified into short-term return flood affected area, mid-term return flood affected area and long-term return flood affected area depending on the flood risk and water level of different return period of the flood. Finally, the analysis reveals that total 448.53 (93%) acre agriculture areas will be affected by short term return flood. Long term return flood will affect 78.82% agricultural use followed by the 60.72 acres (6.6%) residential area, manufacturing and processing activity covers 48.44 acres (5.32%) area. Mid-term return flood will affect maximum 89.7% area in agriculture use where 3.98% manufacturing and processing activity use and 3.16% area in residential use. The appropriate measures of disaster management in urban planning will reduce its vulnerability of different disasters to make the secondary town of Bangladesh more sustainable.

Introduction

Floods are annual phenomena with the severe occurring during the months of July and August. Seasonal flood is a very common and familiar phenomenon of Sunamganj Upazila under Sunamganj district (CDMP, 2014). It is same for Chhatak Pourashava, the secondary town of Sunamganj district. In the rainy season, flood is occurred in this area due to heavy rainfall and upstream water from Meghalaya Hill. It damages in the sector of agriculture, fishery, livestock, infrastructure, homes, education, health, trees etc. Though it occurs every year, a seasonal flood of 2004 and 2012 were devastating (CDMP, 2014). In the flood of 2006, about 91 % of households were affected by flood at Chhatak Pourashava. Most of these affected households lost crops. Total 31.51 % lost crops valuing up to Tk10000, followed by 42.37% up to 20000. Total 27.12 % people lost their crop valuing more than Tk. 20000 (UTIDP, 2010). In future, flash flood may happen frequently due to climate change which can be severe for secondary cities. Agriculture sector may have huge damage from this. It may have a negative impact on the livelihood of the people. Bangladesh tries to live with flood as well as other disasters with structural and non-structural measures. So, it is crucial need to know the flood risk for reducing the damages. Considering that, this study aims to assess the flood Risk of Chhatak Pourashava, one of the flood-prone secondary towns in Bangladesh. It will assist to ensure urban resilience and reduce the vulnerability of this Pourashava.

Methodology

Different impacts of the flood have been prepared based on the contour data of Chhatak Pourashava and the flood level data (highest water level) of the different time period in Sunamganj Station at Surma River as Surma River is passing through the Chhatak Pourashava and Sunamganj Station is the nearest station on this river from the study area. Recorded maximum flood level 9.46 m (Flood Response Preparedness Plan of Bangladesh, 2014) is considered as long term return flood level (for 100 years return); the flood level of 1988 is 9.03 m considered as mid-term return flood level and the flood level of 1998 is 8.90 m considered as short-term return flood level for the analysis of flood affected area.

Analysis and Findings

Depending on the water level of different return period of flood the study area broadly classified flood affected area and flood free area. From the analysis, it is found that total 1419.31 acres land which is 45.86% total area of Chhatak Pourashava and its proposed extended area will affect by the long term return floods. The

[1]*Jr. Urban Planner, Sheltech Consultants (Pvt.) Ltd., Dhaka, Bangladesh.*
[2]*Manager, Sheltech Consultants (Pvt.) Ltd., Dhaka, Bangladesh.*
Email of Corresponding Author – farzana.mouurp29@gmail.com

midterm return flood will affect 26.03% area and short term return flood will affect 22.29% area of the study area. On the other hand, 64.60% area will be remained flood free during short term return flood, followed by midterm flood 60.86% and 41.02% in long term return flood. Table 1 and Figure 1, 2 illustrates the details.

Table 1. Flood Risk Scenario at Different Return Period Floods at Chhatak Pourashava and its proposed extended area

Flood Affected Area			**Flood Free Area**		
Type	**Area(acre)**	**%**	**Type**	**Area(acre)**	**%**
Short-term return	689.76	22.29	Short-term return	1999.10	64.60
Mid-term return	805.38	26.03	Mid-term	1883.48	60.86
Long-term	1419.31	45.86	Long-term return	1269.55	41.02
Main Flood Flow Channel	380.37	12.29			
Auxiliary Flood Channel	25.39	0.82			

Source: Calculated by Author, 2016 based on the GIS data of UTIDP, 2010 and flood level data from Flood Response Preparedness Plan of Bangladesh, 2014

In the case of existing land use, total 448.53-acre agriculture areas will be affected by short term return flood which is near to 93% of the total affected area of short term return flood. In case of long term return flood maximum affected area will be in agricultural use 78.82% followed by the 60.72 acres (6.6%) residential area, manufacturing, and processing activity will be covered by 48.44 acres (5.32%) area within the study area. In the case of mid-term return flood maximum, 89.7% affected area will be in agriculture land use. It will be followed by 3.98% manufacturing and processing activity use and 3.16% area will be in residential use. A detailed scenario is given in the following Table 2 and Figure 1 and 2.

Table 2. Flood Risk Scenario at Different Return Period of Floods on Existing Land Use

Existing Land Use	Short-term return flood		Mid-term return flood		Long-term return flood	
	Area (acre)	%	Area (acre)	%	Area (acre)	%
Agriculture	448.53	92.52	505.76	89.7	718.11	78.82
Circulation Network	1.31	0.27	2.06	0.37	10.52	1.16
Commercial Activity	0.09	0.02	0.101	0.01	1.28	0.14
Community Service	0	0	0.008	0	1.05	0.12
Education and Research	0.50	0.11	0.52	0.09	1.27	0.14
Governmental Services	0.28	0.06	0.55	0.1	4.36	0.48
Manufacturing and Processing Activity	11.69	2.41	22.44	3.98	48.44	5.32
Miscellaneous	0.05	0.01	0.16	0.03	0.66	0.07
Mixed Use	0.10	0.02	0.11	0.02	0.27	0.03
Recreational Facilities	0	0	0	0	0.51	0.06
Residential	13.03	2.69	17.83	3.16	60.72	6.66
Service Activity	0.0001	0	0.001	0	0.46	0.05
Urban Green Space	0.018	0	0.08	0.01	5.57	0.61
Vacant Land	2.23	0.46	5.73	0.83	37.26	4.09
Water body	6.95	1.43	8.48	1.5	20.60	2.26
Total	484.79	100	563.84	100	911.07	100

Source: Calculated by Author, 2016 based on the GIS data of UTIDP, 2010 and flood level data from Flood

Response Preparedness Plan of Bangladesh, 2014

The total length of road network in Chhatak Pourashava is 68.7180 km. Among them, 23.8650 km is katcha, 0.972 km semi-pucca and 43.8810 km pucca road (UTIDP, 2010). A mentionable number of roads are in thread of flood risk. Total 2058.98-meter road will be affected by short term return flood, 3107.1-meter road will be affected by mid-term flood and 13850.63-meter road will be affected by long term flood. Detailed scenario is given in Table 3.

Table 3. Type of Flood Risk on Existing Road of Chhatak Pourashava

Type	Short-term return flood		Mid-term return flood		Long-term return flood	
	Length (m)	%	Length (m)	%	Length (m)	%
Katcha Road	683.05	33.17	1250.49	40.25	5578.76	40.28
Pucca Road	1375.93	66.83	1856.52	59.75	8151.37	58.85
Semi pucca Road	0	0	0	0	120.5	0.87
Total	2058.98	100	3107.01	100	13850.63	100

Source: Calculated by Author, 2016 based on the GIS data of UTIDP, 2010 and flood level data from Flood Response Preparedness Plan of Bangladesh, 2014

Pourashava has 5730 structures which include 2350 katcha, 1671 pucca structure and rests 1704 semi pucca structures (UTIDP, 2010). Considering flood risk within the study area total 111structures will be affected by short term return flood, 173 structures were affected by mid-term return flood and in case of long-term return flood, 825 structures will be affected. Detailed scenario of type wise flood risk structure is given in Table 4.

Table 4: Type Wise Distribution of Flood Risk Structures

Type	Short-term return flood		Mid-term return flood		Long-term return flood	
	No.	%	No.	%	No.	%
Katcha	62	55.86	104	60.12	442	53.58
Pucca	22	19.82	33	19.08	197	23.88
Semi Pucca	27	24.32	36	20.81	186	22.55
Total	111	100	173	100	825	100

Source: Calculated by Author, 2016 based on the GIS data of UTIDP, 2010 and flood level data from Flood Response Preparedness Plan of Bangladesh, 2014

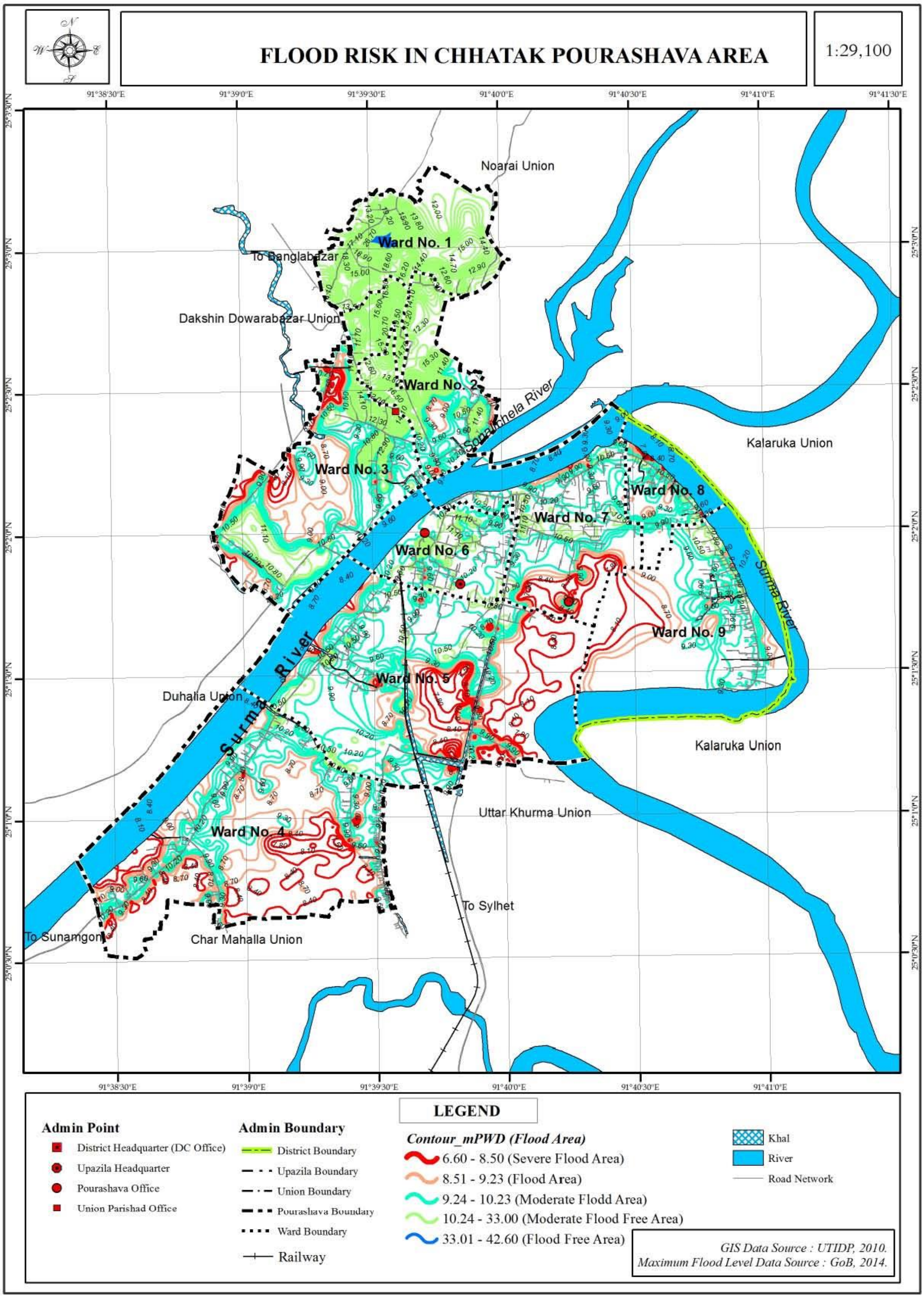


Figure 1. Flood Risk in Chhatak Pourashava

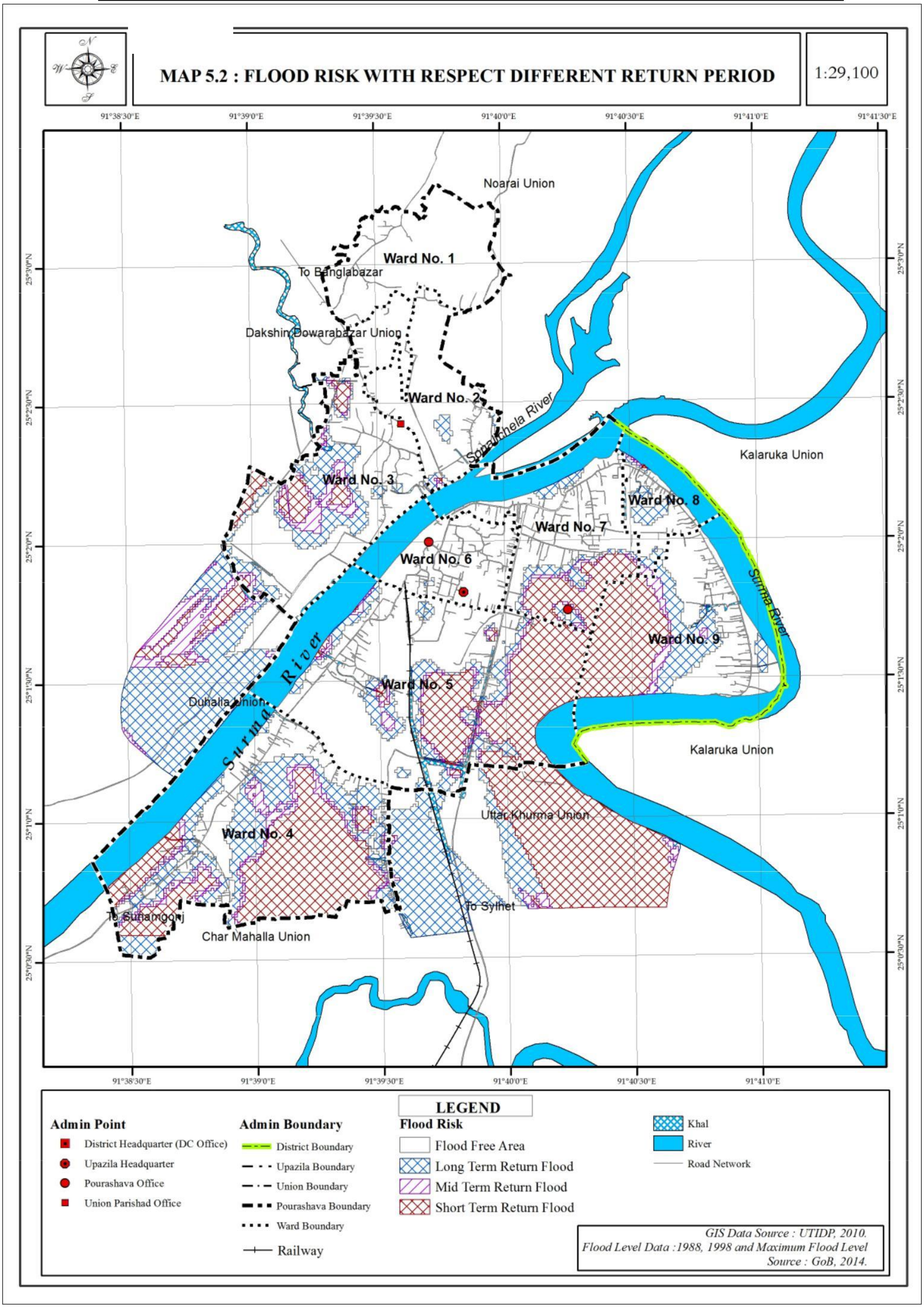


Figure 2. Flood risk with respect different return period

Conclusions

This research paper analyzed flood vulnerability within Chhatak Pourashava. Findings of this research show 45.61% of Chhatak and its proposed extended area will be in flood risk. Such analysis will help to take measures at pre, during and post disasters which can decline the risk and assist to build capacity from the severity of secondary town for ensuring sustainable disaster resilience urban area.

References

Ansary, M. A. and Islam, M. R. (2008) "Microzonation of Sylhet City", Journal of South Asia Disaster Studies, Vol. 1, No. 1, pp. 179-195.

Coaffee, J. (2008) "Risk, resilience, and environmentally sustainable cities, Energy Policy", Vol. 36, Issue 12.

CDMP (2014) District Level Disaster Management Plan Development: District – Sunamganj, Comprehensive Disaster Management Programme (CDMP II), Dhaka: Ministry of Disaster Management and Relief, Government of the People's Republic of Bangladesh.

GoB (2009) The Local Government (Pourashava) Act 2009, Dhaka: Government of the People's Republic of Bangladesh.

GoB (2010) Standing Order on Disaster (SOD), Ministry of Food and Disaster Management, Disaster Management & Relief Division, Disaster Management Bureau, Dhaka: Government of the People's Republic of Bangladesh.

GoB (2014) *Flood Response Preparedness Plan of Bangladesh*, Department of Disaster Management, Ministry of Disaster Management and Relief, Dhaka: Government of the People's Republic of Bangladesh.

Parvin, G. A., Ahsan, S.M.R., and Shar, R. (2013) Urban Risk Reduction Approaches in Bangladesh, Springer Japan: Kyoto.

RCC (2011) Promoting Use of Disaster Risk Information in Land-use Planning, Regional Consultative Committee on Disaster Management.

Shaw, R. (2008) "An Overview of Urban Risk of South Asia: Issues, Approaches, and Thoughts", Journal of South Asia Disaster Studies, Vol. 1, No. 1, pp. 69-84.

UTIDP (2010) Chhatak Master Plan (2011-2031), Upazila Towns Infrastructure Project (UTIDP), Dhaka: Local Government and Engineering Department, Government of the People's Republic of Bangladesh.

World Bank (2012) Building Urban Resilience: Principles, Tools and Practice, Washington, DC: The World Bank.

SPATIOTEMPORAL EVOLUTION AND TRENDS OF DROUGHT IN WESTERN BANGLADESH OVER 1980-2017

Nilufa Yeasmin[1] and A.R.M. Towfiqul Isla[2]

ABSTRACT

The objective of the study is to assess the spatiotemporal evolution of drought and its relation with ENSO teleconnection indices in western Bangladesh. The daily climatic data were collected from Bangladesh Metrological Department (BMD) from 1980 to 2017. The comparison of the four drought indices e.g., SPEI, SPI, PET and Pa based on the drought events confirms the application of the Pa, PET, SPI, and SPEI for determining uninterrupted drought events in western Bangladesh. The results indicate that the SPEI shows a better correlation with PET, and SPI is better with Pa in the sequence such as SPEI>SPI>PET>Pa. The most of the western region was found very low and weak relation with ENSO and drought, indicating a weak connection with increasing drought in the study area. In north regions of western Bangladesh characterized by high PET, drought severity is mostly determined by changes in PET. The results will help to identify drought events using multi-indices at spatiotemporally to take proper adaptation strategies in western Bangladesh.

Keywords: Drought events, Teleconnection indices, precipitation anomaly, Potential evapotranspiration.

Introduction

Extreme climate event has become a hot topic, especially in the field of climate change, drought, as the most important natural disaster, causes the most serious influences on human and the society (Dai 2011; Rohli et al. 2016, Yao et al. 2018). The Standardized Precipitation Evapotranspiration Index (SPEI) SPEI which includes temperature and other climatic factors in its structure has a more robust link to El nino southern Oscillation (ENSO) than the SPI. Consequently, the developed ENSO-SPEI prediction structure can provide quantitative information about the spatial extent and severity of predicted drought disorders in a way that reveals more closely the level of risk in the global warming context of the sub-region. The spatial and temporal variations of the precipitation anomaly(Pa), precipitation evaporation transpiration(PET), The Standardized Precipitation Index(SPI) and SPEI are compared with severe or extreme drought events. Natural disasters, particularly meteorological disasters, are harmful and can cause immense losses of approximately 85 % (Sun et al. 2014). Previously, Bangladesh has familiar with different degrees of drought that have mainly affected agricultural land, resulting in the loss of huge food grains. Moreover, it affects the socio-environment and development activities of the country (Shahid and Behrawan 2008). The increases of the Pa, PET, SPI, and SPEI suggest in general relief of drought situations during 1977-2017. Most of the study of Bangladesh did not much focus on efficient modeling and forecasting, scheduling. A few studies have shown a drought index model in developed countries, but earlier studies in Bangladesh is lacking behind it. So far, no studies have been undertaken by integrating drought monitoring indices to show the relationship between ENSO indices with drought in western Bangladesh. This study aims to investigate the spatiotemporal evolution of drought in western Bangladesh during 1980-2017 using four drought indices.

Literature Review

A significant number of studies have been performed on the relationship between drought and ENSO indices in worldwide (Ma et al. 2015, Yu et al. 2014; Mera et al. 2018). For instance, Mera et al (2018) showed drought forecasting system, based on ENSO and Drought indicator. They found the most dominant relationship between ENSO and drought indices. Ma et al (2015) reported the higher drought probability and forecast skill are found over regimes where ENSO has less impact. Yu et al. (2014) showed that severe and extreme droughts have become more serious increasing by persistent multi-year severe droughts. Yao et al (2018) evaluated drought severity and trend in the main land China over 1961-2013 using multi-drought indices. Currently, a number of researches in Bangladesh have been performed to assess drought using single drought indices (Shahid and Behrawan, 2008; Abdullah 2014; Rahman and Lateh 2016; Rahman et al. 2016;

[1] *Department of Disaster Management, Begum Rokeya University, Rangpur5400, Bangladesh.*
[2] *Department of Disaster Management, Begum Rokeya University, Rangpur5400, Bangladesh.*
[1]*Author: nilu.csm@gmail.com*
[2]*Corresponding author: towfiq_dm@brur.ac.bd*

Islam et al. 2017). Islam et al (2017) presented the drought hazard index in terms of drought frequency and intensity to evaluate the Boro paddy growing season drought hazard in western Bangladesh. Another recent study performed by Rahman et al, (2016) analyzed drought using Standardized Precipitation Index (SPI) and Mann-Kendall (MK) Trend Test in the context of the impacts of drought on groundwater table (GWT) during the period 1971-2011 in the Barind area. Rahman and Lateh (2016) used SPI and monthly rainfall dataset for the period of 1971–2010 to outline the drought years and severity in Bangladesh. Abdullah (2014) assessed the spatial and temporal changes of drought in Bangladesh using the SPEI. However, most of those studies are concentrated on single drought monitoring index and spatiotemporal changes of drought in overall Bangladesh s. Taking into consideration integrated several drought indices for monitoring and evaluation of drought in western Bangladesh are still missing.

Methodology

The daily climatic data of the 38-year period (1980–2017) were used in this study. The 8 meteorological stations data in western part of Bangladesh (e.g., minimum and maximum temperature and precipitation) were collected from the Bangladesh Meteorological Department (BMD). The El Nino Southern Oscillation Index (ENSO) data were collected from American National Climate Prediction Center (CPC). The data quality was firmly controlled by BMD before its release. Missing data were taken from neighboring stations. Pearson correlation matrix was employed for this study. Precipitation anomalies were calculated using precipitation datasets.

Standardized Precipitation Evapotranspiration Index (SPEI)

The attitude of SPEI is using the degree of the difference between precipitation and evapotranspiration that diverges the average status to symbolize the regional drought. The SPEI as an improved drought index of SPI was first proposed by Vicente-Serrano, who calculated climatic water balance, the difference between precipitation and reference evapotranspiration (P−ET0), rather than precipitation (P) as the input (Vicente-Serrano et al.2010).

Standardized Precipitation Index (SPI)

The Standardized Precipitation Index (SPI) is used in order to estimate the drought conditions prevailing in the study areas. SPI is an index that uses only precipitation data, and it is based on the probability of precipitation for a number of consecutive months, and its main objective is to represent the deficit of precipitation over an area on multiple time scales relative to its climatology. (McKee et al.1993, McKee et al. (1995), Guttman. 1998)

Linear regression model

To find out the relation between SPEI, SPI, Pa, ENSO, IOD; linear regression model was used. To understand how the variables are linked with each other, we have used the formula and software which help to figure out the graph. Linear correlation can be signified by "R" and the value will be between -1 and 1.

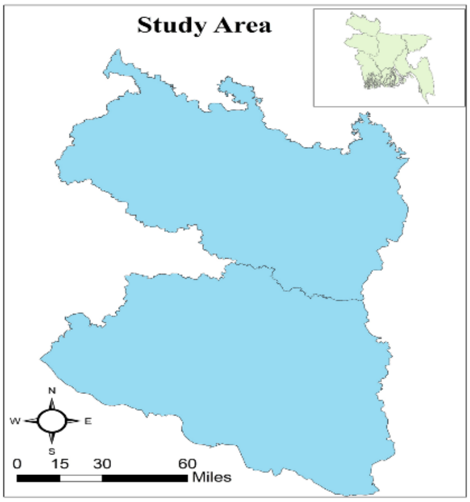


Figure 1: The location map showing the study area.

Result

Table 1 shows that the R (Correlation coefficients) values between SPEI and ENSO was lower ranging from (-0.083 to -0.306) and SPI vs ENSO (-0.40 to -.269) at different timescales. Generally, high R values for SPI vs. SPEI were found than those for SPEI vs. ENSO or for SPI vs. ENSO. There were found a strongly positive correlation between SPEI vs Pa and SPI vs Pa. (Table 1)

Table 1. Correlation coefficient (R) between SPEI, SPI, PET, Pa, and ENSO at the 3,-6,-12,-24-month timescales.

SPEI vs PET				SPEI vs Pa				SPEI vs ENSO			
3M	6M	12M	24M	3M	6M	12M	24M	3M	6M	12M	24M
-.320	-.188	-.189	-.194	.543*	.528*	.585*	.131	-.184	-.083	-.118	-.306
SPI vs PET				SPI vs Pa				SPI vs ENSO			
3M	6M	12M	24M	3M	6M	12M	24M	3M	6M	12M	24M
-.375	-.148	-.188	-.064	.774	.509	.511	.056	-.040	-.062	-.171	-.269

Note:**.Correlation is significant at the 0.01 level,
*. Correlation is significant at the 0.05 level.

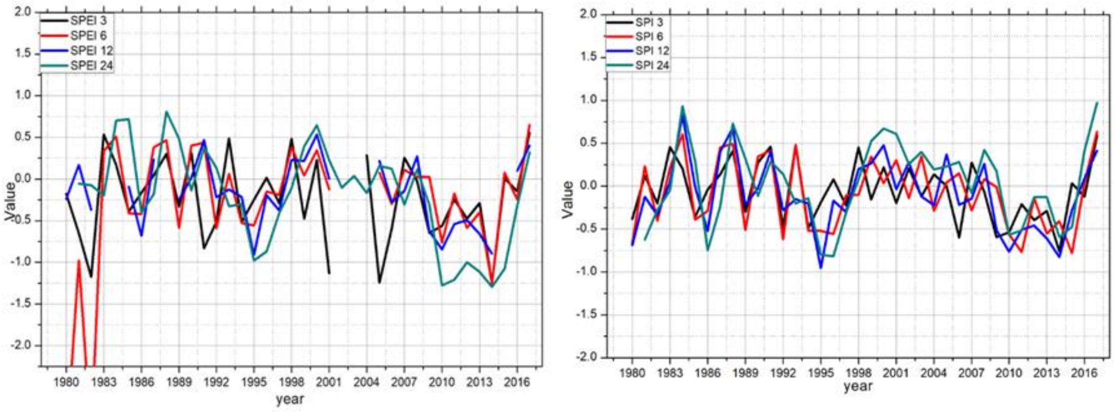


Figure 2. The temporal variation of SPEI and SPI in the western part of Bangladesh at different time scales over 1980-2017.

Figure 2 shows exemplify the temporal variation of SPEI and SPI during 1980–2017. It can be pragmatic from Fig.2 that moderate droughts are frequent in about 80 % of the province except for a small pocket in the northern part. Figure 2 shows the SPI and SPEI values of the nominated stations for different short-month length (3M-, 6M-, 12M- and 24M). Though the patterns for 3M and 6M are almost similar with a small shift and discontinuity (especially in SPEI), but 12M and 24M have the continuous frequency in the aspect of drought occurrence. The frequency of drought is intended from the statistical totals of drought spell of SPI and SPEI values, which represent the drought characteristics of western part in Bangladesh.
Figure 2 shows the trend value of SPI at different time scales. In this study, an estimation of the drought condition shows their variation for the periods 1980–2017, using the emission scenarios of the SPI and SPEI in the western region of Bangladesh.

Discussion

The main objective of the study is to evaluate spatiotemporal pattern of drought and its relation with ENSO teleconnection indices in western Bangladesh. In this study, a strongly positive correlation between SPEI vs Pa and SPI vs Pa was observed. The spatial distributions of R (Correlation coefficients) values between combinations of SPI, SPEI, and ENSO were illustrated. Table 1 shows that the weak and very weak correlations between ENSO and the drought indices were found in the study region. Based on the PET results, SPEI has a negative significance result with it. The analysis generally shows that the north eastern parts of Bangladesh suffer from severe and extreme drought events, whereas the north-western portion suffers from mild to moderate drought events. These findings are consistent with the previous results of Shahid and

Behrawan, 2008, Rahman et al. 2016; Islam et al. 2017. Bangladesh is one of the most vulnerable countries in the world due to frequently affected by the extreme climatic disaster. This is especially true for northwestern part of Bangladesh (Rahman and Lateh 2016). This study shows that spatiotemporal trends of drought have increased significantly in Bangladesh during the study period. Consequently, Rangpur is considered as a most drought-prone district. Due to anthropogenic activities, the northern part of Bangladesh is suffering more severe drought than other regions of Bangladesh. The most dominant relationship, in all cases, between SPEI and SPI with Pa was detected, suggesting drought persistent prolong time at both spatially and temporally. Although a negative and very weak relation among SPEI, SPI with ENSO were observed, indicating there is a very low connection of ENSO indices with increasing drought severity and intensity in western Bangladesh. The increased tendency of drought in the study area may be due to climatic changes (Abdullah 2014). This study also reveals that the intensity of droughts is higher in the northern part of the country which makes it susceptible to both moderate and severe droughts at spatial scale. On the other hand, temporally the frequency and intensity of drought have been increased over time.

Conclusion

Drought is regarded as an environmental disaster that has significantly affected on economic and social development in recent eras. This study intends to assess the spatiotemporal evolution of drought in western Bangladesh using four indices. The study also evaluates the relationship among SPEI, SPI, Pa and PET with ENSO teleconnection indices. Drought occurrences demonstrated in the study area that, comparatively moderate drought occurred more frequently than severe and extreme. It is found that the ENSO has the weaker linear relation with SPI and SPEI at different timescales. Though precipitation is the predominant variable influencing drought growth during the rainfall of Bangladesh, it is sensible to first outline its unique characteristics in relation to ENSO. This study provides as a data-based framework for finding drought and its relation with ENSO teleconnection. It will help to find out consequence of drought events for taking proper adaptation plans in western Bangladesh. Future study should be concentrated on forecasting outline of drought for proper evaluation across Bangladesh under changing the climate.

Reference

Abdullah, S.M., (2014) Standardized precipitation evapotranspiration index (SPEI) based drought assessment in Bangladesh, in Proceedings of the 5th Proceedings of International Conference on Environmental Aspects of Bangladesh (ICEAB ’14), pp. 40–44

Dai A (2011) Drought under global warming: a review. WIREs Clim Chang 2:45–65.

Islam, A.R.M.T., Shen, S., Hu, Z., Rahman, M.A., (2017) Drought Hazard Evaluation in Boro Paddy Cultivated Areas of Western Bangladesh at Current and Future Climate Change Conditions, Advances in Meteorology, 2017, Article ID 3514381, 12 pages, doi:10.1155/2017/3514381

Ma, F., Yuan, X., Ye, A., 2015. Seasonal drought predictability and forecast skill over China.J. Geophys. Res. Atmos. 120 (16), 8264–8275.

McKee TB, Doesken NJ, Kleist J (1993) The relationship of drought frequency and duration to time scales. Preprint Eighth Conference, on Applied Climatology. American Meteorology Society, Anaheim, pp 179–184.

McKee TB, Doesken NJ, Kleist L (1995) Drought monitoring with multiple scales. In: Proceedings of the 9th conference on Applied Climatology, Boston, MA, U.S.A, pp. 233–236.

Rahman, A.T.M.S., Kamruzzaman, M., Jahan, C.S., Mazumder, Q.H. (2016) Long-Term trend analysis of water table using ‘MAKESENS’ model and sustainability of groundwater resources in drought-prone Barind Area, NW Bangladesh. J. Geol. Soc. India., 87(2):179-193.

Rahman, M.R., Lateh, H., (2016) Meteorological drought in Bangladesh: assessing, analyzing and hazard mapping using SPI, GIS, and monthly rainfall data, Environmental Earth Sciences, 75(12).

Rohli RV, Bushra N, Lam NSN et al (2016) Drought indices as drought predictors in the south-central USA. Nat Hazards 83:1567–1582. https://doi.org/10.1007/s11069-016-2376-z.

Shahid, S., Behrawan, H., (2008) Drought risk assessment in the western part of Bangladesh,” Natural Hazards, 46(3):391–413.

Sun Z, Zhang J, Zhang Q, Hu Y, Yan D, Wang C (2014) Integrated risk zoning of drought and waterlogging disasters based on fuzzy comprehensive evaluation in Anhui Province, China. Nat Hazard 71:1639–1657. doi:10.1007/s11069-013-0971-9.

Vicente-Serrano, S. M., Beguería, S., & López-Moreno, J. I. (2010). A multi-scalar drought index sensitive to global warming: the Standardized Precipitation Evapotranspiration Index—SPEI. Journal of Climate, 23(7), 1696–1718.

Mera, Y.E.Z., Jonny Fernando Riva Deneira, J.F.R., et al. (2018). Linking El Niño Southern Oscillation for early drought detection in tropical climates: The Ecuadorian coast. Linking El Niño Southern Oscillation for early drought detection in tropical climates: The Ecuadorian coast, Sci. Total Environment, 643:193-207

Yu, M., Li, Q., Hayes, M.J., Svoboda, M.D., Heim, R.R., (2014). Are droughts becoming more frequent or severe in China based on the standardized precipitation evapotranspiration index: 1951–2010? Int. J. Climatol. 34 (3), 545–558.

SPATIO-TEMPORAL DISTRIBUTION OF LIGHTNING AND ITS RELATED FATALITIES IN BANGLADESH

F. Rahman[1], M. A. Mannan[2] and M. Moniruzzaman[3]

ABSTRACT

Bangladesh is extremely susceptible to the lightning hazard. Fatalities, injuries and affected number of peoples due to lightning is significant which is found to increase in recent years. To address this issue, attempts have been made to analyze lightning event day and lightning event frequency for the period of 2001-2016 collected from the Bangladesh Meteorological Department (BMD). Information about fatalities, injuries and affected people related to lightning are from the three dailies of 'The Daily Ittefaq', 'The Daily Jugantor', 'The Daily Prothom Alo' during March to November of 2012 to 2016. Lightning event frequency is the highest in May followed by June and April with the magnitudes of 28.1, 24.1 and 19.1 respectively. The number of fatalities during 2012-2016 is the highest in May and then April and June with the magnitudes of 373, 206 and 144 respectively. Accordingly, the maximum number of injuries are in May and then in April and June with the magnitudes of 196, 152 and 92 respectively. The annual rate of fatalities, injuries and affected peoples due to lightning are 111, 68 and 179. The percentage of fatalities (22.3%) related to lightning is the highest at noon and then in the morning. The percentage of injuries (22.2%) is the maximum during noon and then in the morning. Spatial distribution reveals that fatalities due to lightning is the higher over Sylhet-Mymensingh region with the highest in Sunamganj district and then in Kishoreganj and in Comilla and Netrokona.

Keywords: Fatality, Hazard, Injury, Lightning, and Risk

Introduction

Lightning is found to occur individually as well as with all thunderstorms. The creation of lightning is a complicated process. It is the result of the build-up and discharge of electrical energy. The air in a lightning strike is heated to 50,000 degrees Fahrenheit. Rapid heating of the air produces a shock wave that results in thunder (NOAA, 2001). Lightning is a gigantic electrical spark traveling between cloud to cloud or cloud to earth containing an average charge of 30 to 50 lakh Volts and a current of 30 Kilo amperes with a speed of 220 km per hour. Lightning is due to upward vertical motions accompanied by microphysical processes at elevations with typical ambient temperatures between -5° and -15°C.

A huge amount of charge has to build up before the strength of the electric field overpowers the atmospheres insulating properties. At last, it can be said that the current of electricity forces a path through the air until it encounters something that makes a good connection. The current is driven by a high voltage between the cloud's charge centers or between them and the earth. Tropical regions of the world, including both land and water, are estimated to account for 78% of global lightning mainly in where there are marked elevation changes and land-water boundaries (Albrecht et al., 2016). Asia has the second-most lightning hotspots with its most active regions located in the northwestern ridges of the Himalayas, near Daggar, Pakistan and South America is third in hotspots, followed by North America and Australia (NASA, 2002).

About two-thirds of lightning occurs during the afternoon due to the strongest heating of the land surface during this time. At higher latitudes in both hemispheres, about two-thirds of lightning occurs during the three summer months. Holle and López(2003) made an assessment of the worldwide impact of lightning and concluded that 24,000 deaths and 240,000 injuries occur per year. The ratio of injuries to deaths appears to be 10 to 1 based on an intensive search of Colorado medical records. Bangladesh (0.9) and Sri Lanka (2.4) annual fatality rates are higher than in the more developed countries (Gomes *et al*., 2006). Bangladesh has seen a near-record number of deaths in 2016 from a phenomenon that appears to be worsening with climate change: lightning strikes. So far in 2016, 261 people died from lightning in Bangladesh, putting the South Asian nation on track to beat last year's 265 deaths. Most lightning deaths usually occur during the warm months of March to July. According to the Bangladesh Meteorological Department (BMD), prior to 1981, the country saw lightning strikes on average nine days each May. Since that time, the country has seen strikes

[1] *Student, Department of Geography & Environment, Jagannath University, Dhaka, Bangladesh*
[2] *Bangladesh Meteorological Department, Agargaon, Dhaka, Bangladesh*
[3] *Department of Geography and Environment, Jagannath University, Dhaka, Bangladesh*

an average of 12 days each May. The problem has prompted Bangladesh's government to add lightning strikes to the country's list of official types of disasters, which includes floods, cyclones and storm surges, earthquakes, drought, and riverbank erosion, among others. National Oceanic and Atmospheric Administration (NOAA) stated about lighting and safety tips for the mariner. From 1990 to 2016 from a variety of sources that contains a total of 5,468 casualties comprised of 3,086 fatalities and 2,382 injuries in Bangladesh (Dewan et al., 2017).

The main aims of this study are: to investigate the spatiotemporal distribution of lighting days during 1981-2016 over Bangladesh; to review the intensity of lighting frequency since 2001-2016 in Bangladesh; to assess the variation of lightning days and frequency of selected weather stations (located over divisional headquarters) in Bangladesh during last 35 years and to explore the lightning induced human fatalities and injuries of last five years of 2012-2016.

Methodology

Lightning-induced fatalities and injuries data and information are collected from three national dailies (The Daily Prothom Alo, The Daily Jugantor, and The Daily Ittefaq) from March to November each year of 2012-2016. Collected data and information are compiled and cross-checked to avoid overlapping and inconsistency for a validation check. To avoid overlapping data are first matched using all of the demographic variables and locations. Then the data are punched against the corresponding day and year in MS Excel. Cases are excluded if any duplication and overlapping are encountered. Analysis has been conducted using SPSS and MS Excel. Both the number of lightning days (1981-2016) and lightning frequency (2001-2016) collected from synoptic weather stations of Bangladesh Meteorological Department (BMD). Spatial distributions are generated using WinSurfer (Version 10) software.

Result and discussions

Monthly distribution of lightning days and frequency of Bangladesh

Figure 1: Monthly distribution of lightning days in Bangladesh

Figure 2: Monthly distribution of lightning frequency in Bangladesh

Monthly distribution of lightning days is depicted in Figure 1. Figure 1 indicates that the number of lightning days is the highest in September and then in August, May, and June. The number of lightning days in September, August, May, June, and April are 4.9, 4.7, 4.7, 4.2 and 3.4 respectively. It is also observed that the number of lightning days in November, December, and January are very low.

Monthly distribution of lightning frequency is displayed in Figure 2. It is found that the numbers of lightning frequency are the highest in May followed by June and April but it is very low and not considerable in November, December, and January. Frequencies of lightning during the successive three months of April, May, and June are the most substantial, which are highly relevant to the death toll and injuries in Bangladesh.

Variation of lightning days and frequency in Bangladesh

Variation of annual lightning days and frequency of eight divisional headquarters stations of BMD during the observed period of 1981-2016 are calculated and analyzed. At Barisal location, lightning days are found higher in 1981-1983, 1996-1999 and 2004-2014. Similarly, at Sylhet location lightning days are found higher in 1981-1987, 1989-2001 and 2006-2016. Again, annual numbers of lightning frequencies are found higher in 2005-2007, 2010-2012 and 2016. Details are given in Table 1 and Figures 3 and 4.

Table 1. Trends of annual lightning days and lighting frequencies

Location	Trends (Per year) during 1981-2017	
	Lightning days	lightning frequency

Dhaka	-1.28	-0.07
Rajshahi	-1.11	-7.50
Khulna	-1.64	-1.06
Rangpur	-0.96	-2.59
Barisal	+0.33	-0.63
Chattogram	-0.53	-2.11
Mymensingh	+0.38	-1.68
Sylhet	+0.54	+1.12

Spatial distribution of lightning days and lightning frequency

Spatial distribution reveals that the highest annual average number of lightning days are higher in Sylhet, Sunamganj regions, then in Faridpur, Dhaka, Tangail, Mymensingh, Pubna, Bogra and Rangpur regions and then other parts. Lightning days are low at Noakhali, Feni and Chittagong regions. The highest annual average lightning frequency is found in Sylhet, Sunamganj, Moulvibazar, Habiganj, Kishorganj, Netrokonaand then in Mymensingh, Sherpur, Jamalpur, Tangail, Nilphamari, Rajshahi and then in Panchagar, Khulna, Pirojpur, Nawabganj and then others parts of the country (Figure 4).
Spatial and temporal distribution of lightning-induced fatalities and injuries in Bangladesh
The highest fatalities and injuries are found in May than in April June (Figure 5). Most incidents are found to occur in homestead then cropland and who moves towards outside frequently are highly affected by lightning. The highest death is found among farmers in the observed period. Compiled database predicts that most of the incident occurred during noon and then in the morning. The compiled database which is prepared for the present study concluded by that the percentage of fatalities (22.3%) are related to lightning is the highest during noon and then during the morning; percentage of injuries (22.2%) is the maximum during noon and then in the morning (Figure 6).

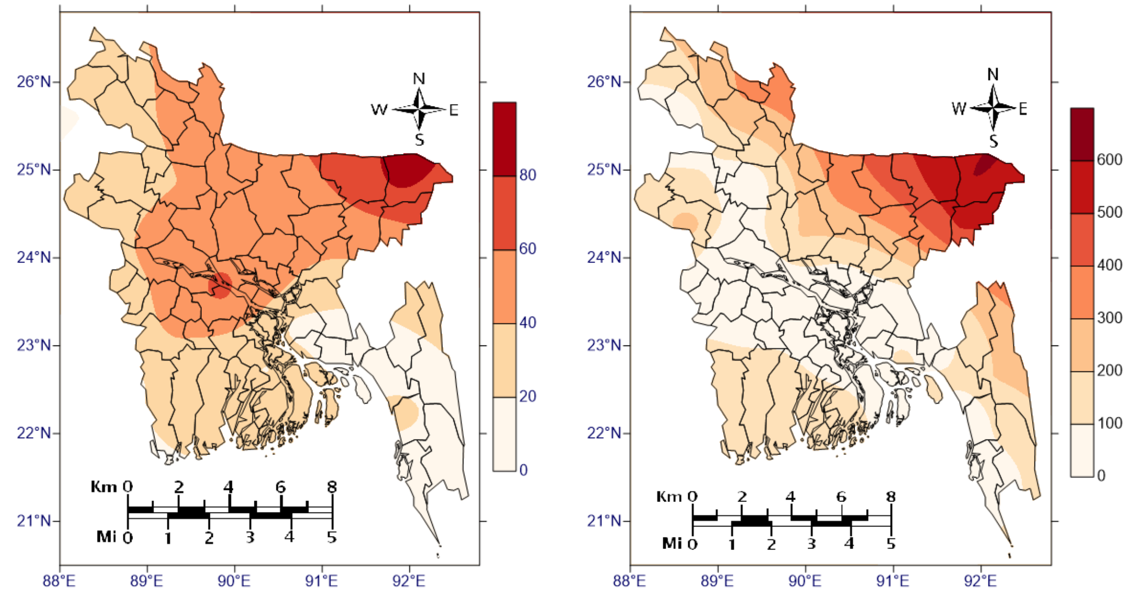


Figure 4. Distribution of average of (a) annual lightning days and (b) Annual frequency in bangladesh

The study also revealed that pre-monsoon (March to May) season is the most lightning induced fatalities recorded season. Total recorded fatality during pre-monsoon season is 617, which is about 61.6 percent of total fatalities of the observed period.

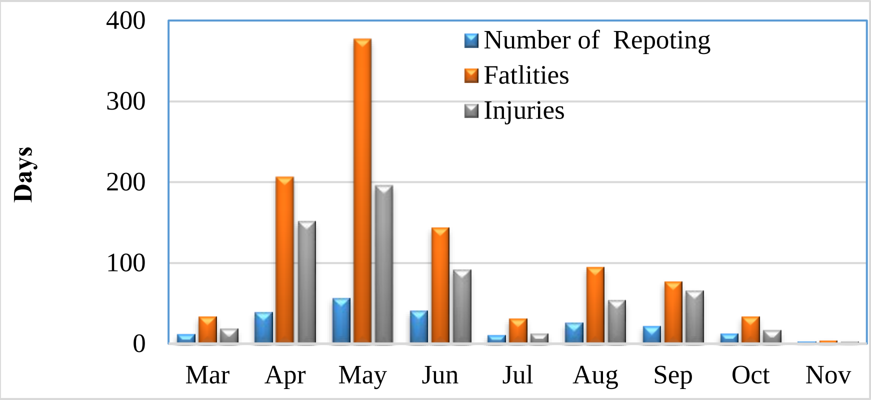


Figure 5. Distribution of fatalities and injuries due to lightning in Bangladesh during 2012- 2016

Table 2 shows detail information about season wise fatality distribution. Spatial distribution reveals that fatalities due to lightning is the higher over Sylhet- Mymensingh region and lower over Noakhali- Chittagong region with the highest in Sunamganj district and then in Kishoreganj and in Comilla and Netrokona during the observed period. The number of fatalities in Sunamganj, Kishoreganj, Comilla, and Netrokona are 69, 48, 35 and 35 respectively. On the other hand, it is lower in Feni district but nil in Barguna district during the study period (Figure 7).

Table 2. Seasonal variation of the number of fatalities

Season	2012	2013	2014	2015	2016	Total
Pre-monsoon	180	148	67	76	146	617
Monsoon	42	94	49	49	113	347
Post-monsoon	10	11	6	3	8	38

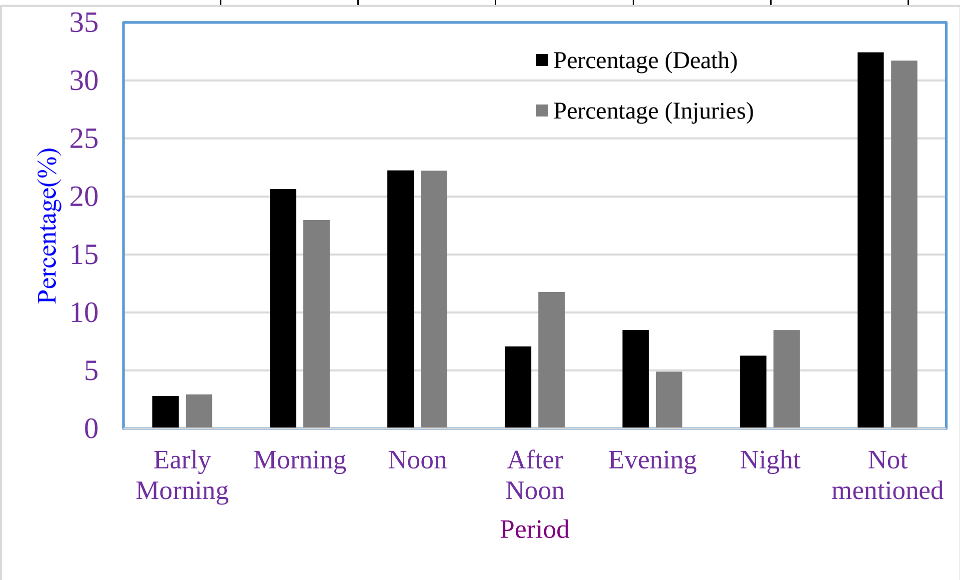


Figure 6. Temporal duration of Fatalities and Injuries due to lightning in Bangladesh during 2012-2016

The compiled database explore district wise fatality distribution and indicated that the number of fatalities was the highest of 20 in Sunamganj and then 11 in Nilphamari and 10 in Dinajpur, Jamalpur, and Satkhira. A number of fatalities were within the range of 1-9 at other districts. but no fatalities were reported in Feni, Jhenaidaha, Barguna, Joypurhat, Khagrachari, Meherpur, Narail, Natore and Rajbari in 2012. In 2013, district wise fatality distribution indicated that the number of fatalities was the highest of 17 in Comilla and then 16 in Kishoreganj and 14 in Brahmanbaria. A number of fatalities were 1-13 at other districts but no fatalities were reported for Barguna, Bandarban, Bhola, Dhaka, Jhalokathi, Jhinaidaha, Joypurhat, Magura, Narshingdi and Patuakhali. The statistics from the dailies, in 2014, district wise fatality distribution indicates that the number of fatalities was the highest of 8 in Chapainawabganj and then 5 in Brahman Baria, Habiganj, Kishoreganj, Meherpur, Mymensingh and 6 in Nilphamari. A number of fatalities were of 1-7 at other districts but no fatalities were reported for Barguna, Barisal, Bhola, Comilla, Feni, Gaibandha, Gopalganj, Jessore, Joypurhat, Khagrachari, Khulna, Kurigram, Lakshmipur, Narshingdi, Natore, Patuakhali, Rajbari, Sylhet and Thakurgaon. District wise fatality distribution of 2015 indicated that the number of fatalities was the highest of 10 in Sunamganj and then 8 in Comilla, Netrokona, Habiganj and 7 in Rajbari. Number of fatalities were of 1-6 at other districts but no fatalities were reported for Barguna, Bagerhat, Bandarban, Bhola, Cox's Bazar, Dhaka, Feni, Jamalpur, Jhalokathi, Joupurhat, Khagrachari, Kurigram, Kushtia, Lalmonirhat, Madaripur, Meherpur, Naogaon, Nilphamari, Noakhali, Panchager, Patuakhali, Satkhiraa, Shariatpur and Sylhet.

In 2016, district wise fatality distribution indicated that the number of fatalities were the highest of 25 in Sunamganj district and then 17 in Kishoreganj and 13 in Pabna. A number of fatalities were 1-12 at other districts but no fatalities were reported in Barguna, Barisal, Bandarban Bhola, Chandpur, Chuadanga, Kushtia, Lalmonirhat, Magura, Meherpur, Rangamati and Shariatpur. Spatial distribution of total fatalities from 2012 to 2016 is depicted in Figure7.

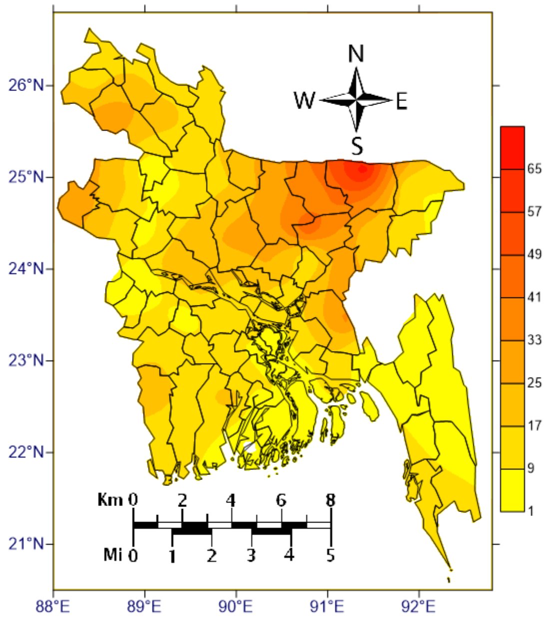


Figure 7. Spatial distribution of total lightning fatalities in Bangladesh (2012-2016)

Conclusion

From the analysis the following conclusions can be drawn:

i. The highest annual average lightning frequency is found in Sylhet, Sunamganj, Moulvibazar, Habiganj, Kishorganj, Netrokona regions and the highest annual average number of lightning days are found in Sylhet, Sunamganj then Faridpur, Dhaka, Tangail, Mymensingh, Pubna, Bogra and Rangpur regions.
ii. Fatalities due to lightning is the higher over Sylhet- Mymensingh region but lower over Noakhali-Chittagong regions with the highest in Sunamganj district and then in Kishoreganj, Comilla and Netrokona during the observed period.
iii. The trends of lightning days and frequencies are positive in Sylhet region. The temporal distribution shows that the frequency of lightning is higher in May, June and then April.
iv. Lightning frequency is the highest in May than in April and June. The study reveals that the highest numbers of people are affected by lightning in May, then April and June in Bangladesh.
v. Severe lightning is associated with the squall line in Bangladesh.

References

Albrecht, R. I., S. J. Goodman, D. E. Buechler, R. J. Blakeslee, and H. J. Christian (2016), Where are the lightning hotspots on Earth?, Bull. Amer. Meteor. Soc., 97, 2051-2068.

Cherington, M., J. Walker, M. Boyson, R. Glancy, H. Hedegaard, and S. Clark (1999), Closing the gap on the actual numbers of lightning casualties and deaths, paper presented at the 11th Conference on Applied Climatology, Dallas, Amer. Meteor. Soc., 379-380.

Dewan, A., M. F. Hossain, M. M. Rahman, Y. Yamane, and R. L. Holle (2017), Recent lightning-related fatalities and injuries in Bangladesh, Weather, Climate, and Society, 9, 575-589

Facts about lightning, Safety tips for the mariner, (2011). National Oceanic and Atmospheric Administration (NOAA) of U.S. Department, USA.

Gomes, C., M. Z. Ab Kadir, F. Hussain, and K. R. Abeysinghe (2006), Lightning accidents and awareness in South Asia: experience in Sri Lanka and Bangladesh, paper presented at the 28th International Conference on Lightning Protection, Kanasawa, Japan, 1240-1243.

Holle, R. L. (2012). Diurnal Variations of NLDN Cloud-To-Ground Lightning in the United States,22rd International Lightning Detection Conference (2-3 April) and 4th International Lightning Meteorology Conference (4-5 April), Broomfield, Colorado, USA, 2012.)

Holle, R. L., and R. E. López (2003), A comparison of current lightning death rates in the U.S. with other locations and times, paper presented at the International Conference on Lightning and Static Electricity, Blackpool, England, Roy. Aeronautical Soc., paper 103-34 KMS, 7 pp.

PREDICTION OF SEVERE THUNDERSTORM ASSOCIATED WITH INTENSE LIGHTNING AND HEAVY RAINFALL IN BANGLADESH

F. Akter[1], M. A. Mannan[2], M. A. M. Chowdhury[3], S. Karmakar[4] , and S. Ahmed[1]

ABSTRACT

Thunderstorm, lightning and heavy rainfalls are extreme weather phenomena that usually develop in the pre-monsoon season (March to May) in Bangladesh. These are very frequent and devastating sometimes. These are associated with gusty or squally wind (strong wind) and often cause for great loss of lives and properties. The triggering factors of these phenomena are instability, advection of moisture and convergence at a low level of troposphere and presence of upper-level divergence. To understand the inherent properties eight prominent events occurred during 2018 are simulated using the WRF-ARW model. It is found that strong moisture field with vertical extension up to 300 hPa levels, the signature of K-index with a value of ≥ 40, high CAPE with its extension up to 700 hPa level, notable magnitudes of LI, PW and LPI are main features of a thunderstorm with strong lightning and heavy rainfall in Bangladesh. The simulation result is found to be very helpful for detecting the occurrence area with little spatiotemporal variations, which is quite useful for operational forecasters.

Introduction

Lightning occurs typically during a thunderstorm, is a leading cause of injury and death. Thunderstorms are often accompanied by lightning, large hail and torrential rains with potential consequences to human life and considerable damages to electrical infrastructures (Lynn and Yair, 2010). Nowadays many real-time lightning detection systems are now able to accurately determine the location of cloud-to-ground lightning (MacGorman and Rust, 1998). Although several stability indices are used by meteorologists to forecast the probabilities of thunderstorms (such as Total Totals Index (TTI), K Index (KI), Convective Available Potential Energy (CAPE), Precipitable Water (PW), and Cloud Physics Thunder Parameter (CPTP), these are not based on the microphysics of charge separation in thunderstorms and rely on thermodynamic instability parameters, thus resulting in coarse scale outputs (Lynn and Yair, 2010). Lynn and Yair (2008) and Yair *et al*. (2010) described the development and utilization of the Lightning Potential Index (LPI) for evaluating the potential for lightning activity from WRF model output.

Yair *et al*. (2010) showed that the LPI correlates positively with observed lightning density and also heavy rainfall and suggested that the LPI could be used to predict the occurrence of lightning to improve short-range forecasts. The LPI is calculated within the charge separation region of clouds between 0° and -20°C, where the non- inductive mechanism by collisions of ice and graupel particles in the presence of super-cooled water is most effective. LPI is also an empirical equation consisting of cloud-physical parameters, so it can measure the potential for electrical activity. Lightning (LT) is very frequent in association with thunderstorm (TS) and heavy rainfall (HR) in Bangladesh in the pre-monsoon season.

There are several TS events associated with intense LT and HR occurred in Bangladesh in the pre-monsoon season of 2017 and 2018. Eight of those severe TS events are selected for detail analysis (Table 1). The maximum amount of rainfall recorded during these dates are 56 (17 April, at Sitakunda), 78 (29 April, Dhaka), 77 (30 April, at Srimongal), 61 (10 May, at Sandwip), 69 (11 May, at Hatiya), 58 (18 May, Chandpur), 84 (23 May, Madaripur) and 82 mm (31 May, at Dhaka). Spatial distribution of rainfall (RF) of these event days is depicted afterward. Few studies have so far been conducted for TS with HR prediction (Mannan *et al.*, 2017) but very limited studied are conducted so far on LT with TS and HR prediction. Considering the importance, the present study suggests how to predict severe TS, intense LT and HR which occur in Bangladesh.

Data used and Methodology

Dates of the occurrences of TS with LT and HR during pre-monsoon season of 2018 are collected from the record of Bangladesh Meteorological Department (BMD). Thermodynamic indices of Total Totals Index

---

[1] *Dept. of Geography and Environment, University of Dhaka, Dhaka, Bangladesh*
[2]*Bangladesh Meteorological Department, Agargaon, Dhaka-1207, Bangladesh*
[3] *Department of Physics, Jahangirnagar University, Dhaka,*
[4] *National Oceanographic and Maritime Institute (NOAMI), Dhaka, Bangladesh*

(TTI) (Miller, 1972; Asnani, 1993), K Index (KI) (George, 1960), Convective Available Potential Energy (CAPE) (Williams and Renno, 1993)and Precipitable Water (PW) (Zhai and Eskridge, 1997; Zhang and Sumi, 2002) are calculated as per the standard procedure (Mannan, 2017) using the Rawinsonde observations collected at Dhaka at 00 UTC and 12 UTC of each of the occurrence day. The magnitudes of the indices are also given in Table 1. The definitions of these indices are as follows:

$$Total\,Totals\,Index(TTI) = (T_{850} - T_{500}) + (T_{d850} - T_{500}) \ldots\ldots\ldots\ldots\ldots\ldots(1a)$$

Where T_{850} and T_{500} are the temperatures in Celsius at 850 and 500 hPa levels; T_{d850} is the dew point temperature in Celsius at 850 hPa level.

$$K\ Index(KI) = (T_{850} - T_{500}) + T_{d850} - (T_{700} - T_{d700}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1b)$$

Where, T_{850} T_{700} and T_{500} are temperatures in Celsius at 850, 700 and 500 hPa levels respectively; T_{d850} and T_{d700} are dew point temperatures in Celsius at 850 and 700 hPa levels.

$$\text{Convective Available Potential Energy}\ (CAPE) = \int_{p_n}^{p_f} (\alpha_p - \alpha_e)\,dp \ldots\ldots\ldots\ldots(1c)$$

where α_e is the environmental specific volume profile, α_p is the specific volume of a parcel moving upward moist-adiabatically from the level of free convection, p_f is the pressure at the level of free convection, and o_n is the pressure at the level of neutral buoyancy. If $x(p)$ is the mixing ratio at the pressure level, p, then the precipitable water vapor, W, contained in a layer bounded by pressures p_1 and p_2 is given by

$$\Pr ecipitable\,Water(PW) = \frac{1}{\rho g}\int_{p_1}^{p_2} x\,dp \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1e)$$

Where ρ represents the density of water and g is the acceleration due to gravity. For more understanding all of these selected events are simulated using WRF model (version 3.8) with nested domains of D1 (30 km) and D2 (10 km), NCEP-FNL data is used as initial and boundary conditions, Simulated parameters are displayed using GrADS software and analyzed results are given in the following sections. The calculation process of LPI (Frisbie *et al.*, 2013) is given below:

$$A = (RH)^2 \times (\Theta_e\Gamma) \times (LI)^2 \times (-1) \ldots\ldots(2a), \qquad B = (muCAPE)^2 \times (PW) \times (RH)^2 \times (0.001) \ldots\ldots(2b)$$

$$LPI = (A + B) \times (T_{850} - 272) \ldots\ldots(2c)$$

Where, 'RH' is relative humidity at -10°C, '$\Theta_e\Gamma$' is equivalent potential temperature lapse rate at 600 hPa level, 'LI' is the lifted index, 'muCAPE' is the most unstable CAPE at 0-3 km above ground level, 'PW' is precipitable water, T_{850} is temperature in Kelvin at 850 hPa level.

Results and discussion

Observed Thermodynamic Indices

The magnitudes of thermodynamic indices of Total Totals Index (TTI), KI, CAPE, PW along with relative humidity (RH) and the mixing ratio (MR) at 500 hPa are given in Table 1. Indices depict the unstable condition of the lower troposphere but the available information is not sufficient for the evolution of TS events as required.

Table 1. Magnitudes of the thermodynamic indices recorded at Dhaka on TS days ('' indicates time in UTC)*

Dates	TTI		KI		CAPE		PW		RH (500hPa)		MR(500hPa)	
	00*	12*	00*	12*	00*	12*	00*	12*	00*	12*	00*	12*
17April 2018	48.8	56.1	32.9	37.4	191.9	13.0	34.5	39.9	28	8	1.0	0.3
29April 2018	49.0	47.8	35.3	39.4	0.0	0.0	40.5	47.6	8	27	0.3	1.2
30April2018	49.3	44.4	31.8	34.5	35.8	0.0	43.8	42.1	18	48	0.7	2.1
10 May 2018	45.2	-	32.5	-	1317.5	-	48.1	-	6	-	0.3	-
11 May 2018	-	-	-	-	-	-	-	-	-	-	-	-
18 May 2018	42.2	40.8	31.3	28.9	945.9	131.5	50.6	46.9	23	60	1.3	2.2
23 May 2018	41.8	42.6	29.1	32.5	657.1	101.6	53.1	58.0	81	79	4.4	4.5
31 May 2018	41.4	43.0	36.4	-	511.7	-	55.8	-	26	-	1.6	-

Evolution of simulated thermodynamic Indices

Simulation using the WRF model exposes the development, progression, and movement of TTI as an essential property of TS with LT and HR in Bangladesh. Signature of TTI is found as an indicator of the selected events. As such the minimum threshold value of 40 can be treated as the indicative parameter of these events (Figure 1(a)) as found in Table 1. KI index has a good indication of the events. Simulation exposed that KI with the magnitude of ≥40 is the most suitable for the occurrence of TS over an area but it is found to occur occasionally with the ranges 30-40. Signature and evolution of KI with these thresholds may, therefore, be the indication of these types of events (Figure 1(b)).

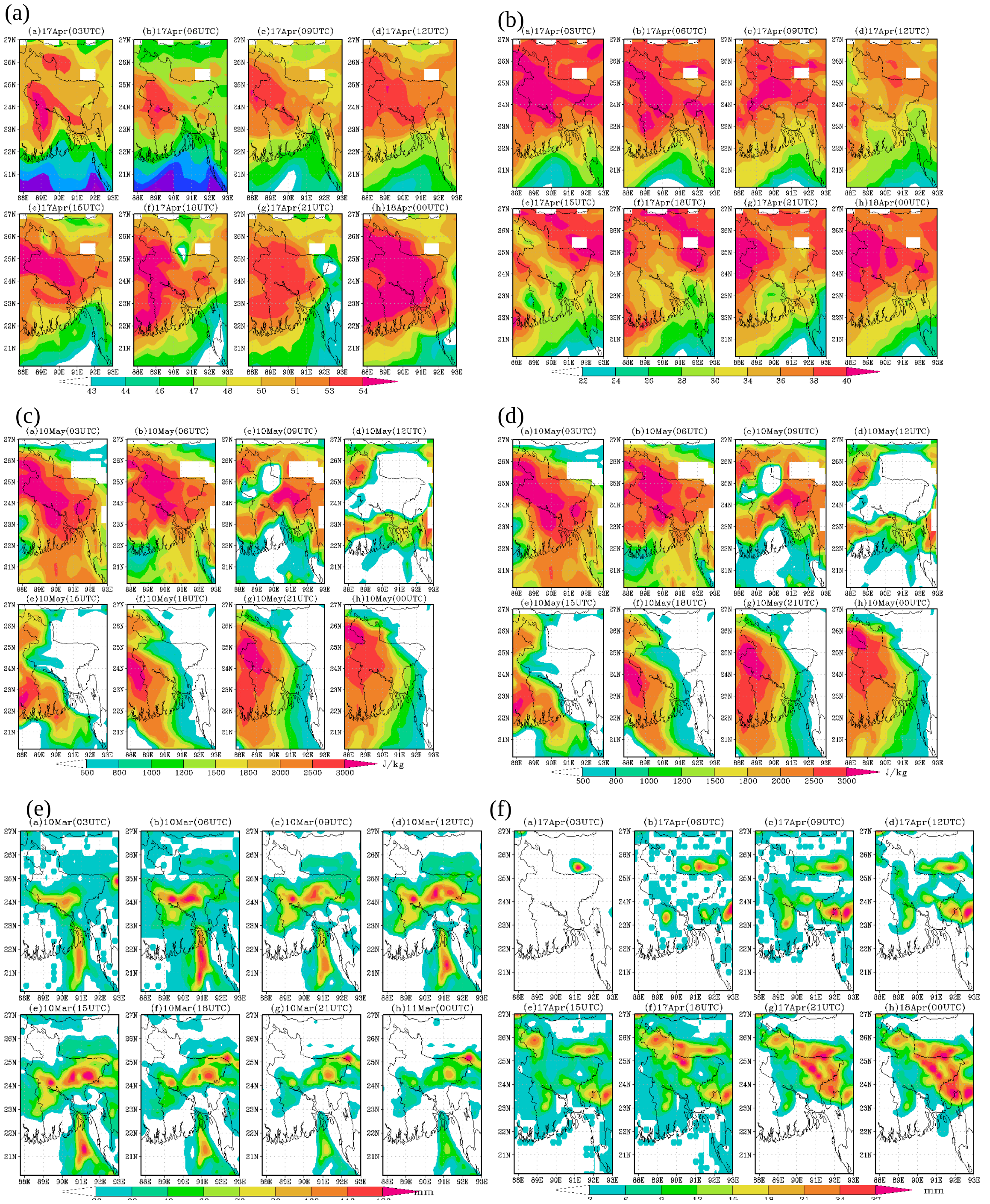


Figure 1. Evolution of (a) TTI on 10 May 2018. (b) KI on 29 April , (c) CAPE on 10 May, (d) CAPE on 31 May 2018, (e) PW on 30 April and (f) PW on 31 May, 2018

Himalayan West Bengal of India and adjoining western part of Bangladesh in the early hours of the day which then expanded over the interior of Bangladesh. In the late hours of the day, CAPE field is found to reenergize and enlarge further over Bangladesh (Figure 1(c & d)). TS with LT and HR are found to occur over the areas with the CAPE of 1500 JK^{-1} and it's above.

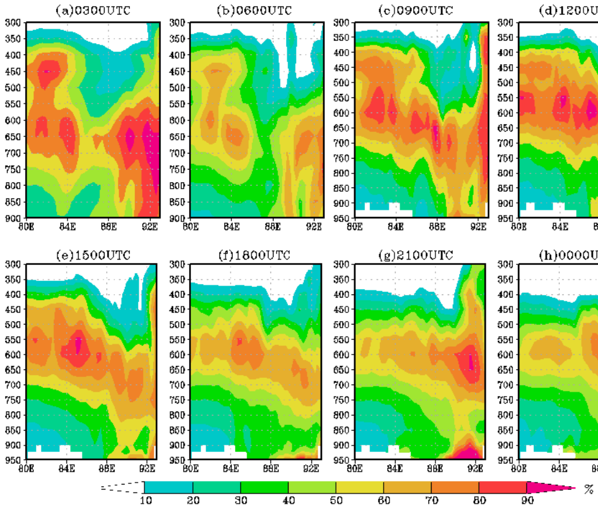


Figure 2. Vertical profile of relative humidity (RH) along 23 °N on 17 April 2018

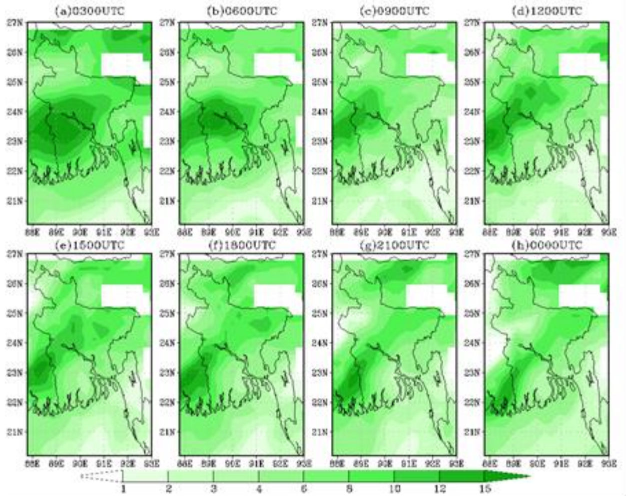


Figure 3. Spatial distribution of LPI at different selected times on 23 May 2018

Vertical profile of CAPE indicates that the system organized and developed vertically with time and finally moved east-southeastwards over Bangladesh following the TS system. The analysis illustrates that the progression of PW, as well as TS, are coherent with each other. Similarly, intensification and coverage area of PW is pertinent with the rainfall. This situation is demonstrated in Figure 1(e & f)). The minimum threshold value of PW for the occurrence of TS is 60 mm but in few cases, 40 mm with other favorable cases. Due to convection and atmospheric process, high RH is seen extending up to 600 hPa level but it is found to extend occasionally at 500 hPa level and remains below this level in some cases.

Similarly, a significant amount of MR (as expressed in percentage of relative humidity) is found to carry on up to 500 hPa level in maximum number cases but in some cases, it expands up to 300 hPa level (Figure 2). LPI specified the likelihood of potential TS in the selected dates. But there is a little shipment of LPI indicated area found from the simulation and potential HR area as found from the observation (Figure 3).

Observed and Simulated heavy rainfall

17 April 2018, HR is recorded over central parts of Bangladesh but model simulates HR over northeastern part. On 29 April HR is seen over central part but HR is simulated over Rajshahi, Mymensingh and Sylhet regions. On 30 April observed and simulated HR are coherent over central, northeastern and northwestern parts.

On 10 May signature HR is found over northeastern, northwestern, southwestern parts but for simulation, it is over Dhaka, Mymensingh, Tangail and Bogra regions. On 11 May, observed HR concentrates over southern and northeastern parts but simulated HR is seen over Jessore and Srimongal regions. On 18 May, observed HR is seen over southcentral and southwestern parts but simulated HR is in the Jessore and Sylhet regions. On 30 April, HR is recorded over Dhaka, Comilla, Noakhali and Khulna regions but model simulates HR over Rangpur region. On 31 May, HR is detected in Dhaka, Comilla, Noakhali, Barishal, and Cox's Bazar but model simulation shows at Tangail, Jessore, Sylhet, Mymensingh Faridpur regions (Figures 4 and 5).

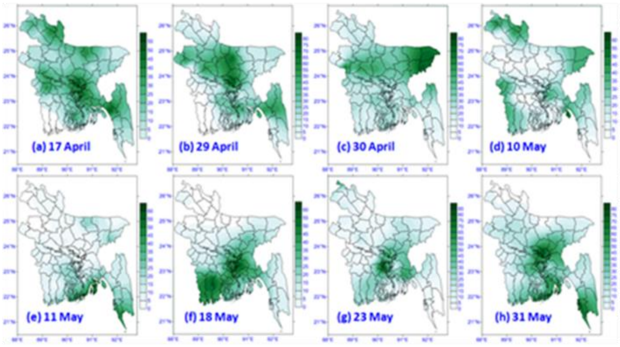


Figure 4. Spatial distribution of rainfall (mm) of selected dates

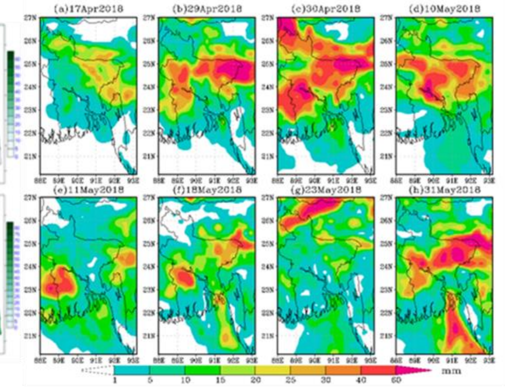


Figure 5. Spatial distribution of simulated rainfall

Conclusion

The study reveals the threshold magnitudes of thermodynamic indices of TTI, KI, CAPE, PW, and strong vertical profile of RH and moisture contents for prediction of TS with LT and HR. Radiosonde observations are not sufficient to detect the evolution process of these events. Simulation through WRF model may contribute to generating in this aspects. LPI is also found to be an efficient tool to detect genesis, intensification, and progression of such an event. Detailed analysis is required to formulate a result.

References

Asnani, G. C., 1993: Tropical meteorology, 2, p824.

Frisbie P. R. *et al*. (2013): Lightning Prediction by WFO Grand Junction using Model Data and Graphical Forecast Editor Smart Tools, NOAA/ NWS, Colorado, http://www.crh.noaa.gov/gjt

George, J. J., (1960): Weather forecasting for aeronautics, Academic Press, New York, 407-411.

Lynn B. and Yair Y. (2010): Prediction of lightning flash density with the WRF model", Adv. Geosci., 23, 11–16, www.adv-geosci.net/23/11/2010/

Lynn, B. H., and Yair, Y. (2008): Lightning Potential Index: A new tool for predicting the lightning density and the potential for extreme rainfall. Geophysical Research Abstracts, Vienna, Vol. 10.

MacGorman, D. R. and Rust, W. D. (1998): The Electrical Nature of Storms, Oxford Univ. Press, pp 422.

Mannan, M. A., Chowdhury M. A. M. and Karmakar, S., (2017): Simulation of heavy rainfall in association with a severe thunderstorm in Bangladesh during pre-monsoon season- a case study', The Journal of NOAMI, 34(1): 69-85, June 2017.

Miller, R. C. (1972): Notes on analysis and severe storm forecasting procedures of the Air Force Global Weather Control (AFGWC), Tech.Rep. 200(Rev) Air weather Services, U.S. Air Force.

Williams, E., and N. Renno (1993): An analysis of the conditional instability of the tropical atmosphere, Mon. Weather Rev.,121, 21–36, 917

Yair, Y., *et al*., (2010): Predicting lightning density in Mediterranean storms based on the WRF model dynamic and microphysical fields, Adv. Geosci., 23, 11–16.

Zhai, P. and Eskridge, R. E. (1997): Atmospheric Water Vapor over China. J. Clim. 1997, 10, 2643–2652.

Zhang, R. and Sumi, A. (2002): Moisture Circulation over East Asia during El Niño Episode in Northern Winter, Spring, and Autumn. J. Meteorol. Soc. Jpn. 2002, 80, 213–227.

CAPACITY OF ROOF CLADDING OF RURAL HOUSING AGAINST BLOWING DUE TO STORM WIND

M. M. Asif[1], M. Z. Alam[2] and R. Ahsan[3]

ABSTRACT

Due to the geographic location, coastal areas of Bangladesh suffer from catastrophic cyclones every year. These cyclones cause severe damages to the rural infrastructures. Therefore, a study was conducted on 100 houses in six coastal areas to investigate different failure patterns of these houses due to the cyclone. Since blowing off the roof was found as the predominant damage type and CGI sheets were commonly used as roofing materials in those houses, a laboratory test was conducted to determine the strength of CGI sheets of different thicknesses. Nine 508 mm×508 mm wooden frames with 508 mm×355 mm CGI sheets of 0.22 mm, 0.32 mm and 0.34 mm thickness were constructed. Then these specimens were tested by applying load along the perpendicular to the CGI sheets gradually and measuring the corresponding deflections. The experimental results show that 0.34 mm thick CGI sheet can sustain 6% and 40% greater load than 0.32mm and 0.22 mm thick CGI sheet respectively. Then a timber roof frame with CGI sheets was modeled and analyzed against different wind speeds. Analysis report shows that CGI sheets of 0.32 mm and 0.34 mm thickness can sustain 13.9% and 17.6% greater wind speed than 0.22 mm thick CGI sheet before failure.

Introduction

Bangladesh is situated at the interface of the two contrasting settings with the Bay of Bengal to the south and the Himalayas to the north (Rahman and Rahman, 2015). Land characteristics with low and almost flat topography, a multiplicity of rivers and the monsoon climate make it subjected to the catastrophic ravages of natural disasters (Islam et al., 2010). Almost one-sixth of tropical cyclones that develop in the Bay of Bengal make landfall on the Bangladesh coast causing heavy loss of life and property jeopardizing the development activities (Ali, 1999). Sidr (2007) destroyed more than 150,000 houses and killed 3,500 people (Sarker and Azam, 2012). In 2010, Aila caused huge damage to private properties including houses of coastal areas (Kabir et al., 2016). 54% of crops land of a particular coastal union was damaged for the cyclone Mahasen in 2013 (Talukder et al., 2018). Most inhabitants in these coastal areas live in houses made of locally available materials (Bern et al., 1993). A survey was regulated on 100 houses in coastal areas of Satkhira, Barguna, Bhola, Noakhali, Chittagong and Cox's Bazar to find out the constituent materials and different failure patterns. According to the survey, 38% of the houses failed by blowing off the roof and the 66% of the roofs made of CGI sheets (Ali et al., 2017). Therefore, the objective of this paper is to make a comparative study among CGI sheets of different thicknesses in terms of their capacity, deflection and maximum wind speed before failure. Besides, timber roof structures are analyzed against different wind speeds to evaluate the maximum wind speed causing the failure of different components of the roof structure.

Experimental Program

Nine specimens were investigated in this study. At first nine 508 mm×508 mm raintree wooden frames were built. Three types of CGI sheets were used in this experiment. All of them were 508 mm×355 mm in size but having different thicknesses. Three wooden frames were attached with three 0.22 mm thick CGI sheets individually. In the same way, three 0.32 mm CGI sheets and three 0.34 mm CGI sheets were used. 6 screws and 6 washers were used to attach each CGI sheet with each frame. The details of the specimens are presented in Table 1. The schematic plan view of the specimen is illustrated in Figure 1.

[1]Post Graduate Student, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh
[2]Post Graduate Student, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh
[3]Professor, Dept. of Civil Engineering, BUET, Dhaka-1000, Bangladesh
Email of Corresponding Author – md.mahirasif92@gmail.com

Table 1. Details of the specimens

Specimens	Frame size	CGI sheet size	CGI sheet Thickness	Screw size	Nail size	Washer (dia)
1 to 3	508 mm×508 mm	508 mm×355 mm	0.22 mm	44 mm	63 mm	25 mm
4 to 6	508 mm×508 mm	508 mm×355 mm	0.32 mm	44 mm	63 mm	25 mm
7 to 9	508 mm×508 mm	508 mm×355 mm	0.34 mm	44 mm	63 mm	25 mm

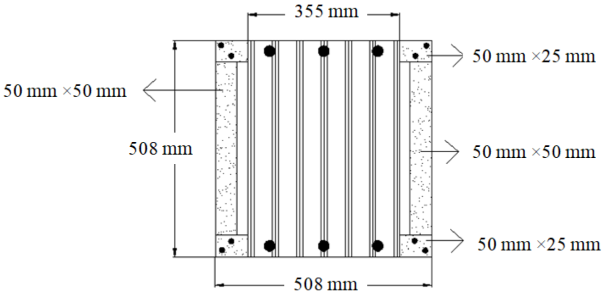


Figure 1. Schematic plan view

Figure 2. Experimental setup

Each corner of the specimen was placed on firm support and a dial gauge was set under the specimen to measure the deflection of the CGI sheet at mid-point as shown in Figure 2. Then equivalent weights were applied along the perpendicular to the specimens since wind loads acting on the roof surface perpendicularly. A steel plate (305 mm×305 mm×19 mm) was used to distribute the loads uniformly on the sample.

Structural Modeling and Analysis

Timber roof structures were modeled by using SAP2000. Details of the structural model are provided in Table 2. Properties of raintree timber were collected from the study conducted by Hossain and Awal (2012).

Table 2. Details of the structural model

General descriptions	Section properties		Material properties
	Component	Dimensions	
• Plan: 6.1 m × 3.66 m • Total height: 3.66 m • Mean height of roof: 3.05 m • Roof slope: 33.7° • Exposure category C	Top Chord	50 mm × 75 mm	Timber: Raintree • Compressive strength: 20 MPa • Tensile strength: 16.6 MPa • Unit weight: 6.3 kN/m^3 • Modulus of elasticity: 7929 MPa
	Bottom chord	50 mm × 75 mm	
	Purlin	50 mm × 25 mm	
	Vertical	50 mm × 50 mm	
	CGI sheet	0.22 mm, 0.32 mm & 0.34 mm	

These models were analyzed against wind loads ranging from 50-250 kmph. Only the unfactored wind load in combination with dead load was used. All the loads were calculated as per BNBC 2006. All the connections were assumed to be pinned. Geometric dimensions of the house and model of the roof structure are illustrated in Figure 3 and Figure 4 respectively.

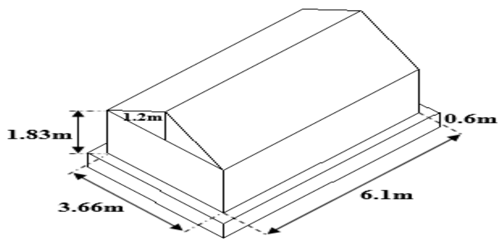


Figure 3. Geometric dimensions of the house

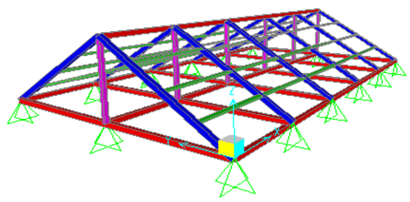
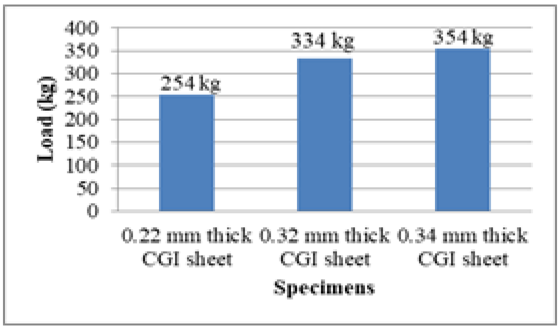


Figure 4. Model of the roof structure

Results and Discussions

The failure occurred due to bearing failure of CGI sheet at the connection with timber frame. The average capacity of the specimens is illustrated in Figure 5. Corresponding deflections were also measured during the experiment. Load-deflection curves of CGI sheets up to 134 kg are illustrated in Figure 6.



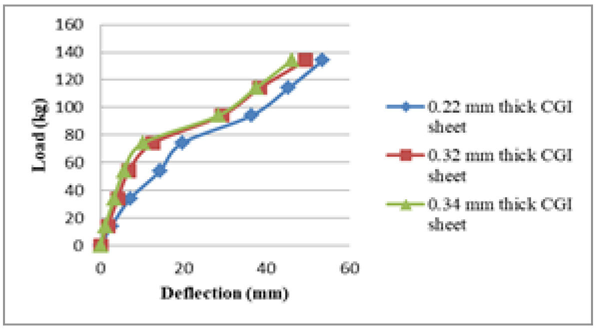
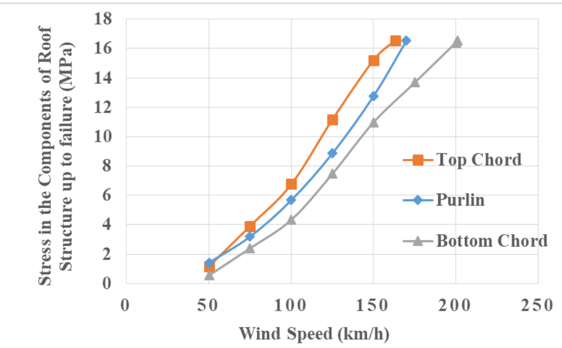


Figure 5. The average capacity of specimens *Figures 6. Load vs deflection curve*

After analyzing the roof structure, it is found that CGI sheet and top chord have been stressed more than the other components. Besides, flexural stress in the components has been found dominant. So, failure is initiated in the top chord and purlin due to flexure which is followed by the blowing of the CGI sheet. Variation of stress in different components of the roof structure with wind speed is shown in Figure 7. Comparison of maximum wind speed before failure of CGI sheets is provided in Figure 8.



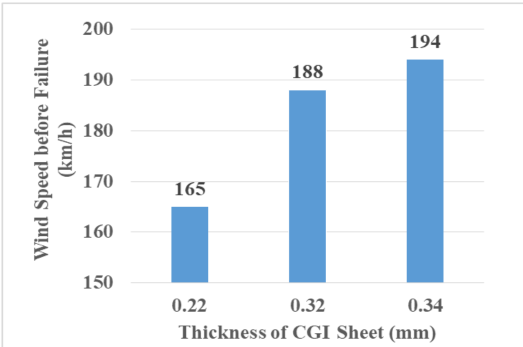


Figure 7. Stress in different components of roof *Figure 8. Wind speed before failure of CGI sheets*

The slope of the roof affects the failure wind speed of CGI sheets. Wind speed at failure is minimum when the slope of the roof is 10°-15°. This is applicable only for the roof having mean height less than 4.5 m from the ground. Effect of roof slope on the failure wind speed of CGI sheet is provided in Figure 9.

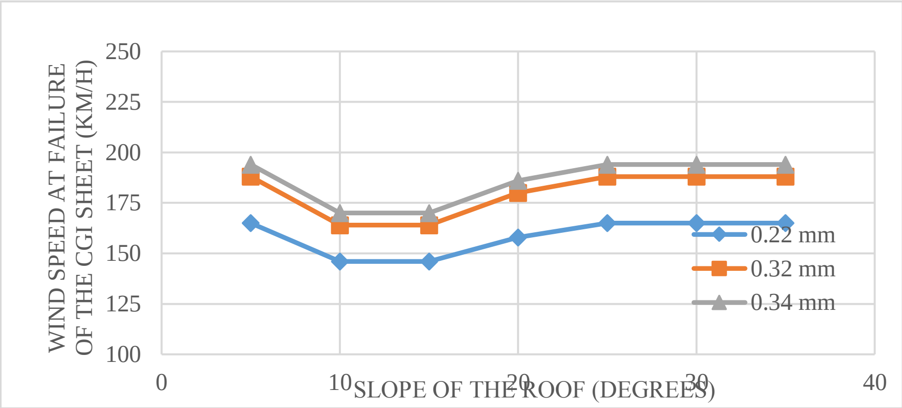


Figure 9. Effect of the slope of the roof on the failure wind speed of CGI sheet (h<4.5 m)

Conclusion

The following conclusions may be drawn from the present study-

(i) From experimental results, it is found that 0.34 mm thick CGI sheet can sustain 6% and 40% greater load than 0.32 mm and 0.22 mm thick CGI sheet respectively. Besides, load-deflection curves of the CGI sheets indicate that 0.34 mm and 0.32 mm thick CGI sheets have a greater stiffness than 0.22 mm thick CGI sheet. So, 0.34 mm and 0.32 mm thick CGI sheets are more suitable roofing materials than 0.22 mm thick CGI sheet.

(ii) From the structural analysis, it is clear that the failure of the roof structure is initiated in the top chord and purlin resulting in the blowing of CGI sheet which leads to the collapse of the entire roof structure. Before the failure, CGI sheets of 0.32 mm and 0.34 mm thickness can sustain 13.9% and 17.6% greater wind speed than 0.22 mm thick CGI sheet. Besides, failure of top chord, purlin, and bottom chord occur at a wind speed of 163 km/h, 170 km/h and 201 km/h respectively.

Acknowledgment

The authors would like to acknowledge support from the project conducted jointly by the Institute of Water and Flood Management (IWFM) of BUET and Kyoto University under "Science and Technology Research Partnership for Sustainable Development (SATREPS)" of JAICA.

References

Ali, A. (1999) "Climate change impacts and adaptation assessment in Bangladesh", *Climate Research*, 12, 109-116.

Ali, M. M., Alam, M. Z., Asif, M. M., Purkayastha, S. and Ahsan, R. (2017) "Damage assessment of rural infrastructure due to a cyclone in Bangladesh" *International Conference on Disaster Risk Mitigation 2017*, Dhaka, Bangladesh.

Bern, C., Sniezek, J., Mathbor, G. M., Siddiqi, M. S., Ronsmans, C., Chowdhury, A. M., Choudhury, A. E., Islam, K., Bennish, M., and Noji, E. (1993) "Risk factors for mortality in the Bangladesh cyclone of 1991", *Bulletin of the World Health Organization*, 71(1),73-78.

BNBC (2006) "Bangladesh National Building Code", 2(6), Housing and Building Research Institute, Bangladesh.

Hossain, M. B. and Awal, A. S. M. A. (2012) "Mechanical properties and durability of some selected timber species.", *Malaysian Journal of Civil Engineering*, 24(1), 67-84.

Islam, A. S., Bala, S. K., Hussain, M. A., Hossain, M. A., and Rahman, M. M. (2010) "Performance of coastal structures during cyclone Sidr", *Natural Hazards Review (ASCE)*, 12(3), 111-116.

Kabir, R., Khan, H. T. A., Ball, E., and Caldwell, k. (2016) "Climate change impact: the experience of the coastal areas of Bangladesh affected by cyclones Sidr and Aila", *Journal of Environmental and Public Health*.

Rahman, S., and Rahman, M. A. (2015) "Climate extremes and challenges to infrastructure development in coastal cities in Bangladesh", *Weather and Climate Extremes (Elsevier)*, 7, 96-108.

Sarker, T., and Azam, M. (2012) "Super Cyclone SIDR 2007: Climate change adaptation mechanisms for coastal communities in Bangladesh", Asian Journal of Environment and Disaster Management, 4(2), 85-90.

Talukder, M. F., Shamsuzzoha, M., and Hasan, I. (2018) "Damage and agricultural rehabilitation scenario of post cyclone Mahasen in coastal zone of Bangladesh.", *Journal of Sociology and Anthropology*, 2(1), 36-43.

THE RISE OF A NEW DISASTER IN BANGLADESH: ANALYSIS OF CHARACTERISTICS AND VULNERABILITIES OF LIGHTNING DURING MARCH TO SEPTEMBER 2018

M. S. Uddin[1] and R. H. Suravi [2]

ABSTRACT

Bangladesh is a country of disasters, mostly triggered by the hydro-meteorological hazards, with climate change directly influencing their intensity and frequency. In recent years, lightning incidents are becoming more frequent and claiming more lives than the past. This research is a systematic effort to understand the characteristics and vulnerabilities of lightning hazards based on observation during March to September 2018. The main objective of this study is to increase the understanding of lightning hazard and disaster in the context of Bangladesh and support risk reduction initiatives for saving lives.

Introduction

The current world is highly concerned about severe weather phenomena (Kohn, et al., 2011). Bangladesh is a country of natural disasters. Tropical cyclones, storm surges, coastal submergence, river erosion, floods, and droughts occur almost annually and cause substantial loss of life and property. The country is also very vulnerable to climate change (Kreft et al., 2016). Changing climate is modifying the frequencies and intensities of hydro-meteorological disasters and introducing new threats (Dastagir, 2015). For the last few years, lightning casualties have been one of the most discussed issues in Bangladesh.

"Lightning, one of the most powerful forces in nature, once was mysterious, magical and feared as the great weapon of the Gods" (Kuleshov, 2004). Lightning has been an object of interest and study for decades. According to Christian et al. (2003), the research effort on lightning is recently getting pace for their potential relationships with future global warming and their year to year fluctuations as a result of the ENSO phenomena.

The main objective of this study is to increase the understanding of lightning hazard and disaster in the context of Bangladesh and support risk reduction initiatives for saving lives. The research carried out a systematic process to understand the characteristics and vulnerabilities of lightning hazard based on the observations from March to September 2018. In addition, an extensive literature review was conducted to understand the global context of lightning threats and vulnerabilities and possible relationship with global warming and climate change and their relevance to Bangladesh. The findings and discussion of this research will potentially contribute to knowledge sharing, awareness raising and support decision-making for future disaster risk reduction

Lightning and Bangladesh

The country is very sensitive to climate change. Bangladesh is surrounded by the Indian subcontinent on the northeast, the Meghalaya plateau to the northeast and faces the Bay of Bengal to the south. The seasonal climatic dynamics of Bangladesh is mainly governed by the surrounding mountains and the sea (Ali, 1996). During the monsoon, the wind blows from the southwesterly direction, carrying a huge amount of moisture from the sea and after reaching the north-east part, creates huge rainfall due to orographic effect (Robinson and Sellers, 2014). Such an orographic effect not only creates rainfall but also generates thunder, lightning, hails etc. Highly unstable and intense convection during the monsoon generate thunderstorms and lightings in Bangladesh, Sri Lanka, India, Bhutan, and Nepal; and sometimes bring havoc for the communities in extreme weather conditions (Mäkelä et al., 2014).

Many researchers (Koutroulis et al., 2012) have reported the strong correlation between accumulated rainfall and lightning activity. The occurrence of heavy to very heavy rainfall associated with the severe thunderstorm is the climatic phenomena in the northeastern part of Bangladesh. A 2 °C warming combined with a 10%

[1]*Doctoral Candidate, Asian Institute of Technology (AIT), Pathumthani-12120, Thailand*
[2]*Master's Student , Dept. of Architecture, BUET, Dhaka-1000, Bangladesh*
Email of Corresponding Author – shamimmsu@gmail.com*;* st113965@ait.ac.th

increase in precipitation in the Ganges-Brahmaputra-Meghna (GBM) river basin (Dastagir, 2015) is an alarming forecast for future lightning hazard.

Bangladesh is one of the most densely populated (1,265 people/km2) countries in the world (World Bank, 2017). For a huge number of communities, there is no or limited scope of getting suitable land for living and farming (Hasan et al., 2017). In addition, the state of the environment in Bangladesh is at stake. Air pollution is a serious environmental issue (Alam, 2009). Degradation of natural resources is also a serious problem, particularly land use and forest management (Kibria et al., 2011).

During the last 8 years (2011-2018) lightning has claimed more than 200 lives each year. Analysis of 29 years (yearly) of casualty data found a clear increasing trend in lightning casualty. From 1990 to 2000, the rate of yearly casualty was 30 (±22), it was 116 (±39) during 2001 to 2010, and 249 (±45) during 2011 to 2018 (Figure 1).

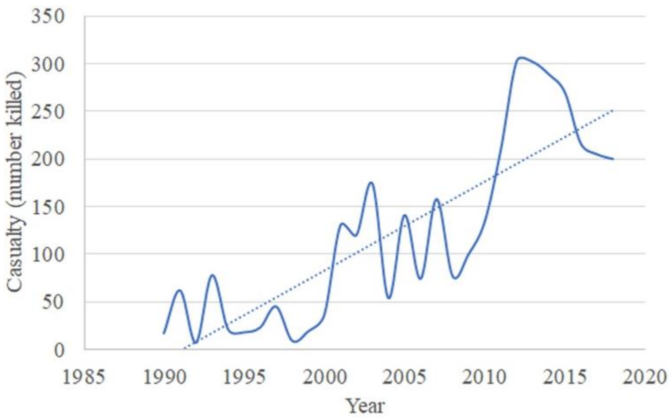


Figure 1. The trend of lightning casualties in Bangladesh (data collected and verified from many different sources)

Research Methodology

The study used both qualitative and quantitative secondary data adopting a mixed research method. Lightning hazard and casualty data were collected from daily newspapers reports (Bengali and English). Satellite images of MODIS land cover and ASTER GDEM (Digital Elevation Model) from NASA websites. Data were analyzed using the simple statistical tool and GIS platform and are visualized in figures and maps. This research also did a very extensive literature review to understand the global context of the issue and a possible solution.

Findings

The research findings are based on 184 reported casualties from 42 districts of Bangladesh. Spatial analysis indicated wetlands and agricultural farmlands around Bangladesh are at high risk, mostly due to the absence of any tall tree or pole. Most of the victims were found as working age male doing farming activities. Female casualties mostly occurred close to their homes. The temporal analysis found May as the riskiest month and first half of the day (morning to midday) as the riskiest time. The overall research observations suggest that geomorphology, climate change, environmental degradation, pressure on land use and lack of community awareness are potential factors in the lightning disaster of Bangladesh. For their climatic and geomorphological settings, great Sylhet region was found more prone to lightning hazard and disasters. Under existing climate change scenario, there is a higher risk a lightning casualty in Bangladesh in future.

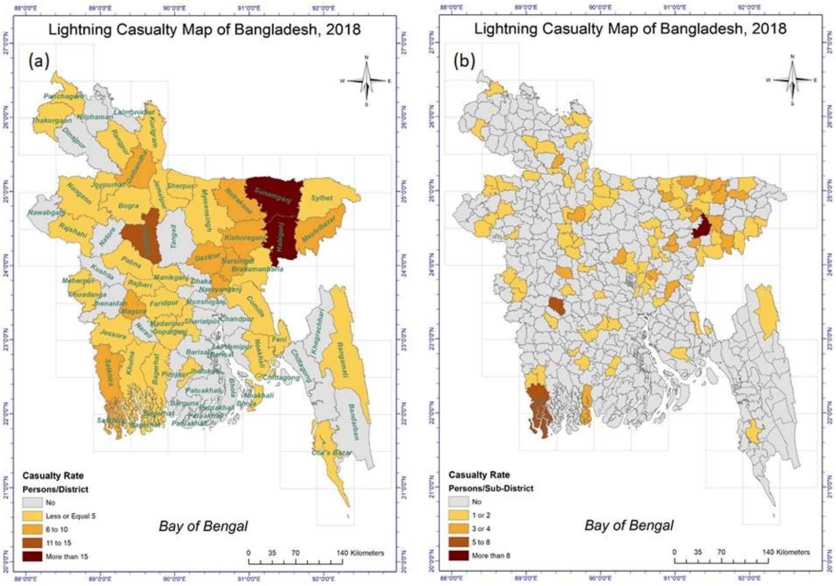


Figure 2. Density distribution of casualties in of Bangladesh [(a) district-wise casualty distribution, and (b) sub- district-wise casualty distribution]

Out of total 64 districts in Bangladesh, 42 districts were exposed to a different level of lightning casualties from March to September 2018. Among 42 districts, Habiganj and Sunamganj were found as the riskiest place for lightning disaster, claiming 21 and 20 lives respectively (Figure 2a). Among the subdistricts, maximum casualties (11 killed) were reported in Baniachong of Habiganj district (Figure 2b).

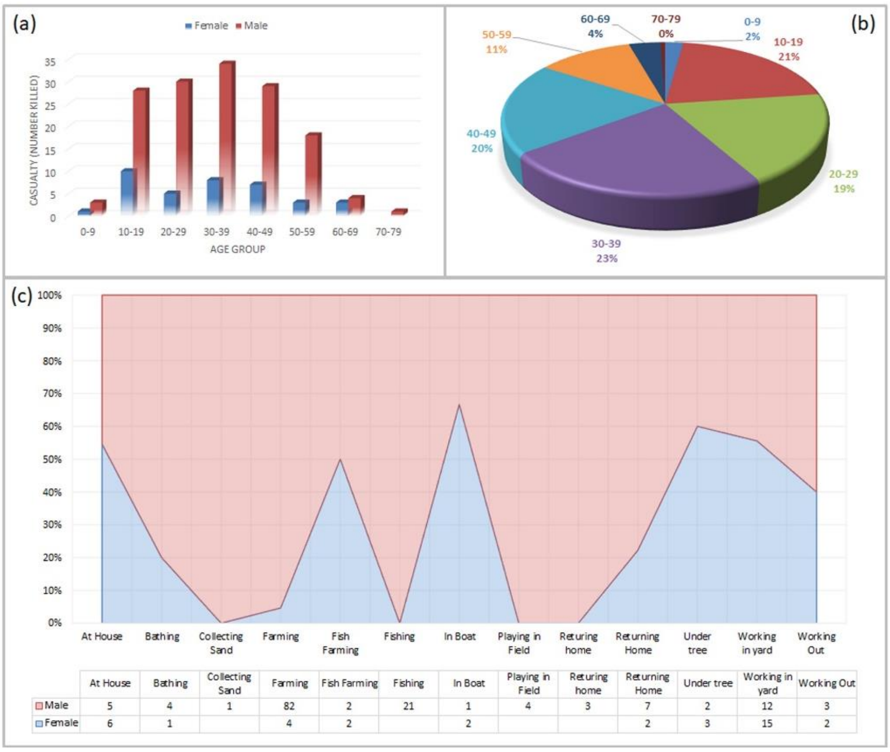


Figure 3. Distribution of casualties based on age, gender and circumstances [(a) different groups and gender, (b) proportion of casualties for different age groups, and (c) gender and circumstances of event location]

The dominant portion of people killed by lightning hazards during the year 2018 in Bangladesh is male. This research used information of 184 death reported between March and September 2018. Among the casualties, 80% were male (147) and 20% female (37). 73% of the victims are working age (20-59 years old), only a few (4%) are elderly (60-79 years old) and remaining 23% belong to age group below 20 years (Figure 3a & 3b). Almost all (94%) of lightning casualties happened outdoor. 86 people died when they have engaged in farming in large open agriculture fields away from the locality. 35 of 86 casualties occurred in the Haor (permanent wetland) areas (Figure 3c).

The figure (Figure 4) below illustrates the temporal (times of day, specific days, months) distribution of casualties. Lightings occurred mainly during midday and morning, constituting 77% of total casualties. 15% casualties occurred in the afternoon and only 8% at night. Lightning killed 21 people on 09-May, 20 people on 29-April, 15 people on 30-April and 24 people on 10-May. Those 4 days constituted 38% (killed 70) of the overall casualties. Monthly analysis of data showed that May is the most critical month for lightning disaster followed by April. Lightning killed 79 (43%) in May and 43 (23%) during the month of April. A small rise in casualties was also observed during September when 25 (14%) were killed by lightning hazards.

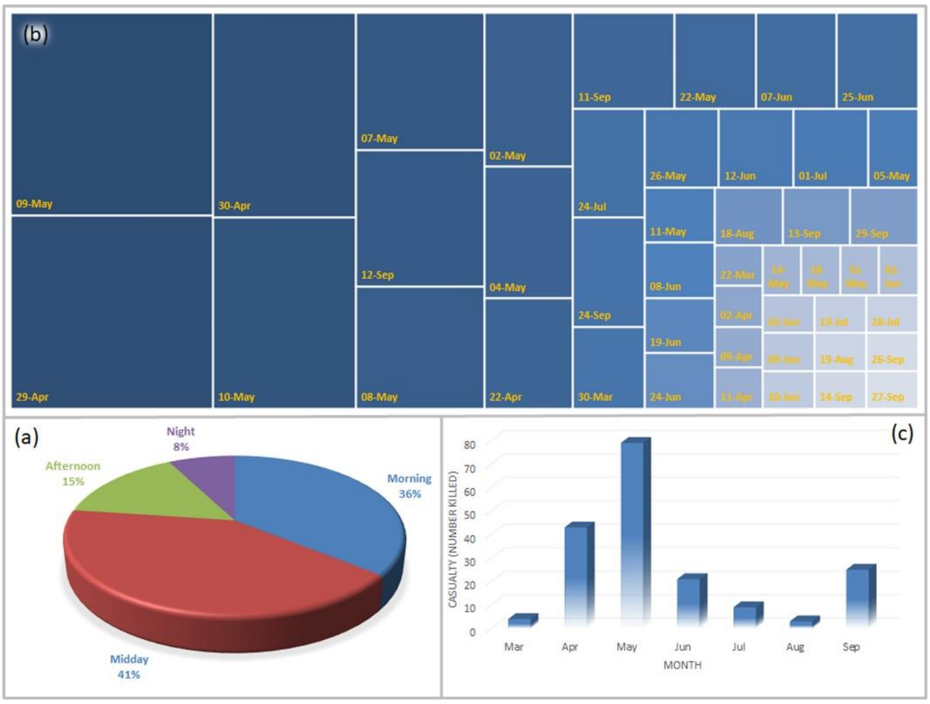


Figure 4. Temporal distribution patterns of casualties [(a) distribution of casualties during different times of day, (b) casualty distribution according to date; the size of the rectangle represents the number of victims, and (c) casualty distribution according to month]

Causes of Lightning Casualties

Hazards alone cannot create disasters. To make disasters happen, a community must be exposed to a substantial hazard. Hazard and exposure are dynamic in nature. Frequency and intensity of hazards may change with the changes in geomorphology, climatic patterns and other reasons (Romps et al., 2014). Similarly, the level of exposure of a community may change with modification in the environment, demands of livelihoods, awareness, and preparedness, organizational capacity, and many other parameters (Islam et al., 2001; Hasan et al. 2017). The level of risk and probability of lightning disaster will increase if there is a rise in frequency and intensity of hazards, or if the community increase their exposure to hazard (when the level of hazard is static). However, when hazard and exposure increase their level, it can bring catastrophe for the community (Figure 5). Observation of this research concluded that in respect to lightning disaster in Bangladesh, hazard, and exposure, both are potentially moving towards higher risk in the future.

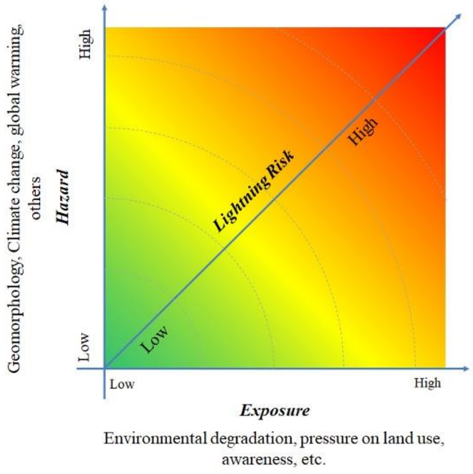


Figure 5. Conceptual relationships between lightning hazard, exposure, and risk

It is important to note that a big portion of casualties (43 of 184) occurred in the hoar (permanent wetland) areas (see Figure 2 and Figure 6). *Haors* are marginal land without any shelter, big tree, and infrastructures. Farmers go to *haor* areas for farming activities, mostly staying the whole day. It is inconvenient for the farmers to return home if the weather gets bad and there is no place for taking shelter during bad weather condition. Moreover, while people are working in the *haors*, they are the tallest objects in the widespread, totally flat swampy lands. Many experts also identified population density and deforestation as reasons for lightning casualties (Islam 2016).

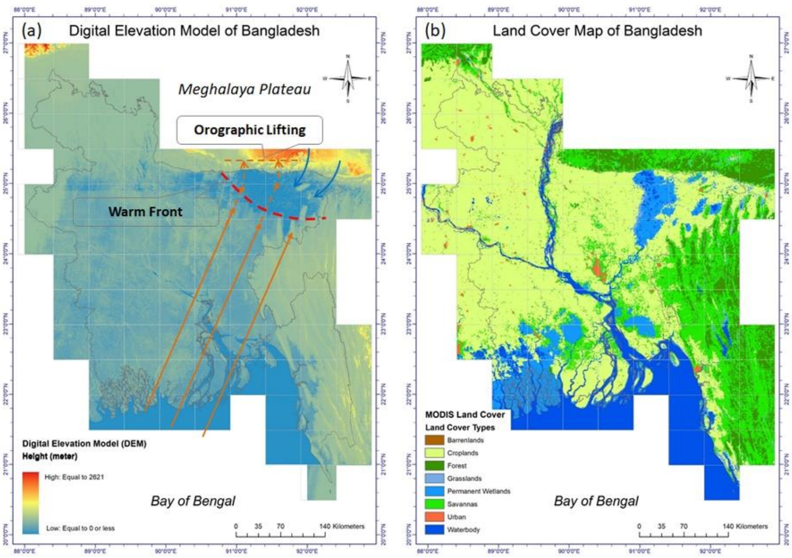


Figure 6. Maps of Bangladesh [(a) Digital elevation model and (b) MODIS land cover]

Future Risk Reduction Strategies (Recommendation)

Community awareness like ‘When Thunder Roars, Go Indoors!’ is the first and best tool for any disaster preparation and response. The government should teach the communities ‘Do’s and Don’ts’ for lightning safety through mass awareness campaigns involving Print, TV, Radio, Social Media, etc. People in risky areas should be taught to avoid open areas; stay away from isolated tall trees, towers or utility poles; stay away from metal conductors; and if with a group of people, spread out to reduce casualties.

The government of Bangladesh, with the help of international organizations and community, must allocate priority budget for technical interventions for monitoring, forecasting and documenting lighting hazards for disaster prevention and future research. A thunderstorm is a small-scale phenomenon with three hours (maximum) temporal resolution and 2 km to 20 km dimension. Hence, global scale General circulation models (GCM) is not suitable for lightning. Modern satellite images are also not that suitable for their data capturing and processing time. The Doppler Weather Radar is a good tool for lightning observation and the country needs a wider network of radars for monitoring and early warning.

People can save themselves and their home from lighting by adopting the simple idea of 'Franklin's Lightning Rod'. But for outdoor, it is more challenging than indoor. The local government of many lightning prone areas of Bangladesh is now planting palm trees for the safety from the lightning hazard. But trees need a certain amount of time to grow and may not grow in many conditions. The immediate solution of lightning hazard safety in large open space could be a combination of 'electric pole' and 'Franklin's Lightning Rod'.

Conclusion

In the last few years, one of the most discussed issues in Bangladesh is the lightning casualties. Even though the government declared lightning casualties as a disaster for Bangladesh, there is no concrete initiative for the prevention and management of any future event. The events of rainfall and lightning storms naturally depend on the local climate, land and ocean surface characteristics. Their forecasts are of critical importance when they occur in overpopulated area like Bangladesh. It is also important to understand that government efforts alone may not be enough to get rid of casualties from lightning and other disasters. Communities themselves must take some initiatives by themselves to reduce the damage done by lightning. Through raising community awareness and taking proper measures, it can be hoped that Bangladesh will be able to mitigate the adverse effect of lightning hazards in the near future.

References

Alam, G. J. (2009) "Environmental pollution of Bangladesh—it's effect and control", *Pulp and Paper*, 51, 13-7.

Ali, A. (1996) "Vulnerability of Bangladesh to climate change and sea level rise through tropical cyclones and storm surges", Springer, Dordrecht.

Christian, H. J., and et al. (2003) "Global frequency and distribution of lightning as observed from space by the Optical Transient Detector", *Journal of Geophysical Research: Atmospheres*, 108(D1), ACL-4.

Dastagir, M. R. (2015) "Modeling recent climate change induced extreme events in Bangladesh: a review", *Weather and Climate Extremes*, 7, 49-60.

Hasan, S. S., Deng, X., Li, Z., & Chen, D. (2017) "Projections of future land use in Bangladesh under the background of baseline, ecological protection, and economic development", *Sustainability*, 9, 1-21.

Islam, K. R., Ahmed, M. R., Bhuiyan, M. K., & Badruddin, A. (2001) "Deforestation effects on vegetative regeneration and soil quality in tropical semi-evergreen degraded and protected forests of Bangladesh", *Land Degradation & Development*, 12(1), 45-56.

Islam, S. (2016) "Bangladesh declares lightning strikes a disaster as deaths surge", *REUTERS*.

Kibria, M.G., Rahman, S.A., Imtiaj, A. and Sunderland, T.C.H. (2011) "Extent and consequences of tropical forest degradation", *Journal of agricultural science and technology*, 1(1), 29-37.

Kohn, M., Galanti, E., Price, C., Lagouvardos, K., & Kotroni, V. (2011) "Nowcasting thunderstorms in the Mediterranean region using lightning data", *Atmospheric Research*, 100(4), 489-502.

Koutroulis, A. G., & et al. (2012) "Lightning activity, rainfall, and flash flooding–occasional or interrelated events?", *Natural Hazards and Earth System Sciences*, 12(4), 881-891.

Kreft, S., Eckstein, D., & Melchior, I. (2016) "Global Climate Risk Index 2017", Germanwatch, Germany.

Kuleshov, Y. (2004) "Seasonal and latitudinal variations of lightning ground flash activity in Australia", *Australian Meteorological Magazine*, 53(3), 197-204.

Mäkelä, A., Shrestha, R., & Karki, R. (2014) "Thunderstorm characteristics in Nepal during the pre-monsoon season 2012", *Atmospheric research*, 137, 91-99.

Robinson, P. J., & Henderson-Sellers, A. (2014) *"Contemporary climatology"*, Routledge, New York.

Romps, D. M., Seeley, J. T., Vollaro, D., & Molinari, J. (2014) "Projected increase in lightning strikes in the United States due to global warming", *Science*, 346(6211), 851-854.

SOIL SALINITY HAZARD ASSESSMENT IN BANGLADESH COASTAL ZONE

M. H. Hasan[1], M. R. Rahman[2], A. Haque[3], T. Hossain[4]

ABSTRACT

The coastal zone of Bangladesh covers about 20% of total land in the country and over 30% of the cultivable lands. According to the National Adaptation Program of Action (NAPA), water-related hazards due to climate change are likely to become a critical issue for Bangladesh. Salinity in surface water, groundwater, and soil have become a dominant hazard in Bangladesh coastal zone. There is a number of studies in the region that address surface water and groundwater salinity. But very few studies deal with soil salinity. There is no study in the region that particularly deals with the soil salinity hazard assessment. This study is aimed to fill this research gap. In this study, soil salinity hazard is assessed by using historical secondary data related to the area affected by soil salinity. By using the normalization method, soil salinity hazard map is prepared in a GIS environment. The results show that the western region is very high saline zone and eastern region is a low saline zone in terms of soil salinity. This study tries to find out the saline affected area from 1973 to 2009 and also tries to give a salinity risk map in the southern part of Bangladesh. Amount of saline affected area is considered as the parameter and by normalizing the number of affected areas the salinity risk maps are prepared. About 0.223 million ha (26.7%) new land is affected by various degrees of salinity during the last four decades. The maximum saline affected area is found at Galachipara Upazila in Patuakhali District while the minimum saline affected area is found at Maladi Upazila in Barisal district. The saline affected areas are increased in Khulna, Bagerhat, Satkhira, Patuakhali districts. From the risk map, it is identified that the lower middle and the corner of the southern part of Bangladesh fall at the zone of high and very high risk.

Introduction

Salinity in surface, ground, and soil in the coastal zone has become a very crucial matter in southern coast in Bangladesh (Mondal, Bhuiyan, & Franco, 2001) (Institute (SRDI), 2010) (Rahman, Majumder, Rahman, & Halim, 2011). When the soil salinity exceeds a plant's tolerance, growth reductions occur. Salinity intrusion in river water may cause economic loss in terms of crop yield reduction, hampering industrial production, increasing health hazard and reducing the productivity of the forest species (Haque, 2006). Agriculture production is likely to decrease as saline containing water and soil reduce plant growth through concentrating salt in the root zone of plant and resulting in nutrients imbalance and yield loss (Pitman & Läuchli, 2002) (Haque, 2006). Average soil salinity concentrations at the coast are higher in the low flow season than the high flow season because of less freshwater flow from the upstream. Waterlogging is another problem that likely to increase soil salinity in the coastal zone (Awal, 2014). According to Karim and Mimura (2008), Sluice gates of different polders were blocked in the coastal areas for sediment deposition from rivers. As a result, saline water from high tide or storm surge interred into the polders but could not drain out properly, resulting in waterlogging and causes soil salinity. The salinity generally increases from October to the late May (Karim, 2008). In this condition, soil salinity maps are very useful to identify vulnerable area addressing salinity and help to create saline-induced risk map in the southern part of Bangladesh that might be helpful for decision makers and planners. As salinized soil has a negative impact on agricultural production in this region especially during the pre-monsoon season, so, identification of soil salinity area through risk mapping is now very essential for developing proper management strategies (Çullu et al., 2002).

Objective

The objective of this study is to identify the vulnerable area through salinity hazard map of the southern part of Bangladesh.

[1,2] *Graduate Research Associate, Institute of Water and Flood Management, Bangladesh University of Engineering & Technology, Dhaka-1000, Bangladesh.*
[3]*Professor, Dept. of Civil Engineering, XY University, City-1025, Country*
[4]*Post Graduate student, Institute of Water and Flood Management, Bangladesh University of Engineering & Technology, Dhaka-1000, Bangladesh*
Email of Corresponding Author – hasibulurp@gmail.com

Methodology

The study was conducted on the southwest coast of Bangladesh. Secondary data of soil salinity was collected from SDRI report of Bangladesh. Also, other data needed for the study were collected from different journal papers, reports, articles related to salinity. To show the soil salinity hazard, risk mapping was used. Salinity maps are prepared based on the soil salinity data determined in two different years 1973 and 2009 using GIS. There are 116 Upazilas situated in the study area. Amount of saline affected area was considered as the parameter to prepare the salinity risk map where the saline affected area was normalized by using the equation:

$$\frac{(F - Fmin)}{(Fmax - Fmin)} \quad \ldots\ldots (1)$$

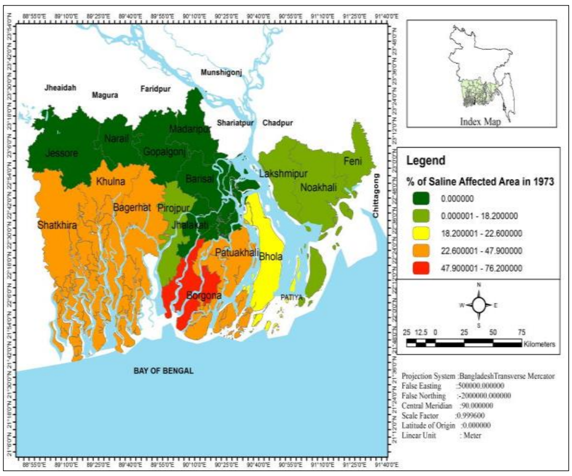
Where, F = Value of saline affected area of any location, F_{max} = Maximum value of the saline affected area of any location and F_{min} = Maximum value of the saline affected area of any location. The maximum value was found at Galachipara Upazila (F_{max} = 53390 ha) and the minimum value is found at Maladi Upazila (F_{min} = 110 ha). Five categories were considered to prepare risk mapping for salinity affected area (Table 1).

Table 1. Risk category of saline affected zone for risk mapping.

Risk category	Range
Very low	0.00-0.009
Low	0.01-0.05
Medium	0.051-0.30
High	0.31-0.50
Very high	0.51-1.00

Discussions

The total area of Bangladesh is 147,570 sq. km and it extends inside up to 150 km from the coast (Petersen & Shireen, 2001). The coastal area of Bangladesh is divided into three categories. South-west, the mid-central and south-east coastal area of Bangladesh includes 16 districts. A comparative study of the salt-affected area of 1973 and 2009 showed that about 0.223 million ha (26.7%) new land was affected by various degrees of salinity during the last four decades. Figure 01 shows that about 22% to 47% of soil was found as soil saline in Shatkhira, Khulna, and Patuakhali while Borguna was found as the most vulnerable because of saline soil (about 48 to 76%).



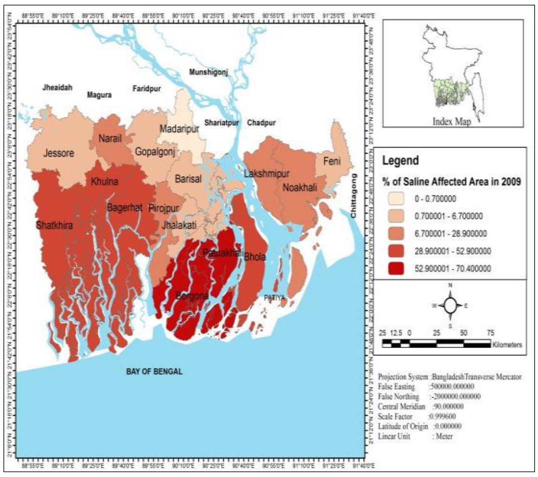


Figure 1. District-wise comparison of salinity affected areas (%) in 1973.

Figure 2. District-wise comparison of salinity affected areas (%) in 2009

From figure 1 it has been seen that in 1973, Jessore, Narail, Jkalakhati Barishal, Gopalganj, and Madaripur had a little salinity effect. In 2009, salinity in Khulna, Bagerhat, Satkira, Patuakhali, and Bhola did not change while Jessore, Narail, Jkalakhati Barishal, Gopalganj, and Madaripur has been affected a lot by salinity (figure 3)

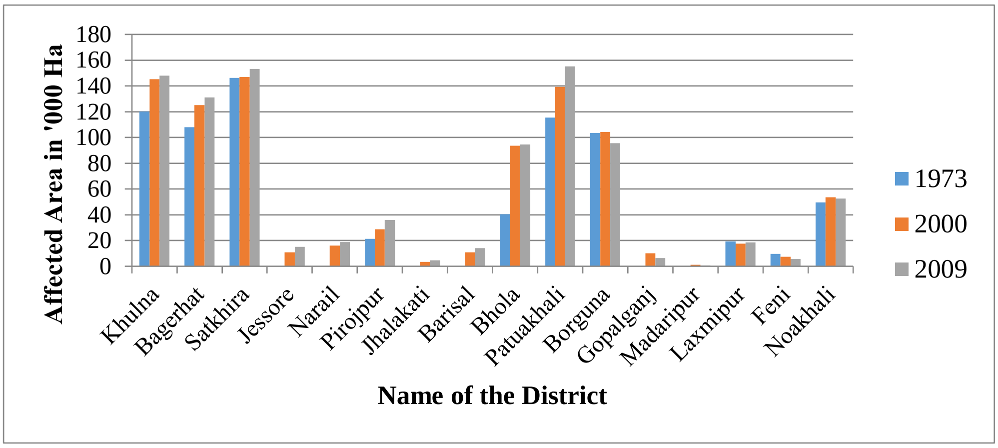


Figure 3. Comparison of soil salinity affected areas 1973, 2000 and 2009

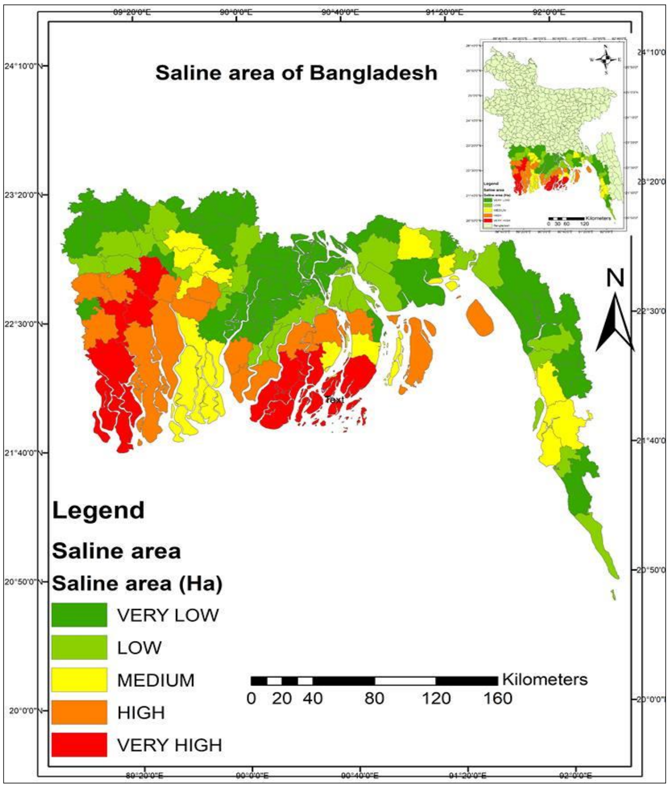


Figure 4. Risk zoning map of saline affected area

According to the range, a risk map is prepared (shown in figure 4). From the risk map, it can be said that the lower middle and the corner of the southern part fall at the zone of high and very high risk. Those high and very high-risk zones have a lot of saline affected area. Due to a large amount of saline area people cannot grow a significant amount of agricultural product. People also face scarcity of fresh water in those areas.

Conclusions

The lower middle and the corner of the southern part fall at the zone of high and very high risk. Those high and very high-risk zones have a lot of saline affected area. Due to a large amount of saline area people cannot grow a significant amount of agricultural product. People also face scarcity of fresh water in those areas. From 1974 to 2009 the salinity affected area was increased. As a result, in future, the southern part of Bangladesh will face a great problem due to salinity. In this situation management of salinity intrusion is the vital issue for Bangladesh. With the mission of saline waterproofing by structural management: like coastal embankment projects, dam, sluices, and coastal area zoning as well as non-structural management: to change the land use and research, training, awareness raising etc. can be the vision of sustainable livelihood and environment of the coastal zone of Bangladesh.

Acknowledgment

The authors are grateful to the Institute of Water and Flood Management, BUET for creating an environment in writing this paper. Special thanks are also due to Dr. Anisul Haque for his valuable suggestions in the early stages for the development of these ideas.

References

Comprehensive Disaster Management programme (CDMP II), 2014. "Policy Brief: Local Level Hazard Maps for Flood, Storm Surge & Salinity" Ministry of Disaster Management and Relief, Dhaka.

Shahid, S. (2010) Impact of Climate Change on Irrigation Water Demand of Dry Season Boro Rice in Northwest Bangladesh. Climatic Change, 105, 433-453.

Yadav, J.S.P., Sen, H.S. and Bandyopadhyay, B.K. (2009) Coastal Soils-Management for Higher Agricultural Productivity and Livelihood Security with Special Reference to India. Journal of Soil Salinity & Water Quality, 1, 1-13.

Gowing, J.W., Tuong, T.P. and Hoanh, C.T. (2006) Land and Water Management in Coastal Zones: Dealing With Agriculture-Aquaculture-Fishery Conflicts. Environmental Livelihoods in Tropical Coastal Zones: Managing Agriculture-Fishery-Aquaculture Conflicts.

CCC (Climate Change Cell) (2007) Climate Change and Bangladesh. Department of Environment, Government of the People's Republic of Bangladesh, Dhaka.

World Bank (2000) Bangladesh: Climate Change & Sustainable Development. Report No. 21104 BD, Dhaka.

Miller, G.T. (2004) Living in the Environment. Brooks/Cole—Thomson Learning, Pacific Grove.

Karim, M.F. and Mimura, N. (2008) Impacts of Climate Change and Sea-Level Rise on Cyclonic Storm Surge Floods in Bangladesh. Global Environmental Change, 18, 490-500.

Haque S.A. (2006), Salinity problems and crop production in coastal regions of Bangladesh, Pak. J. Bot, 38(5): 1359-1365, 2006.

Bangladesh Bureau of Statistics (BBS): http://203.112.218.65:8008/ Dhaka, Bangladesh.

Awal, M. A. (2014). Water logging in south-western coastal region of Bangladesh: local adaptation and Policy options. Science Postprint, 1(1), e00038.

Çullu, M. A., Almaca, A., Sahin, Y., & Aydemir, S. (2002). Application of GIS for monitoring soil Salinization in the Harran Plain, Turkey. In proceeding of the international conference on sustainable Land use and management, Çanakkale, Turkey (pp. 326–332).

Haque, S. A. (2006). Salinity problems and crop production in coastal regions of Bangladesh. Pakistan Journal of Botany, 38(5), 1359–1365.

Institute (SRDI), S. R. D. (2010). Saline Soils of Bangladesh.

Mondal, M. K., Bhuiyan, S. I., & Franco, D. T. (2001). Soil salinity reduction and prediction of salt Dynamics in the coastal ricelands of Bangladesh. Agricultural Water Management, 47(1), 9–23.

Rahman, M. A. T., Majumder, R. K., Rahman, S. H., & Halim, M. A. (2011). Sources of deep groundwater Salinity in the southwestern zone of Bangladesh. Environmental Earth Sciences, 63(2), 363–373.

ASSESSMENT OF SOCIAL VULNERABILITY TO FLOOD HAZARD USING NFVI FRAMEWORK IN SATKHIRA DISTRICT, BANGLADESH

M. S. Alam[1], T. Chakraborty[2] and M. D. Islam[3]

ABSTRACT

Satkhira, a coastal district in south-western Bangladesh, is prone to numerous natural catastrophes due to its geophysical settings characterized by low-lying tidal plain and flood is the most recurring and devasting disaster among them. Many national and international organizations have endeavored to assess the flood vulnerability in the different period, but it has consistently undervalued the social impacts associated with flooding. Considering the district of Satkhira as the study area, this paper aims to evaluate the social vulnerability to flooding using the NFVI (Neighborhoods Flood Vulnerability Index) framework. NFVI expresses the neighborhood's social characteristics that influence the potential to experience a loss of wellbeing when exposed to a flood. Using this framework to the local context, 27 supporting factors were developed under 12 sub-domains and 5 major domains. The geographic information system was applied to map the spatial variability of the social vulnerability at union level of Satkhira district to flood hazard. The result revealed that Shymnagar and Kaliganj upazila of Satkhira are highly vulnerable to flood whereas only Debhata Upazila is categorized as socially low vulnerable. This analysis is expected to help in designing appropriate disaster preparedness planning and mitigation initiatives.

Keywords: Social vulnerability, Flood hazard, NFVI framework, Geographic Information System

Introduction

Bangladesh is one of the most disaster-prone countries of the world which faced about 219 natural disasters including flood, cyclone, drought, storm surge, earthquake, etc. between 1980 to 2008 (UNDP,2010). Understanding the complexity of vulnerability caused by various natural disasters is the most challenging task of disaster risk reduction of an area. Flood is one of the major hazards that Bangladesh suffers every year and about 64% area of the country is vulnerable to flood hazard (BBS,2015). Satkhira, one of the most disaster vulnerable coastal district of Bangladesh, is located south-western part of the country and worst sufferer of flood hazard due to its geographic location, geophysical setting characterized by low lying tidal plain, socio-economic backwardness, etc. More or less every upazila of Satkhira had suffered by severe flooding & water logging in the previous year with significant casualties and economic losses. It is essential to assess the flood vulnerability of Satkhira district to prioritize risk reduction activities and reduce the sufferings of the local people. Many researchers along with national and international organization had attempted to assess the flood vulnerability of Satkhira district in different time period, but consistently devalued the social dimension of flood vulnerability. As a result, most of the previous attempt failed or slightly succeeded due to less acceptability in the local socio-economic context. This study aims to assess the social vulnerability of Satkhira district against flood hazard comprising the local indicators.

One of the major challenges of flood vulnerability assessment, especially social flood vulnerability, is to find the appropriate method and researchers all over the world assess earthquake vulnerability using various method for different spatial scale. Birkman et al. (2013) had developed a method known as the MOVE framework (Method for the Improvement of Vulnerability Assessment in Europe) which is only applicable in the European context. Guillard-Gonçalves et al. (2015) had used the Social Vulnerability Index(SoVI) method to assess the hazard risk of Portugal, but this method is not solely developed in the context of flood hazard. Balica, Wright and van der Meulen (2012) had developed a Coastal City Flood Vulnerability Index (CCFVI) for coastal cities which is not social vulnerability driven. In this circumstance, a more focused, effective and sustainable method is needed to be deployed which is solely developed to assess flood vulnerability of social dimension at the neighborhood scale. A comprehensive literature review has been done to find out the appropriate method with abovementioned capacity. It is found that Sayers, Penning-Rowsell, & Horritt. (2018) has developed a Neighborhoods Flood Vulnerability Index (NFVI) which specially focused on the social vulnerability of the neighborhoods against flood hazard. NFVI considers five major social vulnerability dimensions including susceptibility, ability to prepare, ability to respond, ability to recover and community support to assess social flood vulnerability. This study will use NFVI method to evaluate the

[1,2,3]*Student, Urban and Rural Planning Discipline, Khulna University, Khulna-9208, Bangladesh)*
Email of Corresponding Author – shaharier3@gmail.com

social vulnerability to flood of Satkhira district. Using this framework to the local context, 27 supporting factors were developed in this study under 12 sub-domains and 5 major domains. This study expected to be helpful in deciding proper risk reduction strategies and resource targeting at the most vulnerable areas.

Study Area

Satkhira, a southwestern coastal district of Bangladesh, is chosen as the study area because it continuously facing multihazard risk including flood, cyclone, salinity inclusion, sea level rise, storm surge etc. It also has many socio-economic issues such as extreme poverty, high population density, low literacy rate, inaccessibility to major service due to its remote location, etc. The total administrative area of Satkhira district is 3817.29 Square km with 7 upazila, 2 paurashava and 79 unions. This study will assess the social dimension of flood vulnerability of the seven upazila of Satkhira district.

Methodology

Understanding Neighborhoods Flood Vulnerability Index (NFVI)

The NFVI expresses the neighborhood's characteristics that influence the potential to experience a loss of wellbeing when exposed to a flood and over which flood management policy has limited or no control (Sayers, Penning-Rowsell, & Horritt, 2018). The assessment of vulnerability is based upon one or more indicators under five major dimension viz. susceptibility, ability to respond, ability to recover, ability to prepare and social support. In NFVI, each indicator is normalized to a z score (derived by subtracting the mean value and dividing by the standard deviation). The framework of NFVI is shown in **Figure 1.**

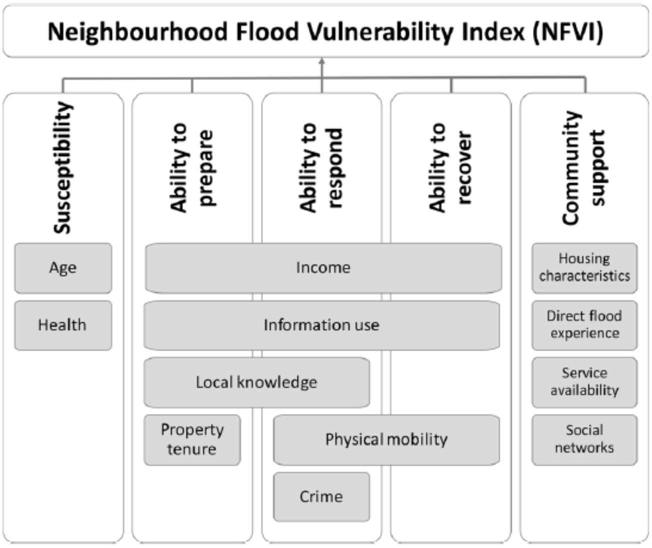


Figure 1. The Framework of Neighborhood Flood Vulnerability Index (NFVI)

Indicators of NFVI

For assessment of social flood vulnerability, Sayers, Penning-Rowsell, & Horritt (2018) had developed NFVI comprising five major dimensions under which 12 subdomain and 27 supporting indicators. They also provided weights to those indicators and sub-domains for calculating NFVI using z score. The indicators of NFVI is shown in **Table 1.**

Approach to Calculating the NFVI

The Neighborhood Flood Vulnerability Index (NFVI) is determined through a three-stage process as outlined below;

- Stage-01: Determine the z-score for Individual Indicators

In this stage, each indicator is normalized to a z score. The z score is derived by subtracting the mean value and dividing by the standard deviation.
Z score = (X – Mean)/SD

- Stage-02: Determine the z-score for each domain

Z scores for the individual indicators that contribute to each domain (Susceptibility, Ability to Prepare, Respond and Recover, and Community Support) are combined based upon the assumption of equal weighting (Shown in **Table 1**).

- Stage-03: Determine the NFVI

For each neighborhood, the z scores derived for each Indicator are summed with equal weighting (**Table 1**). The final z score is calculated based on these results and used as the NFVI. The final NFVI score is imported to ArcGIS for mapping spatial variation of social flood vulnerability of Satkhira District.

Table 1. Indicators of NFVI (Source: Sayers, Penning-Rowsell, & Horritt, 2018)

Indicator	**Variables**		**Effect on NFVI**	**Data Source**	**Weight**
Age (0.10)	a1	Young children (% people under 5 years)	+	Community Report,2011	0.05
	a2	Older people (% people over 65 years)	+	Community Report,2011	0.05
Health (0.10)	h1	Disability (%)	+	Community Report,2011	0.05
	h2	Households with at least one person with long-term limiting illness (%)	+	District Statistics,2011	0.05
Income (0.30)	i1	Unemployed (%)	+	Community Report,2011	0.06
	i2	Dependent Population (% of people under the age of 15 and upper 65)	+	Community Report,2011	0.06
	i3	People under lower poverty line (%)	+	BBS,2010	0.06
	i4	People under lower poverty line (%)	+	BBS,2010	0.06
	i5	People engaged in Agri based farming	+	Agriculture Census 2008	0.06
Information use (0.12)	f1	% of illiterate people	+	District Statistics,2011	0.06
	f2	% of Household without Electricity	+	Community Report,2011	0.06
Local knowledge (0.04)	k1	Urban resident (%)	+	Community Report,2011	0.04
Tenure (0.04)	t1	Private renters (% households)	+	Community Report,2011	0.02
	t2	Social renters (%)	+	Community Report,2011	0.02
Physical mobility (0.12)	m1	Physical Disability(unable to move)	+	Community Report,2011	0.04
	m2	Physically dependent age group (%)	+	Community Report,2011	0.04
	m3	Lack of private transport (%)	+	Community Report,2011	0.04
Crime(0.02)	c1	High levels of crime(%)		Literature review	0.02
Housing	hc1	Temporary Household(kutcha,	+	Community	0.02

characteristics (0.02)		jhupri)		Report,2011	
Direct flood experience (-0.02)	e1	Population with previous flood experience	–	World Food Program,2011	-0.02
Service availability (0.09)	s1	Inaccessibility to flood shelter (%)	+	District Statistics,2011	0.02
	s2	Inaccessibility to hospital (%)	+	District Statistics,2011	0.02
	s3	No sanitation service (%)	+	Community Report,2011	0.02
	s4	Inaccessibility to drinking water (%)	+	Community Report,2011	0.02
Social networks (0.07)	n1	Ethnic group (%)	+	Community Report,2011	0.07
	n2	Inaccessibility Co-operative Society (%)	+	District Statistics,2011	0.07
	n3	Children of primary school age (4–11 (%)	-	Community Report,2011	-0.07

Result

Using NFVI approach, the spatial variation of social vulnerability to flood hazard is analyzed in this study. The result indicates Shymnagar has very high social vulnerability and Kaliganj Upazila has high social vulnerability against flood hazard. On the contrary, Debhata upazila has very low social vulnerability though upazila is adjacent to the Shymnagar and Kaliganj Upazila. The leftover three upazila including Kalaroa, Tala and Satkhira Sadar has low social vulnerability to flood hazard. The spatial variation of social vulnerability among residential neighborhoods is visually shown in **Figure-2**.

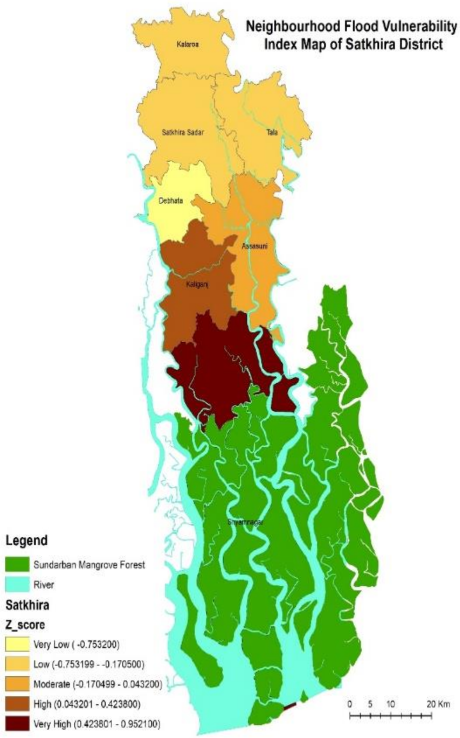


Figure 2. Social Vulnerability of Satkhira District to Flood hazard

Conclusions

Social impacts are often experienced as being severe in flood events which is consistently underscored by the researcher all over the world. This paper applied NFVI approach which is a powerful tool for mapping of vulnerable areas and provide improved expression of flood social vulnerability at neighborhood scale with the application of GIS technology. The use of the NFVI can make inhabitants and governments aware of vulnerability in their area. Thus, the analyses showed in this paper can help policymakers and urban planners in making decisions with regard to development in specific areas and possible funding allocation for adaptation and reduction of flood vulnerability in local areas.

References

World Bank.(2010). Economic of Adaptation to Climate Change: Bangladesh. Washington, DC: The World Bank Group

BBS.(2008). Agriculture Census 2008, Bangladesh Buero of Statistics, Dhaka, Bangladesh.

BBS.(2010). Poverty Map of Zila and Upazila, Bangladesh Buero of Statistics, Dhaka, Bangladesh.

BBS.(2015). Bangladesh Disaster-related Statistics 2015: Climate Change and Natural Disaster Perspectives, Bangladesh Buero of Statistics, Dhaka, Bangladesh.

BBS.(2011). Community Report: Satkhira. Bangladesh Buero of Statistics, Dhaka, Bangladesh.

BBS.(2011). District Statistics: Satkhira. Bangladesh Buero of Statistics, Dhaka, Bangladesh.

Birkmann, J., Cardona, O. D., Carreño, M. L., Barbat, A. H., Pelling, M., Schneiderbauer, S., ... & Welle, T. (2013). Framing vulnerability, risk and societal responses: the MOVE framework. *Natural hazards*, *67*(2), 193-211.

Guillard-Gonçalves, C., Cutter, S. L., Emrich, C. T., & Zêzere, J. L. (2015). Application of Social Vulnerability Index (SoVI) and delineation of natural risk zones in Greater Lisbon, Portugal. *Journal of Risk Research*, *18*(5

Balica, S. F., Wright, N. G., & van der Meulen, F. (2012). A flood vulnerability index for coastal cities and its use in assessing climate change impacts. *Natural hazards*, *64*(1), 73-105.

Sayers, P., Penning-Rowsell, E. C., & Horritt, M. (2018). Flood vulnerability, risk, and social disadvantage: current and future patterns in the UK. *Regional Environmental Change*, *18*(2), 339-352.

WFP. (2011). A Rapid Food Security Assessment in Satkhira in the Context of Recent Floods and Water Logging, World Food Program

EVALUATION OF URBAN FLOOD RISK WITH EXISTING LAND USE PATTERN: A CASE STUDY OF SEVERAL SELECTED WARDS OF KHULNA CITY

Nilanjana Bhowmick[1], Md. Ashraful Alam[2] and Saima Rahman[3]

ABSTRACT

Urban flooding is deemed as one of the rising problems in the urban area in a developing country like Bangladesh. Changing land use pattern and unplanned urbanization is responsible for increasing the severity of this hazard day by day. The relation between existing land use pattern and the associated risk of affected people (16, 19, 23 and 27 no ward of Khulna City Corporation) regarding urban flood is revealed in this paper. Required information regarding the issue has been collected from both primary and secondary sources. A questionnaire survey (household) and Participatory Rural Appraisal (PRA) method have been applied for collecting data in this regard. Vulnerability index has been prepared considering components (social, economic, physical and environmental) and factors (exposure, susceptibility and resilience) of vulnerability. Weight for each indicator has been assigned by expert opinion. On the other hand, Hazard index has been calculated using FIGUSED model. Weight has been assigned by the Analytical Hierarchy Process for hazard indexing. Then vulnerability and hazard index have been accumulated to obtain risk of affected people. Finally, the paper draws an effective relationship between existing land use pattern and risk of urban flooding with some effective solution to reduce urban flooding.

Keywords: Urban Flooding, Land use Pattern, Hazard Index, Vulnerability Index, Risk Index

Introduction

Urban flooding has become a very common problem in the urban area especially in Bangladesh. In most of the cases in urban areas urban flood causes water-logging and overflow of the drainage system. The land-use pattern could potentially lead to increase flood risk in urban areas which may have a deleterious impact on Infrastructure (Leander, et al., 2008). For unplanned urbanization and lack of maintenance of drainage system often causes water logging to the urban area.

In the past, the stormwater of Khulna city had been drained out through some natural drainage (e.g., creek and canals). Due to rapid urbanization and increasing development over the years, these natural drainage and other water retention areas have gradually been converted into built-up areas. Most of the urban flood-affected areas of Khulna City are located in Ward No. 30, 10, 14, 27, 23, 24 and 31. In these Wards, the percentages of households affected by annual water logging are 94 %, 100 %, 93% and 98% respectively. In Khulna city, 38% of households regularly experience short-term waterlogging (e.g., 1day). Victims of longer-term duration water logging live in Ward no. 31, 21, 20 and 22 (Murtaza, 2001). There are various type of land use exist in Khulna City but the major land use occupied by Built-up Area which consists of 30.5% of Khulna City. On the other hand Vegetation, water bodies, Agriculture consist of 20%, 3.5% and 29 % respectively (Ahmed, 2011). The study focuses on the situation of the urban flood with the existing land use of the study area and finds out the relationship between urban flooding risk and the existing land use in the study area.

Methodology

Study Area Selection, Variable Selection and Weight Assessment

The selected study area was 16, 19, 23 and 27 no. ward of Khulna City Corporation (shown in Figure. 1). To analyze Existing Landuse Pattern, Hazard Index, Vulnerability Index and Risk Index about thirty-seven variables had been selected. Among them twenty-seven variables had been used to calculate the vulnerability index of the area. Weighting this large number of variables was not an easy task. The importance given to the

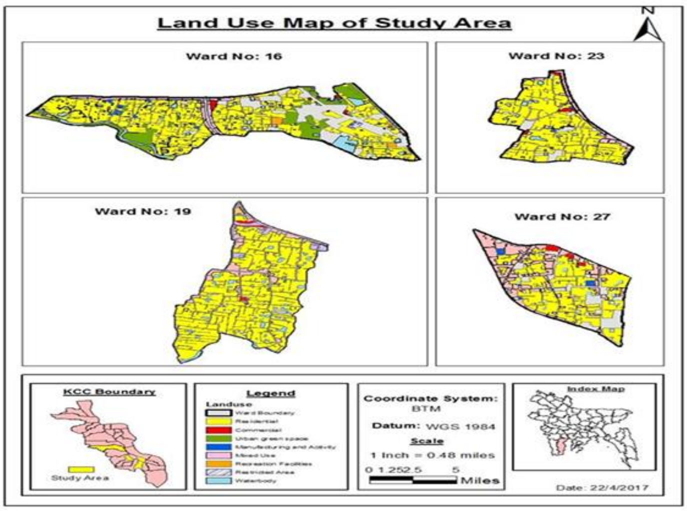
[1] *Postgraduate Student, Institute of Disaster Management, Khulna University of Engineering & Technology (KUET), Khulna-9203, Bangladesh*
[2] *Undergraduate Student, Department of Urban and Regional Planning, Khulna University of Engineering & Technology (KUET), Khulna-9203, Bangladesh*
[3] *Assistant Professor, Department of Urban and Regional Planning, Khulna University of Engineering & Technology (KUET), Khulna-9203, Bangladesh*
Email of Corresponding Author – bhowmicknilanjana.17@gmail.com

indicators of vulnerability can be done by interviewing experts (Muller, et al., 2011). Hence weight assignment in this study to vulnerability indicators has been done through a process of expert interviews. Five variables in hazard index calculation and weight assignment of those variable had been done through a mathematical process known as the analytical hierarchy process (AHP). The process has been used by Kazakis, et al., 2015 and Seekao & Pharino, 2016 in flood hazard and vulnerability analysis. Seven variables were used in analyzing existing Landuse Pattern Analysis and two variables (elevation and land use of the area) overlapped for calculations so the total variables were 37. All the variables are shown through in the Appendix section.

Existing Landuse Pattern

There are various type of land use in the study area but major six types of land uses are noticed in all the selected wards. In ward no 16-land use pattern is residential about 52 % (318.59 acre), Commercial about 0.85 % (5.207 acre), Manufacture activity about 0.83% (5.066 acre), urban green space about 10.66% (65.295 acre), Recreational about 1% (6.16 acre), Mixed-use about 3.58% (21.94 acre) etc. In ward no 19-land use pattern is residential about 70.943% (85.136 acres), Commercial about 2.029 % (2.435 acres) and Mixed land use about 7.292% (8.752 acres). Like 16 or 19 in ward no 23 residential land use covers more area than other land uses almost 46.912% (57.019 acres). The next important land use is Mixed land use about 23.65% (28.745 acres) and Commercial land use (about 1.728% or 2.101 acres) because this ward is situated within the Central Business District (CBD). In the ward no 27 residential land use is about 75.24% (153.81 acres). The other major land uses are Commercial about 0.975% (1.994 acres), Recreational about 0.4807% (0.983 acres) and Mixed land uses about 6.783% (13.866 acres). The overall land use of the study area is shown in Figure. 1 which shows a wide range of land use variety of the selected wards.

Figure 1. Land Use Map of the Study Area, 2017



Index Calculation

Hazard Index Calculation

In this study, five indicators among seven indicators used in FIGUSED model with weight assessment had been used for hazard index. The values of the Hazard Index of the selected wards are shown in Table 1.

Table 1. Urban Flood Hazard Index for the Study Area, 2017

Ward no	Hazard Index	Ward no	Hazard Index	Whole study area
16	0.069658	23	0.053027	0.068017
19	0.046526	27	0.102856	

Vulnerability Index Calculation

Urban Flood vulnerability index is the average of social (S), economic (E), physical (P) and environmental

(En) vulnerability index (Balica, et al., 2013).

$$FVI = \frac{FVI_{Social} + FVI_{Economic} + FVI_{Physical} + FVI_{Environment}}{4} \quad (1)$$

FVI (S, E, P, En (2)

Where, FVI = Flood Vulnerability Index. Ward Wise vulnerability had been calculated by using Eq. 2 after analyzing the exposure, susceptibility and resilience of individual ward. The total urban flood vulnerability index has been calculated using the Eq. 1. Urban Flood Vulnerability Index has been shown in Table 2.

Table 2. Urban Flood Vulnerability Index, 2017

Ward no	Urban Flood Vulnerability Index				FVI
	FVISocial	FVIEconomic	FVIPhysical	FVIEnvironmental	
Ward no 16	0.01057	0.07657	0.03357	0.0613800	0.046055
Ward no 19	0	0.07135	0.01743	0.0835400	0.043080
Ward no 23	0	0.06178	0.05511	0.1524000	0.062323
Ward no 27	0.01289	0.08267	0.08672	0.2310085	0.103322
Whole study area	0.005865	0.0730925	0.0801753	0.1156738	0.068702

Risk Index Calculation

Risk can be estimate through the following equation (Tingsanchali, 2012).

Risk Index = Vulnerability * Hazard (3)

Ward Wise and total Risk Index of the study area had been calculated by using Eq. 3 through multiplying Hazard Index with the Vulnerability Index. Urban Flood Risk Index has been shown in Table 3.

Table 3. Urban Flood Risk Index, 2017

Ward no	Hazard Index	Vulnerability Index	Risk Index
Ward no 16	0.069658	0.046055	0.003208
Ward no 19	0.046526	0.043080	0.002004
Ward no 23	0.053027	0.062323	0.003305
Ward no 27	0.102856	0.103322	0.010627
Whole study area	0.068017	0.068702	0.004673

Results and Discussion

The amount of built-up area, of ward no 27 is higher than the other three wards. From Table 2 and Table 3 it has been found that the value of Risk Index is also higher in the ward no 27. In ward no 16 urban amount green space reduces the risk of urban flooding. Lack of green space and water body of ward no 23 is responsible for risk index value than that ward no 19 and 16. From the result it can be said that the high amount of built-up area and lack of green space, water body increases urban flood vulnerability and risk of any area.

Recommendations and Conclusions

Proper waste management, improvement of drainage management, rain water harvesting, green roofs or roof gardens, Storm water Infiltration and attenuation system installation, Separate sewage systems installation can be some probable solutions for the existing problem and to reduce the occurrences of urban flooding. The outcomes of the study can help urban planner and decision maker to prepare the land use zoning plan to reduce urban flooding risk. The study also encourages measuring the vulnerability of urban flooding for other big city in Bangladesh. In this study a major limitations were (a) value of vulnerability index became zero where the value of susceptibility index was zero whether there is high value in exposure index, (b) Ward no 16 has not been surveyed by PRA technique as the area of the ward is very large and most of the people living in this area are not likely to participate, (C) from FIGUSED model five criteria have been used as to evaluate the hazard index where the model consists of seven criteria.

Acknowledgments

We are thankful to Abir-Ul-Zobbar, Chief Town Planner, Md. Anisur Rahaman, Conservancy officer, Khulna City Corporation, the staffs of Ward Councilor's Office and the survey participators for helping us.

Appendix

Seven variables for existing land use pattern are percentage of various land use, amount of vacant land, amount of water body, amount of field, elevation of the area, existing road network and drainage system. Twenty-seven variables for vulnerability index are Mental Disorder, Household size, Home ownership, % child/elderly per household, % female per household, % disabled person per household, Occupations, Household Income, % Illiteracy, Knowledge of flood risk, Awareness/ Preparedness, Participation, % of unemployed person, Cost of Losses, Land use wise economy, % of poor household, Loan / financial support, Assets / Savings, Access to working place, House type, Construction material, Road type, Drainage type, Land cover, Mosquito breakout, Access to safe water, Amount of water bodies. Five variables for hazard index are Rainfall intensity, land use, elevation, Slope, Distance from the Drainage Network.

References

Ahmed, B. (2011) "Modeling spatio-temporal urban land cover growth dynamics using remote sensing and GIS techniques: a case study of Khulna city", *Journal of Bangladesh Institute of Planners,* 4, 15-32.

Balica, S., Popescu, I., Beevers, L. & Wright,NG (2013) "Parametric and physically based modelling techniques for flood risk and vulnerability assessment", *Environmental Modelling and Software,* 41, 84 - 92.

Kazakis, N., Kougias, I. and Patsialis, T. (2015) "Assessment of flood hazard areas at a regional scale using an index-based approach and Analytical Hierarchy Process: Application in Rhodope–Evros region, Greece", *Science of the Total Environment,* 555-563.

Leander, R., Buishand, T. and Hurk, B. J., (2008) "Estimated changes in flood quantiles of the river Meuse from resampling of regional climate model output", *Journal of Hydrology,* 351(3-4), 331–343.

Muller, A., Reiter, J. & Weiland, U. (2011) "Assessment of urban vulnerability towards floods using an indicator-based approach: a case study for Santiago De Chile", *Natural Hazards and Earth System Sciences,* 2107-2123.

Murtaza, G. (2001) "Environmental problems in Khulna city, Bangladesh: a spatio-household level study", Journal of Global Bussiness and Economic Review, 1(2), 32-37.

Seekao, C. & Pharino, C. (2016) "Key factors affecting the flood vulnerability and adaptation of the shrimp farming sector in Thailand" International Journal of Disaster Risk Reduction, 17, 161-172.

Tingsanchali, T. (2012) "Urban flood disaster management", *Procedia Engineering,* 25-37.

DEVELOPING LOCAL LEVEL DISASTER RISK REDUCTION STRATEGIES CONSIDERING THE SPATIAL VARIATION OF STORM SURGE RISK: A CASE STUDY ON GABURA UNION, SYAMNAGAR UPAZILA

R. Hassan[1] and S.M. Haque[2]

Abstract

Storm surge is one of the most disastrous natural hazards in the coastal regions of Bangladesh. Very often disaster risk reductions (DRR) strategies to minimize risks stemming from this hazard are ineffective due to the gross aggregation and have been found taken without considering spatial variations of risk profiles at local levels. This study aims to find out the spatial variations of storm surge risk at the local level and formulation of DRR strategies according to the variations of local level storm surge risk profile. For risk profiling, a GIS-based multi-criteria approach (MCA) has been adopted with four hazard indicators along with eleven vulnerability indicators. Gabura, a coastal union of Syamnagar upazila (sub-district) of Bangladesh has been selected as the study area. Data and information have been derived from administering a questionnaire survey and relevant searching of secondary sources. Analytical hierarchical process (AHP) has been used for selecting weights of the indicators. Findings suggest that the risk profile of the study area vary spatially since hazard exposure and vulnerability indicators showed significant variations across nine wards (smallest administrative units) of the study area. By analyzing DRR strategies of different Government agencies and non-governmental organizations, it has been observed that such variations in risk situations across the study area have largely been ignored while taking DRR strategies for the study area. Therefore, some new DRR strategy guidelines incorporating variations in the risk profile of the study area have been proposed.

Keywords: Storm Surge Risk Profile, Spatial Variation, Multi-Criteria Approach, GIS, Disaster Risk Reduction Strategy.

Introduction

Bangladesh is one of the most vulnerable countries to different natural disasters due to its geographic location. Cyclone and storm surges are the most disastrous natural hazards in the coastal regions as it frequently damages the life and properties of the people of these localities (Hossain, Paul, Roy, & Hasan, 2014). Natural hazards cannot be stopped fully but the risk of these hazards can be substantially reduced. Risk reduction strategies are very much important to minimize future risks. Historically, the disaster management of Bangladesh is confined to relief and rehabilitation. But, at present, it is more oriented to risk reduction from the previously practiced after a disaster response. In risk management literature, there is a growing consensus that only the reduction of the probability of the occurrence is not enough. The reduction of the consequence of the hazard event is also important. However, there exists a serious understanding gap in risk management policies and local level strategies currently practiced in Bangladesh. The spatial variation of risk is not considered in the risk reduction strategies. Therefore, a widespread misallocation of resources is prevalent. Therefore, this study focuses on assessing the spatial variation of storm surge risk by considering two components of risk formulation, viz., hazard and vulnerability. GIS-based indexing has been conducted to assess the spatial variation of storm surge risk. It is expected that the assessment technique of this study would be an exemplary model for further risk assessment studies, especially in the coastal areas of Bangladesh.

Study area

This study has been conducted in Gabura union, Syamnagar upazila of Satkhira district of Bangladesh. This union is situated between latitude 22̊ 13.2 to 22̊ 18.1 north and longitude 89̊14.9.2 east. The union has an area of 33 sq. km. (BBS, 2011). Cyclone and storm surges are prea dominant natural hazard in this area and cause significant damages to life and properties of people. There are nine wards in the Gabura union.

Methodology

For developing the storm surge risk profile of the nine wards of Gabura union, risk index has been calculated

1 Student, Urban and Rural Planning Discipline, Khulna University, Khulna-9208, Bangladesh
2 Professor, Urban and Rural Planning Discipline, Khulna University, Khulna-9208, Bangladesh
Email of Corresponding Author – rakibul.ku.15@gmail.com

by the following equation developed from (Islam, Swapan, & Haque, 2013) and (Wang, Li, Tang, & Zeng, 2011).

Risk Index (0-2 score) = Hazard Index (0-1) + Vulnerability Index (0-1) …………………..……..(1)
Hazard Index= Reclassify the hazard indicators *Weights…………………………….....……….(2)
Vulnerability Index= IVSP+IVS/2………………………..……………………………..………(3)
Spatial Vulnerability Index=
GIS multi-criteria analysis score ⟶ Clip raster by ward boundary ⟶ Reclassify*Weight…(4)
IVS= Reclassify the social vulnerability indicators* Weight……………………..…………..……(5)

Here, from the equation (1), risk index has been calculated by combining the hazard and vulnerability index scores. Risk index has been calculated in 0-2 scale and both hazard and vulnerability indices have been calculated in 0-1 scale. The hazard index has been calculated from equation 2 with reclassify the hazard indicators into three categories and then multiply those with weights. Equation 3 has been used to calculate the combined vulnerability index which is the summation of social and spatial vulnerability index and then divided by 2. GIS multi-criteria analysis has been conducted in Arc-GIS 10.3. The spatial risk index map is then clipped by ward boundary shape file and then reclassify it according to the reclassification score and multiplied it by weight (Equation-4). The social vulnerability index has been calculated by equation 5 by reclassifying the social vulnerability indicators into three categories and multiply it with weight. The weights of the indicators have been calculated by the analytical hierarchical process (AHP) developed by (Saaty, 1990). The comparative score of AHP has been calculated from FGD with local people and expert opinion. The hazard and vulnerability indicators, their reclassification and weight are as follows (Table-1). The reclassification score is for low risk=.3, medium risk=.6, and high risk=1. The data has been collected by administering a questionnaire survey of 117 sample households of nine wards with 13 households each. For determining the future threat of storm surge in different wards of the study area, the future surge height has been calculated by using the following Gumbel distribution equation-

$$Qt = Qav + K\sigma$$

Here, Qt=t years' highest surge level, Qav=Average surge height of previous storm surge, σ=Standard deviation.

$$K=-\sqrt{6}/\pi(\lambda-\ln(\ln(T-\ln(T-1)))$$

Where, λ is the return period; in this study 10 years return period of the historical surge height data (Table-2), surge height will be=9.21m. Then, the Digital Elevation Model (DEM) of the study area has downloaded from the USGS website. After conducting the unsteady flow analysis in HEC-RAS, clip the raster file by the ward boundary and the percentage of inundated area in each ward have been calculated.

Table 2. Historic surge height data

Year	Surge height (Meter)
1988	13
1996	9
2002	11
2009	15

Source: FGD

Data analysis

The collected data has been analyzed through SPSS, ARC-GIS, and HEC-RAS. The Arc-GIS model builder tool has been used to conduct the multi-criteria analysis by buffering, reclassification and weighted overlay operation. The HEC-RAS has been used to determine the future inundated area. The data has been analyzed and the hazard, vulnerability, and risk index have been calculated in excel.

Table 1. The indicators, their reclassification, and weight

Indicators	Low	Moderate	High	Weight
Hazard				
Frequency of hazard	0	1-3	>3	0.056
Duration of stagnated water	0-6 months	6 months-1 year	1-3 years	0.456
Inundated area (%)	0-20	20-50	>50	0.308
Average damages of households	3500m	1000m	500m	0.181
Spatial Vulnerability				
Proximity to river	2000m	1000m	500m	0.106
Proximity to road	200m	400m	800m	0.260
Proximity to cyclone center	3500m	1000m	500m	0.6334
Socio-economic Vulnerability				
Average monthly income of the household (BDT)	1000-2000	5000-10000	<5000	0.167
Literacy rate (percentage)	50+	30-50	<30	0.108
No. of kutcha households	0-5	5-10	10-13	0.175
Unemployment (%	0-15	15-25	25+	0.137
Population density	Less than 500	500-700	>700	0.133
Training on disaster management (%)	50	50-80	80+	0.071
% of people use the sanitary latrine	25	25-40	>40	0.081
The distance of drinking water source	0-.5km	5-1.5km	>1.5km	0.129

Results and Discussions

The hazard map does not show significant variations for a small study area and the impact of hazard is almost similar across the nine wards of Gabura union (Fig-2) The union is situated in a low-lying area. Therefore, almost all the areas of the union will be inundated due to the surge height of 9.21m in 10 years return period (Fig-1). However, the vulnerability map shows significant variations across the nine wards (Fig-3) Therefore, the final risk map shows variations too (Fig-4). Existing DRR interventions have been analyzed through a thorough review of the information gathered from secondary sources. The Government interventions are mainly income generating activities like VGD, VGF, LGSP. KABITA, KABIKHA etc. Moreover, there are 8 local and international NGO's are working there and they have taken several interventions like providing disaster management training, providing economic support to the people, repair the road and embankment etc. Both Government and NGO.s interventions have taken across the whole union. However, from the risk profiling, it has been observed that ward number 1 and ward number 8 possesses a higher risk than the other 6 wards. Therefore, these two wards need much more DRR interventions such as more income generating activities, disaster risk reduction training facilities and other incentives to reduce their vulnerability than the other wards of Gabura union. Other wards of the union need these strategies too but the riskiest wards need more.

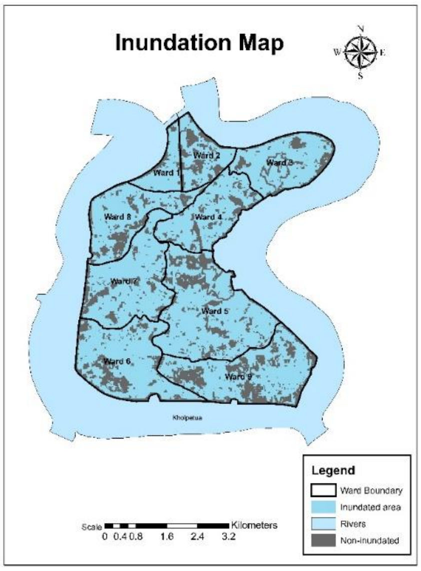


Figure 1. Inundated area due to future surge event

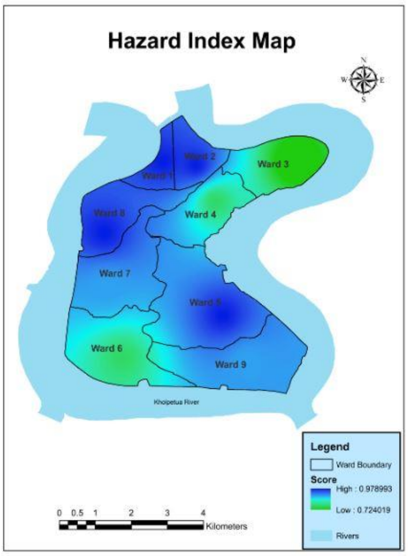


Figure 2. Hazard Index Map

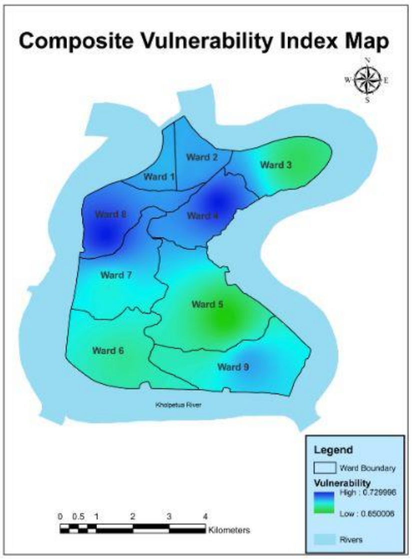


Figure 3. Vulnerability Index Map

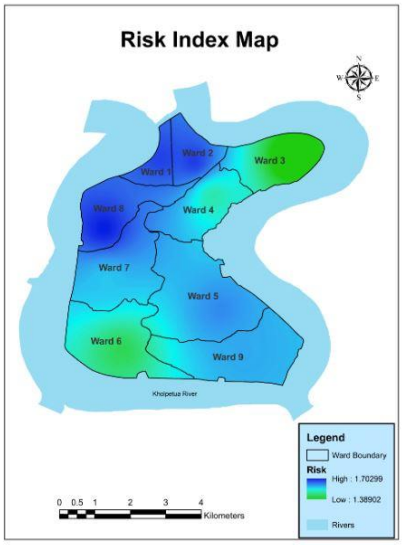


Figure 4. Risk Index Map

Conclusion

The main focus of this study is to develop a risk profile and it shows significant variations across the nine wards of Gabura nation. This study reveals the urgency of formulating space specific risk reduction strategies in the local context too. Especially, in the context of Bangladesh risk assessment should consider both the geographic location and socio-economic variations of the people of the specific area. Future researchers can be directed to risk profiling study on a wider scale and even at the national scale for understanding variations in risk situations while proposing DRR strategies. The methodology adopted in this research could be a useful guideline in this regard. The policymakers should emphasize on space specific disaster risk reduction strategies.

References

Bangladesh Bureau of Statistics (BBS) 2011.

Hossain, M. N., Paul, S. K., Roy, C., & Hasan, M. M. (2014). Factors influencing human vulnerability to cyclones and storm surges in the coastal Bangladesh. J. Geo-Environ, 11, 1-29.

Islam, M. S., Swapan, M. S. H., & Haque, S. M. (2013). Disaster risk index: How far should it take account of local attributes? International journal of disaster risk reduction, 3, 76-87.

Saaty, T. L. (1990). How to make a decision: the analytic hierarchy process. European journal of operational research, 48(1), 9-26.

Wang, Y., Li, Z., Tang, Z., & Zeng, G. (2011). A GIS-based spatial multi-criteria approach for flood risk assessment in the Dongting Lake Region, Hunan, Central China. Water resources management, 25(13), 3465-3484.

PERFORMANCE EVALUATION OF DROUGHT MONITORING INDICES IN NORTH-WEST REGION OF BANGLADESH

Miskun Naher Akhi[1], Md. Shakibul Islam[2], A.R.M. Towfiqul Islam[3]

ABSTRACT

Drought indices are commonly used as a monitoring tool of drought conditions in any area. However, drought is a widespread problem for sustaining food security under climate change condition in the world including Bangladesh. The northwestern Bangladesh is regarded as a drought-prone area. The objective of this study is to investigate the spatiotemporal variation of drought indices in the northwestern part of Bangladesh.

The study was based on meteorological data during the period of 1975 to 2017 covering 6 meteorological stations. Three drought assessment tools such as the Standardized Precipitation Index (SPI) and the Standardized Precipitation Evapotranspiration Index (SPEI), and the De Martonne Aridity Index (IDM) were employed to evaluate the performance of the drought indices in the study area. Thespatial distribution results show that the northern parts are more drought-prone than western parts of the study area. The results of MK (Mann Kandal tau) test and Sen Slope's estimator indicate that there is a significant increasing trend in Rajshahi and Bogra regions of western Bangladesh. The standard errors of these drought indices are 20% for SPI, 9% for SPEI and 23% for IDM respectively. It is observed that the SPEI is the lower RMSE (Root Mean Square Error) than other two indices. Furthermore, the SPEI is the more suitable indices than others for drought monitoring in the northwestern Bangladesh. The outcomes of the study can be guidance for drought adaptation and policy making in Bangladesh.

Keywords: Meteorological drought, IDM, SPEI, SPI, Spatiotemporal Analysis, Interpolation

Background of the study

A drought index is a numerical indicator of the degree of dryness of the climate at a given location. Wetness or dryness condition is one of the alarming factors on agriculture and other economic activities, besides the risk of ecological and human health. Nowadays, drought indices are used for tracking and mapping regional climate change. A drought indicator is calculated using data such as precipitation or soil moisture to provide a measure of the moisture conditions at any location in the world. Drought indicators are calculated with respect to temperature and precipitation condition. The precipitation departure from normal can be considered a drought indicator. A lot of information about temperature and precipitation values can be analyzed for indicate the drought severity. Precipitation from normal cannot be compared spatially because such may be more common at some locations than others across spatial regions and across different seasons. This is done by using historical data at a particular location for a certain time period (week, month, and year) to get normal values, their frequency of occurrence and quantify the precipitation from normal using this historical data. There is no uniform method to characterize drought conditions and there are a variety of drought indices that can be used as tools to monitor meteorological drought (Quiring 2009). The input variables required for the calculation of meteorological drought indices vary depending on the drought index in question, but include precipitation, temperature, and available water holding capacity of the soil which is representative of the moisture in the system. Various meteorological drought indices are existed in the literature. Among them, the De Martonne Aridity Index (IDM), the Standardized Precipitation Index (SPI), the Standardized Precipitation and Evapotranspiration Index (SPEI) are widely used for drought monitoring in the worldwide. The IDM, SPI and SPEI are popular indices that use different approaches for characterizing drought conditions. The SPI and SPEI are similar to each other in calculation, but use two 2 different inputs (precipitation versus

1 Department of Disaster Management, Begum Rokeya University, Rangpur-5400.
2 Department of Disaster Management, Begum Rokeya University, Rangpur-5400.
3 Department of Disaster Management, Begum Rokeya University Rangpur-5400.
Miskun Naher Akhi
miskunnaherakhi@gmail.com
Md. Shakibul Islam
Shakibul_dm@brur.ac.bd
A.R.M. Towfiqul Islam
towfiq_dm@brur.ac.bd

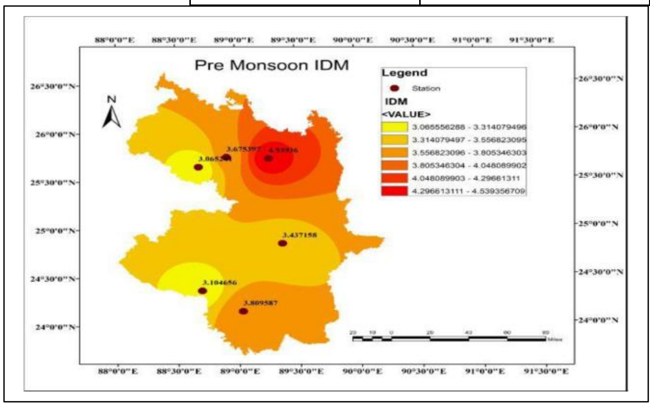
precipitation and temperature) which can be calculated for any timescale of interest. Bangladesh experienced eight severe droughts in the years of 1973-1999 (Shahid and Behrawan 2008). Rainfall pattern changes over time are one of the most relevant characteristics in the climate of Bangladesh. The monsoon rains in Bangladesh will be increased and at the same time as well as winter precipitation will be decreased in future (Islam et al. 2017). This will cause a severe combination of more extreme event like as flood and longer period of droughts. The impacts of global climate change are the most important cause in hydrological cycles. In respect of water resources, Northwest part of Bangladesh is one of the most vulnerable regions of Bangladesh to climate change. These three methods follow three different techniques of prediction (Jin and Heap 2008) which are deterministic, geostatistical and mathematical. Numerous studies have been done to assess the influence of interpolation methods on variables such as precipitation and temperature. Since the variable that is being interpolated, the climatic region, and the topography of the study area all can influence the accuracy of the interpolation, this influence needs to be quantified to understand it better (Carbone et al. 2008).

De Martonne Aridity Index (IDM)

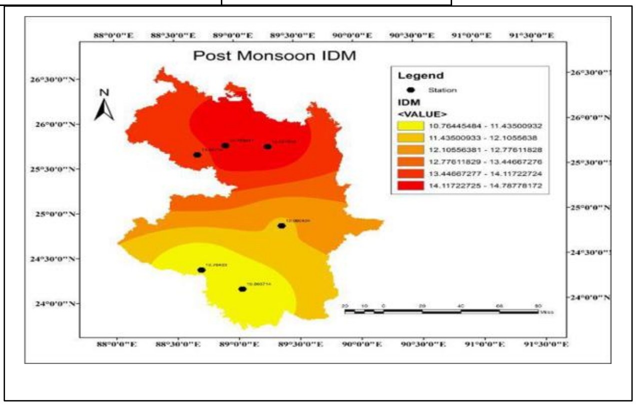
This is an aridity–humidity index and is only applicable locally. Trend of temperature is calculated to envisage the temporal pattern of climate in the study area. Table 4.1 shows the Maan kandel (MK) trend test and Sen's estimation value.

Table 1: MK test and Sen's estimator result of the IDM in the study area.

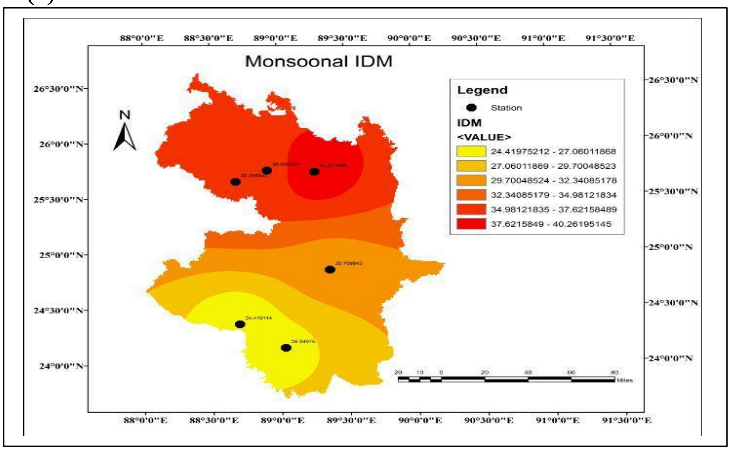
Location	ZMK	p-value	β (mm °C−1)
Rangpur	-0.64022	0.522	-0.07073171
Dinajpur	-1.1645	0.2442	-0.1394958
Sayedpur	-1.051	0.2933	-0.1533333
Rajshahi	-2.325	0.02007	-0.2536585
Bogra	-2.0671	0.03873	-0.2260236
Ishwardi	-2.0332	0.04203	-0.2222224



(a)



(b)



(c)

Figure 1. Spatial Distribution of seasonal (a) Pre monsoon (b) Post Mon soon(c) Monsoon IDM over the

study area

represent the Mann-kendal Trend test and the magnitude of the trend approximate by the sen's estimator result from calculated D Martonne Aridity Index (IDM) value out of six meteorological station for the time period of 1975 to 2015(41 years) of four station, Rajshahi, Rangpur, Bogra, Ishwardi and rest of 2 station Dinajpur from 1981 to 2015 (35 years) and Sayedpur from 1991 to 2015(25years) which denotes the Z value, β (in mm and deg c) and P value. These values indicate the significance the testing of using method. With the aim of detecting temporal trend in the De Martonne aridity index time series the Mann-kendal test is using. After computing the statistic of this trend test increasing trends for the station of Rajshahi ,Bogra and Ishwardi where the value are -2.325, -2.0671 and -2.0332. These indicated by positive value of it and , on the contrary decreasing trends for the station of Dinajpur, Sayedpur and Rangpur and the values are determined the negative values when the absolute value of the statistic is higher than 2.32. This result indicate the significance the decreasing trends in the IDM series at 5% level of significance at 3 locations, all of them in the north part of the region except in the west. It should be noted that decreasing trend means moderately arid to slightly humid condition and the north locations in which in increasing trends are significant in humid or very humid climate according to De Martonne aridity index.

Standardized Precipitation Evapotranspiration Index (SPEI)

The following table represents the Mk test and Sen's estimator of SPEI value of northwestern part of Bangladesh which indicate the increasing value as positive and decreasing value as negative for SPEI value to drought estimate.

Table 2. Mk test & Sen's estimator result of SPEI in study area

Location	ZMK	p-value	β (mm °C−1)
Rangpur	-3.7402	0.0001838	-0.4073171
Dinajpur	-0.65327	0.5136	0.0789916
Sayedpur	-3.2931	0.0009911	-0.4733333
Rajshahi	-1.6286	0.1034	-0.1780488
Bogra	-3.5381	0.0004031	-0.3853659
Ishwardi	-2.5721	0.01011	-0.2804878

SPEI value at different lag shows the intensity of drought related to yearly for agricultural drought and long-term for meteorological drought (Fig.4.3) which shows the occurrences of drought events for the study area using SPEI index. The meteorological drought duration was relatively low, lasting only for 3-4 months. According to the Fig. 4.3 extreme drought events is observed in the Rajshahi and Bogra compared to other sites in the study area. It is evident that annual meteorological drought occurred in the year2015.In Bogra and Rajshahi drought intensity and frequency does not have distinct pattern in yearly due to recurrent drought in 2015. Both the intensity and frequency is bit clear for the case of yearly representing the meteorological drought. It is also evident that number of severe drought event occurs more than that of extreme drought event. On the hand Sayedpur, Dinajpur , Ishwardi experienced moderate drought condition and Rangpur has no significant drought event. However, Drought is a complex phenomena and it is hard to assess physically, because a short spell of rainfall can cover the severe drought in a short time, without fulfilling the actual water demand of the ecosystem.

Seasonal variations of SPEI

The variation of SPEI indicates seasonal differences at shorter timescales (4 months). The correlations were showing within pre monsoon, monsoon and post monsoon. Months at shorter timescales but were positive and relatively stronger during seasons. The Fig4.4 show the seasonal variations and the variations during pre and post monsoon were weaker but positive, whereas the correlations in monsoon were weaker and negative probably due to the increased precipitation and lower SPEI computed from low precipitation and higher potential evapotranspiration. The correlations improved with the increasing seasonal scales with stronger and statistically correlations at 4 months timescales. In general, the results indicate that the precipitation during monsoon, pre monsoon and post monsoon seasons is highly influenced by the SPEI at 4 month timescales.

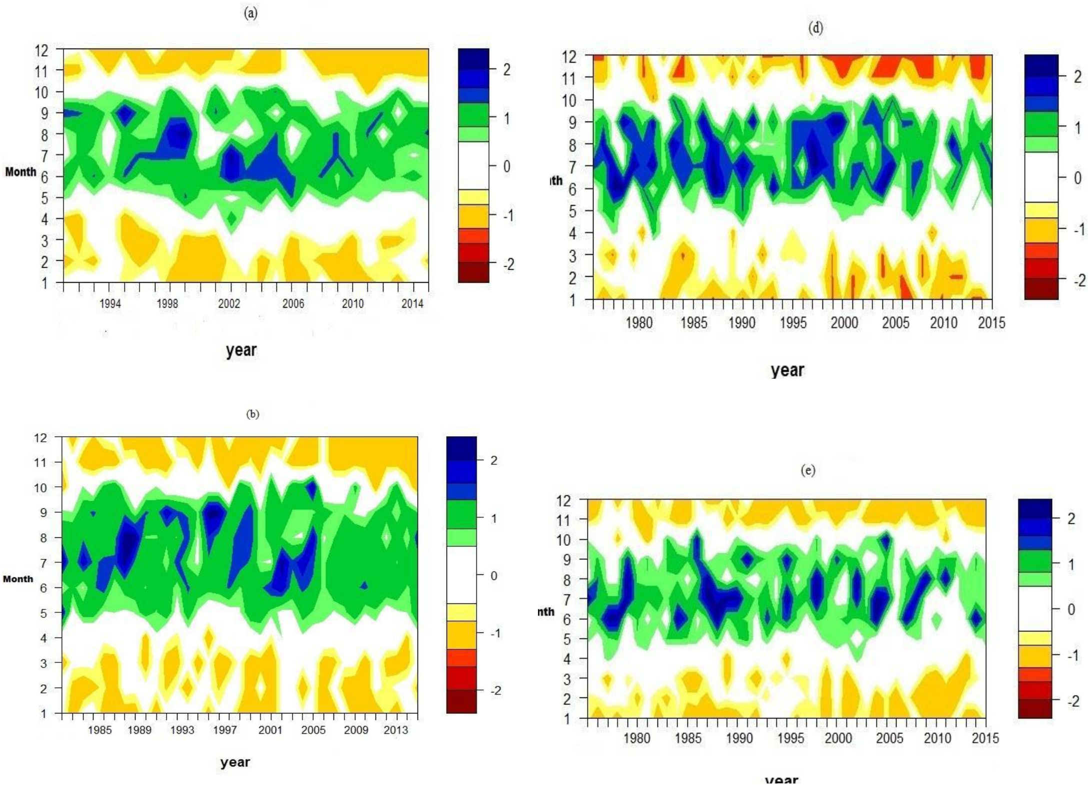
Standardized Precipitation Index (SPI)

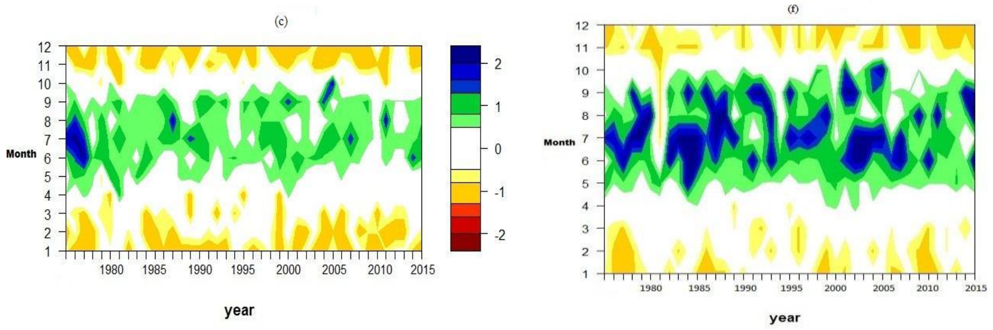
The results of seasonal MK test for SPI values between 1975 and 2015 are shown in following table.

Table 3. Mk test & Sen's estimator result of SPI in study area

Location	ZMK	p-value	β (mm)
Rangpur	-0.2808	0.7789	-0.03170732
Dinajpur	-2.0734	0.03813	-0.2470588
Sayedpur	-1.0977	0.2723	-0.160
Rajshahi	-2.6844	0.007265	-0.2926829
Bogra	-2.1228	0.03377	-0.2317073
Ishwardi	-2.0443	0.04092	-0.2233069

MK Statistics and the corresponding p-value at 5% significance level of yearly rainfall between 1975and 2015 are shown in Table 4.3. Table indicates the p-value is higher than the significance level (0.05).The trend test result showed a decreasing trend of yearly SPI in Rangpur and Sayedpur stations, whereas statistically no significant trend in Dinajpur and Rajshahi, Bogra, Ishurdi respectively. This study indicated amount of annual rainfall is increasing although this trend is not statistically significant. . Since rainfall varies significantly among different regions, the concept of drought may differ from places to places. Standardized Precipitation Index (SPI) therefore monitors the severity of drought events. Negative SPI values show rainfall deficit while positive values show surplus in rainfall. Sen's slopes at different stations were negative, indicating a decline in rainfall. This might have affected the drought phenomena in this region. A decreasing trend of rainfall was found from the annual MK test in Bogra, Ishurdi Rangpur and Sayedpur stations respectively. Sen's slope of six stations (-2.1228, -2.0443, -2.0734, -2.6844, -0.2808 and -1.0977 at Bogra, Dinajpur, Ishurdi, Rajshahi, Rangpur and Sayedpur respectively showed also a declining pattern of yearly rainfall. Trend of SPI showed increasing dryness in this region. This might be the effect of rainfall variations.



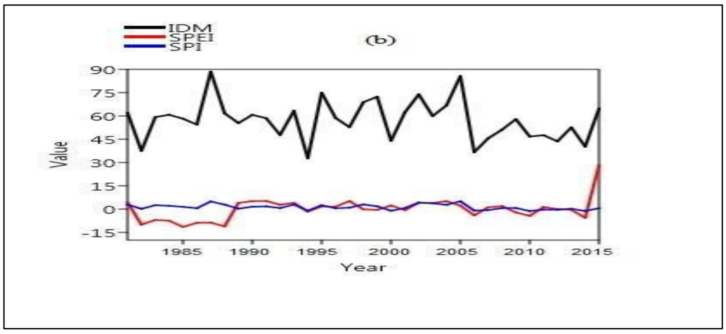


Annual variations of SPI in the study sites (a) Sayedpur,(b)Dinajpur, (c) Ishwardi, (d)Rajshahi,(e) Bogra and (f) Rangpur

The precipitation distributions suggest that the SPI non-normality distribution is closely related to the precipitation distribution. The Fig 4.5 represent the Yearly SPI in 6 station where (a) indicate the Sayedpur, for the time period of 1991 to 2015, (b) indicate Dinajpur for the time period of 1981 to 2015 and (c),(d), (e), (f) indicate the stations of Ishwardi, Rajshahi, Bogra and Dinajpur for the time period of 1975 to 2015.. Most of the precipitation occurs in the middle of a year. On the other hand moderately drought occurs in the first 4 months and last 3 months of every station in the study area except Rajshahi. The annual SPI for the entire study area is depicted in Fig.4.5. There are four to five drought events recorded in Rajshahi, with greatest drought condition occurring during post monsoon season. Deficit of rainfall over a period of time at a certain location could lead to various degrees of drought conditions, affecting water resources, agriculture and socio-economic activities. Mathematically, SPI is based on the cumulative probability of a given rainfall event occurring at a given rainfall station. Based on the historical rainfall data, it is easy for an analyst to tell whether the probability of rainfall is less than or equal to a certain amount. If a particular rainfall event gives a low probability on the cumulative probability function, then this is an indication of a likely drought event. On the other hand, if a rainfall event gives high probability on the cumulative probability function, then that indicates an anonymously wet event.

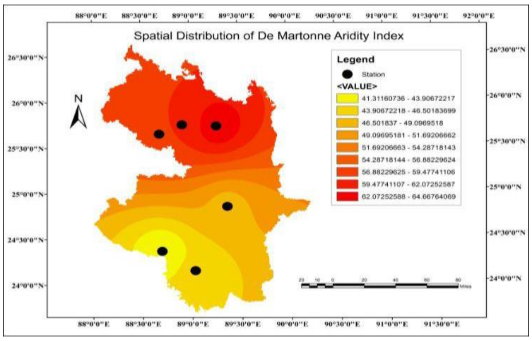
Temporal variation of IDM, SPEI and SPI

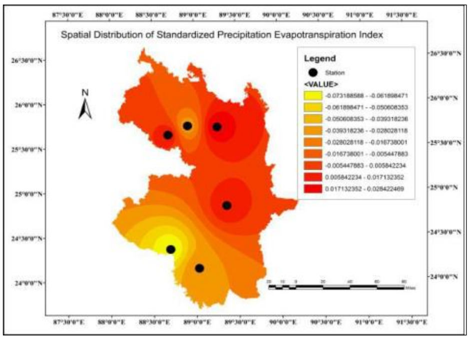
The Fig 4.7 shows the temporal variation of IDM, SPEI and SPI of selected 6 stations. In this figure (a) indicate the Sayedpur station, (b) represent Dinajpur, (c) Ishwardi, (d) Rajshahi, and (e), (f) represent Bogra and Rangpur station. Actually three drought index trends are showed in this figure.Fig4.7illustrates the annual change of the values of IDM, SPEI, and SPI from the six meteorological stations in Northwestern Bangladesh. The results show that IDM, SPEI, and SPI have unevenly distributed and significant variations in their temporal changes (Fig 4.7).The temporal trends of SPEI and SPI are similar. On the other hand, IDM exhibit a single-peak distribution with higher value and upper trend.



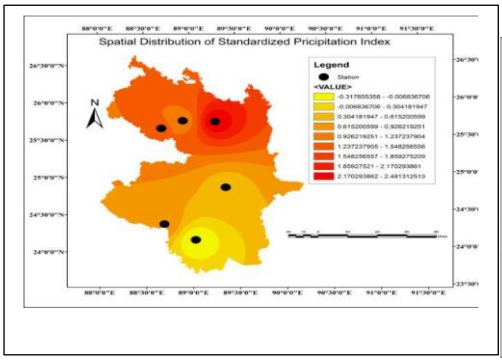
Temporal variations of SPI in the study sites (a) Sayedpur,(b)Dinajpur, (c) Ishwardi, (d)Rajshahi,(e) Bogra and (f) Rangpur

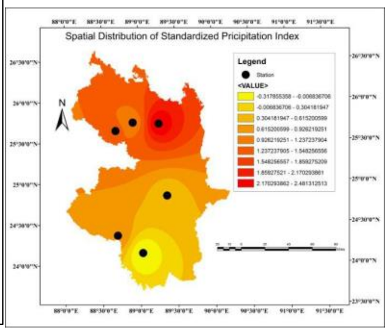
Spatial distribution of annual IDM, SPEI and SPI





Spatial distribution of annual (a) De Martonne Aridity Index(IDM), Standardized Precipitation Evapotranspiration Index(SPEI) and Standardized Precipitation(SPI).





show the spatial distribution of three drought indices IDM, SPEI and SPI. In the figure (a) represent the IDM where higher value for humid condition and lower value for dry condition. In Fig 4.8 (b) and (c) SPEI and SPI, positive value for wet or moist condition and negative value for dry indicated. IDM ,SPEI and SPI spatial mapping were done to identify drought prone area, severity, duration, onset, extent and end. To estimate IDM ,SPEI and SPI, long-term (25,35and 40 years) base data of 6 selected weather stations was used. Intensity of drought was classified in Spatial temporal mapping of drought event shows that Northwestern part is prone to both moderate and severe drought event. Drought can be of three type's e.g. metrological drought (absence of short-term rainfall), agricultural drought (absence of short to medium-term rainfall during crop growing season) and hydrological drought. In this work, I tried to relate drought to climatic parameters. However, droughts do not development singly from climactic phenomenon. Droughts are influenced by local geography, orography, soil parameter and vegetation, and these factors affect its development and localized.

Performance evaluation of drought indices

Methods	RMSE	R Square	Standard error
IDM	0.858	0.002	0.134
SPEI	0.457	0.386	0.094
SPI	0.177	1.237E-016	0.027

Performance analysis of the three indices is compared with observed droughts. The results indicated that four indicators of drought indices can indicate the method performance in Table 4.5. The Table 4.5 show the Root Mean Square Error is greater of IDM and SPEI than SPI and inverse R Square. On the other hand standard error is lower of SPI than the others. This result show the SPI is less error rather than SPEI and IDM. The error of this performance have been expressed in percentage where SPI 2%, SPEI 9% and IDM 13%. As a result it can be say that SPI is more perfect for drought measurement in this study area although the simple SPI, considering only precipitation, can be used to identify characteristics of droughts with certain restrictions. On the other hand, multivariate indices, the SPEI and the IDM would be able to clearly detect the temporal variability of droughts to a greater extent than the SPI index because. But the Table 4.5 interestingly shows the different result. Moreover, the different results derived from using regression method for made a substantial difference to temporal drought severity. Thus, climatic water demand had important aspects in determining the drought conditions for this area.

Comparison of climatic drought indices is varying monthly. The study aimed to analyze the temporal drying trends using three climatic drought indices and to provide useful insights on how different drought indices can be effectively used. The various indicators of different indices can have diverse effects on drought conditions. The simple SPI (considering only precipitation) can be used to identify characteristics of droughts with certain restrictions. Even though the SPI has been put forward by the World Meteorological Organization (2009) as a universal index, a single indicator may not be sufficient to characterize a complicated (e.g., Hao and Singh 2015). Certainly, the use of multivariate indices is more effective in terms of detecting temporal changes in drought conditions than using the stand-alone indicator, the SPI. The results suggested that meteorological data of the northwestern part of Bangladesh were analyzed using statistical methods to understand the dry condition and their changes over time. Yearly and seasonal variations are changing significantly instead of a gradual variation is found from trends. The variability of drought pattern in time scale was also estimated from filtered signals, which might be very useful for drought analysis, agricultural development and disaster management for Bangladesh. Moreover, Aridity Index was checked for climatic classification of the study area. The estimated index represents the climatic condition is less vulnerable to drought and suitable for agricultural practices Therefore, the assessment of patterns and trends of rainfall was conducted in this study. Trend analysis was carried out using a non-parametric MK test. It is a widely used test (Hamed 2008 and Taxak et al. 2014) for its suitability for non-normally distributed data and censored data. The Standardized Precipitation Index (SPI), outlined in McKee et al.(1993) and Guttman (1999), which is measures normalized irregularity in precipitation and has been recommended as a key drought indictor by the World Meteorological Organization (WMO 2006). The widespread acceptance of the SPI does not estimate the atmospheric conditions that may affect drought severity, such as temperature, wind speed, and humidity. To address this, the Standardized Precipitation-Evapotranspiration Index (SPEI) was developed by Vicente-Serrano et al. (2010). The SPEI utilize in a similar way, but instead normalizes anomalies in accumulated climatic water balance, defined as the difference between precipitation and potential evapotranspiration. This study highly represent the a drought index (IDM) and also calculate the Standardizes Precipitation Index and Standardizes Precipitation Evapotranspiration Index based on Temperature & Rainfall data in 6(six) meteorological station over the northwestern part of Bangladesh.

Conclusions

From this study, drought prone areas were observed using the spatial maps which were generated using GIS. The anomalies indicate areas that suffer drought and those that experience wet conditions. Both increasing and decreasing trends were observed in different study areas. I conducted a comparative analysis within the De Martonne Aridity Index (IDM), Standardized Precipitation Index (SPI) and the Standardized Precipitation-Evapotranspiration Index (SPEI) because IDM, SPI and SPEI are multi-scalar indices and have the advantage of identifying the multi-temporal nature of droughts. From the computation and analysis of these indices at meteorological stations spread across the northwestern part of Bangladesh which were depicted by both of these indices based on the meteorological data. Results indicate that there is little difference between the droughts depicted by the IDM and by precipitation based SPI and the temperature influenced SPEI primarily because of the low inter-annual variability of the temperature. However, SPI captured the influence of rainfall and depicted no severe and longer duration droughts except Rajshahi district. These results provide support for the notion that the SPI is relatively a better index for evaluating droughts in the 21st century than SPI with projected decreases in rainfall. Drought can be of three type's e.g. metrological drought (absence of short-term rainfall), agricultural drought (absence of short to medium-term rainfall during crop growing season) and hydrological drought. In this work, I tried to relate drought to climatic parameters. However, droughts do not development singly from climactic phenomenon. Droughts are influenced by local geography, orography, soil parameter and vegetation, and these factors affect its development and localized. Meteorological drought indices are commonly calculated from climatic stations that have long-term historical data and then using spatial interpolation methods. This study focuses on the aridity trends, SPI and SPEI according to meteorological data in northwestern part of Bangladesh.

Refference

Abdullah, HM., Akiyama,T., Shibayama, M.,& Awaya ,Y., (2011). Estimation and validation of biomass of a mountainous agro-ecosystem by means of sampling, spectral data and Quick Bird satellite image, International Journal of Sustainable Development.

Agnew, C., & Anderson, W.,(1992). Water in the arid realm. Routledge: London. TheorApplClimatol. doi:10.1007/s00704-015-1615-7.

Akhtari, R., Morid, S., Mahdian, M. H., &Smakhtin, V, (2008). Assessment of areal

Alam, ATM., Saadat, AHM., Rahman, MS., & Barkotulla, MAB.,(2011) Spatial Analysis of Rainfall Distribution and its Impact on Agricultural Drought at Barind Region, Bangladesh. Bangladesh Water Development Board (BWDB), Land Reclamation Project Report, Govt. of Bangladesh. 1974.

Ali, M. G., Younes, K., Esmaeil, A., &Fatemeh, T. (2011). Assessment of Geostatistical Methods for spatial analysis of SPI and EDI drought indices.World Applied Sciences Journal, 15(4), 474-482.

Alley, W. M. (1984). The Palmer drought severity index: Limitations and assumptions. Journal of Climate and Applied Meteorology, 23(5615), 1100–1109.

Anderson, W. B., Zaitchik, B. F., Hain, C. R., Anderson, M. C., Yilmaz, M. T., Mecikalski, J.,and Schultz, L,(2012)Towards an integrated soil moisture drought monitor for East Africa, Hydrol. Earth Syst. Sci., 16, 2893–2913, doi:10.5194/hess-16-2893- 2012.

Bangladesh (2003).

Banglapedia National Encyclopedia of Bangladesh. Dhaka, Asiatic Society of Bangladesh.

Canziani, Palutikof, J. P., van der Linden,P. J., & Hanson (Eds.), C. E., Contribution of.working group II to the fourth assessment, report of the intergovernmental panel on climate change. Cambridge, UK: Cambridge University Press.

Clark C.,(1993) Crossosoma19(2): 37–48.Climate Change Cell. Department of Environment, Ministry of Environment and Forests. 55

Cook, E. R., Seager, R., Cane, M. A., &Stahle, D. W.,(2007). North American drought: Reconstructions, causes and consequences. Earth Science Reviews, 81, 93–134.

Croitoru AE, PiticarA, ImbroaneAM, Burada DC., (2013) Spatiotemporal distribution of aridity indices based on temperature and precipitation in the extra-Carpathian regions of Romania. Theor Applied Climatology 112:597–607.

De Martonne, E., (1926). Aréismeetindiceartidite. ComptesRendus de L'AcadSci, Paris, 182.

Dracup, J. A., Lee, K. S., & Paulson, E. G., Jr., (1980). On the definition of drought. Water Resources Research, 16, 297–302.

Dutra, E., Magnusson, L., Wetterhall, F., Cloke, H. L., Balsamo, G., Boussetta, S., and Pappenberger,(2013) F.: The 2010–2011 drought in the Horn of Africa in ECMWF reanalysis and seasonal forecast products, International J. Climatol., 33, 1720–1729, doi:10.1002/joc.3545.

.Erinç S., (1996) KlimatolojiveMetodları. Alfa Basic-Yayım-Dağıtım,Istanbul; Geographical Review, 38(1), 55–94.

Goovaerts, P., (2000). Geostatistical approaches for incorporating elevation into the spatial interpolation of rainfall. Journal of hydrology, **228(1)**, 113-129.

Guttman, N. B.,(1999) Accepting the Standardized Precipitation Index: A Calculation Algorithm.J. Am. Water Resour. Assoc. 35(2), 311–322.

Haider S, Adnan S.,(2014) Classification and assessment of aridity over Pakistan provinces (1960-2009). Int J Environ 3(4):24–35.

Hamed KH, Trend detection in hydrologic data: The Mann–Kendall trend test under the scaling

Hao, Z. and Singh, V.P.,(2015). Drought characterization from a multivariate perspective: A10 review. J. Hydrol. 527: 668–678.

Hasan Z, Akhter S, kabir A.,(2014) Analysis of rainfall trends in the South-east Bangladesh. J. Env.; 3(4): 51-56.

Haskett JD, Pachepsky YA, Acock B (2000) Effect of climate and atmospheric change on soybean water stress: a study of Iowa. EcolModel 135:265–277

Hayes, M., Svoboda, M., Wall, N. &Widhalm, M.,(2011) The Lincoln declaration on drought indices: universal meteorological drought 56

index recommended. Bulletin of the American Meteorological Society 92(4), 485–488.

Hays, J. D., Imbrie, J., &Shackleton, N. J.,(1976). Variations in the Earth's orbit: Pacemaker of the ice ages. Science, 194(4270), 1121–1132.

Helsel DR, Hirsch RM.,(2002). Statistical methods in water resources. Techniques of water resources investigations of the US Geological Survey, Book 4, USGS, Reston.

Hrnjak I, Lukić T, Gavrilov MB, Marković SB, Unkašević M, Tošić I., (2014). Aridity in Vojvodina, Serbia. TheorApplClimatol 115:323–332

Huo ZL, Dai XQ, Feng SY, Kang SZ, Huang GH (2013) Effect of climate change on reference evapotranspiration and aridity index in arid region of China. J Hydrol; 492:24–34.

interpolation methods for spatial analysis of SPI and EDI drought indices. International Journal of Climatology, 29(1), 135-145.

IPCC (2007) Climate change 2007: mitigation. Contribution of Working Group III to the fourth assessment

report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge
IPCC. (2007). Climate change 2007: Impacts, adaptation and vulnerability. In M. L. Parry, O. F.
Kamruzzaman,MD, SakiurRahman, A.T.M., Shakil Ahmed ,Md., Enamul Kabir, Md., Quamrul Hasan Mazumder., Sayedur Rahman, M., Chowdhury Sarwar Jahan,(2016). Spatio-temporal analysis of climatic variables in the western part of Bangladesh) Environ Dev Sustain DOI 10.1007/s10668-016-9872.
Karim, Z., Ibrahim, A., Iqbal, A. and Ahmed, M.,(1990). Drought inBangladesh agriculture and irrigation schedule for major crops, Bangladesh Agricultural Research Center (BARC), Publication no. 34, Dhaka, Bangladesh.
Keka IA, Martin I, Rahman M, Banu DA.,(2012). Analysis of drought in Eastern part of Bangladesh. Daffodil Int. Univ. J. Sci. Tech;7(1): 20-27.
Khan, F.H., Geology of Bangladesh: University Press Limited; 207, 1991.
Komuscu AU.,(1999). Using the SPI to analyze spatial and temporal patterns of drought in Turkey Drought Network News; 11: 7-13. 57
Kun FS, Sheng WC, Ting W, Jiang HX, Yu WA, Ji L, Qi LB, Cheng LK, Multiple time scale analysis of climate variation in Macau during the last 100 years, J.Trop.Meteorol. 2012; 18 (1): 21-30.
Lungu M, Panaitescu L, Niţă S.,(2011). Aridity, climatic risk phenomenon in Dobrudja. Present Environ Sustain Dev 5(1):179–190Survey Professional Paper 1130, p. 84.
Matthai, H. F.,(1979). Hydrologic and human aspects of the 1976–77 drought. U.S. Geological Scales.In:Eighth Conference on Applied Climatology, 1993 January 17-22; Anaheim,doi:10.1016/j.jhydrol.2010.07.012, 2010.
McCabe, G. J., Palecki, M. A., & Betancourt, J. L., (2004). Pacific and Atlantic ocean influences onmultidecadal drought frequency in the United States. PNAS, 101(12), 4136–4141.
McKee, T. B., Doesken, N. J. & Kleist, J.,(1993). The relationship of drought frequency and duration to time scales. In: Proceedings of the 8th Conference on Applied Climatology. American Meteorological Society Boston, MA, pp. 179–183.
MH Mondal,(2010). Crop Agriculture of Bangladesh: Challenges and Opportunities. Bangladesh J. Agril. Res. 35(2) : 235-245.
Mishra AK, Desai VR.,(2005) Drought forecasting using stochastic models. Stoch. Env. Res. Risk. A.; 19(5): 326-339.
Mishra, A. K. and Singh, V. P.: A review of drought concepts, J. Hydrol., 391, 202–216,
Moral FJ, Rebollo FJ, Paniagua LL, García-Martín A, Honorio F.,(2015)Spatial distribution and comparison of aridity indices in Extremadura, southwestern Spain.
Moral FJ, Rebollo FJ, Paniagua LL, García-Martín A, Honorio F.,(2015)Spatial distribution and comparison of aridity indices in Extremadura, southwestern Spain. TheorApplClimatol.
Nakken .M.,(1999) Wavelet analysis of rainfall–runoff variability isolating climatic from anthropogenic patterns. Environ. Model.Softw.; 14(4): 283-295. 58
Paltineanu C, Tanasescu N, Chitu E, Mihailescu IF (2007) Relationshipsbetween the De Martonne aridity index and water requirementsofsome representative crops: a case study from Romania. International Agrophysics; 21(1):81
Patel NR, Chopra P, Dadhwal VK.,(2007) Analyzing spatial patterns of meteorological drought using standardized precipitation index. Meteorol. Appl; 14(4): 329-336.
Piazza D. A., Conti F. L., Noto L. V., Viola F., & Loggia, G. L., (2011). Comparative analysis of different techniques for spatial interpolation of rainfall data to create a 140 serially complete monthly time series of precipitation for Sicily, Italy. International Journal of Applied Earth Observation and Geoinformation, 13, 396-408.
Rahman MA, M.K Alam, M.A Ali3 and M.S Islam,(2013). Construction And Study Of Aridity Index Based On Temperature & Rainfall Data In Ishurdi, Pabna, Bangladesh. IOSR Journal of Applied Geology and Geophysics; IOSR-JAGG
Rahman MD, Begum M.,(2008). Application of non-parametric test for trend detection of rainfall in the Schubert SD, Suarez MJ, Pegion PJ, Koster RD, Bacmeister JT, Potential predictability of long-term drought and pluvial conditions in the United States Great Plains. J. Clim.; 21: 802-816.
Saadat, AHM., Alam, ATM., Alam, J. Shovon,M., & Uzzaman, R., (2009) Impact of Drought on Agriculture of Barind Tract: A Case Study of Dharmapur, ChapaiNawabgang.
SH Xenarios, NU Polatidis, Sekhar, Biswas, J.C. Maniruzzaman, Md. and GW Sarker.,(2013). Alleviating climate change impacts in rural Bangladesh through efficient agricultural interventions.RiceClima.
Shahid S.,(2008). Spatial and Temporal Characteristics of Droughts in the Western Part of 2247 Bangladesh, Hydrological Processes;22(13), 2235.

Shahid, S. and Behrawan, H.,(2008). Drought Risk Assessment in the Western Part of Bangladesh, Natural Hazards, Vol.46 (3), 391- 413.

Sigdel M, Ikeda M.,(2010). Spatial and Temporal Analysis of Drought in Nepal using Standardized Precipitation Index and its Relationship with Climate Indices. J. Hydrol. Meteorol; 7(1): 59-74. 59

Stadler, S. J.,(2005). Aridity indexes. In J. E. Oliver (Ed.), Encyclopedia of world climatology (pp. 89–94). Heidelberg: Springer.

Subrahmanyam, V. P.,(1967). Incidence and spread of continental drought: World Meteorological Organization, International Hydrological Decade, Reports on WMO/IHD Projects, no. 2, Geneva, Switzerland.

Tadesse, T., Haile, M., Senay, G., Wardlow, B. D., and Knutson, C. L.,(2008). The need for integration of drought monitoring tools for proactive food security management in sub-Saharan Africa, Nat. Resour.Forum, 32, 265–279.

Taxak AK, Murumkar AR, Arya DS.,(2014). Long term spatial and temporal rainfall trends and homogeneity analysis in Wainganga basin, Central India. Weather Clim. Extremes; 4:50-61.

The World Factbook" Central Intelligence Agency, CIA., Archived from the original on 29 Carbone, G. J., Rhee J., Mizzell H. P., and Boyles R. (2008). A regional-scale drought monitoring tool for the Carolinas. Bulletin of the American Meteorological Society, 89, 20-28.

Thornthwaite, C. W. (1948). An approach toward a rational classification of climate.

Vicente-Serrano, S. M., Beguería, S., Gimeno, L., Eklundh, L., Giuliani, G., Weston, D., El., G. G. S.,(2010): Challenges for drought mitigation in Africa: The potential use of geospatial data and drought information systems, Appl. Geograph., 34, 471–486.

Vicente-Serrano, SM., Begueria, S., Lopez-Moreno, JI.,(2010). A Multi-scalar drought index sensitive to global warming: the Standardized Precipitation Evapotranspiration Index—SPEI. J. Climate 23 (7), 1696–1718.

Walton, K., (1969). The arid zone. Chicago, IL: Aldine Publishing Co.

Wilhite, D., &Glantz, M.,(1985). Understanding the drought phenomenon: The role of definitions. Water International, 10(3), 111–120.

Wilhite, DA.,(2000). Drought: A Global Assessment .Hazards and Disasters: A Series of Definitive Major Works (7 volume series). Routledge Publishers, London, UK.

Williams-Sether, T., Macek-Rowland, K. M., & Emerson, D. G., (1994). Climatic and hydrologic aspects of the 1988–92 drought and the effect on people and resources of North Dakota, Vol. 29, p. 57. 60

WMO,(2006) Drought monitoring and early warning: Concepts, progress and future challenges.WMO.www.theguardianbd.com/geology-of-the-western-shelf-area-of-bangladesh-a-short-note.

Yu PS, Yang TC, Chou CC.,(2002). Effects of climate change on evapotranspiration from paddy fields in southern Taiwan. Climate Change 54:165–179.

Zhang Q, Xu CY, Zhang Z, Chen YD, Liu CL, Spatial and temporal variability of precipitation 1395–1398.doi:10.1007/s00704-015-1615-7.

COASTAL VULNERABILITY ASSESSMENT OF THE SOUTH-CENTRAL COAST OF BANGLADESH AND SUBSEQUENT RELATION TO HUMAN VULNERABILITIES

Monojit Saha[1] and Samrin Sumaiya Sauda[1]

ABSTRACT

According to the Global Climate Risk Index, Bangladesh is one of the top ten vulnerable countries that are most affected by natural hazards and climate change. Owing to low lying land especially along the coastal belt, Bangladesh's south-central coast is under serious threat intensified by extreme population pressure and also inefficient cyclone shelters placement. This study attempted to develop a coastal vulnerability index (CVI) by using eight physical parameters namely: (1) Shoreline Change Rate; (2) Coastal Slope; (3) Vegetation; (4) Rate of sea level change; (5) Salinity (6) Soil Texture; (7) Surface Geology; and (8) Land Surface Evolution.

These variables are considered as relative risk parameters and integrated through geospatial techniques. A ranking procedure is carried out to estimate the degree of coastline vulnerability to hydro-meteorological disasters. It is found in the study that about 38.71% of the south-central coast is moderately vulnerable, 10.31% is highly vulnerable and 4.68% is very highly vulnerable to disasters. After assessment of the physical vulnerability, results where then compared with the union-wise population density and a locational analysis of cyclone shelters located in the coastal areas was also conducted. Char Madras Union of Bhola district has been identified as the most vulnerable coastal union according to the overall assessment. This study could provide information for decision makers and emergency managers to construct adaptive policies for sound coastal planning and management.

Introduction

Bangladesh is often cited as a hotspot for natural disasters, particularly the coastal regions are predominantly vulnerable to hydro-meteorological disasters. The southern coastal areas of the country are periodically experiencing the ravages of cyclonic storms and associated storm surges. (Maniruzzaman et al 2001). One of the key steps towards disaster risk reduction is vulnerability assessment (Roy and Blaschke, 2013). If such assessments take into consideration the spatial variability of vulnerability, this acts as a stepping stone towards effective disaster management. The Hyogo Framework for Action (HFA) emphasizes that sustainable development is inevitably linked to vulnerability assessment (UN 2005). The coastal area of the country comparatively more vulnerable in comparison to the rest of the country due to its exposure to direct impacts of cyclones and associated storm surges. Earliest record of disaster in the region dates back to a great storm that had taken place in 1584 affecting Barishal district (Haider *et al.*, 1991) and since then various kinds of disasters took have occurred causing huge economic and human damages (Karim, 1995). Vulnerability assessment of coastal areas can be broadly subdivided into physical vulnerability assessment and socio-economic vulnerability assessment (Islam, 2016). While several attempts to study the socio-economic dynamics of the people have been made in previous studies (Islam 1974, Haque and Blair 1992, Alam and Collins 2010) and one attempt (Islam et al 2016) has been made to study the physical factors of vulnerability of the coast, a comprehensive study integrated the two streams with spatial dynamics was missing. This paper tries to incorporate physical vulnerability with human vulnerability. The spatial distribution of the vulnerabilities has been identified and therefore shall be very useful for vital decisions for tackling localized issues. The factors behind such increased vulnerabilities and the spatial relationships have been identified.

Study Area

A portion of the South-Central coast of Bangladesh has been designated as the study area. The study area consists of 12 Unions in Bhola, Patuakhali and Barguna districts. The total population of the study area is 292111 (BBS, 2011). We see that the South-Central coast is the most vulnerable section due to its exposure to tidal and estuarine waters. Therefore, considering the size of population and exposure, we decided to conduct our study in this region.

[1] *Undergraduate Student, Department of Geography and Environment, University of Dhaka*

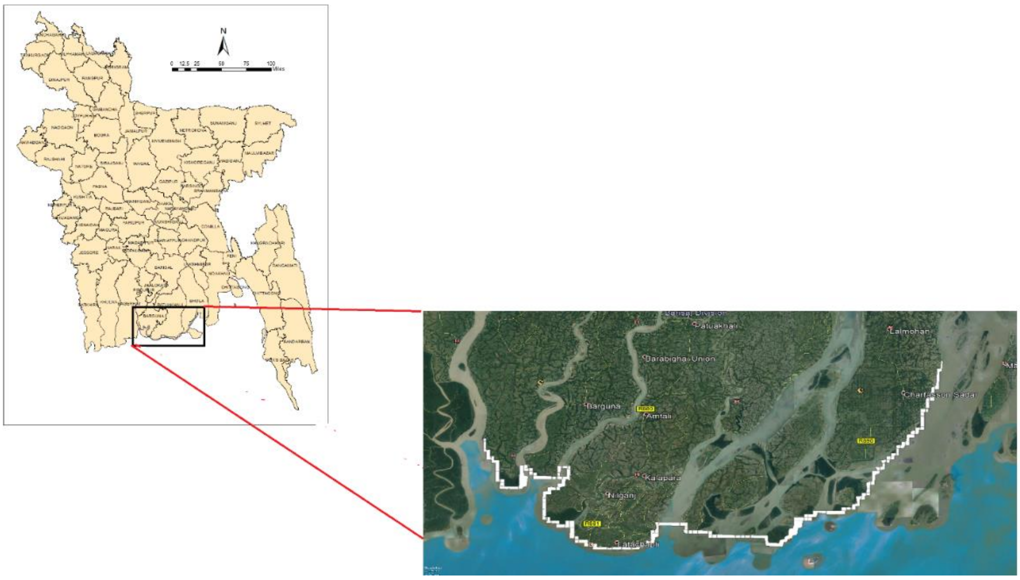


Figure 1: Study area (South Central coast of Bangladesh)

Methodology

Coastal vulnerability index (CVI) is calculated by using eight physical parameters namely: (1) Shoreline Change Rate; (2) Coastal Slope; (3) Vegetation; (4) Rate of sea level change; (5) Salinity (6) Soil Texture; (7) Surface Geology; and (8) Land Surface Evolution. Landsat OLI and TM sensor images have been used to calculate some of the parameters. The parameters are processed and assigned vulnerabilities after reclassification and then final Coastal Vulnerability Index (CVI) is computed using the raster calculator in ArcGIS. After CVI Calculation, spatial analysis using cyclone shelter location and capacity was conducted.

Table 1: Variables used in the study and Data sources

Variables	Data Source
Shoreline Change Rate	Multi-temporal Landsat imagery
Coastal Slope	Aster DEM (30 m)
Vegetation Cover	Landsat 8 OLI, USGS
Rate of sea level change	BIWTA & BWDB
Salinity	Landsat 8 OLI, USGS
Soil Texture	Bangladesh Agricultural Research Council (BARC)
Surface Geology	USGS GIS Dataset
Land Surface Evolution	Geological Society of Bangladesh
Cyclone Shelter Locations and Capacity	GeoDash Portal https://geodash.gov.bd/

Shoreline Change Rate

Dynamic nature of shorelines makes them subject to temporal and spatial change due to various coastal processes (Carter, 1988; Bird, 1993; Kumar et al., 2010). Shoreline change rates (in terms of erosion and accretion) were calculated using cloud free multi-temporal Landsat images. Four Landsat Satellite images with around 10 years intervals (Landsat MSS-1990, Landsat TM-2000 & 2010 and Landsat OLI-2018) were considered for this study. To accomplish this Digital Shoreline Analysis System (DSAS) and its extension for ArcGIS 10.3 was used.

Shorelines subjected to erosion are considered as high vulnerability whereas shorelines prone to accretion are considered to be less vulnerable. Around 2035 transects (100m interval) have been taken along 300 km of shoreline (study area) to assess their vulnerability.

It has been observed that the shoreline change rate has become increasingly dynamic in recent years. This could potentially indicate severe impacts on the coastal people.

Coastal Slope

Slope of the immediate hinterland is treated as one of the important factors for coastal vulnerability assessment (Nageswara Rao et al., 2008). Our study area has mostly gentle slopes which can be associated with high vulnerability. The slope map derived from DEM indicates that the slope in the western part (Barguna) is slightly high (3-6°). 90% of the slope is between 0-1.5° in our study area which indicates extremely high vulnerability.

Vegetation Cover

In order to assess the density of vegetation cover in the regions, Normalized Difference Vegetation Index (NDVI) was computed using Landsat 8 OLI image. It was assumed that the locations with greater vegetation density was less vulnerable than the coasts with less dense vegetation. This is because of the characteristic of vegetation acting as a natural barrier to tidal surges. We see that Patuakhali district has the Kuakata National Park which acts as a great barrier to disaster whereas parts of Bhola and Barguna are exposed and therefore are highly vulnerable.

Rate of sea level change

Sea level reflects a complex and dynamic interaction between local, regional, and global land and oceanic processes (Cooper et al., 2008). Hence, it's an important parameter in determining the CVI. Assessing past literatures (IPCC 2014, Islam et al 2016) it's found that the entire shoreline of the Ganges deltaic coast can be categorized into one vulnerability category i.e., high vulnerability class according to the scale of vulnerability.

Soil Salinity

Soil Salinity is assessed using the Normalized Difference Salinity Index (NDSI) proposed by Soil salinity level is assessed Unions of Bhola district are identified as most vulnerable to Soil Salinity. Patuakhali can be considered as less vulnerable to soil salinity. Naltona and Baliatali unions are two unions in Barguna are highly vulnerable to soil salinity

Soil Texture

Soil texture is directly associated with vulnerability. This is because if the soil erodibility is high, then the soil will easily be washed away or eroded due to erosion or tidal surge. Six soil texture classes have been identified in the study area and the vulnerability values has been assigned. It is seen that clay soils are predominant in Patuakhli region which makes them less vulnerable and soils in the estuarine environment of Bhola has silty clay loam soil and therefore are considered to have high vulnerability.

Table 2: Soil textures and vulnerability

Texture	**Soil Erodibility (K)**	**Vulnerability**
Mostly Clay- Silty Clay	0.11	2
Mostly Silty Clay	0.11	2
Mostly Clay	0.13	3
Mostly Silty Clay Loam	0.17	3
Mostly Silt Loam	0.21	4
Predominantly sand	0.19	4

Source: United States Department of Agriculture (USDA)

Surface Geology

Geomorphology not only mirrors the landscape of a terrain but also defines its classification, historical development, and physical processes acting over a given time. Hence, it has an important role to play in determining the impact of sea-level rise (Nageswara Rao et al., 2008). Four distinct geomorphological units have been identified and their associated vulnerability values are given below.

Table 3: Surface geology and vulnerability

Surface Geology	**Vulnerability**
Mangrove swamp deposit (dsw)	2
Tidal deltaic deposit (dt)	2
Estuarine deposit (de)	3
Tidal mud (dm)	4

Coastal Land Evolution

The evolution period of coastal land can be directly linked to the coastal vulnerability. It has been considered that the older the land, the less vulnerable to erosion it is, due to its permanent nature. Land evolution has been considered to take into account the difference in vulnerabilities to the older and permanent lands and the newly formed land surface. It is observed that most of the land in the estuarine regions i.e. Bhola originated between 1960AD and 1985 AD and therefore are vulnerable to disasters.

Table 4: Land evolution and vulnerability

Land Surface Formation	Vulnerability
Between 1830AD and 1900 AD	1
Between 1900AD and 1960AD	2
Between 1960AD and 1985 AD	3
Between 1985 and 2002 AD	4

Coastal Vulnerability Index (CVI)

The Coastal Vulnerability Index has been used by authors (Gornitz, 1990, 1991; Thieler and Hammer-Klose, 1999; Doukakis, 2005; Diez et al. 2007), based on the square root of the product of vulnerability degrees of the several parameters.

$$\mathbf{CVI} = \frac{\sqrt{a*b*c*d*e*f*g*h}}{8}$$

Where, a= Shoreline change rate, b= Coastal slope, c = Vegetation Cover, d= Land evolution, e= Surface geology, f= Sea level rise, g= Soil Salinity, h= soil texture

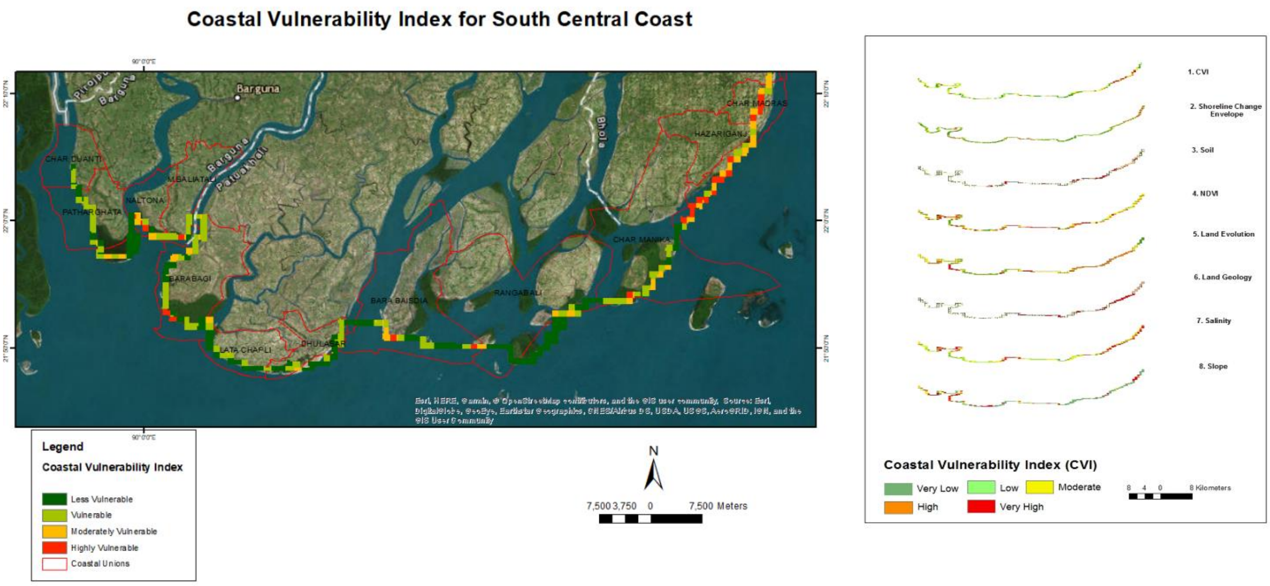


Figure 3: Coastal Vulnerability Index map along with the parameter's distribution map

Table 5: Percentage vulnerability of coastline

Vulnerability	Percentage of shoreline	CVI Index Value
Low Vulnerability	46%	< 3
Moderate Vulnerability	38.7%	3-5
High Vulnerability	10.7%	5-9
Very High Vulnerability	4.69%	<9

Table 6: Union-wise Vulnerabilities

Union Name	District	CVI Index Value	Level of Vulnerability
Char Madras	Bhola	9.32	Very Highly Vulnerable
Hazariganj	Bhola	5.67	Moderately Vulnerable
Char Duanti	Barguna	3.34	Moderately Vulnerable
Char Manika	Bhola	5.00	Moderately Vulnerable
M. Baliatali	Barguna	4.95	Moderately Vulnerable
Naltona	Barguna	6.17	Highly Vulnerable
Patharghata	Barguna	3.49	Moderately Vulnerable
Bara Baisdia	Patuakhali	4.51	Moderately Vulnerable
Rangabali	Barguna	4.38	Moderately Vulnerable
Dhulasar	Patuakhali	3.38	Moderately Vulnerable
Lata Chapli	Patuakhali	2.88	Less Vulnerable

Relating Human Vulnerabilities

After conducting the physical vulnerability index, human vulnerability was assessed. In this spatial assessment, the capacity of cyclone shelters existing in the coastal regions was assessed. A capacity raster was produced using spatial interpolation method, Krigging and then this was overlapped using the CVI raster. Spatial relations were therefore identified. It is seen that the capacity and number of cyclone shelters are very low in the Rangabali and Barabaisdia unions, although there are parts of the union that are very highly vulnerable and highly vulnerable. This indicates spatial inequality in terms of setting up of cyclone shelter.
It is seen from Table 7, that the Unions that are more vulnerable have less percentage of population that may occupy the cyclone shelters in comparison to Less Vulnerable Unions, therefore, we see that there is a significant anomaly in the spatial distribution of cyclone shelters.
From Figure 8, we see that in unions with the Highest Vulnerabilities, there is higher percentage of people under the poverty line. We also see that there is a positive correlation between percentage of people below the poverty line and the CVI index.

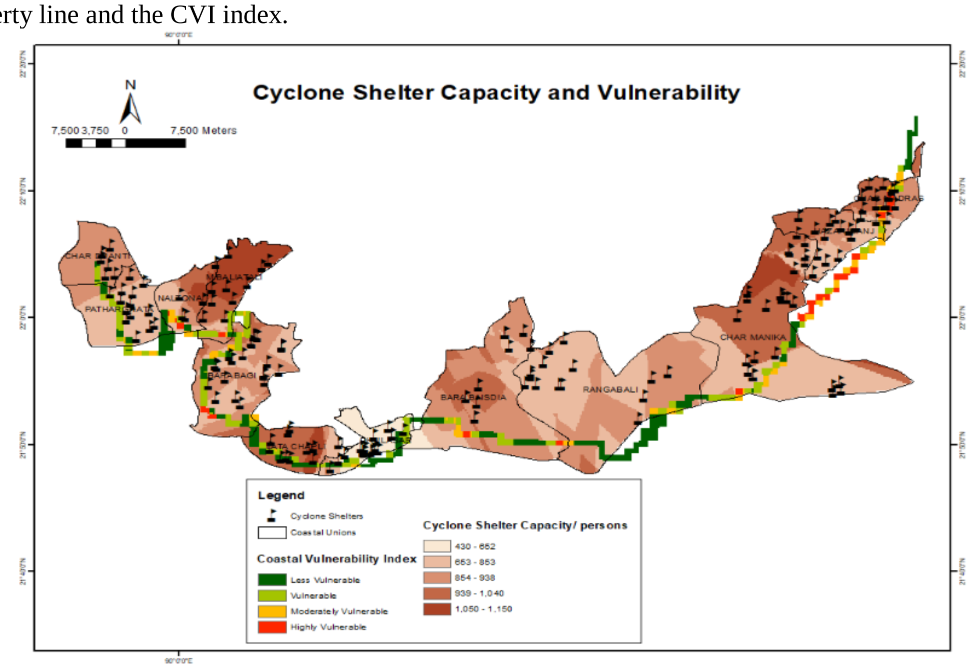


Figure 4: Distribution of cyclone shelter capacity and relationship to physical vulnerability

Table 7: Cyclone Shelter Capacity and Physical Vulnerabilities

Union Name	District	Level of Vulnerability	Cyclone Shelter Capacity / Person	Percentage of Population covered by Cyclone Shelter
Char Madras	Bhola	Very Highly Vulnerable	933	2.8%
Hazariganj	Bhola	Moderately Vulnerable	896	2.8%
Char Duanti	Barguna	Moderately Vulnerable	875	2.9%
Char Manika	Bhola	Moderately Vulnerable	913	3.2%
M. Baliatali	Barguna	Moderately Vulnerable	1066	3.7%
Naltona	Barguna	Highly Vulnerable	903	3.2%
Patharghata	Barguna	Moderately Vulnerable	828	2.9%
Bara Baisdia	Patuakhali	Moderately Vulnerable	885	4.5%
Barabagi	Barguna	Moderately Vulnerable	872	4.7%
Rangabali	Barguna	Moderately Vulnerable	848	4.6%
Dhulasar	Patuakhali	Moderately Vulnerable	525	3.4%
Lata Chapli	Patuakhali	Less Vulnerable	969	6.7%

Table 8: Poverty and Physical Vulnerabilities

Union Name	District	Level of Vulnerability	CVI Index Value	Percentage of People Below Poverty Line (Thana Level Data-BBS, 2010)
Char Madras	Bhola	Very Highly Vulnerable	9.32	14.9%
Hazariganj	Bhola	Moderately Vulnerable	5.67	14.9%
Char Duanti	Barguna	Moderately Vulnerable	3.34	6.1%
Char Manika	Bhola	Moderately Vulnerable	5.00	14.9%
M. Baliatali	Barguna	Moderately Vulnerable	4.95	9.9%
Naltona	Barguna	Highly Vulnerable	6.17	9.9%
Patharghata	Barguna	Moderately Vulnerable	3.49	6.1%
Bara Baisdia	Patuakhali	Moderately Vulnerable	4.51	14.4%
Barabagi	Barguna	Moderately Vulnerable	4.38	12%
Rangabali	Barguna	Moderately Vulnerable	3.5	14.4%
Dhulasar	Patuakhali	Moderately Vulnerable	3.38	9.7%
Lata Chapli	Patuakhali	Less Vulnerable	2.88	9.7%

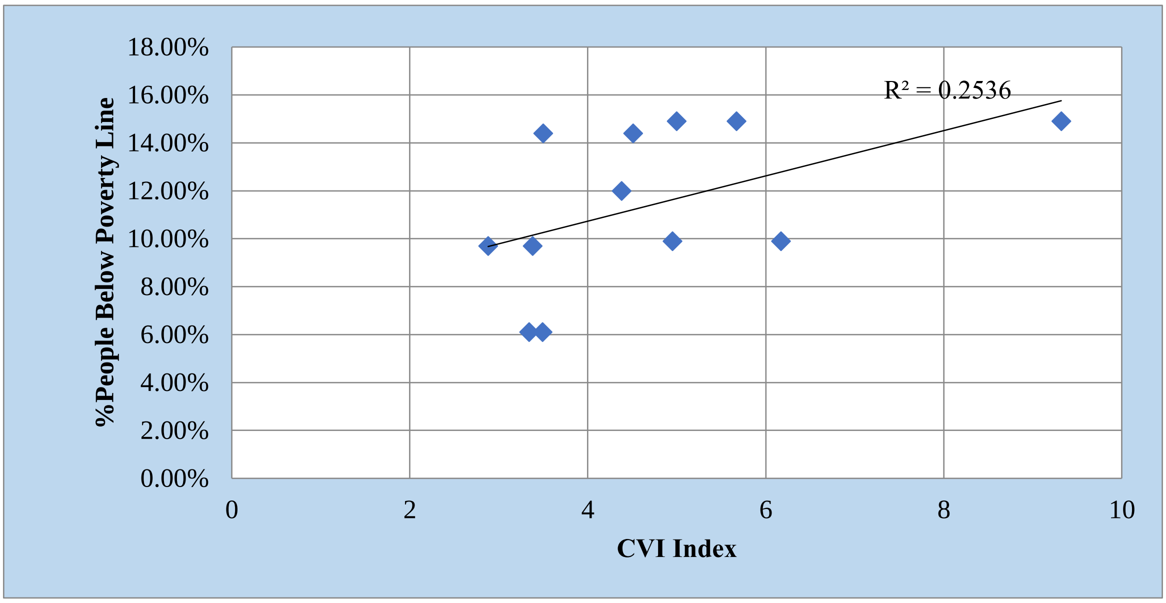


Figure 5: Correlation Between Poverty and Physical Vulnerbailities

Conclusion

Due to the dynamic influence of both tidal and estuarine environments, the unions in Bhola are very vulnerable to hydro-meteorological disasters. The study delineates the spatial distribution of vulnerabilities in the study area. This endeavor incorporates parameters such as Land Evolution, Vegetation cover, Soil texture and Salinity Indexes into physical vulnerability assessment and it is seen that these factors are overall aligning with the trend. Therefore, further studies can take this into consideration. The spatial inequality that the study identifies in terms of human vulnerabilities need to be addressed. Unions that have been identified as most vulnerable needs to be assessed to see which parameter is responsible for the highest vulnerability and thus needs to be addressed. Further, we have seen that the physical vulnerabilities can be closely associated with human vulnerabilities such as cyclone shelter location, capacity and poverty. We see that there is a spatial inequality in terms of distribution of cyclone shelters among the 12 unions. There is also a positive correlation between poverty and the physical vulnerabilities among the unions. Therefore, we believe that our findings shall help in the build up of a comprehensive plan for localized disaster management initiatives in the south-central coast of Bangladesh.

Acknowledgement

The authors would like to thank Bangladesh Agriculture Research Council (BARC), GeoDash Portal Initiative of the Government of the People's Republic of Bangladesh and Bangladesh Inland Water Transport Authority (BITWA) for providing vital data used in this research.

References

BBS (2011) Population and Housing Census 2011, Bangaldesh Beaureu of Stattistics, Government of the People's Republic of Bangladesh.

Bird, E.C.F., (1993) *Submerging Coasts: the Effects of a Rising Sea Level on Coastal Environments*. John Wiley & Sons Ltd., Chichester.

Cooper, M., Beevers, M., Oppenheimer, M., (2008). The potential impacts of sea level rise on the coastal region of New Jersey, USA. *Climate Change*. 90, 475-492.

Carter, R.W.G., (1988) Coastal Environmentean Introduction to the Physical,*Ecological and Cultural Systems of Coastlines.* Academic Press, London.

Haider, R., Rahman, A. A, and Huq, S. (eds) (1991) Cyclone 91: An EnvironmemaI and Perceptional Study, BCAS, Dhaka, p. 17.

Islam, M.A. (1974) Human Adjustment to Cyclone Hazards: A Case Study of Char Jabbar. *The Natural Hazards Research Working Paper Series.* No. 18. Natural Hazards Centre, Boulder, CO.

Islam, M.A, Mitra, D., Dewan, A. and Akhter, S.H. (2016) Coastal Multi-hazard Vulnerability Assessment along the Ganges deltaic coast of Bangladesh- A geospatial approach, *Ocean and Coastal Management*, Elsivier, 127 (2016) 1-15

Kumar, T.S., Mahendra, R.S., Nayak, S., Radhakrishnan, K., Sahu, K.C., (2010). Coastal Vulnerability Assessment for Orissa State, East Coast of India. *Journal of Coastal Research,* 263,523-534

Nageswara Rao, K., Subraelu, P., Venkateswara, Rao T., Hema Malini, B., Ratheesh, R., Bhattacharya, S., Rajawat, A.S., Ajai, (2008) Sea-level rise and coastal vulnerability: an assessment of Andhra Pradesh coast, India through remote sensing and GIS. *Journal of Coastal Conservation*. 12, 195-207.

Roy, D.C and Blashchke, T (2015) Spatial vulnerability assessment of floods in the coastal regions of Bangladesh, *Geomatics, Natural Hazards and Risks*, 6:1, 21-44

UN (2005) Hyogo framework for action 2005–2015: building the resilience of nations and communities to disasters. World Conference on Disaster Reduction, 18–22 January 2005, Kobe, Hyogo, Japan; [cited 2013 Mar 21]. Available from: http://www.unisdr.org/

Karim, N. (1995) Disasters in Bangladesh, *Natural Hazard,* 11: 247-258.

Haque, C.E. and D. Blair (1992) 'Vulnerability to tropical cyclones-evidence from the April 1991 Cyclone in Coastal Bangladesh'. Disasters. 16(3). pp. 217–229.

ASSESSING PHYSICAL VULNERABILITY IN COASTAL BANGLADESH TOWARDS NATURAL DISASTERS: A COMPOSITE INDEX APPROACH

S. M. Moniruzzaman[1], Dr. M. Z. Hossain[2] & N. M. Ha-Mim[3]

ABSTRACT

The increased number of natural hazards due to climate variability has resulted in numerous disasters in southwest coastal Bangladesh. In the recent time, two devastating cyclones – Sidr (2007) and Aila (2009) – hit the coastal areas of Bangladesh within a time span of two years, causing huge damage to the lives and property of coastal people of the south. In order to minimize the disaster impacts and shorten the recovery period, the vulnerability of a disaster-prone area is required to be assessed. Therefore, this research aims to assess the vulnerability towards natural disasters, by establishing an index which is operational in 9 wards of Mongla Port Pourashava in southwest coastal Bangladesh. In this research vulnerability is viewed from the physical aspect and considered parameters such as Household structures, Road and communications, Water and sanitation, Fuel and Electrifications and Physical Adaptation strategies. This research adopted the quantitative method as research strategy where data collection process included analysis of secondary data including questionnaire survey of 98 households. The results show differential vulnerability towards natural disasters for each of the 9 wards with having dynamic difference for each parameter which prove the existence of inequality in terms of physical development of the area. It also highlighted the need for improvements to further reduce the vulnerability of these wards.

Keywords: Physical vulnerability, Coastal Bangladesh, Natural disasters, Dynamic vulnerability differentials.

Introduction

The concept of vulnerability has been used and understood in different ways by scholar of different disciplines. It has been used in a variety of literature which offers different models and approaches for theorizing, conceptualizing and mapping the components of vulnerability in the ground.

Historically the term vulnerability is used by the Romans to describe the condition of a soldier who is injured in the battlefield and indicating the risk of future attack (Adger, 2000). This implies that vulnerability of a person is defined by pre-existing condition. Though it is the historical meaning of vulnerability, in the context of natural disaster it has not always been used in this way. The concept of vulnerability has been reviewed by a number of scholar and academics and a variety of approaches are outlined by them. Smith (1996) and Hewitt (1983) review vulnerability as exposure to hazards where the main focus was identification and prediction of vulnerable groups and critical region through possibility and outcome of hazards and highlighted that vulnerability should be conceptualized through identification of underlying causes of vulnerability to natural hazards and further Blaikie et al. (1994) link this concept with political economy of resource and disaster management.

Considering the above-mentioned facets, the aim of this study is to develop a Physical Vulnerability Index (PVI) for the coastal households of Bangladesh, to assess the physical vulnerability condition in different domains of physical vulnerability in different locations of the study area. Principal component analysis and indexing method is used respectively for the distribution of weight in different dimension and assess the relative magnitude of contributing indicators within concerned physical vulnerability dimension.

[1] *Student, Urban and Rural Planning Discipline, Khulna University, Contact: +01521116846, E-Mail: mabir19april@gmail.com*

[2] *Corresponding Author, Professor, Urban and Rural Planning Discipline, Khulna University, Contact: +01992644569, E-Mail: zakirurp9913@gmail.com*

[3] *Student, Urban and Rural Planning Discipline, Khulna University, Contact: +01521258814, E-Mail: nurhamimurp15@gmail.com*

Methodology

Profile of the study area

The selected study area for this research is Mongla Port Pourashava of Mongla Upazilla under Bagerhat district. The pourashava is located in between 22°20'55" and 22°34'33" north latitudes and in between 89°33'26" and 89°43'10" east longitudes. Mongla river is at the north which divided the pourashava into two parts and Poshur river is to the west. It is one of the most disaster-prone areas of southern coastal Bangladesh.

Data collection

Questionnaire survey was conducted to collect data from 98 households of the study area. Simple random sampling technique was adopted as the sampling technique to conduct the research. At first, population data of the different wards was collected from the Mongla Port Pourashava. Then, according to the percentage of the population in different wards of the pourashava 98 households was divided for the 9 wards. Equal distribution was not considered for each ward.

Analytical Framework

To assess physical vulnerability of the area, physical vulnerability index was calculated for different 9 wards of the Mongla Port Pourashava. The parameters and variables taken under those parameters of physical vulnerability are shown in the **appendix at the Table no. 01.**

Development of the physical vulnerability index (PVI)

The PVI was developed by using a Composite Indicator Framework method, which consists of five main dimensions: Household structures, Road and communications, Water and sanitation, Fuel and Electrifications and Physical Adaptation strategies. Variables or components did not have to normalize. All the variables are at the same scale. Then, to put the weightage Principal Component Analysis was used. By the PCA some major components were found out.

$$\text{Weightage for major/principal components} = \frac{Total\ eigen\ value\ of\ PC}{Cumulative\ total\ eigen\ value\ of\ PC10}\ x100\%$$

For individual variable, this weightage was divided by the number of variables under that principal component.

$$\text{Weightage for each variable} = \frac{\text{Weightage for major/principal components}}{Number\ of\ variables\ under\ the\ principal\ component}$$

The indicator indices, therefore, produced numerical values showing concerned community's (obtained from aggregated response of households) relative status of vulnerability. For an indicator this numerical value ranges between zero to one. The maximum and minimum values were usually adjusted so as to avoid values of more than one. Any remaining values above one or below zero were fixed at one and zero, respectively. Once the indicator index value was obtained; the relative weight obtained through follow-up workshop was multiplied with concerned indicator. This way a weighted score for an indicator as shown by Eq. was determined.

Weighted indicator score (WIS)= Indicator index score x Average weights

Principal components and weightages are shown in the **appendix** at the **Table no. 02**.

Results and Discussion

In this report the results of data analysis for the assessment of physical vulnerability are shown in principal component wise. Different vulnerability pattern of different wards of the pourashava are also discussed in this part.

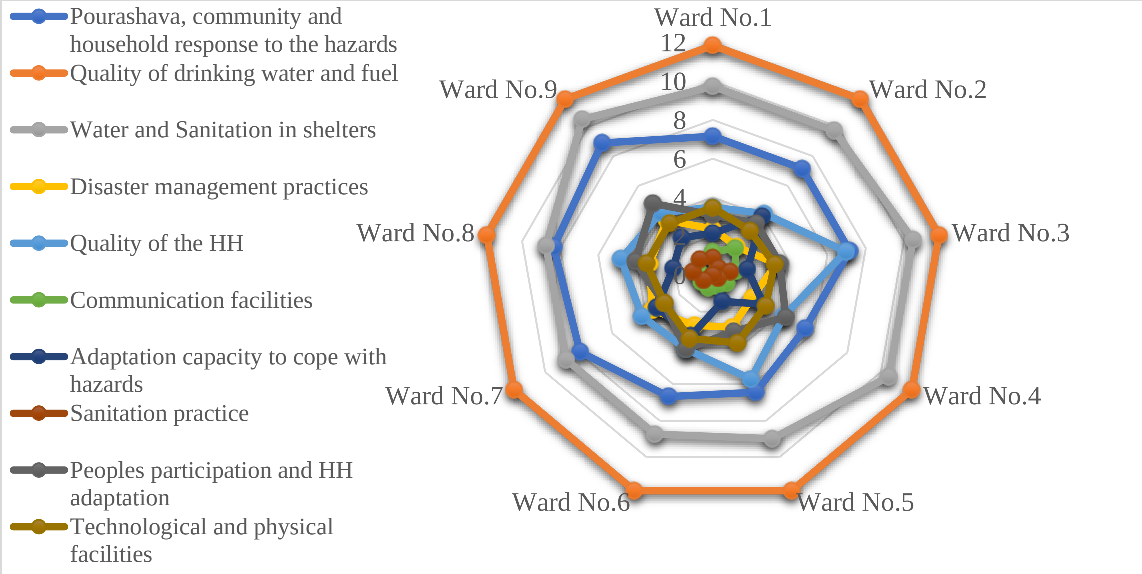


Figure 1: Principal component wise vulnerability scores

For principal component 01, Pourashava, community and household response to the hazards, overall vulnerability score is 7.27 out of 20.So, it can be said less vulnerable in this context. Ward no. 09 was found the most vulnerable ward among the 9 wards of the study area in this context. The vulnerability score of ward no. 9 for PC01 is 8.9. Ward no. 04 was found the least vulnerable ward among the 9 wards of the study area in this context. The vulnerability score of ward no. 4 for PC01 is 5.5. For principal component 02, Quality of drinking water and fuel, overall vulnerability score is 11.84 out of 18. So, it can be said moderately vulnerable in this context. Condition of all the wards are same in this context. For principal component 03, Water and Sanitation in shelters, overall vulnerability score is 9.59 out of 10. So, it can be said highly vulnerable in this context. Ward no. 03,04 and 09 was found the most vulnerable wards among the 9 wards of the study area in this context. The vulnerability score of these wards for PC03 is 10. Ward no. 06,07,08 was found the least vulnerable ward among the 9 wards of the study area in this context. The vulnerability score of these wards for PC03 is 8.74. For principal component 04, Disaster management practices, overall vulnerability score is 2.95 out of 10. So, it can be said less vulnerable in this context. Ward no. 09 was found the most vulnerable ward among the 9 wards of the study area in this context. The vulnerability score of ward no. 9 for PC04 is 3.7. Ward no. 02 was found the least vulnerable ward among the 9 wards of the study area in this context. The vulnerability score of ward no. 4 for PC04 is 1.91. For principal component 05, Quality of the HH, overall vulnerability score is 4.63 out of 9. So, it can be said moderately vulnerable in this context. Ward no. 03 was found the most vulnerable ward among the 9 wards of the study area in this context. The vulnerability score of ward no. 9 for PC05 is 6.97. Ward no. 01 was found the least vulnerable ward among the 9 wards of the study area in this context. The vulnerability score of ward no. 1 for PC05 is 3.5. For principal component 06, Communication facilities, overall vulnerability score is 0.82 out of 8. So, it can be said less vulnerable in this context. Ward no. 02 was found the most vulnerable ward among the 9 wards of the study area in this context. The vulnerability score of ward no. 2 for PC06 is 1.8. Ward no. 09 was found the least vulnerable ward among the 9 wards of the study area in this context. The vulnerability score of ward no. 9 for PC06 is. For principal component 07, Adaptation capacity to cope with hazards, overall vulnerability score is 2.68 out of 8. So, it can be said less vulnerable in this context. Ward no. 02 was found the most vulnerable ward among the 9 wards of the study area in this context. The vulnerability score of ward no. 2 for PC07 is 3.95. Ward no. 05 was found the least vulnerable ward among the 9 wards of the study area in this context. The vulnerability score of ward no. 5 for PC07 is 1.44.

For principal component 08, Sanitation practice, overall vulnerability score is 0.58 out of 6. So, it can be said less vulnerable in this context. Ward no. 08,09 was found the most vulnerable ward among the 9 wards of the study area in this context. The vulnerability score of these wards for PC08 is 1.05. Ward no. 05,06 was found the least vulnerable ward among the 9 wards of the study area in this context. The vulnerability score of ward no. 5 and 6 for PC05 is 0. For principal component 09**, Peoples participation and HH adaptation**, overall vulnerability score is 3.71 out of 6. So, it can be said *moderately* vulnerable in this context. Ward no. 09 was found the most vulnerable ward among the 9 wards of the study area in this context. The vulnerability score of ward no. 9 for PC09 is 4.82. Ward no. 07 was found the least vulnerable ward among the 9 wards of the study area in this context. The vulnerability score of ward no. 7 for PC09 is 2.93. For principal component 10, **Technological and physical facilities**, overall vulnerability score is 3.21 out of 5. So, it can be said *moderately* vulnerable in this context. Ward no. 05 was found the most vulnerable ward among the 9 wards of the study area in this context. The vulnerability score of ward no. 5 for PC10 is 3.72. Ward no. 07 was found the least vulnerable ward among the 9 wards of the study area in this context. The vulnerability score of ward no. 7 for PC10 is 2.89.

Conclusion

From the physical vulnerability index, it is clear that the condition of the disaster or cyclone shelters are not up to the mark and in highly vulnerable condition. The quality of water and sanitation facilities of the cyclone shelters are highly vulnerable. So, for the sustainable development and to make the city of Mongla make resilient this factor should be considered immediately and most importantly. Then there are four principal components which are in moderately vulnerable condition. These are: **Quality of drinking water and fuel**, **Quality of the HH, Peoples participation and HH adaptation** and **Technological and physical facilities**. So, after enhancing the quality of the cyclone shelters concern should be shown towards these components for sustainable development of the city.

References

Adger, W. N. (2000). Social and ecological resilience: are they related? *Progress in human geography*, 24**,** 347-364.

Hewitt, K. (1983). The idea of calamity in a technocratic age. In: Hewitt, K. (Ed.), Interpretations of Calamity from the Viewpoint of Human Ecology. Allen and Unwin, Boston, pp. 3–32.

Blaikie, P., Cannon, T., Davis, I., Wisner, B. (1994). At Risk: Natural Hazards, People’s Vulnerability and Disasters. Routledge, London.

Smith, K. (1996). Environmental Hazards: Assessing Risk and Reducing Disaster, Second ed. Routledge, London.

Appendix

Table 1. Parameters and variables comprising for Physical Vulnerability Index (PVI) developed for Mongla Port Pourashava

Parameters	Sl.	Variables	Definitions
P1: Household structures	Q.1	Quality of dwelling unit	Percentage of household having poor condition or worse than that of dwelling unit
	Q.2	Homestead area	Percentage of household having homestead area of less than 2 katha (3.30 decimal)
	Q.3	Plinth height	Percentage of household having plinth height of less than 1 feet
	Q.4	HHs have opportunity to produce vegetation/develop greeneries	Percentage of HHs do not have opportunity to produce vegetation
	Q.5	HHs waste management practices	Percentage of HHs are not connected with municipal waste collection system
	Q.6	HHs ownership of household physical assets	Percentage of HHs do not have any of the following assets (TV, radio, cellphone)
P2: Road and	Q.7	Type of access road	Percentage of household having mud access road
	Q.8	Width of access road	Percentage of household having access road of less than 5 feet

communications	Q.9	Telecommunication network at the emergency periods	Percentage of household getting no telecommunication network at the emergency period
P3: Water and sanitation	Q.10	Quality of drinking water	Percentage of household having drinking water from pond
	Q.11	Existing sanitation facilities (types)	Percentage of household not using sanitary latrine
	Q.12	Access to toilet for women and children	Percentage of household having poor or worse than that of access to toilet for women and children
	Q.13	Drinking water storage in the HHs	Percentage of households do not have any storage
P4: Fuel and Electrifications	Q.14	Fuel used in the HHs	Percentage of HHs have unsustainable fuel
	Q.15	Fuel storing capacity	Percentage of household having storing capacity of less than 10 kg or liter of fuel
	Q.16	Available sources of fuel during disaster	Percentage of household not having available sources of fuel during disaster
	Q.17	Alternative options of electrification (solar/Generator)	Percentage of household not having alternative options of electrification
	Q.18	Road communication system from house to shelter	Percentage of household having poor or worse than that of road communication system from house to shelter
	Q.19	Water facilities in shelter	Percentage of household having poor or worse than that of water facilities in the shelter
	Q.20	Sanitation facilities in shelter	Percentage of household having poor or worse than that of sanitation facilities in the shelter
P5: Physical Adaptation strategies	Q.21	Alternative cooling facilities	Percentage of households have no alternative cooling facilities
	Q.22	Housing Improvement to cope with hazards	Percentage of household did not improved house to cope with hazards
	Q.23	Increased Plinth Height	Percentage of household did not increase plinth height
	Q.24	Water from municipal climate proofing water supply system	Percentage of HHs did not have water connection in their house
	Q.25	Local government consultation with citizens	Percentage of household which are not engaged with local government consultation
	Q.26	Pourashava reflects the interests of political parties	Percentage of household which thinks that Pourashava reflects the interest of political parties
	Q.27	Fire service and civil defense	Percentage of HHs have dissatisfaction about services provided by fire service and civil defense during emergency
	Q.28	Acknowledged about risk of climate change and climate extreme	Percentage of household which are not acknowledged about risk of climate change and climate extreme

Table 2. Principal components and weightages

Serial No.	**Major Vulnerability**	**Variables**	**Total Initial eigen values**	**Weightage for principal component**	**Weightage for variables**
Major Component 01	Pourashava, community and household response to the hazards	Fire service and civil defense	3.881	20.03	5.01
		Water from municipal climate proofing water supply system			
		Pourashava reflects the interests of political parties			

		HHs waste management practices			
Major Component 02	Quality of drinking water and fuel	Quality of drinking water	3.444	17.77	5.92
		Fuel used in the HHs			
		Available sources of fuel during disaster			
Major Component 03	Water and Sanitation in shelters	Water facilities in shelter	2.032	10.49	5.24
		Sanitation facilities in shelter			
Major Component 04	Disaster management practices	Knowledge about risk of climate change and climate extreme	1.934	9.98	3.33
		HHs have opportunity to produce vegetation/develop greeneries			
		Drinking water storage in the HHs			
Major Component 05	Quality of the HH	Quality of dwelling unit	1.718	8.87	2.22
		Plinth height			
		Homestead area			
		Alternative cooling facilities			
Major Component 06	Communication facilities	Type of access road	1.629	8.41	4.20
		Width of access road			
Major Component 07	Adaptation capacity to cope with hazards	Housing Improvement to cope with hazards	1.457	7.52	2.51
		Road communication system from house to shelter			
		Fuel storing capacity at the time of hazard			
Major Component 08	Sanitation practice	Existing sanitation facilities (types)	1.225	6.32	3.16
		Access to toilet for women and children			
Major Component 09	Peoples participation and HH adaptation	Local government consultation with citizens	1.049	5.41	2.71
		Increased Plinth Height			
Major Component 10	Technological and physical facilities	Alternative options of electrification (solar/Generator)	1.010	5.21	1.74
		Telecommunication network at the emergency periods			
		HHs ownership of household physical assets			

RISK ASSESMENT DUE TO STORM SURGE IN POLDER 70 OF BANGLADESH

Md. Sajidul Hossain[1], Dr. K. M. Ahtesham Hossain Raju[2]

ABSTRACT

Bangladesh is one of the most cyclone prone areas in the world which is bounded on the south by the Bay of Bengal. The coastal area in Bangladesh is 710 km long which is highly susceptible to cyclone. Storm surge associated with the cyclone cause a huge damage to life, property and infrastructure. To protect the vulnerable area from damage, 139 polders are constructed in the coastal zone. This study focused on polder 70 located in Maheshkhali upazila of Cox's Bazar district. The generation of risk map is necessary for the future planning of development works as well as to identify vulnerable areas where protection is necessary. Commonly, the risk map is generated with co-ordination of inundation map and vulnerability map. In the present study, inundation map is generated considering flooding depth of 6 m. The inundation depth is considered as hazard index. The study area has been divided into 5 zones based on fishnet grid size of 4.5km x 4.5 km using ArcGIS. The zones are assigned vulnerability index based on very high, high, medium, low and very low density of different features like social institutions, roads, cyclone shelters, etc. The risk index is calculated by multiplying hazard index with vulnerability index. Finally the risk map for Polder 70 is generated showing different intensity of risk. The risk map provides information on area of respective zones exposed to different risk level.

Introduction

Bangladesh is a land of rivers, canals, coast and islands. Because of its repeated cycle of floods, cyclones, and storm surges; Bangladesh is one of the most disaster prone areas of the world. It meets Bay of Bengal at the southern end of the country. During the time of 19th and 20th century, Bangladesh has been hit by about 60 severe cyclones mostly accompanied by storm surges (Hossain 2018). The coastal zone of Bangladesh is vulnerable to cyclonic storm surge floods because of its location in the path of tropical cyclones, wide and shallow continental shelf and the funneling shape of the coast (Flierl and Robinson, 1972).

Storm surges are oscillations of the water level in a coastal or inland water body in periods ranging from a few minutes to a few days, resulting from atmospheric forces in the weather system. A storm surge is partly caused by pressure differences within a cyclonic storm and partly by high winds acting directly on the water. This results in a mass of water, a huge wave, moving at the same speed as the cyclone.

Polder 70 is situated in the Maheshkhali Upazilla of Cox's Bazar district. A number of cyclone tracks passed around the polder no.70 (Ahmed 2018). This is why polder No.70 is chosen for risk assessment study. The objectives of the present study area selected with a view to determine the extent of damages caused by storm surges and cyclones in the island and to recommend further actions to safeguard people and assets.

Methodology

The digital elevation map of the study area is collected from USGS (https://earthexplorer.usgs.gov/). The study area has been divided into 5 zones namely, A, B, C, D and E (Figure 1) based on fishnet grid size of 4.5 km x 4.5 km using ArcGIS (Hossain 2018). It is assumed that the polder is breached after the storm surge. The maximum

inundation is found to be 6 m in Maheshkhali Upazilla (IWM, 2009). Here inundation map for a depth of 6m has been generated by creating 6m of constant raster from Mean Sea Level (Figure 3). In this study the inundation depth is considered as Hazard Index which is followed in Dinh et al. (2012) and Tingsanchali and Karim (2005). The Hazard Index is assigned a full number starting from 0 to 6 based on maximum inundation depth of 6m. In this study the selected features are: social institutions, roads, cyclone shelters, agricultural land and water bodies (Figure 2). Based on these features, vulnerability is assessed. Each of the zones is given a value named as Vulnerability Index which is assumed to be 1 for very high density, 0.8 for high density,

[1]*Undergraduate Student, Department of Water Resources Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.*
[2]*Assistant Professor, Department of Water Resources Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.*
Email of Corresponding Author - sajidulhossain15@gmail.com

0.6 for medium density, 0.4 for low density and 0.2 for very low density (Dinh et al., 2012). Respective zone is assigned Vulnerability Index based on the density of selected five features as shown in Table 1. Therefore, the Risk Index may be calculated as follows:

$$\text{Risk Index} = \text{Hazard Index} * \text{Vulnerability Index} \quad (1)$$

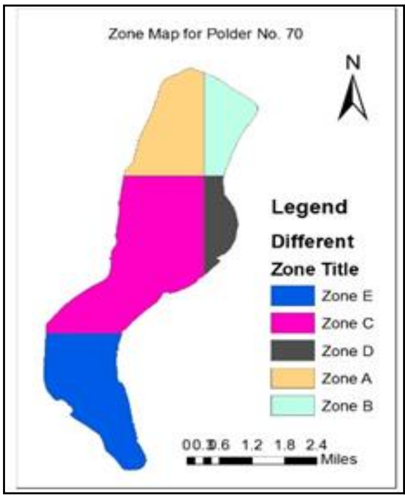


Figure 1. Inundation Map for Polder No.70

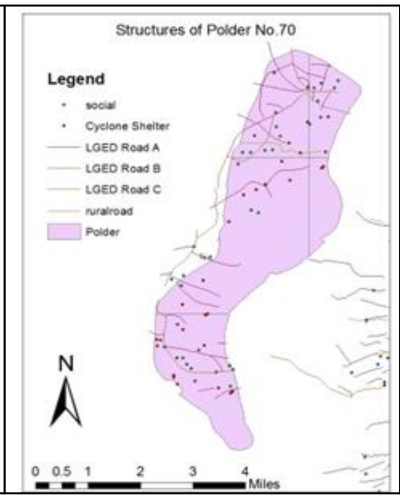


Figure 2. Structures of Polder No.70

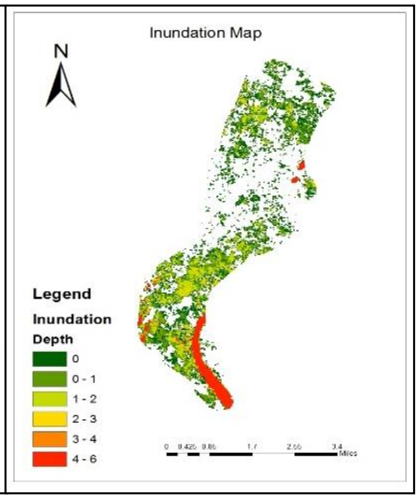


Figure 3. Inundation Map of Polder No. 70

Table 1. Vulnerability Index of different zones

	Zone A	**Zone B**	**Zone C**	**Zone D**	**Zone E**
Social Institutions	0.8	0.6	0.4	0.2	1.0
Roads	1.0	0.6	0.4	0.2	0.8
Cyclone Shelters	0.6	0.2	0.8	0.4	1.0
Agricultural Fields	0.2	0.6	1.0	0.4	0.8
Water bodies	0.4	0.2	0.8	1.0	0.6

Results and Discussions

Figure 3 depicts the inundation scenario indicating the southern part of polder 70 to be mostly affected by the flood due to storm surge. However, it is decided that the flood inundation depth will represent the hazard index. In order to determine risk index, the hazard index (inundation depth) for each cell in a zone is multiplied by the average of vulnerability index for respective zone as mentioned in Table 1. In this way the risk map for each zone is produced as shown in Figure 4.

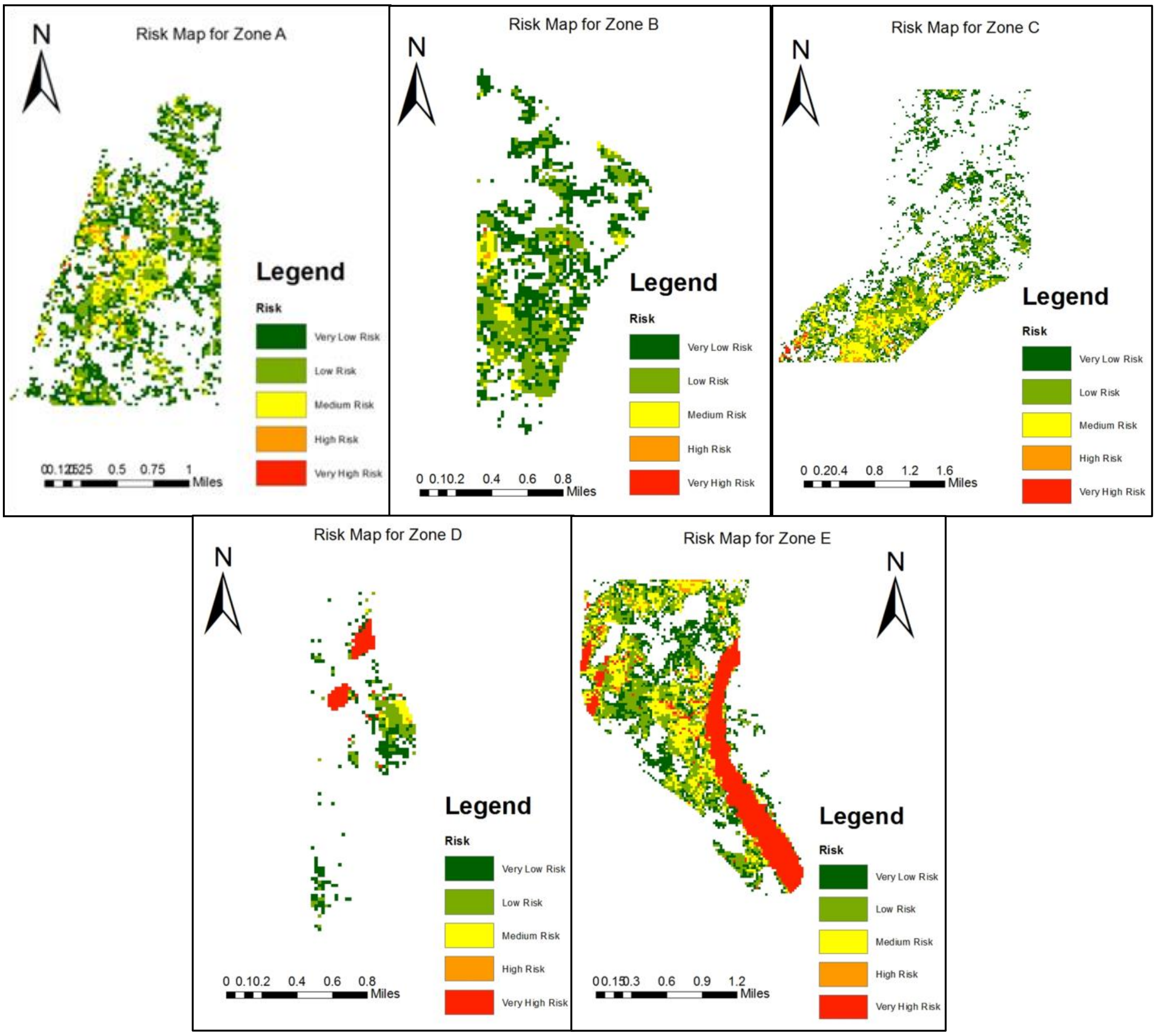


Figure 4. Risk Map for zone A, B, C, D and E.

Table 2. Percentage of inundated area of respective zone exposed to different risk level

	Very Low Risk	Low Risk	Medium Risk	High Risk	Very High Risk
Zone A	23.30%	41.30%	26%	9.10%	0.30%
Zone B	25.70%	45.70%	24.10%	4.30%	0.20%
Zone C	20%	37.80%	28.90%	12.60%	0.70%
Zone D	22.80%	36.30%	17%	8%	15.90%
Zone E	14%	31%	28%	12%	15%

From the risk map developed, it can be seen that zone A, B and C is in low to medium risk. Zone D has some medium to very high risk portion. On the other hand, most of the areas of zone E is located at very high risk zones. The white portions of the map have larger elevation than 6 m and this indicates those areas are located at very low risk zones because those areas are not inundated during flood with 6 m depth. Table 2 shows variation of risk intensity over a particular zone. It gives the impression that each of Zone D and Zone E has 15% area that lies within very high risk level. It is observed that Zone A and Zone B has very close similarity in the risk level.

Conclusion

On the basis of the foregoing results and discussions, few findings and conclusions can be drawn. South-Eastern part of Polder no.70 is located in a high risk coastal zone and special care should be taken during the threat of flooding. The central part (zone C) is relatively of higher elevation and most of its area are exposed to low risk level. Within the total inundated area of polder it is found that around 38% area lies within low risk level, 25% area lies within medium risk level, 21% area lies within very low risk level and 16% area lies within high to very high risk level. It is hoped that this information may be of use for planning future development of infrastructures, to take measures/precautions to mitigate adverse effects at vulnerable areas. However, there are few scopes of improvement for future study, e.g. use of higher resolution DEM, better inundation maps, considering more features, etc. for the generation of comprehensive vulnerability maps and risk maps.

References

Abdullah, and Hoque, M.M. (1997) “Storm surge flooding in Chittagong city and associated risks, in Destructive water: water caused Natural Disasters, their abatement and control”, IFCDR, BUET, Dhaka, Bangladesh.

Ahmed, L. M. (2018). “Start Disaster Summary Sheet: Tropical Storm/ Cyclone”, http://www.nahab.net/wp-content/uploads/2018/06/180409-Start-Fund-Tropical-Storm-Cyclone-Disaster-Summary-Sheet.pdf

Dinh, Q., Balica, S., Popescu, I., and Jonoski. (2012)“Climate change impact on flood hazard, vulnerability and risk of the Long Xuyen Quadrangle in the Mekong Delta”, *International Journal of River Basin Management*, 10, 103-120.

Flierl, G.R., and Robinson, A.R. (1972). ‘‘Deadly surges in the Bay of Bengal”. *Dynamic and storm tide tables*. Nature, 239,213-215.

Hossain, M. S. (2018) “Assessment of Risk Due To Storm Surges by Using ArcGIS in Polder No.70 in Bangladesh”, *B.Sc. Thesis*, Department of Water Resources Engineering, BUET, Dhaka, Bangladesh.

IWM (2009). Institute of Water Modelling *Newsletter No. 38*, http://www.iwmbd.org/iwmwebsite/publication/n-ewsletter/pdf/newsletter38.pdf

Tingsanchali, T. and Karim, M.F. (2005) “Flood hazard and risk analysis in the southwest region of Bangladesh”,*Hydrological Processes*, 19 (10), 2055–2069.

COMPARISON BETWEEN DIRECTIONAL DISTRIBUTION OF OBSERVED AND FORECASTED TRAJECTORIES OF HURRICANE IN NORTH ATLANTIC BASIN

M.S.Rahman[1],[2], T.T. Isaba[2] and A.M.Riyadh[3]

ABSTRACT

Tropical cyclone in North Atlantic basin is one of the major natural hazard in this area. The forecast accuracy of tropical cyclone is important to reduce damage and loss. This paper examines the directional distribution of forecasted and observed trajectories of hurricanes between 2008 and 2015 in North Atlantic Basin. The parameters of directional distribution (standard deviational ellipse) of trajectory are tested using two sample mean paired test to conclude the hypothesis. The Pearson correlation coefficient also applied to find the strength and direction of the relationship between observed trajectory and forecasted trajectory. There is no significant difference between directional distribution parameters of observed and forecasted trajectories. The linear correlation is very strong between observed and forecasted mean center and the correlation is moderate for other parameters.

Introduction

Tropical cyclones are one of the most destructive disasters and cause great loss of lives and property each year throughout subtropical regions of the world (Mu et al., 2009). Many disaster such as storm surge, coastal flooding and high wind followed by tropical cyclone (Nakamura et al., 2009). The risk of landfall of tropical cyclone depends on its trajectories (Camargo et al., 2007). Given the human lives and economic factors involved, forecast and warning system is crucial. A missed forecast can lead to the devastating damage and false warning may decrease public confidence on forecasting system. Many tropical cyclones observed in North Atlantic Basin in every year. It is important to analyze the performance of forecast trajectories. Analysis on past events always helpful for the proration of the future events (Rahman and Kausel, 2012). This study examines the relationship between forecasted track and observed track of hurricanes using spatial description. This study assuming that there is no relation between forecasted trajectory and observed trajectory, in other word, they are different. Therefore, the null hypothesis is set as there is no difference between observed and forecasted trajectory. The parameters of directional distribution (standard deviational ellipse) of trajectory are tested using two sample mean paired test to conclude the hypothesis. The Pearson correlation coefficient also applied to find the strength and direction of the relationship between observed trajectory and forecasted trajectory.

Data and Methods

Two sets of data, observed trajectory and forecasted trajectory are used for this study. Observed trajectories of hurricanes have been collected from 2nd generation hurricane data (HURDAT2) from the National Hurricane Center (NHC), National Oceanic and Atmospheric Administration (NOAA). Advisory forecast track data have also been collected from National Hurricane Center GIS data archive. In this archive, forecast trajectories are available from 2008 to 2015. Therefore, with the objective to compare the observed trajectory and forecasted trajectory, this study examines 51 hurricanes that formed over the North Atlantic Basin between 2008 and 2015. There are number of forecasted trajectories for each hurricane depending on the time of forecast. This study used forecasted trajectory when a tropical storm become hurricane. Thus, this study used point data (shape file format) of observed and forecasted trajectories of 51 hurricanes. Only spatial location (x,y coordinate) of points have been used for this study. The data sets then be projected using WGS_1984_World_Mercator projection system to convert the unit from degree decimal to meter.

[1] *Center for Spatial Information Science and Systems, George Mason University, USA*
[2] *BUET-Japan Institute of Disaster Prevention and Urban Safety, Bangladesh University of Engineering and Technology, Bangladesh*
[3]*Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology, Dhaka-1000*
Email of Corresponding Author – mrahman25@gmu.edu

There are number of spatial statistics function appropriate for the description of point process. Since the hurricane trajectories are linear in nature, the directional distribution (standard deviational ellipse) has been calculated with first standard deviation for observed and forecasted trajectories of each hurricane. The standard deviational ellipse, which calculates two standard deviations-one along a transformed axis of maximum concentration and one along an axis which is orthogonal to this (Wong and Lee, 2005). The standard deviational ellipse analysis is giving mean center of point observations, two standard distance (major and minor axis of the ellipse) and orientation. The orientation refers to the rotation of major axis from north. According to the description given by the ESRI in ARCGIS 10.3 manual, the standard deviational ellipse is given as

$$SDE_x = \sqrt{\frac{\sum_{i=1}^{n}(x_i-\bar{X})^2}{n}} \quad \text{(I)}$$

$$SDE_y = \sqrt{\frac{\sum_{i=1}^{n}(y_i-\bar{Y})^2}{n}} \quad \text{(II)}$$

Where xi and yi are the coordinates for observed and forecasted position of hurricane in 6hrs and 12hrs interval respectively, {X ̅,(Y,) ̅} represent the mean center of observations and n represent the total number of points.

The rotation angle is calculated as:

$$\tan\theta = \frac{\left(\sum_{i=1}^{n} x_i'^2 - \sum_{i=1}^{n} y_i'^2\right) + \sqrt{\left(\sum_{i=1}^{n} x_i'^2 - \sum_{i=1}^{n} y_i'^2\right)^2 + 4\left(\sum_{i=1}^{n} x_i' y_i'\right)^2}}{2\sum_{i=1}^{n} x_i' y_i'} \quad \text{(II)}$$

Where θ is the angle of rotation, x ́i and y ́i are the deviations of the xy-coordinates from the mean center. The standard deviation from x-axis and y-axis are calculated from the following equations:

$$\text{(V)} \quad \delta_x = \sqrt{\frac{\sum_{i=1}^{n}\left(x_i'\cos\theta - y_i'\sin\theta\right)^2}{n}}$$

$$\delta_y = \sqrt{\frac{\sum_{i=1}^{n}\left(x_i'\sin\theta + y_i'\cos\theta\right)^2}{n}} \quad \text{(VI)}$$

Where δ_x and δ_y deviation along the x axis (x distance) and deviation along the y axis (y distance) respectively.

As the observed trajectory and forecasted trajectory are not independent from each other. Then paired two samples mean difference test is applied on each parameter of standard deviational ellipse. In paired observation, the random variables used the difference in measured on each member of the pair. The paired two samples mean difference test can be expressed as

$$T = \frac{\bar{D}-D_0}{S_d/\sqrt{n}} \quad \text{(VII)}$$

Where(D) ̅is the average difference, S_d standard deviation of the difference in paired parameter and n is the number of observations.

Since all parameters of deviational ellipse are positional indicator, the parameter of observed track can be greater or smaller than parameters of forecasted track. Thus, two tail test is appropriate for the hypothesis test at 5% significance level in this case.

Person's product moment correlation coefficient has also been applied on the parameters of deviational ellipse to determine the strength and direction of the relationship between observed and forecasted trajectories. The Pearson's r is calculated as

$$r = \frac{S_{xy}}{S_x S_y}$$

(VII)

Where r is the Pearson correlation coefficient, Sx represent the variability in forecast parameter, Sy represent the variability in observed parameter and Sxy represent the variability of observed and forecasted parameters.

Result Discussion

There are five parameters of standard deviational ellipse such as two coordinates of mean center, semi major axis, semi minor axis and rotation angle. A parameter of deviational ellipse of observed trajectory and same parameter of forecasted deviational ellipse of a hurricane is considered as a pair for the test statistics. The mean center of observed trajectories is shown by green circle and the red triangle is representing the mean center of forecasted trajectories in figure 1.

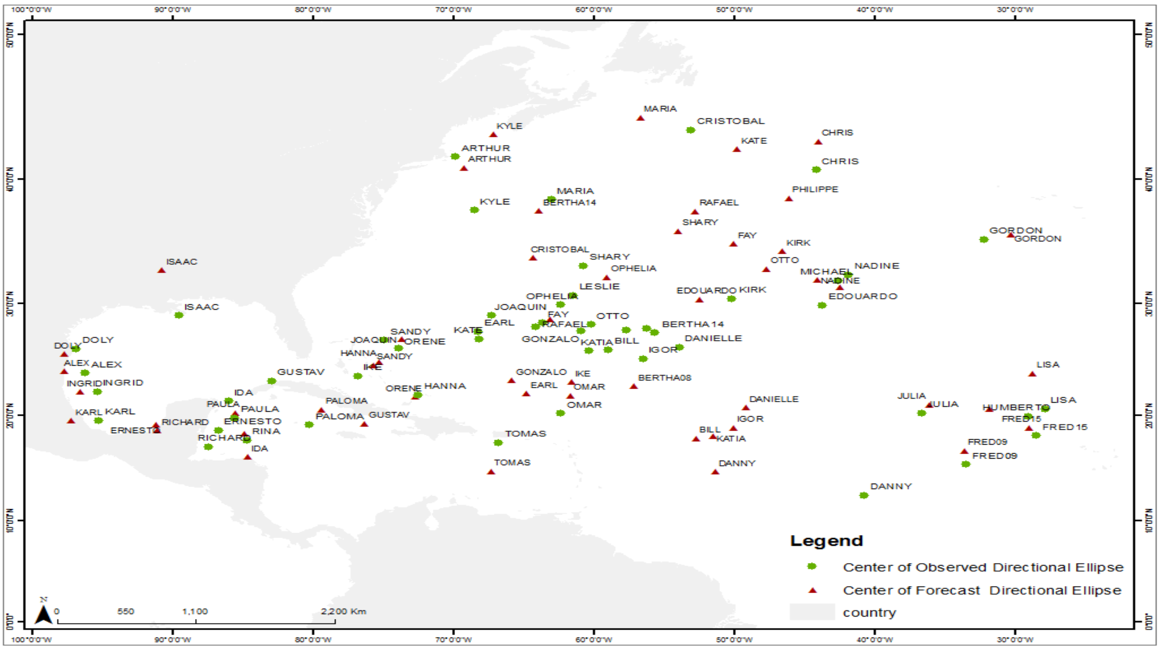


Figure 1. Location of mean center of observed and forecasted trajectories of hurricanes in North Atlantic basin between 2008 and 2015

The figure 1 illustrates that mean center of observed trajectory and forecasted trajectory of some of the hurricanes are close to each other but some are not. The location of mean center directly depends on the length of trajectories. If the life span of hurricane shorter, both the forecasted and observed trajectories are shorter, therefore the mean centers are close to each other. Observed mean center and forecasted mean center of some of the hurricanes are far from each other because of the length of observed track are much longer than its forecasted track and vice versa.

The relation between x-coordinates of observed and forecasted trajectories are tested with paired two mean difference test. The negative values in figure 2 is the directional indicator that North Atlantic basin is located in western hemisphere. The p-value of x-coordinate paired mean different test at 50 degree of freedom is 0.1414 which is greater than the 0.05 (α=5% significance level). Therefore, we cannot reject the null hypothesis at this significance level that there is no difference between x-coordinates of mean center of observed and forecasted trajectories.
There is a strong linear relationship between x-coordinate of mean center of observed and forecasted deviational ellipse. The value of Pearson's correlation is 0.9471 which indicate the strong relation between the variables. The most of the tracks are forwarded to northwest direction, therefore, there are small shift of

mean center from forecast to observed position in x direction. Almost 90% variation of forecasted x-coordinate can be explained by the variation of observed x-coordinate (R2 value of fig: 2).

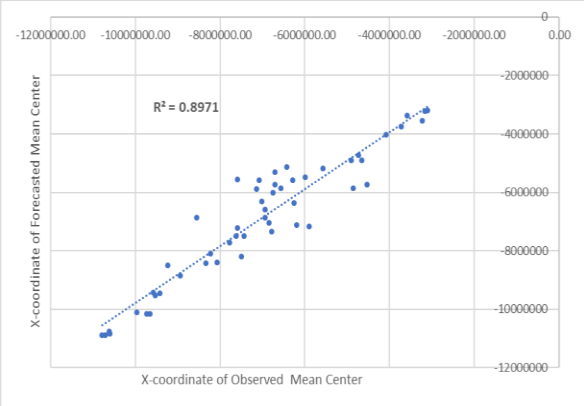


Figure 2. Correlation between X-coordinates of observed and forecasted mean center of hurricane trajectories in North Atlantic basin between 2008 and 2015

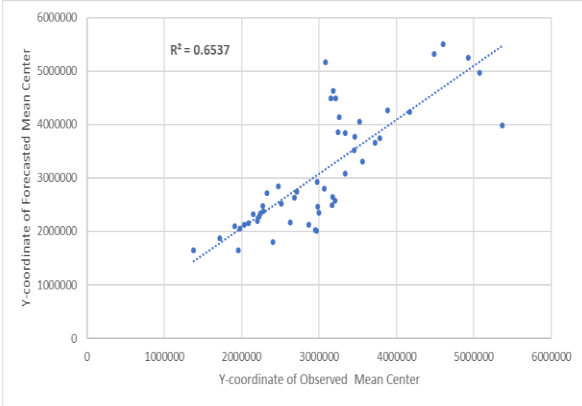


Figure 3. Correlation between Y-coordinates of observed and forecasted mean center of hurricane trajectories in North Atlantic basin between 2008 and 2015

The y-coordinate of mean center of observed and forecasted directional ellipse are also strongly related since the correlation coefficient of this two variables is 0.808. The correlation coefficient of y-coordinates is greater than the correlation coefficient of x-coordinate because the shift of observed mean center from forecasted mean center is larger in vertical direction than horizontal direction. Two factors can contribute to this result one is the direction of hurricanes towards northwest direction. The second is that the track of observed trajectories is longer than the forecasted trajectories. In this case only 63% variation of forecasted trajectories can be explained by the observed trajectories (Fig: 3). The p-value of y-coordinate of mean center in paired mean different test is 0.346 which is greater than 0.05. Therefore, we cannot reject the null hypothesis that there is no difference in y-coordinate of mean center of observed and forecasted deviational ellipse.

The x-distance or semi minor axis of deviational ellipse has been calculated for observed and forecasted trajectories of each hurricane. Figure 4 shows that the semi minor axis of some of the observed tracks are larger than forecasted tracks because of the changing track of hurricane after forecast.
The length of semi minor axis is largely depending on the path of track, if path is near straight the semi minor axis is short but if path is curved semi minor axis is longer.

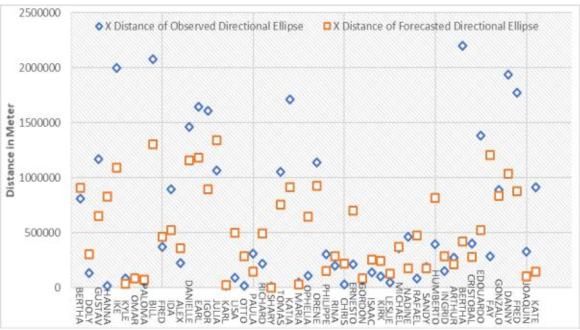


Figure 4. X distance of standard deviational ellipse of observed and forecasted deviational ellipse

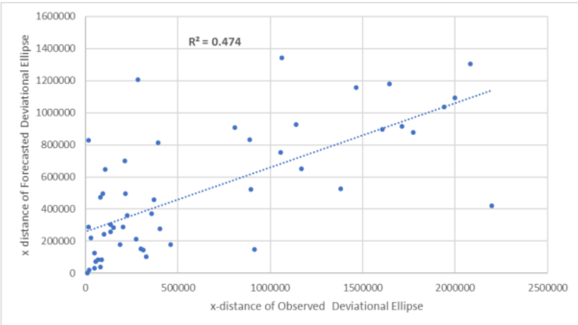


Figure 5. Correlation between semi minor axis (X- Distance) of observed and forecasted deviational ellipse of hurricane trajectories in North Atlantic basin between 2008 and 2015

The semi minor axis of observed and forecasted deviational ellipse is positively correlated however the strength of this correlation is not strong comparing to mean center parameters. The Pearson correlation coefficient is 0.688 where the value of R2 is 0.474 (fig:5) which means only 47% variation in semi minor axis of forecasted deviational ellipse can be explained by the variation in observed variables. The p-value of semi minor axis paired test in a two tail distribution is 0.1135 at 50 degree of freedom. Since this p-value is

greater than the 0.5, therefore, it is difficult to reject the null hypothesis that the semi minor axis of observed deviational ellipse and forecasted deviational ellipse is similar.
The semi major axis or y-distance of deviational ellipse is mostly depending on the length of the track. In most of the cases observed tracks are longer than forecasted tracks. Thus, the semi major axis of observed deviational ellipse is larger than forecasted deviational ellipse of same hurricane. In the following figure it can be seen that some of the hurricane have longer semi major axis in observed deviational ellipse compared to forecasted ellipse and some of the hurricane have opposite. Semi major axis of observed deviational ellipse is larger than forecasted deviational ellipse where observed tack is longer than forecasted track and opposite can be found where cyclone change the direction after forecast. Some of the hurricane has larger major axis in forecasted ellipse than observed ellipse because of the shorter lifespan of these hurricanes such as Maria and Otto than expected.

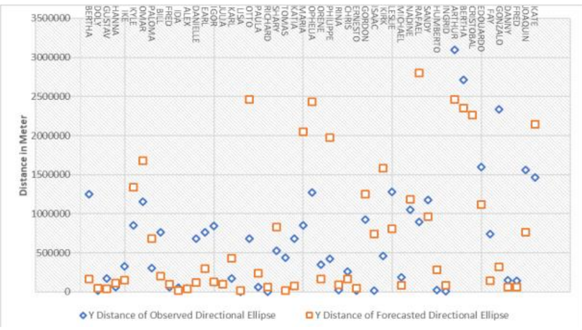


Figure 6. Y-distance of standard deviational ellipse of observed and forecasted trajectories

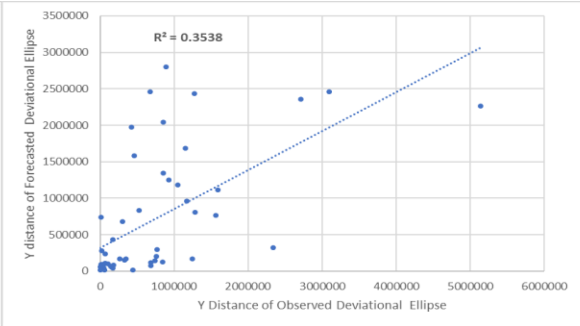


Figure 7. Correlation between semi major axis (Y- Distance) of observed and forecasted deviational ellipse of hurricanes trajectories in North Atlantic basin between 2008 and 2015

The p-value of paired mean different test between semi major axis of observed deviational ellipse and forecasted deviational ellipse is 0.937 which is much larger than the critical p-value 0.05. Therefore, it is difficult to reject the null hypothesis that there is no difference between semi major axis of observed and forecasted deviational ellipse.

The Pearson coefficient is 0.60 between these two variables is indicating moderate correlation of between semi major axis. From the low R2 value, it can be concluded that only 35% of variation in semi major axis of forecasted deviational ellipse can be explained by the variation in semi major axis of observed deviational ellipse. It can be an interesting finding that some of the hurricane has longer major axis in forecasted deviational ellipse than observed one (Fig 7). It is because forecast track was longer and life span of hurricane was shorter than the expected.

Another parameter of deviational ellipse is rotation angle. Rotation angles of all forecasted and observed trajectories have been calculated in degree. Some hurricane has greater rotation angle in forecasted deviational ellipse compared to observed deviational ellipse. This rotation angle also depends on track length and change in track direction.

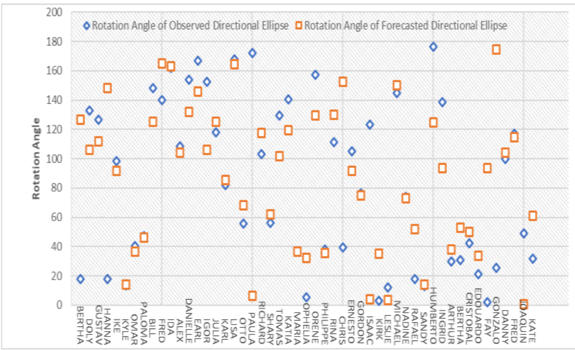


Figure 8. Rotation angle of standard deviational ellipse of observed and forecasted trajectories

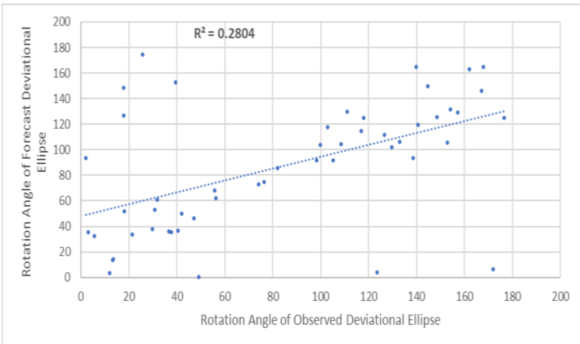


Figure 9. Correlation between rotation angles of observed and forecasted deviational ellipse of hurricane trajectories in North Atlantic basin between 2008 and 2015

The relation between rotation angles of observed deviational ellipse and forecasted deviational ellipse is complex. The Pearson correlation is low compared to other parameters of deviational ellipse. Only 28% of variation in rotation angle of forecasted deviational ellipse can be described by the variation in observed rotation angle (Fig: 9). However, the p-value from the paired mean different test is 0.679 indicating that we cannot reject the null hypothesis that there is no difference between rotation angle of observed and forecasted deviation ellipse.

Conclusion

The accuracy in forecast of tropical cyclone is important to reduce the disaster loss. Five parameters of directional distribution of observed and forecasted track have been studied. Paired mean difference test showing that there is no significant difference between observed track and forecasted track of a hurricane. The life span of the hurricane is the major contributor to determine the relationship between observed and forecasted track. Most of the cases observed directional ellipse is larger than the forecasted directional ellipse. The whole life span is important to analyze this kind of relation. Some of the hurricane changed its path dramatically, in these case relation between the forecast and observed track is difficult to explain. The linear correlation coefficient is high for the mean center but in other parameters of deviational ellipse, this correlation can be found as moderate.

References

Burt, J.E., Barber, G.M., and Rigby, D.L. (2009). Elementary Statistics for Geographers, Third Edition (Guilford Press).

Camargo, S.J., Robertson, A.W., Gaffney, S.J., Smyth, P., and Ghil, M. (2007). Cluster Analysis of Typhoon Tracks. Part I: General Properties. J. Clim. 20, 3635–3653.

Mu, M., Zhou, F., and Wang, H. (2009). A Method for Identifying the Sensitive Areas in Targeted Observations for Tropical Cyclone Prediction: Conditional Nonlinear Optimal Perturbation. Mon. Weather Rev. 137, 1623–1639.

Nakamura, J., Lall, U., Kushnir, Y., and Camargo, S.J. (2009). Classifying North Atlantic Tropical Cyclone Tracks by Mass Moments*. J. Clim. 22, 5481–5494.

Rahman, M.S., and Kausel, T. (2012). Disaster as an Opportunity to Enhance Community Resilience: Lesson Learnt from Chilean Coast. J. Bangladesh Inst. Plan. ISSN 5, 1–11.

Rahman, M. S., Yang, R., & Di, L. (2018). Clustering Indian Ocean Tropical Cyclone Tracks by the Standard Deviational Ellipse. Climate, 6(2), 39.

Wong, D.W.-S., and Lee, J. (2005). Statistical analysis of geographic information with ArcView GIS and ArcGIS (John Wiley & Sons, Inc.).

CYCLONE SHELTERS NEED DEVELOPMENT FOR ENSURING SUSTAINABLE USES: A CASE STUDY IN PATUAKHALI AND BORGUNA DISTRICT

Maruf Billah[1], Tasnim Tarannum[2], Md. Aminul Islam3 and Md. Shahin[4]

ABSTRACT

Bangladesh is one of the most vulnerable countries affected by the climate change and natural disaster. Costal belt is more vulnerable to cyclone, flood and storm surge resulting from climate change. Shelter is a place providing short time safety for disaster victims if hazardous disasters are released into the atmosphere. At present we have to think about cyclone shelter because we are in the front line of the battle against climate change, facing over 200 natural disasters in the last 40 years and most of them are cyclones. A shelter is a simple solution that saves lives during natural disaster like cyclone and storm surge. The major focus of this study is to detect the limitations of the existing and newly constructed cyclone shelters to accommodate and save the community people. To fulfill the goal of this article, field survey with secondary data collection has been done. A questionnaire survey was adopted to accomplish the primary field data while secondary data were collected from academic journals and pertinent offices. This investigation found that the plan, design of shelter, quality of construction, shelter management, capacity, facilities, entrance, exit and policy are not quite capable enough to face upcoming disasters in near future and that's why we should think sumptuously about these shelters. This research finding could be implemented in constructing cyclone shelter to make it more resilient and effective in the coastal belt throughout the world like Bangladesh.

Keywords: Community resilience, Cyclone, Needs for cyclone shelters, Storm surge, Sustainable development

Introduction

In coastal areas, most of the residential houses are pacca, samipacca and wooden frame structures. There are several numbers of houses having a shade of tin and straw and most of them collapse under the action of the cyclones hitting in the coastal areas. Rahman *et al*. (2015) referred that a large part of the country is surrounded by coastal belts like Patuakhali, Kuakata, Mongla, Barguna, Patharghata, Taltoli, Satkhira, Khulna, Cox' Bazaar, Chittagong, Feni, Bhola, Bagerhat, Perojpur, Gopalgonge, Jessore, Barisal, Jhalakathi, Narail, and Laxmipur covering areas of 47201 square kilometer and length of coastline is 710 Km (Haq *et al*. 2012). The average height of coastal belt of Bangladesh from means sea level is 2.5 to 3.5 feet (Rana et al. 2010). Bangladesh being most vulnerable countries to climate change in the world has already been facing several climate change effects such as increasing cyclones, flood frequency probabilities, erosion, inundation, rising water tables, saltwater intrusion and biological effects (Minar *et al*. 2013). Out of 35 million people in 700 kilometers long stretch coastal area of Bangladesh and among them, 7 million people live in the high-risk zone. The coastal area of Bangladesh is naturally susceptible to disaster since climate change asserts a new depressing effect on the lives and agronomy (Sikder and Xiaoying, 2014). A 1m rise in sea level would submerge a full 18 % of the total land area in Bangladesh (Minar *et al*. 2013). It is also predicted that cyclones expect to have 3% to 12% faster wind speeds by the 2020s, rising to 4% to 20% faster by the 2050s in Bangladesh which is the very alarming rate (EM-DAT, 2010).

The Bay of Bengal generates Cyclone for several times of the year. It raises water level from 5 to 12 feet having a great impact on livelihood, residence, livestock, traditional structures and all other structures (Bangladesh Bureau of Statistics, 2011). Water Resources Planning Organization suggested that we should think to save 23% of the total people of Bangladesh who lives in the coastal zone, which was only 8.1 million a century earlier (Mallik and Rahman, 2013). Women are more vulnerable to natural disasters than men in various countries of the world. Traditional home-based responsibilities that limit women's mobility also limit their opportunities for political involvement, education, and access to information, markets, and a myriad of other resources, the lack of which reinforces the cycle of their vulnerability to disaster (Enarson 2000). Following a disaster, it is more likely that women will be victims of domestic and sexual violence; many even avoid using shelters for fear of being sexually assaulted; women, boys and girls are 14 times more likely than

[1]*Graduate student, Instuate of Water and Flood Management, BUET, Dhaka-1000, Bangladesh*
[2]*Lecturer, BUET-Japan Institute of Disaster Prevention & Urban safety, BUET, Dhaka-1000, Bangladesh*
[3]*Lecturer, BUET-Japan Institute of Disaster Prevention & Urban safety, BUET, Dhaka-1000, Bangladesh*
[4]*Assistant Professor, Department of Disaster Resilience and Engineering, PSTU, Dumki-8602, Bangladesh*
Email of Corresponding Author – marufbillah413@gmail.com

men to die during a disaster (Gayen and Raeside, 2010). Community resilience is defined as the ability of communities to withstand and mitigate the stress of a disaster (Chandra et al. 2013). The concept of disaster resilience could be thought of as spanning both pre-event measures that seek to prevent hazard-related damage and losses and post-event strategies designed to cope with and reduce disaster impacts (Cutter et al. 2008). Disaster resilience indicators of a community include the ecological resilience, social resilience, economic resilience, infrastructure resilience, institutional capacity (mitigation) and community competencies (Cutter et al. 2008; Cutter et al. 2010). Resilience is directly associated with the capacity or ability of person, communities, or groups of people to cope with the adverse effects of a hazard impact (Burton 2012). Resilience is the ability of a social system to respond and recover from disasters and includes those inherent conditions that allow the system to absorb impacts and cope with an event, as well as post-event, adaptive processes that help the ability of the social system to reorganize, change, and learn in response to a threat (Cutter et al. 2008). Engineering resiliency for both physical and social systems consist of the properties including robustness, redundancy, resourcefulness and rapidity (Bruneau & Reinhorn 2006).With the aims of protecting the life, and property of the people from the devastating cyclone and flood, the government and non-government organizations, different development partner countries and organizations have constructed a number of shelters called cyclone shelters to increase community resilience to natural disasters.

South and South-eastern parts of the Bangladesh were hit by Tropical Cyclones during the last few years (Sikder and Xiaoying, 2014). Bangladesh faced 150 cyclones from 1960 to 2016 bringing poverty to the community people (Alam and Jabed, 2015). Several types of research have emphasized on the devastating actions of the cyclones in different years and countries. Cyclone SIDR brought storm surge about 20-25ft in Barguna, Patharghata, Nishanbaria and Rangabali (Haq *et al*., 2012).

Community people must have enough residencies to cope with upcoming disasters like cyclone, storm surge and flood. Most of the community people are poor and have no capacity to build costly disaster resilient houses. They are crying for a safe shelter to save themselves from cyclone's attacks. Hence construction of cyclone shelter is one of the resiliency features of disaster resilient community. Few researchers proposed the new model of shelter adapting the community's demand. There is very little research on the sustainable development of cyclone shelter. The main objective of this study to assess the present condition of the existing shelters and quantify the community involvement in every step of construction and management of those shelters.

Methodology

Study Area

Our study area, Patuakhali and Barguna district, stands in front of Bay of Bangle. Patuakhali stands between 22.354º north and 90.3181º east. This is the main entrance to the beach of Kuakata (Daughter of the Sea) famous for watching both sunrise and sunset. The study area covers 3220 km2and 1831.3 km2in Patuakhali and Barguna district (Figure 1). A number of different tribal people live in the district of Patuakhali (Tanner et al. 2007). In the east, it is bounded by Barguna district. On the south, Barguna is bounded by Patuakhali district and the Bay of Bengal. On the western side, it is bounded by Pirojpur and Bagerhat. Important rivers are Payra, Bishkhali, Khakdon, Baleswar.

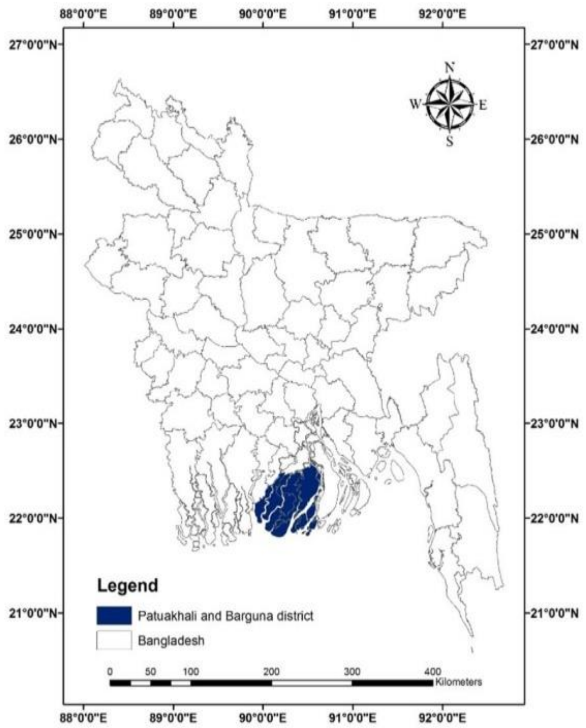


Figure 1. Study area including Barguna and Patuakhali district in Bangladesh.

Some Upazila of Patuakhali and Barguna are in front of Bay of Bengal including Rangabali, patharghta, Taltoli, Kalapara, kuakata (sagor koyanya) Upazila. Cyclone and floods directly hit them coming from the deep sea. So, the people search for safer places during the cyclone. The study areas are two of the most vulnerable districts in the south bangle of Bangladesh. Hence, we selected the study areas based on the severity of cyclones, storm surge and flood.

Primary Data Collection

We have visited several upazila having cyclone shelters named Rangabali, Bauphal, Dashmina, Dumki, Golachipa, Kalapara, Mirjagonj, Patuakhali Sadar, Barguna Sadar, Betagi and Patharghata under Barisal division of Bangladesh. We are presenting some pictures of cyclone shelters collected from the field survey in the study area (Figure 2). Interviews have been taken to know the real situation, use and problems of cyclone shelter in our study area. The local people have shared their experience, ideas and views with us that help us to understand the present situation of the cyclone shelter in the study area. Community people also shared experiences of previous cyclones. In SIDR, they went into the existing cyclone shelters. Their dialogues about that day help us to find out the problems of management and construction of cyclone shelters.

Figure 2. Cyclone shelters in the study area. (a) Represents a shelter having only two rooms in galachipa (b) shelter lacking water supply; (c) shelter having narrow access road; (d) shelter with narrow stair in taltoli.

Secondary Data

Secondary data has been collected from different pre-reviewed journals, articles, newspapers and other secondary sources.

Data Presentation and Analysis

Our research is based on questionnaire survey in the catchment area of cyclone shelter. We have developed a question including plan, design, construction material and quality of construction. We have also investigated the capacity of cyclone shelter, facilities, approach road, stair, ramp, emergency exit, health services etc. We have collected data from the catchment area of 23 cyclone shelter in the field through a questionnaire survey. Here 230 community people were interviewed on the questionnaire including 10 people from each cyclone shelter. They have participated to our questionnaire spontaneously. We have analyzed collected data based on each question. Every information was considered as authentic which was provided by minimum 70% interviewees. Otherwise, data was rejected. After all, we have presented the result in result & discussion section.

Result and Discussion

Due to climate change, the frequency of the cyclone has been raising day by day. As tropical cyclones from the Bay of Bengal accompanied by storm surge are major disasters in Bangladesh, we have to face over 25 major cyclones with storm surge in last 44 years (1960-2013) which were more devastating than others (Figure 4; Figure 5).

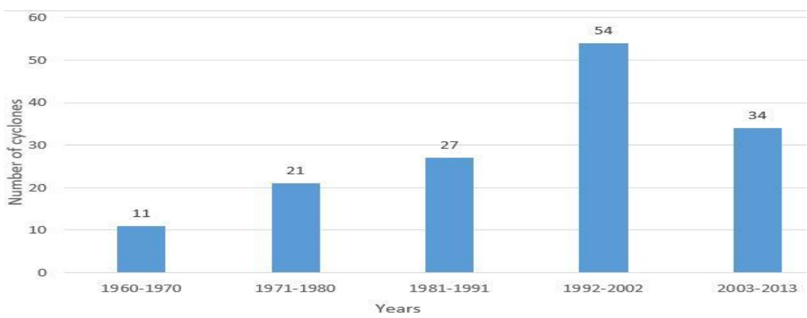


Figure 3. Cyclones strikes in Bangladesh (BBS,EM-DAT, 2010)

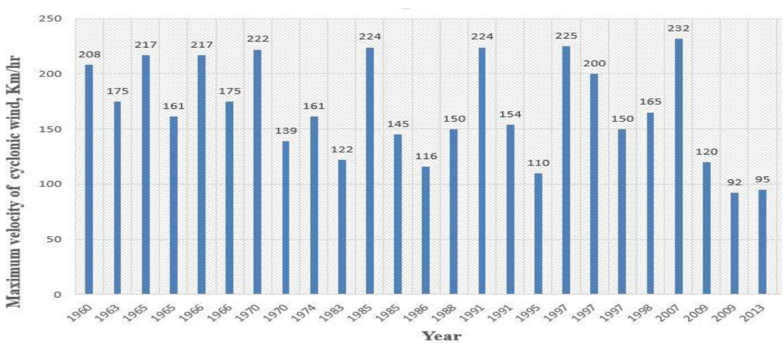


Figure 4. Maximum wind velocity distribution of cyclones (Alam and DomineyHowes, 2015)

According to Saffir–Simpson hurricane wind scale, four cyclones were the tropical storm (64-118 kmph), six were category-1 (119-153 kmph), six were category-2(154-177 kmph), two were category-3 (178-208 kmph), and seven were category-4(209-251 kmph). Cyclone generates most of the year in the Bay of Bengal and raises water level ranging 5 to 12 feet. But some of the cyclone shelters have been put into a devastating situation if the water will rise up to 12 or more. In 2007, storm surge during SIDR was about 20-25ft realized by the affected people in Barguna, Patharghata, Nishanbaria and Rangbali (Haq *et al*. 2012).

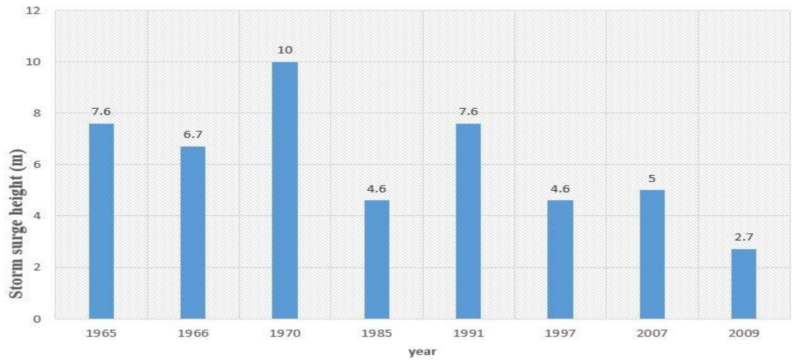


Figure 5. Maximum height of storm surge from 1965-2009 (BBS, 2011).

The cyclone Roanu (80kmph and storm surge height: about 20-25 feet) hit Bangladesh with loss of 23 lives and damaging thousands of houses in Patuakhali, Barguna and Bhola of Bangladesh in May 2016. The distribution of the height of storm surge water is presented in Figure 5.

Although the cyclone shelters always designed and constructed to save lives of the people and livestock. Most of the shelters are providing facilities to save the human being. There are some limitations which need to be solved.

Plan of Cyclone Shelters

Maximum cyclone shelters are being used for multiple purposes like primary school, secondary school, college, market and union parishad. The capacity of shelter varies from 400 to 1600 without separate provision of male and female, also for disabled people. Most of the shelter has capacity varying from 450 to 800. Some of them are capable of accommodating 1200 to 2050 community people. Kinder Not Hilfe (KNH), Tear fund UK & Netherland and Inter serve-Netherland donated Bangladesh to build cyclone shelters supported by HEED Bangladesh. There are three types of a conventional plan of cyclone shelter available in Bangladesh. In the plan-1, there are three rooms for men and other rooms for women. In the plan-2 &3, there are two rooms for men and two for women. But in every case number of rooms is insufficient comparing to the demand of catchment people. Most of the shelters have no water supply and hygienic sanitation system.

Needs for Cyclone Shelters

Devastating cyclones

There is a change in the climatic condition gradually worsens from the last century. Due to the global warming, there is a rise in the temperature which increases the frequency of the cyclone with high intensity. From 1960 to 2013 we have faced 147 cyclones among them 34 has occurred in last 10 years (2003-2013) represented in Figure 3. Intergovernmental Panel on Climate Change (IPCC) has reported in their fourth assessment report that global surface temperature is increased 0.74 ± 0.18 °C during the last 100 years ending in 2005 (Solomon et al, 2007). Alam and Jabed, 2015 found that the average maximum temperature is increasing at a rate of 0.03°C per year but the annual minimum temperature is decreasing at a rate of 0.003°C per year resulting climatic variability in Bangladesh. Increase in temperature will increase the number of the cyclone in every year as the scientist Mc Carthe defines temperature to create cyclone seed is 260C. So the general people search for a safe shelter in case of a cyclone, storm surge, and flood. Cyclone Roanu hit Bangladesh causing the death of 23 people most of them died by falling their houses or tree fall on the houses in May 2016. If they have strong houses to protest the cyclone roanu having velocity 80kmph then they live in the beautiful world. Otherwise, the sufficient number of cyclone shelter encourages the community people to take shelter during hazards with a favorable environment. Hence we can say the number of cyclone shelter should be increased with modern facilities.

Figure 6. Community people of the kackchiramajher char of patharghat sharing experience during cyclone SIDR.

Storm Surges

This is a very common problem during the occurrence of cyclones given in Figure 5. Coastal Climate Resilient Infrastructure Project (CCRIP) of the Government of Bangladesh, in which resource person conducting the training program including community people in the catchment area of the cyclone shelter. Figure 6 shows the conversation among people in Patharghata during the training program. Storm surge also washes out the foundation of the kacha house. Also, wash out the soil under the concrete foundations. This damages the road communication networks which cause disruption of normal movement of the people after disaster. The standing man and women describing the death history of their children and wife during cyclone SIDR in Figure 6. The man said within few moments water enters into his houses and his wife went to take their children but she lost her lives within the houses. A storm surge of cyclone SIDR washes out all types of embankment and road networks of the Patuakhali and Barguna in coastal areas.

Short Comings of Shelters

Awareness

Community people are not conscious of the privilege of the cyclone shelters. They do not know how to use the shelter and when. They are only informed that they should use cyclone shelter during a cyclone. Hence they are not willing to go to shelter leaving the house and other assets. So people should be trained on the use of shelter, time to go to a shelter and return time from a shelter.

Structural design

Cyclone shelters are designed considering the normal rules and regulation for the general building code. The summer temperature is increasing and winter temperature is decreasing in every year in Bangladesh.

Accessibility/Approach Road

Existing shelters is lacking from elevated access road as shown in Figure 2 (c). People in the catchment areas come by walking in the shelter but in the rainy season, most of the connecting roads undergo water. People living in very short distance or the surrounding area of a shelter are highly privileged to get access. But people from more remote places cannot get shelter facilities due to long distance from their home. And it's not easy to move during emergencies for pregnant, old, disables and children. Even people from a short distance cannot make it because of having any direct route towards the shelter. They come by mud road somewhere small narrow bridge which is constructed by using a long log of trees. Tree bridges fail during the cyclone and communication is finally disrupted between the main road and cyclone shelter.

Capacity

Existing cyclone shelter has a very low capacity than the demand of the catchment people. Almost shelter having three or four rooms having a capacity to accommodate about 400 to 1600 people as shown in Figure 2(a). Where, demand of the catchment area is covering 2000 to 2500 people. The almost coastal area more or less in every three villages have one cyclone shelter not only that but also the capacity of those shelter are comparatively very low than the demand.

Provision of Water Supply and Sanitation

Water is the most important element for life, whether to drink, to prepare food and for sanitation. So provision of safe and adequate water is a matter of great importance. However provision of separate latrines for men and women is mandatory to design of a cyclone shelter. But existing cyclone shelters in Bangladesh don't have these facilities. Even the number of latrines and water supply system and its quantity is too much insufficient. In most cases, there is no tube well on the upper floor to supply water during cyclones and flood.

Facilities for Women &Children

In the cyclone shelter there are no facilities for the children but they are the most victims when a disaster occurs. In case of Hurricane Katrina, most of the sufferers were men (50.6%) and women (49.4%) killed; most (60 %) were over the age 65 while half were 75 years or older (Jonkman *et a*l., 2009). A devastating cyclone SIDR hit Bangladesh in 2007 causing 3363 death to human being where mostly was women and children (Haq et al. 2012). Women generally are at greater risk during disasters and their aftermaths because of multiple factors such as poverty, child care, home as workplace, pregnancy; childbirth, body structures and gender-based violence. They need the mental support during a disaster because they are softhearted and not able to cope up with the unwanted situation. If we can keep some space for them in the cyclone shelter so that they can use that place for recreation.

Emergency Health service

Though the cyclone shelters have been constructed for the emergency situation, they should have some health facilities. There should be a separate room with some emergency apparatuses of medical science including tray, hexane, gauge, scissors, bandage, wheelchair, stretchers belt conveyor and ropes etc. But most of the shelters have the lack of these facilities and some have no responsibility or trained person yet to provide the emergency health service.

Independent energy supply

Before, during and after a cyclone, the electricity supply is disrupted by the authorities. So the people are suffering from light, sanitation health service, personal safety, excessively high temperature etc. In the shelter. We need an independent source of energy supply because in a disastrous situation it is quite impossible to supply the electricity in affected areas. Figure 2 shows some cyclone shelter having no energy supply options. The absence of lighting, people of aristocrat family are discouraged to go to shelter regarding their humanitarian safety as discussed.

Narrow entry and Absence of Emergency Exit

Most of the existing cyclone shelters constructed in the coastal belt having narrow stairs capable of carrying highest 2 people during a cyclone. These are now inoperable shelter considering the safety of the people. Figure 2 captures the problem of the narrow stair. These types of design also increase the physical hazard in an emergency situation. Most of the cyclone shelters have low load bearing capacity than its demand and there would arise the risk of collapse when it will be overloaded in a disastrous situation. We don't have any boat landing facilities in these shelters but that will be helpful when the area will be flooded by storm surge. We should consider the salinity problem because of the saline prone environment in the coastal area.

Lack of fire protection facilities

Cyclone shelter accommodates all classes' people. Some of them are habituated with smoking which may lead to fire hazards. Firing may be induced from the cooking or electricity failing. Our cyclone shelters don't have any fire protection system and that may be a great concern issue because when the vulnerable people gather in cyclone shelter then there may be airs the probability to conduct a fire from hurricane, candle or segregate.

Limitation in policy making

Our rural people are not getting much importance yet in the planning of Cyclone shelter because the majority of the people fail to seek out environmentally sustainable cyclone shelter with adequate service facilities with their own effort. General rules and regulation to maintain the material quality and other measurements are followed by the design procedure. Only some ordinary building construction rules that have been maintaining but that is not sufficient to ensure that these shelters are safe for the vulnerable people in the disastrous situation. Sustainable Development Based on Community Perceptions.

Figure 7. Community people sharing the opinion about cyclone shelter maintenance during CCRIP training in chotolobongola in Barguna district.

Expansion of shelter

Maximum existing cyclone shelters are very limited spaces. There is only one floor to accommodate the upcoming people as shown in Figure 2. So extra land should be acquired to expand the existing shelter to accommodate catchment people.

Attachment of Killas

Community people describe the need for skills to accommodate their domestic animals like "we want to get back in stable economic condition after a disaster so we do not want to lose our domestic animals. Our shelter has no floors for cattle, hen, goat, duck etc. if it is provided, we will be more enthusiastic to come into the shelter".

Placing Solar panel

Electricity supply is normally switched off due to the possibility of the damaging connection pool and short circuit that makes a fire during a cyclone. That's why people demand stable power supply. A solar panel may be the simple and best alternative source of power in any building. Now a day's technological advantage has shown that water pump easily works within solar energy. Cyclone shelter may pump water by solar energy has a great advantage on disable people and this water should be provided on washroom.

Figure 8. Participant's observation about the development plan of all cyclone shelter at the end of CCRIP training program in kalmegha of Barguna District.

Facilities for men and women

One of the greatest drawbacks in earlier cyclone shelter is a common arrangement for men and women. There is no separate provision for pregnant guys, girls, old and women. It's impossible that pregnant, sick and disables people stay within common people. Different village people of the cyclone shelter of our study area marked it as a lead problem for maximum women not coming in cyclone shelter during a disaster. They feel unsecured in the common room with all people. There is some example of sexual encroachment in the shelter hence women demand separate accommodation in the cyclone shelters.

Enhancing managing committee and funding

Cyclone shelter managing committee is consisting of illiterate, partially educated and common people of the catchment areas. Peoples of our study area percept that their cyclone shelter managing committee cannot take timely and appropriate decision in a crisis. They demand chain training to increase their awareness and capacity to cope with the situation. If they are properly trained, they will be the effect to manage any crisis and disastrous situation (Figure 8). There are 60000 volunteers in 13 disasters prone district of Bangladesh (Cash et al., 2013). Maximum volunteers are indigent people so when they leave their times for the community people demanding financial help for family support. Such families' only earning person cannot sacrifice for the community day by day. It's true that all people of our country very helpful and they have a responsibility to do for village people. People conclude

Training and Types of equipment for volunteers

For Evacuation purpose, a skilled manpower is very much important. Well trained with strong mentality enhance the possibility to reduce loss otherwise this scenario will be as well as Rana Plaza collapse in Bangladesh. After training, a volunteer must supply proper and enough amount of equipment for any task associated with cyclone shelter management task. Strengthening of disaster preparedness for an effective response in all level requires "search and rescue equipment" in all level of management (Cash *et a*l., 2013).

Conclusion

Bangladesh has been facing devastating cyclone almost in every year such as cyclone SIDR in 2007, AILA in 2009, Mohasen in 2013, Hudhud in 2014, Komen in 2015 and Roanu in 2016. During the half century, Bangladesh has faced some unprecedented cyclonic storm surges that have attracted the whole world's notice which is in 1970, 1991, 1997, 1998, 2007, 2009, 2013, 2015 and 2016. The occurrence of frequent cyclones and storm surges refers the needs for cyclone shelter in the coastal belt of Bangladesh to save lives and make more resilient community against natural disasters. Previously constructed cyclone shelter has only a single floor of 3 or 4 rooms with narrow stairs capable to pass 2 people simultaneously in both directions upward and downward. The shelters lacking from the provision of skills, ramp, sufficient washroom, independent energy supply, separate facilities for men and women, facilities for children, emergency exit, and approach road to a shelter.

Community people realize that the shelter should have sustainability to ensure a safer place in case of a cyclone. When they find the shelter is at risk due to its structural capacity then they are discouraged to go to a shelter. They find that their house is safer than that of cyclone shelter. Hence the community people are suggesting for sustainable development to improve the shelter capacity including construction of alternative stair with ramp, facilities for men& women, placing solar panel, training for managing committee and volunteers, equipment of rescue, expansion of previously existing shelter, construction of secondary washroom, regular training for community people, funding for maintenance and volunteers. The cyclone shelters in Bangladesh have been proven to be less effective; they are currently not adequate, which requires more research and development for more resilience features. This research finding could be implemented in constructing cyclone shelter to make it more resilient and effective in the coastal belt throughout the world like Bangladesh.

References

Alam, E., & Dominey-Howes, D. (2015). A new catalogue of tropical cyclones of the northern Bay of Bengal and the distribution and effects of selected landfalling events in Bangladesh. *International Journal of Climatology, 35(6),* 801-835.

Alam, M. S., & Jabed, M. A. (2015). Cyclones and Causes of Cyclones over the South West Coastal Area of Bangladesh. *Banglavision, 15(1),* 91-104.

Bruneau, M., & Reinhorn, A. (2006, April). Overview of the resilience concept. In *Proceedings of the 8th US national conference on earthquake engineering* (Vol. 2040, pp. 18-22).

Burton, C. G. (2012). The development of metrics for community resilience to natural disasters. *Risk Analysis: An International Journal, 29(5),* 676-698.

Cash, R. A., Halder, S. R., Husain, M., Islam, M. S., Mallick, F. H., May, M. A., ... & Rahman, M. A. (2013). Reducing the health effect of natural hazards in Bangladesh. *The Lancet, 382(9910),* 2094-2103.

Chandra, A., Williams, M., Plough, A., Stayton, A., Wells, K. B., Horta, M., & Tang, J. (2013). Getting actionable about community resilience: The Los Angeles county community disaster resilience project. *American journal of public health, 103(7),* 1181-1189.

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008). A place-based model for understanding community resilience to natural disasters. *Global environmental change, 18(4),* 598-606.

Cutter, S. L., Burton, C. G., & Emrich, C. T. (2010). Disaster resilience indicators for benchmarking baseline conditions. *Journal of Homeland Security and Emergency Management, 7(1).*

Em-dat, C. R. E. D. (2010). The OFDA/CRED international disaster database. *Université catholique*.

Enarson, E. (2000). Gender and natural disasters. ILO Infocus Programme on crisis response and reconstruction. *http://www.awid.org/go.php?list=analysis&prefix=analysis&item=00226*.

Gayen, K., & Raeside, R. (2010). Social networks and contraception practice of women in rural Bangladesh. *Social science & medicine, 71(9),* 1584-1592.

Haq, M. Z., Robbani, M., Ali, M., Hasan, M. M., Hasan, M. M., Uddin, M. J., ... & Karim, M. R. (2012). Damage and management of cyclone Sidr-affected homestead tree plantations: a case study from Patuakhali, Bangladesh. *Natural Hazards, 64(2),* 1305-1322.

Jonkman, S. N., Maaskant, B., Boyd, E., & Levitan, M. L. (2009). Loss of life caused by the flooding of New Orleans after Hurricane Katrina: analysis of the relationship between flood characteristics and mortality. *Risk Analysis: An International Journal, 29(5),* 676-698.

Mallick, F., & Rahman, A. (2013). Cyclone and tornado risk and reduction approaches in Bangladesh. *In Disaster Risk Reduction Approaches in Bangladesh (pp. 91-102). Springer,* Tokyo.

Minar, M. H., Hossain, M. B., & Shamsuddin, M. D. (2013). Climate change and coastal zone of Bangladesh: vulnerability, resilience and adaptability. *Middle-East Journal of Scientific Research, 13(1),* 114-120.

Rahman, M. S., AKMAA, B., Rahman, S., Islam, M. T., Zaman, A. K. M. M., Amin, M. N., ... & Touhiduzzaman, M. (2015). Climatic Hazards and Impacts on Agricultural Practices in Southern Part of Bangladesh. *Journal of Health and Environmental Research, 1(1),* 1-11.

Rana, M. S., Gunasekara, K., Hazarika, M. K., Samarakoon, L., & Siddiquee, M. (2010). Application of remote sensing and GIS for cyclone disaster management in coastal area: A case study at Barguna district, Bangladesh. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science, 38(Part 8),* 122-126.

Saha, S. K., & James, H. (2017). Reasons for non-compliance with cyclone evacuation orders in Bangladesh. *International journal of disaster risk reduction, 21,* 196-204.

Sikder, R., & Xiaoying, J. (2014). Climate change impact and agriculture of Bangladesh. *Journal of Environment and Earth Science, 4(1),* 35-40.

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., ... & Miller, H. L. (2007). IPCC, 2007: Climate change 2007: The physical science basis. *Contribution of Working Group I to the fourth assessment report of the Intergovernmental Panel on Climate Change. SD Solomon (Ed.).*

Statistics, B. B. O. (2011). Statistical Yearbook of Bangladesh. Statistics Division, *Ministry of Planning, Dhaka, Government of the People's Republic of Bangladesh*.

A NEW ELECTRICAL RISK INDEX FOR ELECTRICAL SAFETY ASSESSMENT OF RMG INDUSTRIES IN BANGLADESH

Md. Muntasir Islam[1], Md. Nayeem Ashraf[1] and Mohammed Imamul Hassan Bhuiyan[1]

ABSTRACT

Workplace electrical safety is one of the most prominent issues in industries worldwide with the ready-made garment (RMG) industry of Bangladesh being no exception. Unfortunately, this RMG sector has been fraught with the lack of proper electrical safety. It not only leads to various life-threatening electrical hazards, but also a major cause of fire in the industry. The objective of this paper is to develop an Electrical Risk Index (ERI) for RMG factories to represent the electrical safety condition in this sector. Over 80 randomly chosen inspection reports from ACCORD and ALLIANCE are analyzed to determine the frequency and severity of various electrical safety issues. The ERI is then developed based on the frequency as well as the severity of those findings. The proposed ERI is a 0-5-point scale where 0 indicates a factory with very fragile electrical condition requiring immediate rectification and 5 represents the one with little need for remediation. The value of the ERI is calculated for 60 random factories from the ACCORD, ALLIANCE and Department of Inspection for Factories and Establishments (DIFE). The mean ERI is 2.1 calculated from initial inspection reports indicating a poor electrical safety condition. But from the follow up inspection reports of ACCORD, the ERI is now 4.6 which signifies considerable improvement. Furthermore as stated by DIFE, the progress in remediation of electrical issues is poor whereas according to ALLIANCE, around 90% of the factories have undertaken appropriate measures to improve their condition.

Introduction

The major driving force for foreign exchange earnings in Bangladesh is the readymade garment (RMG) industries. In the past fiscal year, Bangladesh's foreign earning was US $30.61 billion which is more than 80% of the total according to the provisional data of Export Promotion Bureau (EPB) (Dhaka Tribune, 2018). This sector has also played an exigent role in reducing the unemployment problem by giving employment to over 4 million people of which 80% are women. Thus, it is also playing an instrumental role for women empowerment in our society. Again, Workplace safety describes policies and procedures to ensure safety and health of the employees within a workplace. It also involves hazard identification and control according to government standards. A major component of workplace safety in industry is Electrical Safety. Electricity has long been recognized as a serious workplace hazard exposing employees to electric shock, electrocution burns, fires and explosions. Sparks from faulty electrical equipment can serve as a major ignition source for flammable or explosive vapors. As a result, by not securing proper electrical safety measures, the life safety and security of the workers are being jeopardized.

Unsafe electrical acts and conditions are one of the major causes of fire which eventually results in severe property damage and death toll. According to BFSCD, 75 percent fires in Bangladesh originate due to electrical faults (International Labor Organization, 2017). The deadliest factory fire in the history of Bangladesh took place in 24 November 2012, in the Tazreen Fashion factory in the Ashulia district where at least 113 people were confirmed dead and over 172 were injured (The Daily Star, 2018).It was assumed that the major cause of that fire outbreak was electrical short circuit. This scenario is not only evident in Bangladesh but also around the world. According to NFPA research, approximately 16,070 non-home structure fires took place due to electrical failure or malfunction which contributed to ignition that were reported to U.S. fire departments per year (Richard Campbell, 2017). These fires are responsible for approximately 12 civilian deaths, 210 civilian injuries, and $614 million indirect property damage per year.70% of the ignitions were caused by isolated conductors including operators'

bodies leading to spark discharges in Japanese industries which could have easily been prevented if proper awareness about electrical safety was raised among the authority (A Ohsawa, 2011). In 2015/16 there were 303 fire related fatalities and 7661 other non-fatal casualties (Georgina Smaldridge, 2017) and unsafe electrical equipment were one of the primary sources of these accidents.

Risk is a concept that denotes a potential negative impact to an asset or some characteristic of value that may

[1] *Dept. of Electrical and Electronic Engineering, Bangladesh University of Engineering and Technology, Dhaka-1205, Bangladesh.*
muntasirkoushik95@gmail.com

arise from some present process or future event. Risk index exposes aspects of risks that can be subjected to some form of ranking. A risk index gives us a clearer view of what the risk is, what amount of time can be afforded given the severity and probability of the risk event, For example, Fire risk indexing (FRI) (Wadud, Z. and Huda, FY., 2016) is a point system or numerical grading which involves assigning values to some preselected fire safety or fire risk related parameters (or attributes) and then combining them arithmetically to arrive at a single risk index, which numerically summarizes the fire risk of the specific factory (Wadud, Z.; Huda, FY. And Ahmed, NU., 2014). It should be noted that the authors of the above-mentioned papers considered structural and managerial anomalies to calculate the fire risk index and did not focus on electrical safety. On the other hand, electricity being a major hazard itself and also a key factor for causing fire specially in the context of Bangladesh, it is of utmost importance to develop an electrical risk index (ERI) for the RMG industries in Bangladesh. An Electrical Risk Index is a thorough look at the workplace to identify those electrical situations, processes that may cause harm, particularly to people. After identification is made, proper analyzation and evaluation should be made how likely and severe the risk is. When this determination is made, one can decide what measures should be in place to effectively eliminate or control the harm from happening. In a paper on Electrical Safety Risk Assessment (University of Pennsylvania) an electrical safety index is proposed for industries based on the severity and probability of occurrence of various electrical hazard parameters. However, in context of Bangladesh, a limited number of parameters were considered.
The objective of this paper is to represent this electrical safety index incorporating the severity and frequency of the occurrence of different electrical hazard parameters. The severity is represented by using a weightage system in the range of 0-5. Randomly chosen 80 inspection reports were studied to develop the weightage values for different electrical findings and determine their frequency of occurrence. The ERI was calculated for randomly elected 60 RMG factories using the corresponding inspection reports provided by ACCORD (www.bangladeshaccord.org/factories), ALLIANCE (www.bangladeshworkersafety.org/factory) and DIFE (Performed under National Tripartite Plan of Action) (www.dife.gov.bd).

Proposed Method

The proposed index involves the importance and frequency of occurrence of various electrically unsafe conditions in RMG factories. For this purpose, we have analyzed 80 inspection reports from the websites of Accord Bangladesh and Alliance. After analyzing the reports, we have collected around 200 sample findings and we have categorized them on different basis. Firstly, we have categorized the findings on how frequently they occur. We have seen that some common findings like- lack of lighting protection system, dust and lint accumulated on electrical wiring, no presence of single line diagram, inadequate support and protection of cables, deficient circuit breakers, unprotected openings and unsafe earthing (grounding) occur in almost all the factories Accord and Alliance have inspected. We have calculated how many factories face the same problem and thus calculated the percentage value of a specific finding which shows a sample information about the frequency of the finding. Fig 1 represents the most common findings based on the inspection reports of ACCORD and ALLIANCE. These findings have been categorized into three priority levels considering their severity and impact on workers' health and plotted in Figure 2. The severity levels are High, Medium and Low. Higher priority findings can result in electric arc which is sometimes accompanied by blast which is lethal. Besides electric shock can also cause reflex action, paralysis and heart deaths by disrupting heart's electrical system (Cadick, J., Capelli-Schellpfeffer, M. and Neitzel, D., 2006). These type of findings needs immediate recovery. Again, medium priority findings are not lethal but they should be recovered immediately to ensure workplace safety and avoid material losses. For example, by exposing to electrical shock, one can experience pain, tingling, numbness, weakness or difficulty moving a limb. Again, low priority findings also need attention but they are less important in terms of workplace safety.

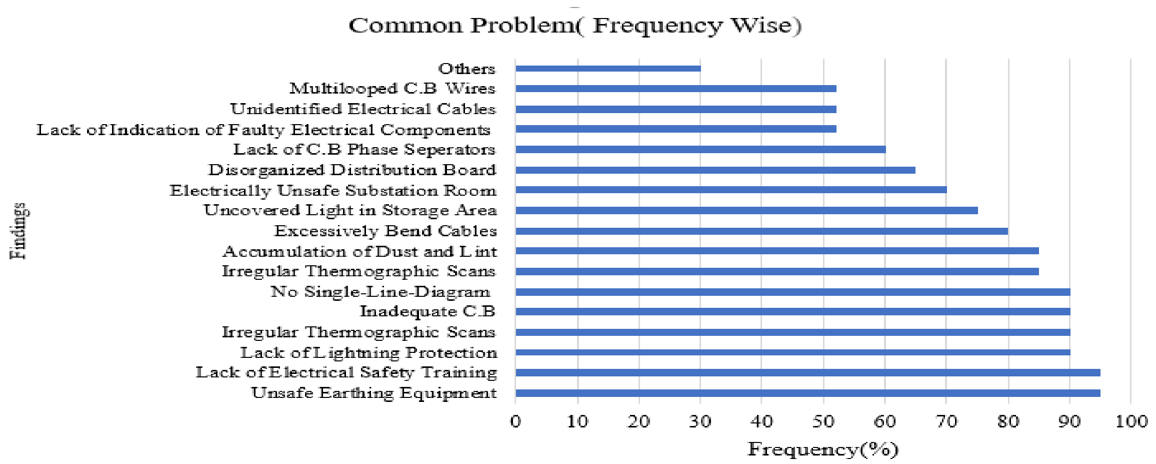


Figure 1: Most common electrical findings (Frequency Wise) according to ACCORD and ALLIANCE.

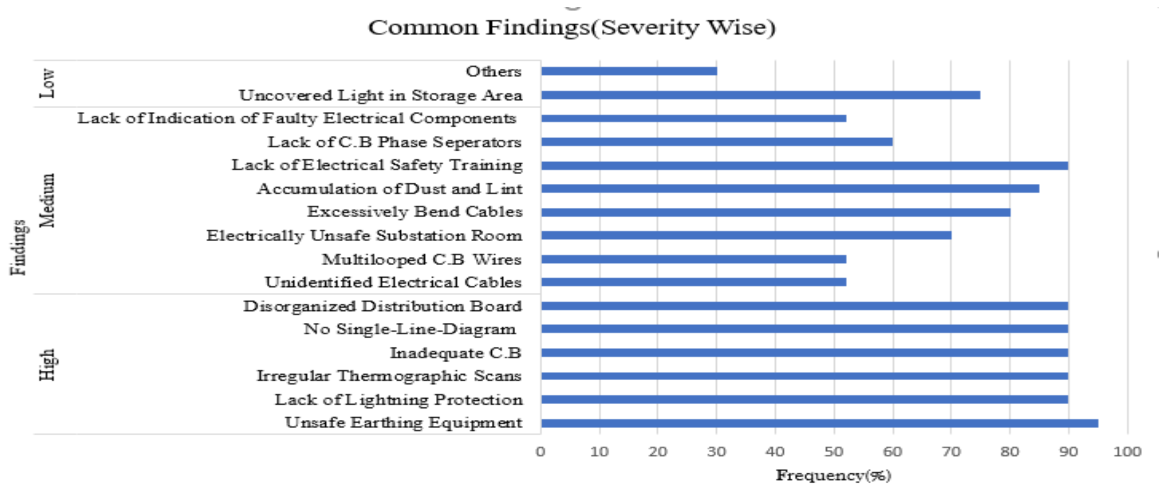


Figure 2: Most common electrical findings (Severity Wise) according to ACCORD and ALLIANCE.

Based on the above analysis, first a categorization of the findings is proposed in table 1. Here 5 represents the finding is in ideal condition and 1 the finding is totally deviated from ideal condition or absent.

Table 1: Proposed categorization of the factories based on their ERI.

Grade (x_i)	**Condition of the finding**	**Deviation from ideal condition**
5	Excellent	Less than 10%
4	Good	From 10% ~ 30%
3	Average	From 31% ~ 60%
2	Poor	From 61% ~ 80%
1	Very Poor	More than 80%

Furthermore, Table 2 lists the various weightages and frequencies against different findings.

Table 2: Weight and Frequency of the Findings (DB = Distribution Boards)

Priority	**Findings**	**Weight (w_i)**	**Frequency (f_i)**
HIGH	Lack of Lightning Protection System	5	40
	Substation room physically not separated	4.9	60
	Unsafe Earthing Equipment	4.7	32
	Metals Connected to Earthing	4.6	44
	Electrical Mats are not provided	4.5	28
	Missing Phase Barrier	4.4	52

	Size of the Generator Room	4.3	4
	Unsolved Hot Spots	4.25	64
	Location of Main Electric Switch Board	4.2	36
	Inadequate Circuit Breakers	4.15	28
	Disorganized Distribution Board	4.1	40
	No Single Line Diagram	4.0	16
MEDIUM	Existence of Electric Overhead Line	3.9	8
	Excessively Bend Cables	3.8	52
	Lack of Cable Support	3.75	48
	Substation Room not Properly Illuminated	3.6	52
	Exposed Electric or Gas Line	3.5	32
	Missing Cable Sockets for Stranded Conductors	3.45	28
	Dedicated Neutral missing in each circuit	3.35	48
	Lack of Proper Identification of Cables and DB	3.3	40
	Accumulation of Dust & Lint	3.25	24
	Lack of Safety Training Program	3.2	48
	Lack of Presence of Alternative Power System	3.1	20
	Uncovered Lights	3.0	36
LOW	Safety Inspection Done Irregularly	2.9	4
	Transformer Analysis not Completed	2.8	36
	Others	Below 2.7	

Based on the analysis described in Table 1 and Table 2, the electrical safety index (ERI) is defined as

$$\text{ERI}=\frac{\int_{i=1}^{n} wi*xi*fi}{\int_{i=1}^{n} wi*fi} \quad (1)$$

where, x_i is a dimensionless score or grade points for findings, w_i the importance of findings, n the number of total findings and f_i the frequency. Furthermore, the following categorization table is proposed in order to classify the RMG factories as per the obtained values of ERIs for them.

Table 3: Categorization of RMG Factories based on the ERI

Grade Point	**Comment**
5	Excellent
4	Good
3	Average
2	Poor
1	Very Poor

In Table 3, grade 1 indicates that the overall condition of the factory is more than 80% deviated from ideal case and the factory needs immediate remediation. Grade 2 indicates that the overall condition of the factory is more than 60% but less than 80% deviated from ideal case. Grade 3 indicates that the overall condition of the factory is more than 30% but less than 60% deviated from ideal case. Grade 4 indicates that the overall condition of the factory is more than 10% but less than 30% deviated from ideal case. Grade 5 indicates that the overall condition of the factory is less than 10% deviated from ideal condition and is in exemplary condition.

Analysis of the Proposed ERI

In this Section, the proposed ERI is calculated for the initial inspection reports of randomly chosen 60 factories under ACCORD, ALLIANCE and DIFE. Figure 3 shows the values of ERI of those factories based on the proposed method.

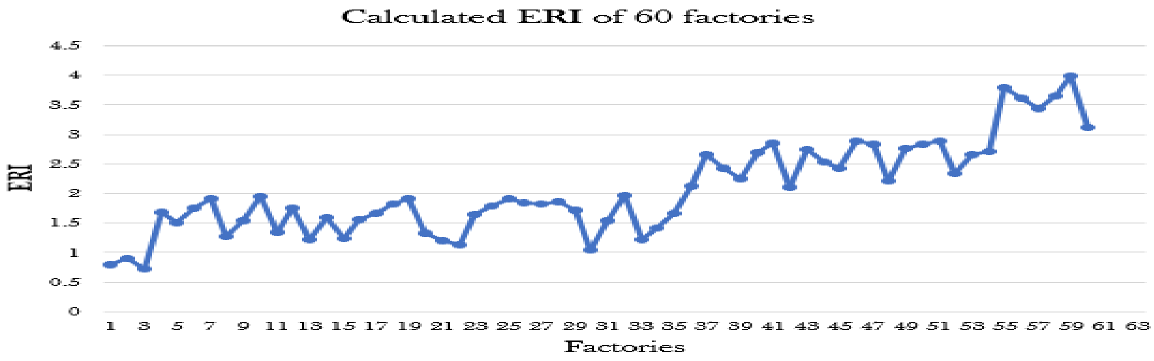


Figure 3: Calculated ERI of randomly chosen RMG factories

In Fig 3, one can observe the distribution of ERI of the 60 RMG factories. One can also see that more than 55% factories have ERI between 1 and 2, about 30% factories between 2 and 3, 10% factories above 3 and 5% factories have ERI below 1. As 55% factories are in a poor condition, they need immediate corrective action plans suggested by ALLIANCE and ACCORD. On the basis of the plot in Fig. 3, the factories are categorized into very poor, poor, average and good classes. Fig 4 shows the various categories the 60 factories are in; 26 factories are inspected by ACCORD, 19 by ALLAINCE and 15 by DIFE. Note that the factories under different initiatives have similar state of electrical safety. It should also be mentioned that the proposed ERI matches with the suggestions of ALLIANCE and ACCORD on the mentioned factories.

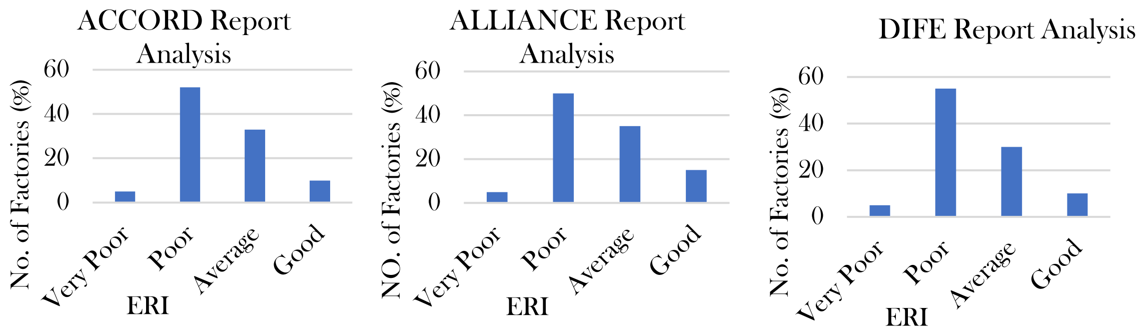


Figure 4: Plots of RMG factory status based on ERI

Almost all the factories which are in a poor or very poor condition, have undertaken corrective action plans in accordance with the suggestions of ACCORD and ALLIANCE. As stated by ACCORD around 84% (ACCORD, 2018) and by ALLIANCE around 90% of the factories that were initially in a poor condition regarding electrical safety, have undertaken appropriate measures to improve their conditions. After analyzing randomly chosen follow up inspection reports from ACCORD database we have found that the mean ERI initially 2.1, is now 4.6. On the other hand, DIFE has stated that only 13% factories have been remediated completely and 52% factories have remediated more than half of their electrical issues. Hence there is still ample scope of improvement as well as the need for the sustainability of the improvement achieved.

Conclusion

A major component of workplace safety in RMG industry is Electrical Safety. Electricity has long been recognized as a serious workplace hazard exposing employees to electric shock, electrocution burns, fires and explosions. In this paper an electrical risk index (ERI) with 0-5 point scale has been proposed to represent the electrical safety condition of the RMG factories. For this purpose, about 80 randomly chosen inspection reports from the repositories of ACCORD and ALLIANCE have been used to determine the appropriate weightage and frequency of occurrence for various electrical conditions. Then the ERI has been calculated for about 60 randomly chosen factories that are under ACCORD, ALLIANCE and DIFE based on their initial inspection reports. A categorization scheme has also been proposed to classify the factories based on their ERI values. It is seen that more than 80% of the factories scores less than 3 and thus belongs to the class with poor electrical safety. However, it has also been mentioned that the situation might have improved due to the initiatives of ACCORD and ALLIANCE. However, it should be kept in mind that a large number of factories under DIFE still needs to do a lot to improve their electrical safety. As for future work, the follow up inspection reports of a larger number of factories from the three initiatives will be studied to calculate their ERI values and classify them with the values in order to reveal the impact of them on improving electrical safety.

Acknowledgments

We thank ACCORD, ALLIANCE and DIFE for providing us the inspection reports on various RMG industries through their website. Any errors remain the responsibility of the authors.

References

ACCORD (2018), *Quarterly Aggregate Report,* 3-18 available in bangladeshaccord.org/progress/

Campbell, R. (2017) *NFPA Research*, *Electrical Fires,* National Fire Protection Association, Quincy, MA,99-103.

Cadick, J.; Capelli-Schellpfeffer, M., and Neitzel, D. (2006), *Electrical Safety Handbook,3rd edition,* McGraw-Hill, United States of America.

DhakaTribune (2018), *RMG exports saw 8.76% growth last fiscal year.*

International Labor Organization (2017), *Towards Improved Fire and Building Safety in Bangladesh,* ILO Country Office for Bangladesh, Dhaka.

Ohsawa, A. (2011) *Journal of Physics: Conference Series 301*, *Statistical analysis of fires and explosions attributed to static electricity over the last 50 years in Japanese industry*, doi:10.1088/1742-6596/301/1/012033, 012033, 1-3.

Smaldridge, G. (2017) *Statistical Bulletin*, *Fire Statistics: England April 2015 to March 2016,* Home Office Statistics, UK, 7-9.

The Daily Star (2018), *Build hospital, dormitory for workers on Tazreen factory land.*

University of Pennsylvania, *Environmental Health and Radiation Safety*, *Electrical Safety Risk Assessment,*1-3[ehrs.upenn.edu/sites/default/files/inlinefiles/Electrical%20Risk%20Assessment.pdf]

Wadud, Z and Huda, FY (2016), *Fire Technology, 53 (2)*, *Fire Safety in the Readymade Garment Sector in Bangladesh: Structural Inadequacy vs. Management Deficiency*, 2-25.

Wadud, Z; Huda, FY and Ahmed, NU, *Fire Technology*, *Assessment of Fire Risk in the Readymade Garment Industry in Dhaka, Bangladesh,* 3-20.

www.bangladeshaccord.org/factories

www.bangladeshworkersafety.org/factory

www.dife.gov.bd

A SIMPLIFIED MECHANISM TO SUPRESS FIRE IN DENSE URBAN AREAS UTILIZING RESIDENTIAL WATER RESERVOIRS

Faisal Bin Iqbal[1], Samiha Haque[2]

ABSTRACT

The narrow streets that run across urban Bangladesh and the greater parts of Dhaka Metropolitan City pose as a threat to emergency services and vehicles during the time of their need. The dimensions of these roads and streets make it difficult for different vehicles responding to emergency situations by obstructing their access to the emergency sites. This in turn, results in further delay of action to mitigate the situation at hand. The frequency of such scenarios is highest when it comes to combating fire in these dense and tight urban areas. This study is solely focused on combating fire in dense urban areas using water from the underground water reservoir stationed underneath residential housing. This will allow fire fighters to tackle the fire without having to bring in heavy machinery and vehicles carrying water. The study also sheds light on the willingness of locals to share their water resources at the time of need and how such resources are more than enough to combat fire in the primary stage and in the shortest of time.

Introduction

Recent development initiatives undertaken by the authorities to develop the fire and civil defense service of Bangladesh has seen the nation's response capabilities to emergency situations drastically improve. With the addition of new vehicles and equipment, the firefighting units of our country have been able to combat many daunting situations and have been able to reduce the damage caused by the fire. However, with the rapid urbanization taking place in the country, the number of dense, congested urban areas is on the rise. This has made roads grow narrower by the day as emergency vehicles are often seen to fail in entering such areas. Thus, we see the need of a self-sufficient water system through which firefighters need not bring in their own heavy water tankers. They will only need to carry their pumps and hoses which can be adjusted in much smaller vehicles. The study talks about a system somewhat similar to that of fire-hydrants used in foreign countries. However, unlike fire-hydrants, the water source mentioned in this paper is not the main water line, rather it is the underground water reservoir located in most of our houses.

Objectives of the study

This study aims to minimize the devastation caused due to fire incidents in dense urban areas by allowing firefighters to ensure rapid response using the underground water reservoirs as potential sources of water in these areas. The provided system will allow servicemen to enter the affected area without any heavy water tanks. Sufficient water can be pumped from the underground sources using a simplified network of pipes and connections, details of which will follow in the latter parts of this study. It is to be noted that the system being used in this research is in no way an alternative to fire hydrants used in foreign countries such as the United States of America. It is however, a system similar to that and has been simplified for the sake of usability. The study was conducted within a short time span and hence, a large-scale survey was not possible. Furthermore, due to certain reasons, a nationwide study as to why this system would be beneficial could not be achieved. The study has been focused around certain areas of Dhaka Metropolitan City and is expected to reflect most areas that fall under the dense category.

Scope and Limitation of the study

Measurements of the roads of some dense urban areas in Dhaka city have been taken for the study. A small scale survey was conducted to see if people were willing enough to share their water resources free of charge during the time of an emergency situation. Further data regarding the dimensions of firefighting vehicles and equipment has been looked into and is presented as per the requirement.

Research methodology

The survey conducted to gather necessary data regarding the opinion of the general people was realised to be insufficient at one point. We then went on to speak directly to different landlords and property owners across dense urban areas which included certain areas of Mohakhali, residential Nakhalpara, FaRMGate,

[1] *Undergraduate, Dept. of Computer Science & Engineering, BRAC University, Dhaka-1205, Bangladesh*
[2] *Undergraduate, Dept. of Computer Science & Engineering, BRAC University, Dhaka-1205, Bangladesh*

Tejkunipara and Shaheenbaag. They were asked about their willingness to share their resources and also about their personal opinions as to why the system would work or fail. Furthermore, we gathered information from related studies conducted in Bangladesh which helped us to understand the firefighting capabilities and equipment which our Fire and Civil Defense unit have. Details about these findings have been discussed later parts of the study.

Setting up the system

In the Dhaka Metropolitan Area, usually one road is seen dividing two lines of buildings or compounds. This study focuses on each of such series of buildings or compounds. From the small scale survey conducted by us on 126 tenants and landlords in Dhaka, it has been found that approximately 30% of buildings have their own underground reservoirs for storing water. The design included in the study consists of a pipe that is to be placed inside the compound or garage of the building that will connect the underground reservoir to an outlet installed into the outer compound walls as shown in Figure 1, where a pipe (D) is linking the outlet (C) directly to the underground water storage tank (E). Each building in every row of housing compounds will have the above mentioned arrangement inside. A connecting pipe will be used to join all the individual housing pipes to each other, that is, to the pipe of the building adjacent to it. The mapping of such an alley with a chain of buildings is displayed in Figure 2. Here, every building has its own outlet and these outlets are connected to other outlets through a connecting pipe that runs along the series of buildings in each row. Hence, the water reservoirs are connected to each other resulting in a huge supply of water.

Improvements made to the design for efficiency

1. There will be two water outlets on one side of every building. This will ensure equal and convenient distance from the front side, left side and right side of each building and thus, firefighters can tackle the fire using shorter fire hose.
2. Through logical mapping of the outlets, every building can have each of its sides face at least one outlet placed either on the opposite side or on its front side as shown in Figure 3 (an extended version of Figure 2). Therefore, the outlets should be placed on the same side for each row of buildings. This will ensure adequate coverage for the buildings and also will require less number of outlets.
3. There will be a valve or tap inside the building/compound to allow and control water flow from their building. This valve is to be closed at all times and should only be opened for emergency situations.

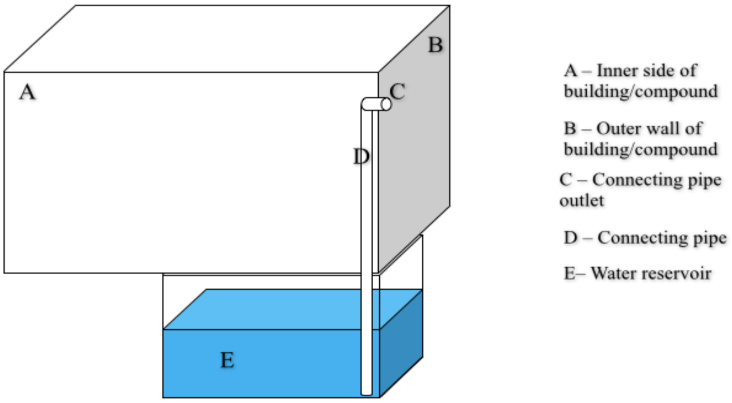


Figure 1. A three-dimensional view of the setup which includes the compound walls as well as the underground water storage.

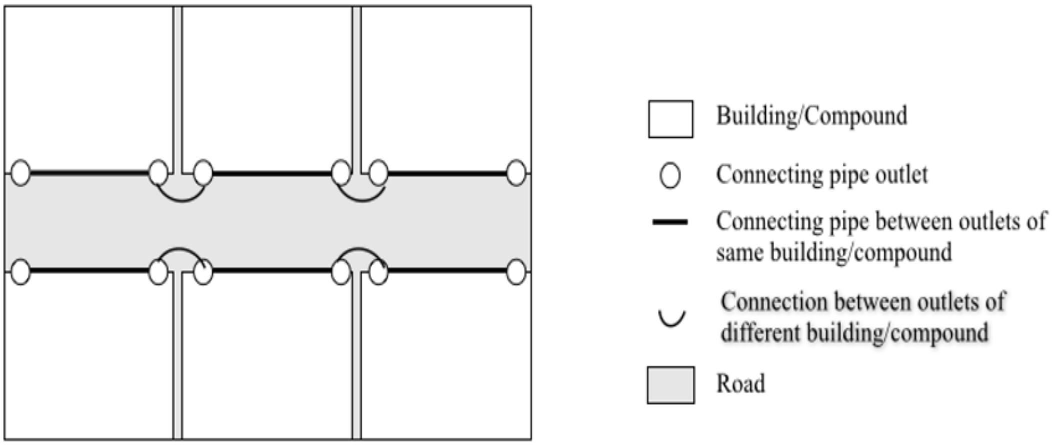


Figure 2. Aerial view of the system in place showing the inter-connectivity between buildings/compounds.

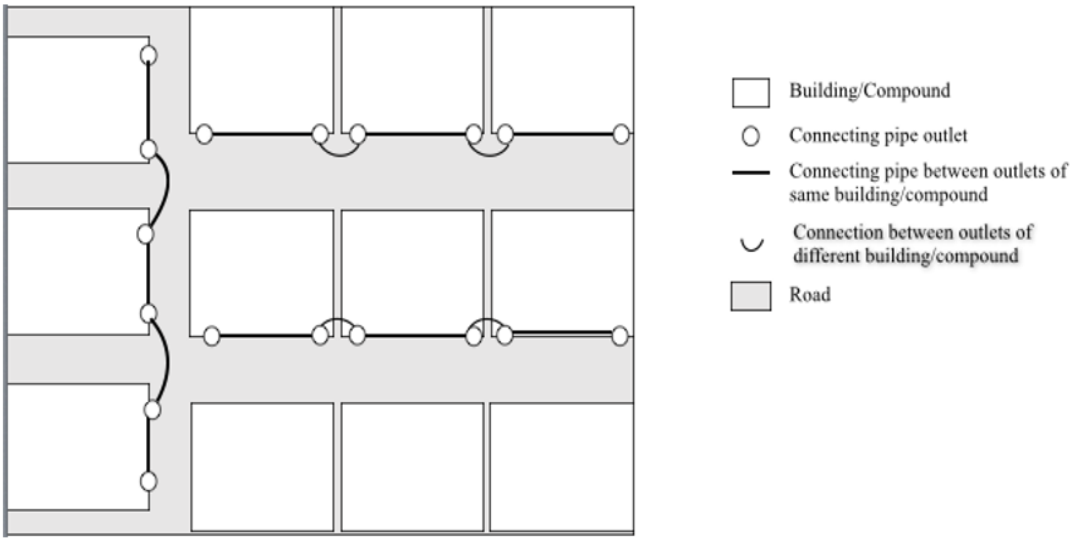


Figure 3. Aerial view of the system in place showing the inter-connectivity between buildings/compound (extended version).

Working procedure

Eliminating the necessity to carry additional water supply, the firefighting units need only to bring their water pump, ladders, safety equipment, tools and hoses. They will then go on to connect their pumps to the water outlets marked as G in figure 4 below. Afterwards, it is all just the matter of dosing off the fire with time. It is to be noted here that the fire incidents that are being focused on are strictly residential fires which are caused due to electric malfunctioning, gas explosions and other residential fire hazards. The resources are inadequate to combat a chemical fire or such other fire accidents.

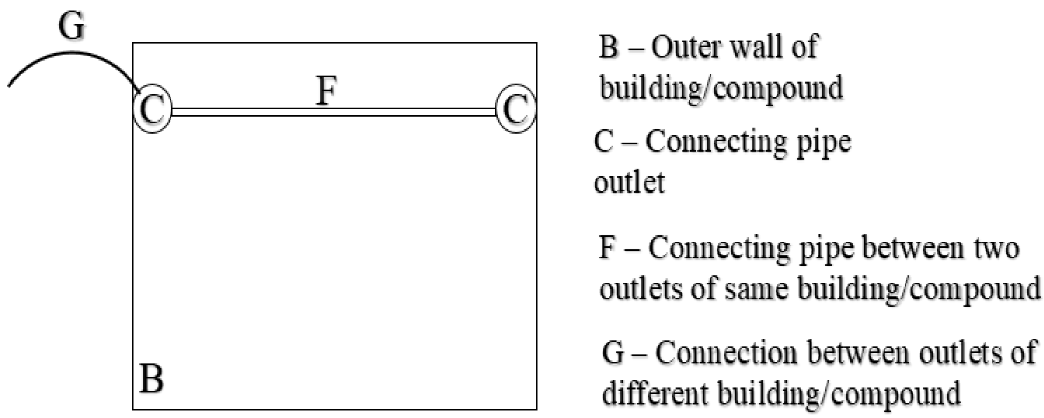


Figure 4. Outer view of the compound/building wall.

Advantages of the system

Compact streets and neighborhoods with road width ranging from 1.5 – 2 m will be highly benefitted with the implementation of such a system. Setting up fire hydrants in such dense areas will make the roads even more congested than they already are. Such a scenario will pose as a threat to normal vehicular movement as well as pedestrian movement. The system mentioned in the study will consume minimal road space which is negligible. Besides, fire trucks over the width of 1.5m will have great difficulty to enter such areas as they will not be able to properly maneuver properly in such tight areas and bends. The underground water reservoirs can hold from 3000 to 7000 liters of water (depending on the dimensions of the house) which is more than what a single fire truck can carry. This, therefore, eliminates the need to carry additional water supply.

Public opinion regarding the system is also to be noted here. They are willing to share their water resources for such emergency situations given that they will only be utilized in emergency disaster related scenarios and not for any other purpose. The general public is also open to receive training in combating emergency situations at basic level.

The result of all this is a comparatively faster response in times of need and a possibility to train locals to combat fire providing them with the right equipment and training.

Why the system will suffice in urban areas

In urban areas, the major causes behind small or large scale fire are electrical or gas explosions. It is to be noted here that urban areas should not contain chemical storage facilities. Even if they do, they should have their own firefighting equipment at ready always. The system described in the paper is clearly not meant to combat chemical hazards and is only sufficient to tackle smaller fires.

Conclusion

Fire accidents take the lives of many citizens every year and damage property worth millions. Despite adequate measures taken by set authorities to counter such incidents, the dense urban areas of our country need to be focused on more. The study is far from perfect but it sets an idea as to how we can proceed with firefighting techniques in near future given the resources we have.

References

Tishi T. R., *A study on frequency of fire incidents and fire fighting capacity in different land use categories of Dhaka metropolitan area*, Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology, 2015. Retrieved from http://lib.buet.ac.bd:8080/xmlui/bitstream/handle/123456789/4518/Full%20Thesis.pdf?sequence=1 on November, 2018.

ANALYZING VULNERABILITY OF A COMMUNITY TO FIRE HAZARD: A CASE STUDY OF CHANDGAON RESIDENTIAL AREA

Nehal A. H.*[1], Hasan M. R.[2] and Islam M. K.[3]

ABSTRACT

A fire hazard is any situation where is a greater than normal risk of harm to people or property due to fire. Greatest loss of life and property in urban areas is caused by fire hazards. Urban fires have most devastating & dangerous impact on communities & residential areas. Unplanned urbanization is mainly behind of intensifying the problem further. To increase the resiliency of a community to natural and man-made hazards, before they become disasters, must first begin with a comprehensive risk and vulnerability assessment. Community vulnerability assessment tool (CVAT) is a useful method to assess vulnerability of a community to any hazard. In this study, the traditional community of Chandgaon Residential Area has been selected to conduct a Community vulnerability assessment. CVAT method has been applied here in several steps. Firstly, a hazard map was created by using six attributes such as transformer and power line, floor area ratio, building material type, accessibility, firefighting scenario and location of risky fire sources in the study area. Every one of them was assigned a value using Analytic Hierarchy Process based on experts' opinions. Then by using Arc GIS, all of the data were processed and maps were prepared. After preparing the hazard map, it was overlaid with each of the maps like, maps of critical facilities, economic activities, etc. Then it was evaluated that how much vulnerable the community was to fire in various aspects from every intersected map. Finally, the overall vulnerability of the community was assessed. After completing the assessment, it was found that vulnerability of the community to fire hazard is low.

Introduction

"A fire hazard is any situation in which there is a greater than normal risk of harm to people or property due to fire" (Raja, 2007, p. 1). Fire, as a calamitous event, will have its origin either in natural or in human activities. It can occur anyplace wherever ignitable materials are present and can cause vast loss of human lives and properties if it's not controlled in due time (Haque, 2001).

The trend of urban fire is closely associated with the amount of urbanization of a section (Wang et al., 2011) and globally this urbanization is happening quickly. In 2007, for the first time in history over 1/2 the world's population, 3.3 billion folks were living in urban areas (FIG, 2010). Urban areas become at risk of differing kinds of natural and artificial hazards (FIG, 2010).

Bangladesh is a developing country in South-east Asia. Because of the geological features, it is affected by numerous types of hazards & disasters every year such as natural hazards that are flood, cyclone, earthquake, landslide, drought etc. It is also affected by several types of manmade hazards such as fire & many more. In Bangladesh around 1142.3 people lives in per square kilometer and nearly about 35.1% people lives in urban areas (World Bank, 2010). Fire is the most common hazard in Bangladesh especially is urban areas. The number of fire incidents in Dhaka was 1,861 in 2003, 2,053 in 2004, and 2,279 in 2005 (Fire Incidence at Rise, February 10, 2007).

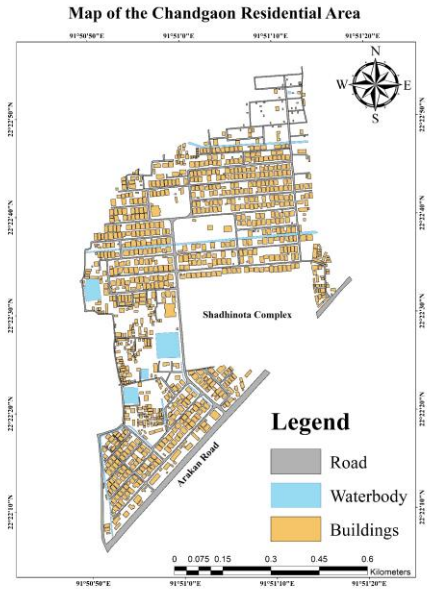
Chittagong is a major coastal city and financial center in southeastern Bangladesh. The city has a population of more than 2.5 million, while the metropolitan area had a population of 4,009,423 in 2011, (Bangladesh Bureau of Statistics, 2012) making it the second-largest city in the country. Because of the port & the railway & other transportation facilities, industrialization & urbanization rapidly dictates the city. For the allocation of all these people, several residential areas along with unplanned areas got developed here. Chittagong is not also free from the grasp of the disaster caused by fire. In February 2006, a fire at a textile factory in the port city of Chittagong kills 65 workers and injures dozens (Reuters, July 4, 2017). Fires broke out at Rahattarpul and Badurtala in Chittagong on 10th March, 2006. The fire, which originated from an electric short circuit,

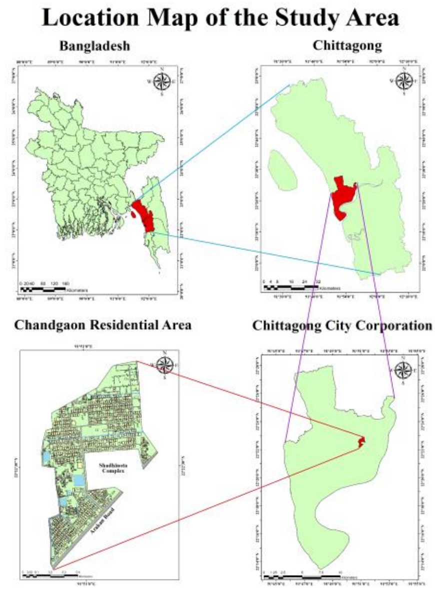
[1] *Undergraduate Student, Dept. of Urban & Regional Planning, Chittagong University of Engineering & Technology, Chittagong-4349, Bangladesh*
[2] *Undergraduate Student, Dept. of Urban & Regional Planning, Chittagong University of Engineering & Technology, Chittagong-4349, Bangladesh*
[3] *Lecturer, Dept. of Urban & Regional Planning, Chittagong University of Engineering & Technology, Chittagong-4349, Bangladesh*
Email of Corresponding Author – ahnehal11@gmail.com

burnt assets worth about Tk.7 lakh, the fire officials said (Fire Incidence at Rise, February 10, 2007). Because of this, the fire vulnerability assessment is very necessary in Chittagong.

Study Area Profile

The study area is Chandgaon R/A at ward no.4 of Chittagong City Corporation situated on the bank of Karnaphuli River. Ward no. 4 is the most densely populated (131,212) ward of Chittagong city and have a residential building value of 129 million US dollar (CDMP. 2009). Chandgaon have a population near 30,000 (Bangladesh Bureau of Statistics, 2012). The global positioning of Chandgaon is around the 91° 52' 10" N and 22° 21' 40" S. It is developed by Chittagong Development Authority (CDA) in 1978, it has 663 multi-storied residential buildings on 741 plots in two blocks. (Alamgir, 2007).





Map 1: Base map of the study area *Map 2: Location map of the study area*

Methodology

Fire Vulnerability Map

It was prepared by combining five layers of info using Arc GIS software. Every layer was prepared on the basis of a single attribute which was selected while the data were collected. Those fire hazard attributes are:

Electric pole & line

The electrical poles and electricity wire were located by field survey. A buffer area of six meter around each pole and four meters along the line was demarcated and the buildings within this buffer area were located.

Existence of fire sources

In the study area, there are sources that can ignite or amplify a fire. Buildings with those were distinguished.

Accessibility

If the road giving access building is too narrow (assumed width less than 10 ft.) for fire engines to enter, the buildings cannot be served effectively by it and the structure became vulnerable to fire.

Building material type

All the buildings were categorized as kutcha, pucca and semi-pucca categorized on the basis of materials.

Floor area ratio (FAR)

For preparing this map, this equation was followed: [Floor area = (Build area × Building height in stories) / Plot area]. Then every building was categorized as very low floor area ratio & moderately low floor area ratio. The data for attributes were collected from the GIS map produced by Chittagong City Corporation of 2007 and field level survey of 2018. But before, the attributes were ranked using the Analytic Hierarchy Process (AHP). AHP requires a pre-defined weight to input which has been taken from 15 famous fire experts of Bangladesh.

Fire vulnerability analysis

Critical Facilities Analysis

This analysis focuses on finding out the vulnerabilities of key facilities or resources within the community. Firstly the critical facilities are to be identified, then a vulnerability assessment would be conducted on those facilities.

Economic vulnerability analysis

The aim of this analysis was to find out economic vulnerability to fire hazard. Firstly, the economic features are to be identified, then a vulnerability assessment would be conducted on those features.

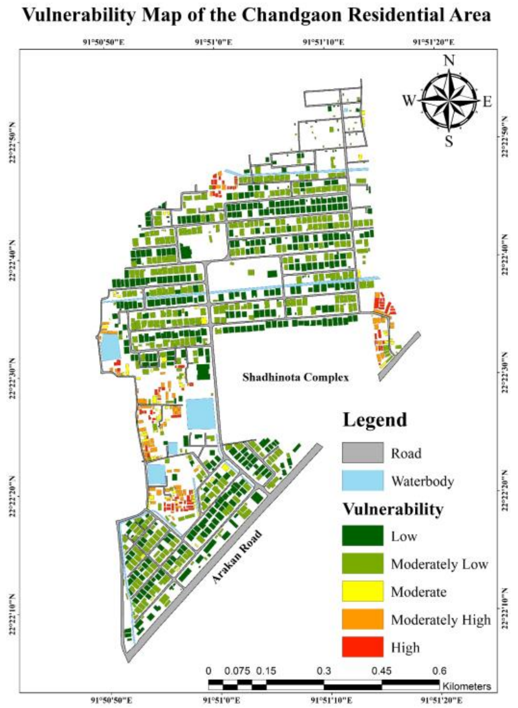
Environmental vulnerability analysis

To find out environmental vulnerability, sorting out secondary hazard risk consideration sites are necessary. Secondary impacts occur when hazard events create new hazards such as toxic releases.

Social vulnerability analysis

In this analysis, vulnerability to fire hazard is cross checked with some social aspects.

The Fire Vulnerability Map



Map 3: The fire vulnerability map

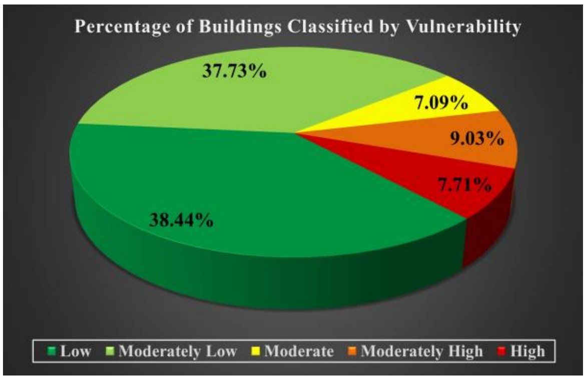


Figure 1: Comparison of vulnerability of buildings

The weight determined the AHP with the basis of the famous expert opinion are: Electric pole and line=

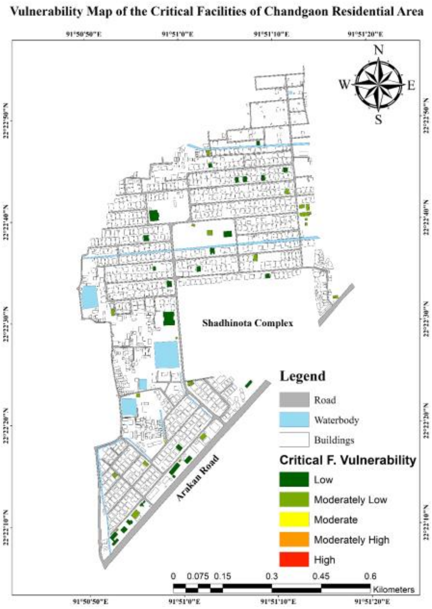
0.122; Availability of fire source= 0.354; Accessibility= 0.247; Material type= 0.135 & FAR= 0.141.
Vulnerability score= Weight for electric pole and line× (0 for Not Vulnerable or 1 for Vulnerable) + weight for availability of fire source × (1 for Available and 0 for Not available) + weight for accessibility × (1 for No access or 0 for Access) + weight for building material type × (1 for Pucca; 2 for Semi-kutcha or 3 for Kutcha) + weight for floor area ratio× (0 for Very Low or 1 for Moderately Low FAR). The buildings of the map were classified according to the score into five classes: low, moderately low, moderate, moderately high and high.

The map shows that most of the buildings are low & moderately low vulnerable for fire. Number of highly vulnerable buildings is significantly low & normally found in the unplanned clusters in the area. Number of moderate & moderately highly vulnerable buildings is also significantly low.

Fire Vulnerability Analysis

Critical facilities vulnerability analysis

At first all the critical facilities in Chandgaon Residential Area were identified such as: Educational institutions, Religious centers, Government organizations, Healthcare facilities, Bank, Community facilities, NGO offices. Finally, the following vulnerability map was prepared that represents which critical facilities.



Map 4: Vulnerability map of critical f.

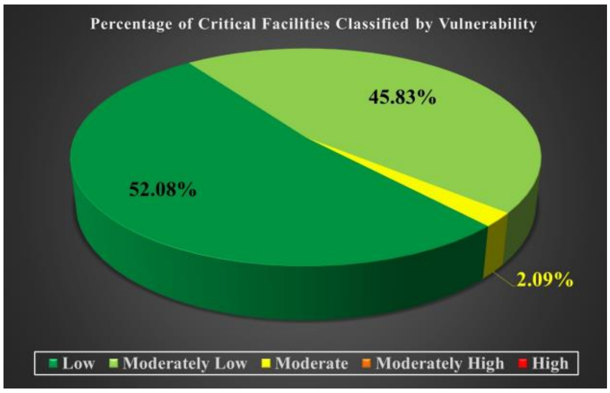


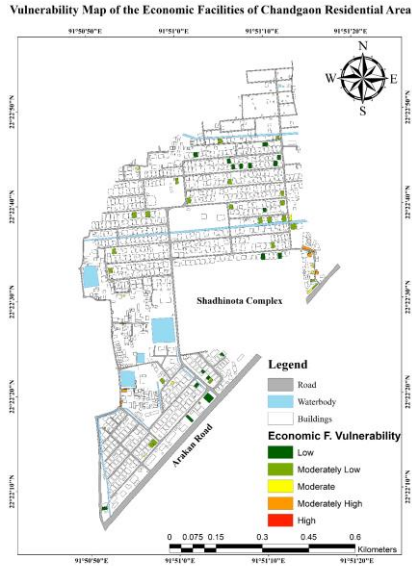
Figure 2: Comparison of vulnerability of critical f.

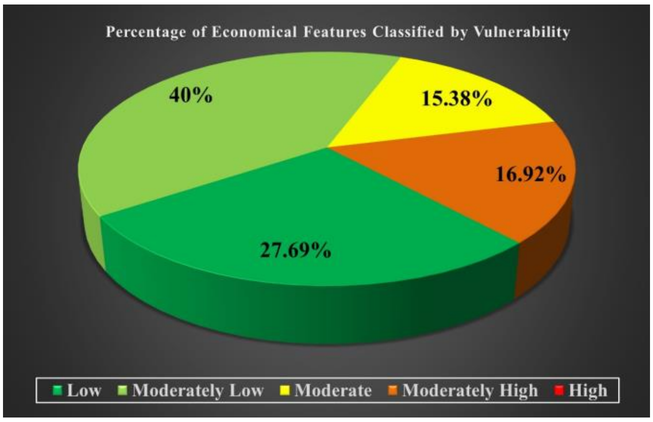
We can see that, most of the critical facilities has low & moderately low vulnerability. Only 2.09% has moderate vulnerability. No economic features have high & moderately high vulnerability.

Economic vulnerability Analysis

Different types of economic activities were found on the study area. Most of them are resident oriented such as grocery stores, pharmacy, restaurants, filling stations, cyber cafes, mobile shops, super shops etc. Only one shopping mall was found in the area.

For preparing the inventory location of these has been collected from the GIS map and field survey regarding the economic features. Finally, the following map was prepared that represents which economic features are vulnerable to fire and which are not.



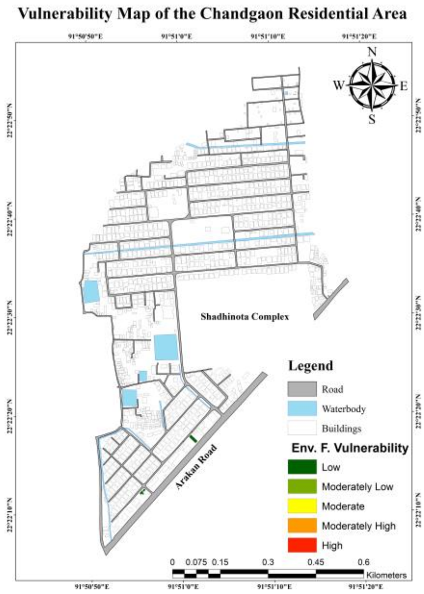


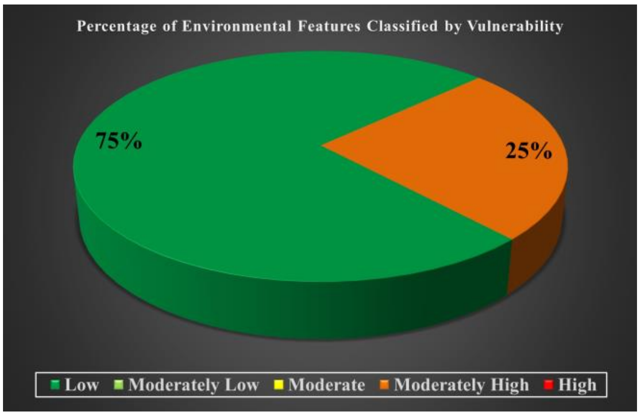
Map 5: Vulnerability map of economic f. *Figure 3: Quantitative comparison of vulnerability of economic f.*

As we can see, most of the economic features have moderately low and low vulnerability. Only 15.38% & 16.92% buildings has moderate & moderately high vulnerability. No economic features have high vulnerability.

Environmental vulnerability analysis

Secondary impacts occur when hazard events create new hazards such as toxic releases. Only features that can cause secondary risk found in the study area are filling stations. For preparing the inventory location of these has been collected from the GIS map and field survey regarding the secondary risky features. Finally, the following map was prepared that represents which secondary risky features are vulnerable to fire and which are not.





Map 6: Vulnerability map of environmental f. Figure 4: Comparison of vulnerability of environmental f.

As we can see, most of the environmental features, specifically 75% has low vulnerability. The rest 25% has moderately high vulnerability.

Social vulnerability analysis

As the Chandgaon Residential area provides housing for middle- & high-income groups, the literacy rate in high here. Various age group can also be found here & the male female ratio is nearly equal. So, the social vulnerability can be defined as the vulnerability of the community as a whole and it is moderately low.

Conclusion

Table 1: Result of the study

Parameter	Status
Critical facilities vulnerability	Low
Economic features vulnerability	Moderately low
Environmental features vulnerability	Moderately low
Social vulnerability	Moderately low
Number of vulnerable buildings	Moderately low
Large fire incidents	No

Taking in account the above status of different factors it can be concluded that the community of Chandgaon Residential Area is not so much vulnerable to fire. But this is an aggregate result, not an absolute decision. Because findings from this study can change if more attributes are considered & also if the method.

References

Alamgir, N. U. (2007, January 17). Chandgaon fast becoming commercial area. *The Daily Star.* Retrieved from http://archive.thedailystar.net/2007/01/17/d701173501156.htm

Bangladesh Bureau of Statistics. (2012). Population & housing census-2011: Union statistics. p. 39. Retrieved from: 203.112.218.66/WebTestApplication/userfiles/Image/BBS/Socio_Economic.pdf

CDMP (2009), "Earthquake Risk Assessment of Dhaka, Chittagong and Sylhet City Corporation Area", General report, pp. 113. Ministry of Food and Disaster Management, Govt. of Bangladesh.

FIG. (2010). Rapid urbanization and mega cities: The need for spatial information management. Copenhagen, Denmark: The International Federation of Surveyors.

Fire incidence at rise. (February 10, 2007). *The New Age*.

Haque Q. M. F. (2001). Fire hazard modeling in Dhaka city using GIS, MURP thesis, Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology.

Paul, R. (2017, July 4). Factbox: Major industrial accidents in Bangladesh in recent years. *Reuters*. Retrieved from https://www.reuters.com/article/us-bangladesh-blast-accidents-factbox/factbox-major-industrial-accidents-in-bangladesh-in-recent-years-idUSKBN19P0JN

Raja, D. R. (2007). Analyzing vulnerability of a community to fire hazard: A case study of ward 72. BURP thesis, Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology.

Wang J. H., Sun J. H., Lo S. M., Gao L.J. and Yuen R.K.K. (2011). Statistical analysis on the temporal-spatial characteristics of urban fires under typical urbanization features, Procedia Engineering, 11, 437-444.

World Bank. (2010). Chapter 7: Governance and growth: The Bangladesh conundrum, *Bangladesh strategy for sustained growth*, The World Bank Office, Dhaka: Bangladesh Development Series.

FIRE SAFETY DESIGN OF RESIDENTIAL APARTMENT BUILDINGS IN NORTH DHAKA: A SEMI-QUANTITATIVE RISK ASSESSMENT USING FIRE RISK INDEX METHOD

Afroza Mallick[1], Md. Shahidul Islam[2] and Abrar Hossain [3]

ABSTRACT

Ensuring safety to buildings against fire hazard is one of the three important factors to improve a person's fire response performance. Continuous construction of high-rise apartment buildings in Dhaka without considering fire safety is increasing the likelihood of fire hazards and damages caused by them. The aim of the study was to assess the fire safety design in residential apartment buildings in Dhaka North City Corporation using FRI (Fire Risk Index) Method. The method is semi-quantitative in nature with seventeen parameters- including presence of detection and signal system, suppression system, ventilation system, escape routes in the buildings and capability of firefighting among others. Another objective of the study was to identify the parts of the Bangladesh National Building Code not being followed by the assessed buildings. The study concluded that most of the buildings lack in providing protection against fire hazards for not following the code strictly. So this study demonstrates which parts of a building need improvement to protect lives and properties against fire hazards according to the code.

Keywords: *fire hazard, fire safety, fire response performance, residential apartment building, Fire Risk Index, semi-quantitative risk assessment.*

Introduction

The present decade opened its curtain with a terrible disaster in the capital city of Bangladesh. A fire in multiple residential buildings in Nimtoli in Old Dhaka left more than 100 people burnt and killed in their own homes. The Fire started in one of the poorly built 5-story brick building in an accommodation block in Nimtoli on June 2010. The building in question had no fire escape and all the windows had metal grills with no openings. Moreover, chemicals were stored in the residential building, which is against the rules set in Bangladesh National Building Code (BNBC). It took the firefighters more than one hour to reach the area due to heavy traffic and narrow lanes. These all helped spread the fire more quickly, killing so many (BBC, 2010).

Another fire disaster in 2017 strongly proved that even the buildings in a developed city are not fully safe. 71 people died when fire broke out at the 24-story residential apartment building in London. The exterior aluminum cladding of the building helped the fire to rapidly spread through the whole building, which was added during renovation in 2016 for improving the building appearance. Built in 1974, the building had 120 flats in total, with only one staircase serving as an escape route during emergencies. The building didn't have any internal sprinkler system. It took 60 hours for the firefighters to put out the blaze. Lack of concern among authorities to ensure safety of the building against fire and improve the standards for fire proofing resulted in this deadly inferno (Knapton & Dixon, 2017).

There are many more instances like these around the world where people were killed or injured from blaze and smoke in high-rise buildings. At present Dhaka is going through rapid and continuous construction of high-rise buildings in the name of urbanization to accommodate the ever-growing population of Bangladesh. Except a few instances, most of the residential buildings are being constructed without taking into consideration the threat of fire and earthquake as set in the BNBC (JICA, 2015). This practice is questioning the safety issues of the people in their own residences against fire hazards.

Review paper by Kobes, Helsloot, Vries, & Post (2010) represents the importance of ensuring building safety for safe escape of its occupants during fire hazards. The main objectives of fire safety are to provide safety to the people living in a building and to provide protection of their properties. Furthermore, fire safety requires prevention of fire by limiting its growth and stopping the spread of smoke as well as the facilities to ensure safe egress from the building. It is a complex system which depends on a large number of factors associated

[1]*Graduate Student, Dept. of Disaster Science and Management, University of Dhaka, Dhaka, Bangladesh*
[2]*Assistant Professor & Chairman, Dept. of Disaster Science and Management, University of Dhaka, Dhaka, Bangladesh*
[3]*Lecturer, Dept. of Disaster Science and Management, University of Dhaka, Dhaka, Bangladesh*
Email of Corresponding Author – mallick.dsm004@gmail.com

with the way a building is constructed (Watts, 1991). Lacking of any one of them may make the whole building vulnerable to fire hazards. Kobes (2008) in his study about fire response performance introduced three factors- fire characteristics, human characteristics and building characteristics. Studies at present mainly focus on the human characteristics associated with evacuation process from high-rise buildings (Ding, Yang, & Rao, 2013). Though the world has moved forward in research related to fire hazards, there is still lacking regarding the building characteristics against fire in Bangladesh. The main focus of this paper is to point out this gap.

Study Area

At present there are two city corporations in Dhaka, namely Dhaka North City Corporation (DNCC) and Dhaka South City Corporation (DSCC). The buildings assessed for this study are all under DNCC, which covers an area of 82.638 square kilometers (DNCC, 2017). For time and resource limitations, only five residential apartment buildings from five different areas of DNCC were selected. The locations are Uttara Model Town, Mirpur DOHS, Gulshan-2, Shewrapara and Indira Road. According to the BNBC 2006, a high rise building has more than 6 stories. The buildings selected for this study are all 6 to 10 stories. According to Section 2.1.1 in Part 3, these are of occupancy type A2 (residential apartment). The definition of high rise buildings changed in 2015 update, which is not considered for this study as the selected buildings were constructed before this year. The selected buildings are expected to deliver a general scenario of the whole DNCC.

Method

It is tough but vital to conduct research related to fire risk analysis for buildings. There exist many methods to perform risk analysis of different types of buildings. But most of them are quite hard to use and require vast knowledge regarding fire and building structure. Also a detailed quantitative risk analysis is costly and time consuming. In this case a semi-quantitative risk tool such as risk indexing is useful, which is easy to apply and produces a rapid and simple estimation of relative fire risks in buildings by scoring various parameters. Though lacks validity, it can help in making decisions about building fire safety (Watts, 1991). Considering these reasons, FRI (Fire Risk Index) method was selected for this study. Although the method is basically for timber-frame multi-story apartment buildings in European countries, it can also be used to assess concrete buildings (Larsson, 2000). 17 parameters are set in the method (Table 1), each having a definite weight and variable grade to finally establish a relation between them using the following formula-

$$S = \sum_{i=1}^{n} w_i x_i \qquad (1)$$

Where, S is the risk index expressing fire safety, w_i is the weight for parameter i and x_i is the grade for parameter i. The range of the weight is 0 to 1 while the range of the grade varies from 0 to 5. So the total score after calculation range from 0 to 5. A score of 5 expresses highest level of fire safety in a building and a score of 0 represents lowest level of fire safety (Larsson, 2000).

Table 1. 17 Parameters introduced in the FRI method (Larsson, 2000)

1) Linings in Apartment	2) Suppression System	3) Fire service
4) Compartmentation	5) Structure- Separating	6) Doors
7) Windows	8) Façade	9) Attic
10) Adjacent Buildings	11) Smoke Control System	12) Detection System
13) Signal System	14) Escape Routes	15) Structure- Load-bearing
16) Maintenance and Information	17) Ventilation System	

Results and Discussion

All the buildings assessed gained scores that are too low in a scale of five and almost similar (Table 2). This is because all these concrete masonry buildings have almost no provision of active fire protection systems (including sprinklers, fire extinguishers, fire alarms, smoke detectors etc.), which constitute a large portion of the parameters used in the method.

Table 2. Scores of the five representative buildings of DNCC

Areas	Uttara	Mirpur DOHS	Gulshan	Shewrapara	Indira Road
Scores	1.859	2.019	1.905	1.743	2.016

According to the BNBC 2006, a high rise building has more than 6 stories or has a height of at least 20 meters. The buildings selected for this study are all 6 to 10 stories residential apartment buildings. According to Section 2.1.1 in Part 3 of the BNBC 2006, these are of occupancy type A2. Section 3.1.1 in Part 3 of BNBC conforms to the construction of high-rise buildings with non-combustible materials. This feature reduces the chance of fire ignition. But as history shows, this is not enough. Regulations required for ensuring safety to lives and properties against fire and explosions while using a specific type of building is provided in the Part 4 of the BNBC (GoB, 2015). This part also provides specific requirements for ensuring prevention of and protection from fire hazards in any buildings. Requirements for fire safety in A2 occupancy is discovered from the observation of the buildings.

According to Part 4 of the Code, installment of sprinklers in A2 type buildings is not required and none of the five buildings have one. According to Section 5.2.1 in Part 4, low-rise buildings for A2 occupancy does not require fire extinguishers. However, according to Section 4.10.1.3 in Part 4 requires fire extinguishers in areas vulnerable to fire i.e. kitchen, electrical distribution point etc. Only the building in Indira Road has fire extinguishers, though not enough in number. The building in Shewrapara doesn’t have any type of extinguisher even though it is 10 stories high with five flats in each floor and only one staircase.

According to Section 1.3.3.1, access road for fire vehicles in front of a building needs to have an unobstructed width of 4.5 meters. But the roads in front of each building are less than that. Access roads with small width make the buildings located far from the main road more vulnerable to fire hazards. This is because such roads make it impossible for the firefighters to get close to the building along with the equipment necessary to put out the fire. However, it is quite common in the over-populated Dhaka city.

Section 2.5.3.2 in Part 3 specifies the provision of at least one operable window or door for emergency escape in ground to second floors of the residential buildings. However, no such windows could be found in any buildings. There are only open balconies in three of the buildings, which can be accessible by the firefighters.

According to section 1.5 in Part 4, the fire resistance rating of building assemblies and structural elements shall be determined in accordance with ASTM E 199. Fire resistance of six-inch concrete and solid brick walls is 4 hours while it is 15 minutes for nails, screws, connectors and bolts. The building assemblies follows this rule. This section also requires the provision of fire doors in accordance with ASTM E 152. Fire resistance of such doors should be 20 minutes to 180 minutes, as mentioned in Section 3.7.5. All the doors for flats and rooms leading out to escape route are wooden. Standard fire test reveal that large timbers burn slowly, at a rate of 0.6mm/minute (CWC, 2000). So, the doors have fire resistance of up to 60 minutes, which is more than required. But they may not be able to resist heat and pressure.

Section 1.5 also requires that windows meet the test requirements of ASTM E 163. Windows can be seen as the weakest part of the building with little or no fire safety provided. Shattering of glass due to heat from fire causes hazardous situation for people near the windows. The assessed buildings have normal tempered glass windows. Shattering of glass causes hazardous situation for people. Fire resistance capability of a building can be greatly affected by the performance of its windows as they may become the medium for fire to spread throughout the building (Zhou, 2014).

Section 2.4.2 in Part 3 states that fire separation distance up to 1.5 meters require an exterior wall with a fire resistance rating of 1 hour. If the distance is more than 1.5 meters no rule is set in the BNBC. None of the buildings have enough separation from adjacent buildings. This increases the chance of fire spreading to nearby buildings if such an event does take place.

No requirements for providing smoke control system in the buildings for A2 Occupancy is set in the BNBC 2006. As such none of the buildings have any equipment for smoke control, which follows the code. Natural ventilation of smoke through windows is expected in case of a fire.

According to Section 5.2.2 in Part 4, low-rise buildings for A2 occupancy does not require fire detection arrangements. However, according to Section 4.6.1, if the size and arrangement of a building is such that only human surveillance isn’t enough to provide timely and adequate warning to its occupants, it is necessary to install fire detectors. The occupants of the five buildings only rely on human surveillance for detection of fire and smoke. The occupants know the possible sources for ignition. They rely on human surveillance for detection of fire and smoke. For A2 type high-rise buildings with more than 16 dwelling units, manual alarm signal must be provided as per Section 5.2.1. According to Appendix D, high rise buildings up to height 26 meters may not need to install signal system if they do not pose risk to the adjacent buildings (Section 17.1). Following the requirement, the buildings in Gulshan, Shewrapara and Indira Road should have signal equipment. But none of them has one.

According to Section 3.16.1 of Part 4, no exit sign is required for A2 Occupancy. Section 3.14.2 states provision of more than one exit if the building has more than 6 stories or 12 dwelling units. All of the buildings assessed do not follow these rules. Travel distance is measured as a straight line from the furthest point of a space of a floor to the exit access door (GoB, 2015). Section 3.15.1 requires the arrangement of exits in a manner that does not exceed travel distance of 25 meters from any point of the building.

Appendix A of the BNBC requires all fire protection systems to be maintained and inspected on a regular basis, preferably twice a year. However, no building owners perform any inspection unless requested by other occupants of the building. The occupants also do not get any information regarding fire suppression or evacuation procedure.

BNBC defines ventilation as flow of air between an enclosed area and outside through natural or mechanical systems. Natural ventilation is provided through openings in buildings, such as through windows. Restricted ventilation can lead to the accumulation poisonous gases and smoke during a fire (GoB, 2015). BNBC Section 2.7.2 in Part 4 requires ventilation system in such a way that fire and smoke doesn’t spread to other areas or floors through the vents. Exhaust fans in kitchen and connected ducts must be of non-combustible materials according to Section 2.12.1. As per Section 3.13.7, enclosed windowless staircases need to have mechanical ventilation installed for letting out smoke in case of a fire. Part 8 Chapter 3 recommends outdoor air quantity of 15-25 liters/second per person for residential kitchens. There is no mention of special ventilation system for fire specifically. None of the buildings have specific smoke spread prevention system. The only ventilation system for the rooms are windows.

These findings reveal some of the important regulations provided in the BNBC to ensure fire safety to high-rise residential apartment buildings, with the help of the parameters provided in the FRI method by fire safety experts.

Conclusions

Even with non-combustible construction materials, the reason fire becomes uncontrollable resulting in high number of fatalities and property loss can be due to poor building performance. The main problem lies in the absence of active fire protection systems and alternative escape facilities in the building. Bangladesh National Building Code has a sole part dedicated to provide regulations for ensuring fire safety to any type of constructions. So maintaining the BNBC strictly can increase the possibility of a building and its occupants to control fire hazards and reduce casualties. The study gives an overview of the lacking a building might have when compared to the BNBC requirements to ensure fire safety. From the assessment some recommendations can be presented. More time and resources are needed to assess more residential buildings for a better picture of fire safety in our country. Considering the number of buildings in Dhaka city alone, it is not enough to assess just a few buildings. However, it is advantageous that most of the buildings in our country are constructed in quite a similar way. Moreover, not all the parameters set in the FRI method are suitable for the types of buildings constructed in our country. So following the common structure of a type of building, it is recommended to have experts’ opinions to add/remove the parameters and to calibrate the values of weights and grades suitable for our building types. It is high time we prepared ourselves against this uncertain and dangerous phenomenon. Further scientific research related to fire hazards and fire safety is of utmost importance in Bangladesh at present.

Acknowledgement

The authors sincerely acknowledge the information provided by the Headquarter of Bangladesh Fire Service and Civil Defense.

Appendix

An example showing how the score was calculated from the FRI Method for the building in Indira Road.

Parameters	Grade for Sub-parameters	Final Grade	Weight	Weighted Grade
P1	5	5	0.0576	0.288
P2	0	0	0.0668	0
P3	0.31*2 + 0.47*3+ 0.22*3	2.69	0.0681	0.183189
P4	2	2	0.0666	0.1332
P5	0.35*5 + 0.28*1 + 0.24*2 + 0.13*5	3.16	0.0675	0.2133
P6	0.67*2 + 0.33*3	2.33	0.0698	0.162634
P7	0	0	0.0473	0.0946
P8	0.41*5 + 0.3*5 + 0.29*5	5	0.0492	0.246
P9	5	5	0.0515	0.2575
P10	0	0	0.0396	0
P11	0	0	0.0609	0
P12	0	0	0.0630	0
P13	0	0	0.0512	0
P14	0.34*1 + 0.16*3 + 0.23*5	1.97	0.0620	0.12214
P15	0.74*5 + 0.26*5	5	0.0630	0.315
P16	0	0	0.0601	0
P17	0	0	0.0558	0
			SCORE =>	2.015563

References

BBC. (2010). Dhaka: City of construction death traps. Retrieved December 30, 2017, from http://www.bbc.com/news/10238855

CWC. (2000). Fire Safety in Residential Buildings. Building Performance Bulletin, Ottawa, Canada: Canadian Wood Council.

Ding, Y., Yang, L., & Rao, P. (2013). Investigating the merging behavior at the floor-stair interface of high-rise building based on computer simulations. *Procedia Engineering*, *62*, 463–469. https://doi.org/10.1016/j.proeng.2013.08.088

DNCC. (2017). Dhaka North City Corporation at a Glance. Retrieved December 10, 2017, from http://www.dncc.gov.bd/site/page/c0b6953f-16d3-405b-85e9-dece13bb98de/%E0%A6%B2%E0%A7%8B%E0%A6%95%E0%A7%87%E0%A6%B6%E0%A6%A8-%E0%A6%93-%E0%A6%85%E0%A6%BE%E0%A7%9F%E0%A6%A4%E0%A6%A8

GoB. (2015). *Bangladesh National Building Code* (Vol. 1). Dhaka.

JICA. (2015). *Data Collection Survey on Urban Building Safety in the People's Republic of Bangladesh*.

Knapton, S., & Dixon, H. (2017). Eight failures that left people of Grenfell Tower at mercy of the inferno. Retrieved December 22, 2017, from http://www.telegraph.co.uk/news/2017/06/15/eight-failures-left-people-grenfell-tower-mercy-inferno/

Kobes, M., Helsloot, I., Vries, B. De, & Post, J. G. (2010). Building safety and human behaviour in fire: A literature review. *Fire Safety Journal*, *45*(1), 1–11. https://doi.org/10.1016/j.firesaf.2009.08.005

Larsson, D. (2000). *Developing the Structure of a Fire Risk Index Method for Timber-frame Multi-storey Apartment Buildings*. University of Lund, Lund, Sweden. Retrieved from https://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=1687186&fileOId=1691831

Watts, J. M. (1991). Criteria for Fire Risk Ranking. In *FIRE SAFETY SCIENCE-PROCEEDINGS OF THE THIRD INTERNATIONAL SYMPOSIUM* (pp. 457–466).

Zhou, B. X. (2014). Application and design requirements of fire windows in buildings. *Procedia Engineering*, *71*, 286–290. https://doi.org/10.1016/j.proeng.2014.04.041

DEVELOPING PLANNING SOLUTIONS FOR MANAGING FIRE RISKS CONSIDERING SPATIAL VARIATION OF THE RISK OF FIRE: A CASE STUDY ON KHULNA CITY

C. Biswas[1] and S.M. Haque[2]

ABSTRACT

Most of the City development plans in Bangladesh are prepared without considering fire risk implications in city planning and management which could be responsible for disastrous fire incidents in cities. As being an important economic hub of Bangladesh, Khulna city has experienced haphazard development that opens up the possibilities of the frequent occurrence of the fire hazard. This paper aims to assess the spatial variation of the fire risk of Khulna city through the index-based approach and to provide probable planning solutions for managing it. Analytical hierarchy process (AHP) is used for developing the index which weights 18 parameters. Experts who have extensive knowledge about fire risk sensitivity are interviewed for weighing in the AHP process. Data and information are derived from relevant secondary sources. Geographic Information System (GIS) is used for analyzing and mapping the spatial variation of fire risk. Findings suggest that fire risk can be categorized into three levels, out of total 31administrative wards in Khulna City 15 wards fall in high risk, 6 wards in medium and 10 in low-risk zones as far as the fire hazard is concerned. These findings are used for suggesting planning solutions for fire risk management of the city.

***Keywords**: Fire Risk, Unpredictable Fire Hazard, Spatial variation, Index, AHP, GIS*

Introduction

Over half of the world's population lives in cities and towns due to rapid urbanization. More than 1billion people live in urban areas today who are at risk of disasters like cyclones, floods, earthquakes, fire, crime, and industrial accidents, because of high concentration of population, residential and commercial buildings, industries (World Disaster Report, 2016). Earthquake, floods, fire incidents, and heatwaves are identified as urban disasters, where fires and explosions are categories as a technological hazard (World disaster report, 2010). The world had experienced 385 massive fire hazards within 2010-2015 and most of the fire hazard occurred in Asia and the number of total affected people in Asia is also highest which is 57 percent of the total number of deaths from fire incidents (World Disaster Report, 2016). Bangladesh had experienced 8063 fire hazards in 2013 and the total amount of losses was 296.4crore Taka in 2013. Among the cities of Bangladesh, Dhaka faced 2334 occurrences, Chittagong faced 1735 occurrences, Khulna faced 1041occurences in the same year (Disaster Report Bangladesh, 2013).
Generally, Spatial variation of fire incidences across a city can be attributed to its spatial heterogeneity, which is the consequence of the difference of spatial characteristics of its built environment. So, fire risk patterns are spatially correlated, e.g, (Adianto, 2015). That is why, to reduce risk, the spatial variation of risk is important to identify. In this study, it is tried to develop fire risk index using analytical hierarchy process. Weighting and classification have been done based on literature review and experts opinion combining 11 parameters to assess the variation of risk. This study classified 31wards of Khulna city based on fire risk score to list out the hotspots to give priority for developing appropriate planning solutions to manage fire risk. It is expected that; this analysis technique would be an usher in a new paradigm in city planning with the integration of fire risk management issues.

Study area

This study is conducted in Khulna, which is the third largest city and economic hub of Bangladesh. Fire hazard has become an important city planning and management issue in this city. According to Fire Services and Civil Defense authority Khulna, total 190 fire incidents occurred within 2014-2017 years (Fire Services and Civil Defense Authority, 2018). The number of occurrences was 29 in 2014, 27 in 2015, 65 in 2016 and 69 in 2017. So, the number fire incidences are increasing at an alarming rate every year. This city has 31 lowest administrative units and the study is trying to find out the spatial variation of fire risk in these wards.

1 Student, Urban and Rural Planning Discipline, Khulna University, Khulna-9208, Bangladesh
2 Professor, Urban and Rural Planning Discipline, Khulna University, Khulna-9208, Bangladesh
Email of Corresponding Author – bonnabiswas9@gmail.com

Methodology

In this paper 3indices, 11components and 11 sub-components are selected based on reviewing the literature, available data, and opinion of experts, have been used to measure composite fire risk index of Khulna city. As risk is a function of the hazard, vulnerability to the hazard and coping capacity to withstand the effect of that hazard, to assess the fire risk it is important to consider vulnerability, hazard, and coping capacity. So, three indices, vulnerability index, hazard index, and coping capacity index are considered to develop composite fire risk index. Components of fire vulnerability are Land use, average road width, building type, and population density and sub-components of land use are waterbodies, vacant land, vegetation, public building, residential, commercial, industrial and mixed-use area and the sub-components of building types are kutcha, semi pucca and pucca and 3 components of hazard are losses in monetary term, number of dead and number of victim and 3 components of coping capacity are availability of hospital, availability of fire services and literacy rate are selected to analyze the risk of fire, which is shown in the table-1.
Analytic hierarchy process is used to produce an index of fire risk which weights and priorities of Vulnerability, hazard and coping capacity parameters in this study. The AHP method includes three major steps. The first step is the generation of binary comparison matrices on a scale of 1–9, 1 indicating that the two elements are equally important, and 9 implying that one element is more important than the other (Saaty, 1990). The pairwise comparison matrix is developed for normalization of each parameter. In the second step, the weight of different parameters is calculated from row multiplied value (RMV), un-normalized value and normalized value using the equation (1) and (2). In equation (2) mi represents the un-normalized value of its parameter and n represents the number of components.

Un-normalized value, mi = $\sqrt[n]{RMV}$ ………………………………………………………. (1)
Normalized value = Mi/ $\sum_{i=1}^{n}$ Mi………………………………..……………………….. (2)

In the third step, the weight of each and the estimation of consistency between judgments are measured. The consistency is measured using consistency index and consistency ratio using the equation (3) and (4). In equation (3) L refers to the largest value of the pairwise comparison matrix and RI represent random consistency index.

Consistency index= (L-n)/(n-1) ………………………..……………………………… (3)
Consistency ratio CR=CI/RI...…………………………………………………….…. (4)

If consistency ratio > 10%, the matrix is inconsistent and pairwise comparison must be re-performed between components and sub-components. The measured ratios are, 1.5%, 5.5% and 5.6% for the components and sub-components of fire vulnerability index and 0.03% for the components of hazard index and 0.3% for coping capacity index and all of them are less than 10% which are consistent. Because each sub-component is measured on a different scale, so it is first necessary to standardize the value of each sub-component.

Normalized value of sub-component = $\frac{So-Smin}{Smax-Semin}$……………………..…...………….. (5)

The equation (5) is used for this conversion was adapted from that used in the Human Development Index (HDI) developed by UNDP, where So refers to the value of the sub-component, Smax means the highest value and Smin indicates the lowest value, e.g, (Hahn, 2008).

The final value of sub-component = $(1 - normalized\ value\ of\ the\ subcomponent)$….. (6)

If the sub-component is negatively correlated with the component, to get the final value of that sub-component equation (6) is used (Pelling, 2003).
The score of component = $\frac{\sum_{1}^{n} Value\ of\ subcomponents}{Number\ of\ subcomponents}$……………………..…...……………..... (7)
Index score, $s = \sum_{1}^{n} wisi$……………………..…...…………………………………….. (8)
Composite Fire Risk Index=
Fire vulnerability index * Fire Hazard Index / Coping capacity Index…………………. (9)

The equation (7) is used for getting the score of components and for calculating index equation (8) is used, which is adapted from FRAME and modified following HDI procedure, where S means index score, n means

the number of components, Wi means weight of component I and Si means normalized score of component i. For computing composite index equation (9) is used which was also developed by FRAME.
Total weight of sub-components of each component is 1, shown in table-1. To find the value of each component, all the normalized value of its sub-components are multiplied with their weight. Then, the results added to find the value of the component. After normalizing the value of each component, they are multiplied with the weight of each component and added together to find the score of each index. Then, the score of composite fire risk is found using the equation (9).

Table-1: Components, sub-components, relation with risk, formula, and weight

Vulnerability					
Component	**Sub-Component**	**Relationship with fire risk**	**Formula**	**Weight**	
				Sub-components	**Component**
Land use	Waterbody %	Negatively correlated	Area of Waterbody*100/total area of the ward	0.14	0.31
	Vacant land%	Negatively correlated	Area of the vacant land*100/total area of the ward	0.04	
	Vegetation %	Negatively correlated	Area of the vegetation*100/total area of the ward	0.06	
	Public building%	Positively correlated	Area of Public building*100/total area of the ward	0.07	
	Residential area %	Positively correlated	total residential area*100/total area of the ward	0.13	
	Commercial area %	Positively correlated	Total commercial area*100/total area of the ward	0.28	
	Industrial area %	Positively correlated	Total industrial area*100/total area of the ward	0.10	
	Mixed-use %	Positively correlated	Total mixed-use area*100/total area of the ward	0.18	
Average road width		Negatively correlated	Total road width/total road number	No sub-component	0.23
Building type	Kutcha%	Positively correlated	Number of Kutcha building*100/total building of ward	0.26	0.27
	Semi pucca%	Positively correlated	Number of semi-pucca building*100/total building of ward	0.32	
	Pucca%	Positively correlated	Number of Pucca building*100/total building of ward	0.41	
Population density		Positively correlated	The total population of each ward/total area of the ward	No sub-component	0.05

Building density	Positively correlated	The total area covered by building/total area of the ward	No sub-component	0.12
Hazard				
Losses in monetary term	Positively correlated	Total loss within 2015-2017 years	No sub-component	0.10
Number of Dead	Positively correlated	Total number of deads within 2015-2017 years	No sub-component	0.68
Number of victims	Positively correlated	Total number of victims within 2015-2017 years	No sub-component	0.21
Coping Capacity				
Availability of Hospital	Positively correlated	Total number of hospitals in each ward	No sub-component	0.34
Availability of fire service facilities	Positively correlated	Total number of fire service centers in each ward	No sub-component	0.57
Literacy Rate	Positively correlated	The literacy rate of each ward	No sub-component	0.08

Data analysis

The weight of the components and sub-components are determined by the Analytical Hierarchical Process. Vulnerability, Hazard and coping capacity data of each ward of Khulna city are put in Excel 2016 in quantitative forms and they are joined with GIS shapefile and analyzed by the tools like frequency distributions, geoprocessing, spatial analysis. After that, wards are classified into three categories such as low, medium and high-risk area using natural breakdown classification in ArcGIS 10.4. Then the vulnerability, hazard, and coping capacity maps are produced separately based on their scores to present the spatial variation of fire vulnerability, fire hazard and coping capacity of each of the wards in Khulna city**.**
The score of Fire Vulnerability Index is classified into three categories which are (0.2915-0.472) low, (0.472-0.669) medium and (0.669-0.885) highly vulnerable. Whereas, fire hazard index is classified in (0-0.0034) low, (0.0034-0.0507) medium and (0.0507-0.6927) highly hazardous and coping capacity index is classified into (0.029-0.045) low, (0.045-0.134) medium and (0.134-0.628) high categories. Finally, the composite fire risk index is classified into (-0.1128-0.304) low, (0.304-0.386) medium and (0.386-0.803) high-risk categories.

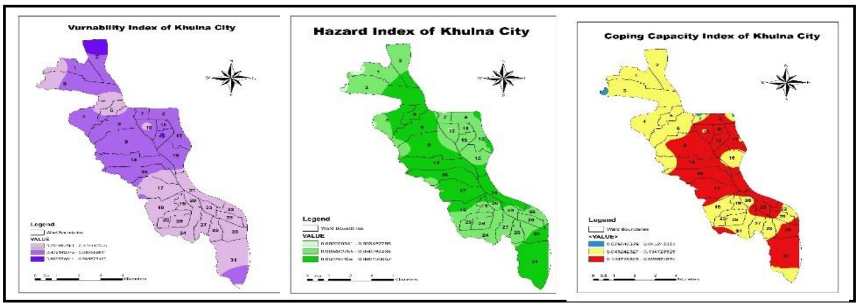


Figure-1: *The Vulnerability, Hazard and Coping capacity map of the study area*

The spatial variation of fire risk is analyzed by modifying FRAME approach of fire risk assessment. By developing and analyzing the composite fire risk index, it is found that 15 wards are at highest risk of fire hazard and 6 words are at medium risk and 10 wards are lowest at risk of fire hazard. The spatial variation of fire risk is visually presented in Figure-2. As 21 words out of 31 words of Khulna city are at highest and medium risk of fire hazard, it is very urgent to develop appropriate planning solutions to reduce the risk. For developing proper solutions focusing on priority areas, it is foremost important to identify main causes which are responsible for risk. Ward no 1, 2, 3, 5, 6, 7, 8, 9, 12, 13, 14, 15, 17, 21 and 31 are extremely at risk of fire due to their least coping capacity in terms of lack of availability of fire service facilities and also most vulnerable to fire hazard because of high building density and narrow road width. That is why these wards have experienced most of the fire hazards in the last five years. So, it is first and foremost important to make sure that availability of fire services can be ensured in these wards. Then, existing roads should be widened and the new wide road should be constructed to ensure easy movement of emergency fire service vehicles. Therefore, medium risk areas are ward no 4, 10, 18, 22, 27 and 28 which are the oldest developed part of the city. Main causes of the frequent fire occurrence in these areas are high building density and also having most of the industrial and mixed-use area. So, it is important to monitor the availability of fire service in these critical areas and also, destruction of the existing building which are not developed following building code. The amount of low-risk area is smaller than high and medium risk areas. So, policymakers should focus more on the high and medium risk areas to reduce fire risk in Khulna city.

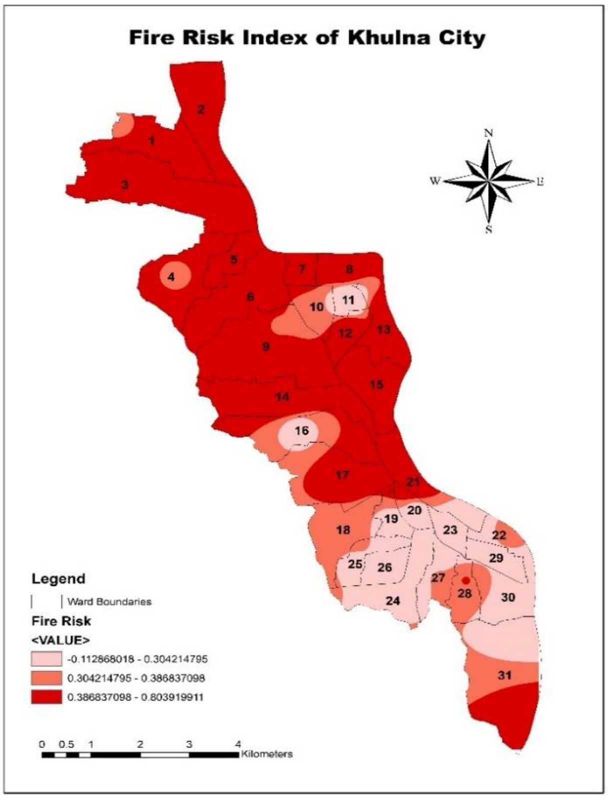


Figure-2: The Fire risk map of the study area

Conclusion

This paper has introduced ward wise fire risk assessment with the application of Index based approach and GIS for Khulna city, which is expected to help the policymakers to identify hotspots for managing fire risks of the city. The analysis technique used in this paper can be applied in any geographic location which is at risk of fire. A more detailed analysis could not be done due to time and resource constraints. Therefore, further researchers are suggested taking more variable at the neighborhood level to develop a more comprehensive fire risk assessment of Khulna city.

Acknowledgment

The authors would like to thank M.D. Rezaul Karim, Aditional Director, fire service and civil defense authority, Khulna and Abu Sayed, Town Planner, KDA for their valuable opinion and also grateful to fire service and civil defense authority for providing the fire incident data those made this analysis possible.

References

International Federation of Red Cross and Red Crescent Societies (2016) *"World Disaster Report 2016"*

International Federation of Red Cross and Red Crescent Societies (2010) "World *Disaster Report 2010"*

Department of Disaster Management (2013*) "Disaster Report 2013"*, Ministry of Disaster Management & Relief, Government of the People's Republic of Bangladesh.

Ardianto, R. and Chhetri, P. and Dunstall, S. (2015) "Modelling the likelihood of urban residential fires considering fire history and the built environment: A Markov Chain Approach", *21st International Congress on Modelling and Simulation*, Australia, 1154-1156.

Saaty, T. L. (1990) "How to make a decision: the analytic hierarchy process", *European journal of operational research*, 48(1), 9-26.

Hahn, S.O. and Riedered, A.M. and Foster, S.O. (2008) "The livelihood vulnerability index: a pragmatic to assessing risk from climate variability and change- A case study in Mozambique", *International Journal of Climate and development,* 2-18.

Pelling, M. (2003) "Vulnerability of cities: Natural disaster and social resilience", *Earthscan publication,* London, 23-49.

STRUCTURAL VULNERABILITY ANALYSIS DUE TO FLAMMABLE CHEMICAL EXPLOSION IN OLD DHAKA

Jerin. Tasnim[1], Khaja. Sameer. Sadat[2] and Tasnuba. Binte. Jamal[3]

ABSTRACT

The city of Old Dhaka is one of the most densely populated area in Dhaka South City Corporation. Many unplanned industries are enhancing the hazard of probable structural damage. There are many stores containing extremely hazardous flammable chemicals that are stocked and handled without any sort of safety measures. All of the surveyed 360 stores, warehouses, factories and shops with the chemicals were found highly hazardous in terms of fire safety, handling of the chemicals and explosion management, according to the findings of a recent fire inspection. In 2010, the Nimtoli inferno was occurred by such flammable chemicals. In this study, the approximate structural vulnerability due to the probable occurrence of explosion by these flammable chemicals will be assessed by ANSYS simulations.

Introduction

The old Dhaka is known as one of the most unplanned and densely populated cities in the world map. In old Dhaka it was surveyed that five families live together in 860 square feet apartment which has limited or no structural design considering the higher amount of live load. Besides, the condition of the roads is deplorable. Moreover, it is estimated that 80% of residential houses in old Dhaka city have some kind of factory or warehouses on the ground floors and residential flats on other floors. Back on 3rd June in 2010 the Nimtoli tragedy took place where a chemical warehouse situated on the ground floor was the root cause which engulfed the entire building and neighborhood in a flash. 117 people died and more than 120 injured just in one night by only one fire hazard which was outcome of an inflammable explosion.

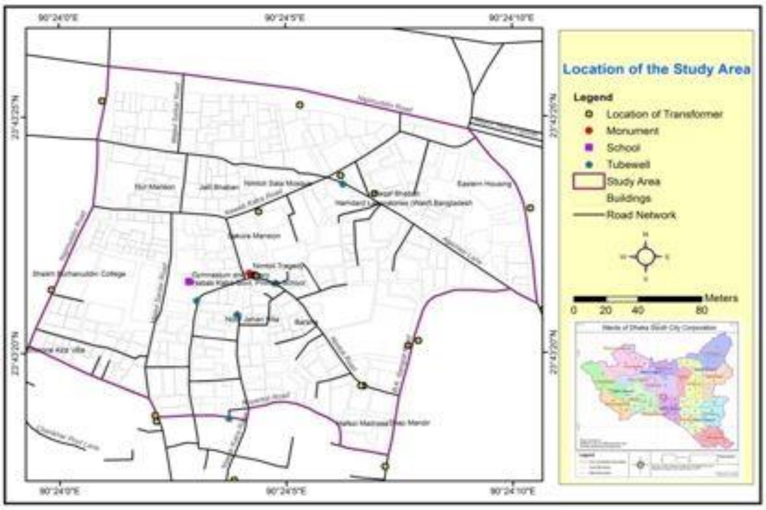


Figure 1. Location of study area (Islam, 2016)

The Nimtoli tragedy has gone through only fire hazard. But explosion is associated with blast and impulse also. And if an explosion occurs which can create blast will simply result in structural failure because the buildings in old Dhaka is not designed properly to carry the code specified loads let alone blast load. Though the authorities promised to shift all chemical stores from the old Dhaka part to a safer place in the city outskirts, the promise simply fizzled out and accidents are occurring now and then. It is also reported that 50 thousand houses of old Dhaka are risky for living. Among them, 22 thousand are at high risk. Nearly 3 million people living in old Dhaka face the risk of death (The Daily Star, 2010).

The Ward number of Nimtoli is 33 (former 69) which is under the Dhaka South City Corporation

[1] *Undergrad Student, Dept. of Civil Engineering, BUET, City-1209, Bangladesh*
[2] *Undergrad Student, Dept. of Civil Engineering, BUET, City-1209, Bangladesh*
[3] *Undergrad Student, Dept. of Civil Engineering, BUET, City-1209, Bangladesh*
Email of Corresponding Author – jerin201572@gmail.com

and Bangshal Thana having a total area of 13 acres 51,550 sq. m.

It is not predictable as to when and where a bigger inflammable explosion may occur. As such vulnerability assessment and identification of blast threat are important. Therefore, the focus of the research will be on the response of a residential building with warehouse on the ground floor under blast loading to show the catastrophe associated with such explosion and also for civil engineers can contemplate on building retrofitting and blast resistant design to specially design the factories and warehouses in a planned and safer place.

Methodology

The overall study was conducted by the following two processes:

Data Collection

A reconnaissance survey was conducted to characterize the building types, plot patterns, mode of land usage and types of roads. Old Dhaka is one of the most densely populated cities, many structures and lands were built up without maintaining proper provisions and codes, so approximation were made in some cases while conducting the survey. The road width was of special concern in this study to measure the standoff distance of explosion from the building. The data found are hereby shown below:

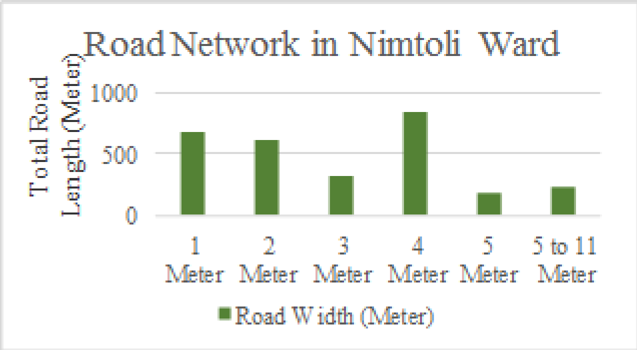


Figure 2. *Road networks in Nimtoli ward (Islam, 2016)*

Here for assuming standoff distance 95th percentile value, i.e. 4m of road width was assumed as detonation point.

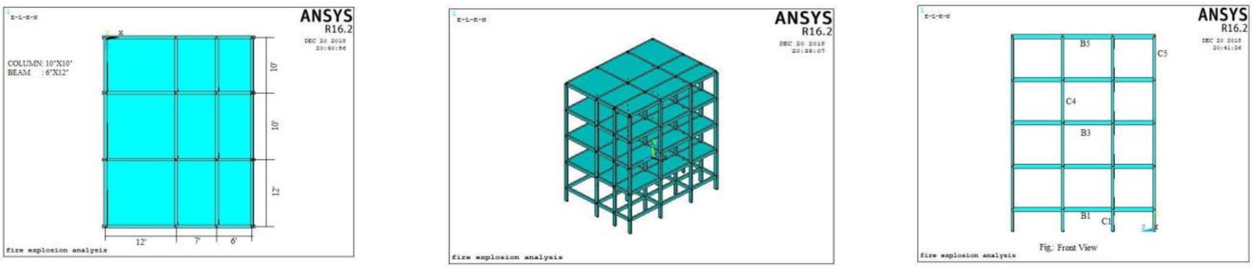


Figure 3. *Plan, isometric and front elevation of the representative structure of Nimtoli showing members under*

The plot area chosen consists of 25X34 sq feet plot area. The building was 4 storied, it was divided into 9 panels. There were 12 columns, each was 10X10 sq inch and 12 beams of 6X12 sq inch area showed in figure 3. There had been visibly no space between two consecutive buildings, closely spaced. The warehouse was only 4m above the plot chosen, so the standoff distance of our structure is considered as 4m. Also, the explosives are inside the warehouse, so confined surface blast criterion is assumed. For analysis purpose, three beams (B1, B3, B5) and three columns (C1, C4, C5) are chosen and their location is showed in figure 3.

Analysis

The structure under experimentation was simulated in ANSYS 16.2 version by mode of superposition transient analysis. This method sums factored mode shapes (eigenvectors) from a modal analysis to calculate the structure's response. Its advantages are; a) it is faster and less expensive than other two, b) element loads can be applied, and c) it accepts modal damping. The disadvantages are; a) time step must remain constant like reduced analysis, b) it cannot be used for floating or disjointed structures, c) it does not accept imposed (nonzero) displacement.

Calculation of Reflected Pressure at Different Point of the Frame Members

There are several approaches to calculate blast load acting on a structure. In this paper the blast loads acting on the members of our designated building is calculated according to JRC Technical Report published by European Commission in December 2013. When blast load acts on a structure, the structure undergoes both positive pressure phase; meaning pressure greater than ambient pressure and negative pressure phase; meaning suction. The peak overpressure can be found at positive pressure phase, so we have calculated our applied pressure considering positive pressure phase. The warehouses in our study area contains many potentially explosive chemicals. For structural blast behavior analysis, most common approach is to assume TNT equivalent detonation. The 1000kg equivalent TNT detonation is considered in this study. The necessary data for calculation is collected from the graph following:

Result and Discussion

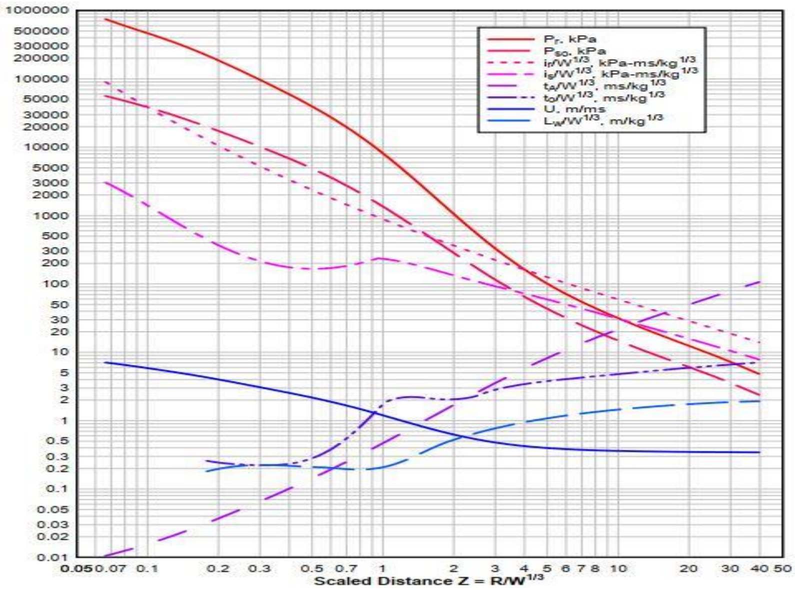


Figure 4. *Parameters of positive phase of shock hemispherical wave of TNT charges from surface bursts (JRC, 2013)*

From our simulation, upon the application of 1000kg equivalent TNT detonation from 4m distance at an arrival time(ta) of 1 milli second and blast duration(td) of 22ms the maximum deflection of the entire structure is shown following:

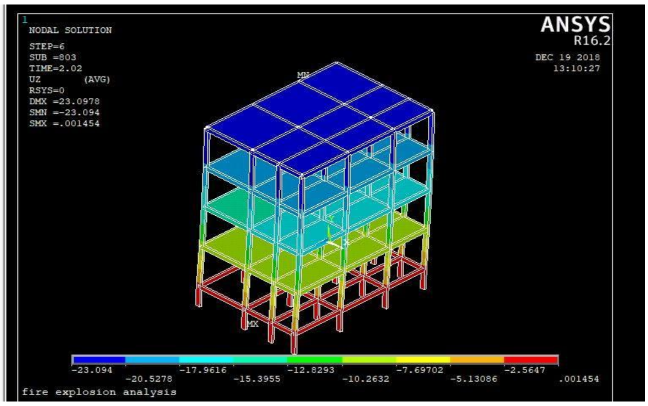
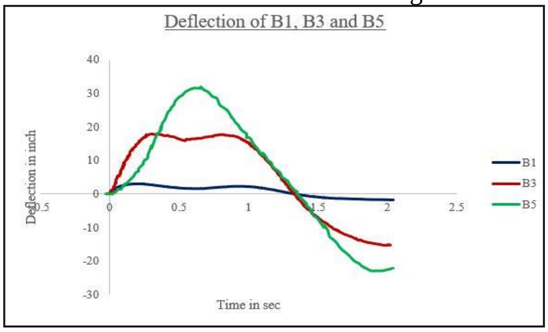
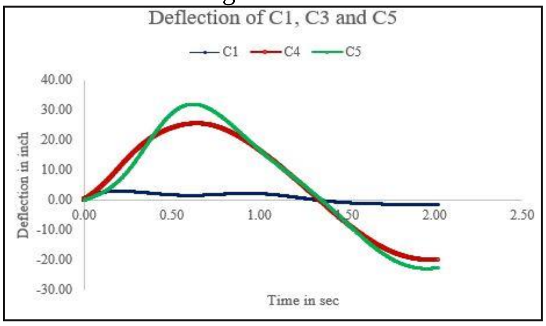


Figure 5. Isometric view of the deformed response of the structure for ta= 1ms and td= 22ms

The maximum deflections for the designated beams and columns are shown following:



(i)

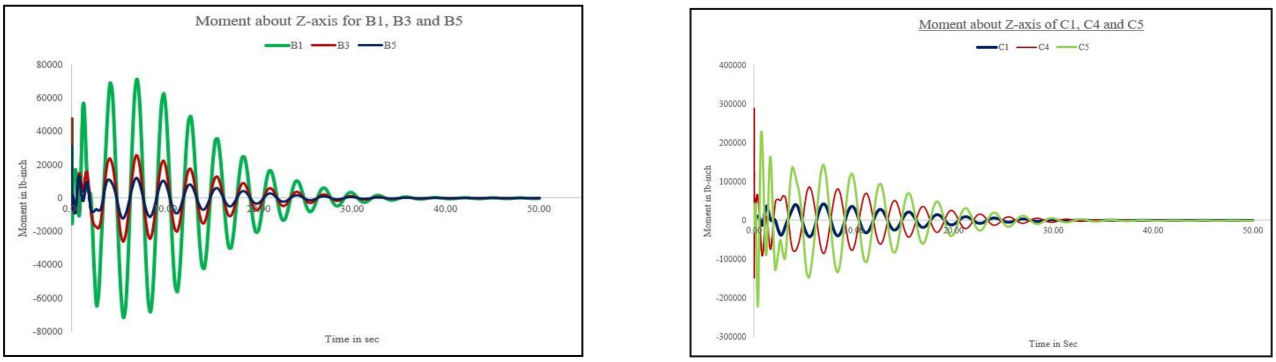


(ii)

Figure 6. Time history for deflection of (i) beams and (ii) columns under blast loading

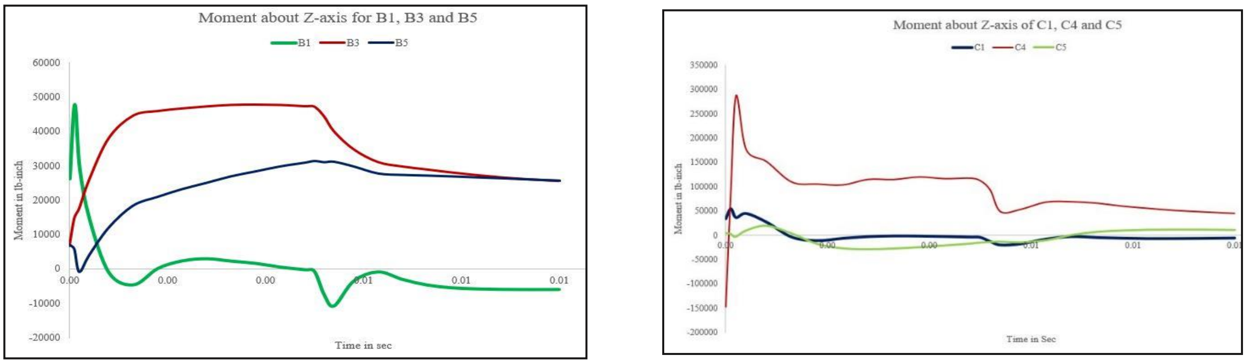
From figure 6 it can be seen that maximum deflection occurs at roof members; the beam undergoes a deflection of 32 inches and column 33 inches. Both of them attain their peak deflection at 0.65sec. The B1 beam and C1 column at 1st floor undergo least deflection, 2.5 inches both. As the allowable deflection of the structure is L/500 = 1.08 inches, the structure undergoes the deflection value far beyond and the top floors will collapse if subjected to blast loading.

The moment variation of various members within first 50 seconds is shown following:



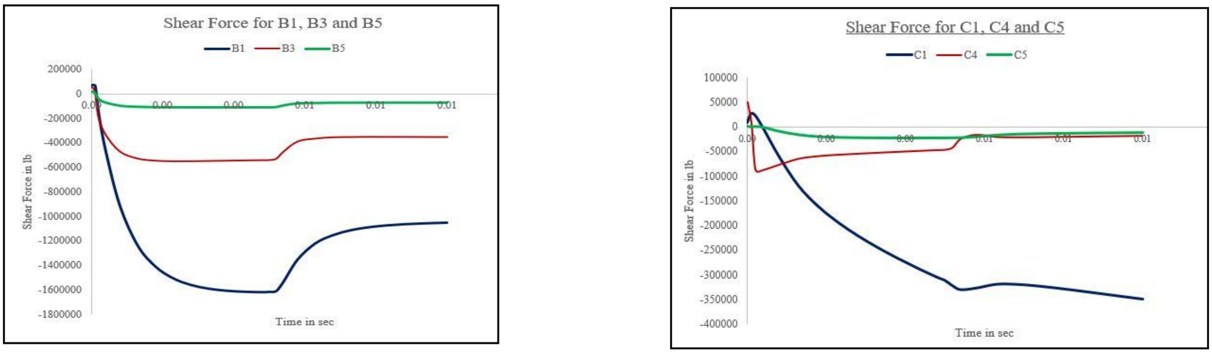
(i) (ii)

Figure 7. *Time history for moment for (i) beams and (ii) columns under blast loading for first 50sec*



(i) (ii)

Figure 8. *Time history for moment for (i) beams and (ii) columns under blast loading for first 10ms*



(i) (ii)

Figure 9. *Time history for shear for (i) beams and (ii) columns under blast loading for first 10ms*

From figure 7 and figure 8 we can see that beam B1 achieves maximum moment at 0.60 sec, same as the time B1 has maximum deflection and the moment value is 74000lb-inch. For column C4 at 3rd story it gains maximum moment at very initial time period and the value is 28000lb-inch. Both of their moment-time history represents oscillation similar to damped harmonic free vibration for under-damped condition.
Figure 9 represents time history for shear force. Here, beam B1 and column C1 of ground floor is susceptible to maximum shear. The beam is more overstressed than that of column. The column and beam of roof undergo least amount of shear in this analysis.

Conclusion

The rationale of the study is to investigate the response of a representative structure in old Dhaka under blast loading occurring from chemical explosion. From our analysis we can visualize that the structure is severely vulnerable to blast loading due to very small standoff distance. The roof of the representative structure collapses due to flexure and the ground floor collapses due to shear. Also, after the detonation takes place, the response of the structure is similar to damped harmonic free vibration up to first 50sec. The structure will

perish if its natural frequency overlaps with the applied frequency.
It would be impractical to ensure safety of the structure by raising the member sizes because this will increase the dead load of the structure, making it more vulnerable to earthquake. Shifting of chemical warehouses is highly recommended. Safety can be ensured also by erecting guard wall around the structure which can resist blast loading.

References

Hossain. Zahid. (2005) "Behavior of Exterior Frame of Buildings Under Blast Loading with Special Reference to Theaters and Halls", *MSc. Thesis,* BUET.

Institute for the Protection and Security of the Citizen (2013) *"Calculation of Blast Loads for Application to Structural Components",* European Union.

Islam. Zahidul. (2016) "An Assessment of Fire Hazard Risk in Old Dhaka: A Case Study of Nimtoli Area", *MSc. Thesis,* Dhaka University.

A STUDY ON FIRE FIGHTING CAPACITY OF FIRE STATIONS OF DHAKA METROPOLITAN AREA

Tanjiba Rahman Tishi[1], Ishrat Islam[2]

ABSTRACT

Among the urban disasters, fire incident is one of the most disastrous which causes property losses and sometimes death and injury within a short time. High density of population and structures make the urban areas more vulnerable to fire hazard than the others and results in huge economic loss. Like many other cities, fire incidents are very common in Dhaka city. Worldwide, fire service or fire station provides predominantly emergency fire-fighting and fire protection services for a specific geographic area and to ensure better urban safety, ensuring optimum fire-fighting capacity is mandatory. In this paper, the overall fire-fighting capacity of twelve fire stations of Dhaka Metropolitan Area (DMA) has been evaluated along with three study area for detail fire-fighting capacity assessment. The capacity has been evaluated from two perspectives: spatial and non-spatial parameters. The spatial parameters include the issues related with the location of the station and the non-spatial parameters include the capacity of staffs, equipment and vehicles. The nature of equipment and vehicles also needs to conform to the land use characteristics and built structures. The capacity has been evaluated compared with different practicing national and international standards. Besides, a comparative scenario of fire-fighting capacity has been depicted among three other cities. The result of the research will help to understand the present capacity of fire stations of DMA and will help the respective authority to identify the sectors where improvement should be done to ensure better fire safety.

Introduction

Fire-fighting capacity means the ability to fight against any fire incident. To ensure urban resiliency optimum fire-fighting capacity is one of the most important issue. The trend of urban fire is closely related to the level of urbanization of an area (Wang et.al, 2011) and due to rapid urbanization, the Greater Dhaka district (Dhaka, Gajipur, Munshigonj, Manikgonj, Narayangonj and Narsingdi) is experiencing more fire incidents compared with other part of the country (Figure 1). Among the total reported fire incidences in Bangladesh, 18.17%, 15.36%, 15.96% and 16.14% incidents were occurred in greater Dhaka district in the year of 2010, 2011, 2012 and 2013 respectively (FSCD, 2013).

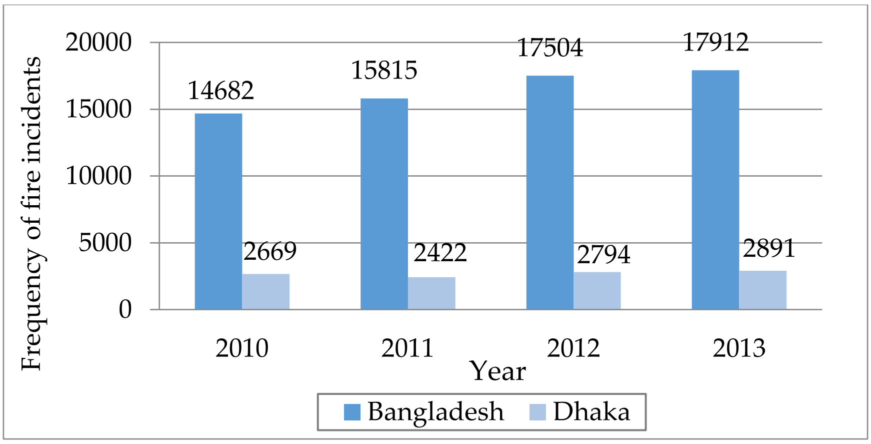


Figure 1. Yearly trend of fire incidents of Bangladesh and Greater Dhaka district, BFSCD, 2014

Worldwide, fire station plays the vital role in ensuring fire safety (Hacıoğlu, 2010). In Bangladesh, the

[1]*Post-graduate, Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh*
[2]*Professor, Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh*
Email of Corresponding Author – tanjiba@yahoo.com

governing authority of Fire Stations – Fire Service and Civil Defence (FSCD) Directorate is the first respondent in all natural and manmade calamities and remains alert round the clock to fight fire and surface rescue operations. At present, in Dhaka, Bangladesh Fire Service and Civil Defence (BFSCD) has 12 fire stations with approximate 400 fire-fighters and rescuers who have to cover 16 million people living in the city. Besides, the number of operational and rescue vehicles and equipment are not sufficient with the increasing demand and most of them are obsolete. Setting up of new planned service stations are also being delayed due to limited resource (FSCD, 2013).
The fire-fighting capacity of any fire station should conform to the national and international standards. The location and the service area of the fire station, are important issues to reduce fire risk. Along with these spatial requirements, a number of non-spatial issues, such as staff, equipment, vehicle, function, organization and technology etc. are also related with efficient fire services (Hacıoğlu, 2010). Optimum level of staff in accordance with the population demand is also important in order to effectively perform fire extinguishing activities (Monday, 2000).

Data and tools

In this research, the capacity of 12 fire stations of DMA has been assessed using two parameters like spatial parameters and non-spatial parameters. Spatial parameters are basically related with the location of fire stations which include:

1. coverage area: the area which is served by a specific station
2. population served: population living within the coverage area
3. standard service area: the area served by a station within a standard response time period

On the other hand, non-spatial parameters include capacity of staff, equipment and vehicles.

The average coverage area per station; average population served per stations; population staff ratio of the stations of DMA has been explored and compared with different international standard as well as with practicing standard of different countries collected from secondary sources. The travel time zones of the fire stations of DMA indicating the standard service area have been generated using Network Analyst tool in Arc GIS 10.1 showing the area that can be reached by the stations within the standard response time.
And to assess the non-spatial parameters; number of fire-fighting staff and fire-fighting equipment and vehicles; data have been collected from the field survey at the fire stations and compared with different standards.

Capacity of fire stations

In Dhaka Metropolitan Area, there are 12 fire stations named i) Mirpur Fire Station ii) Mohammadpur Fire Station iii) Baridhara Fire Station iv) Lalbag Fire Station v) Postogola Fire Station vi) Palashi Barrak Fire Station vii) Kurmitola Fire Station viii) Sadarghat Fire Station ix) Siddiq Bazar Fire Station x) Khilgaon Fire Station xi) Tejgaon Fire Station and xii) Demra Fire Station (Figure 2). From the map, it is clear that the stations are mostly concentrated in the southern part of the area.

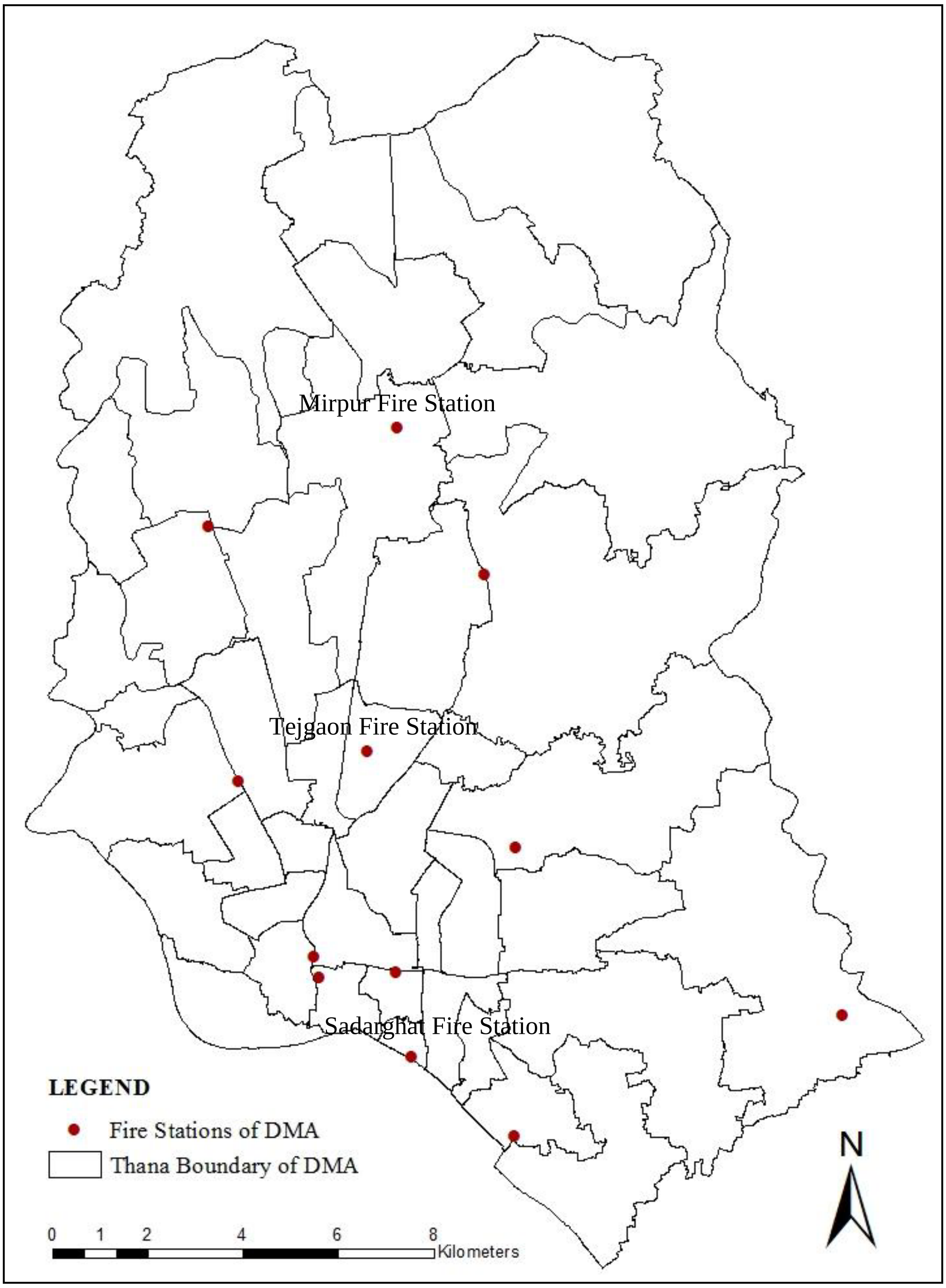


Figure 2. Map of thanas of Dhaka Metropolitan Area with 12 fire stations

Overall capacity of the fire stations has been evaluated for 12 stations and detail capacity has been assessed for three fire stations which have been selected considering three different broad land use categories. The selected stations are: 1. Sadarghat Fire Station- serving mixed land use area (Kotwali *Thana*) 2. Tejgaon Fire Station- serving industrial area (Tejgaon Industrial Area *Thana*) 3. Mirpur Fire Station- serving residential area (Pallabi *Thana*).

Coverage Area and Population Served

According to Bangladesh Fire Service and Civil Defence (BFSCD) rules, there is a designated area for every fire station to respond first in times of any fire incident within that area. This area is termed as 'coverage area' of respective fire station. When the first station cannot put off the fire then the other neighboring stations add their support in fire-fighting activity. In terms of coverage area and number of served population by a station, there is no standard in Bangladesh. In this research, the Environmental Building Guidelines for Hyderabad

Metropolitan Development Authority (HMDA, 2014) has been considered as the standard. Being part of the same sub-continent, the socio-economic condition of Bangladesh resembles greatly with India having deep historical linkage which results in similarity between the type of urban structures and inherited hazards of Dhaka and the prime cities of India. So, this guideline has been considered as a standard. According to the guidelines, there should be at least one fire station or a sub-fire station for a population of 0.2 million people, within 1 to 3 kilometer (HMDA, 2014).

In DMA, overall 12 fire stations are responsible to serve around 340 sq.km. area and approximately 9 million people of Dhaka. On an average, the coverage area per station is 25.17 sq.km. and the population size served per station is 0.742 million which is almost four times than the standard.

In Figure 3, coverage area of the three selected stations has been prepared based on the information collected from three selected fire stations. Then the population within these areas has been calculated from the population data of the Bangladesh Bureau of Statistics (BBS), 2011.

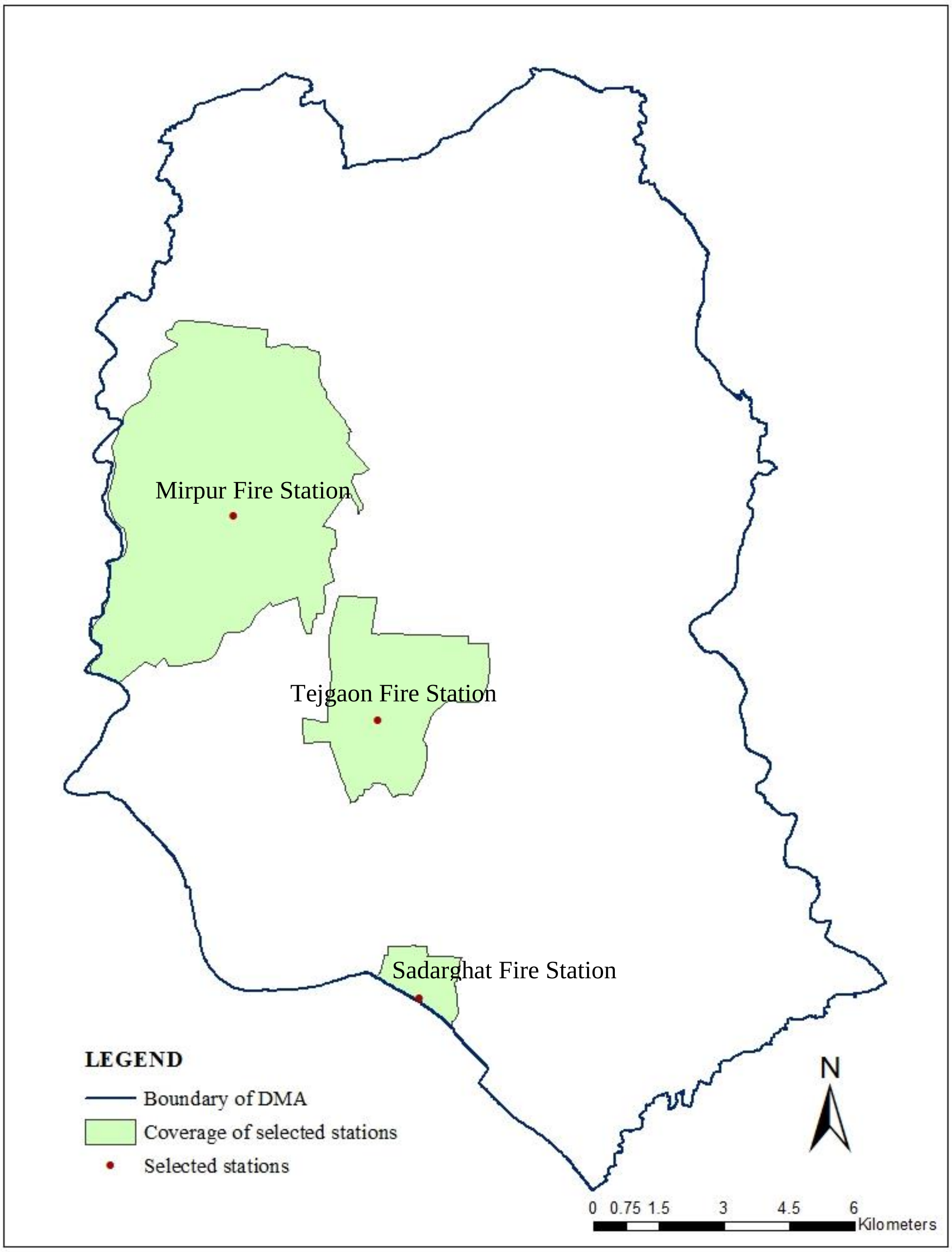


Figure 3. Map of coverage area of selected fire stations

The capacity of the three fire stations are stated below:

Table 1: Coverage area and serving population of selected stations

Station name	Location	Coverage Area (sq. km.)	Population served
Sadarghat Fire Station[a]	Southern part of city	2.14	2,19,133
Tejgaon Fire Station[b]	Middle part of the city	11.12	4,61,801
Mirpur Fire Station[c]	Northern part of city	35.15	17,13,523

Source: a. Sadarghat Fire Station, b. Tejgaon Fire Station, c. Mirpur Fire Station; 2014

The Table 1 shows that, the coverage area and the number of served population differ in a long range from one station to another. As in southern part, the number of the station is higher, their coverage area and size of serving population is lower than that of a station of northern part. The coverage area of Sadarghat Fire Station is about 17 times smaller than that of Mirpur Fire Station. As there is no more station to the north of the Mirpur Fire Station, the designated coverage area of this station is higher than any others.

Comparative scenario of different cities

In different cities of the world there are different practicing standard of coverage area and serving population. In cities of Europe and USA the standard is high whereas in cities of Asia this standard is lower.

Table 2: Coverage area and serving population per station of different cities

Name of the City	Average area coverage (sq.km)/station	Average population /station
Oklahoma city (TriData, 2014)	44.81	14,952
Delhi (Delhi Citizen Handbook, 2014)	36.19	33,600
Bangkok (Sripramai et. al.	44.82	16,290
Dhaka (BBS, 2011)	25.17	7,42,170

In Dhaka city, average area coverage per station is relatively lower than the others. But as the density of population is very high in this city, average population severed by every station is very high which is around 22 times larger than average population served by every station of Delhi, 45 times larger than that of Bangkok and 49 times larger than that of Oklahoma City.

Standard Service Area

In fire-fighting activities, response time is one of the most crucial issue, as the loss due to fire incidents increases with increased response time. Standard service area is the designated area within which the fire-fighting team can reach in standard response time.

Response time is the time duration which starts when the call is received and ends when the fire fighter reaches the fire incident point. While the speed of response is not directly indicative of outcome or quality, response times do affect the number of lives saved and the extent of property losses averted when an emergency occurs. Fire spreads quickly after ignition and the faster it is found and extinguished, the better the results. More people can be helped or the fire can be put out before the entire spot is consumed when emergency personnel arrive in 5 minutes rather than 10 or 20 minutes.

However, there is no single set of nationally accepted response time standards. But, according to National Fire Protection Association (NFPA) standard, the first fire fighting vehicle is supposed to arrive at a fire incident within 4 (four) minutes or less and/or the full assignment team is required to arrive within 8 (eight) minutes or less (NFPA, 2014). But, BFSCD has set their minimum response time as 10 minutes considering the existing road network system (FSCD, 2013). According to BFSCD officials, in times of fire incidents, though the turn-out time of the fire-fighters is only 30 seconds, the team cannot reach the incident spot in due time basically because of huge traffic congestion on their way to destination

So, in this research, standard service area has been identified using the standard response time of 4 minutes, 8 minutes and 10 minutes.

Standard service area demarcation

In this research, the simple road network data has been used with limited information like speed limit, travel time. The speeds of the vehicles of Dhaka city at different roads vary from one another due to different road width and traffic volume. But, this variable speed of different roads could not be found from secondary source. So, the average speed of vehicles of Dhaka city has been used in travel time calculation for fire-fighting vehicles. The Dhaka Transport Coordination Board (DTCB) had found the average vehicle speed of Dhaka city of 15kph (DTCB, 2010) which has been considered as the speed of fire-fighting vehicle. In the process of service area demarcation, a network dataset has been created from the road network dataset having the attribute of road length, average speed and travel time. Then from this network data set the standard service area has been developed for 12 fire stations of DMA for standard response time. As mentioned earlier, NFPA recommended standard response time of fire-fighting team as 4 minutes and 8 minutes. And BFSCD has set their standard response time of 10 minutes. So, service areas of 12 fire stations of DMA have been created for 4 minutes and 8 minutes and 10 minutes travel time (Figure 4).

From the Figure 4, it is depicted that, in case of four minutes travel area there is no overlapping and within this time frame only 18.47 sq.km. area is covered by the stations. In case of eight minute travel area, there is no overlapping in north and east part. But in southern part, the eight minutes travel area of five station overlap with each other. Within eight minute time duration the stations cover additional 51.62 sq.km. As a whole,

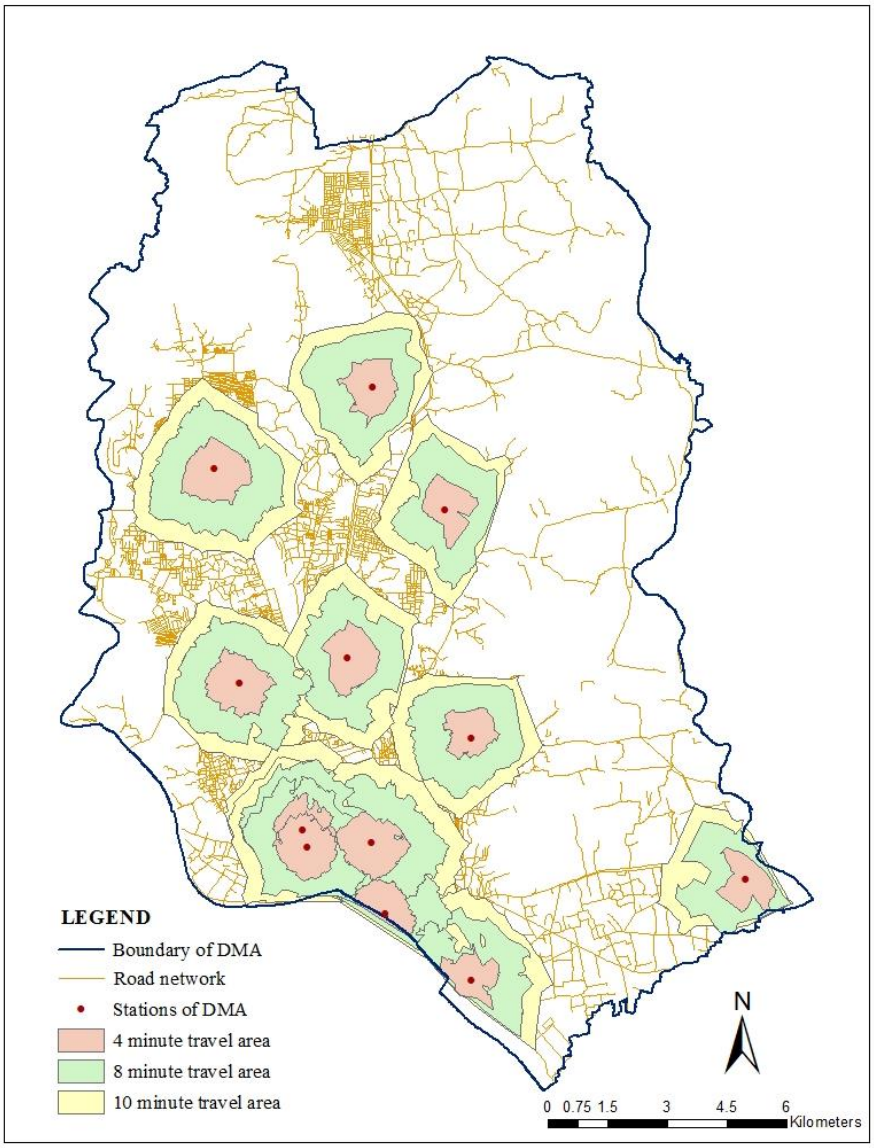


Figure 4. Service areas of 12 fire stations of DMA using standard response time

within 10 minutes travel time the stations cover approximately 100 sq.km. area of DMA. Thus, about two-third area of DMA (242 sq.km.) is out of standard service area. And about 4.13 million population is living within the area. So, around half of DMA population is living out of the standard service area.

Capacity of staff

Efficient fire-fighting is only possible when the service is properly staffed. Total staff includes the officials and the staffs involved in fire fighting activity. As a whole, there are 378 trained fire-fighter which include officials and fire-fighting staffs in 12 fire stations within DMA. All the fire staff get 24 hour gap after a duty of 48 hour. But the officials do not get any prescribed gap within their duty time. If necessary, they have to take leave from their office duty.

The National Fire Protection Association (NFPA) and the International City Managers Association (ICMA) recommend an ideal service ratio of one on-duty fire fighter per 2,000 population served (Orcutt Community Plan EIR, 2014). In DMA, the ratio of population per on-duty fire fighter is approximately 34,250. In the selected stations the number of fire-fighting staffs are given below:

Table 3: Number of manpower in selected fire Stations

Name of fire station	Officials	Leader	Driver	Fire-staff	Total
Sadarghat Fire Station[a]	2	3	5	15	25
Tejgaon Fire Station [b]	2	3	5	19	29
Mirpur Fire Station[c]	2	3	5	22	32

Source: a.Sadarghat Fire Station, b.Tejgaon Fire Station, c. Mirpur Fire Station; 2014

Total number of fire fighters of Sadarghat Fire Station, Tejgaon Fire Station and Mirpur Fire Station is respectively 25, 29 and 32. These stations are supposed to serve a population of about two lac, four lac and seventeen lac respectively. So, with the different size of served population the number of fire-fighters does not vary notably. In practical scenario of three selected stations, this ratio of population and fire fighter is approximately 12,170 for Sadarghat Fire Station, 23,000 for Tejgaon Fire Station and 77,840 for Mirpur Fire Station. Thus, for all selected fire stations this ratio is much larger than the standard ratio.

Comparative scenario of different cities

In different cities, there is different population staff ratio.

Table 4: Population Staff ratio in different cities

City	Population staff ratio
Oklahoma city (TriData, 2014)	645
Delhi (Delhi Citizen Handbook, 2014)	5,115
Bangkok (Sripramai et. al.	3,801
Dhaka (BBS, 2011)	23,686

In DMA, population density is very high compared to other city. So, in Dhaka, the population staff ratio is very high which is approximately 4 times larger than Delhi, 6 times larger than Bangkok, and 36 times larger than Oklahoma city.

Capacity of Fire-fighting vehicle

Fire-fighting vehicle is one of the vital elements of fire-fighting. It is very much necessary to reserve essential vehicles for any type of emergency. The type and capacity of these emergency vehicles must conform to the specific requirement according to built structure, land use characteristics and pattern of fire incidents.

In India, according to National Disaster Management Guidelines of Fire Services, following vehicles are recommended as standard scale for each fire station (NDMA, 2012).

a. Water Tender
b. Extra Heavy Water Tender
c. Ambulance

Besides, in addition to the appliances mentioned above, more specialized appliances should be provided at selected fire stations according to local circumstances. Among which Turn Table Ladder, Hydraulic Platform, Extra Heavy Pumping appliance, Motor Cycle Mist and Foam Tender are important fire-fighting vehicle.

In Bangladesh, the emergency fire fighting vehicles mostly cover the above mentioned vehicles. A list has been provided of the fire fighting vehicles of BFSCD in the appendix.

In written document, the designated type and number of vehicle and equipment did not consider the specific land use characteristics. For example, in the areas with narrow road, there should have more water mist rather than special water tender. Moreover, in the areas of high rise building, big turn table ladder is needed. But, according to Newaz (2014), "In practical scenario, recently the vehicles are being distributed according to the local requirements."
Here, a comparative scenario has been depicted for the mentioned three stations.

Requirement of fire-fighting vehicles in relation to landuse characteristics

From the field survey in the selected three stations, the existing fire fighting vehicles has been enlisted.

Table 5: List of existing fire-fighting vehicles of Three Fire Stations

	Sadarghat Fire Station		**Tejgaon Fire Station**		**Mirpur Fire Station**	
Name of fire fighting vehicle	**Number**	**Capacity**	**Number**	**Capacity**	**Number**	**Capacity**
Water Tender	1	4500 liter	3	4300 litre 4300 litre 1800 litre	1	6,500 litre
Special Water Tender	-	-	-	-	1	11,000 litre
Toeing Vehicle	1	-	1	-	2	-
Pump	3	500 Hz	3	500 Hz	6	500 Hz
Hose pipe	22	Dia: 2.5 Length: 50-100 ft	45	Dia: 2.5 Length: 50-100 ft	60	Dia: 2.5; Length: 50-100 ft
Foam can	5	25 litre	-	-	-	-
Foam Trolly	-	-	1	400 litre	1	300 litre
Snorkel	-	-	-	-	1	7-8 story
Cold-cut			1	-		
Water Mist	4	40 litre	4	30 litre (2) 40 litre (2)	2	40 litre (2)
Ambulance	1		1		1	

Source: Sadarghat Fire Station, Tejgaon Fire Station, Mirpur Fire Station, 2014

To assess the requirement of fire-fighting vehicles in relation to landuse characteristics, firstly information has been collected on structure type, storey of the structures, road width and broad land use of three *thana*s- Kotwali *thana*, Tejgaon Industrial Area *thana*, Pallabi *thana* which are served by the selected stations.

From that analysis, it has been found that, in Kotwali *Thana* major land use is commercial use (30.84%) and mixed use (32.72%). In this type of uses, probability of losses is higher than residential use in case of fire incidents. But in Sadarghat Fire Station, there is only one Water Tender in this station. Maximum structures of this *thana* are pucca and within four storied (80.58%). But, the maximum storied of buildings is 14. So, fire vehicles should be ready to fight against fire up to 14 storied building. But, in Sadarghat Fire Station, there is no Turn-table Ladder. According to Mohammad Belal Ahmed, Station officer of Sadarghat Fire Station, for large scale fire having the fire origin of oil or chemical reaction in the mixed use buildings, the station has to depend on the vehicles stored at head office. At the same time, in times of fire incidents at more than fourth level of the buildings the head office gives them support with Turn-table Ladder. In this area, most challenging issue is narrow roads. According to the fire officials, for the Water Tender more than 10ft width of the road is required to get access. But, in this *thana*, around 65% roads are within 10 ft width. There are four Water Mists in this station to give access to the narrow roads. But the number and capacity of Water Mist is too low to cover a serious incident. There is no water hydrant and no fixed source of water. In case of emergency the fighter has to join the hose pipes from the distant water source and carry it to the spot which process is time consuming and results in greater loss.

Tejgaon Industrial Area *Thana* is mainly an industrial area (25.41% area). For industrial area Foam Tender, Foam Canon and Chemical Tender are special fire fighting vehicle, as in such type of areas probability of being the fire sources of oil or chemical reaction is high. So, it is important to have these vehicles in Tejgaon

Fire Station. But, as mentioned in Table 5, there is a Foam Trolly, which supplies foam, whose capacity is not so high to act with big fire incidents. Besides, in Water Tender, Water Mist and Cold-cut, there is provision of foam. According to, Nuruzzaman (2014),

"Maximum fire incidents can be controlled using the vehicles and instruments stored in the station as the incidents are not always severe. But, in case of severe fire incidents having the fire source as oil or chemical reaction, the station has to depend on Head quarter."

In this *thana*, though 92.27% buildings are within four storied, the maximum storied of buildings is 23. But, in Tejgaon Fire Station, there is no Turn-table Ladder to fight against the fire as upper level of the buildings. Though maximum roads (76.35%) of this area are more than 10ft wide, there are some roads of less than 7ft width (Figure 6.4). To get access to narrow roads there are four Water Mists to handle small size fire as their capacity is low.

In Pallabi *Thana*, major land use is residential use (60.91%) and most of the structures are semi-pucca (47.97%). In residential areas though average loss for fire is lower, number of fire incidents is highest. And the coverage area of this station is higher than the others (Figure 3). So, there is one Water Tender and one Special Water Tender in this station to put off fire. There is also a Foam Trolly to extinguish the fire created from oil. In this *thana*, 92.69 % building are up to four storied. In this station, though there is no vehicle to reach to 14 storied building, but there is a Snorkel to reach up to 8 storied building. Though, the width of the roads mostly (54.2%) range from 10ft to 30ft, there is 33.48% road of less than 10ft width. To get access to narrow roads there are two Water Mists whose capacity is very low.

Conclusions

It is seen from the research that, the stations are more concentrated in the southern part of the city not covering some part of northern and eastern side. Besides, the 10 minutes service areas of 12 fire stations does not cover approximately two third area of DMA (about 242 sq.km.) and approximately half of DMA population. So, the authority should give importance to set new fire stations in these underserved areas with careful planning for setting up new fire stations at appropriate location. Some stations can be relocated in other demanding places. So that the optimum number of fire stations will be well distributed to serve maximum population.

Besides, for covering the large population of DMA more fire-fighting staffs should be recruited according to the requirement. Besides, the officers of the stations do not enjoy any weekend which is pitiful for their personal and social life. For every stations more officers should be recruited so that shift duty can easily be an effective solution in this regard. At the same time, recruitment process should be more efficient. Besides in many countries, volunteer fire fighters play efficient role in times of emergency. In this context, volunteer training in regular basis can be an effective solution to reduce the pressure of regular fire-fighters. So, volunteer training should be arranged periodically to train the general people for fire-fighting.

The fire-fighting vehicles should be placed in every fire station depending on the requirement of that specific station coverage area. Detail research is needed for every service area to understand the pattern of fire incidents and provide vehicles and equipment according to the requirement.

If the government and the local community can work together to fight against the fire, it will reduce the risk of destruction in times of incidents and ensure better safety.

Acknowledgments

The research work has been carried out with the fund of BUET to complete the degree of Master of Urban and Regional Planning (MURP).

Appendix

List of Fire fighting vehicles of BFSCD:

<u>Water Tender:</u> Typical fire fighting vehicle which mainly store water to put off the fire. It can be of having different capacity ranges from 4000 to 8000 liter.

<u>Special Water Tender:</u> One special type of water tender having higher capacity which ranges from 8000 to11000 liter of water. Basically used in severe fire incidents.

Photograph: Water Tender

Photograph: Special Water Tender

Toeing Vehicle: Actually a carrier vehicle which is used to carry different type of equipment including water pump, foam can etc.

Turn-table Ladder: Special type of vehicle giving access to high rise building of different ranges up to 400m.

Photograph: Turn-table Ladder (up to 400m)

Photograph: Turn-table Ladder (up to 300m)

Foam Tender, Foam Canon: Special type of vehicles which use foam to put off fire having the fire origin of oil.

Chemical Tender: Special type of vehicle having four type of fire extinguishing agent- water, foam, carbon-di-oxide, dry chemical powder, which is useful in any type of fire incidents.

Water Mist: Special type of motor cycle used in giving access to narrow roads having water and foam in its reserve chamber. According to the fire officials, for the water tender more than 10ft wide road is required to get access. Where the road width is lower, this Water Mist can be used to extinguish fire which gets easy access to narrow roads. But, their capacity (40 liter) is very low to fight against severe fire.

Photograph: Foam Tender

Photograph: Water Mist

<u>Cold-cut:</u> Special type of equipment carried by toeing vehicle having high pressure hose. It is also used to cut iron sheet in times of fire incident and rescue event.
<u>Ground Monitor:</u> Useful in severe fire incidents to through large volume of water in longer distance.

References

BBS. Population and Housing Census 2011, Community Report: Dhaka. Bangladesh Bureau of Statistics, Statistics and Informatics Division. Ministry of Planning, Government of Bangladesh, Dhaka, 2011.

Delhi Citizen Handbook, Centre for Civil Society, New Delhi, 2006, Retrieved from ccs.in/sites/all/books/com_books/book_dch_2006.pdf on April 23, 2014.

DTCB, "Preparatory Survey Report On Dhaka Urban Transport Network Development Study (DHUTS) in Bangladesh", Dhaka Transport Coordination Board, Ministry of Communications, Government of The People's Republic of Bangladesh, March, 2010.

FSCD Directorate, "Stakeholder's workshop on finalizing strategic management plan," Fire Service and Civil Defense Directorate, Ministry of home affairs, Bangladesh, 2013.

Hacıoğlu Ç., Spatial requirements of fire stations in urban areas: a case study of Ankara, M.Sc. thesis in Urban Design, Department of City and Regional Planning, Middle East Technical University, Turkey, 2010.

HMDA, "An abridged manual on environmental building guidelines for Hyderabad Metropolitan Development Authority", New Delhi, India: TERI Press, 2009. Retrieved from http://www.hmda.gov.in/ebgh/the%20guidelines/calculators/HMDA-Abridged%20 Building%20Guidelines-english.pdf on April 22, 2014.

Monday C. C., "Optimal staffing levels for firefighter effectiveness and mitigation of firefighter injuries," An applied research project submitted to the National Fire Academy, Martinsville Fire Department, Martinsville, Virginia, 2000.

NFPA, Fire Protection Handbook (20th edition). Quincy, Massachusetts USA: NFPA, 2008. Retrieved from https://www.inkling.com/read/fire-protection-handbook-2008-edition-volume-ii/chapter-13/responsetravel-time-standards on May 12, 2014.

NDMA, "National Disaster Management Guidelines—Scaling, Type of Equipment and Training of Fire Services", National Disaster Management Authority, Government of India, New Delhi, April 2012.

Newaz, AKM S., Director (Operation and Maintenance), Fire Service and Civil Defence, (2014, September). Personal interview

Nuruzzaman M., Station officer of Tejgaon Fire Station, (2014, September). Personal interview

Orcutt Community Plan EIR, Long Range Planning Division, Country of Santa Barbara, (n.d.). Retrieved from http://longrange.sbcountyplanning.org/planareas/ orcutt/documents/OCP%20EIR/OCP%20EIR%20Volume%201/5.14%20Public%20Services.pdf on 17 May, 2014.

Sripramai K., Oikawa Y., Kanai M., and Katada T. "The Relationship between Local Government and Residents in Disaster Prevention Activity", (n.d.), Retrieved from dsel.ce.gunma-u.ac.jp/doc/n200.pdf on 13 March, 2014.

TriData, "Oklahoma City Fire Department Fire Station Location Study", TriData, A Division of System Planning Corporation, Arlington, 2006. Retrieved from http://www.okc. gov/fire/fire_report.pdf on April 23, 2014.

A PROPOSED METHODOLOGY FRAMEWORK TO ASSESS THE FIRE RISK IN EXISTING BUILDINGS

S. P. Bhattacharya[1]

ABSTRACT

Fire is one of the major causes of the manmade disaster. A simple fire-related accident may lead to a complete devastation due to the nature of the built forms and practices of the inhabitancies. Fire constitutes a significant threat to life and property mostly in urban setups. In the recent past, in India and abroad, numerous numbers of fire-related accidents broke out. Other than the life and built properly, a huge amount of local and regional economic loss has been recorded. The norms and guidelines are given in National building code (NBC) of India suitable for a new building design. The old buildings and the building is used to undergo certain addition-alteration. The used pattern and the habits of the occupants are also changed during the passage of time. Many times, it has been witnessed that these changes lead to fire hazards. There is an urgent need to supplement those norms and provide a systematic approach to evaluate the fire risk. In this context, this paper proposed a comprehensive framework to assess the fire risk of an existing building. A two-fold approach is considered in the proposed method. The evaluation of risk is based on rapid visual surveys. Two separate parametric matrixes are considered to calculate the potential of fire hazard. Certain physical parameters are evaluated in each building zone and a Space-Physical parameter Matrix (SPM) is established. Similarly, a Space-Socio economical parameter Matrix (SSM) is also established from a group of chosen socio-economic parameters. All the parameters are normalized based on the weighted factor obtained from an expert opinion survey. The statistical hypothesis tests are proposed to be conducted to screen the effective parameters. Finally, an inclusive mathematical approach will provide the total risk assessment index of the building. Further, the analysis of the risk index will provide the scope of capacity building and the reduction of fire disaster vulnerability of the building.

Introduction

Fire is an essential element of energy transformation. It is very crucial for the human civilization and development process. However, in another hand, fire is treated as one of the major causes of the manmade disaster. A simple fire-related accident due to certain disorders may lead to a complete devastation due to nature of the built forms and practices of the inhabitancies. Fire constitutes a significant threat to life and property mostly in urban setups. In India and abroad, numerous numbers of fire-related accidents broke out in the recent past. Other than the life and built properly, a huge amount of local and regional economic loss has been recorded.

With the technological advance on all fronts, not only the factor of susceptibility but the complexity of fires, explosions and other hazards which these buildings are exposed to, have also increased manifold (Hansen et.al, 2018). These hazards have been instrumental in causing heavy losses in lives and property, throwing up fresh challenges to planners, architects and fire protection services in evolving better and improved methods of design and fire protection in order to mitigate such losses.

The National building code (NBC, 2005) of India had a separate section and provisions for fire safety. The norms and guidelines are basically suitable for a new building design. The buildings are used to undergo certain addition-alteration. The used pattern and the habits of the occupants are also changed during the passage of time. Many times, it has been witnessed that these changes lead to fire hazards. There is an urgent need to supplement those norms and provide an extension and systematic approach to evaluate the risk due to fire (Xin and Huang, 2013). In this context, a comprehensive framework to assess the fire risk of an existing building is urgently needed.

[1]*Assistant Professor, Dept. of Architecture and Regional Planning, Indian Institute of Technology Kharagpur, West Bengal, India*
spb@arp.iitkgp.ac.in

Need and Objective of the Study

Since, independence, India has lost several lives and property in fire-related disasters. Fire hazards become very common incidences, particularly in the urban areas. The April 2016 fire destroyed several items in the National Museum of Natural History located in New Delhi, India. Almost 20 million archive items Brazil's oldest and most important historical and scientific museum at Rio de Janeiro has been consumed by fire recently in September 2018. The loses impart to a discontinuation of the nation's history and beyond repair.

The so-called city of joy Kolkata also experiences many fires of a different character in recent past. A fire broke out at 2:00 pm at Stephen Court, near Park Street on 23 March 2010, 43 people died in the blaze. The initiation of fire is due to a short circuit from a lift between the fifth and sixth floors. In 9th December 2011 early morning, the annexe building of AMRI Hospital at Dhakuria gets fire and smoke. The fire was due to alleged negligence, which caused flammable substances kept in the basement of the building to catch fire after a short circuit in the electrical system. It is reported that 95 people, including members of the staff, died (Murali and Vijayalakshmi, 2014). Surya Sen street market fire took place in 27th February 2013. An estimated 19 people, who were mostly labourers working in the market were killed in the accident. The accident occurred at around 3:50 in the morning. Very recently, Bagri market, one of the largest and oldest wholesale markets of Eastern India, comes under huge fire in the early hours 2:45 am on 16th September 2018. Losses due to the fire are expected to be ₹20-25 crore, Restrictions on daily trade around the affected areas are likely to be imposed. This will lead to a further loss of ₹3-4 crore a day.

The change in the socio-economic stratum, enormous development of building and interior finish materials, building an integrated service system provides an extremely high potential for fire-related vulnerability (Yang and Chen, 2014). The proposed fire risk assessment methodology outlines the various causes of fire and provides an overview of building fire hazards. It can be applied to various buildings and marketplaces in urban areas.

To establish a proper framework for assessment techniques following three objectives are suggested.

1. Selection of physical and socio-economic parameters responsible for the fire vulnerability in buildings.
2. Establish the building level data collection survey format to evaluate the selected parameters in response to the fire disaster in building
3. Analysis of the collected data to achieve an index system to assess the fire risk of a building.

Based on the above objectives, the outline of the proposed risk assessment model is discussed in the subsequent paragraphs.

Outline of Risk Assessment Model

The proposed research is executed through parallel steps. A methodology flowchart is established to achieve the research objectives and mentioned in Fig 1. Initially, a space matrix is established based on the building layout. The whole building is segregated based on various activity areas (cell) and the circulation areas (links). The links will create the boundaries or the edge elements. The different zones of the space within a building layout will be formed by a collection of cells and the boundary edges. The physical and socio-economic parameters that responsible for fire disasters are then selected from the literature surveys. The selection of the parameters is accomplished by frequency analysis (Groner, 2016). The nature of the risk due to fire hazard will change with time due to the use of the building and occupancy profile. So, a survey is needed to read this risk pattern.

A Rapid Visual Survey (RVS) is to be conducted to assess the potential vulnerability due to physical parameters. Whereas, a Stakeholder's Questioner Survey (SQS) is planned to measure the socio-economic vulnerability character of the building user group. Seven physical parameters are evaluated in each building zone and a Space-Physical parameter Matrix (SPM) is established. Similarly, a Space-Socio economical Matrix (SSM) is established from the six chosen socio-economic parameters over each building zones. The assessment and allocation of rating points to all the parameters are proposed through the rapid visual and questioner survey respectively. The parameters in each group can be screened through T-test. The parameters having relatively less importance can be eliminated by the T-test. The overall weight of all the selected parameters are also proposed through an expert opinion survey. The overall weight can be assigned by an

Analytical Hierarchy Process (AHP) method.

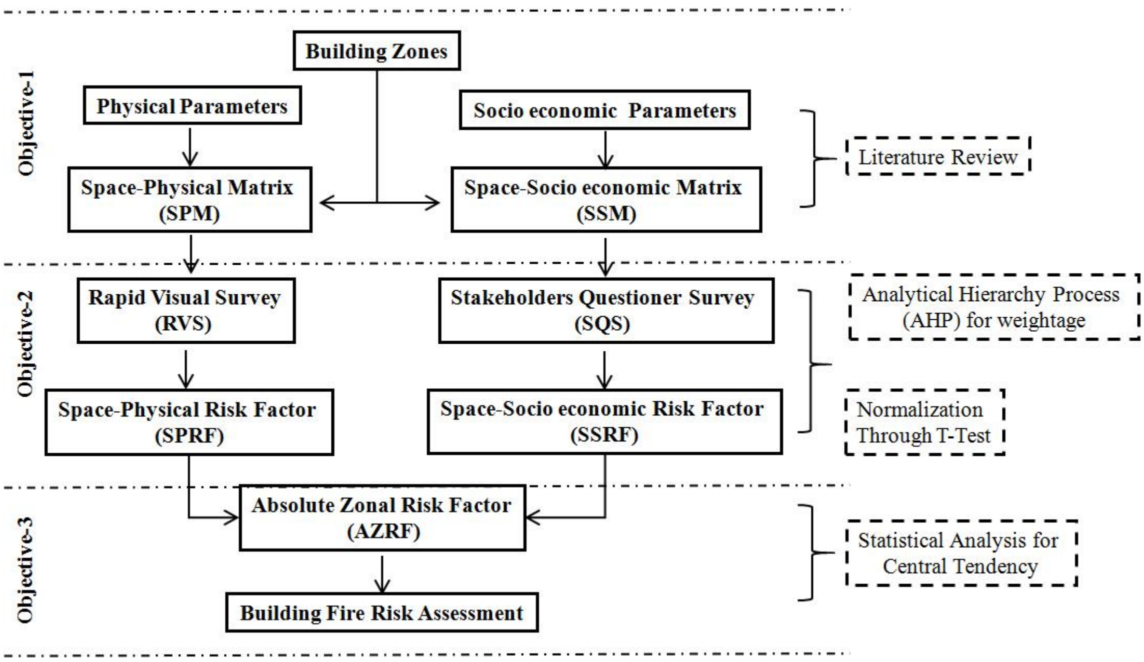


Figure 1. Fire Risk Assessment Methodology

A composite score of physical vulnerability can be obtained by multiplying the respective parameter weight with the Space-Physical parameter Matrix values. Similarly, the composite score of socio-economic vulnerability can also be obtained. Finally, the fire hazard risk index can be achieved by adding both the composite score

Evaluation of Space-Physical Matrix (SPM)

The physical environment of any space has a direct role to play in terms of fire risk. Seven such physical parameters are recognized from the literature review for assessment (Ibrahim at.el, 2011). The description of the parameters is mentioned below.

1. Fire Load: It is a derivative of physical nature of the building interior stored items. This is also depending on the calorific value of all individual materials.
2. Effective Area: It indicates the amount of net area in any particular building zone containing the material having certain fire load. It can be calculated by deducting the circulation area from the total area of the specific zone.
3. Fire Hazard Hot Spots: Certain location in building zone can act as a potential fire hazard source. Example: unprotected and old electrical cable, Electrical overloading points, unsafe uses of LPG or stove burner for shops inside the building, Smoking area.
4. Existing Fire Control System: The placement, distribution and maintenance standards of fire detection and extinguished system installed in the building (if any).
5. Means of Access: The special arrangement of horizontal circulation routes to exit. The placement and distribution of staircases in the building.
6. Floor Position: Floor level of different zones. Higher the floor level, the risk of fire will be increased proportionally.

7. The degree of Encroachment: The means of access many times blocked due to the storing of material and furniture placement. It effectively reduces the emergency evacuation efficiency during a fire event.

The contribution of given physical parameters in various spatial zones is estimated with the help of a Rapid Visual Survey (RVS). The physical parameters are evaluated based on the actual value and normalised into the Likert scale (1-5). The selected seven parameters along with the special zones of the building can be represented through the Space-Physical matrix (SPM) as given in Table 1.

Evaluation of Space-Socio economic Matrix (SSM)

The socio-economic structure any habitat or a group of building occupancy also contribute to fire risk estimation. Six such physical parameters are obtained from the literature review for assessment (Sun and Lou, 2014). The description of the parameters is mentioned below.

1. Total Occupancy: It will provide the exposure level of risk. Corresponding the various zones and its physical fire risk should be overlain with the sectors of occupancy to calculate the risk level.
2. Floating Population: If the fire event occurs during pick hours, then the floating population in various zones will be affected. The proportion of floating population over the total occupancy will also indicate the overall control for any fire hazard to occur. If this ratio becomes higher, the level of control will reduce.
3. Age Group: The age grouping within the total occupancy and the floating population is also contributing to the exposure condition of fire risk estimation. The proportion of infant, old age and mother-child population will provide a more vulnerable situation.
4. Annual Turnover: This parameter can be an indicator to predict the amount of economic loss in terms of running investment may occur due to sudden fire.
5. Fixed Asset Value: The Fixed asset is also indicated the amount of economic loss in terms of capital investment may occur due to sudden fire.
6. Insurance Status: The status of the insurance will infer the capacity or resilience of the mass to any sudden event of a fire.

The six chosen socio-economic parameters are evaluated based on the Stakeholder's Questioner Survey (SQS). The various stakeholder in the buildings and people from building administration should participate in the questioner survey. The socio-economic parameters are evaluated based on the actual value and normalized into the Likert scale (1-5). The selected six parameters along with the special zones of the building can be represented through Space-Socio economic Matrix (SSM) as given in Table 2.

Risk Assessment Method

The Rapid Visual Survey (RVS) and the Stakeholder's Questioner Survey (SQS) will provide normalized Likert points for each building zones. Both the matrixes will show the relative marking against the zones. A T-test is proposed to evaluate the relative importance of the parameters of the two groups. The confidence level may be taken as 90 per cent to screen out the less important parameters. Not all the parameters in the final risk assessment model should have the same weight. Expert opinion surveys are conducted to constitute the parameter weight. The Analytical Hierarchy Process (AHP) method is proposed to assign the respective weight for the parameters. The selected parameters are then multiplied with a weightage factor.
Mathematically, the weight value of a space-physical parameter of each building zones can be defined as

$$P_j^i \times wp_j \qquad (1)$$

Where,
P_j^i is the normalized value of j^{th} physical parameter in i^{th} building zone
wp_j is AHP based weightage factor the j^{th} physical parameter

Similarly, the weightage value of a space-socio economic parameter of each building zones can be defined as

$$S_k^i \times ws_k \tag{2}$$

Where,
S_K^i is the normalized value of kth socio economic parameter in ith building zone
ws_k is AHP based weightage factor the kth socio-economic parameter

If it is considered that, there are total 'nz' numbers of building zones, 'np' numbers of physical parameters and 'ns' numbers socio-economic parameters. Following two more relationships can be made out of those numbers. The Space-Physical Risk Factor (SPRF) is defined as the weighted sum score of all the physical parameter under any specific zone. It can be expressed mathematically as

$$SPRF_i = \sum_{j=1\ to\ np}^{i=1\ to\ nz} P_{ij} \times wp_j \tag{3}$$

Similarly, the Space-Socio economic Risk Factor (SSRF) is defined as the weighted sum score of all the socio-economic parameter under any specific zone. It can be expressed mathematically as

$$SSRF_i = \sum_{k=1\ to\ ns}^{i=1\ to\ nz} S_{ik} \times ws_k \tag{4}$$

Table 1. Space-Physical matrix (SPM) and Space-Physical Risk Factor (SPRF) evaluation

Physical Parameter	Weightage Factor	z_1	z_2	$\ldots z_i$	$z_{(nz)}$
P_1	wp_1	$P_{11} \times wp_1$	$P_{21} \times wp_1$		
P_2	wp_2	$P_{12} \times wp_2$			
$\ldots P_j$	wp_j			$P_{ij} \times wp_j$	
$P_{(np)}$	$wp_{(np)}$				$P_{(nz)(np)} \times wp_{(np)}$
Space-Physical Risk Factor (SPRF) = Sum of all columns (refer Eq. 3)					

Table 2. Socio economic Matrix (SSM) and Space-Socio economic Risk Factor (SSRF) evaluation

Socio economic Parameter	Weightage Factor	z_1	z_2	$\ldots z_i$	$z_{(nz)}$
S_1	ws_1	$S_{11} \times ws_1$	$S_{21} \times ws_1$		
S_2	ws_2	$S_{12} \times ws_2$			
$\ldots S_j$	ws_j			$S_{ij} \times ws_j$	
$S_{(ns)}$	$ws_{(ns)}$				$S_{(nz)(ns)} \times ws_{(ns)}$
Space-Socio economic Risk Factor (SSRF) = Sum of all columns (refer Eq. 4)					

Finally, the Absolute Zonal Risk Factor (AZRF) is obtained from the square root of the sum of squares of Space-Physical Risk Factor (SPRF) and Space-Socio economic Risk Factor (SSRF). It is a zone-specific index number indicates the level of risk involves due to any fire hazard. The Absolute Zonal Risk Factor (AZRF) index can be utilized to rate the fire risk of any building. The building will be subdivided into many zones within a floor and different floors. It will provide as many AZRF index for total numbers of building zones. It is proposed that the AZRF index for all the building zones can be arranged in a descending (or ascending) order. To assess the overall nature of fire risk of the building following two statistical rules may be applied.

1. The range of the AZRF index of all building zones can be read as the difference between 75 and 25 percentiles of the obtained set value. It will give a clear understanding that the central 50 percentile of the zones fire risk character.

2. The mean AZRF index of all building zones can also be read with the above one to understand the central tendency of the grouped data.

Conclusion

Fire is one of the major causes of the destruction of our living and cultural heritage. It has become a common threat to establishments, organizations and individual. Most of the fire hazard related case studies in India reveals that fire occurred due to sheer negligence and building without proper fire preventive system. Many parameters are found responsible for fire phenomenon of the buildings. It makes the control mechanism complex in nature. Type of building, building activities, culture and behaviour of the people, maintenance of the building is few of those parameters. A survey-based assessment tool is proposed to evaluate the fire risk in the building. The Absolute Zonal Risk Factor can be an indication of the risk involved in the building. Further, the building zone wise parametric score can be used to plan the right strategy to improve the resilience to the fire disaster.

References

Groner, N. (2016) “A decision model for recommending which building occupants should move where during fire emergencies”, *Fire Safety Journal,* (80), 20–29.

Guidelines for prevention detection and control of fire in archives and libraries, (1993), National archives of India, New Delhi.

Hansen, N.D., Steffensen, F.B., Valkvist, M., Jomaas, G., and Van Coile, R. (2018) “A fire risk assessment model for residential high-rises with a single stairwell”, *Fire Safety Journal,* (95), 160–169.

Ibrahim, M.N., Abdul-Hami , K., Ibrahim, M.S., Mohd-Din,A., Yunus, R.M., and Yahya,M.R. (2011) “The Development of Fire Risk Assessment Method for Heritage Building”, *Procedia Engineering* (20), 317 – 324.

Murali, L.G., Vijayalakshmi, M.M., (2014), “Fire accidents in buildings – case studies”, *International journal of engineering trends and technology,* 11(4), 178-184.

National Building Code, Part 4 fire and life safety, (2005), Bureau of Indian Standard, New Delhi.

Sun, X., and Lou, M., (2014) “Fire Risk Assessment for Super High-rise Buildings”, *Procedia Engineering,* (71), 492 – 501.

Xin, J. and Huang, C., (2013) “Fire risk analysis of residential buildings based on scenario clusters and its application in fire risk management”, *Fire Safety Journal* (62),72–78.

Yang, J., and Chen, Y., (2014), “Research and application of fire risk assessment system for marketplace buildings”, *Procedia Engineering,* (71), 478 – 480.

A COMPARATIVE STUDY OF FIRE SAFETY CONDITION IN THE READYMADE GARMENT SECTOR OF BANGLADESH BEFORE AND AFTER THE RANA PLAZA ACCIDENT

F. Y. Huda[1]*, M. S. bin Abdul Rani[2] and Z. Wadud[3]

ABSTRACT

Readymade garment industry is the largest export sector of Bangladesh contributing more than 83% of the total export earnings of the country. Yet the workplace safety in this industry has always been a questionable issue due to a lot of parameters. This research mainly focuses on the fire safety condition of this industry through a comparative study of the safety condition before and after the Rana Plaza accident. A total of 15 comparable parameters comprising both structural (hard) and management related (soft) parameters have been considered. Study result reveals that the overall fire safety condition of the garment factories have improved. The average Fire Risk Index (FRI), established earlier, for the same garment factories (surveyed before and after the accident) has increased from 0.64 to 1.57 on a 2-point scale, indicating a much safer place for workers at present. For the same number of mixed garment factories, average FRI increased to 1.46 compared to 0.61, indicating a significant improvement of safety issues in terms of fire safety. Significant improvements of the management related (soft) parameters compared to structural (hard) parameters are the main factors for this notable outcome.

***Keywords**: readymade garment, fire safety, fire risk index, rana plaza accident, workplace safety.*

Introduction

Readymade garment (RMG) industry is the largest export sector of Bangladesh, with more than 83% of the country's total foreign earnings generated from this sector. At present, the industry consists of 4,560 factories, empowering 4.4 million workers, of which 80% are women (BGMEA, 2018a). Over the last three decades, the RMG industry has thrived the economic growth throughout the country (Ansary and Barua, 2015). The government of Bangladesh is providing full support to the RMG industry by offering tariff rationalization, tax reduction on imported materials and machineries and reducing the interest rate on loans (Yunus and Yamagata, 2012). As a result, Bangladesh is now the second largest garment exporter in the world after China with a total export of US $30.61 billion in the fiscal year of 2017-18 (BGMEA, 2018b; UNICEF, 2015). Surely, this is a great achievement for all the personnel associated with this huge industry and the people of Bangladesh. But, unfortunately, the workplace safety in this highly labor-intensive industry has always been a questionable issue. In the last four years only, over 4,500 garment workers have been subjected to severe injuries of which a significant number turned into death (Chowdhury and Tanim, 2016). Out of various types of workplace accidents, fire inducing accidents are the most frequent one in RMG industry of Bangladesh. Although, the Rana Plaza accident in 2013, caused the death of 1,129 workers and another 2,515 workers were the victims of severe life-threatening injuries (ILO, 2018), Hasan et al. (2017) reported that 94.2% deadly incidents in RMG industry are still due to fire.

Rana Plaza which was a nine-storied building is the case of structural failure which has left with the highest number of fatalities and injuries ever been recorded in any single incident involved in the RMG industry of Bangladesh. This catastrophic accident triggered the initiative and commitments from both the government of Bangladesh and the international community to improve the workplace safety in RMG industry. After the incident, several action plans have been undertaken to ensure the overall safety of the RMG sector. Apart from the action plans, the international stakeholders have also formed two inspection programs, ACCORD on Fire and Building Safety in Bangladesh (The ACCORD), and ALLIANCE for Bangladesh Worker Safety (ALLIANCE) to inspect the workplace safety of the garment factories in Bangladesh and work with the factory owners and management body to improve the deficiencies where deemed necessary (Ansary and Barua, 2015). Till date, both the programs have achieved more than 85% remediation progress rate among

[1]*Senior Lecturer, Dept. of Civil Engineering, East West University, Dhaka-1212, Bangladesh*
[2]*School of Chemical and Process Engineering, University of Leeds, Leeds, LS2 9JT, UK*
[3]*Associate Professor, Faculty of Engineering, University of Leeds, Leeds, LS2 9JT, UK*
** Corresponding Author, E-mail – fuad.huda@ewubd.edu*

the factories which have signed and collaborated with these two programs (ACCORD, 2018; ALLIANCE, 2018).

Although the Rana Plaza accident attracted a huge attention from both the stakeholders and regulatory bodies, still fire related accidents are more frequent and catastrophic ones in the RMG industry. However, there is lack of studies that attempt to understand the fire risks associated with this industry. Besides, no studies till date have attempted to quantify the fire risks in the RMG industry of Bangladesh after the Rana Plaza accident. This paper thus aims to investigate the workplace safety in terms of fire safety of the readymade garment factories of Bangladesh at current state (i.e. after the Rana Plaza accident) through a quantitative Fire Risk Index (FRI) method developed by Wadud et al. (2014). Along with this, the paper also investigates whether the fire safety condition of the garment factories have changed compared to the safety condition before the accident and if so, what is the nature of change by a comparative study of the before and after state of the fire safety condition of the garment factories. Finally, this paper also tries to figure out the parameters which possess significant importance to achieve a better workplace safety in short period of time in the RMG industry. Giving the nature of the study, it is believed that the study findings will be beneficial to a wide range of labor-intensive industries. The fire accidents in a firework factory in Indonesia which left 50 fatalities (The Straits Times, 2018) or a footwear factory in Philippines which left 72 fatalities (The Telegraph, 2018) indicates the importance of this research.

Methodology and Data Analysis

The fire safety condition of the garment factories is assessed through a quantitative method, Fire Risk Index (FRI) that has been developed by Wadud et al. (2014). Data of the garment factories before the Rana Plaza incident has been considered from the earlier studies of Wadud et al. (2014) and Wadud and Huda (2017). The current status of the garment factories has been collected from the inspection report provided by the ACCORD and ALIANCE which have been retrieved from their website from 11th to 17th June 2018. The inspection report provides information of the current state of various parameters of the garment factories under three broad categories namely, structural, electrical and fire safety.

In FRI method, a number of parameters which are assessed is first weighted through a panel of fire safety experts. In this study the weight value of the parameters is adopted from the earlier studies of Wadud et al. (2014) and Wadud and Huda (2017) and is based on a 5.0 scale. Individual garment factories are then checked against those parameters and graded for their current state. For this study, a 2.0 scale grading scheme has been considered to rationalize the data between the earlier studies of Wadud et al. (2014), Wadud and Huda (2017) and data extracted from the ACCORD and ALLIANCE inspection reports. Table 1 depicts the modified grading scheme adopted in this study for both the earlier studies and the ACCORD and ALLIANCE reports.

Table 1. Grading scheme for different parameters.

Grade	For the ACCORD and ALLIANCE data	For 'hard' parameters (grade point extracted from Wadud and Huda (2017)*)	For 'soft' parameters (grade point extracted from Wadud et al. (2014)*)
0	No improvement / no changes	0 to 2	1 to 3
1	Under construction / in progress	3	4
2	Fully complete / comply	4	5

* The subjective description and quantifiable parameter of the grade points from their ideal case can be found from the earlier studies of respective hard and soft parameter.

Finally, considering the weight value and grade points of each parameter, the FRI for a garment factory is than calculated in a linear additive model of the following form:

$$FRI = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i} \quad (1)$$

where, w_i is the weight value provided by the safety experts to determine the importance of various parameters relative to each other, x_i is a dimensionless grade point for parameter i and n is the total number of parameters.

For this research, total 15 parameters comprising both 'hard' (structural) and 'soft' (management) parameters, have been considered to be comparable with the earlier studies. It should be reminded here that the 'hard' parameters refer to the structural factors affecting the fire safety which cannot be changed or improved overnight while the 'soft' parameters refer to the management practices affecting the fire safety and can be implemented or improved over a short period of notice. Table 2 depicts the list of the parameters, their nature and weight values.

Table 2. List of parameters and associated weight values.

Ser. no	Type of parameter	Parameters	Parameters description	Weight average
1	Hard	Fire pump	Availability and function ability of fire pump	4.38
2		Boiler room	Segregation of boiler room	4.13
3		Door width	Width of doorway	4.00
4		Exit sign & illumination type	Availability of exit sign and illumination type	4.00
5		Corridor width	Clear width of the corridor	3.88
6		Exit door rating	Fire rating of exit door	3.63
7		Emergency light	Presence of emergency light	3.63
8		Door height	Height of doorway	3.25
9		Exit sign letter size	Letter size of exit sign	2.88
10	Soft	Locked exit	Locked/unlocked condition of exit door	5.00
11		Chemicals	Existence of chemical material inside	4.75
12		Block furniture	Blockade of exit corridor by furniture/other material	4.75
13		Combustible	Presence of combustible item (cotton, cloth) inside	4.00
14		Emergency light	Serviceability/working condition of emergency lights	3.75
15		Door swing	Outward/inward swinging of door	3.63

Source: Wadud et al. (2014), Wadud and Huda (2017).

Results and Discussion

In FRI grading policy, a higher FRI indicates less fire risks. Thus, our study reveals that for a total of 60 garment factories, the mean FRI after the rana plaza incident is 1.46 on a 2.0 scale while before the incident, mean FRI was 0.61. It should be noted here that the 60 factories which have been surveyed after the incident is not the same factories which were surveyed before the incident. We have found 15 similar factories which have been surveyed by the ACCORD and ALLIANCE and in the previous studies. The rest of the factories, we assume did not sign with either these two bodies or shut down their business. Thus, to compare the before and after scenario, we have considered the same number of factories where the rest 45 factories have been selected based on the similar characteristics (i.e. factory location and size of the factory) of the previous ones.

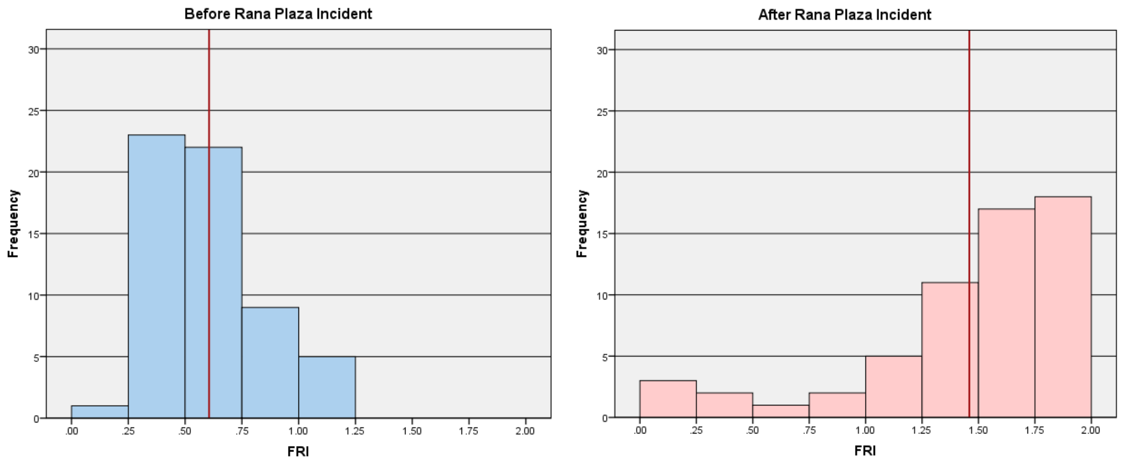


Figure 1. Distribution of FRI's for 60 garment factories before and after the rana plaza incident. Red vertical line indicates the mean FRI.

Figure 1 shows the frequency distribution of FRI of the 60 garment factories for both the scenarios. While no garment factory has achieved FRI more than 1.25 before the incident, after the incident, more than 76% garment factories have achieved FRI 1.25 and above. While 75% garment factories achieved FRI between 0.25 and 0.75 before the incident, after the incident, the percentage is below 10% which indicate that the overall fire safety of the garment factories have improved significantly. Though there are still 8 factories in the sample size which possess 50% deficiency from the ideal case of FRI 2.0.

Comparing the FRI for the same 15 factories which were surveyed by the earlier studies and also by the ACCORD and ALLIANCE, the mean FRI before the incident is 0.64 which increased to 1.57 after the incident. Figure 2 depicts the distribution of the 15 factories where all the factories except factory no 12 shows an increment of FRI at the present context compared to the previous scenario of rana plaza incident. This also depicts a favorable workplace in terms of fire safety at the present context compared to the previous condition. A closer insight of the inspection report for factory no 12 depicts that for many of the parameters, performance of this factory didn't change, even performed worse for some parameters i.e. exit sign and illumination type, corridor width, etc. at the present context than it was before the rana plaza incident. In terms of five most important parameters (denoted by their weight value), i.e. locked exit (w=5), chemicals (w=4.75), block furniture (w=4.75), fire pump (w=4.38), and boiler room (w=4.13), this factory performance didn't change at all after warning them for several times by the ACCORD.

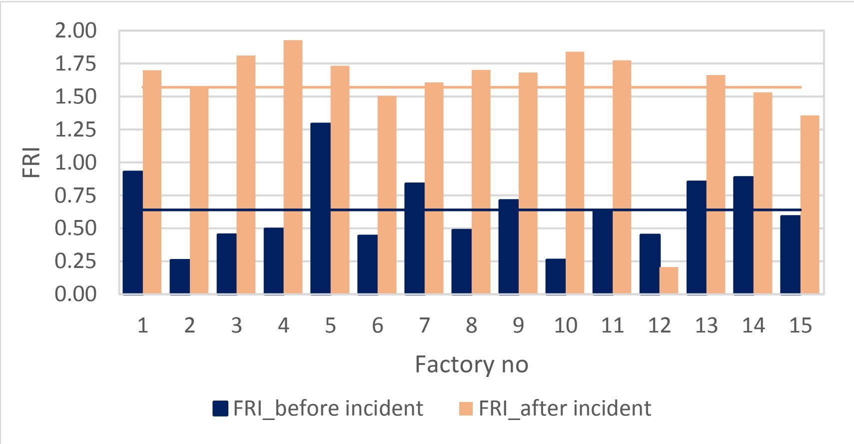


Figure 2. Distribution of FRI's for 15 factories before and after the rana plaza incident. Horizontal line indicates the mean FRI.

To check whether our detailed result for the 60 mixed factories (where 15 same factories are also included) are comparable for the comparison study of the before and after state of the rana plaza incident, a two sample t-test has been performed and found to be statistically significant ($t = 0.687$, $p < 0.01$ for before incident and $t = 0.359$, $p < 0.01$ for after incident). To check the performance of the hard and soft parameters separately, FRI_{hard} and FRI_{soft} has been assessed for the before and after scenario. FRI_{hard} increased from 0.85 to 1.37 while FRI_{soft} for the before state is 0.29 and the after state is 1.57. As hard parameters are related to the structural factors of a factory building which requires significant amount of time and budget from the management body to improve the safety condition thus the increment of 61% FRI_{hard} is reasonable compared to the huge significant change in FRI_{soft} (more than 400%).

Comparing the average grade for 60 factories for individual parameters, it is found that average grade also increased in the after state scenario from the before state scenario. For the hard parameters the difference ranges from 1% for door height to a maximum of 130% for corridor width. For soft parameters, the minimum difference is 134% for block furniture while the maximum difference is recorded for chemicals (from 0.02 for before state to 1.43 for after state). It should be noted here that corridor width which is a hard parameter can be affected due to block furniture which is a soft parameter as often seen from the surprise factory visit that empty boxes, cloths and combustibles are piled up in the exit corridor which in case of an emergency can prove to be highly vulnerable for fire safety. Comparing the average grade for five most important parameters (denoted by their weight values) which include three from soft side (locked exit, chemicals, and block furniture) and two from hard side (fire pump and boiler room), the study result shows that all three soft parameters have performed significantly well in their after state scenario compared to the before state scenario. Locked exit got an average grade point of 1.73 in the after state scenario compared to 0.10 in the before state scenario. Chemicals got an average grade point of 1.43 compared to 0.02 and block furniture got 1.25 compared to 0.53. For the two hard parameters, fire pump got an average grade point 0.55 in the after state scenario compared to 0.52 for the before state scenario and boiler room got 1.28 compared to 0.98. This depicts that garment factories which have achieved higher FRI (safer in context to fire safety), have performed significantly well in the soft parameters compared to their hard parameters. Soft parameters which are related to management practices are relatively easy to improve or upgrade than hard parameters and thus, a better workplace can be ensured in context of fire safety.

Conclusions

This research had three objectives: (i) to assess the fire safety of the readymade garment sector of Bangladesh after the rana plaza accident in a quantitative method, (ii) compare the fire safety condition of the RMG industry through a comparative study of before and after state scenario of the rana plaza accident, and (iii) to identify the parameters which possess important contribution towards the change of the fire safety condition in the present context (after rana plaza incident). Among the 60 factories surveyed, study result shows a mean FRI of 1.46 in a scale of 2.0 which depicts a relatively satisfactory workplace condition for the garment workers compared to 0.61 on a similar scale which was the scenario before the rana plaza accident. A relatively lower FRI for the hard parameter ($FRI_{hard} =$ 1.37) compared to the soft parameter (FRI_{soft} = 1.57) depicts that the factories have performed better in management practices after the rana plaza incident whereas before the incident the hard parameters had better FRI than soft parameters as reported by Wadud and Huda (2017). It should also be remembered that management practices can change over time while structural factors are almost fixed. Thus, regular visit in garment factories to check the management practices would be beneficial to maintain a safe workplace condition in terms of fire safety. We would also like to add here that surprise visits to factories will determine the exact scenario of the management practices compared to any pre-announced visit as our study shows that management practices (soft parameters) are the main factors which are mainly responsible behind achieving a better FRI thus a better workplace in terms of fire safety. Finally, it is important to remember here that the sample factories considered for the present scenario (fire safety condition after the rana plaza incident) in our research have signed either with the ACCORD or ALLIANCE or both of them. These two combinedly covers almost 42% factories out of 4,560 garment factories of the country. Thus, our study results are comparable for a little less than half of the garment factories of the RMG industry of Bangladesh. Therefore, to reveal the whole picture of the present scenario of workplace safety in terms of fire safety in the RMG industry, a comparable study in a big scale would be much beneficial.

References

ACCORD (2018) "News archive", [Online]. [Accessed: 23 November 2018]. Available from: http://bangladeshaccord.org/news/

ALLIANCE (2018) "Alliance Achieves Factory Safety Milestone: 400 Factories Complete Remediation", [Online]. [Accessed: 24 November 2018]. Available from: http://www.bangladeshworkersafety.org/en/486-alliance-achieves-factory-safety-milestone-400-factories-complete-remediation

Ansary, M.A. and Barua, U. (2015) "Workplace safety compliance of RMG industry in Bangladesh: Structural assessment of RMG factory buildings", *International Journal of Disaster Risk Reduction*, 14(2015), 424-437.

Bangladesh Garment Manufacturers and Exporters Association (BGMEA). (2018a) "About garment industry of Bangladesh" [Online]. [Accessed: 23 November 2018]. Available from: http://www.bgmea.com.bd/home/about/AboutGarmentsIndustry.

Bangladesh Garment Manufacturers and Exporters Association (BGMEA). (2018b) "Trade Information" [Online]. [Accessed: 7 August 2018]. Available from: http://www.bgmea.com.bd/home/pages/TradeInformation.

Chowdhury, M. F., and Tanim, T. R. (2016) "Industrial Accidents in Bangladesh Apparel Manufacturing

Sector: An Analysis of the Two Most Deadliest Accidents in History", *Asian Journal of Social Sciences and Management Studies*, 3(2), 115-126.

Hasan, M. M., Mahmud, A., and Islam, M. S. (2017) "Deadly Incidents in Bangladeshi Apparel Industry and Illustrating the Causes and Effects of These Incidents", *Journal of Finance and Accounting*, 5(5), 193-199.

International Labour Organization (ILO). (2018). "The Rana Plaza Accident and its aftermath", [Online]. [Accessed: 24 November 2018]. Available from: https://www.ilo.org/global/topics/geip/WCMS_614394/lang--en/index.htm

The Straits Times (2018) "Major Safety Breaches in Indonesian Factory Fire" [Online]. [Accessed: 24 November 2018]. Available from: https://www.straitstimes.com/asia/se-asia/major-safety-breaches-in-indonesian-factory-fire

The Telegraph (2015) "72 killed in fire at footwear factory in Philippines" [Online]. [Accessed: 24 November 2018]. Available from: https://www.telegraph.co.uk/news/worldnews/asia/philippines/11604522/72-killed-in-fire-at-footwear-factory-in-Philippines.html

United Nation Children's Fund (UNICEF). (2015) "The Ready-Made Garment Sector and Children in Bangladesh" [Online]. [Assessed: 23 November 2018]. Available from: https://www.unicef.org/csr/files/CSR_BANGLADESH_RMG_REPORT.PDF.

Wadud, Z., Huda, F.Y. and Ahmed, N.U. (2014) "Assessment of Fire Risk in the Readymade Garment Industry", *Fire Technology*, 50, 1127-1145.

Wadud, Z. and Huda, F.Y. (2017) "Fire Safety in the Readymade Garment Sector in Bangladesh: Structural Inadequacy vs Management Deficiency", *Fire Technology*, 53(2), 793-814.

Yunus, M., & Yamagata, T. (2012). "The garment industry in Bangladesh". *Dynamics of the Garment Industry in Low-Income Countries: Experience of Asia and Africa (Interim Report). Chousakenkyu Houkokusho, IDE-JETRO*.

RISK ASSESSMENT STUDY OF E-WASTE RECYCLING SHOPS IN DHAKA

Ehsanur Rahman[1], Marfua Mowla[1], Nirupam Aich[2] and. Nafisa Islam[1] *

ABSTRACT

A potential manmade disaster in recent years is the rise of electronic waste (e-waste), however this has not yet been fully recognized as a severe threat. In the last X years, the rapid growth of electronic industries and limited life time of the electronic accessories and gadgets has led to accumulation of electronic waste (e-waste). The problem is compounded by unlegislated dumping of the waste in countries like Bangladesh. In 2010, Bangladesh generated about 2.7 million metric tons of e-waste per year and only 20 to 30% of these were recycled**.** As e-waste contains significant amount of valuable elements (Ti, W, Ta, Sn, Cu, Fe, Al etc.), the recycling shops of e-waste, nucleating around the suburbs of Dhaka, have been a lucrative business. However these local shops are suffering from unhealthy conditions, with lack of technological development and awareness. **This study aims to mitigate the potential threat from e-wastes by raising awareness, studying current recycling practices and characterizing the toxicants exposed to environment and ecology at local sources of e-waste repair and recycle**. The process of informal e-waste recycling and the environmental conditions of two e-waste recycling shops, located in Nimtoli and Elephant road (Dhaka), was studied. The amount of hazardous material in the dust samples surrounding these areas was determined using AAS, which crossed the permissible limit and the potential health risk was found using some empirical co-relations. Taking into account the results of the study of the recycling process in Bangladesh, some awareness strategies have been suggested to keep the risk of toxicological exposure as low as possible and prevent this problem from being a full scale disaster.

Keywords: *manmade disaster, health and environmental hazard, awareness, risk assessment.*

Introduction

With the rapid obsolescence of gadgets and their high demands, electronics waste (e-waste) has become the fastest growing waste stream in the industrialized world. The latest United Nations Environment Programme (UNEP) report shows the generation of 20 to 50 million tons of electronic waste every year (UNEP. 2006), with America in the lead, producing 3 million tons domestically every year, followed by China with 2.3 million tons as well as South Asian countries in the list(ref). The major source of e-waste is the disposal of the hardware and electronic items. Bangladesh, one of world's most populated countries, is fast becoming one of the biggest e-waste dumping sites. It is observed in recent years that 75 to 80% of the generated e-waste is being exported from western countries to Asian countries like India, Bangladesh etc. for recycle and disposal (Diaz-Barriga F. 2013). Also, people are unaware of the environmental and health effects of reckless dumping here in Bangladesh. It is already known that improper handling of e-waste causes harm to the environment and human health because of its toxic components. Regulatory frameworks such as refurbishing, recycling are not in practice; and laws and regulations regarding this dumping are absent in Bangladesh. The severe poisonous effect on central nervous system, immune system and kidneys by the elements (lead, mercury, chromium etc.) of rejected motherboards of CPU, mobile, TV, printed circuit boards (PCB's) etc. have not gone unnoticed and the possibility of severe pollution is soaring upward every day.

Currently in Bangladesh, recycling and manual dismantling has been done in a small scale and the scrapping process results in secondary production of the metals by smelting under the open sky. Wasted electronics from the domestic households are directly dumped into the dustbins from where street children collect them and sell them to the hawkers. The *vangari* shops are sites where all sorts of irreparable electronics are gathered for scrapping. These shops get their e-wastes from various sources like groups of hawkers, individual dealers or street children. All of the electronics from the dustbins are not possible to be collected, as a result, a portion of them are exposed directly to soil and water bodies.

Careful attention to collection and treatment of the materials to be recycled can be a solution for e-waste problem. Dhaka, capital of Bangladesh is a polluted city and two of the e-waste recycling shops locally known as *vangari* shops from Dhaka have been studied as the sampling sites. Due to potentially hazardous collection procedures, recycling and scrapping environment of these shops, we decided to study the indoor dust samples

[1]*Department of Chemical Engineering, Bangladesh University of Engineering and Technology (BUET), Dhaka-1000, Bangladesh*

[2]*Department of Civil, Structural and Environmental Engineering, University at Buffalo, Buffalo, USA*

of two shops to assess the metal concentration for hazard analysis. The digestion of the samples was carried out and the health risks has also been assessed to evaluate the hazardous situation. As preliminary data, concentration of five metals such as Cr, Ni, Pb, Cu and Mn has been analyzed.

In humans chromium (III) plays an important role in glucose, fat and protein metabolism (Anderson 1981). Exposure to chromium compounds has negative effects including a respiratory, cardiovascular, gastrointestinal, hepatic, hematological, renal, ocular and dermal effect which leads to death (S Wilbur. 2012). Lead is absorbed in human bones, blood and tissues where it works as a source of continual internal exposure (Gulson BL. 1995). If lead is exposed to human body it causes abdominal pain, memory loss, pain or tingling in hands or feet etc. Neurological effects and mental retardation have also occurred in children whose parent(s) may have job-related lead exposure (NIOSH. 1995). High level exposure of lead causes brain and kidney damage. Exposure of nickel is very harmful to health. Inhalation and dermal exposure to nickel compounds causes headache, nausea, vomiting, and chest pain, cyanosis, respiratory failure, and death if the exposure is severe (Goyer 1991). Manganese is widely used in the batteries and it can be found in the recycling shops both in organic and inorganic forms. The most common health problems in workers exposed to high levels of manganese involve the nervous system. Manganism, a neurological syndrome that makes the body movement slow and clumsy is caused by manganese. It preferentially damages different areas of brain (Olanow CW. 2004). Copperiedus, a type of metal poisoning which is caused by excess amount of copper in body and it can occur from exposure to excess amount of copper from any type of sources. Its effect should be taken into account as it is used widely in electronic wires. Acute hemolytic anemia, cessation of menstruation, an increased incidence of gall stones and renal stones, a form of osteoarthritis, and some kidney-function abnormalities are the result of continuous exposure to copper (Scheinberg and Sternlieb, 1984; Brewer and Yuzbasiyan-Gurkan, 1992).

The major objectives of this study were as follows: (1) Digestion of the dust sample to determine metal concentration and observe the permissible limits of those in indoor dust sample. (2) Analysis of the working condition and of the *vangari* shops and outside environmental condition of them. (3) Assessment of the health risk of the workers from the exposure via dermal contact.

Materials and Methods

Sampling Site

Dust samples were collected from two e-waste scrapping shops (or *vangari* shops) of two of the major e-waste recycling areas in Dhaka. One of the shops is located at Elephant Road (Science Lab Area), Dhaka and the other at Nimtoli, Dhaka. The dust from these sites have been taken from inside the shops i.e these are indoor samples. Working conditions of these shops were visually observed and verbal interviews were taken of the workers, if and when applicable.

Preparation of dust sample for digestion

The indoor dust sample collection was carried out using a brush and a shovel. At the end of the working day all possible dust was collected from interior of the shops. The dust was kept inside an airtight plastic (Ziploc®) bag so that unnecessary moisture cannot go inside. The airtight bags were kept in a cool and dry place before digestion. Figure 01 shows the dust sample collected from Elephant road.

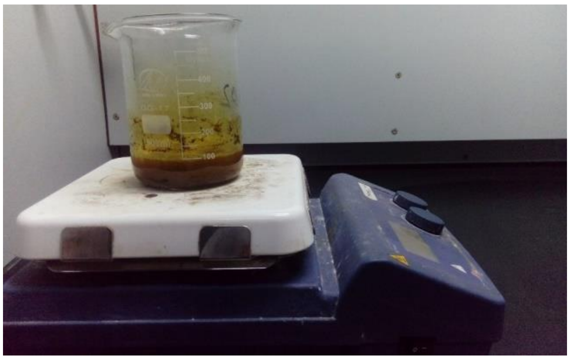
Figure 1: Collected indoor dust sample in an airtight bag from Elephant Road, Dhaka.

Digestion Method for Atomic Adsorption Spectroscopy (AAS)

There are a lot of soil/dust digestion methods amongst which the acid digestion with Aqua regia (MI Kisser. 2004) and digestion using mixture of Hydrofluoric acid and Aqua regia (S Gaudino. 2007(are common and aqua regia has been used for our digestion procedure.

Before digestion, the sample was homogenized using a mortar. There was no need of pre-heating the sample. To 2 g of homogenized dust sample, 20 mL of nitric acid and 60 mL of hydrochloric acid were added inside a fume hood. The mixture was set aside for twenty-four hours before heating the sample on a hot plate inside the fume hood. The sample was heated for three hours between a temperature range of 100°C to 110°C. The leftover 40 mL sample was then cooled and filtered for twenty-four hours. The final solution was light yellow in color as shown in Figure 02 (b). Finally, the sample was stored in a screw cap glass bottle for Atomic Adsorption Spectroscopy (AAS) analysis. The digested samples were analyzed for to quantify the metals, chromium, nickel, lead, copper and manganese using AAS.

(a)



(b)

Figure 2: (a) Acid digestion of indoor sample on a hot plate in the fume hood (b) filtration of acid digested and cooled solution

Health risk assessment

Workers are exposed to heavy metals mainly by three ways: ingestion, inhalation, and dermal contact. In this work the dermal contact is taken into consideration to evaluate the health risk. The average daily dose through skin (ADD_{derm}) may be calculated as,

$$ADD_{derm} = \frac{C \times SA \times SL \times ABS \times EF \times ED \times 10^{-6}}{BW \times AT} \quad \text{..........} \quad \textbf{(1)}$$

Where C is the concentration of the contaminant in the dust (mg/kg). For dermal contact, the exposed skin area was SA=2253 cm^2; the skin adherence factor, SL=0.2 $mg/cm^2/day$; the dermal absorption factor, ABS=0.001 (Jing et al. 2009). The average body weight (BW) of people was 60 kg for adults (Leung et al. 2008). In this study, exposure frequency, EF= 250 days per year; the exposure duration, ED=10 years (the service life of the automatic line). The average time (AT) was 3650 days.

Results and discussion

Working Condition Analysis

The workers in the scrapping shops mainly segregate the electronic appliances by bare hand. They break down the parts using hammer and they never use any mask to protect themselves from the accumulated volatile organics inside which may cause damage in the long run. The leached chemicals from different parts are also present inside various electronics such as Television, CPU, IPS etc. and these chemicals directly come in contact with their skin. Figure 03 shows television that has leached chemicals inside when the workers were scrapping the parts from it.

(a)  (b) 

Figure 3: (a) Inside view of a wasted television yet to be scrapped by hand at Elephant Road. (b) Dumped printed circuit boards piled outside of a shop at Nimtoli

The accumulated dust inside the shops after work, which contains various particles of different metals, glasses and plastics are brushed away either to the ground outside of the shops or nearby drain. As a result, plastics and various metals, especially toxic metal particles directly mix with the soil and water. Not only that, the printed circuit boards and crushed parts of them are piled outside of the shops which mix with the soil and water and pollute the environment. Figure 03 show photographs of the various hazardous components of the e-wastes either exposed or accumulated in open areas.

Assessment of indoor dust sample

The metal concentration from the indoor dust samples the shop of Elephant Road area is shown in Table 1. The results show that all the metal concentrations have crossed their allowable limit. Manganese showed the highest concentration of 2400 mg/kg where allowable limit in the e-waste zone is only 200mg/kg. Allowable limit for Cr, Ni and Pb is 50mg/kg and Cu is 100 mg/kg according to WHO/FAO (2001). The observed metal concentration in the shop for Cr, Ni, Pb and Cu is 990 mg/kg, 470 mg/kg, 510 mg/kg and 710 mg/kg. (Currently we are in the process of determination of the metal concentration from the second shop and thus the relevant data has not been included)

Table 1: Metal concentration of the dust sample from vangari shops in Dhaka and the permissible limit in mg/kg

Metal	Metal concentration in indoor dust sample (mg/kg)	Allowable limit (mg/kg)
Chromium	990	50
Nickel	470	50
Lead	510	50
Copper	710	100
Manganese	2400	200

Assessment of health hazard

The exposure of the workers of the Elephant Road area shop through dermal contact is shown in the Table 2 and it is calculated using equation (1). Here, the model provided by U.S. EPA for health risk assessment is used. Average daily dosage for the exposure through dermal contact is studied here, though exposure through inhalation and digestion is also important. For dermal exposure, the metals showed the sequence of Mn>Cr>Cu>Pb>Ni, while all the values are in the range of reference dose. So it can be concluded that so far the dermal exposure risk is low but it can be high in future because of the accumulation of heavy metals in the working environment. The complete hazard analysis scenario has not been evaluated since the digestion and inhalation exposure has not been analyzed. The combined effect of dermal, inhalation and digestion exposure might yield results such that the reference dose is reached or crossed.

Table 2: Exposure of the workers through dermal contact in shops and the reference dose (U.S. EPA 1994)

Metal	**ADD_{derm} for Shop 1 (mg/kg/day)**	**Reference dose (mg/kg/day)**
Chromium	5.09E-06	3E-03

Nickel	2.41E-06	2E-02
Lead	2.53E-06	5.3E-04
Copper	3.65E-06	4.0E-02
Manganese	12.34E-06	1.8E-03

Conclusion

The working environment of two e-waste recycling shops was assessed in this work. The concentrations of Cr, Pb, Cu, Ni and Mn in indoor dust sample of one of the shops were determined successfully and the concentrations were much higher than the allowable limit. The health hazard for the workers of the recycling shop was also calculated using empirical relations. There is scope to evaluate the exposure by digestion and inhalation in future works and also a complete hazard analysis can be performed by taking more metals in consideration. The result from this study shows higher risk not only for the workers of those shops but also for the nearby residents as the indoor dust is dumped in the local dustbins, which can find its way to soil and water bodies. Although these shops are beneficial for our economy, we believe that if the hazardous working conditions are not addressed, it will do great damage to the people living nearby. It is hoped that the results from this study will help improve the conditions of the e-waste recycling shops in Dhaka with a view to achieve a safer future.

References

Anderson RA. Nutritional role of chromium. Sci Total Environ. 1981;17:13–29.

Brewer, G.J. and V. Yuzbasiyan-Gurkan. 1992. Wilson disease. Medicine 71(3):139–164.

Diaz-Barriga F. (2013) Evidence-based intervention programs to reduce childrens' exposure to chemicals in e-waste sites. Discussion paper for WHO Working Meeting on e-waste and children's health. 1-90

Goyer. R. 1991. Toxic effects of metals, In: *Casarett and Doull's Toxicology*, 4th ed. Amdur, M.O., J.D. Doull and C.D. Klaassen, eds., Pergamon Press, New York. pp.623-680.

Gulson BL, Mahaffey KR, Mizon KJ, Korsch MJ, Cameron MA, Vimpani G. 1995. Contribution of tissue lead to blood lead in adult female subjects based on stable lead isotope methods. Lab Clin Med 125:703–712.

Jing C, Min L, XianHua L, Xiao L, LiLi W, Lei G (2009) Primary research on health risk assessment of heavy metals in road dust of Shanghai. China Environ Sci 29:548–554

K.J.Andersen and M.I Kisser. "Digestion of Solid Matrices – Desk study Horizontal"
March 2004. www.ecn.nl/library/horizontal.

Leung AO, Duzgoren-Aydin NS, Cheung KC, Wong MH (2008) Heavy metals concentrations of surface dust from e-waste recycling and its human health implications in southeast China. Environ Sci Technol 42:2674–2680

Nadkarni RA (1984) Application of microwave oven sample dissolution in analysis. Anal Chem 56:2233–2237

National Institute for Occupational Safety and Health (NIOSH). Report to Congress on Workers' Home Contamination Study Conducted Under The Workers' Family Protection Act (29 U.S.C. 671a) DHHS (NIOSH) Publication No. 95-123

Olanow CW. Manganese-induced parkinsonism and Parkinson's disease. Ann NY Acad Sci 2004; 1012 : 209-23.

Scheinberg, I.H. and I. Sternlieb. 1984. Wilson's disease. Major Problems in Internal Medicine. Vol. 23. Philadelphia: W.B. Saunders.

UNEP(2006) Call for Global Action on E-waste. United Nations Environment Programme.

U.S. EPA 1994. *Methods for Derivation of Inhalation Reference Concentrations and Application of*

Inhalation Dosimetry. Environmental Criteria and Assessment, Office of Health and Environmental Asssessment, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. EPA/600/8-90/066F.

WHO/FAO. (2001). Codex alimentarius commission. Food additives and contaminants. Joint FAO/WHO Food Standards Programme, ALINORM 10/12A. Retrieved from www.transpaktrading.com/static/pdf/research/achemistry/introTofertilizers.pdf

Wilbur S, Abadin H, Fay M, et al. Toxicological Profile for Chromium. Atlanta (GA): Agency for Toxic Substances and Disease Registry (US); 2012 Sep. 3, HEALTH EFFECTS. Available from: https://www.ncbi.nlm.nih.gov/books/NBK158851/

SPREAD AND PROPAGATION OF GENERIC SHOPPING MALL FIRE OF BANGLADESH UNDER DIFFERENT SCENARIOS

M. A. M. S. Shoshe[1] and M. A. Rahman[2]

ABSTRACT

Devastating loss of property and lives due to shopping mall fire incidences is a recurring hazard in context of Bangladesh. The present study investigates the spread and propagation of such generic shopping mall fire with the use of Fire Dynamics Simulator (FDS) at different fire scenarios. The simulations are carried out for two typical shopping mall designs with 246 m^2 and 315 m^2 floor area, for two fire sources, with two different fuels of different heat release rates (HRR) in actual and grid system fuel distribution, a total of seven different fire scenarios. The spread of fire, propagation of the buoyancy driven fire induced smoke, temperature profile and carbon monoxide concentration along the shops, hallways and nearby stairs are analyzed. The propagation of fire and smoke dispersion are found to be highly depended on the fire source position, fuel type, fuel distribution and design geometry of the mall. Results shows, the standard grid system fuel distribution can delay the maximum temperature and lethal CO concentration for about 100s.

Introduction

In the recent past, there are many instances of fire in the shopping malls of Dhaka city, causing significant damage of property and loss of lives. Basundhora city, the second largest shopping mall in Bangladesh, witnessed two fire incidents in March 2009 and again in August 2016, Zahur (2009), Rabbi (2016). Dhaka North City Corporation (DNCC) market faced a devastating fire on January 2017, which destroyed 296 shops, a portion of the market was collapsed on impact, and a loss of nearly Taka 200 crore, Hasan (2017). These statistics are just the tip of the iceberg, according to Bangladesh Fire Service and Civil Defense, there were as many as 18,048 fire incidents from July 2016 to June 2017, causing an estimated loss of Taka 430 crore, BSS (2017). There are already 3000 shopping malls in Dhaka city and the number is increasing continuously, Rahman (2010). The fuel distribution in shops of any typical shopping malls in Bangladesh, is even more alarming, as typically these shops have compact stacking of ordinary combustibles, thus, high density of fuel loads on an event of fire. Researchers are giving more attention to fire safety in accordance to the recent fire events. The use of Computational Fluid Dynamics (CFD) to effectively simulate fire would be beneficial and less costly than conducting a large-scale fire testing for planning of fire safety on future designs or modification on existing ones. Ryder (2004) and Ryder (2006) investigated Fire Dynamics Simulator (FDS), an LES code developed by the National Institute of Standards and Technology (NIST), for several validation runs. They suggested FDS as more effective in simulating fire and smoke dispersion, than traditional CFD codes, and also reported that, FDS required less computational power. Shen (2008) validated FDS in a hotel arson fire and Wahlqvist (2013) validated FDS in much sophisticated well-confined mechanically ventilated fire scenarios with the likes of nuclear industry.

Due to this wide spread acceptability of FDS software, researchers are now highly depended on FDS to investigate the fire propagation and smoke dispersion in large open spaces like shopping mall, subway atrium and underground tunnels. Khan (2017) with Fire Dynamic Simulator with an evacuation software and predicted the total evacuation time for seven fire scenarios with 100 evacuees in a single storied 64 m^2 floor area shopping mall consisting seven shops. They reported a 390% increase in the total evacuation time (TET) for a 50% increase in soot yield, thus concluded that the evacuation is highly affected by the fuel's thermal and reaction properties. Albis (2015) simulated four scenarios of fire for a two storied shopping mall of 50,753 m^2 floor area in each floor having 144 stores with FDS. They reported that the smoke propagated to the second floor at approximately 180s and covered the total floor within 900s after ignition. Gao (2012) with large eddy simulator (LES) studied the dispersion of fire induced smoke in a subway atrium for six fire scenarios. They reported, within 200s of ignition the atrium was filled with smoke and mechanical ventilation was found useful to disperse the smoke effectively. To reduce the horizontal dispersion of smoke roof windows were suggested.

[1]*Assistant Professor, Dept. of Mechanical and Production Engineering, AUST, Dhaka-1208, Bangladesh*
[2]*Associate Professor, Dept. of Mechanical Engineering, BUET, Dhaka-1000, Bangladesh*
Email of Corresponding Author –ashiqurrahman@me.buet.ac.bd, ashiqur78@yahoo.com

Figure 1. Typical shops of Co-Operative market and MultiPlan Shopping Complex (First floor).

Figure 2. PyroSim models of Co Operative market and Multiplan Shopping Complex.

Ji (2015) proposed an empirical correlation for predicting the maximum upstream temperature in inclined urban road tunnel fires with FDS. They reported the dimensionless upstream maximum temperature had a nonlinear and non-monotonous relationship with tunnel slope. Although FDS was used to simulate different fire situations as mentioned above, the literatures in context of Bangladesh were limited, and specific attention to the high fuel density usually seen in typical shops, was absent. This study thus, investigates two typical shopping malls of Dhaka, with high density of fuel loads in each shop, by FDS. Emphasis was given to the nature of propagation of fire and dispersion of smoke in those shopping malls, specifically at staircase, with the fire source, fuel type and fuel arrangement variations.

Simulation Method

The physical model

The shopping malls investigated in this study were Co Operative market at Mirpur and Multiplan Shopping Complex in Elephant Road, Dhaka, Bangladesh. The investigated shopping malls were visited and photos had been taken with permissions from the shop owners to replicate the shop interiors, as shown in Figure. 1. The FDS software used in this study was a CFD model of fire-driven fluid flow. It solves Navier-Stokes equations for low-speed, thermally-driven flow and gives emphasis on smoke and heat transport from fires. The FDS code treats turbulence by Large Eddy Simulation (LES). The FDS codes were generated by PyroSim, a graphical user interface for FDS. The physical models were designed in accordance to the photos taken. Figure. 2 shows the PyroSim model for Co Operative market and Multiplan shopping complex. The Co Operative market was designed for two types of shops, clothing stores and furniture stores. The legend CS1 stands for the fire source at shop 1 with clothing, CS2 for fire source at shop 2 with clothing, FS1 for fire source at shop 1 with furniture and FS2 for fire source at shop 2 with furniture in Co Operative market. MS1 stands for the fire source shop at MultiPlan shopping complex CH1, CH2, MH1 and MH2 stands for the hallways in those shopping malls. The zoomed portion in Figure. 3 shows the mesh refinement in near fire regions than the other regions.

Validation and Mesh Sensitivity Study

The validation and mesh sensitivity analysis were done with an ISO-9705 compatible room from Zalok (2007). In the FDS user guide McGrattan (2013), suggested a non-dimensional expression D*/dx to be used to find mesh resolved case, where D* is a characteristic fire diameter as shown in Eq. 1. Here, $\dot{Q}$ is the total heat release rate of the fire, $\rho_\infty, c_\infty, T_\infty$ are the ambient density, specific heat, and temperature. McDermott

(2010) suggested that D*/dx =10 would be sufficient for a mesh resolved case. The validation works was done for four D*/dx values in accordance with FDS user guide. Summery of the mesh sensitivity analysis was given in Table 1.

Table 1. Summary of the mesh sensitivity study

Mesh	D*/dx	Cell Size (cm)	Elements	Time*
Coarse	4	28.4	768	0.044
Moderate	10	11.36	18432	1
Fine	16	7.1	64800	4
Finer	25	4.5	218700	34.67

Dimensionless computation time, was obtained from McDermott (2010) suggested minimum D/dx value.

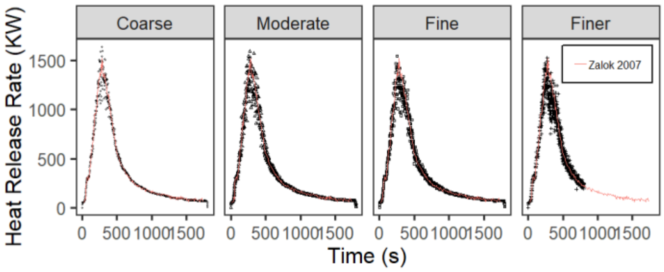


Figure 3. Validation of Zalok (2007) and mesh sensitivity analysis.

The computation times were non-dimensionalized by the time required for the D*/dx =10 case, named moderate in representations, to observe the improvement in results by cost of resources. The results of the mesh sensitivity analysis were shown in Figure. 3. Observing the Figure. 4 and Table 1, the mesh size of D*/dx =25, named finer, was discarded due to excessive resource uses with virtually no improvement in results. The D*/dx =4 case, named coarse was also discarded due to its widespread data points. The D*/dx =10 and D*/dx =16 cases, namely moderate and fine, were within acceptable range in both resolution of result and demand of resources.

$$D^{*}=\left(\dot{Q}/(\rho_{\infty}c_{\infty}T_{\infty}\sqrt{g})\right)^{\frac{2}{5}} \quad (1)$$

Simulation Details

The simulations were done with two fire sources, two types of fuel and two types of fuel arrangements in two shopping malls. For the Co Operative market two fire sources at CS1/FS1 and CS2/FS2 were simulated as clothing and furniture stores in actual fuel distribution observed from the shopping mall visits. The resulting simulation cases for Co Operative market were CCS1 fire at clothing store 1, CCS2 fire at clothing store 2, CFS1 fire at furniture store 1, CFS2 fire at clothing store 2. Then the clothing stores fuels were redistributed to grid system distribution, a standard and less compact distribution, this results two simulation cases, CCS1G for fire at clothing store 1 in grid system and CCS2G for fire at clothing store 2 in grid system. The MultiPlan shopping complex was simulated for fire at MS1 for clothing store only and named MCS1. The present study used D*/dx =15 near fire source and D*/dx =7.5 in other regions. The mesh elements for the CCS1, CFS1 and CCS1G case were 362,040, for CCS2, CFS2 and CCS2G case were 419,300, and for MCS1 case were 523,560. In FDS, the parameters for fabric were used from Zalok (2007), the heat release rate per unit area HRRPUA was taken to be 1528 kW/m^2 and CO yield as 0.0369. For furniture the default red oak wood parameters available in PyroSim was used. The end of the hallways and staircase celling were designed as open boundary. The investigated different fuel types and distribution in PyroSim are shown in details in Figure. 4.

Results and Discussion

The simulations of the present study were conducted for 600s (10 minutes) to observe the flame propagation and smoke dispersion in PyroSim. The fire was started with a fixed temperature igniter of one mesh element size. Ignition occurred after the self-ignition temperature of the fuel was reached and the fire was then propagated to other areas, measures were taken to ensure multiple flame fronts were not originated from the igniter itself. The Figure. 5 shows the fire scenarios for CCS1 and CFS1 case for 150s, 300s, 450s and 600s. From the Figure. 5 it was observed that the flame was propagated much rapidly with for the furniture store than clothing store.

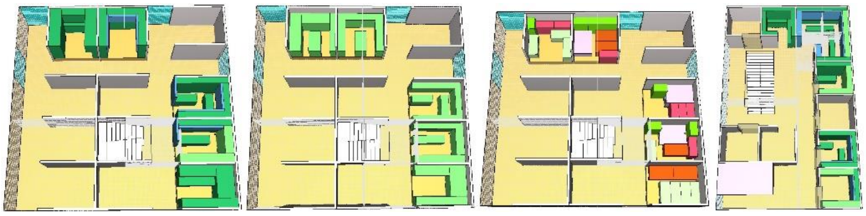


Figure 4. Fuel distributions of CCS1/CCS2, CCS1G/CCS2G, CFS1/CFS2 and MCS1 (from left to right) .

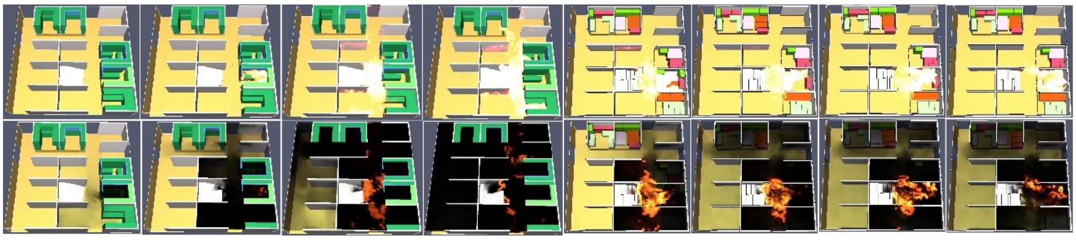


Figure 5. Fire and smoke propagation for CCS1(left) and CFS1(right) for 150s, 300s, 450s and 600s.

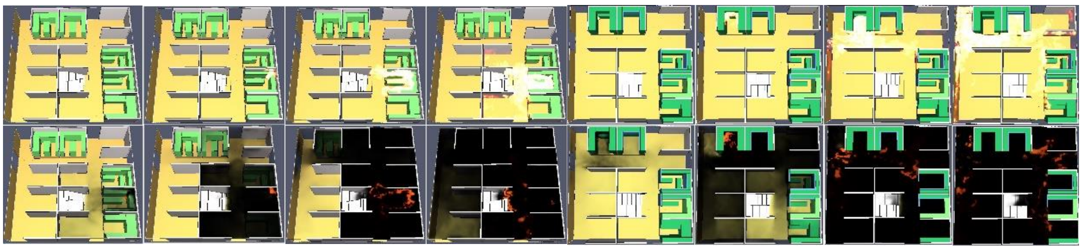


Figure 6. Fire and smoke propagation for CCS1G(left) and CCS2(right) for 150s, 300s, 450s and 600s.

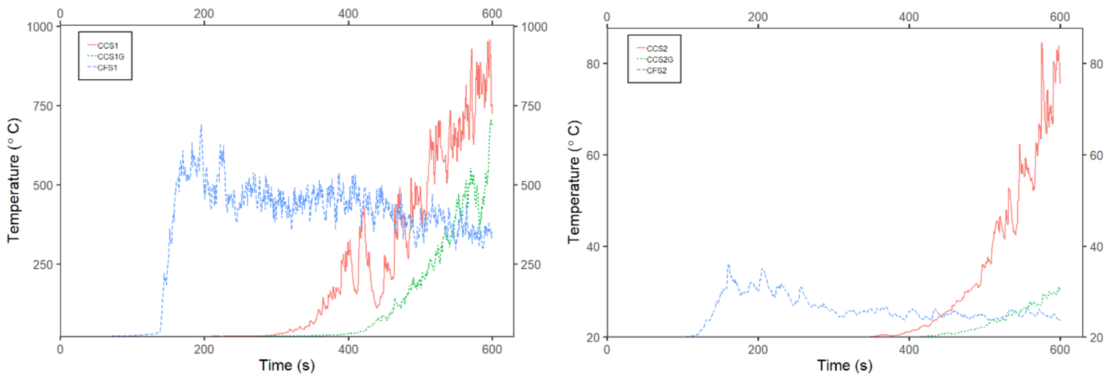


Figure 7. Temperature at staircase celling in function of time for fire source at CS1/FS1(left) and at

CS2/FS2(right).

The intensity of the furniture store fire was already diminishing at 600s with its peak at around 450s, but the clothing store fire was still burning at 600s and would engulfed the total floor space if more time was given. The smoke of the furniture store fire was confined in fire source surroundings and never fully covered the total floor, where the clothing store fire fully occupied the floor area around 540s. Figure. 6 represents the fire scenarios for CCS1G and CCS2 cases. Changing the fuel distribution and stacking compactness in CCS1G clearly improved the fire situation as the intensity of flame and smoke dispersion both were smaller than the actual distribution CCS1 case.

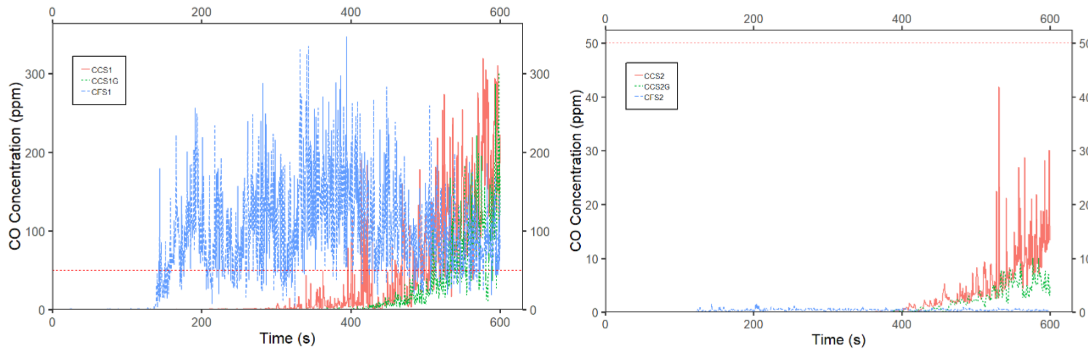


Figure 8. CO concentration in function of time for fire at CS1/FS1(left), and at CS2/FS2(right).

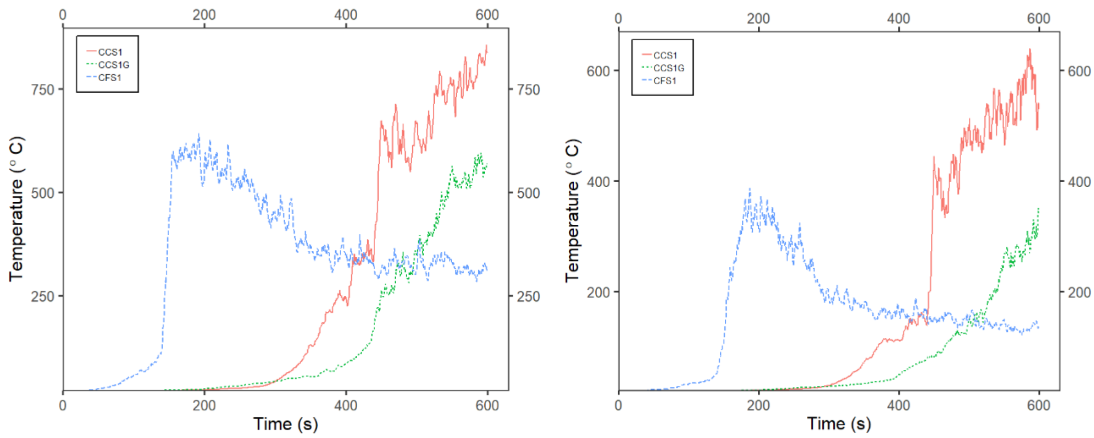


Figure 9. Temperature at CH1 hallway celling in function of time at 3m(left) and 6m(right) from CS1/FS1.

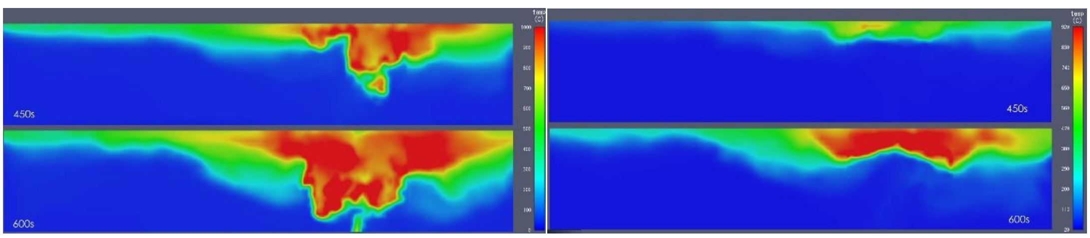


Figure 10. Comparison of hallway temperature profile at 450s and 600s for CCS1(left) and CCS1G (right).

Changing the fire source to a different location in CCS2 delays the dispersion of smoke and flame propagation to staircase due to the design of geometry but had the same intensity and propagation as of CCS1. Figure. 7 shows the temperature at staircase celling in function of time for the fire at shop 1 case, i.e., CCS1, CFS1 and

CCS1G at left and for the fire at shop 2 case, i.e., CCS2, CFS2 and CCS2G at right. The furniture fuel case for CFS1 had reached maximum temperature of around 160s much faster than the CCS1 and CCS1G cases. The grid system of CCS1G clearly delayed the temperature increase at staircase for 100s than the actual CCS1 case. As the fire source was moved at shop 2, the flame had minimum influence on the temperature at staircase due to geometric restrictions. Figure. 8 represents the CO concentration at staircase celling for fire at shop 1 case, i.e., CCS1, CFS1 and CCS1G at left. The red dashed line shows 50 ppm, the lethal dose for CO concentration. As the furniture store had rapid flame movement 50 ppm threshold exceeded for furniture fire much earlier than that of clothing fire at around 160s and continued to be higher than the threshold for the entire simulation time. For the clothing store CCS1 at around 400s the lethal concentration of CO exceeded, CCS1G here also delayed the CO lethal range for around 100s. For the cases fire at shop 2 the design geometry again played important role to restrict the CO concentration under the lethal threshold at staircase celling for the entire simulation time.

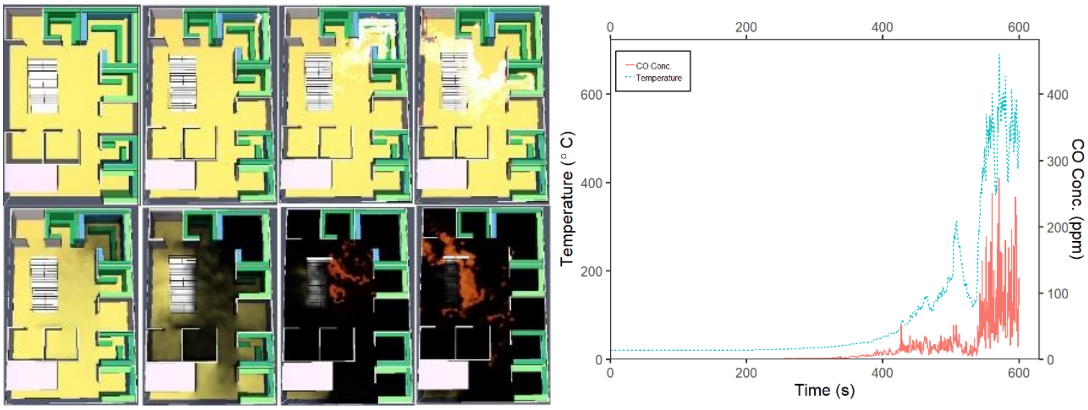


Figure 11. Fire and smoke propagation for MCS1 model for 150s, 300s, 450s and 600s (left) Temperature and CO concentration in function of time at staircase for MCS1 case (right)

Figure. 9 shows the temperature profile at celling for the CH1 hallway at 3m(left) and 6m(right) horizontal distance from the fire source for shop 1 cases. The temperature distribution portrays that, for furniture fire, the temperature of the entire hallway reached around 400°C just 150s after ignition, and gradually declined to 130°C at 600s. For clothing fire, the temperature reached around 100°C at 360s and jumped suddenly to 400°C due to flash over at 450s. The grid distribution again delayed the fire propagation for 100s and the sudden flash over was absent in this scenario. On Figure. 10 the temperature profile at the middle of CH1 hallway was shown, for CCS1(left) and CCS1G(right). These temperature profiles further suggest that using a grid system distribution and less compact stacking of the combustibles reduced the intensity of the fire. From the Figure. 8, 9 and 10 it was concluded that, the furniture fire was rapid and the temperature and CO concentration breached the lethal threshold as hallways was fully engulfed by flame in just under 3 minutes of ignition. For the clothing fire the fire engulfed the hallway just under 8 minutes despite reducing the fuel load to more than half of the actual load in grid distribution. On left of Figure. 11 the fire scenario of MCS1 was portrayed. The large open space in the middle aids the smoke to disperse more horizontally rather than concentrate on hallways thus delaying the loss of visibility and CO concentration threshold. The right of Figure. 11 shows the temperature and CO concentration for MCS1 case at staircase, the increase temperature and CO concentration found to be delayed due to the large open space as also observed from the flame and smoke dispersion from left of Figure. 11. Despite the large open space the MCS1 fire too become deadly in about 8 minutes. Observing from these results it can be suggested that, the flame propagation and smoke dispersion depends highly on the fuel type and fuel distribution at fire source, also with the placement of source with respect to the design geometry of the shopping mall.

Conclusions

A numerical study was performed with FDS to observe the flame propagation and smoke dispersion in two typical shopping malls with highly compact fuel distribution in context of Bangladesh. Investigations were carried out for two shopping malls with two fire sources and two fuel types common typically in those shopping malls. A standard grid type less compact fuel distribution was investigated and compared against the actual fuel distribution. The findings can be summarized as follows,

- The propagation of flame and smoke were highly influenced by the fuel type used and fuel distribution of the shops. The geometric position of the fire source shop was critical for the temperature and CO concentration at staircase, a critical position for evacuation.
- The grid type fuel distribution was able to delay the lethal CO concentration threshold and maximum temperature for a minimum of 100s for the clothing fire cases.
- The fire produced by the furniture store was rapid and fully engulfed the hallway in under 3 minutes (180s) of ignition. And for all the clothing store cases considered, the fie engulfed the adjacent hallway within 8 minutes (480s) of ignition. Diminishing the fuel load to more than half in grid distribution failed to produce any eye widening results in this regard.

The present study did not consider different types of fuels in adjacent shops, a common situation in shopping malls, this could be studied further to improve the prediction of the fire situations considered.

Acknowledgments

The PyroSim software support from ThunderHead Engineering is gratefully acknowledged.

References

Albis, K. A., Radhwi, M. N., and Gawad, A. F. A. (2015) “Fire Dynamics Simulation and Evacuation for a Large Shopping Center (Mall): Part I, Fire Simulation Scenarios”, *American Journal of Energy Engineering*, 3 (4-1), 52-71.

Bangladesh Sangbad Sangstha (2017) “Fire causes Tk 430cr loss in one year: Fire chief”, *The Daily Star online.* [Accessed on July 12, 2018]

Gao, R., Li, A., Hao, X., Lei, W., and Deng, B. (2012) “Prediction of the spread of smoke in a huge transit terminal subway station under six different fire scenarios”, *Tunnelling and Underground Space Technology*, 31, 128-138.

Hasan, M. K., Rabbi, A. R. and Mahmud, A. H. (2017) “Fire partially destroys Gulshan market”, *Dhaka Tribune online*. [Accessed on July 12, 2018]

Ji, J., Wan, H., Li, K., Han, J., and Sun, J. (2015) “A numerical study on upstream maximum temperature in inclined urban road tunnel fires”, *International Journal of Heat and Mass Transfer*, 88, 516-526.

Khan, E. A., Ahmed, M. A., Khan, E. H., and Majumder, S. C. (2017) “Fire Emergency Evacuation Simulation of a shopping mall using Fire Dynamic Simulator (FDS)”, *Journal of Chemical Engineering*, 30 (1), 32-36.

McDermott, R. J., Forney, G. P., McGrattan, K., and Mell, W. E. (2010) “Fire Dynamics Simulator Version 6: Complex Geometry, Embedded Meshes, and Quality Assessment”, *National Institute of Standards and Technology, NIST.*

McGrattan, K., Hostikka, S., McDermott, R., Floyd, J., Weinschenk, C., and Overholt, K. (2013) “Fire dynamics simulator, user’s guide”, *NIST special publication*, 1019, 41.

Rabbi, A. R. (2016) “Bashundhara mall fire under control”, *Dhaka Tribune online*. [Accessed on July 12, 2018]

Rahman, M. S. (2010) “The Only Solution”, *Forum - A Monthly Publication of The Daily Star*, 3 (3).

Ryder, N. L., Sutula, J. A., Schemel, C. F., Hamer, A. J., and Van Brunt, V. (2004) “Consequence modeling using the fire dynamics simulator”, *Journal of hazardous materials*, 115 (1-3), 149-154.

Ryder, N. L., Schemel, C. F., and Jankiewicz, S. P. (2006) “Near and far field contamination modeling in a large scale enclosure: Fire Dynamics Simulator comparisons with measured observations”, *Journal of hazardous materials*, 130 (1-2), 182-186.

Shen, T. S., Huang, Y. H., and Chien, S. W. (2008) "Using fire dynamic simulation (FDS) to reconstruct an arson fire scene", *Building and environment*, 43 (6), 1036-1045.

Wahlqvist, J., and Van Hees, P. (2013) "Validation of FDS for large-scale well-confined mechanically ventilated fire scenarios with emphasis on predicting ventilation system behavior", *Fire Safety Journal*, 62, 102-114.

Zahur, A.B.M.S. (2009) "Bashundhara City on fire", The Daily Star online. [Accessed on July 12, 2018]

Zalok, E. and Hadjisophocleous, G. (2007) "Characterizing of design fires for clothing stores", *Proceedings of the 5th International Seminar on Fire and Explosion Hazards*, 23, 27.

RECONSTRUCTION OF FIRE INCIDENT OCCURRED IN GULSHAN DNCC MARKET OF BANGLADESH AND SUBSEQUENT FIRE AND EVACUATION MODELLING FOR THE MARKET DURING PEAK TIME

Md. Ariful Hoque[1], Tanveer Islam Joy[1], Rafsun Hossain Mridha[1], Md. Rubel Mia[1], Shawon Kumar Saha[1], Abrar Amin Khan[1], and Md. Ashiqur Rahman[2]

ABSTRACT

A severe fire broke out in Dhaka National City Corporation Market (DNCC), a very popular two-storied shopping complex in the capital Dhaka on 3rd January, 2017. As per the official report, fire was originated from the electric circuit board in front of a General Store. The fire caused significant property loss (around 300 crore BDT) by damaging about 234 shops but there was no casualty as the fire started slightly after midnight. The application of fire science-based systematic study and computer modeling has been proven to be an effective tool in the field of fire forensics. The present study demonstrates the reconstruction of the fire scenario for the same incident and subsequently modelling fire and evacuation during peak time in the market. The fire scenario is reconstructed in PyroSim (a computational fluid dynamic tool) and further modeled for peak time that includes analysis of fire and smoke propagation, temperature distribution, concentration of CO and visibility at different sections of the market with respect to time. The possible evacuation scenario for the shoppers and shop owners during this fire incident at peak shopping time is analyzed using Pathfinder. This study can be helpful in assessing the fire risk and enhancing safe evacuation of occupants in markets and shopping complexes in Bangladesh

Introduction

Fire is a major concern for the scientists and researchers due to its destructive characteristics, though the scope of experimental validation is quite limited because of its violent nature. Among different commercial occupancies, fire in a market represents a challenging and significant fire hazard due to some of its characteristics such as presence of large amount of volatile and flammable materials which include polyester, nylon, plastic, particle board and many more, congested and narrower space, high density of occupants and so on.

Growth of fire and smoke spread can be modeled with the help of different computational tools like large eddy simulation (LES) and computational fluid dynamics (CFD). For simulating fire hazards and accidents, PyroSim is widely used which is a CFD tool based on fire dynamics simulator (FDS). It optimizes low speed and thermally driven flow. Different fire and smoke propagation scenarios for a variety of occupancies, such as fire in a cinema hall and multistoried dormitory building have been modeled using PyroSim by different researchers (Glasa, 2012; Long, 2017).

It is immensely beneficial to construct occupant evacuation model to estimate the probable evacuation scenario in the case of a fire, as any fire hazard in any occupancy seizes significant risk to human lives. Considerable studies have been carried out on the effect of different parameters such as type of fire, occupant characteristics, building geometry etc. on the evacuation behavior in different types of occupancies. The relationship between the number of evacuees and emergency exit for safe evacuation has been perused (Chen and Mao, 2018). Adequate facilities to prevent smoke intrusion into the layers of space for better protection of the personnel are recommended (Li, 2018). Pathfinder is an evacuation modeling software which allows varying psychological aspect of human behavior while evacuation. It has two models to simulate evacuation process which include Society of Fire Protection Engineers model and Steering model, while different evacuation characteristics vary between the two models.

From the point of view of fire scenario reconstruction, the present work is relevant to a study which involved reconstruction of a fatal fire that occurred in an indoor shooting range in Korea in 2009 where 15 occupants were killed and one survived among all the 16 occupants present (Wang, 2017). In addition, a previous work Could be found on the modeling of fire and smoke in a commercial market that included use of both PyroSim

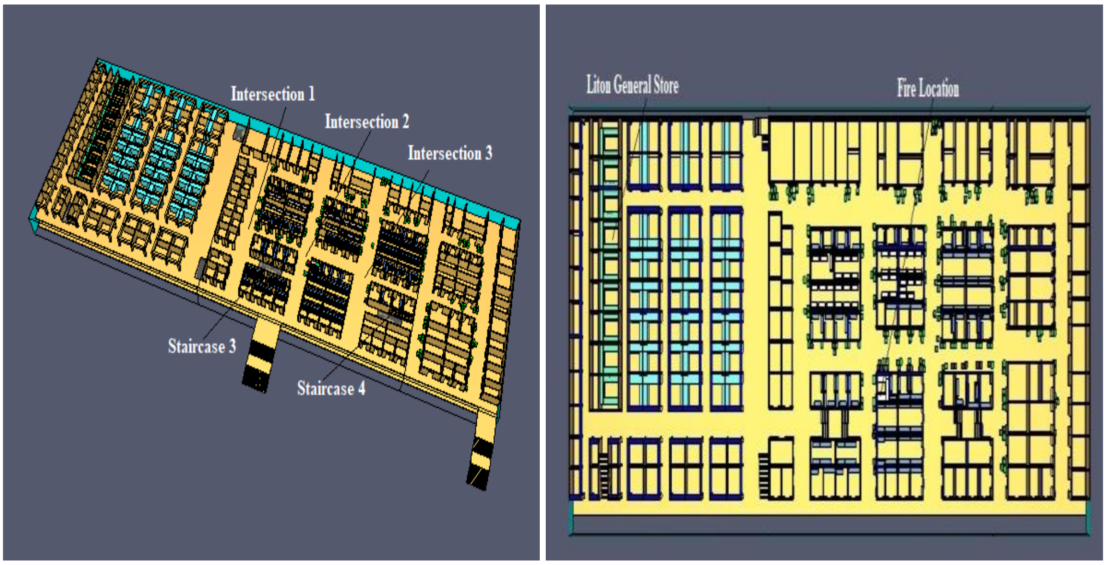
[1] *Student, Dept. of Mechanical Engineering, Bangladesh University of Engineering & Technology, Dhaka-1000, Bangladesh*
[2] *Associate Professor, Dept. of Mechanical Engineering, Bangladesh University of Engineering & Technology, Dhaka-1000, Bangladesh*
Email of Corresponding Author – ashiqurrahman@me.buet.ac.bd

and Patfinder in order to determine the egress time along with the safe evacuation condition of the market (Dong, 2014).

The goal of the present study is to reconstruct the fire incident that occurred in Gulshan DNCC Market of Bangladesh on 3rd January, 2017 and further model fire and evacuation for the same commercial market during peak time when the occupant density is generally high, to address the fire risk and examine the building performance in terms of safe evacuation in the event of fire incidents. All the geometric features of the market such as size and location of the shops, hallway, stairway, number of shops were modeled very precisely to resemble the market where the actual fire incident took place. Fire and smoke propagation as well as subsequent evacuation of the occupants have been modeled for the same building in Gulshan-1 having same geometrical dimensions and number of shops. The characterization of the fuel properties and fire dynamics are carried out according to the Society of Fire Protection Engineers (SFPE) handbook. Two different fire scenarios at two different times of the market which include night (when the actual incident occurred) and day (peak time) have been considered and the resultant fire and smoke spread scenario and the subsequent evacuation characteristics of the building occupants have been modelled and the results are reported here. The application of fire modeling tools to assist the fire scene reconstruction has proven to be a very useful approach throughout the world.

Building Geometry and Simulation Methodology

To analyze the fire hazard and consequences, the 2- storied commercial market building of 'Dhaka National City Corporation Market' at Gulshan-1 was taken into consideration where fire accident of 3rd January, 2017 was reconstructed. Three different fire scenarios was considered using different fuel load of only Particle Wood, only plastics and Particle Wood and Plastics which was based on the common materials used in a general store. In addition with the reconstruction of the fire incident, a fire scenario also was considered using a fuel load of Polyester in a clothing store at the peak time of a day. Simultaneously an evacuation model was developed observing the human behavior for this particular case of fire. The corresponding heat release rate and reaction for particle wood, plastics and polyester was determined from the SFPE handbook. The t-square growth model for the fire was used to determine the ramp-up time for the fuels.



(a) (b)

Figure 1. (a) 3D view of the 2-storied commercial market for which fire scenario was reconstructed (b) Layout of the fire floor where the fire initiated, fuel source and the location of corridors and staircases.

Table 1. Salient Features of 2 storied Commercial Market that is under consideration for Reconstruction of fire incident

Features	Quantity
Total Number of Floors	2

Area of Each Floor	5658.75 m^2 (60910.28 ft^2)
Number of Shops in Each Floor	188(Ground Floor), 103(2nd Floor)
Location of Fire Source	A General Store located in the South-East Corner on Ground Floor
Fuel Source	Particle Wood, Plastics
Peak Heat Release Rate of Particle Wood	176.4 KW/m^2
Peak Heat Release Rate of Plastics	782 KW/m^2

For the reconstruction of the real fire scenario, the commercial market under consideration was designed in in Pyrosim (Fig 1), which is based on fire Dynamics Simulator (FDS) from NIST. The two storied building had total number of 291 shops (188 at ground floor and 103 at 1st floor) and each floor had an area of 5658.75 m^2. The fire originated at night on the 1st floor, in 'Liton General Store' which was located at the south-east corner of the market. Some of the salient characteristics of the market, material properties and fire incident are provided in Table 1.

For evacuation modeling, the occupant density was chosen keeping in mind of the rush hour of the market when selling goes to peak on the basis of survey. The total number of occupants was considered 1310. The total occupants were categorized into some groups. The allocation is given in Table 2.

The shop type in each floor of the market had influence on the population distribution which was validated in the base of age group distribution data from the work of (Khan and Choudhury, 2016). The occupant density in the 1st floor was 0.222 person/m^2 and in the ground 0.242 person/m^2 which is within the range of the literature value found from (Chen, 2014). In case of fire emergency, gender, physical characteristics like height, shoulder width, walking speed plays an immense role on evacuating. Anthropometry data reported from (Khadem and Islam, 2014) have been used in this study, added in the Table 2.

Table 2. Allocation of the occupants

Category	Ground floor (Number of People)	First floor (Number of People)
Male	52	-
Male who will assist other	70	87
Female	84	159
Female who needs assistance	75	125
Female who will assist other	5	5
Shopkeepers	371	201
Elderly male	10	10
Elderly Female	5	5
Child	12	34
Total	684	626
		1310

Table 3. Detail of the body dimension considered for Bangladeshi male and female

Gender	Dimension	Minimum (in)	Maximum (in)	Mean (in)	Standard Variation
	Shoulder Breadth	13.685	19.307	16.496	0.937
Male	Height	59.82	72.22	66.02	2.067
	Shoulder Breadth	14.382	20.1	16.925	1.5
Female	Height	57.3	64.7	60.32	1.2

Table 4. Detail of walking speed in emergency considered for Bangladeshi young male and female, child and elderly

Category	Distribution type	Speed (m/s)
Adult male	Normal	Min= 2.36 Max=3.4 Mean=2.944 SD=.41
Adult female	Normal	Min=2.336 Max=2.52

		Mean= 2.432 SD=.09
Elderly male	Constant	1.05
Elderly female	Constant	1.04
Child	Uniform	Min=1.14 Max=2.23

As stated earlier walking speed is one of the prime factors in evacuation, this speed varies for various people depending on their age, gender, physical fitness the experimental data of (Wong and Cheng, 2006) was selected as it resembles the demographic of the market occupants closely. The speed of the child and elderly people is obviously different from adult male and female, child speed has taken from (Larusdottir and Dederichs, 2012) and elderly people from SFPE handbook added in Table 3. The behavioral factors were set at such pattern that any occupant can choose any exit.
Another key factor is the pre evacuation time, quite obvious that people would not react immediately after fire broke out, there would be a delay period. Since the pre evacuation time for shopkeepers likely to be higher than other customers for ensuring there goods safety, in addition to that 20% shopkeepers will assist other occupants for evacuation so it was considered pre-evacuation time with minimum of 23 seconds to a maximum of 152 seconds having a mean of 74 seconds. This data is found in Society of Fire Protection Engineers handbook for business category occupancy level. For other occupants who will not be assisted, pre-evacuation time is set with a mean of 40s within a range of 20s to 50s.
The simulation strategy was on the basis of certain parameter, Smoke concentration, visibility and temperature. Therefore, these parameters were measured at different locations of the market in order to determine the tenability. The critical concentration of CO was taken as 3000 ppm. For heat factor, the threshold temperature was taken as 60°C. The cause of picking this value is, 60°C has been found to be the maximum temperature at which 100 % water vapor saturated air can be breathed. For visibility when the value goes above 13 then it becomes untenable. It was set that when any of these tenability surpasses of any of these factors the occupants cannot go further in that route. These values have been established as the criteria of tenability as per the standard values prescribed in the SFPE handbook.

Results and Discussion

(a) Recreation of the Fire Incident

There is certain abridgement while working with fire dynamics in general and especially in fire scene reconstruction. While the use of computational model to simulate fire, dynamics is relatively common for design purposes, it is less common for fire scene reconstruction. There are many possible scenarios that Might have taken place during the origin and propagation of fire, which cannot be known unless properly identified and documented immediately after the fire incident. Since science-based fire scenario is not manifested in Bangladesh, the official report on the fire incident does not include many scientific details. Therefore, the knowledge of scientific principle and fire dynamics, detailed analysis of possible fire scenarios have been used in this study to carry out the reconstruction of the fire incident.
In the present study, a computer modeling-based approach has been taken to reconstruct a fire incident in a commercial market that took place at night in Dhaka, Bangladesh, 2017 and caused a collapsing of one side of the market. According to the official report by the Fire Service and Civil Defense Department of Bangladesh on this fire incident, the fire was first started by the electric spark inside the market. The source of the fire was in a shop named 'Liton General Store' situated on the south-east corner of the ground floor. According to the eyewitness, fire was initiated approximately in between 01:30 a.m. to 01:40 a.m. and smoke came out from the east corner of the market at around 01:56 a.m. of 3rd January. The fire service was informed of the fire at 02:30 a.m. and one side of the market was collapsed in 2-3 minutes after the fire market service department reached the place. The generation of excess heat due to the fire incident and

Table 5. Various Fire Scenario Considered

Scenario Designation	Characteristics
A	Only plastics acted as a fuel source burning surface area of (68.88ft*49.56ft)

B	Only Particle wood acted as the fuel source burning surface area of (13.12ft*2.16ft)
C	Fire ignited in the Particle Wood and then spread into Plastics total burning surface area of (82ft*54.72ft)

Infrastructural error was reported as the reason for the collapsing of the one side of the market. The generation of excess heat due to the fire incident and infrastructural error were reported as the reason for the collapsing of the one side of the market. The amount of loss due to this fire incident was approximately 300 crore BDT. It is natural to raise questions on which type of fuel source the spark was fallen and caused a huge loss. This study has taken a simulation-based path to demonstrate the events and attempt to address the question in quantitative manner.
In order to analyze the fire growth and propagation, three different scenarios with 4% shutter opening at the bottom of the store were simulated considering the variation of fuel source in Table 5.

Scenario A: Fire Scenario Considering Plastics as the only fuel source

Plastics was chosen as a fuel source for this scenario as plastics is one of the most common and widely used materials in a general store. The total burning surface area was considered (68.88ft*49.56ft) which is closely reassemble with the amount of plastics used in a general store. It was found that smoke came out from the store after 2 minutes and from the east corner of the market in less than 5 minutes which is quite dissimilar with the FSCD report. It was very common to get such a result as plastics is highly flammable and ignited readily. The rate of burn and smoke and amount of smoke generation is very high for plastics. According to SFPE Handbook, the value of CO Yield and flame spread rate of plastics is 0.024 gm/gm and 0.6 m/s respectively.

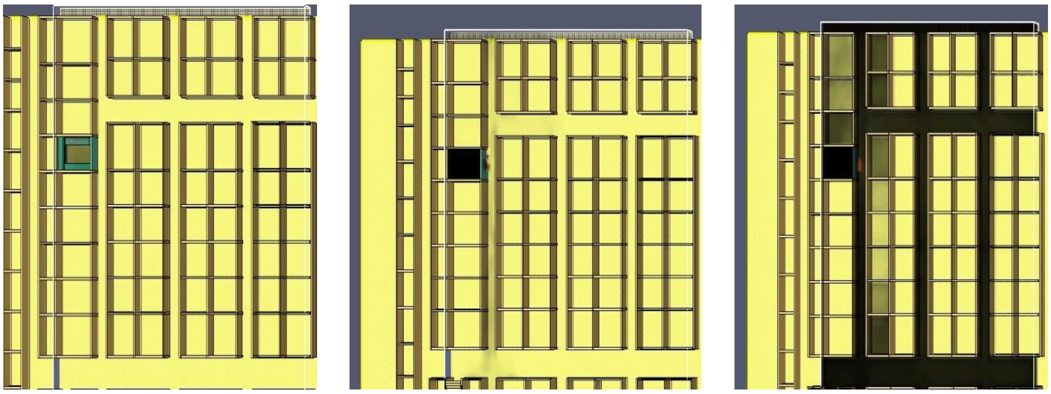
Scenario B &C: Fire Scenario Considering Wood as fuel Source (Scenario B) and Wood and Plastics (Scenario C)

Most of the shelf of a general store is made of particle wood. In scenario B, it was considered that spark fell on the top of a shelf of particle wood having a burning surface area of (13.12ft*2.16ft). It took 4 minutes for the smoke to go out from the shop to the corridor and more than 12 minutes from the east corner of the market to outside.
The propagation of fire and smoke throughout the market is displayed for scenario C in Fig 2. Fire was assumed to ignite in the top of the shelf and allowed to spread to plastics which was inside the shop. Almost Similar results found for this case with scenario B. Within 4 minutes smoke emerged from the store and four hundred seconds later the smoke left outside from the east corner of the market. The time required for coming out of the smoke is nearly similar to the evidence of the eyewitness of the incident according to the FSCD report.
It can be concluded that, on 3rd January the spark might be fell on the wood at first and then extended to the other combustible materials present in the store as the fire smoke propagation for scenario B and C is closely analogous to the FSCD report.

(b) Fire and Smoke Propagation Scenario for the Peak Time of a Day

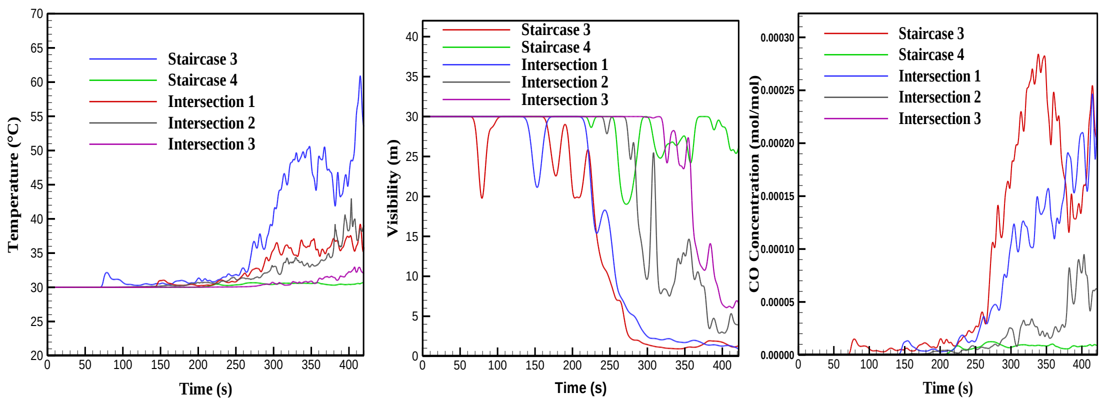
As mentioned before, along with the recreation of fire, a fire and evacuation modeling were done simultaneously for the same market at a peak time of a day. For analyzing the fire growth and smoke propagation, a scenario was simulated considering polyester as a fuel source. The source of the fire was a clothing store located on the ground floor of the market. Polyester was selected as a fuel source since it is very common and widely used material in textile industry. The total burning surface area of the polyester was 958.75 ft^2 having a peak heat release rate of 685 KW/m^2. The amount and distribution of the fuel were taken as concordant with the existing commercial market in Bangladesh. Different devices were placed on the fire floor as well as the upper floor of the building to measure temperature, visibility, CO concentration, CO_2 concentration. The devices were placed at 4 different heights of 0.45 m, 0.9 m, 1.45 m, 1.55 m. These heights were taken because 0.45 m, 1.45 m, 1.55 m are the crawling height, female eye height, male eye height, respectively. Distances between the devices were maintained 5 m in the corridors. A number of devices were also set on the base and landing of each staircase. Intersections 1, 2 and 3 were selected between different corridors. These intersections and the nearest staircases from the fire location were taken into consideration for analyzing the temperature, visibility, and CO concentration.

Temporal variation of different tenability parameters in different locations for this particular fire scenario have been displayed in Fig 3. It is evident that staircase 3 was the most affected as this staircase is the nearest from the fire source. The maximum temperature was found in staircase 3 (63°C), while the temperature in other staircases was under tenability limit certain as these staircases were at a certain distance from the fire source. The visibility drops under the tenability limit for staircase 3. Intersection 1 and 2 after 400s (Fig 3). As the simulation was performed considering the peak time of the day, all the shop inside the market was open. So the corridors at a distant from the fire source were not that much affected.



t=120s t=300s t=600s

Figure 2. The spread of fire and smoke throughout the market after the initiation of fire for scenario C



(a) (b) (c)

Figure 3. The variation of (a) temperature (b) visibility (c) CO concentration with time in different staircases and intersection between the corridorrs on the fire floor for fule load of Polyester.

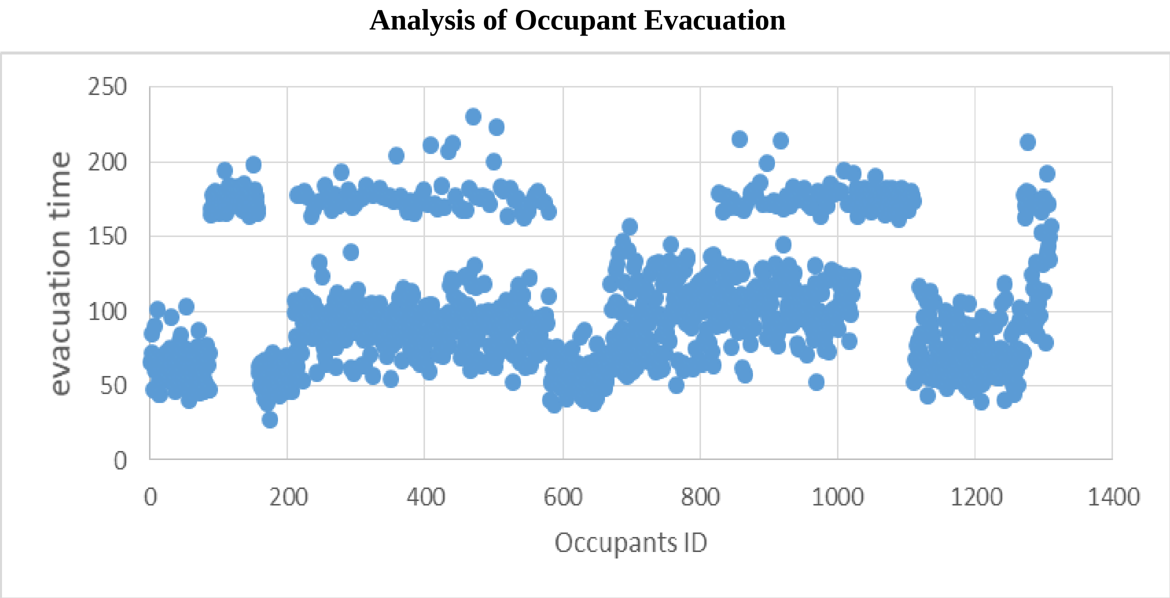


Figure 4. The evacuation time required by each occupant from the market

From the simulation the evacuation time required by each occupant are obtained and plotted in Figure 4. The minimum evacuation time by an occupant is about 25 seconds whereas maximum time requirement is 230 seconds. For a two storied shopping complex the time requirement is quite high. This evacuation time represents some common behavior of Bangladeshi people during panic attack.

Firstly, the shopkeepers always give priority to their property rather than their lives. During a fire, the shopkeepers, instead of evacuating as fast as possible, try to protect their properties or try to suppress the fire which is supposed to be done by fire fighters. This caused them higher pre-movement time which ultimately increase total evacuation time.

Secondly, the market is always crowded with occupants of different age group starting from child to elderly people. Under panic attack during any sorts of hazard, the children, elderly people and some percentage of adult female cannot move by their own. They need to be accompanied by other adult male or female occupants.

This scenario causes a reduction of moving speed for both assisted and assisting occupant and results in higher evacuation time.

Thirdly, the results from fire dynamics shows that the smoke spread through the staircase close to the fire source in the ground floor. The staircase is found to be untenable to use due to low visibility within 170 seconds of fire ignition. The occupants had to change their route to avoid smoky staircases and travel a longer distance causing the evacuation time to be higher.

Conclusions

A fire reconstruction has been performed using computer modeling for the fire that took place in Dhaka, Bangladesh in 2017 in a 2- storied commercial market. The study took a simulation-based accession to demonstrate that events which causes a huge loss. As the geometric feature of this market represents many of the commercial markets in Bangladesh and unique occupancy features, further a fire and evacuation modelling have been performed simultaneously assuming at the peak hour of the day. For the fuel load of similar to an actual clothing store it was observed that nearest staircases and corridors were mostly affected by high temperature, visibility reduction and high carbon monoxide concentration. For the fire scenario considered in this study it was seen that no people were stuck. Due to multiple exit routes, severe harm for people may not be seen. However, if the goods of the shops were distributed in a uniform pattern and obstruction different things were minimized inside and outside each shop, the required safety egression time, the time for the last individual to exit the building could have been slightly lower.

Acknowledgements

The authors would also like to express their sincere gratitude to Bangladesh Fire service and Civil Defense authority for their support.

References

Chen, H.N. and Mao, Z.L., (2018). Study on the Failure Probability of Occupant Evacuation with the Method of Monte Carlo Sampling. *Procedia engineering*, *211*, pp.55-62

Chen, J.J., Fang, Z., Sun, J.Y. and Wang, J.H., (2014). Research of occupant density in the wholesale and retail market. *Procedia engineering*, *71*, pp.265-270

Dong, S., Li, M. and Lin, Y., (2014). Study on Numerical Simulation of Fire and Evacuation for a Supermarket. *Applied Mechanics & Materials*.

Glasa, J., Valasek, L., Weisenpacher, P. and Halada, L., (2012). Use of PyroSim for simulation of cinema fire. *Int. J. on Recent Trends in Engineering and Technology*, *7*(2), pp.51-56.

Hurley, M.J., Gottuk, D.T., Hall Jr, J.R., Harada, K., Kuligowski, E.D., Puchovsky, M., Watts Jr, J.M. and Wieczorek, C.J., (2015). *SFPE handbook of fire protection engineering*. Springer.

Khan, M.M.H. and Choudhury, A., (2016), IMPACTS OF SHOPPING MALL ATTRIBUTES AND ENVIRONMENT ON CUSTOMER BUYING ATTITUDES: AN ANALYSIS ON DHAKA CITY.

Khadem, M.M. and Islam, M.A., (2014). Development of anthropometric data for Bangladeshi male population. *International Journal of Industrial Ergonomics*, *44*(3), pp.407-412.

Long, X., Zhang, X. and Lou, B., (2017). Numerical simulation of dormitory building fire and personnel escape based on Pyrosim and Pathfinder. *Journal of the Chinese Institute of Engineers*, *40*(3), pp.257-266.

Li, M.X., Zhu, S.B., Wang, J.H. and Zhou, Z., (2018). Research on Fire Safety Evacuation in a University Library in Nanjing. *Procedia engineering*, *211*, pp.372-378.

Larusdottir, A.R. and Dederichs, A.S., (2012). Evacuation of children: Movement on Stairs and on Horizontal plane. *Fire technology*, *48*(1), pp.43-53.

Wang, Z., Jia, F., Galea, E.R. and Choi, J.H., (2017). A forensic analysis of a fatal fire in an indoor shooting range using coupled fire and evacuation modelling tools. *Fire Safety Journal*, *91*, pp.892-900.

Wong, L.T. and Cheung, T.F., (2006). Evaluating probable risk of evacuees in institutional buildings. *Safety science*, *44*(2), pp.169-181.

ANALYSIS OF LNG STORAGE TANK HAZARDS AND CORRECTIVE MEASURES USING HAZOP AND BOW-TIE DIAGRAM

Ifat Sharmin[1] and Easir A. Khan[2]

ABSTRACT

This paper represents a study of hazard identification and consequence evaluation of LNG tank facilities using logical sequence of cause-deviation-sequences of process parameters. The qualitative risk analysis approach; HAZOP and Bow-tie (BT) is used for evaluating hazards and risk in a LNG tank facility. HAZOP carries out a structured analysis of the process and identifies the deviations that may take place with regard to the intended functioning, as well as their causes and consequences. HAZOP has been widely used for identifying, analyzing and evaluating hazards occurred in a system. The Bow tie (BT) risk analysis approach represent a complete scenario starting from accident causes and ending with its consequences. One of the major properties of bow-tie concept is its illustrative graphical nature which is easy to understand for management or operations in controlling potential risk through an effective barrier management system. Most of the accidents occurred in petrochemical industry are fire and explosion due to equipment failure, overpressure, leak or pipeline rapture, corrosion, human error, poor operation and maintenance. Application of these HAZOP or bowtie methods to identify potential hazard and appropriate corrective measures could avoid catastrophic incidents in oil and gas industry in future.

Introduction

Liquefied natural gas (LNG) plays an increasingly important role in the petroleum industry and global energy markets. In fact, worldwide, total consumption of natural gas is predicted to rise by an average of 1.3 percent per year, from 3.2 trillionm^3 in 2010 to 5.2 trillion m^3 in 2040. In 2011 the natural gas dependency rate of the European Union with 28 countries was about 67% and it has grown almost 2 percentage per year till now. Worldwide, there are at least 60 operating import ("regasification") marine terminals across 18 different countries. Both on- and off-shore technologies are adopted. In addition to operating terminals, there are more than 180 terminals that are still in the design or construction stages (Paltrinieri et al., 2014). The LNG supply chain allows the long distance transportation of large amounts of natural gas, providing supply opportunities that may not be realized using pipeline transportation. Bangladesh government has founded a LNG regasification plant in Maheshkhali which has not started full operation yet. So we have an opportunity to secure a place in fuel market, that's why it is high time we ensured a safe dealing with LNG terminal. If the storage of flammable and explosive hazardous chemical is improper, it will cause a vicious disaster such as fire, explosion with casualties, property damage and environment pollution (Xuanya et al., 2017). The loading and unloading activities from the storage tank are more prone to accidents. In case of overpressure, structure collapses and gas releases into the atmosphere. Low pressure can cause incoming of atmospheric air into the tank, which heats and vaporizes the LNG. When a flammable liquid is leaked from a storage tank, it forms a pool resulting in evaporation and dispersion. If the flammable vapor meets an ignition source, a flash fire or explosion can occur. The flame can also travel back to the spill causing a pool fire. If the LNG is released from the tank, the LNG will evaporate and mix with air. Natural gas will burn if the air- gas mixture concentration is between 5% and 15%. In case of a major leak, a continuous release with jet fire or pool fire is possible.LNG is a cryogenic liquid and its boiling point is -162^{0}C. Its direct contact with skin causes freeze burn and its contact with the eyes also causes harm. When LNG is spilled into water a violent vaporization is happened and the explosion is known as Rapid Phase Transition which develops overpressure creating potential damage. The accident process is comprised of three steps: initiation, propagation and termination. The typical sequence includes material and energy release, dispersion of material and energy, ignition, spreading of fire and exposure to human, property and environment. Once ignition starts, the disaster propagates triggering one or more secondary events which is known as domino effect (Rathnayaka et al., 2012).During unloading from ship to tank the presence of strong waves in water body initiates a transient event. High temperature and interruption in electric power supply also cause disaster. Offshore plants have higher frequencies of plant damage compared to the onshore. Offshore plants face higher quantity of release along longer distance and more adverse effects (Aneziris et al., 2014). However the social acceptance of LNG regasification facility depends largely on safety standards which result in low risk for both the population and

[1] Graduate Student, Department of Chemical Engineering, BUET, Dhaka-1000, Bangladesh
[2] Assistant Professor, Dept. of Chemical Engineering, BUET, Dhaka-1000, Bangladesh
Email of corresponding author-eakhan@che.buet.ac.bd

the environment. An appropriate and effective method of hazard identification, evaluation and prevention is required to avoid any catastrophy (Giardina et al.,2015). Many techniques have been developed for hazard identification in the processing industry, but no single technique can assess potential hazard and risk posed on process facilities. Besides, previously unidentified accident scenarios have to be considered. However, the process of risk assessment can be best achieved using a combination of different techniques. Detailed description of the possible accident scenarios and component failures can be attained by applying well known methods. The major accident in LNG facilities and its consequence is reported in Table.1.

Table 1: Major LNG accidents and consequences (Martins et al., 2016):

Date	Location	Description	Fatalities	Cost(US$ millions)
January 19th, 2004	Skikda, Algeria	A steam boiler that was part of an LNG production plant exploded and a vapor-cloud explosion and fire was created. The explosions and fire destroyed a portion of the LNG plant and caused 27deaths,74 injuries, and financial loss outside the plant boundaries.	27	54
October 20th, 1944	Cleveland, Ohio, USA	At the peak-shaving plant, a leak in a tank spread LNG into the street and storm sewer system, which resulted in an explosion and fire. The main cause was that the tank was built with a steel alloy that had low-nickel content, which made the alloy brittle when exposed to the extreme cold LNG.	130	890
February 10th, 1973	Staten Island, New York, USA	After a power failure and the automatic closure of the main liquid line valves, 40 gallons of LNG leaked as it was being loaded onto a barge. The LNG leaked from a one-inch nitrogen-purge globe valve on the vessel liquid header, which caused several fractures on the deck plate.	40	15
October 6th, 1979	Cove Point, Maryland, USA	Anexplosionoccurredinsidetheelectricalsubstationatthereceivingendof Cove Point. The LNG leaked through the electric pump seal. The vaporized natural gas went through 70 m of pipeline and electrical wires penetrating the substation. During construction, no gas detectors were installed in the building, because it was not expected to have natural gas in this area.	1	9
March 18th, 1971	La Spezia, Italy	This accident was caused by "rollover" which is a sudden increase in pressure resulting in the release of large amounts of vapor. In this case, about 2000 tons of LNG vapor discharged from the safety valves of LNG tank and vents over a period of a few hours, damaging the roof of the tank.	0	1
May 3rd, 1965	Canvey Island UK	An explosion occurred at the time of the construction of the LNG transport onshore.	1	2
Dec 20th, 1983	Bontang Indonesia	A rupture in an LNG tank occurred as a result of over-pressurization of the heat exchanger caused by a closed valve on a blow-down line. The exchanger failed and the explosion occurred.	0	15
May 10th, 1988	Boston, Massachusett, USA	LNG facility spilled 30,000 gallons of LNG.	0	12

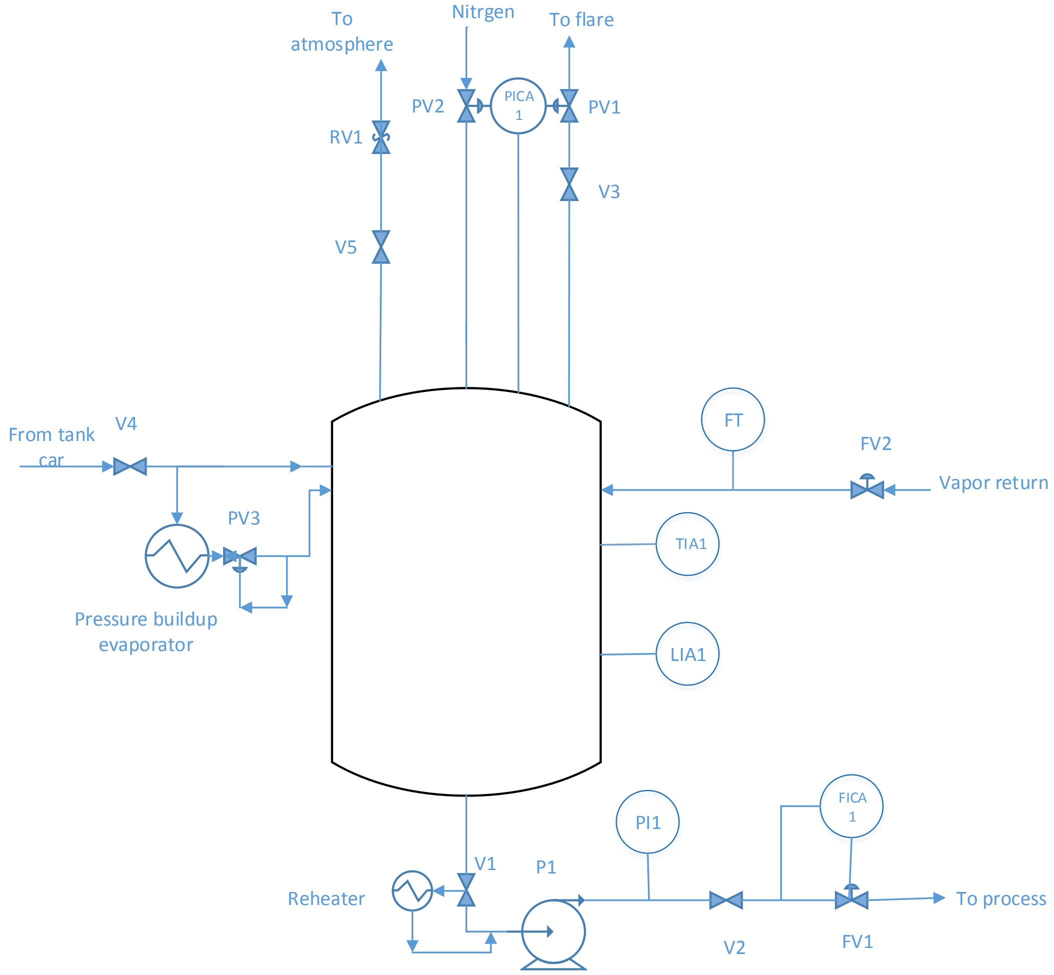
There are numbers of methods that can be used in hazard identification and risk evaluation. HAZOP (Hazards and Operability) method is simple but structured methodology for hazard identification and assessment. HAZOP is an appropriate tool to assess the safety of a system before proceeding with the detailed design, engineering and operation. The aim of the HAZOP study is to identify potential hazardous events and significant operability problems associated with the concerned operations. BT (Bow Tie) is a graphical relationship among fundamental causes, critical incidents and final consequences of undesired events by combining a fault tree and an event tree. The best part of the bow-tie is the clear picture of the risk that is easily understood by humans even less experienced ones. On the contrast, the greatest drawback is the uncertainty of quantification (Ibrahim et al,. 2017).Fault tree analysis is an analytical tool that uses deductive reasoning to determine the occurrence of an undesired event. FTA, along with component failure data and human reliability data, can determine the frequency of occurrence of an accidental event. Failure mode effect analysis (FMEA)is an examination of individual components such as, vessels, pumps, valves, etc. to identify the failures which could have unwanted effects on process operation. FMEA is a qualitative inductive method and is easy to apply. The What if method involves asking a series of questions beginning with what if as a procedure of identifying risks. Apart from checklists, What if analysis is possibly the oldest method of hazard identification and is still popular (Faisal et al., 1998). All these methods described above are qualitative analysis of hazards and risk. In order to get quantitative access to the analysis one has to adopt some other method like Bayesian approach which allows to construct risk analysis from real data and improve it by adding a new numerical that enables us to implement the appropriate preventive and protective barriers in a dynamic way.

The results allow for the collection of a significant amount of information regarding the LNG storage process, which can be useful in the planning of the maintenance procedure or the design of appropriate safety control for the process. Compliance with national and internationally accepted codes and standard for designing terminals, inspection and maintenance can minimize accidents in LNG as well as all process plants. Government of Bangladesh has newly started the LNG project and yet has no codes and standards of its own but implemented some legislations for the occupational health and safety, such as: The Boilers Act 1923, Nuclear Safety and Radiation control Act 1993, Environmental Protection Act 1995 etc. In Bangladesh, foreign codes and standards are followed. The European code EN1473 “installation and equipment for LNG design on onshore installation” is risk based meaning focused on outcomes rather than specific ways to achieve a desired level of safety. Additional codes are EN1160, EN1474, EN1532, EN13645.Canadian standard CSAZ276-01 requires underground unloading lines at important terminals, encased in a concrete caisson with a nitrogen inert atmosphere. The European Pressure Equipment Directive (PED) has been transposed in the Pressure Equipment (Commodities Act) Decree in the Netherlands. The requirements of the European Directive for design and new build are further interpreted in harmonized European standards. There were number of deadly incident occurred in chemical industry in Bangladesh. Thus, it is important for regulatory authority to develop methodologies, code and standards hazard and risk assessment, safety management to prevent accidents in industries deal with hazardous chemicals in Bangladesh.

Hazard and Risk in LNG storage system

In the first step of hazard and risk analysis, the safety analysts must have an accurate description of the facility and the process such as process flow diagram, piping and instrumentation diagrams, component reliability data, safety instrumentation, operating instructions, emergency shutdown procedures, process limits etc. (Giardina et al., 2015). A sample safety and control devices of the storage system are represented in figure 1. The liquefied natural gas supplychain maybe divided in 5 main steps. These are as follows:1. Production. 2. Liquefaction. 3. Transportation. 4. Storage. 5. Regasification. The last 2 phases of the LNG chain take place in regasification terminals, which are usually the final destination of LNG carriers. The LNG is offloaded from the carrier vehicle and is transferred to storage tanks. In some configurations (e.g. in Transport and Regasification Vessels (TRV) terminals) there is no LNG storage and LNG is vaporized onboard and offloaded as compressed natural gas through a sea line. In the other cases, LNG is transferred via the unloading arms from the moored carrier to the LNG storage tanks by cryogenic pipelines. Cool-down of the unloading arms introduces a small LNG flow. The pressure in the LNG of the carrier during unloading operations is maintained constant by a back flow of LNG vapor from the storage tanks to the carrier (Paltrinieri et al., 2014).

LNG is usually stored and transported at less than 5 psig. in well insulated container. There is a boil off line in order to prevent over pressure in the storage tank. Inevitable heat conduction causes liquid evaporation and removal of the blow off gas helps maintain the LNG in its liquid state by auto refrigeration. For large scale storage the boil off gas is compressed and recondensed to limit losses. LNG tanks must have double wall. Pressure relief equipment is fitted to prevent the pressure in the storage tank from rising too high in any situation. This equipment includes pressure safety devices or blow-off safety devices. A pressure build-up evaporator is often fitted to the LNG storage tank. This converts liquid from the tank into gas and returns it to the tank, as a result, the pressure remains at the desired level. A pressure reducing valve itself regulates the pressure in the tank. As an alternative, sometimes an automatic control valve is used, controlled by a pressure switch. A system that deals with gas must be carefully controlled to ensure the security of the system. As the tank pressure gauge controls the pressure of the tank, if the pressure reaches the maximum rated pressure it activates the relief valves. There is also a temperature controller to ensure that the temperature of the LNG is correct. The level in the tank is normally measured using a differential pressure measurement over the liquid height. All liquid connections to the tank are fitted with shut-off valves to prevent the storage tank emptying in case of disasters. A pump may be used to fill the tank. This pump delivers the required booster pressure for the tank to be filled. It is advisable that the pressure of the LNG storage tank remains low. The temperature of the LNG is then also low. The temperature of the LNG will therefore need to be increased, to prevent the pressure in the transportation pipe quickly falling again, and no longer ensuring the supply to the process. A reheater can be fitted to do this. Sometimes nitrogen is delivered to the tank to build up necessary pressure and provide inert environment to avoid the formation of flammable mixture.



Control Parameter/Instrument	Symbol	Control Parameter/Instrument	Symbol
Controller	C	Relief Valve	RV
Level	L	Alarm	A
Temperature	T	Valve	V
Pump	P1	Pressure	P
Indicator	I	Pressure indicating and controlling alarm	PICA
Pressure Control Valve	PV	Flow indicating and controlling alarm	FICA
Flow control valve	FV	Level Indicator Alarm	LIA

Figure 1: A simplified sample Piping and Instrumentation diagram (P&ID) of LNG storage tank

Hazard and Operability (HAZOP) Studies

A HAZOP study is a detailed hazard and operability problem identification procedure, carried out by an experienced team. The results are highly dependent on the experience and synergism of HAZOP team which requires personnel from process plant, laboratory, technical, maintenance and safety professionals. This procedure is an effective method in identifying hazards and is well accepted by the chemical process plant.

The detailed process information must be available in order to perform HAZOP studies including updated PFD, P&ID, equipment specs, material of construction, mass and energy balance. HAZOP analysis is usually done at the design stage, which has to determine the hazards and operational problems that exist in engineering and has to take comprehensive measures to reduce the risks caused by ill-consideration.

Table 2: HAZOP study applied to LNG storage unit as shown in Figure 1

Item / Line / Stage Guidewords	Deviation	Causes	Consequences	Existing safeguards	Preventive or corrective measures /Action required
Pressure	More	1. High temperature 2. Relief valve RV1 fails to open, Isolation valve V5 closed 3. PICA malfunctioning and alarm system fails	1. Tank or pipe line rapture 2. LNG release 3. Fire and Explosion 4. Injuries and Fatalities 5. Property damage	1. Temperature indicator Alarm (TIA) 2. Pressure indicator and control system (PICA1) 3. Relief valve (RV-1)	1. Install rapture disk before relief valve and additional relief valve 2. Install knockout dram and connect it with relief line 3. Ensure isolation valve is locked open 4. Ensure regular inspection and maintenance of safety critical instrument
	Less	1. PICA malfunctioning and alarm system fails 2. Leakage or pipeline rapture	1. Pressure increase 2. Tank or pipe line rapture 3. LNG release 4. Fire and Explosion	1. PICA1 2. Level Indicator (LIA1)	1. Ensure regular inspection and maintenance of safety critical instrument
Temperature	More	1. Failure of insulation 2. External heating or fire 3. Failure of Temperature indicator (TIA)	1. LNG release 2. Fire and Explosion	1. TIA1 2. PICA1	1. Install temperature controller and additional heat exchanger/cooler 2. Ensure regular inspection and maintenance of insulation and safety critical instrument
Level	More	1. Failure of level indicator alarm (LIA) 2. Failure of flow controller and alarm system (FICA1)	1. Tank overfilling 2. High pressure 3. Tank or pipeline rapture and LNG release 4. Fire and Explosion	1. LIA1 2. Relief system (RV-1)	1. Install level controller and interlock with emergency shutdown 2. Ensure regular inspection and maintenance and safety critical instrument
	Less	1. Failure of level indicator alarm (LIA) 2. Pipeline rapture or leakage	1. Empty tank 2. LNG release 3. Fire and explosion	1. LIA1	1. Ensure regular inspection and maintenance of safety critical instrument

The special point being analyzed is called “the node” in the process or operation. One purpose of the use of guiding words is to analyze all the deviation parameters of the process and then to analyze their possible causes, consequences (Shinu et al., 2015). In order to carry out the HAZOP evaluation about the LNG storage facility, a sample P&ID of typical storage unit shown in Figure-1 is used. The deviation term is used as ‘Less’/ ‘More’/ ‘No’ for process control parameters available in the storage unit. Table 2 shows the HAZOP of LNG storage unit. HAZOP deals with the identification of potential deviations from the design intent, searches for their possible causes and assess their consequences. The HAZOP examination is carried out under the guidance of a leader who ensure comprehensive coverage of the system under study. It systematically identifies engineering and management safeguards and the consequences of safeguard failures. HAZOP focuses on single events rather than combinations of some possible events. It is labor-intensive and time consuming, thus expensive. Also a quantitative part is not included most of times. There are some chances of overlooking some scenarios that are not related to guide-words.

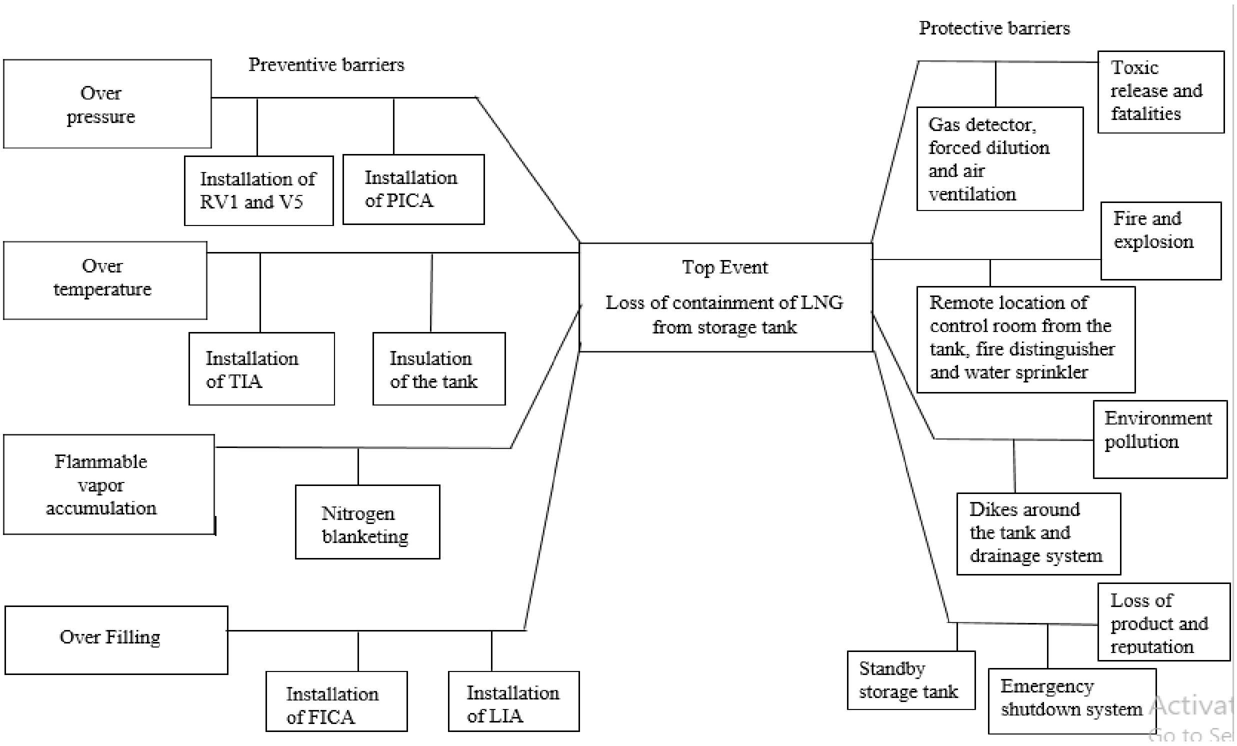


Figure 2: Bow tie diagram

Bow tie analysis

The bow-tie diagram is a risk assessment method that is used to identify critical events, build accident scenarios, review causes of accidents, and to study the effectiveness and influence of safety barriers to the faults and events as shown in Figure 2. The bow-tie diagram is described as the combination of a fault tree and an event tree, connected by a critical event (CE) which lies in the center of the diagram. On the left side the fault tree identifies the plausible causes for a critical event to happen. The right side represents an event tree. After the Critical Event has occurred, Secondary Critical Events (SCE) and Tertiary Critical Events (TCE) may occur which lead to Dangerous Phenomena (DP) and finally Major Events (ME). Bow-tie analysis is used for identifying occupational risks and many other risks in process industries. In this analysis the top event is positioned in the middle of a diagram. The probable reasons of the incident are placed to the left and consequences are placed to the right of the top event. The whole diagram gives the shape of a bow-tie. Once the risks are evaluated, risks are prioritized using risk priority matrix. The significant risks are considered first for mitigation where mitigation strategies are based upon failure mode and effect analysis. Considering deviation of pressure, temperature and level in the storage tank as top event, the fault tree and the event tree have been established. A significant component of the BT risk analysis process is the identification of the safety systems which are essential to prevent or control unexpected and uncontrolled blowout offluids (Ibrahim et al., 2017). The historical analysis of past accidents has shown the great necessity of safety barrier for prevention of accident.

Over liquid filling and more vapor accumulation are two initiator events of over pressure, more level as well as over temperature. On the contrary, loss of liquid is the initiator event of less pressure and lower level. Any of the undesired events and critical events are responsible for the initiator events. Tank rupture is the second effect and liquid-vapor release is the dangerous effect. Toxic effects to persons, loss of product, pool or jet fire or explosion, interruption to the process are major events. Main use of bow tie is qualitative to obtain an overview of accident scenarios, risks and safety barriers. A bowtie becomes quickly very complex, so systems have to be looked at section wise. FT and ET can be obtained quantitatively but that is usually done separately. Barriers need not to be fully independent, so common factors have to be investigated. Human and organizational factors require special attention.

There are two types of barriers: preventive and protective barriers. Preventive barriers prevent the causes or faults from happening. The protective barriers mitigates the consequences after the top event occurs. Some systems must be present in the LNG terminal or the ship to mitigate hazards. The preventive barriers can be existence of a monitoring system indicating the pressure and temperature of LNG, existence of an alarm and a control system for detecting LNG leak, combined temperature and density sensors to detect rollover potential, leak detection in annular space of tanks, LNG tank gauging that provide remote reading etc. Explosion risk is reduced by keeping LNG slightly above atmospheric pressure so that air cannot leak into the tank. Fire water tanks and pumps should be placed properly considering overall plot plan. Overall emergency system instead of individual emergency system, backup system for power supply, process functional segregation to isolate accident area, proper spill control or drainage system. Better equipment orientation and proper ventilation system have to be ensured. Some plants apply air fin cooler to reduce the amount of accumulated flammable gas (Tanabe et al., 2012). Static charge can produce spark which plays role as ignition source for the flammable gas to be burned. So earthling system for the storage tank mitigates this problem. If the terminal is at least 1810 m away from the coast, it is possible to keep the individual risk on the coast at less than 10^{-6}/year and the social risk to the local population is not created. Existence of a secondary tank for storing the LNG leaked from the damaged tank, embankments or dikes surrounding the tank, existence of water sprinkler and emergency shutdown system can be protective barriers. Different barriers can be adopted. Operational failures, technical faults and maintenance faults are responsible for the failure of barriers. Active and passive barriers are used to prevent accidents such as air ventilation, forced dilution, gas detection etc (Rathnayaka et al., 2012).

Conclusion

The bow-tie diagrammatic approach and HAZOP method for evaluating hazard and risk of LNG storage facility have been successfully applied. However, there may be some deviations with causes that are conceivable and consequences that are potentially serious. The potential problems are then noted for urgent remedial action. The immediate solution to a problem may not be much helpful and may need further consideration either by a team member or perhaps a specialist. The main advantage of this technique is its systematic thoroughness in failure case identification. The method may be used at the design stage, when plant alterations or extensions are needed, or applied to an existing facility (LNG BC D3.12 'Security & safety issues implementation'). Bow-tie diagrams effectively include the major elements of the hazard management process: identify, prevent, mitigate, and assess. To enhance a risk-based approach, any tabular risk identification can be customized to identify preventive safeguards (barriers) that can be exported to a bow-tie diagram. These methodologies can be used for any type of hazard analysis especially safety and security risks in chemical/petrochemical process plant in Bangladesh. This paper lays the foundation for a formal act/regulation that may be introduced in Bangladesh in the near future.

Reference

Aneziris, O., N., Papazoglou, I., A., Konstantinidou, M., Nivolianitou, Z., 2014. Integrated risk assessment for LNG terminals. J. Loss Prev. Process Ind. 28, 23-25.

Badreddine, A., Amor, N., B., 2013. A Bayesian approach to construct bow tie diagrams for risk evaluation. Process Safety and Environmental Protection, 91, 159-171.

Daniel A. Crowl, Joseph F. Lowar, Chemical Process Safety Fundamentals with Applications, 2nd ed., Prentice Hall PTR, chapter. 10. 429-454

Giardina, M., Morale, M., 2015. Safety study of an LNG regasification plant using an FMECA and HAZOP integrated methodology. J. Loss Prev. Process Ind. 35, 35-45.

Ibrahim, H., Rao, P., J., 2017. Review of Practical Applications of the Bow--Tie Approach Especially in Offshore Oil and Gas Industry. IJREAT. ISSN: 2320 – 8791.

Liu, X., Li, J., 2017. Study of Dynamic Risk Management System for Flammable and Explosive Dangerous Chemicals Storage Area. J. Loss Prev. Process Ind. 49, 983-988.

Martins, M., R., Pestana, M., A., Souza, G., F., M., Schleder, A., M., 2016. Quantitative risk analysis of loading and offloading liquefied natural gas (LNG) on a floating storage and regasification unit (FSRU). J. Loss Prev. Process Ind. 43, 629-653.

Natural gas – liquefied natural gas (LNG) delivery installations for vehicles. Hazardous Substances Publication Series 33-1:2013 version 1.0 (2013)

Paltrinieri, N., Tugnoli, A., Cozzani, V., 2015. Hazard identification for innovative LNG regasification technologies. Reliability Engineering and System Safety 137, 18-28.

Rathnayaka, S., Khan, F., Amyotte, P., 2012. Accident modeling approach for safety assessment in an LNG processing facility. J. Loss Prev. Process Ind. 25, 414-423.

Saud, Y., E., Israni, K., Goddard, J., 2013. Bow-Tie Diagrams in Downstream Hazard Identification and Risk Assessment. Wiley Online Library (wileyonlinelibrary.com). DOI 10.1002/prs.11576.

Shinu, M., M., Avinashe, K., K., 2015. Hazard Analysis in Distribution Section of P-Lng using HAZOP Methods,(4). Paripex - Indian journal of research.

Slevin, E., Espada, G., V., Bruce, A., Gevers, S., 2017. LNG Handling System. European Project

Tanabe, M., Miyake, A., 2012. Approach enhancing inherent safety application in onshore LNG plant design. J. Loss Prev. Process Ind. 25, 809-819.

A REVIEW OF THE APPLICATION OF REMOTE SENSING TECHNOLOGIES IN EARTHQUAKE DISASTER MANAGEMENT: POTENTIALITIES AND CHALLENGES

Md. Abdul Kader[1]* and Israt Jahan[2]

ABSTRACT

Ample amount of research has been done in the field of earthquake starting from prediction to prevention, preparedness, mitigation, vulnerability, risk reduction, adaptation, response, recovery, sustainability, and so on. Advanced technologies also facilitated the research work with efficient results. Remote sensing techniques are one of such advanced methods that can detect and monitor the physical characteristics of an area at a distance by measuring the reflected and emitted radiation from the target location. The applications of remote sensing for earthquake exploration had first started in the early ‘70s. Gradually it placed high acceptability in the real-world problem-solving. This article reviews previous studies on the potentialities and challenges of remote sensing application in earthquake research. For example, Landsat satellite imagery has historical images since 1972. LiDAR provides three-dimensional data of the affected area. Optical satellite imagery provides a two-dimensional image of the earthquake affected area immediately after hours to days. InSAR can also supply images immediately after the earthquake, even can acquire data at night and through clouds. DEMETER is another successful addition in earthquake research. Though earthquake prediction is a burning issue in the research arena, no operational methods were successful in predicting an earthquake. Finally, this paper summarizes the case study area-based findings of remote sensing applications in earthquake assessment.

Keywords: *Earthquake; Remote Sensing; Optical Satellites; Landsat, InSAR; LiDAR; DEMETER;*

Introduction

Earthquake is one of the most disastrous natural hazards in the world (Dong & Shan, 2013). It has several effects, for example, land subsidence, surface faulting as primary effects, and liquefaction, seismic conditions, pressure on soil, groundwater level, tsunami, landslides as secondary effects (Choudhury, Verma, & Saha, 2016). The earthquake killed more than 0.8 million people from 2000 to 2015 (USGS, 2018). On an average, there are 17 major, 134 strong, and 1319 moderate earthquakes per year (Paul Denton, n.d.). Recently, an earthquake of magnitude 7.5 struck in Indonesia where at least 1571 people died with more than 2 million lives affected and 0.19 million people required humanitarian assistance (USAID, 2019). With the increasing disasters, a proper management system is highly required and appreciated to overcome the crisis. Several modern techniques have been used to improve the management system. ‘Remote sensing is a scientific technology that can be used to measure and monitor important biophysical characteristics and human activities on earth’ (Jensen, 2000, p.xiii). In the 1970’s the remote sensing applications were first initiated in earthquake research (Andrew A Tronin, 2010). At first, structural and geological studies have used it. Later, the active faults were mapped using satellite images (A. A. Tronin, 2006). Gradually, the remote sensing technology placed high acceptability in earthquake disaster management. Vital developments are needed to minimize the after-effects of an earthquake, though it is applied widely (Rathje & Adams, 2008). Remote sensing is used to detect damage, and identify changes in the affected areas comparing before and after an earthquake (Stramondo, Bignami, Chini, Pierdicca, & Tertulliani, 2006). It plays a crucial role in building damage assessment without having direct contact with the earth (Dong & Shan, 2013). Moreover, it is cost-effective, quick, and multi-temporal data is available in case of some sensors. This study reviews the literature on remote sensing applications in earthquake management. The scope of this study is to introduce challenges and opportunities of the remote sensor in the application of earthquake management.

Application of Remote Sensing in Earthquake Disaster Management

Remote sensing technologies advanced the earthquake management system a lot. One application is to

[1] *Undergraduate Student, Department of Urban and Regional Planning, Chittagong University of Engineering and Technology (CUET), Chittagong-4349, Bangladesh;*
[2] *Assistant Professor, Department of Urban and Regional Planning, Chittagong University of Engineering & Technology, Chittagong 4349, Bangladesh;*
**Email of corresponding author: abdulkader.cuet.14urp@gmail.com*

measure building damage due to an earthquake. Usually, earth observation provides data at various damage levels. Dell'Acqua and Gamba (2012) showed three divergent outcomes of remote sensing i.e. basic mapping, rapid damage assessment, and detailed damage assessment. Basic mapping includes delineating density of population, infrastructure etc. Again, rapid damage assessment refers to damages occurred immediately. Detailed damage assessment denotes damage impact and damage estimation within a few days (Dell'Acqua & Gamba, 2012). Damages are most critical to cities with large concrete blocks. For measuring earthquake damage, spatial resolution of the data must be high to differentiate between buildings and other objects. Different characteristics of buildings (texture, morphology, shape etc.) can be extracted using optical image (Dong & Shan, 2013). On the contrary, Digital Elevation Model (DEM) is used to derive building height (Turker & Cetinkaya, 2005). Several methods are applied to detect building damage. These are (i) change detection between pre and post disaster and (ii) detail change detection using only post disaster data. The second one is more accurate than the other (Dong & Shan, 2013). Post disaster damage assessment was done in many earthquakes such as Central Java earthquake 2006. In the Gujarat earthquake on 26 January 2001, post-earthquake damage assessment was done utilizing IKONOS satellite images (Saito, Spence, Eeri, Going, & Markus, 2004). Rapid post-earthquake damage assessment can be made using high resolution spatial data. QuickBird images provide high resolution spatial data and identifies areas with severe building damage. Pixel-based and object-based classifications are used to compare the pre-event and post-event situations (Yamazaki & Matsuoka, 2007). It has significant value in emergency management and post-earthquake recovery operations. Remote sensing can produce crucial clues about earthquakes prediction by identifying ground temperature changes. Ground temperature of a tectonically active region can increase due to pressure acting before an earthquake. A study based on Bam earthquake at 26 December 2003 showed pre-earthquake thermal anomalies before the earthquake through analyzing NOAA-AVHRR data (Choudhury et al., 2016). Moreover, it is found that there is a correlation between thermal anomaly Land Surface Temperature (LST) and pre-seismic activity. MODIS (Moderate Resolution Imaging Spectroradiometer), onboard NASA terra and aqua satellites data were used in such study (Ouzounov & Freund, 2004). Ouzounov *et al.*, (2008) made a multi-sensor approach using global remote sensing data with ground observations to identify and interpret atmospheric signals before major earthquakes. The study aimed to produce a time series baseline over a historical multi-year through continuous monitoring of different types of precursor including atmospheric and ionospheres' signals (Ouzounov et al., 2008).

Remote Sensor in Earthquake Disaster Management

Optical Satellites

Optical satellite imagery is generated from multispectral sensors in the optical part of wavelength spectrum, and includes visible, near infrared and short-wave infrared wavelengths (Håkan Olsson, 2018).

Landsat

Landsat TM data archives were used in southwestern China Wenchuan earthquake on 12 May 2008 (magnitude was greater than 8) to identify ecosystem damage after the earthquake (Lu et al., 2012). In Kokoxili earthquake, Landsat-7 ETM + images were used to identify the surface rupturing utilizing panchromatic bands with 15m spatial resolution (Liu & Haselwimmer, 2006) (Figure 2).

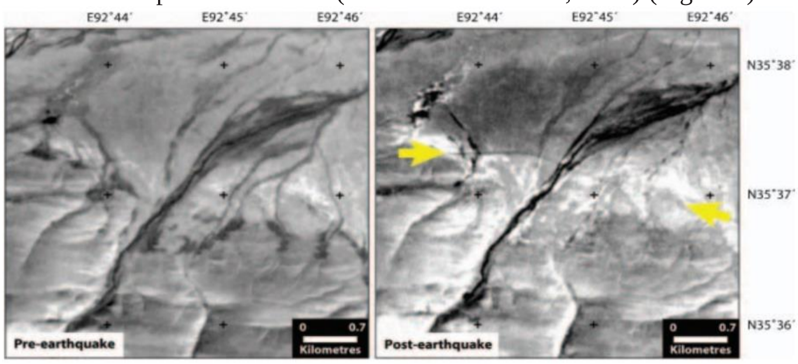


Figure 2. Pre- and post-earthquake Landsat 7 ETM + satellite images highlighting rupturing southwest of Kusai Lake (taken from Liu & Haselwimmer, 2006).

Fu & Lin (2001) worked on similar earthquake. They used Landsat ETM/TM, SPOT, and ASTER to identify spatial distribution of the surface rupture zone (Fu & Lin, 2001). Landsat ETM+ was used in damage assessment comparing optical images with panchromatic bands after 2001 Gujarat earthquake. It showed important changes after earthquake. After earthquake aerial photographs were used to validate the findings of Landsat image analysis and similar results were found (Yusuf, Matsuoka, & Yamazaki, 2001). After 2001 El Salvador earthquake, a study was carried out for damage detection and identification of landslides using enhanced pre-event and post-event images of Landsat ETM+ (Estrada & Kohiyama, 2001).

IKONOS

Ikonos satellite image (1m resolution) was used to assess damage after 2003 Bam earthquake. It found that 80% of the occupants dead, 20% injured in case of heavy damage and 5% of the occupants dead, 60% injured in case of moderate damage (Chiroiu & Eeri, 2005). Besides, Ikonos was used as a powerful tool for calculating co-seismic strike-slip offsets of 2-16.7 m and identifying the ground deformation in Kunlun earthquake (Lin, 2001). Ikonos satellite data were also used after Bam earthquake to demonstrate the capacity of automated detection algorithm and fly-over visualization (Vu, Eeri, Matsuoka, & Eeri, 2005). Kashmir region was attacked by a catastrophic earthquake and 80000 people were killed. The earthquake generated thousands of landslides. Ikonos could capture an image of landslide due to the earthquake (Kathryn FREE, 2016) (Figure 3).

Figure 3. Ikonos captured before earthquake and after earthquake (landslide occurred) image of 2005 Kashmir earthquake (taken from Digital Globe) (Kathryn FREE, 2016)

QuickBird

Eight days after 2003 Bam earthquake, QuickBird (a high resolution satellite) images were captured to carry out visual interpretation of building damage (Yamazaki, Yano, & Matsuoka, 2005). University of California at Irvine (UCI) and Earthquake Engineering Research Institute (EERI) acquired QuickBird images of Bam area before earthquake (Figure 4a) and after earthquake (Figure 4b). Figure 4(a) was taken 3 months before the earthquake and figure 4(b) was acquired after one week of earthquake (Adams et al., 2004).

(a) before earthquake (b) after earthquake

Figure 4. QuickBird image of Bam earthquake affected area (taken from Digital Globe) (Adams et al., 2004)

Interferometry Synthetic Aperture Radar (InSAR)

'InSAR is a method by which the phase differences of two or more SAR images are used to calculate the differences in range from two SAR antennae having slightly different viewing geometries to targets on the ground'(Andrew A Tronin, 2010, p. 128). It can be used in deformation field to measure small-scale objects. InSAR data was used after Maule earthquake to recover the slip distribution (Delouis, Nocquet, & Vallée, 2010).

Light Detection and Ranging (LiDAR)

LiDAR is a powerful tool for 3D analysis. Airborne LiDAR images can be utilized to prepare DEM models and morphological properties of buildings and other features (Costanzo et al., 1900). Devastating tsunami occurred after 2011 Tohoku earthquake. LiDAR was used with TLS(Terrestrial Laser Scanning) that produced a 3D point cloud data sets and then camera fields of view was calibrated in real world co-ordinates (Fritz et al., 2012). LiDAR introduced a new method for ground surface motion utilizing quantitative measurement. Researcher uses LiDAR measurement for producing DEM to extract ground displacement (Manchun, Liang, Jianya, Yongxue, & Zhenjie, 2008).

DEMETER

DEMETER was launched on June 29, 2004 to study ionospheric disturbance associated with seismic activities. A study that was done prior to Wenchuan Earthquake showed that anomalous EM emission and big variations of plasma criteria. Furthermore, geomorphological conditions were also identified and pre-earthquake perturbations were discussed (Zeng, Zhang, Fang, Wang, & Yin, 2009).
Overall Table 1 shows the summary of the selected studies covered in this paper.

Table 1. Summary of studies discussed in this paper

Study Area	Name of Earthquake	M_w	Date Occurred	Remote Sensor	Source
Southwestern China	Wenchuan earthquake	>8	12 May 2008	Landsat TM	Lu et al., 2012
China	Kokoxili earthquake	8.1	14 November 2001	Landsat ETM+	Liu & Haselwimmer, 2006
China	Kokoxili earthquake	8.1	14 November 2001	Landsat ETM+,	Fu & Lin, 2001
India	Gujarat Earthquake	7.1	26 January 2001	Landsat-7	Yusuf et al., 2001
El Salvador	El Salvador earthquake	7.6	13 January 2001	Landsat ETM+	Estrada & Kohiyama, 2001
Iran	Bam earthquake	6.6	26 December 2003	IKONOS	Chiroiu & Eeri, 2005
China	Kunlun earthquake	7.8	14 November 2001	IKONOS	Lin, 2001
Pakistan	Kashmir earthquake	7.6	8 October 2005	IKONOS	Kathryn FREE, 2016
Iran	Bam earthquake	6.6	26 December 2003	Quickbird	Yamazaki et al., 2005
Iran	Bam earthquake	6.6	26 December 2003	Quickbird	Adams et al., 2004
Japan	Tohoku earthquake	9.0	11 March 2011	LiDAR	Fritz et al., 2012
Japan	Iwate-Miyagi Nairiku Earthquake	7.2	14 June 2008	LiDAR	Manchun et al., 2008
Chile	Maule Earthquake	8.8	27 February 2010	InSAR	Delouis et al., 2010
China	Wenchuan Earthquake	7.9	12 May 2008	DEMETER	Zeng et al., 2009

Potentialities and Challenges

Previous literature shows the potentialities of remote sensing in earthquake disaster management. But there are always some challenges like operational, technical, etc. (Rathje & Adams, 2008). Though earthquake prediction is a burning issue in the research arena at present, no operational methods were successful in predicting an earthquake (Roy, Dwivedi, & Vijayan, n.d.). Therefore, effective and useful development of earthquake prediction method is essential. Moreover, VHR (very high resolution) data is expansive and less affordable by developing and under-developed countries. More importantly, communication between satellite data providers and data users must be developed. New technologies, new satellites, new stations are created and used day by day. There must be a continuous validation framework. No data fusion system among various types of satellite data is present. So, data fusion approach can be introduced to allow and merge the information acquired by multiple sensors (Dell'Acqua & Gamba, 2012).

Conclusions

Remote sensing is widely applicable in earthquake disaster management as revealed in several studies. In the same manner, various satellite data and methods have been used effectively. Further research in this field can create more effective improvements. Specifically, mentioned challenges can promote the developments.

Acknowledgments

At first, we would like to express our gratitude to Allah who gives us ability to complete this work. There is no word to express profound gratitude to Dr. Mehedi A. Ansary, Professor, BUET for his effective guidelines. We are also grateful to ICDRM committee for giving opportunity of working on this study.

References

Adams, B. J., Huyck, C. K., Mio, M., Cho, S., Ghosh, S., Chung, H. C., Eguchi, R. T., Houshmand, B., Mansouri, B. (2004). The Bam (Iran) Earthquake of December 26, 2003: Preliminary Reconnaissance Using Remotely Sensed Data and the VIEWS (Visualizing the Impacts of Earthquakes with Satellite Images)System. Retrieved November 16, 2018, from http://mceer.buffalo.edu/research/Reconnaissance/Bam12-26-03/bamprint.asp

Chiroiu, L., & Eeri, M. (2005). Damage Assessment of the 2003 Bam , Iran , Earthquake Using Ikonos Imagery, *21*(December), 219–224. https://doi.org/10.1193/1.2119227

Choudhury, M., Verma, S., & Saha, P. (2016). Effects of Earthquake on the Surrounding Environment : an Overview, (December).

Costanzo, A., Montuori, A., Silva, J. P., Silvestri, M., Musacchio, M., Doumaz, F., & Stramondo, S. (1900). The Combined Use of Airborne Remote Sensing Techniques within a GIS Environment for the Seismic Vulnerability Assessment of Urban Areas : An Operational Application. https://doi.org/10.3390/rs8020146

Dell'Acqua, F., & Gamba, P. (2012). Remote Sensing and Earthquake Damage Assessment: Experiences, Limits, and Perspectives. *Proceedings of the IEEE*, *100*(10), 2876–2890. https://doi.org/10.1109/JPROC.2012.2196404

Delouis, B., Nocquet, J. M., & Vallée, M. (2010). Slip distribution of the February 27 , 2010 Mw = 8 . 8 Maule Earthquake , central Chile , from static and high - rate GPS , InSAR , and broadband teleseismic data, *37*, 1–7. https://doi.org/10.1029/2010GL043899

Dong, L., & Shan, J. (2013). A comprehensive review of earthquake-induced building damage detection with remote sensing techniques. *ISPRS Journal of Photogrammetry and Remote Sensing*, *84*, 85–99. https://doi.org/10.1016/j.isprsjprs.2013.06.011

Estrada, M., & Kohiyama, M. (2001). Paper presented at the 22nd Asian Conference on Remote Sensing, 5 - 9 November 2001, Singapore. Copyright (c) 2001 Centre for Remote Imaging, Sensing and Processing (CRISP), National University of Singapore; Singapore Institute of Surveyors and Valuers (S, (November), 5–9.

Fritz, H. M., Phillips, D. A., Okayasu, A., Shimozono, T., Liu, H., Mohammed, F., Skanavis, V., Synolakis, C. E. (2012). The 2011 Japan tsunami current velocity measurements from survivor videos at Kesennuma Bay using LiDAR, *39*, 1–6. https://doi.org/10.1029/2011GL050686

Fu, B., & Lin, A. (2001). International Journal of Remote Spatial distribution of the surface rupture zone associated with the 2001 Ms 8 . 1 Central Kunlun earthquake , northern Tibet , revealed by satellite remote sensing data, (November 2014), 37–41. https://doi.org/10.1080/0143116031000075918

Håkan Olsson. (2018). Optical satellite images | Externwebben. Retrieved November 16, 2018, from https://www.slu.se/en/departments/forest-resource-management/sections/forest-remote-sensing/arbetsomraden/optical-satellite-images/

Jensen, J. R. (2000). Remote Sensing of the Environment An Earth Resources Perspective. New Jersey.

Kathryn FREE. (2016). Looking Back on the 2005 Kashmir Earthquake | EOS Blog | Earth Observatory of Singapore. Retrieved November 16, 2018, from https://earthobservatory.sg/blog/looking-back-2005-kashmir-earthquake

Lin, A. (2001). International Journal of Remote Coseismic lateral offsets of surface rupture zone produced by the 2001 M w 7 . 8 Kunlun earthquake , Tibet from the IKONOS and QuickBird imagery, (November 2014), 37–41. https://doi.org/10.1080/01431160600647233

Liu, J. G., & Haselwimmer, C. E. (2006). International Journal of Remote Co - seismic ruptures found up to 60 km south of the Kunlun fault after 14 earthquake using Landsat - 7 ETM + imagery, (December 2014), 37–41. https://doi.org/10.1080/01431160600784283

Lu, T., Zeng, H., Luo, Y., Wang, Q., Shi, F., Sun, G., Wu, Y., Wu, N. (2012). Monitoring vegetation recovery after China ’ s May 2008 Wenchuan earthquake using Landsat TM time-series data : a case study in Mao County, (May 2008), 955–966. https://doi.org/10.1007/s11284-012-0976-y

Manchun, L. I., Liang, C., Jianya, G., Yongxue, L. I. U., & Zhenjie, C. (2008). Post-earthquake assessment of building damage degree using LiDAR data and imagery, *51*(40701117), 133–134. https://doi.org/10.1007/s11431-008-6014-1

Ouzounov, D., & Freund, F. (2004). Mid-infrared emission prior to strong earthquakes analyzed by remote sensing data. *Advances in Space Research*, *33*(3), 268–273. https://doi.org/10.1016/S0273-1177(03)00486-1

Ouzounov, D., Habib, S., & Ambrose, S. (2008). Application of Remote Sensing Technologies Mutisensor approach of analyzing atmospheric signals and search for possible earthquake precursors Application of Remote Sensing Technologies for Disaster Risk Management : Mutisensor approach of analyzing atmosp, *2004*.

Paul Denton. (n.d.). *How frequent are earthquakes?* British Geological Survey. Retrieved from https://www.bgs.ac.uk/downloads/start.cfm?id=663

Rathje, E. M., & Adams, B. J. (2008). The role of remote sensing in earthquake science and engineering: Opportunities and challenges. *Earthquake Spectra*, *24*(2), 471–492. https://doi.org/10.1193/1.2923922

Roy, P. S., Dwivedi, R. S., & Vijayan, D. (n.d.). Earthquake and Active Faults. In *Remote Sensing Applications* (pp. 339–351). National Remote Sensing Centre.

Saito, K., Spence, R. J. S., Eeri, M., Going, C., & Markus, M. (2004). Using High-Resolution Satellite Images for Post-Earthquake Building Damage Assessment : A Study Following the 26 January 2001 Gujarat Earthquake. *Earthquake Spectra*, *20*(1), 145–169. https://doi.org/10.1193/1.1650865

Stramondo, S., Bignami, C., Chini, M., Pierdicca, N., & Tertulliani, A. (2006). Satellite radar and optical remote sensing for earthquake damage detection: results from different case studies. *International Journal of Remote Sensing*, *27*(20), 4433–4447. https://doi.org/10.1080/01431160600675895

Tronin, A. A. (2006). Remote sensing and earthquakes: A review. *Physics and Chemistry of the Earth*, *31*(4–9), 138–142. https://doi.org/10.1016/j.pce.2006.02.024

Tronin, A. A. (2010). Satellite Remote Sensing in Seismology . A Review, 124–150. https://doi.org/10.3390/rs2010124

Turker, M., & Cetinkaya, B. (2005). Automatic detection of earthquake-damaged buildings using DEMs created from pre- and post-earthquake stereo aerial photographs. *International Journal of Remote Sensing*, *26*(4), 823–832. https://doi.org/10.1080/01431160512331316810

USAID. (2019). Indonesia Earthquakes and Tsunami, 1–3.

USGS. (2018). Earthquake Statistics. Retrieved November 15, 2018, from https://earthquake.usgs.gov/earthquakes/browse/stats.php

Vu, T. T., Eeri, M., Matsuoka, M., & Eeri, M. (2005). Detection and Animation of Damage Using Very High-Resolution Satellite Data Following the 2003 Bam , Iran , Earthquake, *21*(December), 1–5. https://doi.org/10.1193/1.2101127

Yamazaki, F., & Matsuoka, M. (2007). Remote sensing technologies in post-disaster damage assessment. *Journal of Earthquake and Tsunami*, *1*(3), 193–210.

Yamazaki, F., Yano, Y., & Matsuoka, M. (2005). Visual damage interpretation of buildings in Bam city using QuickBird images following the 2003 Bam, Iran, earthquake. *Earthquake Spectra*, *21*(SUPPL. 1), 1–5. https://doi.org/10.1193/1.2101807

Yusuf, Y., Matsuoka, M., & Yamazaki, F. (2001). Damage Assessment After 2001 Gujarat Earthquake Using Landsat-7 Satellite Images, *29*(l), 1999–2000.

Zeng, Z. C., Zhang, B., Fang, G. Y., Wang, D. F., & Yin, H. J. (2009). The analysis of ionospheric variations before Wenchuan earthquake with DEMETER data. *Chinese Journal of Geophysics-Chinese Edition*, *52*(1), 11–19.

DISASTER MANAGEMENT: SOCIO-ECONOMIC CONDITIONS AND ROLE OF INSTITUTION: A CASE STUDY OF KOLKATA

Mahalaya Chatterjee[1]

ABSTRACT

Natural disasters are not uncommon to the Planet Earth from time immemorial. But it has become a matter of concern in the age of urbanization with the spread of built up environment. Natural disasters are of many type and the particular geo-morphological and climatic conditions of an area determines the type and frequency of the disaster. There are degrees of damage and loss to the private and public properties in case of strike of disaster. Any area has its degree of preparedness for the most common disaster of the region; it often ignores the other possibilities. Disaster management ideally should have a two-pronged approach – with technological ability and public participation. Both of these are crucially dependent on the social and economic condition of the area and the concerned institutions – which are guided by the political ethos of the government. Keeping this perspective in mind, this paper will critically explore the functioning of the disaster management unit of the urban local bodies in the Kolkata Metropolitan Area – the largest urban agglomeration in the Lower Ganga Plain. The main form of natural calamity here is flooding due to excessive rain in the monsoon months which affects the functioning of civic amenities and in turn the daily lives of the common people.

Keywords: *natural disaster, built up area, civic amenities, technological preparedness, public participation, Kolkata Metropolitan Area;*

Introduction

Disaster management has become very important in present-day world. Disaster may be natural or man-made. Before going into the details of the role of the urban local body, let us first discuss some preliminary concepts about disaster, risk and management.

A hazard may be defined as a potentially damaging physical event, natural phenomenon or human activity that may adversely affect human life, property or cause social and economic disruption or environmental damage, whereas a disaster is an extreme disruption of the functioning of community/society that causes wide spread human, material, economic or environmental losses which exceed the ability of the affected community to cope. The vulnerability conditions are determined by physical, social, economic and environmental factors which increase the damageability or proneness of an individual or community/society to impact of hazards. In this situation, we can say that the risk is the probability of harmful consequences or expected/anticipated losses from impact of a hazard at a given place over a specific period of time.On the other hand, the **capacity** of an economy/society is the combination of strength, efficacy and resources available within a community/ organization that can be harnessed to reduce the level of risk or the effect of a disaster – viz. the ability of the stakeholders to cope with/resist/respond to the effects of a hazard or a catastrophic event.

Now, when we talk about disaster management, we generally combine two aspects of it. The first is the management of the risk itself, which involves systematic process of using administrative decisions, organization, operational capabilities for implementing policies, strategies, coping capacities to lessen impact of hazards – it is a combination of prevention, mitigation and preparedness. The second is the reduction (or minimization) of disaster risk which can be a conceptual framework including all the elements of the society to avoid or to limit the adverse impacts of hazards with the long term aim of inclusive sustainable development.

As we have already stated that hazards/disasters can be natural or man-made. The natural disasters are not bound by political boundaries or even temporal limits. The same can be said about man-made disasters, depending on the location of the occurrence. In this paper, we are concerned with natural disasters only and the preparedness of the city of Kolkata for that through its body of local self-government the Kolkata Municipal Corporation (KMC hereafter).

The City of Kolkata

Kolkata, which started its urban journey in late seventeenth century, was the capital of British India till India (as Calcutta) till 1911. It is the first metropolitan city of India and also the oldest riverine port in this part of the country, serving a vast hinterland in the eastern and north-eastern part of the country. It was also a premier industrial zone with a variety of industries, the main being jute, followed by engineering, metal, chemical, cotton textile and others. Apart from the original inhabitants, there has been steady influx of migrants not only from different parts of the country, but also neighbouring countries as well. Apart from the resident population, the city also has to take care of 6 million floating population daily. There are about 1500 slum pockets within the city, in which about 31% of the city population resides. The city has faced the pressure of unbalanced urban growth with inadequate and old infrastructure.

It is to be noted that Kolkata Metropolitan area is consisted of two other municipal corporations and 38 municipalities along with some rural mouzas. It is spread over five districts and the disaster management plan of those urban areas are part of the district plan. In this article, we are concentrating on the city of Kolkata only.

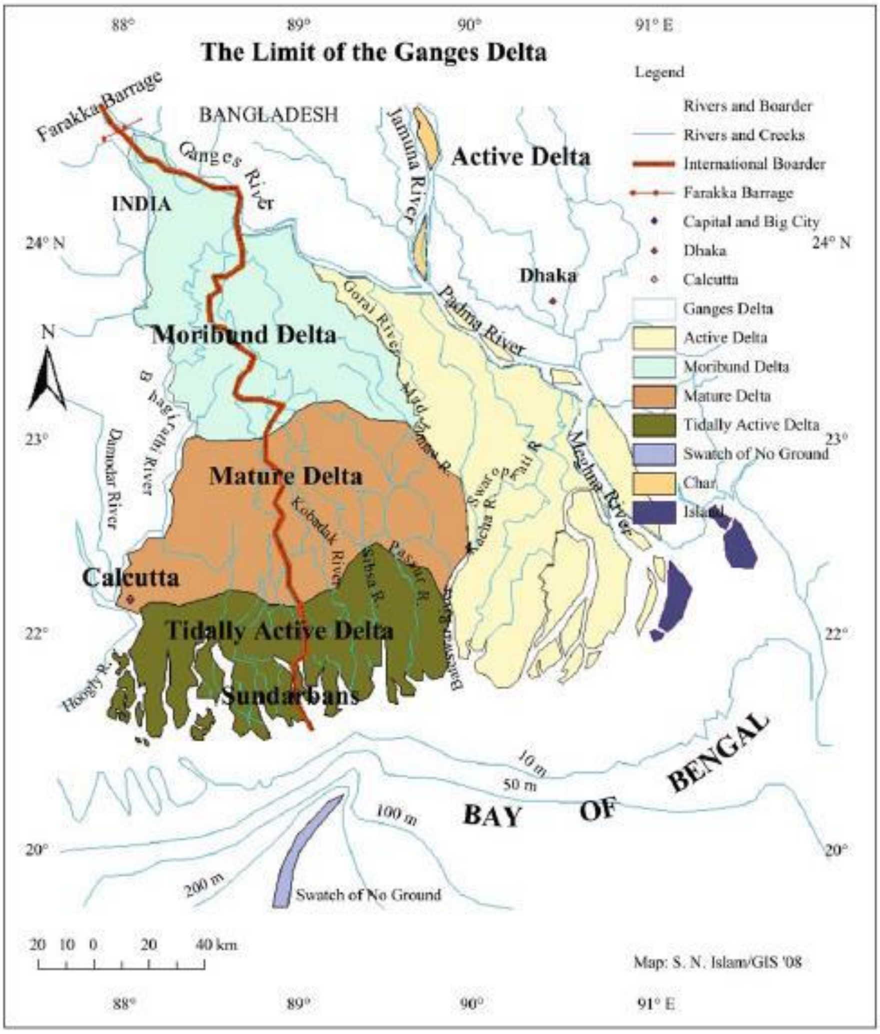


Figure 1. Geographical Location of the City in Ganga Delta

The Indian subcontinent is highly prone to natural disasters. Floods, wind, cyclones, droughts, landslides and earthquakes are recurrent phenomena. Kolkata, because of its geographical position and geomorphological characteristics are not free from either of this.

The following table gives an idea about the vulnerability of the city regarding major natural calamities.

Table 1: Vulnerability of Kolkata from natural calamities

Wind & Cyclone Zone	Earthquake Zone	Flood Zone	Overall Risk Rating
Very High(B)	III	High	Very High(B)

Source: Sengupta (2007)

These natural calamities are the result of the location of the city in the deltaic region and very near the geological location where two of the sub-surface plates meet. Some of the natural calamities can be forecasted and appropriate measures can be taken in time. Predictions of cyclone, heavy rain in appropriate time can allow the authorities to take preventive measures to reduce risk from disaster. However, there is still no prediction system for earthquake.

Apart from these natural calamities, there are few man-made hazards which frequently visit the city again and again. The first of it is fire. Fire may take place in residential areas or commercial areas. However, both of them are result of carelessness and negligence. The second is building collapse. A city with a history of more than three hundred years has its stock of old and dilapidated buildings. The maintenance of most of the buildings are not done for economic reasons, sometimes legal. The third recurrent hazard is vector-borne diseases like malaria and dengue. The main reason behind it, is lower level of sanitation, which may be caused by human behavior and also institutional lethargy.

Disaster Management Strategy of Kolkata Municipal Corporation

The Kolkata Municipal Corporation is the elected local self-government for the city of Kolkata. The city has got 144 wards with elected councilors. These 144 wards are clustered into sixteen borough, with a chairman in each. . At the central level, there is a Mayor-in-council system, where apart from Mayor and Deputy Mayor, there are twelve MICs, and the departments are assigned among them. In this way, it is a system of collective responsibility of the elected representatives. The executive system is headed by a municipal commissioner. The whole executive system are under his monitoring and supervision.

As far as disaster management is concerned, the recently published plan of KMC talks about a three-pronged approach. They are:

1. Strengthening of KMC Infrastructure'
2. Awareness generation, Training and Capacity building of people at all levels (from administration

to grass root level)

3. Enactment and proper enforcement of suitable legislations related to land use policies and planning, town & country planning, building bye laws.

For the first one, the main components are as follows:

- Control Room
- Water Supply
- Solid waste management
- Lighting and electricity
- Sewerage and Drainage
- Health Services
- Building
- Roads
- Early Warning and Information Dissemination system

Apart from KMC's own infrastructure, it has to keep close coordination with other departments like police, transport, fire services at the state level and the National Disaster Management department at the central level (along with the National Disaster Management Battalion).

For the second one, awareness generation is done through workshops and meetings educational institutions with the help of other government departments and NGOs and CBOs.

The third approach is for risk reduction in future through better planning. Sometimes execution is delayed for legal hassles, sometimes new laws have to be enacted (like prosecution for non-maintenance of private property or incentives for demolishing old buildings and building new one.

A Critique

If we have to take a critical look at the disaster management plan of the city, we have to do it from two angles. The first is maintaining the present status, i.e. to arrest further degradation causing from either of the hazards and second is planning for a better future for the city.

Now, what are the major factors contributing to the vulnerability of the city?

1. Unusual pressure of urban growth;
2. Pollution of water and air
3. Extraction of ground water
4. Inadequate waste management
5. Degradation of wetland
6. Climate change

Kolkata faced unusual pressure of urban growth after 1947 because of the partition of erstwhile Bengal. Most of the habitation grew on the suburbs of the main city without any proper infrastructure. And this also put huge pressure on the infrastructure of the main city. The increasing population had to survive on the informal sector economy .Slum pockets also grew and thrived for the colonial priorities and later it became the resident for the poor. Though comprehensive planning efforts started for the city in late fifties, the full advantage was never available for political instability and economic downturn of the sixties of the last century. Some positive efforts came with the Left Front Government, which went for *in-situ* infrastructure development for the city including slums and augmentation of water supply and others. KEIP with ADB assistance is one of the notable example of such an effort.

Climate change along with air and water pollution are two things which are beyond the control of the local government. But it should take efforts to mitigate all of them within their command area. Sometimes electoral compulsions give priority to populist politics over rational economics. So, important policies like charging for water or phasing out of old vehicles cannot be implemented.

Strengthening of infrastructure is for maintain the *status quo* but for long term sustainable development, attention should be given for the other two aspects, i.e. creating awareness and capacity building along with better planning combined with modification of legal and administrative structure, accepting technological progress. Here we find efforts which are less than adequate, sometimes only cosmetic and perfunctory.

In this context, one should think in terms of a more responsive participatory democratic set up to the grassroots as one of the way out.

References

Kolkata Municipal Corporation (2008), City Disaster Management Plan for Kolkata Volume 1 & 2, (updated/modified 2018), Accessed from http:// wbdmd.gov.in/ writereaddata/uploaded/ DP /DPKolkata 33359 on December 6, 2018

National Centre for Sustainable Coastal Management, Ministry of Environment and Forest (2014); Transformation and Resilience of Urban Coast, Kolkata, A Case Study, accessed from

http://www.bel-truc.org/downloads/case-study-kolkata.pdf on December 6, 2018Sengupta Samanjit (2007), Status of Kolkata megacity disaster management, accessed from http://siteresources.worldbank.org/CMUDLP/Resources/SamanjitSengupta.pdf on December2018.

PROBLEMS OF POST-DISATER PHILANTHROPIC ACTIVITIES: A STUDY IN THE AFTERMATH OF NEPAL EARTHQUAKE 2015

Rabindra Timsena[1]

ABSTRACT

Disasters are the natural or man-made events that damage the property and negatively affect the life of people. The impact varies according to the nature and intensity of disaster as well as the socio-economic condition of the particular area. Definitely the least developed countries are more affected by disaster in compared to the developed countries and it becomes the challenge for disaster management in those countries. The philanthropic activities conducted after the disaster are also affected negatively in such countries. Nepal, one of the least developed countries in the world had to face so many problems for the post-disaster philanthropic activities in the aftermath of Nepal Earthquake 2015.

Introduction

United Nations International Strategy for Disaster Reduction (UNISDR) defines disaster as "a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts" (UNISDR, 2017). This definition as well as many other definitions emphasizes disaster as a social phenomenon. So, the poor people, society and country are more victimized by the impact of the disaster. "Since human life developed and human societies formed, natural hazards have affected vulnerable societies" (Albrecht, 2017). Since the beginning of human civilization, there is worldwide trend to support the disaster victims as soon as the disaster occurs, this is in fact a part of disaster management. There are widely accepted four phases of disaster management - mitigation, preparedness, response and recovery. Among them, mitigation and preparedness are the pre-disaster management phases which are especially taken care by the government of respective country whereas responses and recovery are the post–disaster management phases that are undertaken by government and various parties including philanthropic organizations i.e. Non-Governmental Organization (NGO)s, International Non-Governmental Organization (INGO)s.

The history of philanthropy is also very long. "Most of the activities we label "philanthropy" have been going on for a very long time. Organized charity is older than democracy and capitalism, older than Christianity and Buddhism, older than societies and many other traditions that no longer exist" (Payton & Moody, 2008). So, post-disaster philanthropic activities are considered to be very important. Lester M. Salamon defines philanthropy as "the private giving of time or valuables (money, security, property) for public purposes; and/or one form of income of private non-profit organizations" (Salamon, 1992). Such activities undertaken for public purposes are very helpful for the victims to come into their normal daily life. However, there are so many problems occurred for the post-disaster philanthropic activities, especially in the least developed countries which were realized after Nepal Earthquake 2015 too. As long as the problems occurred, the needy were deprived of taking help and support from the philanthropists. Reversely, they were and still are likely to be more victimized by the disaster. According to Ministry of Home Affairs (MOHA), massive earthquake of 7.6 ml on April 25, 2015 took the life of around nine thousands people along with injuries and damage to the properties on an unprecedented scale (MOHA, 2015). Soon after the earthquake, national and international call for help was intense and praiseworthy. However, due to the large intensity of the earthquake, people were severely affected and various humanitarian and philanthropic activities were undertaken in the affected areas. There were multiple problems and difficulties to carry out the philanthropic activities, sometimes due to monetary factors and sometimes due to non-monetary factors i.e. social, political, governmental etc.

Monetary Factors

Lack of financial resources is one of the major problems of undertaking philanthropic activities. Post Disaster Need Assessment done by National Planning Commission (NPC) estimated that the total value of disaster effects (damages and losses) caused by earthquake was NRs 706 billion which is equivalent to US$ 7 billion

[1]*Editor, Nepal Academy, Kathmandu - 44600, Nepal*
thenitsok@gmail.com

(NPC, 2015). In Nepal, the government itself didn't have sufficient fund which became more insufficient for the disaster management after Nepal Earthquake 2015. Govinda Raj Pokhrel, the then CEO of Nepal Reconstruction Authority (NRA) told, “The government treasury is very small so we can hardly be flexible to run or utilize the reconstruction fund” (Pokhrel, 2017). Since, government treasury was small; the role of philanthropic organization became more important since the least developed countries are heavily dependent upon the Non-Government Organizations. The number of INGOs working in Nepal as of March 2014 According to Social Welfare Council (SWC) was 254 (SWC, 2018a) and the Number of NGOs affiliated to SWC from 2034 to June 2017 was 46,235 (SWC, 2018b) However, there were limited organizations having their primary objective to work for the disaster management. However, other organizations which had not have their primary objective to work for the disaster management also started to work for the disaster management. However, they had to be dependent on the donation amount. Collecting donation itself is the difficult task. Moreover, it was more difficult when the committed amount couldn't be collected after running philanthropic project. Pankaj Pradhan, the Finance Manager of Chaudhary Foundation told, “Some donors became back from their previous commitment and in this situation it was very difficult for us to execute our project as planned earlier” (Pradhan, 2018). Moreover, collecting and utilizing the donation amount was also not hassle free process. Philanthropic activities were difficult because of the poverty among the affected area too. Because of the poor housing conditions, the people were more affected by the disaster and couldn't overcome it because of lack of sufficient money. While conducting philanthropic activities in cost bearing basis, they couldn't contribute from their side which became the problem of post-disaster philanthropic activities. It was found that the earthquake victims spent the amount provided by the government for the household activities which was supposed to be spent for the arrangement of temporary shelter.

Least developed countries are poor in information technology due to the lack of financial resources. Because of lack of the advanced technology and respective technician, Search and Rescue as well as debris management activities couldn't be effective. Chaudhary Foundation had to collaborate with SEEDS India to help the earthquake affected people to construct the semi-permanent shelter due to lack of capable human resource inside Nepal itself (Pradhan, 2018). Also, due to the lack of proper database and information system, it was very difficult to obtain the proper data which created ambiguity for the organizations to run their activities. Similarly, due to lack of right information, the rumor about the next possible quake created fear among the public by which they couldn't come into normal life. This was also the problem for the philanthropic activities.

Non-monetary Factors

Policy related problems were more prominent in the post-disaster philanthropic activities. Natural Disaster Calamity (Relief) Act 1982 formulated before 33 years was in existence when Nepal was struck by the earthquake, which in fact was not able to address the issues of present day. Because of lack of proper and updated policy, the government entities couldn't work effectively nor were they be able to coordinate each other properly. Philanthropists had to take approval from ward, Village Development Committee/Municipality and District level, even sometimes from SWC, NRA and Ministry of Finance (MOF) in some cases. Because of lack of proper policy, civil servants, the philanthropists and even the people were in confusion about providing and accepting the support. Civil servants didn't coordinate with the philanthropic organizations especially because their roles and responsibilities were not clearly indicated for such situations. They seemed not to be ready to take the personal risk for the public purposes. Some of them misused this situation as an opportunity for the corruption. Many representatives of the philanthropic organizations informed that they had to pay from under the table to take the approval and even for the completion certificate after completing their activities. The affected people were also in confusion on whether they would be eligible to take the support from the government if they accept the support from the I/NGOs. Even after taking the approval from the government bodies, the reconstruction project of Chaudhary Foundation was not undertaken because of the confusion among the people (Pradhan, 2018).

Poor governance is also the major problem of post-disaster philanthropic activities. Most of the fund to conduct philanthropic activities in the least developed countries comes from developed countries and is given through NGOs. So the utilization of such fund becomes difficult because of the poor social, political condition and the governance system. Each NGO should apply in SWC before 45 days to take the grant from abroad (SWC, 2014). The other problem is that the philanthropic organizations themselves should allocate cost for SWC monitoring (SWC representatives go to the project area for the monitoring of foreign funded projects). Likely, poor preparedness was the result of poor governance which contributed to increase problems of post-disaster philanthropic activities. In the absence of emergency warehouse and stock of food and non-food item the relief work was negatively affected. The cabinet declared for the custom exemption to relief goods and visa fee exemption to Search and Rescue team and humanitarian actors but being unable to identify the proper individual or team the genuine was not taken care and time and money was misused for the unnecessary people. NRA, the legally mandated agency for leading and managing the earthquake recovery and reconstruction in Nepal was established after eight months of the earthquake. Various agreements were done in order to route the fund by Ministry of Finance before establishing NRA and there was reconstruction fund only theoretically (Pokhrel, 2017). Ministry of Finance was preparing for dissolving the reconstruction fund of NRs. 28 billion after two years (Onlinekhabar, 2018). Theoretically, there was reconstruction fund but it was never established. However, that has not been dissolved so far. Government decided to provide 300 thousands NRs. to support earthquake victims to build the shelter in installment basis. However, only 75.6 percent victims received first installment of 50 thousands among three installments during the period of three years (NRA, 2017).

Political instability was also the problem for the post-disaster philanthropic activity. People's representatives were not elected in local bodies for 20 years. The second time elected Constitution Assembly even was not able to promulgate the constitution which had increased frustration among the people. So they thought that the political leaders and the government were not able to solve the problems. The government wanted to apply one door policy to support the victims and requested to deposit the amount in Prime Minister Disaster Relief Fund publicly. Since, the government was missing the public faith; representatives of many organizations neglected the request and went to the affected areas to support the victims. Also, because of political instability, government and the leadership of NRA also were changed five times during the period of 3.5 years. Because of such conditions, the reconstruction and philanthropic activities couldn't be continued smoothly. When lately established NRA formulated the criteria for the reconstruction, some of the organizations were restricted to undertake the same project they had been running earlier. Philanthropic organizations found to realize problems of political pressure. Sometimes they felt political pressure to support in particular area and sometimes to include the particular victims.

Because of being a landlocked country, Nepal had to face the unofficial blockade in the border by India following the formulation of the constitution which created fuel shortage that resulted transportation problem; price hike became the major problem for supporting the disaster victims. Frequent aftershocks after the main quake also became the problems. Geographical difficulty and donor dependent attitude of the people were also found as the problem.

Conclusions

Since, this study examined the problems of post-disaster philanthropic activities; this may be helpful for the government and its bodies especially of developing countries to formulate suitable disaster management plan and create favorable environment for the philanthropic organizations in post-disaster period. It might be worthy for the philanthropic organizations to get rid of those problems in order to undertake philanthropic activities in effective and efficient manner in future.

References

Albrecht, F. (2017). The Social and Political Impact of Natural Disasters. Investigating Attitudes and Media Coverage in the Wake of Disasters. Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Social Sciences 143.

MOHA. (2015). *Nepal Disaster Report 2015*. Kathmandu.

NPC. (2015). Post Disaster Needs Assessment. Nepal Earthquake 2015 , A . Kathmandu.

Onlinekhabar. (2018). Ministry of Finance Preparing to Cancel the Reconstruction Fund of 28 Billion.
Retrived on Apr 1, 2018, from <https://www.onlinekhabar.com/2018/03/668342>.

Payton, R. L., & Moody, M. P. (2008). Understanding Philanthropy: Its meaning and mission,
Bloomington: Indiana University Press.

Pokhrel, G.R. (2017, August 14). Personal Interview.

Pradhan, P. (2018, January 26). Personal Interview.

Salamon, L. M. (1992). *America's nonprofit sector: A Primer.* New York: Foundation Center.

SWC. (2014). Guideline for Taking Approval of Foreign Support. Kathmandu

SWC. (2018). List of NGOs Affiliated with SWC. Retrived on May 20, 2018, from <http://www.swc.org.np/wp-content/uploads/2017/08/ngo_rec.pdf>.

SWC. (2018). List of SWC INGOs. Retrived on May 20, 2018, from <http://www.swc.org.np/wp-content/uploads/2018/03/ingoo.pdf>.

UNISDR. (2017, Feb 2). Terminology on Disaster Risk Reduction. Retrieved on December 5, 2017, from
<https://www.unisdr.org/we/inform/terminology>.

DISASTER MANAGEMENT APPROACHES IN BANGLADESH TOWARDS INTEGRATION OF SUSTAINABLE DEVELOPMENT

M. M. Hasan[1*1], S. Yeasmin[2]

ABSTRACT

A disaster is a serious damage or natural catastrophe that causes great damage and widespread human, material, economic or environmental losses, and impact. These create various difficulties for achieving sustainable development of vulnerable people, especially developing countries like Bangladesh. Bangladesh experienced over 2000 natural disasters since 1980, leaving a total death toll of approximately 200,000 people and causing economic loss worth nearly $17 billion. The fact is that diverse natural hazard will happen and the certain level of planning and preparation is needed to abate the negative impact of these. After the devastating cyclone of 1991, the concept of response has been changed and establish a new concept of total disaster management which includes response, recovery, prevention, mitigation, building resilience and reducing risks, learning from experience and avoiding past mistakes**.** The objective of this study is to show disaster management approaches that help to integrate sustainable development for Bangladesh. Development processes should be done in such a way that people, livelihoods and infrastructure have lower levels of risk and be oriented to avoid forming new risks in the future.This paper has concluded on the note that Disaster Management is working towards meeting sustainable development goals.

Keywords: Disaster management, Sustainable Development, Hazard, Vulnerability

Introduction

Bangladesh is geographically located between the Himalayas Mountains in the north and the Bayof Bengal in the South. Bangladeshis likely to be one of the worst affected nations who face different types of climate change situation because of this geographical position(Harmeling, 2014).Every year Bangladesh experience floods, cyclones, droughts, river bank erosions, salinity intrusions, tornados and other natural calamities that have an adverse effect on human health, agriculture, fishery, infrastructure, water, livestock (ADPC & BCAS, 2008).In recent years Bangladesh faced devastating disasters like Sidr in November 2007, Aila in April 2009, series of the flood of 2004,2007 and 2009, Nargis in 2010 and Mahasen in May 2013 (Ahmed , 2010 ; MOEF, 2009).

Disaster management is such process that the organization and management of resources and responsibilities for dealing with all humanitarian aspects of emergencies, in particular, preparedness, response, and recovery to minimize the impact of disasters. It does not eliminate the threats of disaster but creating plans to decrease the effect of disasters. (Chatterjee, 2016).Disaster Management in Bangladesh had gone through a significant reformation process. The main mission of the Government is to bring a paradigm shift in disaster management approach from conventional response and relief to a more comprehensive risk reduction culture and to promote food security as an important factor in ensuring the resilience of the communities to hazards (MFDM, 2008).

Sustainable development is the organizing principle that meets human development goals and at the same time sustaining the ability of natural systems to provide the natural resources and ecosystem services upon which the economy and society depend. Reducing risks and vulnerability, saving lives and property are all sound strategies for long-term sustainable development, which ultimately can provide livelihood safety nets and stable income generation for communities (Chatterjee, 2016). Different types of disaster management process that would foster sustainable development such as the adaptation of climate change; multistoried cyclone center that can be used both for educational purpose and shelter when need; disaster preparedness activities like training, voluntary service, group discussion that helps to create awareness on disaster and create resilience for sustainable development.

Methodology

Data is collected from different secondary sources which were published a document of government like MOEF (Ministry of Environment and Forests), MFDM (Ministry of Food and Disaster Management), a

[1] *Economics Discipline, Khulna University, Khulna-9208, Bangladesh.*
[2] *Economics Discipline, Khulna University, Khulna-9208, Bangladesh*

different private organization, case studies, international journals, papers, websites, and different maps of government organizations. Secondary data source involves collecting, reviewing, and drawing conclusions from findings.

Discussion

All countries especially developing countries are subject to all major types of natural hazards that disrupt human lives and property. Natural hazards in Bangladesh are costing millions of Taka in the form of lives lost and destroyed public and private properties. Many disasters like floods, cyclones, earthquakes, droughts, tornadoes affect the country almost every year. These disasters undermine sustainable development of the country. Conversely, however, many actions to advance sustainable development can potentially strengthen disaster resilience.

Disaster is the barrier of development

Disasters create a barrierto sustainable development. They result in loss of human life and property. It also destroys social and economic infrastructure as well as damaging the natural environment. These direct, physical losses create further indirect consequences, disrupting livelihoods, education, access to health care and so forth, together with leading to adverse secondary impacts on social and economic aggregates such as GDP, budget deficits and balance of payments (Benson, 2016).

Disaster Management and Development

Disasters which happened by climate change are an outcome of development failure as much as failed development is the action of disasters (UNDP, 2004). In absolute terms richer nations bear the greater proportion of losses but when the loss is measured in proportion of GDP poorer countries suffer more (WorldBank, 2004). Both direct and indirect losses are held because of disasters. Disaster management and development are two sides of the same coin. Reducing losses to climate-related disasters for meeting the sustainable development that can only be accomplished if they are undertaken in an integrated manner (Schipper & Pelling, 2006).

Disaster Management in Bangladesh

Coordination of national disaster management efforts is done by the Ministry of Food and Disaster Management (MoFDM) of the Government of across all agencies. In January 1997 the Ministry issued the Standing Orders on Disaster (SOD) to guide and monitor disaster management activities in Bangladesh. The National Disaster Management Council (NDMC) and Inter-Ministerial Disaster Management Coordination Committee (IMDMCC) will ascertain coordination of disaster-related activities at the National level. Coordination at district, upazilla and union levels will be performed by the respective District, Upazila and Union Disaster Management Committees. (MFDM, 2008).

Sustainable development Goals in Bangladesh

The Sustainable Development Goal sponsored by the United Nation, is a universal call of action to end poverty, protect the planet and ensure that all people of their respective country enjoy peace and prosperity. The government of Bangladesh is politically committed to meet the UN-sponsored SDGs. Different government and non-government organizations work together to meet SDGs goals.

Linking between disaster and SDG Goals

Disasters have a devastating impact on development. People lose homes, livelihoods, business, jobs, health and educational facilities, infrastructure etc. Understanding disaster risk is necessary to achieve the sustainable development goals as many of these goals are closely disrupt because of the destroying impact of the disaster. These documents confirm that the implementation of disaster management would provide “an opportunity to encourage increased political commitment and economic investment to reduce risks and take development action that considers disaster resilience as critical to poverty reduction and the key enabler of sustainable development” (UNISDR, 2015).

Table 1:Disaster Management Approaches to sustainable development goals in Bangladesh

Sustainable Development Goals	Impact of Disaster or Opportunity of Meeting SDG
Goal 1: No Poverty	This link to directly impact of disasters on livelihood sustainability and the indirect impacts on macroeconomic growth and social support. Build proper infrastructure for vulnerable people and reduce their exposure on economic, social and environmental disasters.
Goal 2: Zero Hunger	During disaster food scarcities becomes an extreme condition. Ensure a sustainable food production system and implement various seasonal agricultural practices that increase the productivity of different types of crops with concern about the ecosystem.
Goal 3: Good Health and Well-Being	During a disaster, health-related mortality will be higher among people whose health or livelihoods have already been weakened by the disaster. Ensure health services and strengthen the capacity of countries, especially developing countries, for disaster warning, risk reduction and management of national and global health risks.
Goal 4: Quality Education	Educational institutions used as shelter during a disaster. Build and upgrade educational facilities and ensure that all children acquire the knowledge and skills needed for sustainable development.
Goal 5: Gender Equality	Social inequality associated with disasters can make women and girls more vulnerable to sexual violence and without sensitive emergency relief programmes. Ensure gender equality in all fields and empower women’s so that they can handle any situation especially disasters.
Goal 6: Clean Water and Sanitation	Promote hygienic sanitation facility with soap and water, equitable sanitation for specific needs of women and girls and also elderly and disabled person.
Goal 7: Affordable and Clean Energy	It is undermined that reduces the disaster risk and also helps to manage during the disaster and after the disaster
Goal 8: Decent Work and Economic Growth	Ensure sufficient employment opportunities, productive employment, require diversification and upgrade technology, entrepreneurship for creating sustainable economic growth.
Goal 9: Industry, Innovation, and Infrastructure	Develop quality, reliable, sustainable and resilient infrastructure to support economic development and human well-being, with focus on affordable and equitable access for all and also build industrialization with an innovative way that may not hamper sustainable growth.
Goal 10: Reduced Inequalities	Reduces disaster through disaster management helps to reduce income inequality.
Goal 11: Sustainable Cities and Communities	Support financial and technical assistance for sustainable and resilient buildings utilizing local materials in developing countries.
Goal 12:ResponsibleProduction and Consumption	Promote eco-friendly, sustainable production methods and reducing the amount of waste.
Goal 13: Climate Action	Climate change creates disasters that may hamper any locality. Reduce vulnerability and strengthen adaptive capacity to climate-related hazards and natural disasters in all countries.
Goal 14: Life Below Water	Disaster destroys water resources that become necessary for fulfilling people’s food demand. Sustainably manage and protect oceans, seas and marine ecosystems to avoid significant adverse impacts and take proper action for their restoration in order to achieve healthy and productive oceans.
Goal 15: Life on Land	The ecosystem, forests, and biodiversity become devastating situation because of disaster. Protect forests and combat desertification, restore degraded land and soil, including land affected by the disaster, and strive to achieve a land degradation neutral world.
Goal 16: Peace, justice, and Institutions	Reduces inequalities among the people to manage and reduces disaster risk. Create peace and justice between and among different countries by various programmes.
Goal 17: Partnerships for the Goals	In the future many low land areas are threatened by sea-level rise and global climate change. Protect these low land areas by different global partnership

	activities at the time of risk.

Findings and Conclusion

Disaster poses a significant risk to development. It creates a great barrier for any development process. Development as a process of improvement has always been undermined by the occurrence of disasters. By managing this disaster raises a path for sustainable development. Plans and programs have been formulated to manage natural disasters. Disaster preparedness program such as early warning, community preparedness, training, vulnerability, and capacity assessment in the proper way can create awareness and also attain development. Build a strong infrastructure for reducing disaster risk also foster development process. Disaster risk reductions reduce socio-economic vulnerabilities to the disaster that integrated into sustainable development. Disaster management requires investment towards achieving sustainable development goals as well as a preparedness for disastrous events in the future. Disaster management involves every part of individuals, societies, government and private sectors. Thus. Disaster is the barrier of development and Disaster management integrated towards meeting the sustainable development goal but Disaster management process integrated into sustainable development.

References

Ahmed, A.U. (2010). “Reducing Vulnerability to Climate Change: The Pioneering Example of Community Based Adaptation in Bangladesh.” Dhaka: Centre for Global Change (CGC) and CARE Bangladesh.

Asian Disaster Preparedness Centre and Bangladesh Centre for Advanced Studies. (2008). "Draft Disaster Management Information Link Report." Ministry of Food and Disaster Management, Government of the Peoples Republic of Bangladesh, Dhaka, Bangladesh.

Benson, C., (2016) “Promoting Sustainable Development through Disaster Risk Management.” NO. 41. ADB Sustainable Development Working Paper Series.

Chartterjee, S. (2016). “Disaster Management definition, process, various phases and key components of preparedness”

http://www.linkedin.com

Harmeling, S. and Eckstein, D. (2014). “Global Climate Risk Index”,

http://germanwatch.org/en/download/8551.pdf

Ministry of Environment and Forests. (2009). “Bangladesh Climate Change Strategy and ActionPlan.” Government of the People’s Republic of Bangladesh.

Ministry of Food and Disaster Management (2008). “National Plan for Disaster Management” Government of the People’s Republic of Bangladesh.

Petrovic, N., Bošnjak, I., & Nedeljković, s. (2017). “DISASTER RISK REDUCTION FOR SUSTAINABLE DEVELOPMENT GOALS.”

https://www.researchgate.net/publication/322138433

Schipper, L., & Pelling, M. (2006). “Disaster risk, climate change, and international development: scope for,and challenges to, integration.”

UNDP (2004) Reducing Disaster Risk: A Challenge for Development. UNDP, Geneva.

UNISDR (United Nations Office for Disaster Risk Reduction). (2015). Disaster Risk Reduction and Resilience

in the 2030 Agenda for Sustainable Development. Retrieved from http://www.unisdr.org/files/46052_disasterriskreductioninthe2030agend.pdf.

World Bank (2004) ‘Natural Disasters: Eluding Nature’s Wrath’ (mimeo). World Bank, Washington, D.C.

ANALYSIS ON COMMUNITY MANAGED INFRASTRUCTURE AND HOUSING TO MITIGATE LANDSLIDE RISK AND HAZARD IN HILLY AREAS OF BANGLADESH - A CASE STUDY IN SHONDIP COLONY, CHITTAGONG, BANGLADESH

F. S. Sonia[1], A. J. Tonmoy[2] and M. Z. Haque[3]

ABSTRACT

Landslide, though is a continous natural process, causes major disaster events especially in the hilly areas. The district Chittagong of Bangladesh falls under the northern and eastern hill unit is vulnerable to landslide and characterized by mountainous topography with many unplanned settlements. The aims of this study are to analyze and find out the infrastructure and housing solution through community participation in Shondip Colony in Chittagong which is highly landslide risk settlement due to excess rainfall in rainy season and illegal excavation of hills for settlement & mud business. The study states that in recent times, landslide caused major disaster resulted in human and other animals' death and the death toll rises with its frequency. The community in the study area are practiced with landslide mitigation strategies and developed landslide resilient infrastructure and housing system through community participation. The study also states that in the case of community participation, a bottom up approach may provide sustainable resilient settlement which may mitigate the risk of landslide hazard. Furthermore, this initiative may also serve to build a sustainable community with participatory action. The study reveals that developing of landslide resilient settlement through community managed infrastructure and housing system has a high demand in Bangladesh and indicates that the community participatory approach is a suitable strategy to mitigate the landslide risk in a sustainable way.

Keywords: *Community participation, landslide resilient settlement, risk and hazard of landslide. landslide mitigation strategies.*

Introduction

Like the other natural disasters, landslide is one of the most powerful and destructive natural and environmental events which destroys life and property in a very short space of time (Baum et al., 1983). During landslide event, dynamic earth layers including topples, slides, creeps, slumps, flows, torrent move altogether due to imbalance of stored kinetic energy within those layers, at a descending manner to reach an equilibrium state until it stops (Burton, 1993). In translational landslides, surface material is separated from more stable underlying layer of a slope which cause shake the loosen top layer of soil from the harder earth beneath (Varnes, 1978). This creates a chain reaction resulting landslide. Three major causes associate with geology, morphology, and human activity for such natural phenomena. These are: 01) geological activity where geology refers to characteristics of the material itself. The earth or rock might be weakening or fractured, and different layers may have different strengths and stiffness due to geological and environmental variety. 02) Morphology refers to the structure of the land such as slopes or inclination of the topography. These are more vulnerable to landslides due to deforestation and climatic changes which lead to soil erosion or weakening the earth by rainfall or thunderstorm event. 03) Human activities play important role to destabilize or weaken the slopes which may cause due to population growth, migration, deforestation, unplanned urbanization, agriculture, vibration from heavy traffic and poor development. Such consequences thus escalate the risk of landslide in many regions in Bangladesh. These significant natural disasters that causes loss of human life and damage to natural and social environment, effect on economy, decimate infrastructure, impact landscape and sometimes change the river system (Kjekstad and Highland, 2009). Further, the Hyogo framework for action 2005-2015 (ISDR, 2005) and the Sendai Framework for Disaster Risk Reduction 2015-2030 (UNISDR, 2015) emphasize the importance of improved resilience at national and local community level. In this study enhancing the resilience was considered as the capacity of the

[1]*Urban Community Architect, LICHSP, IMC Worldwide, Dhaka-1212, Bangladesh*
[2]*Principle Architect, Exposition Associates, Dhaka-1225, Bangladesh*
[3]*Mohammad Zahirul Haque PhD, Assistant Chief Conservator of Forest, Ban Bhaban, Dhaka-1216, Bangladesh*
Email of Corresponding Author – architect.sharminsonia@gmail.com

community to manage itself to reduce the impact of landslide by managing and protecting lives, livelihoods, infrastructure, housing and basic services. "Shondip Colony"- the case study area in Chittagong has been facing such frequent landslide and soil erosion every year due to their soil condition and hill cutting for settlement growth. UPPR *(Urban Partnership for Poverty Reduction)* project of UNDP created significant impacts regarding such issues and initiated a pilot work on secured tenure ship in community driven approach to build a resilient community against landslide hazard where a community managed infrastructure and housing solution by "community driven participatory approach" to mitigate the landslide risk for low-income settlements. The objectives were to escalate such practices in landslide prone community around the world to achieve a sustainable community according SDG.

Methodology

Study Area

Shondip colony is situated in the district of Chittagong under Hathazari upazilla. Mainly Shondip colony is placed over a hill, covering mostly east to west part which has a top altitude of approximately 150 meters from the mean sea level. Soil texture is mainly sandy clay loam and the mean slope percentage is approximately 50 %. Mean annual rainfall is approximately 1800mm (Figure: 1). The area of the research study is 0.92 square kilometer.

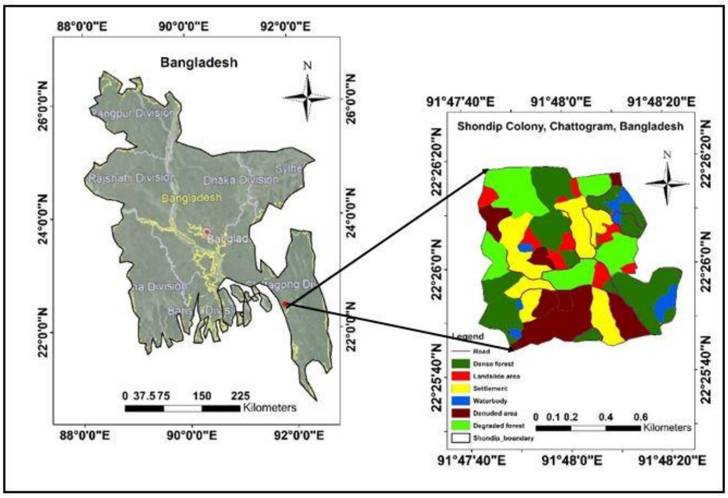


Figure 1: Map of the study area

Methods

The method consists of fundamental three phases. In 1st phase, extensive field work through surveying and collection of data were carried out on site with community people along with analysis of these collected data. Following that a series of maps were prepared in ArcGIS (vr.10.2) environment. Different types of survey were conducted in the settlement like socio economic survey, infrastructure, built environment, living pattern etc. In 2nd phase R-CAP was introduced with community people, community-based organizations, some local NGOs, local leaders and local builders. Data were analyzed from R-CAP to understand the risk, vulnerability, capacity, needs and resources of community. In 3rd phase probable mitigation measures had been proposed through architectural and engineering solutions. Drawings were created through AUTOCAD-20017 (x64) and by hand sketches. These phases established a relationship between onsite expertise and community people.

Results and Discussions

During 1973, small group of migrated family from Shondip *(Sandvip)*, an island near the south eastern coast of Bangladesh in Chittagong District, had developed a settlement in the study area. The site is 31.16 km (19.36 miles) away from Chittagong city. This area also locally known as "Chorar Kul" meaning *"a bay of islanders"*, have become vulnerable to landslides. Therefore, habitants of Middle Shondip Colony are

selected vulnerable target community for this research.
Monsoon (during the months of June and July) is the landslide prone season in the study area. The population density there is around 1930 per square kilometer. Man-made hazards including illegal land tenure by hill cutting with deforestation (Figure:2) are the main causes of landslide at the area. Hill erosion due to rain water decreases downward slopes and creates vulnerable cliffs. This results in landslides vulnerability (Figure: 3). Poor sanitation, lack of safe drinking water, fire hazard and hill diplomacy facilitate the poor people with earthen roads to access. People excavate shallow drains to channel out hill track rain water and grey water from household. Some inadequate RCC drain, guide wall and stair case on access route have been provided by NGOs on need basis. During rainy season people collect soil with geo bag through barrage and use them as guide wall, stair to protect their land and houses from erosion. Scarcity of safe drinking water is acute during summer season. Houses are constructed with Mud, bamboo, thatch and CGI (Corrugated Galvanized Iron) sheet. Affordability and eviction-threats encourage them to build temporary houses there (Figure: 5).

Figure 2: Potential Landslide Risk area

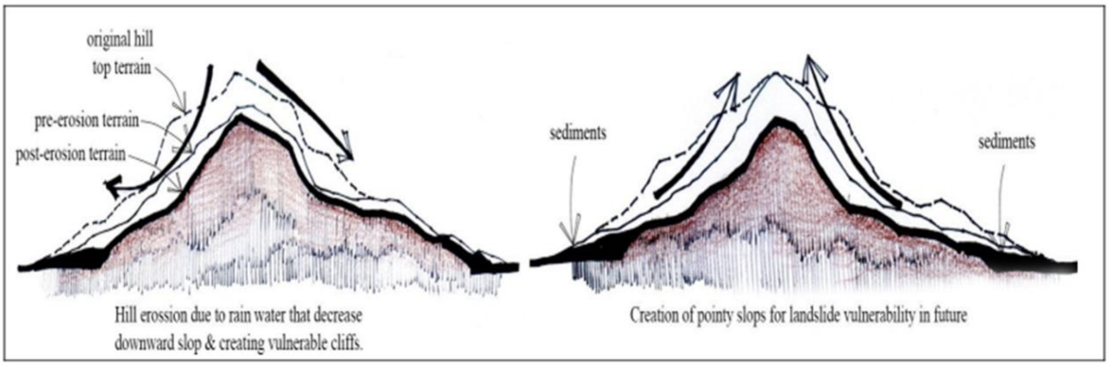
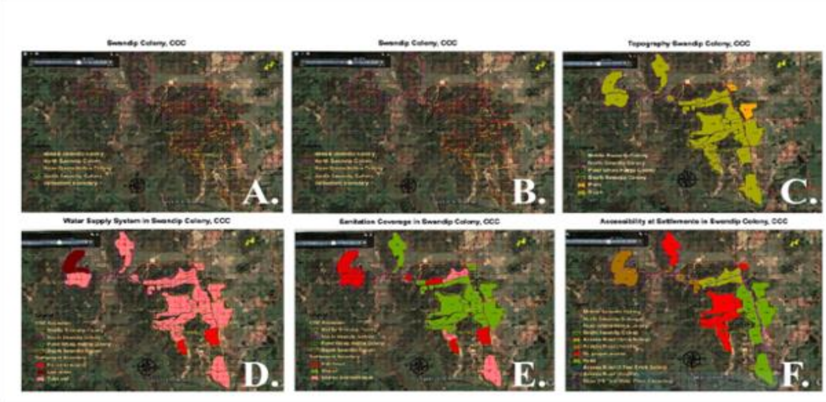


Figure 3: Hill slope erosion creates cliff in the study area

A Bottom up Approach from Survey to R-CAP

Community driven pilot works for "Secured Tenure for Low Income Settlements" started with several transect walks through settlement in the study area. Mobilization works were found very challenging although CDC (Community Development Committee) leaders were involved with expert teams. An extensive survey was done by community surveyors and experts on different socio economic and technical aspects. These trained surveyors were selected by CDC leaders from settlement area. A well-structured Community-Based Organization (CBO) in the settlement area influenced the general mass to be motivated for this work. After demarcation of the boundary of settlement, the community profile was prepared and assessed based on the survey data. Prepared digitized maps were utilized to identify infrastructures in the site (Figure:4*)* and scope of works. Community prepared a social map which indicated their capacity development. The workshops on R-CAP (Resilient Community Action Plan) with primary and secondary stakeholder's participation take place regularly. These help them to identify risk, hazards, vulnerability of landslide prone site and needs of community as well. This workshop also reveals the mitigation strategies for those hazards. An effective integrated mitigation measures were designed with bottom up approach which was generated by experts and implemented by the community.



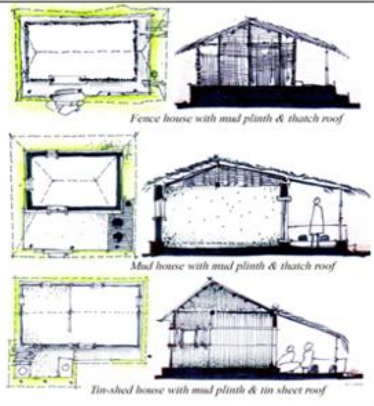


Figure 4*: (A) Boundary demarcation, (B) Topography map, (C) Water supply map, (D) Sanitation map, (E) Drainage map (F) Accessibility map*

Figure 5*: Existing housing structure in the study area*

Community Adaptation System and Mitigation Measures

However, the people of Shondip Colony had no option other than forcefully adaption of the landslide hazards. Integrated roads with stair case, adequate drainage system and retaining wall design were proposed by engineers according Local Government Engineering Department (LGED) standard. Some community-based water collection locations were proposed based on the community needs. Two pit latrines were already proposed to upgrade sanitation system. Local adaptation of drainage system was found around hill slopes (Figure:6). Affordable housing design was developed according to the demand of individual household by considering the availability of construction materials and existing topography. Community were mobilized to avoid the practice of cutting and deforestation of hills and were motivated towards more tree plantation on hill slopes and preservation of existing trees as well. Some alternative livelihood options were developed for farmers through income generation microcredit by NGOs to protect people from cutting of hills and encouraging agriculture activities. To ensure integrated community approach for mitigating landslide damages and support post disaster recovery, medical aid was introduced through community resource center and community clinic in the settlement.

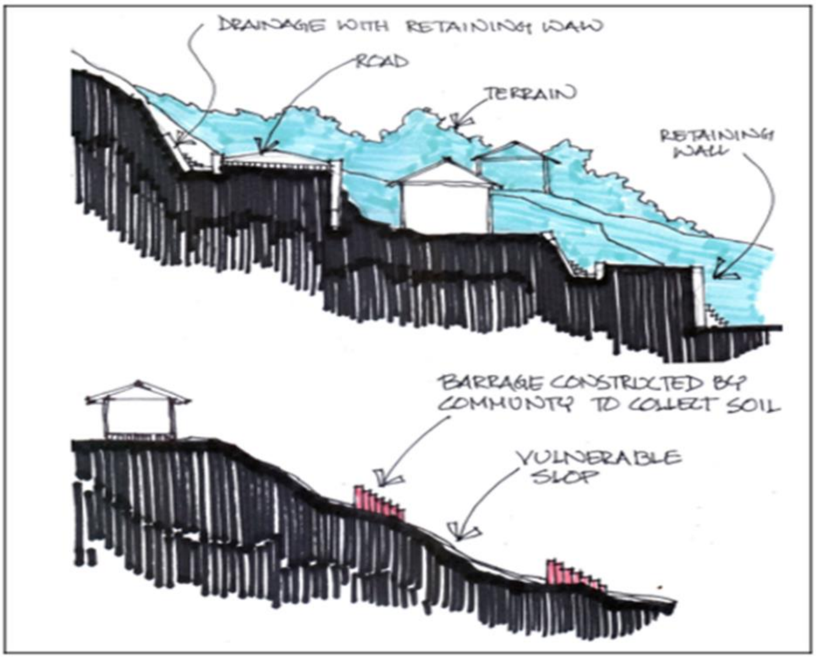


Figure 6: Local adaptation of drainage system around hill slope (down), Proposed mitigation measures at hill slope (up).

Some NGOs work for the building of social awareness through child and adult education, woman empowerment, family planning and capacity building of community. Involvement of local government encouraged the community to prevent social crimes and ensure civic facilities, early warning system during monsoon period and institutional capacity building through overall monitoring system.

Conclusion

Infrastructure and housing are the main physical structures of a settlement which can enhance the loss and damages of disaster with defective management. Community driven practice is a sustainable way to mitigate landslide vulnerability in low income settlement although a big challenge is to mobilize community and other stakeholders to work under an umbrella. It is very hardship to stop informal settlement growth at foothill area due to population pressure. But a well-managed community can reduce their vulnerability through integrated mitigation strategies with all relevant stakeholders. This study also explored the role of community-based knowledge and local structures in disaster management and especially how these could be used for disaster management. The findings of this study also reveal that, expansion of community-based landslide mitigation can be scaled up by government policies and encouragement which will make the foothill community more sustainable and disaster resilient. The study reveals that developing of landslide resilient settlement through community managed infrastructure and housing system might have a high demand in Bangladesh. This study might indicate a modality and strategy of community participatory approach towards suitable mitigating measures for the landslide risk in a sustainable way.

References

Baum, A., Fleming, R. and Davidson, L.M., 1983. Natural disaster and technological catastrophe. Environment and Behavior, 15(3): 333-354.

Burton, I., 1993. The environment as hazard. Guilford press.

ISDR, U., 2005. Hyogo framework for action 2005-2015: building the resilience of nations and communities to disasters, Extract from the final report of the World Conference on Disaster Reduction (A/CONF. 206/6). The United Nations International Strategy for Disaster Reduction Geneva.

Kjekstad, O. and Highland, L., 2009. Economic and social impacts of landslides, Landslides–disaster risk reduction. Springer, pp. 573-587.

UNISDR, U., 2015. Sendai framework for disaster risk reduction 2015–2030, 3rd United Nations World Conference on DRR. UNISDR Sendai, Japan.

Varnes, D.J., 1978. Slope movement types and processes. Special report, 176: 11-33.

UNDERSTANDING WARD DISASTER MANAGEMENT COMMITTEE (WDMC) FOR COMMUNITY BASED DISASTER MANAGEMENT IN DHAKA CITY CORPORATION (DCC): CONCEPT, FORMATION, EXISATANCE AND CHALLENGES

Atif Ibne Zoha Sreezon[1], Saraf Anjum Disha[2], Tasnim Tarannum Isaba[3], Ahmad Mojtoba Riyadh[4], Uttama Barua[5] and Dr. Ishrat Islam[6]

ABSTRACT

In case of a disaster, community people face the immediate impact of damage or loss. They also act as the first responders to withstand in the situation before arrival of rescue and relief. As such, at present community-based disaster management is getting more and more popularity. Its underlying principle is to manage disaster at community level by integrating the community people in the process. Dhaka, the capital city of Bangladesh, experiences various dreadful disasters from time to time, including flood, earthquake, building collapse and fire incidents. Due to unplanned urbanization and high population density, Dhaka city is considered to be one of the most vulnerable cities to disasters. Vulnerability to these disasters has further been multiplied due to lack of preparedness and community-based disaster management. According to the disaster management legislations, there is a structured regulatory framework and institutional setup for disaster management in Bangladesh. In urban areas, disaster management at local level largely depends on the involvement of local organizations and coordination among them. Therefore, the existence of Ward Disaster Management Committee (WDMC) is crucial for effective disaster management ensuring stronger community awareness and participation. Considering the importance of community-based disaster management and risk of Dhaka city to disasters, the importance of establishing WDMC at all of the wards in Dhaka City Corporation (DCC) is undeniable. Despite such importance, WDMC cannot be found in all of the wards in the city. In this background, the focus of this research is to explore the existence, nature and challenges of WDMC in DCC. This research has been done through participatory approaches: focus group discussion and key informant interview. This study will help the policy makers to identify the wards of the necessity and absence of WDMC, and take necessary actions thereby to establish WDMC in those wards.

***Keywords**: Ward Disaster Management Committee (WDMC), community-based disaster management, Dhaka City Corporation (DCC)*

Introduction

Natural disasters such as cyclone, flood, earthquake etc. cause immense destruction every year around the world. Apart from causalities, such events hamper the lifeline system, cause widespread loss of life and property by damaging social and physical infrastructures (Haque & Jahan, 2016). Bangladesh, a third-world country of 163 million of population, is one of the most disaster-prone countries in the world due to its geographical location, soil characteristics, diversity of rivers and monsoon climate (U. Barua, 2016). According to World Risk Report (2016), Bangladesh is the fifth most vulnerable country to disasters (United Nations, 2016). Between 1980 and 2008, Bangladesh faced 219 natural disasters – or more than seven disasters per year – causing a catastrophic US$16 billion in damage (UNDP, 2011). Capital city of Bangladesh, Dhaka, is one of the most densely populated cities of the world with a population of 18.89 million (BBS, 2015). Rapid urbanization, unplanned physical development and high population density of Dhaka makes it extremely vulnerable to urban disasters (Rahman, 2006). Due to geographical location and historical

[1]*Undergraduate, Dept. of Urban and Regional Planning, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.*
[2]*Undergraduate, Dept. of Urban and Regional Planning, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.*
[3]*Lecturer, BUET-JIDPUS, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.*
[4]*Grad Student, Dept. of Urban and Regional Planning, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.*
[5]*Lecturer, Dept. of Urban and Regional Planning, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.*
[6]*Professor, Dept. of Urban and Regional Planning, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh.*
Email of Corresponding Author - saraf.a.disha@gmail.com

earthquake events, Dhaka is among the 20 major world cities that are at the greatest risk (M. M. Rahman, 2018).

In urban context, nature of climate change and its effects transmute, accumulating towards secondary hazards causing further damages. With the recent awareness of Disaster Risk Reduction (DRR), it has been realized that to combat and reduce the effects of natural and man-made disasters, a local level disaster management body is an absolute necessity. In urban area such as Dhaka city which has an urbanization rate recorded for 2010 of 44 per cent (Zaman & Akita, 2011), disaster risk management is a crucial task which if not handled properly, can result in a catastrophic failure of the city in the event of a large-scale disaster. Among the hazards which is faced by Dhaka city are flooding and severe water-logging, earthquake, and fire are mentionable (Stott & Nadiruzzaman, 2014). These hazards are not isolated-events that occurs without any secondary consequences. These disasters can expose the residents of the city to a multitude of hazards such as road blockage, electrical failure and secondary fire hazards. To manage and reduce the damage, a local level disaster management body that can coordinate with the local community and the government institutions in times of natural disaster is vastly important.

Though government at all institutional levels are involved in disaster management, the role and activities of local government are particularly critical. Organizations at local level can play a key role in protecting life and reducing loss and damage through immediate actions (Col, 2007). Having profound knowledge about the area and community, local government plays an important role before, during and after the disaster. Effective collaboration between local community and local government authorities is an essential part of natural disaster management (Perry, 2007). This local level committee can interface with both the government bodies and people from local communities. This committee can also be utilized as the platform to bring together people who want to help out and are actively working for the community, so that a recognition can be given to them. Furthermore, it would help in raising necessary resources to work effectively and accountability of the people working of the community.

Despite the increasing importance of role of local government in disaster research, there have been few comprehensive studies, particularly with regard to developing countries. While managing the Bantul Earthquake (2006) in Indonesia, the capability of local government was very weak due to lack of training and experience in pre and post disaster management (Kusumasari & Alam, 2012). In China, effective preparedness, continuous monitoring and quick decision making of the local government helped managing the Tangshan Earthquake (1976) of magnitude 7.8 in Qing long County (Col, 2007). The inadequate capacity of local administration to deal with relief and rescue work caused immense destruction during Gujarat Earthquake (2001) in India (Tiwari, 2015). Previous research works have also addressed issues of public participation for sustainable hazard mitigation, resource capability of local government, local capacity building and involvement of local institutions in disaster management (Pearce, 2003; Messer, 2003; Allen, 2006; Kusumasari, Alam, & Siddiqui, 2010).

Considering the importance of local level community-based disaster management and risk of Dhaka city in Bangladesh, it can be said that disaster management committee at Ward level (smallest administrative unit of DCC) is required to coordinate mitigation, preparedness, response, and recovery activities at local level. But no research has been carried out till date on this issue. In this background, the objective of this study is to understand the current concept, existence, formation and challenges of Ward Disaster Management Committee (WDMC) for community-based disaster management in Dhaka City Corporation (DCC).

Methodology

For the purpose of this study, firstly secondary data on general profile of Dhaka North and South City Corporation (DNCC and DSCC) including Ward map (2015) and demographic information, etc. were collected from Capital Development Authority (RAJUK), Bangladesh Bureau of Statistics (BBS, 2011) . To understand basic concepts of local disaster management in DCC, the disaster management related legislations in Bangladesh were reviewed. For understanding the existence of WDMC in different Wards of DCC, key informants from DNCC and DSCC were contacted. For further detailed information, key informant interviews were conducted with the Senior Project Officers of SEEDS Asia and International Federation of Red Cross and Red Crescent Society: Bangladesh Delegation, through DNCC and DSCC. From the interview, a detailed framework of the process of WDMC formation and structure of the committee were gathered. Then the Wards with WDMCs were contacted for a detailed understanding of how they performed their duties and what their roles and responsibilities were. From these interviews and discussions, the current nature of WDMC in Dhaka City Corporation area was analyzed and the challenges of disaster risk management and reduction were interpreted.

Study Area Profile

Dhaka city has rapidly grown in an organic pattern towards the north following physical configurations of the landscape after the liberation war (RAJUK, 2016). The city is classified into three hierarchies of coverage based on jurisdiction and administrative boundary – RAJUK area, Dhaka Metropolitan Area and then the Dhaka City Corporation (DCC) area. DCC area was divided into two sections of Dhaka North City Corporation (DNCC) and Dhaka South City Corporation (DSCC) in 2011 following the amendment of Local Government City (City Corporation) Act 2009 (Ahmed & Mohuya, 2013). A total of 92 wards forms the DCC area (Table 1).

Table 1. Geographical comparison of DNCC and DSCC

	DNCC	**DSCC**
Zones	5	5
Wards	36	56
Area	85.26km^2	48.63km^2

(Source: DNCC & DSCC, 2017)

Demographic information from Bangladesh Bureau of Statistics shows that 7.64% of the population are infants below 5 years of age, 8.49% in primary school are children of age group (5-9), 9.4% are in junior high school age (10-14), 10.55% are in youth age (15-19), 13.36% are in the age group 20-24, 12.92% are in age 25-29, 27.69% are in age 30-49, 5.64% are in age 50-59, 1.9% are in age 60-64 and 2.41% are in the old age group of above 64 (BBS, 2011).

Table 2. Demographic information for DNCC and DSCC

	DNCC	**DSCC**
Population	3,956,302	3,014,803
Literacy rate	75.23	75.31
Sex ratio	123.58	149.73

(Source: BBS, 2011)

Concept and Formation of WDMCs

National Plan for Disaster Management (NPDM) (2010-2015 and draft 2016-2020) has already been developed in Bangladesh which provides a simple model to guide disaster management and emergency response efforts in Bangladesh. Disaster Management Act (2012) provides the legal mandates for government agencies and non-government actors. Standing Order on Disasters (SOD) (first published in 1999 and revised in 2010) clearly outlines the responsibilities of public representatives, ministries, agencies and non-governmental organizations related to disaster management. According to these legislations, local level coordination in Bangladesh consists of disaster management committees at City Corporation, district, upazila, municipality and union level. Ward-level disaster management committee can be formed under City Corporation Disaster Management Committee (CCDMC) depending on local situations and has not made compulsory in SOD (GoB, 2010). Thus, from the review of the disaster management legislations in Bangladesh, it has been found that WDMC has not been made mandatory in DCC despite its importance. The city corporation authority might not be able to carry out immediate response operations in all the affected wards because of its limited capacity, resource constraint and priority of actions (GoB, 2014). Therefore, existence of a Ward level government organization is required for effective disaster management at the smallest administrative unit in Dhaka city.

From key informant interview with key personnel from DNCC and DSCC it has been found that in practice they do not establish or manage WDMC within their jurisdiction. The formation of WDMC first started in 2010 under the Disaster Preparedness European Civil Protection and Humanitarian Aid Operations (DIPECHO) program. As a part of the program, ten international non-government organizations (NGOs) established a consortium termed as the National Alliance for Risk Reduction and Response Initiatives (NARRI). The consortium consisted of ActionAid, Concern Universal, Concern Worldwide, Islamic Relief, Oxfam, Solidarités, Plan, Care, HelpAge and Handicap. The purpose of the consortium was to understand necessity of introducing local level disaster management committee. The committee acknowledged the importance of the existence of a local level disaster management organization for urban areas. But there was no act which will obligate in formulating such committee. Therefore, the consortium proposed the idea of WDMC in DIPECHO 6 and started forming committees in Sylhet, Mymensingh and Dhaka in 2011. During DIPECHO 7 and 8 of 2011 and 2012, the formation of WDMC expanded to the Gazipur City Corporation and some of the municipalities of Bangladesh.

From 2011, after four years of practicing WDMC under DIPECHO program, the Government of Bangladesh

(GoB) realized the importance of it. In 2012, after the city corporation mayor election, the government declared a gazette mentioning the tasks that the mayors had to perform. The gazette included the formation of WDMC as a responsibility of the mayors but was not mandated. The NARRI consortium has been working to include the WDMC in a government mandate such as Disaster Management Act and Standing Orders on Disaster (SOD). The SOD mentioned the establishment of WDMC in every ward but since it was not imperative, so it mostly depended on the governing bodies.

Selection, Existence, Structure and Role of WDMCs

Under the NARRI consortium, a baseline study was conducted to identify which of the Wards in DCC were better suited for the committee formation. The factors considered for selection of Wards for establishment of WDMC were vulnerability of disaster, risk of damage, geographical location of the Wards which were more susceptible to disasters and few other parameters. The top Wards were then shortlisted and sent to the Mayor for the final selection. Based on the discussion with the Mayor the Wards were selected and the process of forming WDMC was started. Figure 1 shows the Wards in DSCC and DNCC where WDMC were formed.

The structure of committees consist of total 35 members in 21 posts and the members would be selected such that they represent every stakeholder group in respective wards. It also has representatives of 200 trained volunteers who function as the working force for implementing any small initiatives. The structure was formulated by the NARRI consortium and later polished by the Government authorities. At present, the structure follows the government ratification.

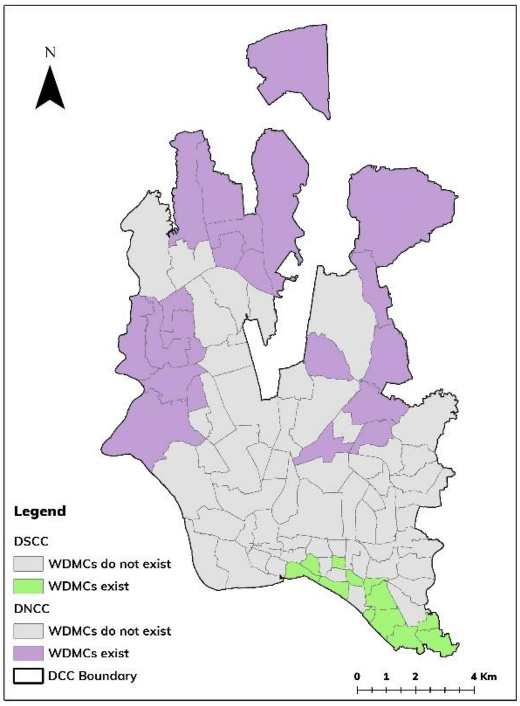


Figure 1: Location of the existing WDMCs (Source: Key informant interview)

Table 3: List of members of Ward Disaster Management Committee (WDMC)

Designation in Committee	Representative
Chairman	Ward Councilor
Vice-chairman/ Advisor	Reserved Ward Councilor
Member Secretary	Ward Secretary
Member	DWASA, TITAS Gas, Bangladesh Telecommunications, Company, Local health personnel, Ansar and VDP, Local mosque/ religious institution, Local volunteer Organization, Freedom fighter, Civil society, Local High School/ College/ Madrasa, Local NGO, Bangladesh Red Crescent Society (BRCS), Women representative, Physically challenged people

(Source: Ward Survey and Key informant interview)

The main role of WDMC is to act as a supporting body and ensure that every project, development initiatives are Disaster Risk Reduction (DRR) inclusive. The WDMC would be able to conduct their own study to find the vulnerabilities and needs of the communities, and recommend specific actions to the ward counselor. In case of any new construction or development initiative, the counselor would work with the committee to prepare the list of suggestions of which way the development effort should be directed. In case of any disaster, WDMC would work as a coordinating authority which will be organizing and systemizing all the relief and rescue operations. There would be bimonthly meetings, disaster risk reduction training programs, attending seminars on DRR and performing social works.

Challenges of WDMCs

While forming the committees and activating them, there were a number of constraints that hindered the process. The challenges can be stated below:

1. The interview pointed out the most crucial or root cause of challenges faced by WDMC and implementing authority that the existence of WDMC is not mandated in any of the government acts. Therefore, there are currently no incentive for the WDMCs to work actively for the community. As such, it generates all other challenges mentioned here.
2. The committee faced administrative and political hindrance in case of functioning and formulation. It resulted in to uncooperative counselors affected smooth nature of activities in the wards.
3. The criteria for selection of member proved to be too rigid sometimes.
4. People who were actively helping the community would not be included due to shortage of posts.
5. Training volunteers also proved to be difficult, as people could not relate to the significance of it. Availability of volunteers at times of necessity was also disappointing.
6. Inter-authority coordination gap was one of the major constraints.
7. There was not enough budget from the City Corporation authority which would able the WDMCs to accomplish tasks and avail necessary resources.

Discussion and Conclusion

WDMCs consisting of local people as volunteers, which can ensure community participation, can function like a bridge between governing bodies and community. The community people know the best for the community and has better knowledge about its resources. At times of disasters, it is the community which can reach out prior to other organizations. Supervising disaster management centrally is not possible and quite wholesome during and after any occurrence. Hence, the government needs to understand the indispensability of such organizations for easier and better performance.

References

Ahmed, S. U., & Mohuya, F. A. (2013). *Growth and Development of Dhaka North: 1971-2011.* Dhaka: Journal of the Asiatic Society of Bangladesh.

Akhter, S. H. (2010). *Earthquakes of Dhaka. Environment of Capital Dhaka—plants wildlife gardens parks air water and earthquake.* Dhaka: Asiatic Society of Bangladesh.

Allen, K. M. (2006, March 1). Community-based disaster preparedness and climate adaptation: local capacity-building in the Philippines. *Special Issue: Climate change and disasters, 30*(1), 81-101. doi:10.1111/j.1467-9523.2006.00308.x

BBS. (2011). *POPULATION AND HOUSING CENSUS* . Dhaka: Ministry of Planning.

BBS. (2015). *Population & Housing Census-2011.* Bangladesh Bureau of Statistics.

CDMP. (2014). *Scenario Based Earthquake Contingency Plan of Mymensingh Municipality Area.* Ministry of Food and Disaster Management, Government of the People's Republic of Bangladesh. Retrieved October 08, 2018, from https://www.scribd.com/document/261613689/Earthquake-Contingency-Plan-of-Mymensingh-Pourashava-Area

Col, J.-M. (2007). Managing Disasters: The Role of Local Government. *67*, 114 - 124.

GoB. (2010). *Standing Order on Disaster.* Disaster Management and Relief Distribution and Disaster Management Bureau (DMB), GoB, Dhaka: Ministry of Food and Disaster Management (MoFDM).

GoB. (2014). *Scenario based ward level spatial contingency plan (Ward no. 11, DNCC).* Government of the People's Republic of Bangladesh, Ministry of Disaster Management and Relief. Retrieved October 8, 2018, from https://www.adpc.net/igo/category/ID848/doc/2015-oTKv4A-ADPC CP_Ward_No._11_of_DNCC_English_Full.pdf

Haque, A., & Jahan, S. (2016). Regional Impact of Cyclone Sidr in Bangladesh: A Multi-Sector Analysis. *International Journal of Disaster Risk Science*, 7(3): 312-327.

Jain, G., & Bazaz, A. (2017). *Urban Risks and Resilience in India. Indian Institute of Human Settlements.* India: Indian Institute for Human Settlements. Retrieved December 8, 2018, from http://iihs.co.in/knowledge-gateway/wp-content/uploads/2017/10/Urban-Risk-and-Resilience-in-India.pdf

Kusumasari, B., & Alam, Q. (2012, January). Bridging the gaps: the role of local government capability and the management of a natural disaster in Bantul, Indonesia. *Natural hazards, 60*(2), 761-779. doi:https://doi.org/10.1007/s11069-011-0016-1

Kusumasari, B., Alam, Q., & Siddiqui, K. (2010, August). Resource capability for local government in managing disaster. *Disaster Prevention and Management: An International Journal, 19*(4), 438-451. doi:10.1108/09653561011070367

Messer, N. M. (2003). *The role of local institutions and their interaction in disaster risk mitigation: A* *literature review*. United Nations, Food and Agriculture Organization.

Paul, B. K., & Bhuiyan, R. H. (2010, October). Urban earthquake hazard: perceived seismic risk and preparedness in Dhaka City, Bangladesh. *Disasters*, *34*(2), 337-359. doi:10.1111/j.1467-7717.2009.01132.x

Pearce, L. (2003). Disaster management and community planning, and public participation: how to achieve sustainable hazard mitigation. *Natural hazards, 28*(2-3), 211-228. doi:10.1023/A:1022917721797

Perry, M. (2007). Natural disaster management planning: A study of logistics managers responding to the tsunami. *International Journal of Physical Distribution & Logistics Management, 37*(5), 409-433. doi:10.1108/09600030710758455

Rahman, M. A. (2006). *State of disaster risk management in Dhaka city*. BRAC University.

RAJUK. (2016). *Dhaka Structure Plan Report 2016-2035*. Dhaka: Rajdhani Unnayan Kartripakkha.

Stott, C., & Nadiruzzaman, M. (2014). *Disaster Risk Reduction in Dhaka City: From urban landscape analysis to opportunities for DRR integration.* Dhaka: International Centre for Climate Change and Development. Retrieved November 2018

Tiwari, A. (2015). Capacity Crisis After the 2001 Earthquake in Gujarat, India. *In The Capacity Crisis in Disaster Risk Management*, 19-29.

UNDESA. (2017). *World Population Prospects: The 2017 Revision*. (P. Division, Producer) Retrieved from United Nations Department of Economic and Social Affairs: https://population.un.org/wpp/DataQuery/

UNDP. (2011). *Supporting Transformational Change.* United Nations Development Programme. Retrieved November 2018, from http://www.undp.org/content/undp/en/home/librarypage/poverty-reduction/supporting_transformationalchange.html

United Nations. (2016). *World Risk Report 2016*. Retrieved from https://collections.unu.edu/eserv/UNU:5763/WorldRiskReport2016_small_meta.pdf

World Bank and Earthquakes and Megacities Initiative (EMI). (2014). *Legal and Institutional Arrangements (LIA) Framework Guidebook.* Dhaka: Bangladesh Urban Earthquake Resilience Project.

Zaman, K. A., & Akita, T. (2011). *Spatial Dimensions of Income Inequality and Poverty in Bangladesh: An Analysis of the 2005 Household Income and Expenditure Survey Data.* International University of Japan, IUJ Research Institute. doi:10.13140/RG.2.1.3512.2004

CHALLENGES IN CLIMATE FINANCE GOVERNANCE IN BANGLADESH

Md Nurul Momen[1]

ABSTRACT

Bangladesh has been identified globally as one of the most vulnerable countries due to climate risks, however, climate finance covers to both mitigation and adaptation programs. As the main objective of the paper, it identifies governance challenges in regard to climate change adaptation and mitigation programs in Bangladesh, how and to what extent malpractices have taken place in this sector. In regards to methodology, adopting qualitative approach this paper is based on secondary sources of information in order to explore the level and extent of integrity, accountability and transparency in case of financing adaptation and mitigation programs in Bangladesh.

Keywords: *Adaptation, Bangladesh, Climate Change, Governance, Mitigation*

Nature of Inquiry

The effects of changing climatic condition are now widely recognized with significant negative consequences on economy and social livelihood. No doubt, identifying its root causes, and impacts has now become a global agenda in many international convention and protocols. Poor people, especially in the developing world, now face devastating consequences arising out from climate risks. Climate change mitigation programs in its efforts for keeping the low level of greenhouse gas emissions especially from the industrialized countries are yet to take off. It is predicted that climatic change will get worse, and may extend its magnitude further in the future. Variability in climatic conditions threatens to the future generations of human beings, and pushes people further into poverty and underdevelopment, and lock millions of people in the world deeper into it.

In order to deal with climate change, a significant amount of fund is required to prevent current resultant climatic condition and the future effects of global warming. Added to that, climate financing is very important to deal with the challenges posed by global climatic variability, it is imperative for climate vulnerable countries like Bangladesh to identify the available sources of climate funding network, and utilize the funds in an effective way. However, mitigation and adaptation programs for climate crisis as a long-term strategy in poor countries like Bangladesh is not well equipped to encounter with the challenges. These programs require a sound governance environment that provides an effective utilization of fund. Given the context, the paper examines the current state of funding mechanisms and its governance challenges in regards to climate finance in Bangladesh.

Theoretical Underpinning

A proper understanding of climate variation and change is important for better climate change governance. It is argued that any solution with regards to climate mitigation and adaptation cannot be possible without an understanding of the nature of the climate risks. Hence, it requires legal and institutional framework and participation of multi-stakeholders who shape climate change programs as planned and effective (Fröhlich and Knieling 2013).

Climate funds are channeled to tackle climate change, as it is illustrated by saying that climate finance are required to manage development challenges. The landmark Paris Agreement (PA) adopted under the UNFCCC in 2015 presents future strategic plan of action for climate risks. It outlines new international framework to maintain the synergy in processes and strategies to support climate action over time. The PA also warns to the parties to maintain transparency and accountability for the uses of climate fund (worker and Northrop, 2018). On the other hand, at domestic level, political agenda for climate finance and its action; introducing sound legal framework and mechanisms for transparency and accountability, institutional arrangement for public participation; and strengthening the capacity of concerned public institutions are the key issues in fulfilling the obligations adopted under the PA. However, it is to be noted that Paris declaration of 2015 in regard to climate governance are also closely aligned with the goals and targets of the 2030 Agenda

[1]*Associate Professor, Department of Public Administration, University of Rajshahi, Rajshahi-6205, Bangladesh. Email-* nurulmomen78@gmail.com

on Sustainable Development (Worker and Northrop, 2018).

Transparency is essential in the processes of climate finance that the activities under the funds and their financial entities will be conducted in a transparent way. Transparency International has examined the phenomena is such a way that it is the governments, organizations and/or individuals who should be opened to the public about the information in terms of their rules, processes and actions (Alexandraki, 2016). When it is talked about climate finance, transparency requires the disclosure of information regarding adaptation and mitigation programs in order to make sure that the funds have been effectively used as planned, which fulfills objectives of climate finance. On the other hand, transparency can play an important role to promote accountability, as it helps to safeguard accountability of the entities for their actions with respect to climate finance (Alexandraki, 2016).

However, accountability is defined as the process of holding entities for executing of their any decisions. An important challenge under climate finance is to ensure accountability through monitoring and evaluation of climate-related projects and programs. For the achievement of objectives with respect to implementation of climate-related projects and programs, the entrusted entities with the administration and disbursement of the funds must be legitimate. It is important to note that the institutional legitimacy refers to whether decisions are adopted in a transparent and accountable manner (Alexandraki, 2016). (Pieter et.al, 2012) points out five basic principles with respect to climate finance, including transparency (how entrusted entities effectively perform activities and use funding); ownership (stakeholders decide what actions need to be taken); responsiveness (resources are directed in a way to fulfill the particular needs of the most vulnerable people and communities); participation (processes allow to a range of stakeholders (government, private sector, civil society, and affected communities) to provide timely, and quality information); equity (actions remove inequalities in society and promote equality). Given the context, it can be argued that transparency and understanding of the financial mechanism of the entities can be helpful in building trust in society. This will assist to reduce the high level of transaction costs, inefficiencies in activities (Forstater and Rachel 2012).

Keeping in view the objectives of the paper, the analytical framework of independent variables are determinants of governance with respect to climate finance (fund allocation process, their transparency, monitoring status, political and administrative culture, and existing legal and institutional framework for utilization of climate fund). The dependent variable is governance of climate change adaptation and mitigation programs in Bangladesh.

Climate Change Fund in Bangladesh

Bangladesh is an early signatory party of the UNFCCC and maintains its active participation in the UNFCCC's annual COP. However, the Ministry of Environment and Forest (MoEF) represents the GoB as the UNFCCC's focal point of communication (Glen et al, 2017). Jurisdictionally, MoEF is responsible to create climate financing bodies and coordinate its activities. MoEF is also responsible to formulate climate-related law, and implementation of policies and strategies and also to ensure transparency, accountability, and building capacity of climate adaptation and mitigation projects. However, Bangladesh Climate Change Trust Fund (BCCTF) and Bangladesh Climate Change Resilience Fund (BCCRF) are the two major bodies for climate financing.

Governance Challenges of Climate Change Adaptation Fund in Bangladesh

The PA on Climate Change and the UN Sustainable Development Goals (SDG) keeps pressure on developed countries in order to fulfill the objectives of climate change mitigation and adaptation programs of the affected developing countries. For doing so, required amount of climate financing will have to be made available. It is pointed out that to achieve SDG13, it needs availability of climate fund, and also requires sound policies, good practices and strengthen institutions, accountable and transparency of the project at all levels, inclusiveness and local participation in case of decision and implementation of climate funds that '*no one is left behind*' (Transparency International, Bangladesh 2018).

However, this part will explore the climate finance governance, especially how the fund allocation process made for climate adaptation and mitigation programs in Bangladesh. In the process, this section will asses some issues, such as the transparency in activities, monitoring mechanisms, political and administrative culture, and existing regulatory framework with respect to climate fund utilization in Bangladesh.

Climate Finance Gaps and Challenges

Bangladesh ranked 6th among the world's top 10 deadly affected countries (Kreft et al, 2017) for its severe effects of climate variation and change, but the country received a small of amount of climate change fund compared to other countries vulnerable affected by climate change. Hence, it needs a proper flow and supply of climate fund from protecting climate risks, especially for the affected vulnerable communities. Having reviewed the climate expenditures, it is found that Bangladesh is spending about USD 1 billion per year, of these fund, 75% comes from national revenue (Baboyan, et.al, 2014), which makes a challenge to the GoB how to negotiate and bring more funds from developed countries to tackle climate risks. By rules, financing for BCCTF projects come through the national budget in every year. It allocated to $100 million per year in the first three years from July 2009 to June 2012 but got lessened to $15 million in FY 2015- 2016 (Glen et. al 2017). So, disbursement of climate fund does not fulfill the actual requirement for Bangladesh, for example, between 2009 and 2013, the country required US$ 5 billion as the amount of expenditure for climate projects, but only leveraged US$1 billion (The International Institute for Environment and Development (IIED) 2014). Hence, to reduce the deficit, it needs to make an established mechanisms and strategies to support climate goals, for doing so; it requires better synergy in activities across the financial bodies of the country and to establish linkages with development partners.

The current budgetary allocations for climate change fall short of what is actually required in Bangladesh. Undoubtedly, different forms of natural disasters including storm surge in the coastal areas, unexpected floods and severe droughts in the northwestern region have long been caused to damage lives and property. It is to be said that the strength and unpredictability of the new forms of natural disasters that have been increased in manifold in the recent years, however, the country lacks the financial resources to bear the costs incurred by climate change. The World Bank estimated the costs of climate impacts on Bangladesh; it has been projected that $5.5 billion annual recurrent expenditure will be required until 2050 (Chowdhury, 2012).

To defray the costs incurred by climate change, Bangladesh needs support from development partners. However, GCF is the newly introduced climate finance set up under the UNFCCC to distribute $100 billion in every year from the developed countries to the affected climate risks countries (Huq, 2016). All the climate affected developing countries in the world are eligible to receive GCF by submitting their proposal with strong negotiation with the partner countries and international organizations. However, Bangladesh, being one of the most vulnerable climate risks countries, will have to struggle over it with other developing countries in order to get significant amounts from the GCF. It is noteworthy that $100 billion per year committed by the developed countries, which will begin from the year 2020 (Huq, 2016). And there are the further possibilities of increasing GCF in future. Undoubtedly, the GCG will not come to the Bangladesh automatically, rather showing the vulnerabilities and practicing good governance in regard to the utilization of climate fund.

Transparency, Accountability and Integrity of Climate Fund

Let's discuss some of the challenges that the country faces in regards to using and receiving climate change adaptation and mitigation fund. Bangladesh needs to stress strengthening governance in case of utilization of climate funds, as the Transparency International Bangladesh (TIB) reported that the country scored 3.09 on a 5.00 scale in climate change adaptation (CCA) finance (The Daily Star 2017). However, the study covered five key governance indicators in CCA program, including transparency, accountability, participation, coherence and integrity in regard to scrutinizing, approval, implementation and monitoring of the project.

The volume of global climate change adaptation funds have been increased significantly, but donors are much concerned about the transparency, accountability and integrity of how the fund recipient countries decisions regarding climate expenditure are being undertaken. Donors focus on zero tolerance on corrupt practices and wastage of climate funds from its intended goals. Theoretically, any deficiencies in the regulatory framework might increase the extent of corruption. Transparency International in every year ranks the country as one of the top corrupt countries where corruption seems to entangle in every societal network; hence, Bangladesh faces a number of governance challenges, as far as mitigation and adaptation program for climate impacts are concerned.

Violation of rules has taken place in case of BCCTF's project approval that can be revealed in here. The BCCTF's project selection process starts with reviewing submitted projects where a 13-member technical committee is headed by the secretary of the MoEF. After scrutinization of the projects, they are supposed to provide recommendations for approval to a 17-member trustee board headed by the Minister of Environment and Forests (MoEF, 2016). Surprising, the technical committee had never met to scrutinize the project proposals, rather it were directly submitted to the BCCTF secretariat and the BCCTF's Board of Trustees approved it without being reviewed by a technical committee. In that way, as of March 2016, 397 BCCTF projects got approval for implementation with respect to climate-related projects (MoEF, 2016).

Donor countries always present resentment over the corrupt practices that have also been a major stumbling block for Bangladesh for climate projects. It is noteworthy that political consideration takes place in project screening and its subsequent approval process, and without a proper scrutinization at least five projects received approval notification by BCCTF, according to field visit conducted by Haque et.al (2012). On the other hand, Glen et al (2017) found that project monitoring and reporting basically focuses on expenditures, it never assess the status of project implementation and its impact issues, hence, it fails to readjust project designs or any lessons learned.

Multi-Stakeholder Partnerships

Global Witness (2012) opined that active civil society participation and engaging local citizens with climate-related policy and programs are crucial for quality climate governance. It is added by arguing that in case of decision making of the concerned authority that should be transparent by providing documents and justification for decisions in public. However, to say that multi-stakeholder partnerships are not followed in the climate change projects and programs. Opinion of the affected people in the project approval process is not maintained. Added to that, there is lack of functioning local government, and with the absence of planning at local level, there is no participation of local community in the program for climate change.

Whatever the amount of climate change fund allocated in the affected area, no doubt, effective utilization of funds depends on the participation of local people at the different stages which starts from the project approval to implementation, but in reality, it is not specified clearly in the implementation manual of both funds (Haque, et. al. 2012). In transitional democratic countries, citizens' participation in climate-related programs may be limited. Transparency International's country reports in every year present that there is absence of transparency in regard to decision-making processes, and hold the authority accountable. In Bangladesh for example, citizens are suspicious regarding some mitigation and adaptation measures, suspecting political influence in project approval (The International Institute for Environment and Development (IIED) 2014).

Global Witness (2012) argues that if sub-national entities or local bodies' access to climate finance, this may be an effective way for better utilization of project activities and reduces misappropriation of climate fund. It is found that insufficient capacity of the local bodies to plan and manage climate change adaptation and mitigation program that continues to challenge for making climate aid effectiveness in the affected areas. Furthermore, according to public procurement regulations introduced in 2008, in case of monitoring climate funds, provision is absent in engaging local community to monitor the status of ongoing climate project (Global Witness, 2012).

There is currently a gap in developing the capacity of local government bodies. As the lowest tier of government, local government might support initiatives for climate mitigation and adaptation program. Regardless of the number of actors involved, climate adaptation and mitigation program through the local government bodies would introduce an institutional framework at local level. If we also look at the existing capacity of the local government bodies in this regard, they do not have the appropriate plan and sufficient manpower to explore the magnitude of climate risks on affected communities at the local level (The International Institute for Environment and Development (IIED) 2014). Hence, local government bodies needs to develop their own capacity to tap fund from different national and international sources.

Coordination and Collaboration

In theory, effective coordination among different ministries and departments of the government has to be ensured for smooth functioning of the processes. There is an absence of coordination and collaboration among different government departments and agencies, as many actors are involved in dealing with climate variation and change what overlaps with functions. Different agencies of the government have the similar plan of action which hinders the processes of synergy in activities. As a consequence, it often fails to coordinate the activities and fund received from the partner countries and international organizations. However, MoEF is responsible in implementing climate-related adaptation and mitigation program, organizational supported by the both BCCTF and BCCRF, hence it requires collaboration and coordination among the bodies including BCCTF, BCCRF, CCU and World Bank, which is immensely important. It helps to bring coherence in decision-making among the involved agencies and to avoid duplication of funding with respect to climate project (Haque, et. al. 2012).

Bangladesh adopts different kinds of strategies to bring into climate fund both from national and international sources. For instance, Bangladesh Climate Change Trust Fund (BCCTF) receives fund from its own national revenue; Bangladesh Climate Change Resilience Fund (BCCRF) receives fund from bilateral sources, including UK, EU, Sweden, Switzerland, USA, Australia and Denmark; and the Strategic Climate Fund's Pilot Project for Climate Resilience receives fund from multilateral sources (International Institute for Environment and Development (IIED) 2014). Bangladesh also depends on multilateral development banks and agencies (including World Bank, Asian Development Bank and International Finance Corporation) to tap resources to facilitate low-carbon resilient development (LCRD) (The International Institute for Environment and Development (IIED) 2014). Given the scenario, there is a risk of overlapping functions among the involved bodies, hence, it needs better coordination and synergies in activities.

Conclusion

In conclusion, climate finance governance is very critical to the countries like Bangladesh where resources are limited. Even there is availability of climate funding, but that is below the requirement level to support the adaptation and mitigation activities for climate change. Although there has been a significant development in terms of raising climate funds, as the developed countries have promised to support the affected developing world. However, Bangladesh suffers most due to climate impacts do not have the capacity and negotiation skills to access and properly manage the available climate funds. The GoB has to realize the fact that it would not be good decision to rely solely on external finance which is quite low as per the need of the adaptation and mitigation program. Therefore, it is important for the GoB to develop mechanisms for generating domestic sources of fund to avert external finances on climate change.

References

Alexandraki, Chrysa. 2016. "*Strengthening Accountability in Climate Finance, an Agenda for Change*." Faculty of Law, University of Oslo, pp. 1-93.

Baboyan, K. Le, H. Rashid, A.K.M, Steele, P. 2014. "*Bangladesh Whole-of-Government Approach to Climate Finance.*" Governance of Climate Change Finance to Benefit the Poor and Vulnerable in Asia-Pacific, UNDP & UNEP, October 2014. Retrieved from http://undp.dev.dotography.net/sites/default/files/documents/10_02_15/Country_Brief_Bangladesh_FINAL_28102014.pdf

Chowdhury, Faiz Ahmed. 2012. "*Climate Change Finance and Governance: Bangladesh Perspectives*." Institute of Governance Studies, BRAC University, IGS Working Paper Series, No. 02.

Forstater, Maya and Rachel Rank. 2012. *"Towards Climate Finance Transparency*." Published by the Global Campaign for Aid Transparency and a Development Initiative, May 2012, pp. 1-41.

Fröhlich, J. and Knieling, J. 2013. "*Conceptualising Climate Change Governance*." pp. 9-26, in J. Knieling and W. Leal Filho (eds.), Climate Change Governance, Climate Change Management, Springer-Verlag Berlin Heidelberg, 2013.

Glen Anderson, Charlotte Mack, M. Zakir H. Khan, Rezai Khondker, and Eric Hyman. 2017. "*Climate Finance in Bangladesh: Situation Analysis*." Washington, DC: Climate Economic Analysis for Development, Investment, and Resilience (CEADIR) Activity. Crown Agents USA and Abt Associates. Prepared for the United States Agency for International Development.

Global Witness. 2012. "*Safeguarding REDD+ finance: ensuring transparent and accountable international financial flows*." Retrieved from http://www.globalwitness.org/sites/default/files/library/Safeguarding%20REDD+%20Finance.pdf

Haque, M. Rouf, M. and Khan, M. Zakir, H. 2012. "*Challenges in Climate Finance Governance and the Way Out*." Working paper of Climate Finance Governance Project (CFG) project, Transparency International Bangladesh.

Huq, Saleemul. 2016. "*Climate finance in Bangladesh, Learning from Experience*." The Daily Star, April 16, 2016 retrieved from **https://www.thedailystar.net/op-ed/politics/climate-finance-bangladesh-1209307**

The Daily Star. 2017. "*Governance in climate finance needs to improve*." March 13, 2017, retrieved from **https://www.thedailystar.net/city/governance-climate-finance-needs-improve-1375027**

The International Institute for Environment and Development (IIED). 2014. "*Climate finance governance in Bangladesh: synergies in the financial landscape*." Policy and Planning Briefing, This research was funded by UK aid from the UK Government, April 2014.

Kreft, S. Eckstein, D. and Melchior, I. 2017. "*Who Suffers Most From Extreme Weather Events? Weather-related Loss Events in 2015 and 1996 to 2015*." Global Climate Risk Index 2017, Briefing Paper, Germanwatch.

Pieter Terpstrai, Annaka Peterson Carvalho, and Emily Wilkinson. 2012. "*Adaptation Finance: Accountability, Transparency and Accessibility at the Local Level*.**"** pp. 1-8. retrieved from http://conferences.asucollegeoflaw.com/februaryworkshop2014/files/2012/10/Pieter_Terpstra_memo.pdf

Transparency International (Bangladesh). 2018. "*Climate Finance & Governance Engaging the Youth for Transparency*." Accountability and Integrity International Debate Competition, 12-13 May' 2018, Dhaka, Bangladesh. Retrieved from https://my.rtc.bt/images/main/Concept%20Note_%20CFG%20International%20Debate%202018_TIB.pdf

Worker, Jesse and Northrop, Eliza. 2018. "*Assessing and Addressing Climate Governance Challenges in Low- and Middle-Income Countries*." Agence Française de Développement (AFD), An Operational Guide, Technical Report, No. 39, January 2018.

RISK FINANCING TO MANAGE CLIMATIC DISASTER SHOCKS IN BANGLADESH

M. Das[1], M. Bodrud-Doza[2] and M. A. Asad[3]

ABSTRACT

Bangladesh is exposed to severe natural hazards and more than 1% of its GDP is lost annually for disasters. Climate change is exacerbating the disaster intensity and frequency in the country in the form of temperature extremes, erratic rainfall, intensified and increased number of flood, drought-like situation, cyclone, salinity intrusion, etc. These climatic disasters not only lead to loss of lives and livelihood, it is consequently affecting economic development of the country. From 2000 to 2013, more than US $10 billion lost due to climate impacts, whereas total funding available for relief, rehabilitation and reconstruction was US $2 billion. Till now, financing for disaster risk management is largely focused on relief assistance through various social safety nets, and disaster risk reduction funding largely financed through international cooperation. Disaster risk finance can be an effective way of protecting livelihoods and development of the national and sub-national governments, private sectors, and the vulnerable communities against natural disasters through implementation of sustainable financial protection policies. Therefore, there is an urgent need to develop relevant policies and strategies based on risk financing experiences in other regions of the world, paving way to have different disaster risk financing models and tools in place.

Introduction

The effective management of disaster risks is a key public policy challenge for governments around the world, particularly those faced with significant exposures to such risks and/or limited capacity to manage the financial impacts of climate change induced natural disasters. Bangladesh is exposed to severe natural hazards like flood, river erosion, cyclone, drought, tornadoes, cold wave, heat wave, lightning, etc. Moreover, often more than 1% of GDP is lost annually for disasters, and climate change impacts exacerbated the disaster intensity and frequency in the country (GoB, 2017). Impacts of climate change are visible in Bangladesh in the form of temperature extremes, erratic rainfall and increased number of intensified flood, drought-like situation or water scarcity, cyclone and salinity intrusion. These climatic disasters not only lead to loss of lives and livelihood, it consequently affects economic development and sustenance of the country. As the frequency and severity of climate extremes continues to rise, governments are having to consider new ways of meeting the growing financial consequences of natural disasters. In post-disaster situations, the requirements for critical and rapid expenditures can lead to governments using slow or expensive instruments, such as budget reallocations or borrowing on unfavorable terms (Benson and Clay, 2004). In an attempt to be better financially prepared for when disasters occur, there is an increasing interest amongst governments in implementing comprehensive sovereign Disaster Risk Finance (DRF) strategies, defined by World Bank Group (2014) as “the bringing together of pre- and post-disaster financing instruments that address the evolving need of funds–from emergency response to long-term reconstruction–and are appropriate to the relative probability of events”.

Country with significant exposure to disaster risks may use DRF which may prove helpful in managing economic impacts. Effective DRF is crucial to promoting financial resilience against disasters in order to safeguard economic growth and development (OECD, 2015). DRF should cover the financial aspects of all measures of a comprehensive disaster risk management (DRM) system, which comprises pre-disaster and post-disaster measures (Figure 1) (Mita, 2016). An organized DRM system can enable development of and effective DRF tool-. As part of the pre-disaster measures, increasing the risk awareness will lead to demand for DRF as well as recognition of the financial burden that might be caused by disasters. By carrying out a comprehensive risk assessment of climatic and non-climatic disasters and shocks, which consists of hazard identification and impact assessment, a country can develop the right measures to reduce financial

[1]Senior Programme Manager, Climate Change Programme, BRAC
[2]Senior Officer, Climate Change Programme, BRAC
[3]Senior Manager, Climate Change Programme, BRAC
Email of Corresponding Author – mrjoy.d@brac.net

vulnerabilities to disaster risks and also develop risk financing evaluation. This paper seeks to review disaster risk financing options, opportunities and strategies in the context of Bangladesh, in order to manage climatic disaster shocks.

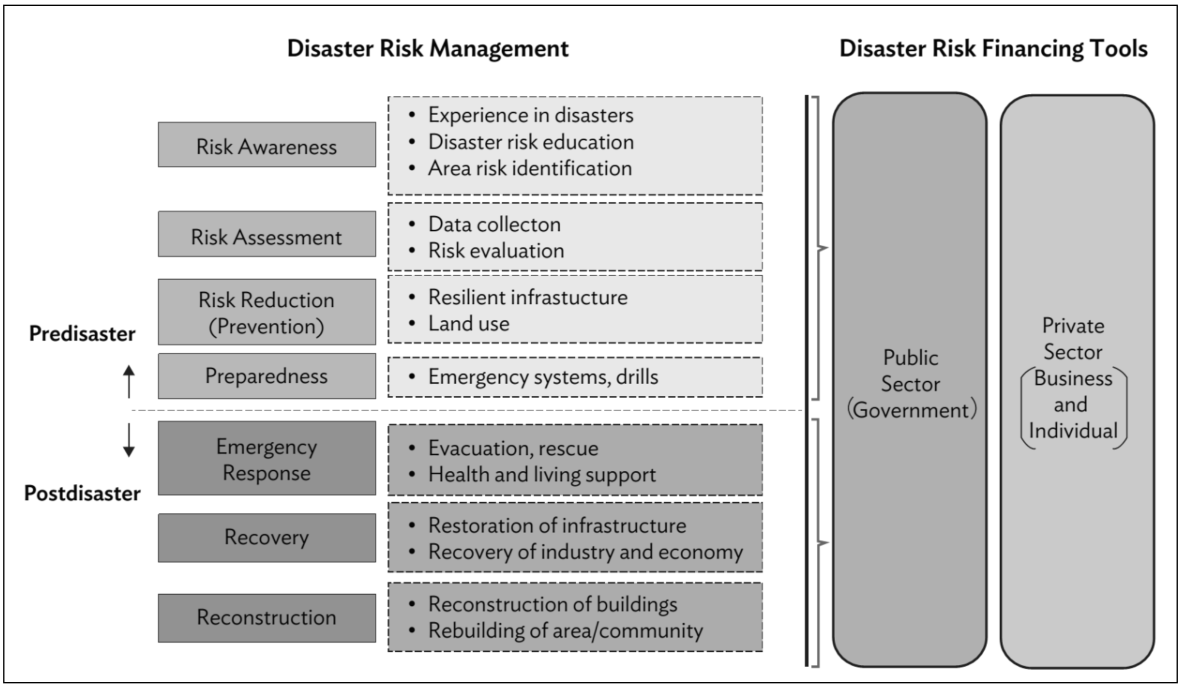


Figure 1. Disaster Risk Financing Framework (Source: Mita, 2016)

Method

A comprehensive literature review was used as the research methodology for this paper. A keyword search for natural disasters, hazards, vulnerability, disaster risk reduction, and risk financing in Bangladesh was used to find literature from number of sources such as electronic library database, peer-reviewed journals, published reports, policy papers and e-books. The findings from this extensive literature review was structured and presented within different categories of climatic hazards and disaster risk reduction and financing strategies.

Findings and Discussion

Principle of Disaster Risk Financing

Disaster Risk Finance is necessary for increasing the speed, predictability and transparency of disaster response and early recovery, ensuring support reaches people who need it the most and when they need it the most, based on a robust risk financial planning and operational mechanism. This aims to protect investments in human development and productive assets and planning on how to prepare to meet the cost of possible disasters before they happen keeping the vulnerability, exposure and likelihood of a hazard in consideration. Disaster Risk Finance is the way of protecting livelihoods and development by increasing the financial resilience of the national and subnational governments, businesses, households, farmers, and the most vulnerable against natural disasters by implementing sustainable and cost-effective financial protection policies and operations. A successful shock responsive social safety net (SRSN) programme has to be part of a disaster risk finance strategy. Shock responsive social safety net (SRSN) are composed of three key (and integrated) building blocks which are delivery mechanism, risk information and disaster risk financing (World Bank, 2018). The principle of risk financing are illustrated in the figure 2.

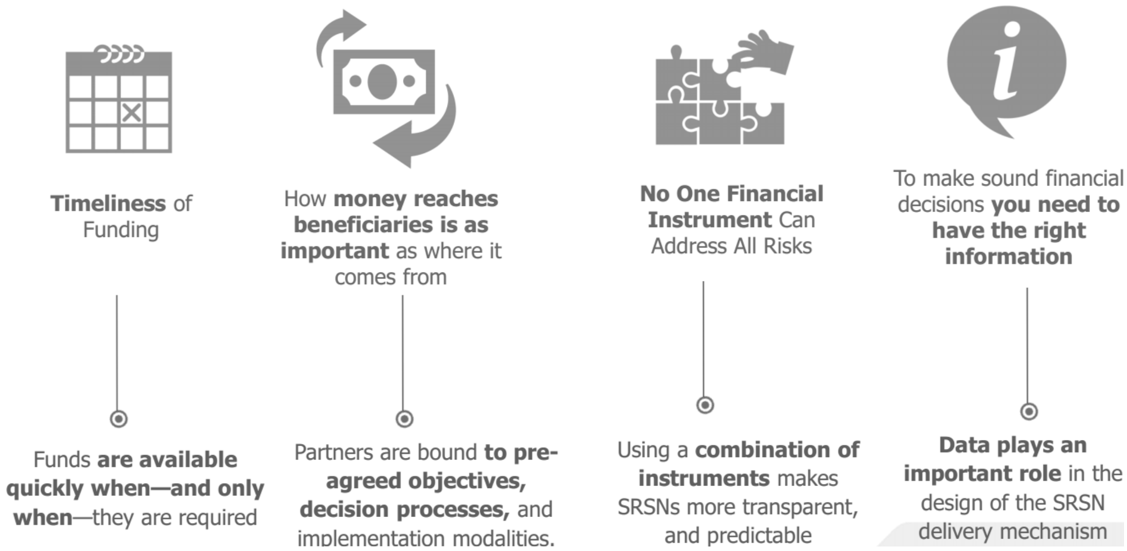


Figure 2. Core principle of disaster risk finance (Source: Modified after World Bank, 2018)

Disaster Risk Financing in the Context of Bangladesh

Natural hazard events in Bangladesh have cost economic losses of more than US$10 billion from 2000 to 2013, but the total funding available for relief, rehabilitation and reconstruction for the said period was US $2 billion only. It is estimated that Bangladesh will incur a financial impact of about US $3.2 billion each year due to cyclone and flood alone, or about 2.2% of gross domestic product (ADB, 2016). A big question remains how to compensate people for this huge losses to be incurred.

To address the impact of climate change and natural disasters, the Government of Bangladesh has developed Bangladesh Climate Change Strategy and Action Plan (BCCSAP) in 2009 where comprehensive disaster management was prioritized as one of the six thematic areas. In order to create a legal basis in the area of disaster management, the Disaster Management Act has been enacted in 2012 by the government. But as specified in the 7th five-year plan the financing for Disaster Risk Management is largely focused on relief assistance through various social safety nets (2.0 % of GDP invested in extensive social safety net programmes) with disaster risk reduction (DRR) investment largely financed through international cooperation. The disaster management act recommends the establishment of a disaster management fund.

The 7th five year plan of Bangladesh also mentions that the government will consider developing a policy on DRR financing, considering different financing models, and allocate sufficient national budget to initiate action whilst welcoming international contributions in support of national efforts, as well as Public-Private Partnerships and the support of civil society and volunteer organizations, to deliver sustainable resilience against climatic and non-climatic disasters. As outlined in the Standing Orders on Disaster (SoD), all ministries, divisions, departments, committees and other organizations must be involved in disaster risk reduction. In this context, capacity development programmes need to be initiated for further strengthening of the risk financing capacity, transparency and accountability of DRR related activities of both government and civil society organizations.

Disaster Risk Finance Options and Institutional Framework

Climatic disaster and catastrophes have a significant impact on the growth in GDP in Bangladesh. The 100-year loss (a loss expected to happen once every 100 years) for flood is equivalent to 8%–9% of GDP, and for tropical cyclone around 5% of GDP. Practice of insurance for both individual and business is very low in the country putting almost sole responsibility on the government. There is a clear dearth of alternative financial coping mechanisms for catastrophes in the Bangladesh. In Figure 3, the ADB analysis shows that the lower area covers the funding gap which is best managed through internal budgetary and reserve mechanisms. In case of a more significant funding gap (i.e., greater than $250 million), in some years, require an alternative risk financing mechanism such as contingent credit (middle part). However, for any major disaster event happening in every 5-10 years, it will be helpful for Bangladesh to have a proper risk transfer mechanisms, both in public and private sectors, in place. This can ease the pressure on individual and government as losses resulting from major disaster can be burdensome for the state and society and it becomes very difficult to *build back better* from such condition.

In Bangladesh, the Finance Division under the Ministry of Finance is the authority to allocate the national disaster-related funding across different governmental and nongovernmental stakeholders. Like most other countries, the Ministry of Finance allocates budget for different line ministries at the beginning of each financial year. It is to be noted that the budgetary system has small pockets of money to deal with disasters. Some of the identified pockets are disaster risk reduction fund, emergency fund disaster management and fund for unforeseen incidents (ADB, 2016). Also, Bangladesh Bank, insurance sectors and microfinance sectors and NGOs are playing a role in disaster risk reduction by helping their clients in coping with the impact of catastrophes.

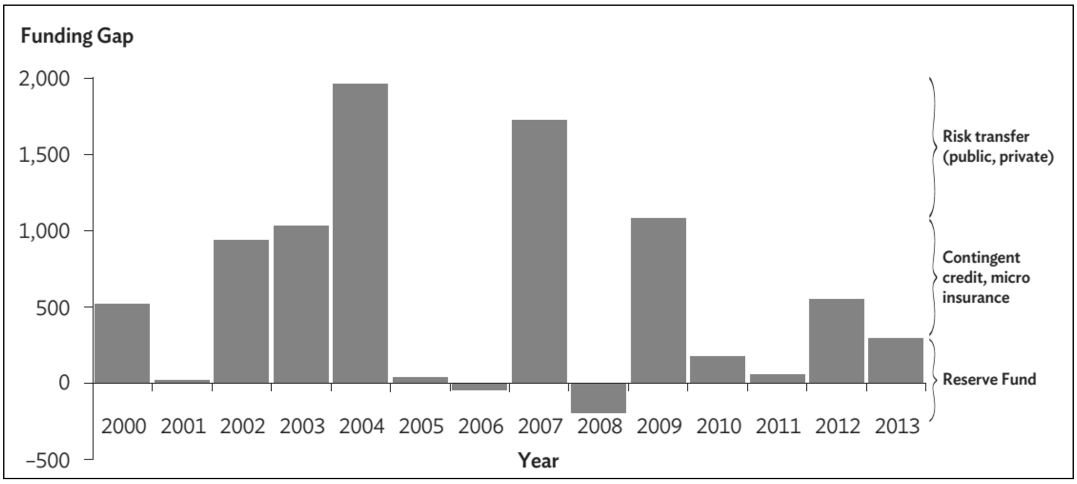


Figure 3. Funding Gap Results Summary with Risk Financing Options (Source: ADB, 2016)

Conclusions

Climatic disasters pose a big threat for the economies of Bangladesh, both in terms of fatalities and economic losses. One of the government roles in mitigating the impact of disaster risks is to strengthen financial resilience to disasters by developing a sound disaster risk financing system. It is necessary to integrate disaster risk financing strategies into the overall disaster risk management and public finance management to minimize the financial and economic consequences of disasters for the households, the private sectors, and the government. Right policies, regulations, and adept institutions is essential for the successful implementation of disaster risk financing in Bangladesh.

Acknowledgments

We are thankful to the Cambridge Institute for Sustainability Leadership and the World Bank Group for selecting BRAC in the Executive Education Program titled “Analysis to Action: Disaster Risk Financing and Financial Protection”.

References

ADB (2016). Disaster risk financing in Bangladesh. Working paper series 46. Asian Development Bank.

Benson, C. and Clay, E. (2004) “Understanding the Economic and Financial Impacts of Natural Disasters”. World Bank.

GFDRR and World Bank Group (2014) “Financial protection against disasters: an operational framework for disaster risk financing and insurance.” World Bank.

Government of the People's Republic of Bangladesh (GoB) (2017) “Climate Protection and

Development. Budget Report, 2017-18." Finance Division. Ministry of Finance.

Mita, N. (2016) "The Development of Disaster Risk Financing Strategies in Japan." Presentation at OECD–ADBI Seminar on Disaster Risk Financing in Asia. Asian Development Bank Institute, Tokyo. 24 June.

Organization for Economic Co-operation and Development (OECD) (2013) "Disaster Risk Financing in APEC Economies: Practices and Challenges." Survey report. Paris.

PREDICTION OF THUNDERSTORM EVENT IN BANGLADESH USING WRF-ARW MODEL

Ayesha Islam[1], Md. Marufur Rahman[2], Fatima Akter[3] and Md. Abdul Mannan[4]

ABSTRACT

Thunderstorm (TS) events are becoming extremely severe day by day in Bangladesh. Because of its association with heavy rainfall, hail, and lightning, TS incurs great damage to the physical properties as well as loss of lives. Therefore, prediction of TS event has become demandable in recent years. In this study WRF-ARW model of 30 and 10 km horizontal resolutions have been used for simulation of TS event occurred on 30 March 2018 over Bangladesh. The 6-hourly NCEP-FNL data from 00 UTC of 30 March to 00UTC of 31 March 2018 have used as initial and boundary conditions. The outputs of the model have been analyzed through different instability indices and their spatial distribution in every 3-hour interval. Convective indices are found to vary during the period of this day as- Total Totals Index (TTI): 43.0-57.1, Severe Weather Threat (SWEAT): 195.4-520.2, K index (KI): 8.3-33.6, Convective Available Potential Energy (CAPE):1115-2239 Jkg^{-1}, Convective Inhibition Energy (CINE): 1-175 Jkg^{-1}, Perceptible Water (PW): 0.7-18.1 mm. For verification of rainfall both 10 and 30 km horizontal resolutions information are utilized. The model captures the TS event well with some spatial and temporal biases. However, the model couldn't determine the rainfall amount precisely. Model underestimates rainfall amount by 5.5% and 7.92% for inner and outer domains.

Introduction

Bangladesh is one of the most disaster-prone countries in the world (World Bank, 2018). The complex geographical location and the influence of tropical climate have made Bangladesh vulnerable to different kinds of natural hazards. The convective parameters are the most analyzed indicators for understanding the TS events. In many studies the convective parameters such as- Convective Available Potential Energy (CAPE), Showalter Index (SI), Total Totals index (TTI), Precipitable Water (PW), Severe Weather Threat Index (SWEAT), K-Index (KI) have been studied for understanding the formation of TS scenario (Ferdousi, Debsarma, Mannan & Sarker, 2015; Mannan *et al*., 2015). KI value of 26 defines 50% probability of TS (George, 1960); SWEAT value between 300 to 400 indicates moderate TS activity (Miller, 1972); TTI value between 50to 55 indicates the possibility of severe TS (Miller, 1972); CAPE value less than 300 Jkg^{-1} indicates little or no convection (Knutsving, 2009); Convective Inhibition Energy (CINE) value greater than 200 Jkg^{-1} signifies sufficient to predict convection (Knutsving, 2009). Litta *et al.* (2012) studied severe TS with high-resolution WRF model considering the critical values of CAPE >1500 Jkg^{-1}, K index >33, TTI >44, SWEAT > 250. Tajbakhsh *et al.* (2012) considered KI, LI and SWEAT Index for forecasting of a thunderstorm. Weather research and forecasting (WRF) model is widely used for prediction of the mesoscale atmospheric phenomena (Kain *et al.*, 2006). Yamane *et al.* (2010b) investigated on the severe local convective storm (SLCS) and listed the average magnitudes of KI, TTI, LI, PW, CAPE and CINE during SLCS days in the pre-monsoon period for Bangladesh are 27.6, 68.0, -0.2, 38.2 mm, 1336 Jkg^{-1} and 332 Jkg^{-1}.

Mannan *et al.* (2015) studied the severity of TS in Bangladesh and its surrounding areas occurred on April 19, 2013 using the WRF-ARW model. Mannan *et al.* (2017) also studied on the heavy rainfall (HR) associated with severe TS in Bangladesh using the WRF-ARW model. But the prediction of TS remains as a challenge to the operational forecasters. In this study, severe TSs which occurred on 30 March 2018 has been considered for understanding its evolvement through different indices for inclusion in the prediction system.

Methodology

As per the record, a severe TS visited Bangladesh during 09-15 UTC of 30 March 2018. During this period gusty or squally wind, severe lightning (LT) and high amounts of rainfall recorded at different places of Bangladesh. The maximum wind of 78 km/hr recorded at Sylhet, which followed by 67 km/hr at Dhaka. Rainfall recorded mainly over Rangpur, Dhaka, Mymensingh and Sylhet divisions with the highest amount of 31mm at Tetulia. 6-hourly NCEP-FNL data with $1^{\circ}\times1^{\circ}$ grid resolution have been used as initial and

[1]*Masters Student, Department of Disaster Science and Management, University of Dhaka, Bangladesh*
[2]*Department of Disaster Science and Management, University of Dhaka, Bangladesh*
[3]*Department of Geography and Environment, University of Dhaka, Bangladesh*
[4]*Bangladesh Meteorological Department, Agargaon, Dhaka, ,Bangladesh*

boundary conditions for simulating the event using WRF-ARW model. Nested domains (Figure 1) of with 30 km (D1) and 10 km (D2) resolution are considered with existing facilities with the model. For the qualitative depiction of the TS event six convective parameters have been analyzed. Finally, simulated rainfalls have been compared with the observed rainfall of BMD. GrADS and Win Surfer software are used for extracting the model parameters and creating spatial maps from observations.

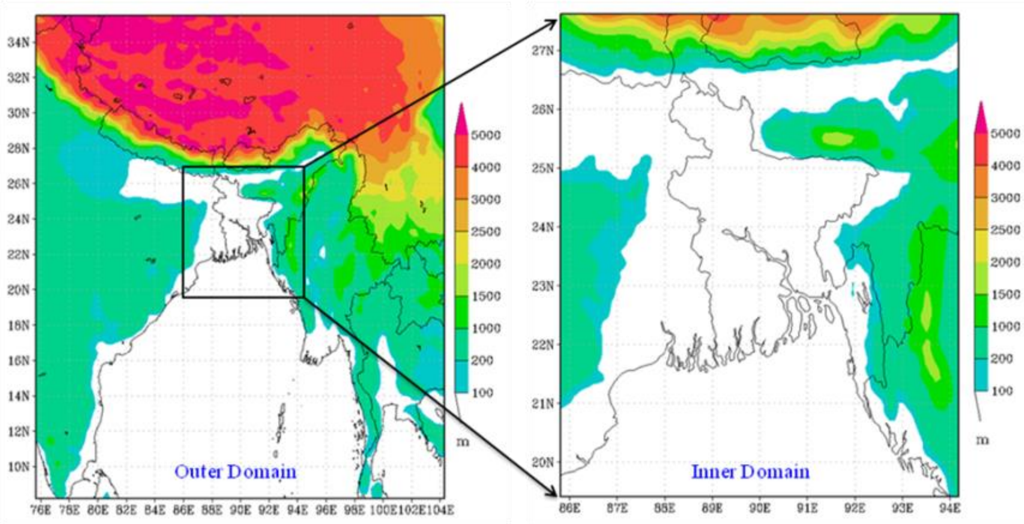


Figure 1: Selected model domains (with terrain height) for conducting an experiment with WRF Model

Results and Discussion

Origination of event

Simulation exposes that wind, convergence and vorticity fields are favorable to originate the TS event over the northwestern part of Bangladesh, which then moved southeastwards over Bangladesh covering northern and central parts. During this period rainfall evolved and severe LT activity has been observed (Figures 2 and 3).

Total Totals Index (TTI) and Severe Weather Threat Index (SWEAT)

TTI and SWEAT are found to evolve with the progress of time and the life cycle of TS and are found to cover Rangpur, Rajshahi, Dhaka, Mymensingh and Sylhet divisions with higher values over north central part. The magnitudes of TTI and SWEAT are found to reach as high as 48-57and 250-500. These ranges can be treated for most likely severe TS but below these ranges of TTI and SWEAT may have the possibility of TS (Figures 4 and 5).

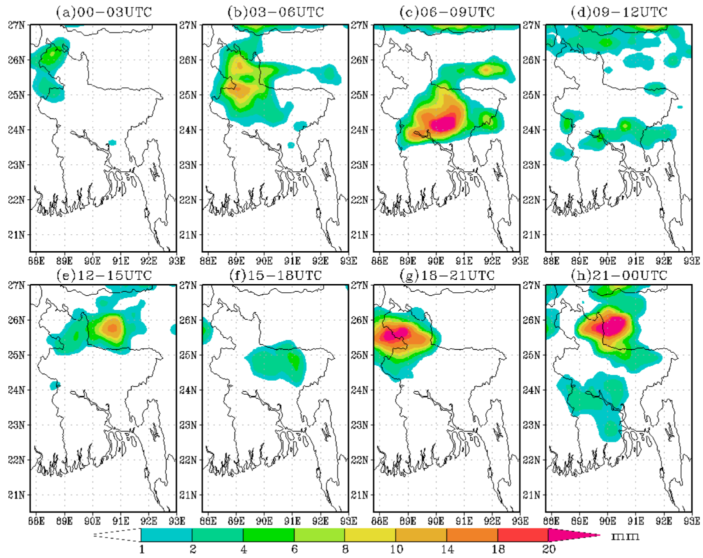


Figure 2: *Evolution of simulated rainfall (mm)*

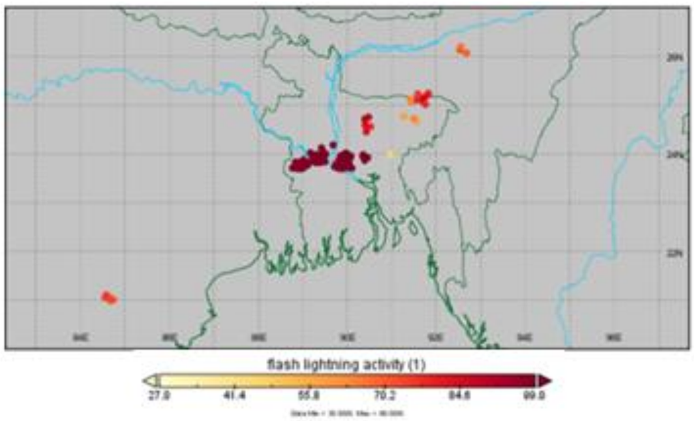


Figure 3: *LT flash activity over Bangladesh on 30 March 2018*

K Index (KI)

KI is found high over northern and northeastern parts but its range of 34-38 is found over Sylhet and Mymensingh. However, it is less than 24 over the central part. The evolution of KI (Figure 6).is very similar to TTI but it has the strong signature over intense SWEAT generated area. TSs are recorded but TTI and SWEAT indices are found less than the critical value (Figure 4).

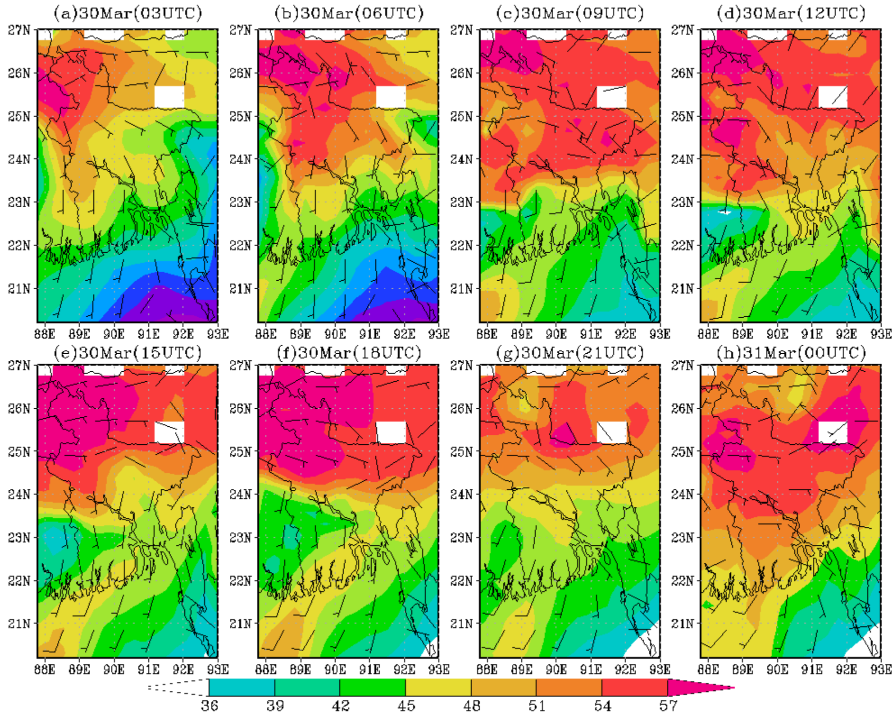


Figure 4: Evolution of TTI on 30 March 2018

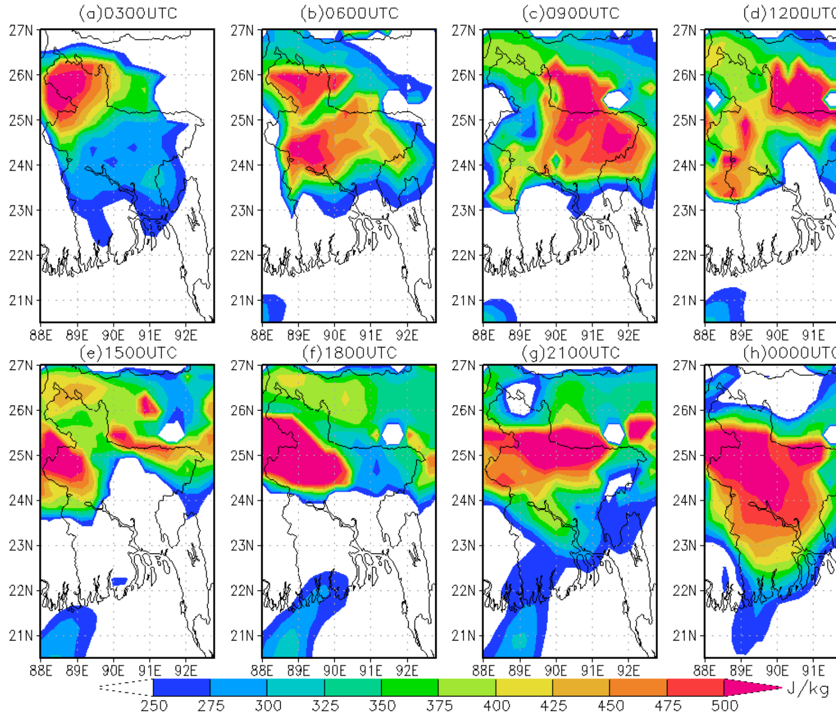


Figure 5: Evolution of SWEAT on 30 March 2018

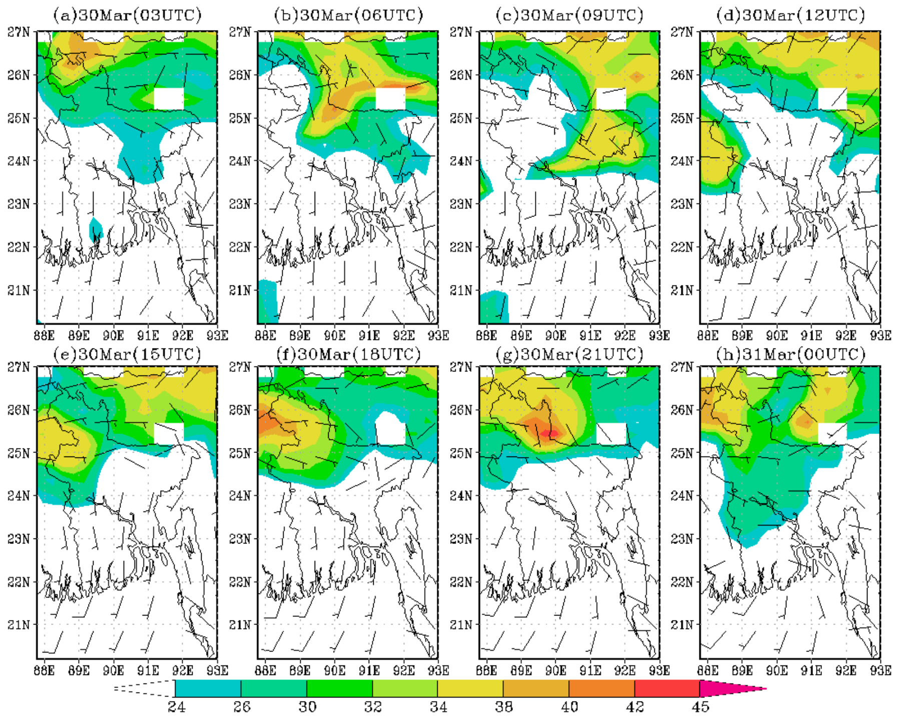
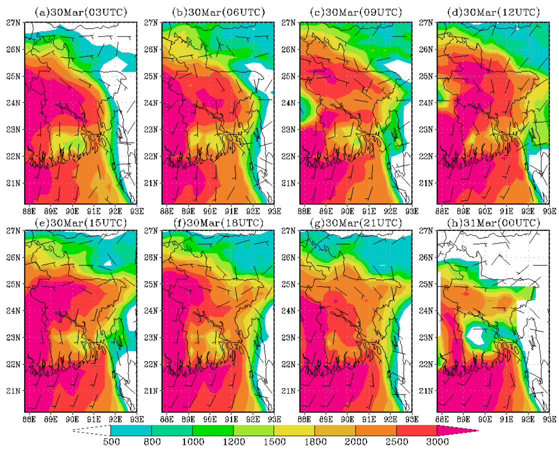


Figure 6: Evolution of KI on 30 March 2018

Convective Available Potential Energy (CAPE) and Convective Inhibition Energy (CINE)

CAPE field is found to evolve over the western part, which then expands to the east and covers whole Bangladesh by 12 UTC. CAPE reaches its high magnitudes of 2000-3000 Jkg^{-1} over Mymensingh, Faridpur and Dhaka regions. CAPE becomes high over most parts of Bangladesh by 12 UTC (Figure 7). The behavior of CINE is fully opposite of CAPE (Figure 8). So, CAPE and CINE are found favorable for this TS occurrence.



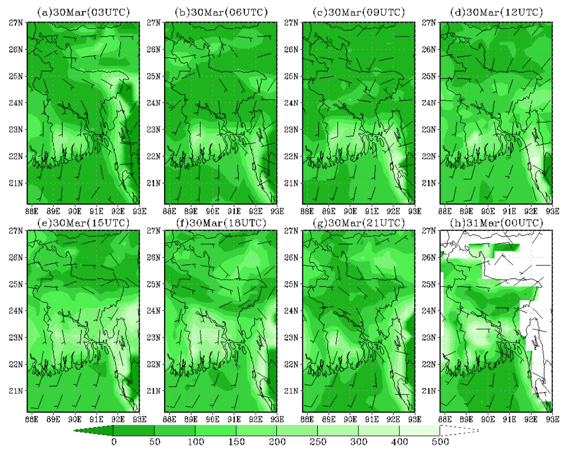


Figure 7: Evolution of CAPE on 30 March 2018

Figure 8: Evolution of CINE on 30 March 2018

Precipitable Water (PW)

PW is found as high as of 35-40 mm during 09-12UTC over Dhaka, Tangail and adjoining area. It is of 5-15 mm over Mymensingh region. Strong signature is found to move and vary with the TS and its associated rainfall (Figure 9). Similarly, a clear signature of PW is also found for domain D2 (Figure 10) Location specific magnitudes of TTI, KI, CAPE, CINE, SWEAT and PW are given in Table 1.

Simulated rainfall

The model couldn't estimate rainfall precisely at different station location in Bangladesh. But the model is able to capture the spatial distribution of rainfall in a good manner. Moreover model over estimated the rainfall at Dhaka, Faridpur and Mymensingh locations (Figure 11). However, average model rainfall of 8.6 mm well matched with the observation of BMD. For domain D1 model estimated average rainfall is 8.1 mm and for domain D2 it is 7.9 mm.

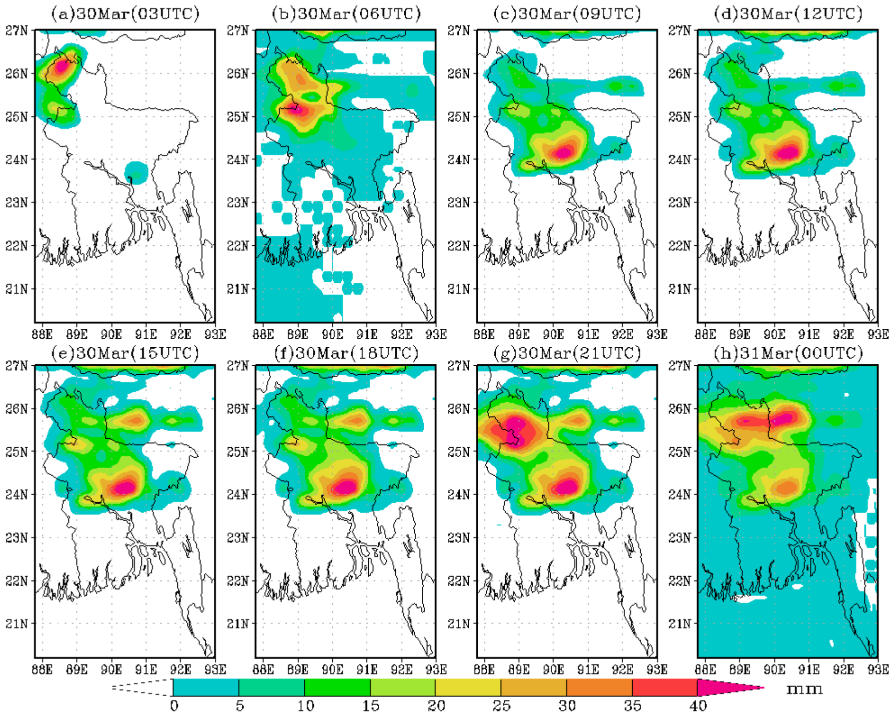


Figure 9: Evolution of PW (for D1) on 30 March 2018

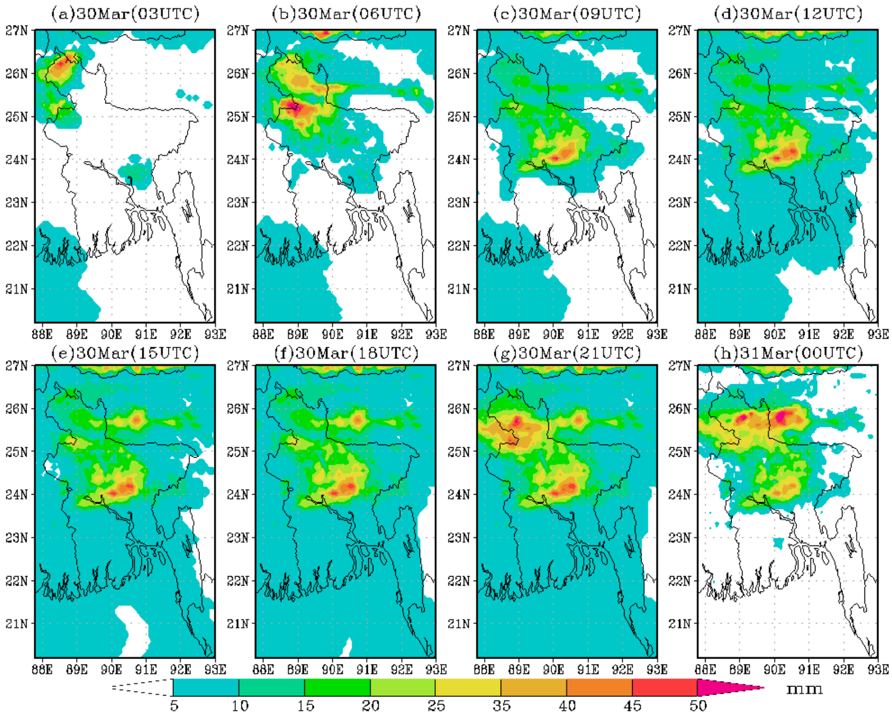


Figure 10: Evolution of PW (for D2) on 30 March 2018

Table 1: Simulated values of the convective parameters on 30 March 2018

Station Name	TTI	KI	CAPE(Jkg^{-1})	CIN(Jkg^{-1})	SWEAT	PW(mm)
Dhaka	54.5	27.1	2046.0	0.6	492.6	18.1
Faridpur	52.0	23.8	2238.7	46.9	258.5	6.5
Mymensingh	57.1	23.8	1954.0	78.8	520.2	18.0
Chittagong	43.0	8.3	1114.5	174.7	195.4	0.7
Sylhet	56.6	33.6	1391.4	24.2	487.4	3.7

Estimation of Rainfall

By comparing the model simulated station average rainfall with the recorded heavy rainfall (HR) at different locations in Bangladesh it has found that; model couldn't estimate rainfall precisely for different station location in Bangladesh (Figure 11). In the case of rainfall simulation, the model has captured the spatial distribution of rainfall well. Moreover, the station wise rainfall amount was highly overestimated for the Dhaka, Faridpur and Mymensingh stations (Figure 11).

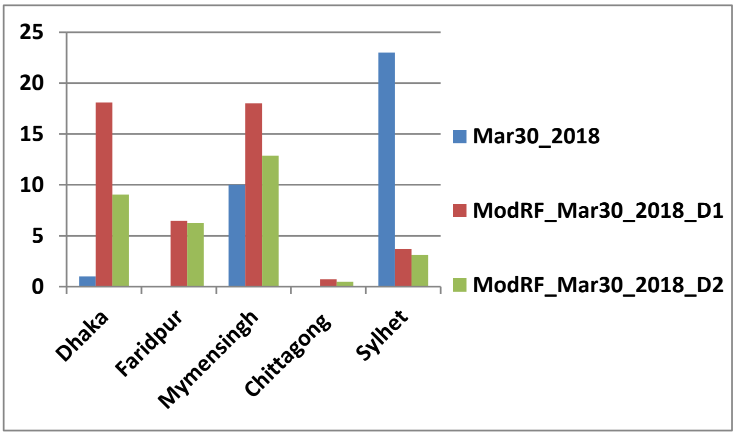


Figure 11: Comparison of model rainfall with observed rainfall (mm)

Conclusions

- The spatial and temporal distribution of TS was captured well by the WRF-ARW model.
- Model is competent to simulate the TS event occurred on 30 March 2018 with considerable values of TTI, SWEAT, KI, CAPE, CIN and PW. However, over Chittagong region, the indices TTI, KI, SWEAT and CAPE have shown a lower value than the critical value.
- Among the six selected indices TTI, SWEAT, CAPE, CIN shows favorable values comparing to the critical values at each TS recorded stations. But KI has shown lower value. The magnitude of KI of 33.6 is found only at Sylhet.
- Simulated station average rainfall for D1 is lower by 5.5% and for D2 it is lowered by 7.92% compared to the average rainfall.

References

Ferdousi, N., Debsarma, S. K., Mannan, A., & Sarker, M. A. (2015). Impact of Data Assimilation in Simulation of Thunderstorm Event over Bangladesh Using WRF Model, 35–48. Retrieved from https://doi.org/10.1007/978-3-319-10217-7

George, J. J. (1960). Weather forecasting for aeronautics. New York and London Academic Press. Retrieved from https://doi.org/https://doi.org/10.1002/qj.49708737120

Litta, A. J., Mohanty, U. C., & Idicula, S. M. (2012). The diagnosis of severe thunderstorms with high-resolution WRF model, (2), 297–316.

Mannan, A., Ahasan, N., & Alam, S. (2015). Study of Severe Thunderstorms over Bangladesh and Its Surrounding Areas During Pre-monsoon Season of 2013 Using WRF-ARW Model. Retrieved from https://doi.org/10.1007/978-3-319-10217-7

Mannan, A., & Chowdhury, A. M. (2017). 'Simulation of Heavy Rainfall in association with Severe Thunderstorm in Bangladesh during pre-monsoon season, *The Journal of NOAMI*, 34(1), 69-85, June 2017.

Miller MJ (1976). The dynamics and simulation of tropical cumulonimbus and squall lines. Q J R Meteorol Soc 102:373–394

Yamane, Y., Hayashi, T., Mahmmood, A., & Akter, F. (2010). Severe local convective storms in Bangladesh : Part II . Environmental conditions. *Atmospheric Research*, *95*(4), 407–418.

AGROMETEOROLOGICAL ADVICES FOR SUSTAINABLE AND ADAPTIVE FARMING IN CLIMATE VULNERABLE AREAS OF BANGLADESH

Jannat, F[1], Chakraborty, T. R.[2] and Akter, M. P.[3]

ABSTRACT

Climate vulnerabilities in Bangladesh resulted significant changes in agriculture. The traditional cultivation practices are struggling to cope with this climate challenge. Targeting sustainable and climate resilient agriculture, Oxfam and Monash University have been implementing the project called Participatory Research and Ownership with Technology, Information and Change (PROTIC) since 2015 in the Char land, Coast and Haor where female farmers of the community are equipped with smart phones. Information on sustainable and adaptive agriculture is being provided through SMS, OBD, IVR and Call Center. Agro-meteorological advisory services were found very useful to them in terms of preparedness and protecting assets. The technical limitation of providing local context specified agro advice to the community has been a challenge for the project.

Introduction

Increased climate change and different weather variability has elicited reduction of agricultural yields and increased vulnerability. Bangladesh has total of 30 agro-ecological zone with huge diversified ecosystem and cultivation and adaptation practices. The increased variation in weather/monsoon patterns challenges the in-built traditional patterns and ability of farmers to take any strategic agricultural practice decisions which curved up the interest towards climate change adaption agricultural information/solutions. This growing interest and easy availability of mobile phones and network service created an opportunity for sharing sustainable agriculture information among the farmers. Oxfam in Bangladesh and Monash University have been implementing the project PROTIC since 2015. It has been initiated to develop a knowledge hub for female farmers that disseminates weekly information on adaptive and sustainable agriculture viz. agrometeorological advices through SMS. This following research is an initiative of portraying the role of agrometeorological advices in promoting sustainable and adaptive agriculture practice in climate vulnerable areas of Bangladesh.

Method

The process of developing an effective agrometeorological content was documented based on the direct observation from the project activities. The effectiveness and the user potential of the advisory services was consulted with the project beneficiaries also considered as the animators of the project who are trained on the participatory action research tools. They are the rural female farmers and half of them are illiterate. To set the criteria of justifying the effectiveness of the services they use the major benefits of warning services as indicators, viz., (1) Scope of preparation for action, (2) Loss reduction, (3) Lead time, (4) Assets protection. For this study, in all three areas the 12 people who entered first to the venue for the monthly meeting of July were interviewed. They followed a numerical scale (from -5 to +5) to assess the effectiveness of the agrometeorological services [Table 1]. The value was calculated based on the following formula;

Usefulness = Number of Response X Score on the Numerical Scale (1)

Table 1. Numerical Scale to Assess the Effectiveness of Agrometeorological Services

– 5	– 4	– 3	– 2	– 1	1	2	3	4	5
Unacceptable	Very Bad	Bad	Fairly Bad	Somewhat bad	Neither Good nor Bad	Somewhat Good	Considerable	Good	Superb

[1]Project officer, ICT& Development (ICT), OXFAM in Bangladesh, Dhaka - 1206, Bangladesh
[2] ICT& Development Coordinator, OXFAM in Bangladesh, Dhaka - 1206, Bangladesh
[3]Project officer, ICT& Development (Action Research), OXFAM in Bangladesh, Dhaka - 1206, Bangladesh
Email of Corresponding Author – fjannat@oxfam.org.uk

Findings

Agro-diversity

Community has identified that there is a growing need of both spontaneous and planned adaptation. The crop diversity has been decreasing but some new species and verities were discovered as well. In Dimla, around fourteen crops are being cultivated and around eighty farmers from PROTIC animators are only cultivating paddy, maize, wheat and pumpkin etc. The diversity of the homestead cultivation is increasing. And, in Shyamnagar, the cropping pattern has been shifted intensely. Although due to climate change the agrarian community is being shifted to fishery viz. shrimp cultivation, community is still cultivating sixteen crop species.

Agrometeorological Service

To sustain the increased variation in weather/monsoon patterns, there has been a lot of efforts of disseminating agrometeorological advices following the current weather trends. For PROTIC, the target audiences of the project get a regular weekly agrometeorological information. The regular early weather warning from Bangladesh Government is being blended with the situation of standing crop being shared with the female farmers through SMS from PROTIC [Figure 1]. For example, if there is a possibility of heavy fog, along with the weather warning, there will be advice to the farmers to cover their crops (that gets damaged due to fog).

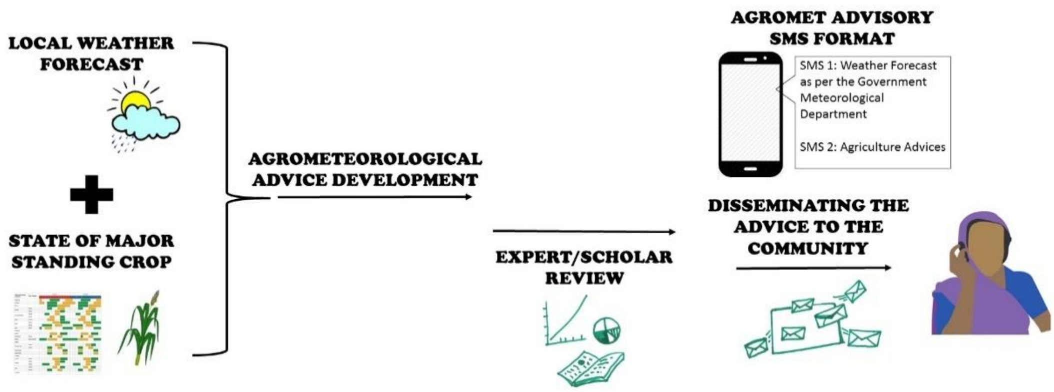


Figure 1. Development Process of the Agrometeorological Services

Usefulness of Agrometeorological Service

Preparedness prior to any event is the most supported response from the community as the reason behind the usefulness of agrometeorological services in PROTIC. It gives them information to prepare beforehand regarding cultivation and other livelihood activities and common preparations like collect and store firewood, food and clothes in a safe place to fight the disaster itself as well. One of the participants has shared that in terms of preparedness agrometeorological information is considerable. There were also responses which shows that it can protect area resource investment and reduces crop loss. On the other hand, the lead time in the agro-meteorological services of PROTIC had the lowest ranking among the indicators. According to the community a service advice for one week is not enough to plan the cropping season. While comparing the response variation in three different areas, it is visible that Dimla shows less variation in their response than other two areas whereas Tahirpur has the most diverse response (described in Figure 2 explanation) [Table 2].

Table 2. Community Responses on the Usefulness of Agrometeorological Service

	Dimla		Shyamnagar		Tahirpur		Total
Preparedness	(6*5) +(6*4)	54	(12*5)	60	(1*3) +(3*4) +(8*5)	55	169
Reduce Loss	(6*5) +(6*4)	54	(10*4) +(2*5)	50	(2*2) +(4*3) +(6*4)	40	144
Time	(6*5) +(6*4)	54	(10*3) +(2*4)	38	(2*2) +(8*3) +(1*4) +(1*5)	37	129
Protect asset	(6*5) +(6*4)	54	(5*3) +(5*4) +(2*5)	45	(1*2) +(2*3) +(5*4) +(4*5)	48	147

On 9 December 2016, in Shyamnagar the animators of PROTIC received an agrometeorological advice stating, "This week there will be a deep fog in the river bank area, the day and night temperature will remain same. Deep fog may result in early leaf blight of potato. If you cultivate early variety please ensure balanced fertilizer and timely irrigation. If leaf blight symptoms occur irrigate using 2 gm revirol per litter in 7 to 10 day intervals". Following the information, farmers cultivated potatoes later than regular times and experienced better production of potato in Shyamnagar and got survived from a huge loss.
In terms of analyzing the responses of the different locations, there are slight differences noticed based on location pattern and behaviors. The importance of the defined indicators was decided by the people's reaction towards disasters. For example, in Dimla, they have smaller number of sudden disasters. They experience similar disasters every year which influenced to shape their responses steadier than other areas. However, in Shyamnagar, they had quite a few experiences of sudden disasters like Aila and Sidr, so they find preparedness more important than any other things. And, for Tahirpur, they have lost so much asset due to flash flood, so, saving asset is more important for them and they think proper information to take preparation will help them a lot [Figure 2].

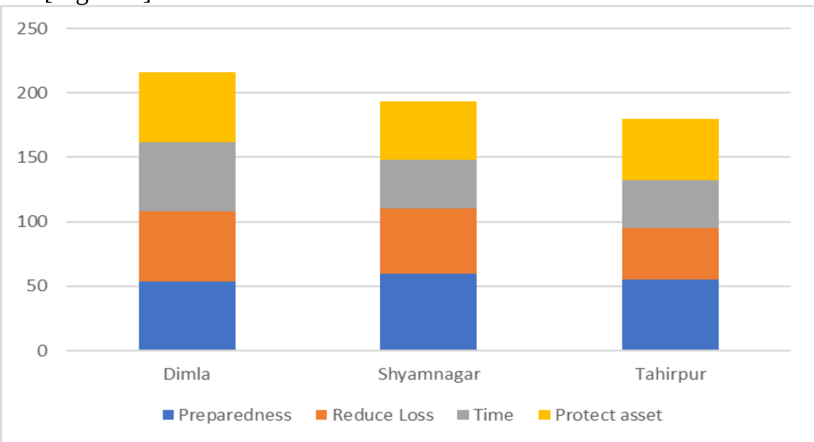


Figure 2. Variation in Community Response in Different Location on Agrometeorology

Scope and Challenges

Some challenges are identified in developing agro-meteorological contents. Firstly, only Bangladesh Meteorological Department (BMD) has the authority to provide basic weather forecasting and PROTIC has been blending the BMD weather alert with the growth stage of standing crop. To ensure effective information, the specific detail of the crop stage information with proper support of specialized and expert knowledge support is required which is very costly. For PROTIC, to develop content for a week it costs 19,400 BDT.
Besides, the location-specific information is not available in the BMD data. For example, the BMD information for the south-west coast covers Khulna and Shyamnagar, but according to the local animators, the weather of the PROTIC project area which is on the Sundarbans's periphery varies from Satkhira township. In 2017, while producing the agrometeorological information for mango when there was heavy fog, the flowing of mango in Shyamnagar is nearly 2 week ahead then the core mango land Chapai Nawabganj. Animators identified that there are no similarities of the average growth stage of homestead crops including vegetables in the three locations of PROTIC.
Moreover, the project expected a wider impact of the disseminated advices that were send to the community, but the mobility of the information from the device owner to the others was quite slower than expected. Four non-animator male farmers out of 10 in Shyamnagar was found unaware of the agrometeorological services. Instead of being a community information hub, the mobile set was found more like a personal device.

Discussion

In India, agrometeorology has a rapid increase of fame and small family farms get the direct impact of climate change. The Integrated Agrometeorological Advisory Service (AAS) of India offers different services like including weather observation, forecasting, and agricultural advisories to the district level farmers (Tall, 2013). One of the potential characteristics of future global climate change is increased frequency and magnitude of extreme events (Salinger, Stigter and Das, 2000). The intensity of frequency of climate-induced hazards and the extreme weather conditions (floods and cyclones) have been increased in Bangladesh (Iqbal and Siddique, 2014). Even small changes in the frequency of extreme events have an adverse effect. For instance, the life cycle of perennial plants reacts to the frequency of extremes increases, because of the sensitivity of seedling establishment and mortality of these plants towards extreme changes (Salinger, Stigter and Das, 2000). So, more specified agrometeorological advices can help the farmers to cope with the challenges and it must be a part of Climate-Smart Agriculture in Bangladesh.

Recommendation

From the local experiences of the following research, some recommended actions were identified. There could be more localized weather bulletin from BMD so that the agrometeorological advices can be more specific. Besides, promoting citizen science for local crop information to ensure authenticity of the information. Lastly, developing an android application with the support of BMD so that the farmers do not need to depend on external stakeholder and the process can be more cost-effective.

Conclusion

In agriculture, climate and weather are the basic resources. It can affect every crop development process from growth to getting enough yield. In this era of diversified climate patterns, it has become a need for the farmers to get the specified and authentic agrometeorological advices for adaptive and sustainable agriculture production. This research is believed to have a strong impact in the process of developing a user-friendly and location-specific agrometeorological advice by addressing the learning from the fields.

References

Grazulis, T. P. (1991). "*Significant Tornadoes 1880–1989 Vol. 1, Discussion and Analysis*". Environmental Films, St. Johnsbury, Vermont, United States

Iqbal, K. and Siddique, A. (2014). "The impact of climate change on agricultural productivity: evidence from panel data of Bangladesh", *Discussion Paper 14-29,* The University of Western Australia, Australia.

Salinger, M. J., Stingter b, C. J. and Das C, H. P. (2000) "Agrometeorological adaptation strategies to increasing climate variability and climate change", *Agricultural and Forest Meteorology*, 103 (2000), 167–184.

Realities: Response Farming and the Consequences of

Stigter, K., Winarto, Y. T., Ofori, E, Zuma-Netshiukhwi, G., Nanja, D, and Walker, S. (2013). "Extension agrometeorology as the answer to stakeholder realities: Response farming and the consequences of climate change" *Agrometeorology: From Scientific Analysis to Operational Application. Atmosphere*, 4 (3), 237-253.

CGIAR Research Program on Climate Change, Agriculture and Food Security (2013). "Scaling Up Climate Services for Farmers in Africa and South Asia Workshop Report", Denmark.

COMMUNITY BASED APPROACHES TO RESILIENCE: RESPONSE TO VULNERABILITY OF COASTAL HABITAT IN CHANGING CLIMATE

Syed Monirul Islam[1] and Maher Niger[2]

ABSTRACT

The coastal zone of Bangladesh is generally perceived to be a zone of multiple vulnerabilities. The people of that area are familiar with these natural activities, but recently climate change phenomenon adding fuel to these natural disasters. Although the death toll from cyclone event has been decreasing in recent years by constructing cyclone shelter and improving early warning systems, cyclones continue to put heavy burdens on the socio-economic life of Bangladesh. Coastal habitat and livelihood of the people are severely damaged because of natural hazards and climate change. However, these seems to be lack of overall solutions of livelihood with planned settlements for building disaster resilient community in hazard exposed areas. This research recognizes local resources and indigenous knowledge is a domain, which provides physical, social and financial capacity of coastal people towards community resilience. Indigenous communities living in the coastal areas for centuries have a unique cultural identity based on a close contact with nature. It is assumed that they have developed an indigenous perception of natural hazards and, thereby, possess effective survival strategies. The research also argues that community approaches to disaster management is essential for the adaptation of coastal people to take effective actions to reduce losses, damages and sufferings caused by climate change.

Introduction

The coastal zone of Bangladesh is generally perceived to be a zone of multiple vulnerabilities. Last 200 years at least 70 major cyclones hit the coastal belt of Bangladesh and during the last 35 years nearly 900,000 people died due to catastrophic cyclones. However, varying extents of disastrous natural events regularly occur in Bangladesh and the people of the country are familiar with these natural activities, but recently the climate change phenomenon adding fuel to these natural disasters. Extreme weather events are increasing in terms of frequency and intensity in the changing climate. These include: floods, cyclone, storm surges and salinity intrusion, river erosion, and droughts. Although there is no rigorous scientific evidence that tropical storms in the Bay of Bengal are increasing in frequency and intensity, the coastal people perceive an increased number of cyclones over the past few years. Although the death toll from cyclone event has been decreasing in recent years by organizing CPP (Cyclone Preparedness Program) like, constructing cyclone shelter and improving early warning systems, cyclones continue to put heavy burdens on the socio-economic life of Bangladesh.

The sectors which are severely damaged because of natural hazards and climate change are coastal habitat and livelihood of the people. However, these seems to be lack of overall solutions of livelihood with planned settlements for building disaster resilient community in hazard exposed areas. Livelihood and settlement in the coastal areas tends to focus more on the physical improvement with little attention to the socioeconomic issues of the community. Climate variability and change are predicted to impact on coastal habitat and local communities who are dependent on natural resources.

This research argues that community-based approaches is an integral part of the strategy and policy for the development of community people to disaster risk reduction in changing climate. This research recognizes that local resources and indigenous knowledge is a domain, which provides physical, social and financial capacity of coastal people towards community resilience. Community approaches to disaster management is essential for the adaptation of coastal people to take effective actions to reduce losses, damages and sufferings caused by climate change. Through the experiences of natural disasters the local people have developed several strategies to survive and protect their houses and other valuable belongings. It is assumed that they have developed an indigenous perception of natural hazards and, thereby, possess effective survival strategies. They have inherited the time-tested experiences of generations internalized through a process of socialization.

[1]*Assistant Professor, Dept. of Architecture, Ahsanullah University of Science and Technology, Dhaka-1208, Bangladesh, Email of Corresponding Author – monirul1971@gmail.com*
[2]*Assistant Professor, Dept. of Architecture, Ahsanullah University of Science and Technology, Dhaka-1208, Bangladesh, Email of Corresponding Author – maherniger@gmail.com*

The anonymous local builders show a unique talent for setting their houses with natural surroundings and house-building techniques, including planning for every detail of construction, which is surprising to tackle the cyclone attack.

Research Methodology

To achieve the objective, the research will adopt the following strategy:
Literature review: A critical review of contemporary relevant literature on the body of knowledge that the research is premised upon.
Case Studies: To structure the investigation, the research will be based on the case study approach having diversified characteristics of coastal habitat and execution of local resource and indigenous knowledge by the community people.

Human Settlement with focus on Coastal Settlement in Bangladesh

Characteristics of coastal area adds a significant dimension in the settlement research and is becoming a research interest in the field of disaster management, development studies, built environment planning and design to examine the scope and possibilities of development to adapt with the changes. Very limited studies have been conducted on form and feature of disaster resilience human settlement.
There are few literatures that describe the pattern and form of coastal settlement in Bangladesh and how the local factors influence it. A research report by World Bank (2010) is an important source that describes the coastal settlement pattern in general. Linear settlements have been found along the coastal embankments, especially on the islands, and along the roadsides and riverbanks in the eastern districts. Other patterns of human settlements in the coastal areas include nucleated, scattered/ dispersed, and mixed type settlements.
The settlement of coastal areas is mostly influenced by geographical and geological characteristics, natural disaster (especially cyclone, storm surge and tidal surge) and livelihood pattern of the people. But livelihood patterns throughout the coastal belt in Bangladesh are not similar, such as, the people of Chittagong coast mostly depend on fishing rather than agriculture, because soil of these area is not fertile enough for good yield of crops. On the other hand, soil of coastal areas near Meghna estuarine is very fertile, so agriculture is more preferable livelihood for the people of these areas. The significant features of settlement in the coastal areas of Bangladesh are as follows:

a) Houses on raised plinth.
b) Surrounded by coastal green belt (especially by Mangrove forest)
c) Coastal embankment.
d) Killa for cattle (raised earthen platform for safety from tidal surge)
e) Killa both for cattle and human
f) Cyclone shelter, etc.

Present Status of Coastal Habitat in response to Natural Disaster

There are few literatures that describe the pattern and form of coastal settlement in Bangladesh and how the local factors influence it. The settlement of coastal areas is mostly influenced by geographical and geological characteristics, natural disaster (especially cyclone, storm surge and tidal surge) and livelihood pattern of the people. People in the coastal areas of Bangladesh are mostly depends on natural resources. But livelihood patterns throughout the coastal belt in Bangladesh are not similar, such as, the people of Chittagong coast mostly depend on fishing rather than agriculture, because soil of these area is not fertile enough for good yield of crops. On the other hand, soil of coastal areas near Meghna estuarine is very fertile, so agriculture is more preferable livelihood for the people of these areas.

Evaluation the impact of 1991 Cyclone: Urir Char Project 1985

Urir char located in the Meghna estuary was devastated by a severe cyclonic surge on the night of May 24, 1985, inflicting serious loss of life and property. There after a national committee was formed by the government for making recommendations of appropriate settlements planning for the area. Baqee (2011) reported that the Urir char settlement has remarkably passed its first field test by withstanding furry of 1991 cyclone storm with no loss of life and property. The author observed that after 6 years of completion of the project the houses the homesteads, the clusters, the village and even the central community zone has grown exactly the way it was conceived by the designer.

Field Survey on Housing at 1991's Cyclone Affected Areas

With this objective German Red Cross initiated a survey and study through us which resulted into a published report titled "BATTLING THE STORM" STUDY ON CYCLONE RESISTANT HOUSING. This study was conducted in six different locations of Cox's Bazar. The survey was based on the premise that problems in housing should not be defined by experts only but should be based on the dialogue with local people of the target areas. A direct involvement of the local people in problem identification was ensured, so local perceptions, attitude, values, shared knowledge etc. could be taken into account.

Field Survey and Study on SIDR Affected Areas, December 2007

Within a week after the cyclone, many development and humanitarian agencies together with the Government established the Shelter Coordination Group or the Shelter Cluster. An Early Recovery Assessment was carried out (within three months) followed by the Early Recovery Action plan, which emphasised the need to build Transitional or Core Family Shelters and to assist in repairing the houses.

Recommendation

To build a resilient community to combat with extreme natural events or to get rid from poverty it is required to develop the socio-economic condition. And to develop the socio-economic condition, concentration should be given on the following issues **a.** way to build a resilient habitat, **b.** scope of alternative and supplemental livelihood suitable for the community, and **c.** way to integrate livelihood with housing and settlement for increased income.

Approaches

1. Empowerment of community people

Local communities have their own coping and survival strategies to respond to any incidents long before any outside support would arrive. They are interested in protecting themselves from climate risks through community-based disaster preparedness and mitigation. However, empowering communities toward the use of technologies and viable adaptation practices for better management of climate change risks is essential for further improving livelihood adaptation and enhanced community resilience. To empower local communities it is necessary to work on four key areas, these are:

a. Social action: Access to government policy and services and fighting against corruption.
b. Governance and accountability issues: Representation in local level institutions.
c. Economic action: Establishing rights over natural resources such as khas land and open water body.
d. Gender issues: Establishment of women's rights and empowerment.

2. Building a resilient settlement through active participation of community people

a. Settlement and land use planning to resist cyclone hazard: Coastal afforestation and construction of embankment are two planned measures should be adopted to protect the human settlement from sea born hazards. Inventory of safe havens, connection between different units inside the community and the outer places with roads network and proper drainage should be considered regarding settlement pattern. Land use patterns of a place need to be analysed prioritizing safe habitations, areas with potential resources and future extension of different functions. Hazardous areas need to be avoided of vulnerable practices like habitation, school and hospital locations. Infrastructures outside embankments should be discouraged by all means.

b. Coastal mangrove afforestation: As a measure of planned adaptation, the forest department of Bangladesh Govt. had implemented mangrove afforestation along the shoreline of coastal areas at Sitakundu. Experiment shows that the mangrove plantations along the coast are playing an important role in reducing the impact of cyclones and accompanying surges. It has been estimated that a 100 - 200 m wide mangrove belt reduces wave heights by 20 to 25% (Islam, 2004). Mangrove plantation also helps in land maturation and makes the land suitable for human settlement.

Figure 1. Plan and Section of coastal Mangrove forest for a safer settlement

c. Semi-hard embankment: The embankment acts as first line of defence to dissipate the energy of cyclonic wave and prevent surge water to get inside. Apart from that, the road cum embankment is constructed above regular surge level and mostly remained inundation free in past years. This facilitates uninterrupted communication and provides shelter for the refugee during post disaster period. As a measure of protection, however, the effectiveness of embankment is not unquestioned. The height, width and slope of the embankment should be maintained properly and should be guided with proper vegetation to protect erosion.

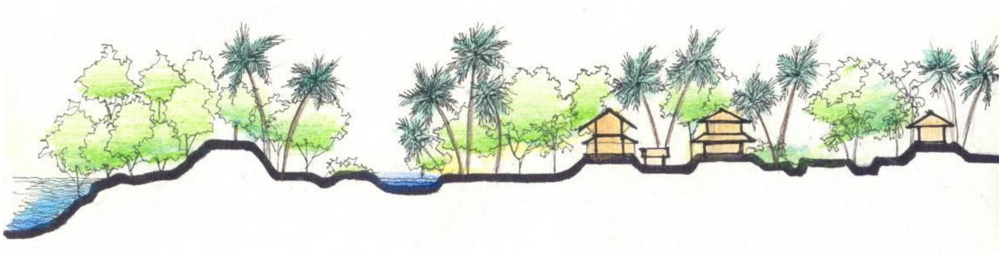


Figure 2. A safer settlement with Mangrove forest, embankment and plantation

3. Using indigenous knowledge to build durable houses

The houses in the coastal areas need to be hazard resilient so that least damaged of the structures and assets occurred due to tropical cyclone, and the dwellers always do not have to evacuate to cyclone shelters. These should be easy to construct and repair, cost effective and durable. Lightweight structures, especially older buildings with deteriorated condition are the most vulnerable to cyclones. Identifying indigenous technology and shared knowledge of the communities in home building will be effective in cyclone resistance. And combining local knowledge with easily applicable intervention of appropriate technology might be able to contribute towards the destruction of houses.

Figure 3. Hazard resilient indigenous houses

4. Upgrading the living standard of inhabitants by providing diversified livelihood

Livelihood diversification is a process by which rural families construct a diverse portfolio of activities and social support capabilities in their struggle for survival and in order to improve their standard of living (Ellis, 1998). People attempt to diversify their income portfolios into both on- and off-farm activities in response to a risk, when primary activities fail to satisfy their subsistence needs (Hussein and Nelson, 1999). Datta *et al.* (2003) expand this notion in the context of Bangladesh.

Basically there are two ways to upgrade the living standard of inhabitants by providing diversified livelihood.

a. Integrated Homestead Farming (IHF): Meeting the need of year-round income generating activities

b. Intervene the financial capacity of community people through appropriate and alternative livelihood.

In this section, it has been tried to find out different types of alternative and supplementary livelihood (as diversified livelihood) which are suitable for the coastal settlement. These alternative and supplemental livelihoods can be cope by the local community within the homestead as well as in the settlement. So that it is also necessary to integrate the livelihood and the habitat for this kind of diversification.

Figure 4. A DRH with Integrated Homestead Farming

5. Capacity building through training, monitoring and evaluation

Regular training, monitoring and evaluation is necessary for local communities to establish their own learning and action platforms to increase their understanding and ability to diagnose social issues that play an important role in mainstreaming and up-scaling climate risk management and potential adaptation options.

Conclusion

From the overall discussion and recommendation it is found that to build a resilient community, it is necessary to consider the above mentioned aspects. A strong house or a cyclone shelter solely cannot protect the coastal settlement from extreme weather events. To do this it is also required to make them economically self-sustained. Home based and community based alternative and sustainable livelihood approaches can provide an opportunity to increase their income level and reduce poverty and vulnerability. So that we have to provide sustainable income generating activities with disaster resilient habitat, both in the household level and community level.

References

Baqee, A., (2011), "Grameen Bosoti: Boishisto, Kathamo o Porikolpona Proshongo", Sujenashu Prokachoni, Dhaka.

Datta, A., Frans, D., and J, Soussan. (2003), "Coastal Zone Policies and Livelihoods in Bangladesh, in Water and Poverty-The Realities: Experiences from the field", Asian Development Bank, Manila.

Ellis, F., 1998. Livelihood strategies and rural livelihood diversification. J. Dev. Stud., 35(1):1-35.

Hussein, K., and Nelson, J. (1999) "Sustainable Livelihoods and Livelihood Diversification'', IDS Working Paper 69, Institute of Development Studies, Brighton.

http://nijerakori.org/wp-content/uploads/2015/08/Organisational-Annual-Report-for-the-period-of-January-to-December-2017.pdf

Islam, S. A. (2004). "Overcoming poverty in Bangladesh: Search for a new paradigm", Bangladesh e-Journal of Sociology, 1(2), 29-49.

World Bank. (2010) "Climate Risks and Adaptation in Asian Coastal Megacities: A Synthesis Report", World Bank, Washington, DC.

STUDY OF AN INCREMENTAL HOUSE MODULE FOR COASTAL FISHERMEN COMMUNITY AT SALIMPUR, CHITTAGONG, BANGLADESH

Shajia Mumtahina Niha[1] and Sajal Chowdhury[2]

ABSTRACT

The rising number of homeless people in Bangladesh is a major social problem. The primary cause for this problem is due to natural and manmade catastrophes that happen frequently. When a disaster occurs, people in the low-income group become homeless and unemployed. The government helps them by providing permanent shelter, but due to poverty and lack of employment, the victims rent out the spaces provided to them to make a living and in turn they choose to live in slums. Hence, the most affected people are fishermen and they live by the coast. The slum population increases rapidly along the coast which changes the urban fabric of the city and the Karnafully coastline. This study aims to improve the lifestyle of the fisherman community in an incremental manner by developing the 'Delipara' slum area –that currently has informal settlements occupied by the fishermen families. Observation, data collection & analysis have been used as research methodology for this study. The proposed permanent shelter modules along with a community core will help in community redevelopment that facilitates transition from informal settlements into permanent settled neighborhoods. The social community will benefit from the on-site facilities by creating an opportunity for psychological healing through community support and social harmony.

Introduction

'Fishermen own the fish they catch, but they do not own the ocean'– portrays of a glimpse, the common lifestyle of the fishermen community on besides of the coastal land of BANGLADESH. In the whole world, Bangladesh produces 50-60% of Hilsha fish every year. The fishing sector contributes more than 5% of Bangladesh's GDP & it creates job opportunities of 1.4 million people, but the main conductor of this profession who are Fisherman are still deprived from all kind of basic facilities: In every year they are affected by the flood and disasters and lose their houses. As a result, they're changing their profession and creating an unplanned urban development within city & breaking their traditional community. The purpose of this project is to provide that community a better solution with all kinds of facilities. With the inception of a "Sustainable fishermen community development" the project 'Incremental Housing Township for Fisherman Community' seeks to confirm that the biggest community which is living their life by catching fish (mainly HILSHA fish) and stay over at the side of the river. To improve the situation an affordable development proposal is developing their living condition in such a manner that is self-sufficient to serve the whole community. To achieve this, the development has to have an incremental quality. This will give a better option for living and help to serve the futuristic growth also. The allocated site for this housing project is owned by the Government in the South Kattali area of Chittagong named Delipara where the mass flow of population is yet to expand its territory. Though, on the one side of the site, there remains a residential zone for the middle- & low-income group of people of the city. Whereas, on the opposite side of the site, there prevails industrial zone which is full of industrial buildings serving as factories and garments, and moreover agricultural fields. And the sea beach is growing as tourist zone of the city. Thus, the site acts as a crucial transition from residential to the industrial and recreational zone. To find a proper location for the housing from these industries will be one of the challenges of the site. On the other hand, the proposed site is on the east of Mangrove forest, adjacent to the Shangu Road and Beribadh near the sea. Due to the topography of Salimpur a green belt flows over the site arisen from the forest. Treating these open spaces will also be an interesting feature of the project. Moreover, Access to land and houses has long been a problem for the urban poor.

[1]*Author, Graduate Architect, Chittagong University of Engineering and Technology, Chittagong-4349, Bangladesh*
Email- Sajia011@gmail.com
[2]*Assistant Professor, Dept. of Architecture, Chittagong University of Engineering and Technology, Chittagong-4349, Bangladesh.*

Methodology

Problem Statement and Background

The total state of the problem was reviewed first. It cooperated to find out the answer questioning what, how, when, why, whom etc. In assessing the location, settlement pattern, distribution, networking system & problem assessment, it gave a salient view before starting the work.

Project Proposal

A lot of background studies about related issues and projects have been done. Then collected a lot of field survey, data analysis & compare them with background studies.

Data Collection

This report is prepared based on both primary & secondary data. It is nit strict; its variations came on the dependency on the reconnaissance survey of the study area.

Collection of Primary Data

Relevant primary data has been collected through 3 prime tools of data collection are structured questionnaire, screening questions and checklist to fulfill the objectives of the project. Several types of survey, such as socio-economic survey, land environmental analysis, infrastructure survey, FGD (Focused Group Discussion) and some others type has been conducted for the primary data collection.

Collection of Secondary Data

All data and information have been collected from different Government and non-government organizations, Statistical report articles, published material, officials, records and literature review that are also necessary for getting secondary information.

Findings and Analysis

Computer software MS Word, MS Excel, AutoCAD, Photoshop, Sketch up and Corel Draw have been used for graphical analysis and presentation. From starting to end, the result of each criterion was identified in the input system & output or resulted form. In this case, observation & reconnaissance survey fixed up the variables input it processing subsystem result.

Conceptualization

After conducting a detailed research & analysis on the collected data we have tried to conceptualize a framework of policies & program to meet the challenge of the specific issues of the project.

Development of a Sustainable Project

The total process is divided into 3 major parts are briefly discussed below.

Policy Formulation

Developed a set of policies in different aspects to try to meet the challenge of the site and develop a design.

Design Development

A design is developed to fulfill the objectives of the research. An approach towards final solution was avoided rather we tried to develop a process which will work for the betterment of the community. A very bottom to top approach was taken.

Impact Forecast

After applying the policies & design solutions we tried to forecast the impacts of the applied modification on macro & micro levels.

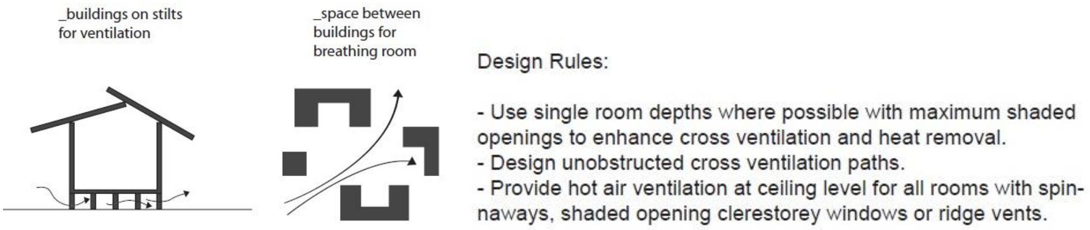
Report Finalization

After completing all necessary procedures the last step of the thesis is report finalization wher all the factors that needed to be considered are organised in chapters in the final report.

Design Proposals

Ideas

1) To make a sustainable structure, 1st idea was to build houses on stilts to pass the wind pressure through the voids of the stilts.



2) Main Idea was to Sharing of common; **Column, Wall, Utility, Roof**
3) The main challenges & goals of the project were:

PROJECT GOALS	CHALLENGES
• Ensuring a better Future • Using local materials for the basic structure • Involving whole community in design phase • Providing the facility for Employment • Protecting the Existing Natural Resources • To Provide a better living condition in low cost	• **Blocking Gentrification** • **Protecting Environment** • **Arranging Houses keeping their belief safe** • **Develop Fish Business in a planned Manner**

Figure 1. Project Goals and challenges

Form Analysis

At first we calculated the minimum space requirements.

Space Requirement (From Standards)	Sleeping	Utility				Multipurpose Room
		Toilet		Kitchen		
		W/C	Wash	Cooking area	Storage area	
2 person 4 person 6 person	**6'-7"/ 5'-0"**	**4'/3'**	**4'/3'**	**5'/4'**	**X**	**Min 10'/6'**
Thinking About future Expansion	Closet + Prayer Space	**5'/4'**	**5"/6'**	**5'/6'**	**5'/4'**	**10'/10' or 10'/20'**
Total	**(6'- 7"/ 5'- 0" + 3'-0"/ 2'-0") = 9'- 7"/7'-0" ~ 10'/ 10' (with circulation)**	**(5'/4'+ 5'/6') = 10'/5'**		**(5'/6' + 5'/4') = 10'/5'**		**=10'/10' (taking minimum)**

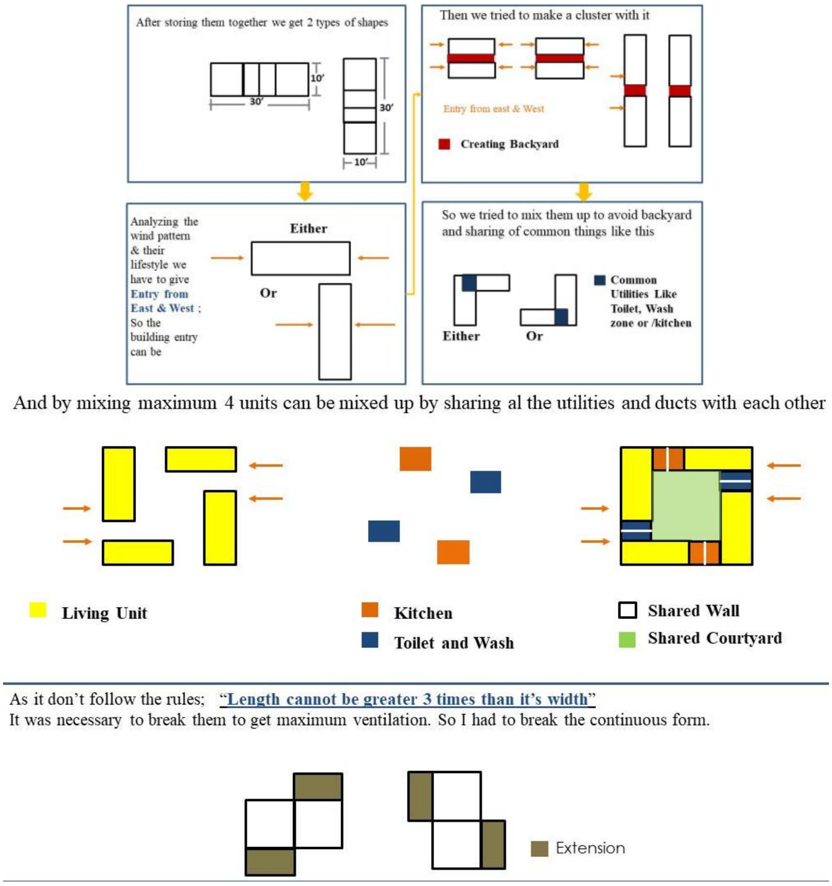


Figure 2. Form Generation

Figure 3. Master Plan

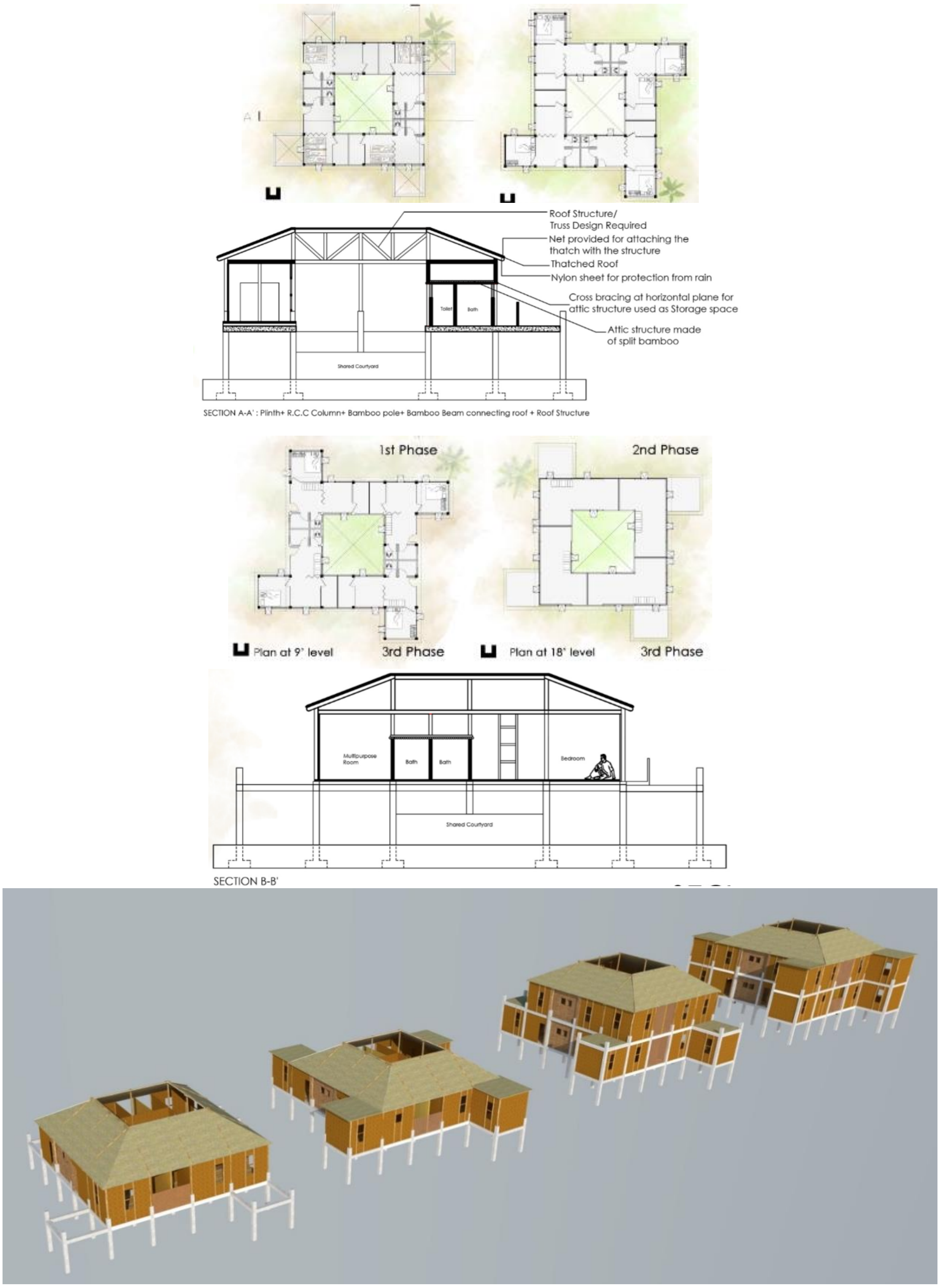


Figure 4. Phase Wise Development (Incremental House) with sectional details

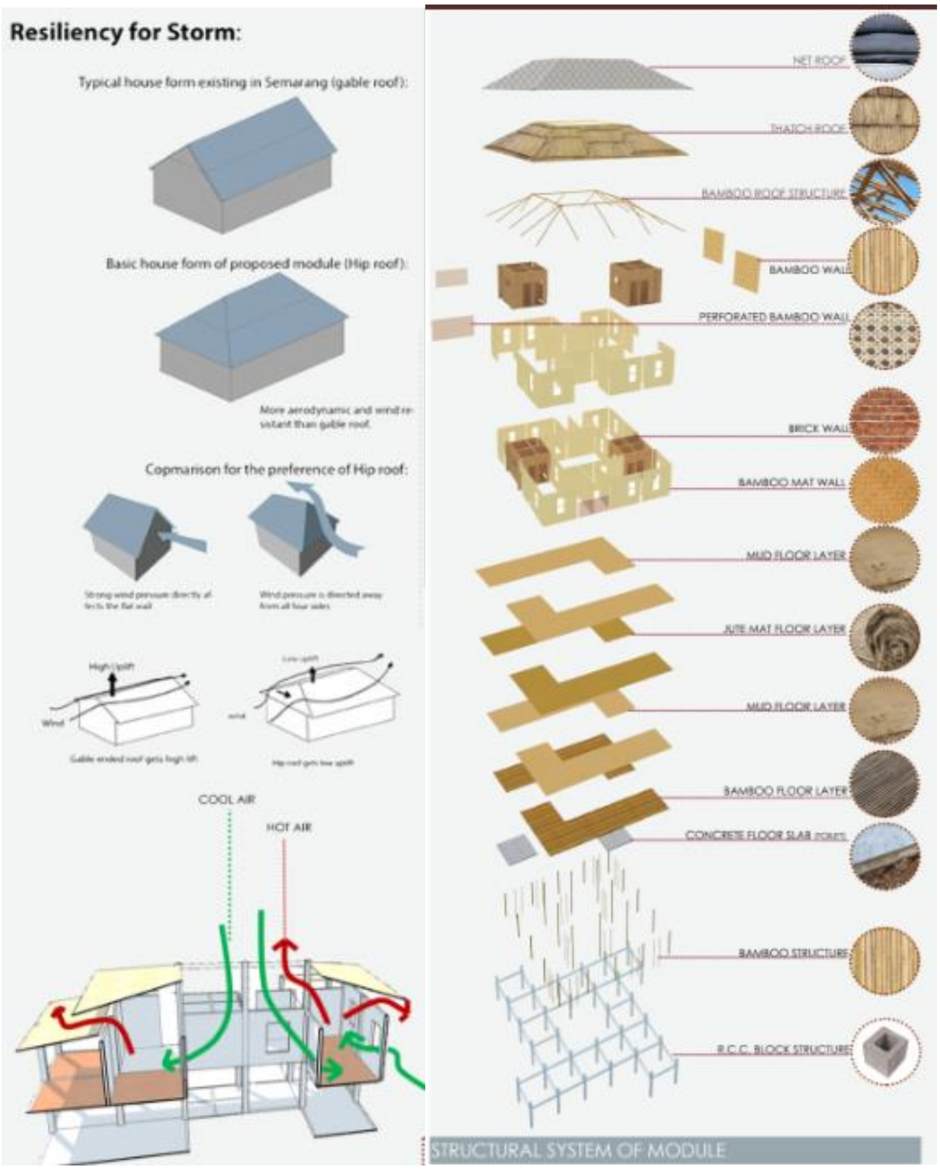


Figure 5. Structural System

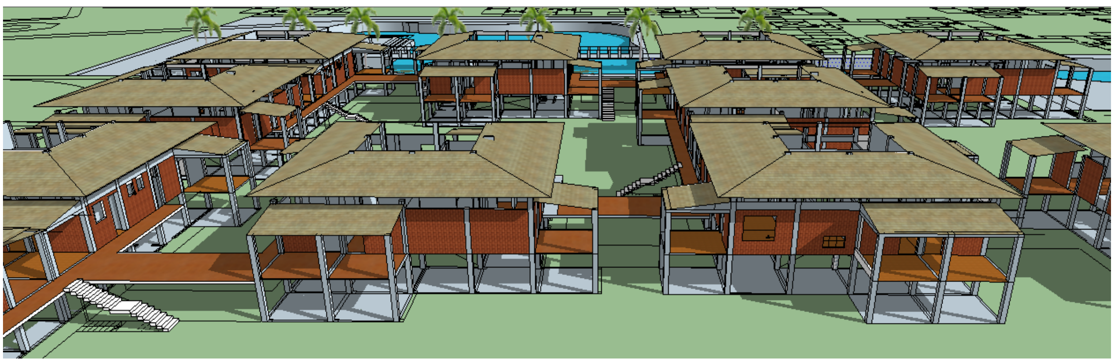


Figure 6. Cluster are networked by a deck walkway for the flood seasonConclusions

Jaladas is a Bangla word which means “servant of water”. Jaladas are traditional fishermen by generations and live on fishing only. They have no other occupational skill other than fishing and strangely they are very much reluctant also to move into other professions even though fish resources are sharply declining and also under the threat of over fishing by other communities. As a result, more and more Jaladas are becoming jobless and unemployed. Due to seasonal nature of fishing, the Jaladas fisher folk have to borrow money. Alternative income source is also very poor. Lack of organizational capacity has totally clipped them. So, they are socially neglected, politically under estimated, culturally ill-treated and geographically isolated and vulnerable. The fisher folk communities are generally excluded from every sector of life.

This project can provide compact permanent shelter that has a possibility to grow horizontally and vertically to adapt to the constant changing needs of the family, which is climate responsive, cost effective and sustainable. Creating the opportunity to allow potential growth of the allocated parcel where each family develops a sense of responsibility to modify the property according to the growing needs of the family. The proposed community design is self-sustaining with rainwater catchment system to provide potable water for its residents. The produce from the kitchen garden will be sufficient to feed the entire township throughout the year. It also complements the city's effort at Slum eradication. Any Architectural design requires vast study, analysis and understanding. It was a great experience for us to work with this project because here we had to deal with different issues and possibilities of the site. Despite of limitations, there was no deficiency of enthusiasm from us, and it would be a great pleasure if this paper is considered as a record for the prospective explorers.

References

Assessment, management and future directions for coastal fisheries in Asian https://books.google.com.bd/books?id=JzW4DQAAQBAJ&printsec=frontcover#v=onepage&q&f=false

https://www.slideshare.net/witnolbenko/disaster-resist-house-with-stand-cyclone-and-earthquake

Ahmad, J (2002) Low cost Housing in 4 Flood-Prone villages: A participatory design Approach

Alam, K (1996) 2 fishing village of Bangladesh: A community Study

Habib, A. (1996) DeliPara: An obscure Fishing Village of Chittagong

COMMUNITY MAPPING AS AN APPROACH TO IDENTIFY AND MITIGATE DISASTER RISKS IN AN URBAN NEIGHBORHOOD IN SRI LANKA

Ashra M. Wickramathilaka[1] and Nirmani V. Liyanage[2]

ABSTRACT

Active community participation is the most effective means to achieve sustainable management of natural and man-made disaster risks. People who live in disaster-prone areas are aware of the disaster calendar because of their ground-level experience. In-depth mapping of such experience, identifying vulnerable locations forms an essential (but overlooked) component of disaster management planning. This study reveals that GIS-based community mapping is an effective approach to identify and understand community's own coping mechanisms/strategies/interventions, from their individual voices, to manage, for example, urban floods. The maps depict actual land use beyond standard categories in the area through the lens of "disaster resilience" of the Sendai Framework. The research presents the use of community-based mapping, as opposed to remote sensing and mainstream GIS-based modelling. The paper argues that through the examination of local-level information on disaster risks and responses can be better managed through the facilitation of improved community-based disaster management mechanisms.

Introduction

As Sri Lanka moves up into a middle income and post-war economy, the post-war governments have relied on heavy-infrastructure driven urban development. The prime commercial city of Colombo continues to change at a fast pace. The past 10 years and future plans for the city indicate greater levels of urbanization. The first policy priority for Sri Lanka's urban development is to promote its western region –around Colombo-- as the economic hub of the southern Indian sub-continent (De Silva et.al., 2018)

Colombo is a coastal city that annually experiences flooding and for the past 30 years, these floods have led to large economic losses. According to Buhr, 0.2 percent of the annual GDP over the past 20 years was lost due to floods (Buhr, 2018). Floods have also affects over 1.2 million Sri Lankans annually (World Bank, 2013), and the poorest city dwellers, who live in underserved settlements in low lying areas, in canal and river banks, or in vulnerable areas with limited access to and from the settlement are the most affected (UN-HABITAT, 2012). Causing more damage is the decrease in wetands due to land reclamation. Although Colombo has been named the "World's First Wetland City" by the RAMSAR Convention, more built up spaces, less absorption capacity and climate change impacts have led to more frequent flooding in the city (UNDP, 2018). Colombo being the main economic hub of the country with better services, floods and flood damage have not detered people's desire to live and work in the city. Hence the city grows, generating greater challenges for the city, and making its planners, managers and residents to increase their resilience to floods.

One of the key tasks for town planners, disaster managers and policymakers is to reduce the level of (urban) floods in Colombo. The *Act No 13 of 2005* introduces 'disaster management' as a main subject and the Sri Lankan government is streamlining disaster management activities through the Disaster Management Center (DMC) (Sugathapala, 2010). It is the responsibility and duty of the Urban Development Authority (UDA) to plan cities and manage urban resettlement issues. The Centre for Urban Water (CUrW) is currently monitoring flood risks of the Metro Colombo Area using GIS modeling and remote sensing to analyse identify the building clusters in Colombo affected by floods (CUrW, 2018). While advance technologies such as satellite-based remote sensing and GIS modelling provide overall information of a particular area with regard to disaster risks, they are unable to capture small pockets of safety created by people within the area. This is due to the scarcity of location-specific information. For example, the map of 'flood inundation of Colombo' (Annex 3) shows that the entire study area is flooded during the particular period. However, there were settlements that did not flood during that period. There are several governmental bodies that should coordinate

[1]*Junior Research Professional, Centre for Poverty Analysis, Colombo-00070,Sri Lanka*
[2] *Researcher and the Project Cordinator,Search for Common Ground,Colombo-00050,Sri Lanka*
Email of Corresponding Author – ashra@cepa.lk

and collaborate when planning and managing flood-prone and vulnerable communities in a city. Furthermore, in compliance with the United Nations Sendai Framework for Disaster Risk Reduction, these entities should have the capacity to use and access geo-spatial data to identify disaster risks and improve urban resilience (United Nations, 2015). This data should also include specific ground-level information. Then, town planners and physical development experts can use relevant spatial information to plan, design and implement compatible structural and non-structural measures to improve the urban resilience in Colombo.

Research Design

Study Area

The study area Wekanda, is a 48-acre urban neighborhood Wekanda is bounded by road arteries and a railway track. It is located in the ward of Slave Island (*Kompannweediya*), in Colombo (Annex 1). While the community is predominantly Islamic, Wekanda is also home to small numbers of Buddhist, Hindu and Christian communities; they have a history of living in harmony, with one another. The site is located in the middle of an upcoming commercial hub (Annex 2), and is surrounded by the massive ongoing construction projects.

Methodology

The study employs both qualitative and physical-based methodologies to collect and record data respectively. The mapping techniques of “Deep Mapping” by Denis Wood (Wood, 2015) was used to capture information on resilience. The software – SocNetV was used to analyze economic centrality in Wekanda. As there is no up-to-date map produced by responsible authority, the initial step was to create and updated base map. For this, we used images from Google Earth as reference and digitized the buildings on ArcGIS platform. The printed map was then verified on the ground, updated and digitized. This step was repeated until the research team was satisfied with the results in regard to all physical elements including buildings, addresses, roads, alleyways, paths, boundary walls, and trees.

The “land use” of the buildings were fed onto a separate layer and the information was verified by the community. Data was then inserted to the map as separate ArcGIS layers. Each layer was printed and taken back to the community for a further verification of details, ensuring the accuracy of the feedback provided during each consultation. Similarly, the people’s attempts to reduce disaster risk by, for example, increasing foundation heights, constructing boundary walls as flood barriers and an upper storey to live during floods were observed and mapped.

Results and Discussion

Capturing diversity of livelihoods and use of space

Figure 1 shows the detailed land-use map of the study area. Planners usually use the following mand uses to map an urban area: residential; commercial; industrial; public uses; parks and recreation; agricultural; transportation; and utilities. In this, land uses are abstracted into pure categories that only exist in plans. When the categories are broken down, there emerges the richness and variety of land use inside the neighbourhood, reflecting the lifestyles of residents. Most businesses classified under commercial would also include businesses such as - retail groceries, salons, snack sellers (mobile vendors) and many other formal and informal business activities while industries would include automobile repair centres, garages and hardwares. Most of these businesses are the main livelhoods of the residents, and 50% of them are run by women inhouse. Therefore the income is neither stable nor regular. Hence during floods, both their homes and livelihoods are simultaneously vulnerable. However, the level of vulnerabililty depends on the household status and the type of livelihood. For example, a flash flood damage the motors of vehicles and machines in automobile repair shops. This level of detail allows for the identification of differences and plan for individuals needs, without catergoring into large groups. For example, such detailed data is necessary when relief packages are handed out, a community is relocated or when an area are rebuilt.

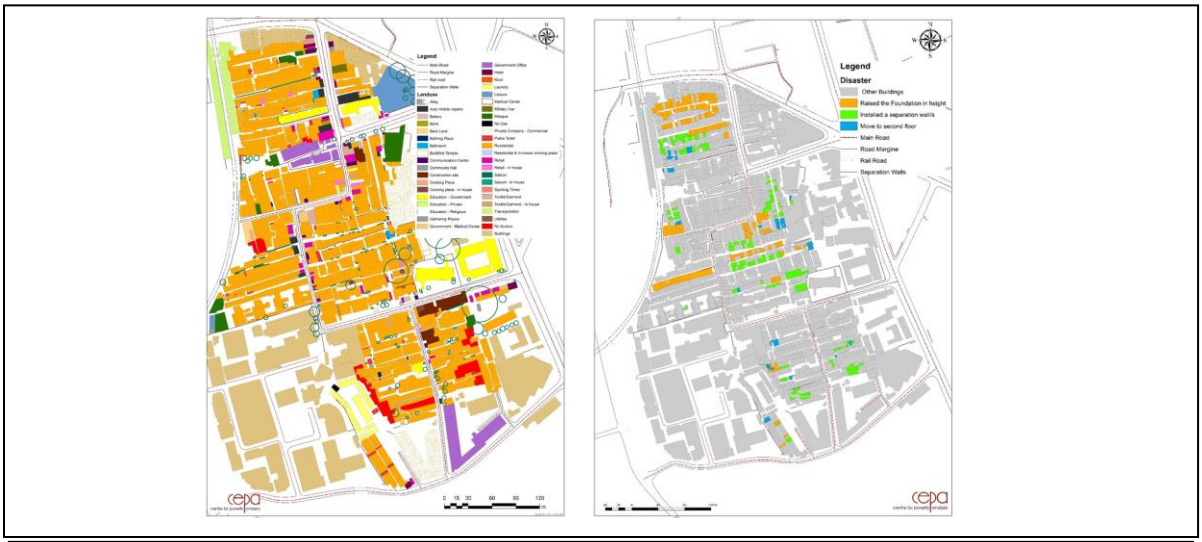
Securing their homes

Figure 2 shows the buildings (eg., houses, commercial and religious buildings) that have incorporated structural resilience strategies. These include – raised levels of foundations, high front door steps and the construction of boundary walls. The maps confirm that –as shared during conversations with the community-

- the entire neighborhood does not feel the effects of flood as certain areas are more prone to flooding than others. In addition, physical changes also vary depending on the income of the household. For example, certain households are unable to construct an additional (upper) storey to live in during floods. Instead, they raise the height of their boundary walls to prevent the flood from water entering their houses. Understanding these differences can help to know who needs what relief and/or additional assistance such as temporary relocation. This points to the fact that 'one size fits all' solutions cannot be applied when the needs and requirements of the residents are diverse.

Gathering points

Figure 3 highlights open spaces where men and women informally gather daily. Firstly, these spaces of informal gathering are not prone to flooding. Hence, during a flood, it is probable to use such spaces for relief operations as they are familiar to people and do not flood. These spaces can also be used to conduct awareness sessions and to colleat and distribute information. These spaces could be further used to conduct planing meetings with the community with regard to how the community itself can engage in disaster preparedness activities.



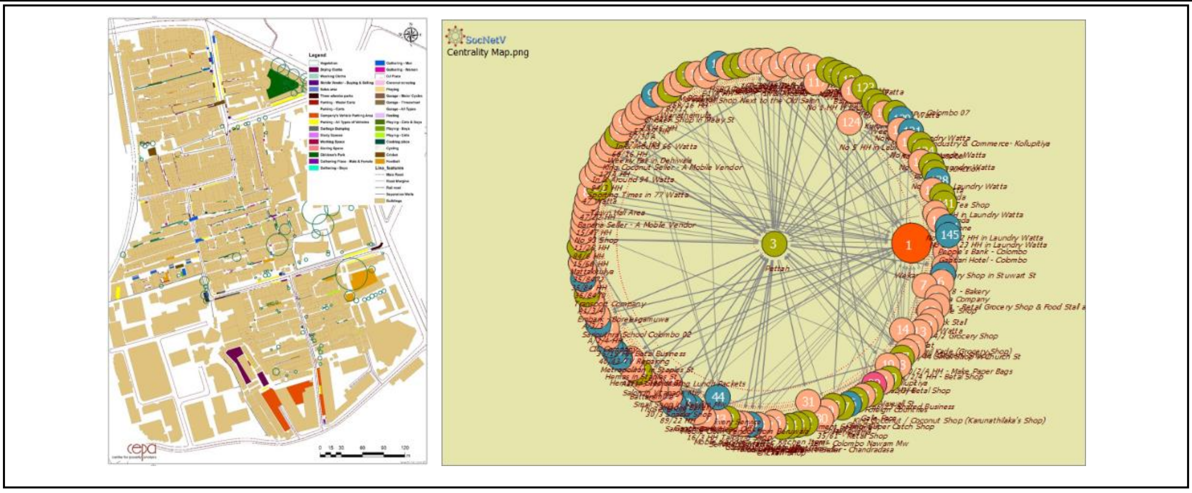


Figure 3. Detailed Open-Space Uses Map *Figure 4. Supply Chain Analysis*

Maintaining connectivity outside of the community

Figure 4 is a "Supply Chain Map" that shows the connectivity of the various economic activities that the people of Wekanda engage in. The centrality for most of the economic activities of Wekanda depends on

Pettah[1] – a central location for commercial activities in the neighborhood. The second most important location is Wekanda itself. The mapping of economic chains of people's day-to-day activities helps to understand significant micro scale geo-spatial economic routes that need to be maintained or reinforced for the Wekanda community to return to their daily routines soon after a flood.

Conclusions

The significance of this study is that it attempts to expose how community-based activities incorporated through spatial data can inform planners how citizens' everyday routines and their own, personal small resilience measures can help to improve micro resilience enhancement within Colombo. The study shows that micro scale data is important to understand why urban resilience relief-packages cannot fit into a 'one size fits all' model. The study shows that if a more location-specific solution is developed, the response would then suit the activities and circumstances of the people, and can build on community-based resilience methods, instead of foreign and alien concepts to tackle issues of natural disaster. The combination of the local context and the lived experience of the community in disaster management is essential for an inclusive policy.

Visualization tools such as maps are useful for more concrete analysis and decision making. During local-scale disaster management plan preparation and implementation, incorporating location-specific data, town planners and disaster management specialists will be able to make more accurate urban planning decisions. Additionally, government and private sector officials can strengthen the affected community and improve various capacities (individual or community) by providing necessary assistance during and after flooding, rather than presuming the assistance that the community needs.

This method can be applied to any type of community or an area as an approach to identify community-based reliance strategies. However, several drawbacks were noted, the main one being that this approach is time consuming, particularly if the base map is not up-to-date. Once we spent considerable time updating the base map, new constructions tend to continue, making it necessary to continuously update the base map. Since the neighborhood is dynamic, it is also hard to capture the land use of a particular area on a map. In addition, during community consultations, it is necessary to conduct participatory observation along with the ongoing interviews in order to ascertain what exactly the buildings and lands are used for, not least because the community members might be hesitant to tell the truth for undisclosed reasons.

Acknowledgments

The research team of CEPA's Infrastructure and Poverty thematic wishes to acknowledge Health Bridge's Livable Cities programme for the financial sponsorship and guidance received for the "Mapping Colombo" Project. This study comes as a part of the aforesaid study and the research team includes Senior Researcher-Karin Fernando, Mentor-Professor Nihal Perera, Researcher-Nirmani Liyanage and Research Assistants – Dilini Amarasinghe, Dinuka Sandaruwan and Viduranga Thennakoon.

References

Buhr, B. e. (2018, December 05). *Publications.* Retrieved from UN Environment: http://unepinquiry.org/wp-content/uploads/2018/07/Climate_Change_and_the_Cost_of_Capital_in_Developing_Countries.pdf

Centre for Urban Water. (2018, November 9). *Home*. Retrieved from Centre for Urban Water: http://www.curwsl.org

De Silva, I. e. (2018). *Satate of Sri Lankan Cities 2018.* Colombo: UN-Habitat.

IWMI, D.-S. (2018, December 2). *Update.* Retrieved from Reliefweb: https://disasterscharter.org/image/journal/article.jpg?img_id=269316&t=1464072924093

Sugathapala, K. M. (2010). *Risk Mapping as a Tool for Disaster Risk Reduction in Urban Areas of Sri Lanka.* Colombo: NBRO.

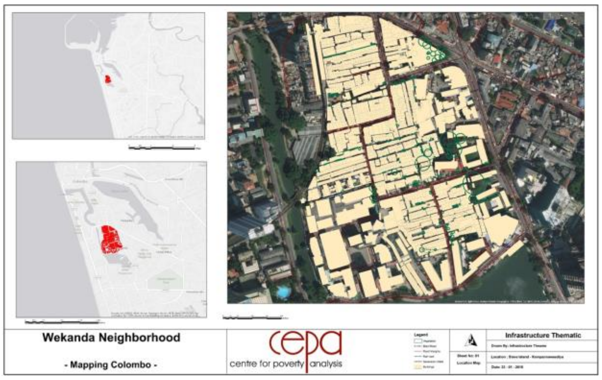
UNDP. (2018, December 07). *Hazard Profile of Sri Lanka.* Retrieved from Disaster Management Centre: http://www.dmc.gov.lk/images/hazard/hazard/Report/UNDP%20BOOK%20CHAP%2004_%20Flood.pdf

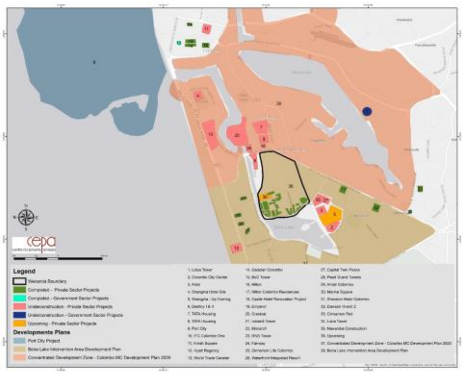
UN-HABITAT, C. (2012). *Colombo City-Livelihood Assessment of Flood-Prone Low Income Settlements.*

[1] *Pettah is an area in Colombo, which is the central place for wholesale and retail markets for textile, vegetables etc.*

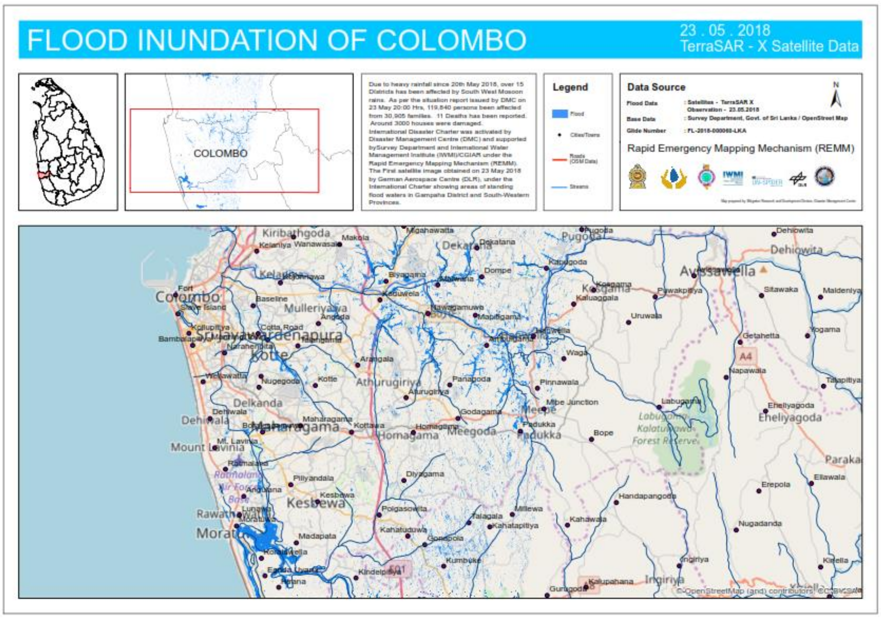
Colombo: World Bank.
United Nations. (2015). *Sendai Framework for Disaster Risk Reduction 2015-2030.* United Nations.
Wood, D. (2015). Mapping Deeply. *Humanities*, 304-318. doi:10.3390/h4030304
World Bank. (2013). *Transforming Colombo into a Flood Resilient Middle Income Country Capital.* Colombo: World Bank.

Appendix





Appendix 1: Location Map **Appendix 2:** Ongoing development projects of in and around the study area.



Appendix 3: Flood inundation of Colombo (IWMI, 2018)

INCLUSION OF PARTICIPATORY ACTION RESEARCH AS A CRUX FOR SUSTAINABLE AGRICULTURE IN A CLIMATE FRAGILE ECOSYSTEM

Akter, M. P.[1], Chakraborty, T. R.[2] and Jannat, F.[3]

ABSTRACT

The char land of the Teesta is vulnerable to flood, land erosion and extreme weather. Crop loss due to climate change is frequent and to cope with the climate vulnerabilities the inhabitants of Daskin Kharibari are practicing adaptive agriculture. The community has developed a knowledge hub using different ICT tools specifically mobile phones under an action research project named 'PROTIC' by Monash University and Oxfam in Bangladesh. Due to climate change and development driven migration, there is huge feminization in agriculture which adds the responsibility of field cropping along with domestic work for women. Hundred female farmers from Daskhin Kharibari village are equipped with mobile phone set who are the action research animators of the project. They receive SMS, OBD, IVR and advisory support from a Call Center on sustainable and adaptive agriculture. By following the action research tools animators identify the required farming information. Thereafter, they use the information, assessing the utilization of the agricultural advice that resulted 8 to 10 % increase of their crop production.

Introduction

The Teesta floodplain is very unstable. Flooding, land erosion and erratic rainfall is very common. Due to climate change the intensity and frequency of hydro-meteorological hazards have increased. The people of the village Dakshin Kharibari of Dimla Upazila under Nilphamari district are exposed to river bank erosion and flooding. The sandy crop lands are not fertile for most of the varieties. Limited livelihood opportunities have triggered male migration in an alarming rate, that makes females bound to take the burden of cultivation in all sorts. Therefore, the action research is designed to explore how female farmers select crops for cultivation. To cope with climate change there is diversification in cropping which started initially by the externals as form of planned adaptation. Two factors; migration of male members and crop diversity are happening simultaneously. In this context, Oxfam and Monash University have decided to provide ICT support to the marginalized communities in three climate vulnerable ecological zones of Bangladesh. The PROTIC project is being implemented in this village since October 2015. One hundred female farmers from different economic classes are receiving regular agricultural advisory services.

Method

As mentioned earlier, 100 rural women of Dakshin Kharibari village have been trained on participatory research tools. Using sustainability criteria, PAR (Participatory Action Research) method is used to have a holistic analysis of primary scenario of the agriculture, feminization status as well as other livelihood opportunities of rural women and local community, thus defines an objective, and realistic situation of the community. PAR methods help the group to grasp the anticipated goals and to start linking them with other groups, making up networks and associations that enable change at different levels, and establish firm foundations for sustainable development. As part of project activities these 100 animators sit in the monthly meeting where they discuss and analyze the progress by using participatory tools specifically the consultation among small groups. The present research is a compilation of the monthly meetings from April 2018 to October 2018, along with 2 Focus Group Discussions (FGD) and 4 Key Informant Interviews (KII).

Findings

Feminization in Agriculture

It was found that the number of females in nearby agriculture research field has increased. This is because of (1) migration of male members to other urban centers for income generation, (2) Availability of information

[1] Project officer, ICT& Development (Action Research), OXFAM in Bangladesh, Dhaka - 1206, Bangladesh
[2] ICT& Development Coordinator, OXFAM in Bangladesh, Dhaka - 1206, Bangladesh
[3] Project officer, ICT& Development (ICT), OXFAM in Bangladesh, Dhaka - 1206, Bangladesh
Email of Corresponding Author – pakter@oxfam.org.uk

on farming. According to the community, feminization in agriculture in the northern Teesta has been started rapidly since 1998, the year of the construction of the Bangabandhu bridge and continued increasing after the flood of 2003. The flooding in the year of 2015 has fasten the rate, which was alarming. There is a significant shift in the cropping due to feminization of farming, though being influenced by local attempt of planned adaptation. Non-paddy crops are being cultivated more yet there is no noteworthy loss in paddy cultivation. The farmland in the village- neighborhood has been converted to maize land.

Access to information

Due to the feminization in agriculture mobility of women has been increased. From dawn to dusk, women are engaged with cattle grazing, collecting grass for cattle, collecting fuel wood, bringing cattle back to shed, taking bath, doing household chores, meeting neighbors and relatives living nearby and remaining at home after evening. All these activities are ranging between 0 to 2 km. On an average day, the longest distance a common female farmer travels are now 2 km. Information for them which is within this 2 km is easily accessible. According to the female farmers, the mobile phones have been the primary and reliable information source. This includes the commercial advertisement as well as the government and attention of development actors.

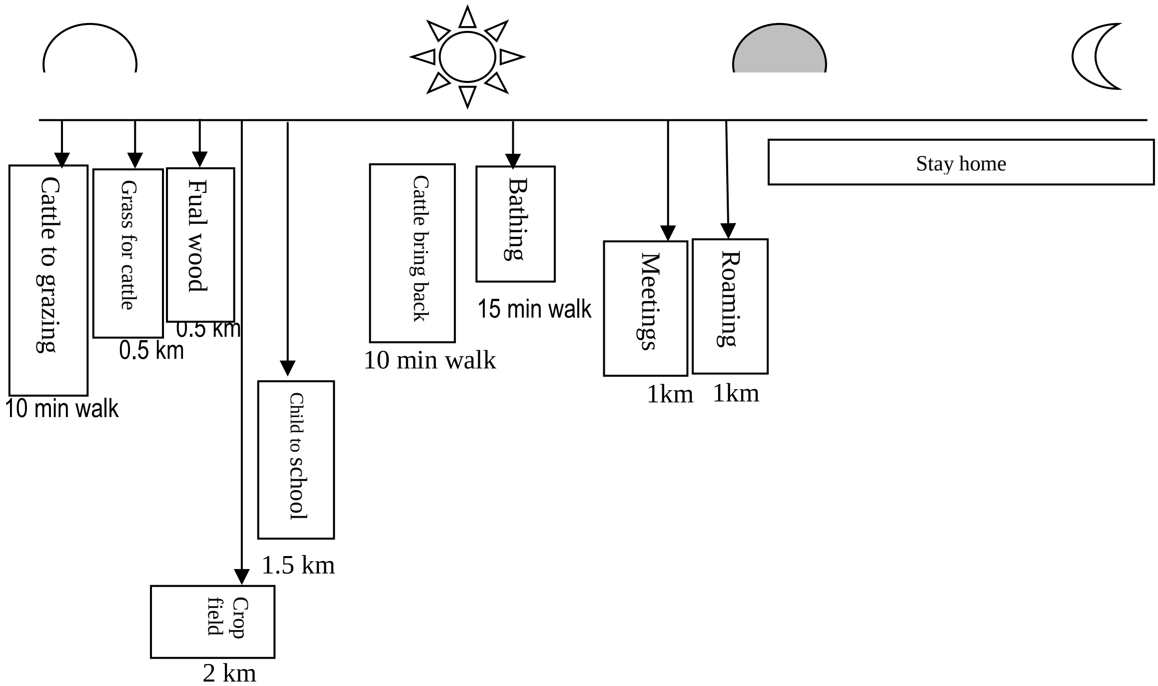


Figure 1. Development Process of the Agrometeorological Services

Use of information

Every week animators receive SMS and OBD along with agrometeorological information from PROTIC via smart mobile phone regarding their contextual seasonal crop demand. In the monthly meetings, animators share the use and effectiveness of those information they have received throughout the month. In April 2018, following the SMS on rain forecast PROTIC animator Ms Moyful (28) have collected the corn flower before the beginning of rainy season which has reduced the supposed loss. She was one of the poor farmers in the village with no cultivable land of her own, now she has taken land of contract farming and cultivating maize, onion and garlic in the char. She along with her husband are motivated to cultivate maize for double profit and all the information is available in the maize app. Using the information via SMS homestead cultivation has increased; livestock diseases now become manageable with vaccination and medicine; poultry diseases are also decreased. All the animators cannot use all the information they receive every week as all the information are not relevant to all, but they are smart enough to pick the information on cropping that are relevant to them. Due to unavailability of medicine, fertilizer or land sometimes they cannot adapt some information. They receive information not only through SMS, for better understanding they are getting same information in Out Bound Dial (OBD), apps and internet etc.

Increase of crop production

Due to the information availability, the crop production in the village has been increased. According to the assessment by the Animator it has been estimated that the crop production in last 3 cropping seasons has increased 8 to 10 percent more than the crop production of the year 2014. They have identified insect control as the main cause followed by fertile and section of varieties.

Empowerment

Empowerment in agriculture is generally defined as one's ability to make decisions on matters related to agriculture as well as one's access to the material and social resources needed to carry out those decisions (Alkire *et al* 2013). In this study, according to the local community, women empowerment has identified in two ways; one is decision making and another is income diversification. The consultation found that most of the women are now capable to take their own decision regarding agricultural activities, mobility, food, clothing etcetera. However, in the context of rural Bangladesh some critical areas of decision making are not accessible for all women in the study community such as decision towards ownership, buying and selling land is not possible without the consent and intervention of male members (specially husband) in the family. According to them their mobility has increased due to awareness, knowledge and success by following those knowledges in agriculture, livestock rearing, fishing et cetera. Among all the animators, 5% of them are earning money by doing immunization of cattle. Regarding leadership, one among 100 women beneficiaries of the project got the JOYEETA award of Bangladesh Government.

Sustainability

The figure 2 below delineates the data about the progress by practicing PAR with information support from PROTIC. Five components (economic, physical, natural, social and human) are compared between October 2015 and November 2018 to state the impact of PAR in the growth of resources.

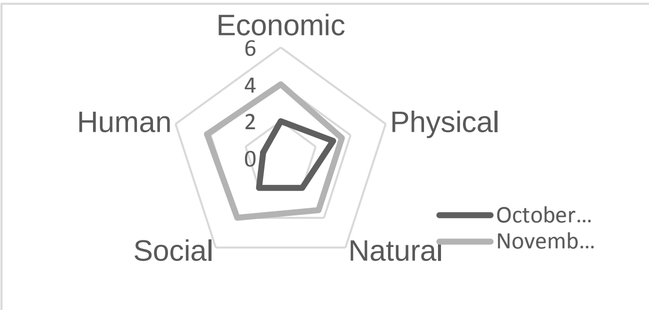


Figure 2. Progress in resources due to Action Research with adaptation advisory services.

According to the participants of the FGD in October 2015 (before starting PROTIC) economic, social and natural resource condition were in scale 2 which means not sufficient or solvent. In terms of human resource, they were not capacitated with modern information and training, with the intervention of PROTIC, a notable change has been brought by the community women. With the available information on agrometeorology, women with the smart phone know when and how they need to be prepared to face natural calamities. With information support through modern technology new agriculture adaptation has been practiced, such as homestead vegetable cultivation by adapting 3D tower method. In terms of Physical (infrastructural resources) resilience a slight change has come due to financial growth of the families. Now they can build resilient infrastructure which can tolerate disaster such as flood. One scale upward change is reported regarding natural resources in the graph, effective use of knowledge has brought the change according to the animators. The significant change has come in economic resource, as in char land maize cultivation has increased in tremendous amount because of following information of Maize app developed by PROTIC. Usually women who were domestic care worker in earlier, now are going to the char which is 3-5 km far from their house and taking care of the crops with sufficient knowledge. In terms of social resilience, the monthly meeting is the platform of sharing climate change vulnerabilities among all the animators and some villagers. Thus, a strong social network has been formed where local government authority, civil society is also a part.

Discussion

Organizing the female farmers in action research to know what works well was found the best changes happened in the community by this intervention. Edward Chambers (2003) described as relational power, where all concerned parties have an equitable voice in the decisions regarding the innovation process. It was found that the implementation of the project has increased the voice of the community people. Learning by doing is not an easy task for an individual, specifically in cropping when there is resource constrain. But when the community is organized, they can have it done easily. Emancipatory learning and empowerment are strong thematic trends within the action research literature (Selener, 1997) which is strongly relevant to community development. Rahman (2016) identified several barriers for ICT accumulation in agriculture in Bangladesh, those are unskilled person for operating, inadequate farmer knowledge, lack of infrastructure, lack of financial support, lack of technical support, lack of innovation, lack of research etcetera. Through the action research by the community, animators can find a path to solve the problem. It is true that in case of evaluation there is a risk of over assessment. The changes in the five capital of sustainable development (Figure 2) that was done by the community seems an over estimation a bit. But self-evaluation of community has positive result on confidence level. The conceptual framework of the research work by Dey *et al* has detailed the behavioural intention and actual behaviour of the farmers in welling ICT for framing.

Recommendation

Some specific recommended actions have been identified from this study. Starting with the stronger PAR facilitation that needs to be conducted to ensure the objective result/estimation of the research. There should also be less tier of deriving information in PAR research to avoid information deviation. Besides, promoting citizen science and journalism to generate the information by the community.

Conclusion

Study finds that Action Research is needed to build resilience among people through transformative leadership to initiate effective changes in the community. According to PROTIC and other research studies, if the problem and solution is identified by the community, stepping towards sustainability is faster and more effective.

References

Alkire, S., Meinzen-Dick, R., Peterman, A., Quisumbing, A. R., Seymour, G., and Vaz, A. (2013) “The Women’s Empowerment in Agriculture Index” *OPHI Working Paper 58,* University of Oxford, Oxford

Chambers, E. T. (2003) “*Roots for radicals: organizing for power, action, and justice”,* The Continuum International Publishing Group, New York, United States

Dey, B. L., Prendergast, R. and Newman, D. (2008) "How can ICTs be used and appropriated to address agricultural information needs of Bangladeshi farmers?" *GLOBDEV*, 2008, 21.

Rahman, T. (2016, May 15) The potential of ICT for Agriculture in Bangladesh [Blog Post]. Retrieved from https://europe.ypard.net/2016-may-15/potential-ict-agriculture-bangladesh

Selener, D. (1997) “*Participatory Action Research and Social Change”*, The Cornell Participatory Action Research Network, Cornell University, Ithaca, New York, U.S.A.

ASSESSING VULNERABILITY TO EARTHQUAKE THROUGH PARTICIPATORY APPROACH: A CASE STUDY OF ULON, DHAKA

Md. Musfiqur Rahman Bhuiya[1], Khandaker Nabid Md. Morshed[2], M. Imtiaz Rahman[3] and Dr. Ishrat Islam[4]

ABSTRACT

As community people are endowed with deep insights about their community, their local knowledge can be greatly utilized in disaster management. This study aims to assess vulnerability of Ulon community of Dhaka North City Corporation though participatory approach which has been found highly vulnerable to earthquake by Comprehensive Disaster Management Program. To assess earthquake vulnerability of Ulon,an earthquake vulnerability map has been produced showing highly vulnerable, moderately vulnerable and less vulnerable areas and zones of Ulon based on road width, structural fragility, accessibility to critical facilities and open space, maintenance of building construction regulations etc. As National Disaster Management Plan urged for community involvement in disaster management, a guideline for community based disaster management has been provided to make Ulon resilience against earthquake based on suggestions of residents of Ulon.

Introduction

Bangladesh is highly vulnerable to earthquake due to it's geological location as it is only on 60 km distance from seismically active Madhupur fault line. It has been found that Dhaka is among five cities of South Asia which are at most risk to earthquake in terms of both human life and economic loss (CDMP,2009). Historical records show that Bangladesh experienced five major earthquakes of magnitude 7 or greater in last 150 years(Akhter, n.d.). Recent study shows that an earthquake of magnitude 7 or above will have a catastrophic damage to Dhaka because of poor building structures, unplanned urbanization, high population density, lack awareness among people regarding response and recovery process etc (RAJUK,2015).

In the advent of an earthquake in Dhaka, it is the people of the community hit by earthquake will become the first victims. On the contrary, it is community people who are the first responders. Considering this fact, they should be effectively involved in earthquake management at community level to ensure prompt actions in occurrence of an earthquake (Hossain,2013). Besides, community people have deep insights about their community which can be utilized to identify the sources of vulnerability and address those sources of vulnerability in earthquake management at community level following participatory approach (Hossain,2013). Among various tools of participatory vulnerability assessment, vulnerability mapping has been widely used to assess the earthquake vulnerability (Action Aid,n.d.,World Bank,2013). This study aims to identify factors which are contributing to earthquake vulnerability of Ulon, one of the most earthquake vulnerable communities of Dhaka, by applying participatory techniques. Findings of this study can be effectively utilized to make plan for taking prompt action at different stages of disaster management, including rescue operation and disaster risk mitigation for the selected study area as well as for raising awareness among it's people (Edward, Gustafassan and Näslund-Landenmark,2007).

Study Area Profile

Ulon of West Rampur under Ward No 22 has been selected as study area. According to study of Earthquake Megacities Initiatives (World Bank,2013) Ulon community has been found highly vulnerable to earthquake in terms of building damage. EMI model has predicted total number of building that may be damaged in a magnitude 7 earthquake can be 300-625 in number (World Bank,2013,CDMP,2010).

Methodology of Study

In order to prepare the vulnerability map, a focus group has been formed with 15 randomly selected

[1]Assistant GIS Specialist, Capital Development Authority (RAJUK), Dhaka, Bangladesh
[2]Transport Analyst, Baseline Mobility Group, North Carolina, USA
[3]Planning Engineer, Desh Contractors and Developers Ltd., Dhaka, Bangladesh
[4] Professor, Dept. of Urban and Regional Planning, Bangladesh University of Engineering and Technology, Bangladesh
Email of Corresponding Author: musfiq.sifat@yahoo.com

community members from Ulon belonging different age group, gender, profession, tenure etc. Before preparing earthquake vulnerability map, a transect walk has been carried out along with Focus Group Members throughout the Ulon to conduct Rapid Visual Assessment (RVA) to identify sources of vulnerability and capacity and resources of the community to withstand earthquake. Later, an extensive Focus Group Discussion (FGD) has been arranged with the selected community members to determine level of vulnerability of different parts of Ulon. Then, a vulnerability map has been produced in a drawing paper showing level of vulnerability of different parts of the Ulon according to suggestions of FGD members.

Findings from Participatory Vulnerability Mapping

FGD members discussed with authors in great detail about source of earthquake vulnerability of different parts of Ulon. Based on their perception, whole community has been divided into three types of zone: Highly vulnerable area, moderately vulnerable area, less vulnerable area for earthquake in vulnerability map given in Fig 1. In order to maintain continuity, three zones have been divided sub-zones.

Highly Vulnerable Zone and Area (HVZ)

According to the members of FGD, early development of Ulon took place in this part of the area. Most of the buildings have been developed by sand filling of water bodies in early day's development. Many buildings developed in unplanned manner. Buildings have been designed and constructed without following instruction of engineers and Building Construction Rules (BCR) in filled up land. Participants informed that, a structurally weak building in a slightly slanted position exists in this zone (Fig8). Most of roads are below 8 feet width. It will be very difficult for rescue team to enter into in this zone during emergency. The buildings of this zone have been developed in a very congested way and rarely followed set back rules. Participants have commented that, any building in case of an earthquake may fall on building on the rear side. A few multi-storied buildings have been developed besides the tin shed and low (2-3) storied building in this zone. These tin shed and low storied buildings are very much vulnerable to earthquake.

Moderately Vulnerable Areas

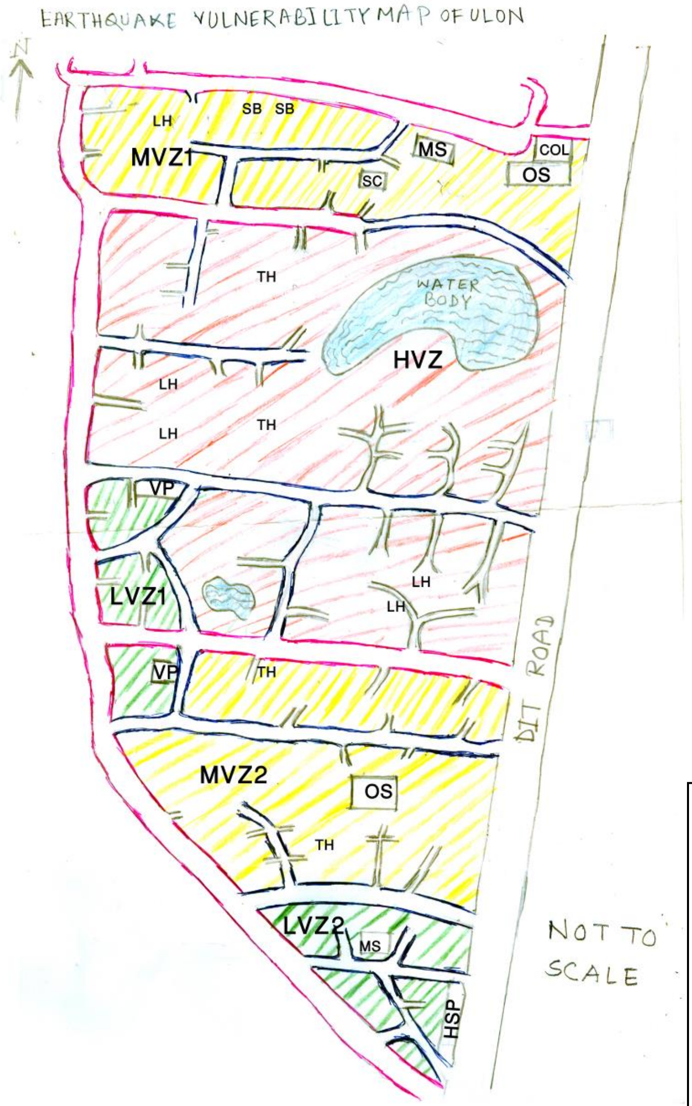
Zone 1 (MVZ1): This zone has access of roads greater than 20 feet with few roads 8-20 feet in width. So, this area will be relatively better accessible for fire brigade to reach to a collapsed building. Some soft storied high rise buildings have been developed in this zone which have greater possibility to collapse in the event of an earthquake. Low storied buildings besides the high rise buildings are vulnerable to earthquake. A mosque is located in this zone which does not have sufficient structural capacity to take the load of the Muslims coming to the prayer. According to the Imam of the Mosque, "The whole mosque building shakes when Muslims go for Sijdah." Playfield and college with playground can be used as a temporary shelter which contributes to increase capacity to withstand earthquake and reduces vulnerability.

Zone 2 (MVZ2): This zone has access of roads greater than 20 feet. Besides, there are few 8-20 feet wide roads in this zone. But most of the roads are below 8 feet wide and are not easily accessible for fire brigade. Tin shed buildings besides high rise buildings are vulnerable to earthquake. Buildings are safe in consideration as most of the buildings have been built of high land without land filling. There is a playground in this area which could be used as a shelter in post recovery stage of earthquake.

Less Vulnerable Areas

Zone 1 (LVZ1): This zone has access of roads greater than 20 feet with number of roads 8-20 feet in width. So, this area will be relatively better accessible for rescue team at the time of emergency. Buildings of this part of the area have been developed with deep piling and maintaining building construction rules. Existence of vacant plots enhances capacity of people nearby in living areas as people will have the opportunity to move promptly to those plots to take shelter in the advent of an earthquake.

Zone 2 (LVZ2): This zone is accessible by roads with width greater than 20 feet. There are number of roads which are within 8-20 feet wide as well. So, this area is relatively better accessible for fire brigade for emergence response. Only few roads in this area have width less than 8 feet. Buildings have been developed on high land in this area. Majority of the buildings of this have followed set back. There is a structurally sound mosque and hospital in this region, Mosque could be used as temporary place of rehabilitation for earthquake affected people. Due to existence of hospital in close proximity, it would be possible to transfer people injured due to earthquake quickly which is likely to reduce casualties caused by earthquake.



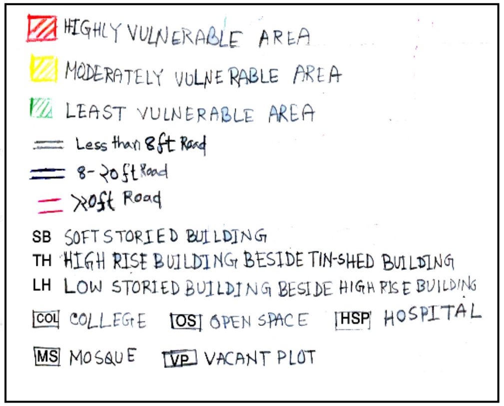


Figure 1. Earthquake Vulnerability Map of Ulon

Figure 2. High rise building constructed beside a tin shed house

Figure 3. Multi-storied building constructed on both side of 8 ft road

Figure 4. A Soft storied building

Figure 5. Building constructed without following set-back rules

Figure 6. High rise buildings constructed besides a one storied

Figure 7. A narrow road of 4 feet

Figure 8. A structurally weak building in a slanted position

Figure 9. Playground at Ulon

Figure 10. A Vacant plot

Result and Discussion

The ultimate outcome of the study is Vulnerability of Map of Ulon and identification of possible sources of earthquake vulnerability of Ulon. The sources of vulnerability includes: narrow road, violation of setback rules, construction of buildings without following building by-laws, construction of building on sand filled land, incompatible of building structures (low rise building or tin shed building with multi-storied building), development of soft storied buildings etc. The study has identified location of hospital, open spaces and vacant lands which are contributing to capacity development of people of Ulon against earthquake.

Recommendation

This study has identified possible sources of earthquake vulnerability of Ulon from the perception of its inhabitants which made the people aware of their risk to an earthquake. In order to enhance resilience of Ulon, people of Ulon came to a consensus to address sources of vulnerability rigorous monitoring. For this, a framework of Community Based Disaster Management Committee (CDMC) has been proposed for Ulon based on suggestions of its residents (Table 1). CDMC will consist of number committees and teams. Members of committees and teams will be selected from people living in Ulon.

Table 1. Draft Framework for Community Based Disaster Management Committee

Committee	Members
School Disaster Management Committee	At least 4 members (Principal, Headmaster, Teachers for local educational institutions)
Mosque Disaster Management Committee	At least 2 members from each mosque (Imam and Khatib)
Building Construction and Management Committee	At least 10 (Local leaders, building owners and influential people of the community, Leaders from Community Based Organization
Voluntary Organizations for Civil Defense	At least 5 members for each of the teams:Awareness Raising Team, Rescue and Search team, First Aid Team, Shelter Management Team, Financial Management Team, Relief Distribution Team

Conclusion

Community involvement has always been encouraged in disaster management (Action Aid,n.d., NDMP,2010). This study has aimed to develop an earthquake vulnerability map integrating relevant sources of vulnerability on the basis of perception of community people of Ulon. Narrow road, violation of building constructions rules, construction of building with considering soil characteristics, incompatible development of building structures have been found prime reasons behind earthquake vulnerability of Ulon. The study has also identified open spaces in vulnerability map where residents will be able take shelter in case of emergency situation caused by earthquake. This study has made people of Ulon aware of sources of earthquake vulnerability through vulnerability assessment with their active involvement and motivated them to take active steps to make their community resilient against disaster. Therefore, participatory vulnerability mapping can be applied to explore vulnerability of other communities or wards of Dhaka city and make local people aware to take initiative to become resilient against earthquake and other disasters.

References

CDMP.2009. Comprehensive Disaster Management Programme. Ministry of Food and Disaster Management . Government of the People's Republic of Bangladesh.

Akhter, S.H. n.d. Earthquakes of Dhaka. URL: https://www.academia.edu/429823/Earthquakes_of_Dhaka accessed on 8/04/2015

RAJUK.2015.Development Project Proposal of Urban Resilience Project:RAJUK Part.

Hossain,M.A. 2013. "Community Participation in Disaster Management: Role of Social Work to Enhance Participation".*Antrocom Online Journal of Anthropoly*. 9(1),179-191.

Action Aid.(n.d.).Participatory Vulnerability Assessment: A Step by Step Guide for Field Staff.

World Bank (2013). Earthquake Risk Atlas for Dhaka.

Edward, J., Gustafassan, M. and Näslund-Landenmark,B.2007.Handbook for Vulnerability Mapping. Swedish Rescue Services Agency, Sweden.

NDMP.2010. National Disaster Management Plan 2000-2015. Disaster Management Bureau,

Bangladesh.
NDMP.2010. National Disaster Management Plan 2000-2015. Disaster Management Bureau, Bangladesh.

UNRAVELING THE LIVELIHOOD-INDUCED RISK OF RESOURCE DEPENDENT COMMUNITIES: A CASE OF VULNERABLE FISHERMEN IN SOUTH-CENTRAL COASTAL BANGLADESH

K.M.Sujauddin[1] & Mohammed Moniruzzaman Khan[2], Choyon Kumar Saha[3]

ABSTRACT

In developing country like Bangladesh, agriculture is the dominant sector of livelihood. Fishing is also considered as the significant source of livelihood pattern. Most of the impoverished people and hunger-bit of a poor country live in rural areas and they are totally relying on farming, fisheries, forests and livestock for attaining their livelihoods. This study attempts to examine the salient features of livelihood-induced risks among the fishing community in southern regions of coastal Bangladesh. A triangulation approach was administered to depict the risks of the community following face-to-face interview schedule, a total of 184 samples were surveyed and six focus group discussions were also performed to collect the data. The results of the study depict that most of the people are sustaining their livelihood by catching fish, making net and boat, sorting out the collected fish, and drying fish. The vulnerable people are encountered with several social risks such as communication problems with community (32.6%), occupational stress (12.9%), fishing problems (3.4%), social communication (36.7%), conflict (8.0%), mistrust (1.9%), and breaking down family bondage (4.5%) etc. In addition, uncertain disasters are also exacerbating their livelihood risks by creating food shortage (6.2%), scarcity of safe drinking water (4%), submerging the boat (5.5%), and destruction of communication network (4.7%). The study, furthermore, reveals that health related risks, for examples dehydration (12.8%), eye problem (13.4%), skin diseases (7.9%), and scabies (3.6%) are also persistent among the fishing community in coastal Bangladesh due to dearth of health services. Lack of appropriate technology is also identified by the participants as a key barrier, which discards their communication network. Despite their lives at multifarious risks, the destitute people are maintaining their livelihood by hardship in coastal Bangladesh.

Introduction

Livelihood is as a set of activities, involving securing water, food, fodder, medicine, shelter, clothing and the ability to attain aforementioned necessities working either individually or group for meeting the requirements of the self and his /her household on a sustainable basis with dignity (Stevenson, 2011). Livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living. When livelihood becomes sustainable then it can cope with or recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation (Krantz, 2001). Comparatively in a poor or less developed country most of the people live in the rural areas and many who live in urban areas are engaged in an unremitting struggle to secure a livelihood in the face of hostile social, economic and often political circumstances (Murray, 2001). It is suggested that two points are central to an understanding of such struggles (Murray, 2001). The first point is that even the circumstances of poverty and the reasons for poverty have to be understood through detailed analysis of social relations in a particular historical context: between those with land and those without land, between men and women, between rural and urban households. The second point is that the modes of livelihoods that typically prevail both within households and between households are highly diverse.

Diversified households and less diversified households are differed significantly in terms of variables related to household assets, markets and institutions. Both household welfare and rural non–farming diversification decisions are mostly driven by household assets including good health, education, and household age composition (Asmah, 2011). As Bangladesh is a developing country and significant portion of the people are engaged in fishing related livelihoods but natural disasters along with other significant factors play critical role in shaping the livelihoods of fishing communities. The fishermen of

[1] *Lecturer, Department of Sociology, Jagannath University, Dhaka 1100, Bangladesh, e-mail:* sujasocjnu@gmail.com

[2] *Associate professor, Department of Sociology, Jagannath University, Dhaka 1100, Bangladesh, e-mail:* zontu75@yahoo.com

[3] *Assistant professor, Department of Sociology, Jagannath University, Dhaka 1100, Bangladesh, e-mail: choyon.soc@gmail.com*

south-central Bangladesh are in vulnerable situations; and they are not able to recover it as these poor and marginalized people are more severely affected by natural disasters and climate extremes for several reasons (Arnold and Cosmo, 2015).

Methodology

A methodological triangulation (both qualitative and quantitative approach) was administered to depict the risks of the community following face-to-face interview schedule, a total of 184 samples were surveyed and six focus group discussions were also performed to collect the data. The study was conducted in three different villages of Patuakhali district namely Fashipara, Nayoripara, khajura of Latachaply Union at Kalapara Upazila (sub-district) of Patuakhali District.

Results and Discussions

Almost every member of the fishing community is related to fishing either direct or indirectly. Someone is the owner of fishing tools someone are labor where as someone provide money for the fishing activities and they have a share to the profit of the collected fish. The data indicate that, as the fishermen in the area engaged with more than one fishing related profession, it is found that they involves in activities like netting, boat construction, lending money, buying boat, taking money instead of interest at composition of 81.1%, 45.4%, 39.5%, 37.8% and 40% respectively.

The results of the study depict that the vulnerable people are encountered with several social risks such as communication problems with community, occupational stress, fishing problems, lack of social communications, conflict, and mistrust and breaking down family bondage etc.

Social risks at fishing		Responses		Percent of Cases
		N	Percent	
	Communication problems with community/society	86	32.6%	50.9%
	Occupational stress	34	12.9%	20.1%
	Fishing problems	9	3.4%	5.3%
	Social communication	97	36.7%	57.4%
	Conflict/misunderstanding	21	8.0%	12.4%
	Mistrust	5	1.9%	3.0%
	Breaking family relations	12	4.5%	7.1%
Total		264	100.0%	156.2%

In addition, uncertain disasters are also exacerbating their livelihood risks by creating food shortage (6.2%), scarcity of safe drinking water (4%), robber's attack (24.8%,) uncertain disaster (31.7%%), and destruction of communication network (4.7%).

The study, furthermore, reveals that health related risks, for examples dehydration (12.8%), eye problem (13.4%), skin diseases (7.9%), and scabies (3.6%), are also persistent among the fishing community in coastal Bangladesh due to dearth of health services. Lack of appropriate technology is also identified by the participants as a key barrier, which discards their communication network. Despite their lives at multifarious risks, the destitute people are maintaining their livelihood by hardship in coastal Bangladesh.

Conclusions

The most exposed community is not necessarily the most sensitive or least able to adapt because livelihood vulnerability is a result of combined but unequal influences of socio-economic characteristics of communities and households. But within fishing community, where households are similarly exposed, higher sensitivity and lower adaptive capacity combine to create higher vulnerability. The vulnerabilities of the fishermen in coastal area have increased day by day due to engage in fishing related activities. Their exposure, sensitivity and adaptive capacity affect the vulnerability situation.

Acknowledgements

It is one of my greatest wonders on the unraveling of the vulnerable community in south central coastal areas of Bangladesh. Hereby I am gratitude to the Almighty Allah for special blessing in completing the research work with the assistance of Jagannath University. The completion of the study could not have been possible without the assistance and participation of Mohammed Moniruzzaman Khan, (Associate professor, department of sociology, Jagannath University) and Choyon Kumar Saha (Assistant professor, Department of Sociology, Jagannath University) who have always been helpful in making me understanding the different aspect of conducting a research as well as how to co-relate a theory with a study. Their contributions are sincerely appreciated and gratefully acknowledged. I would like to express my sincere thanks toward their deep appreciation and indebtedness.

Appendix

Table 1. Maintenance of livelihood

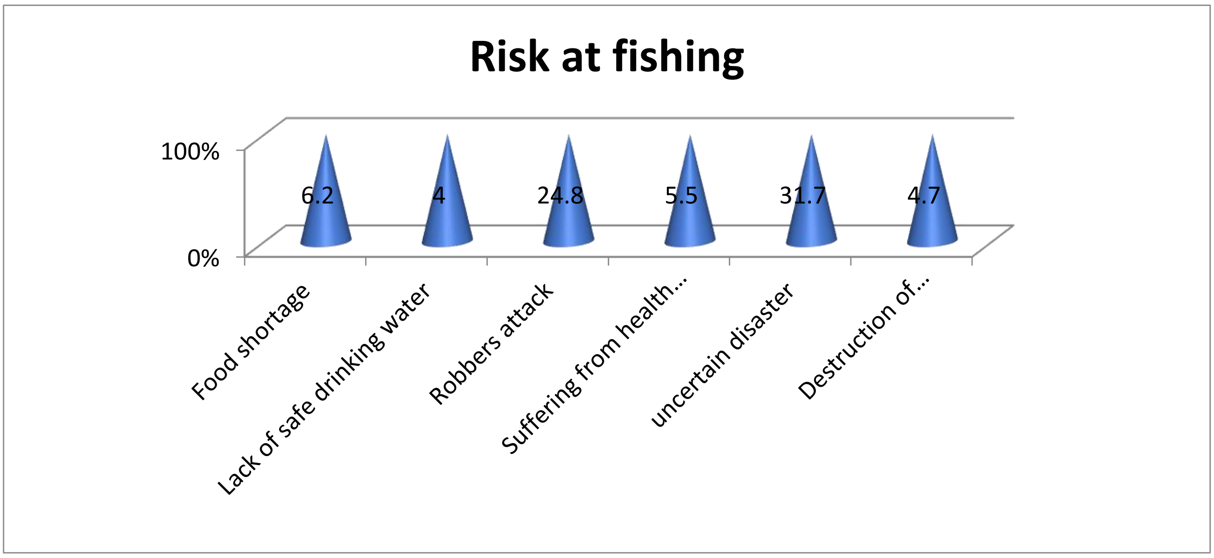
Maintenance of livelihood

		Frequency	Percent	Cumulative Percent
Valid	Netting	71	38.4	38.6
	Boat construction	29	15.7	54.3
	Money lending	46	24.9	79.3
	Buying boat	18	9.7	89.1
	Money lending by interest	20	10.8	100.0
Total		185	100.0	

Table 2. Health risk of the community

		Responses		Percent of Cases
		N	Percent	
Health	Conjunctivitis	66	20.1%	41.0%
	Scabies	12	3.6%	7.5%
	Itch	45	13.7%	28.0%
	Skin diseases	26	7.9%	16.1%
	Eye problem	44	13.4%	27.3%
	Dehydration	42	12.8%	26.1%
	Malnutrition	36	10.9%	22.4%
	Vomit	13	4.0%	8.1%
	Pain	45	13.7%	28.0%
Total		329	100.0%	204.3%

Table 3. Risks at fishing



References

Arnold and Cosmo, S.(2015), Building social resilience protecting and empowering those most at risk, International Bank for Reconstruction and Development / International Development Association or, The World Bank

Asmah, E. E., (2011), *Rural livelihood diversification and agricultural household welfare in Ghana*, Journal of Development and Agricultural Economics Vol. 3(7): 325-334.

Bennett, N, (2010), *Sustainable Livelihoods from Theory to Conservation Practice*: An Extended Annotated Bibliography for Prospective Application of Livelihoods Approaches in Protected Area Community Research; Marine Protected Areas Research Group (MPARG), University of Victoria.

FAO (Food and Agricultural Organization), (2013), *Disaster risk reduction for food and nutrition security*, Food and Agriculture organization of the United Nations, Rome, Resilient Livelihoods.

Krantz, L. (2001) *The sustainable livelihood approach to poverty reduction: an introduction*, SIDA (Swedish international development cooperation agency, Division for policy and socio-economic analysis.

ARE MIGRANT WOMEN MORE VULNERABLE IN URBAN CONTEXT? A CASE STUDY ON FOUR SLUMS OF DHAKA CITY

Dr. Mumita Tanjeela[1]

ABSTRACT

Every year thousands of people are migrating to Dhaka from other parts of the country and many of them are driven by climate induced hazards. A larger section of the migrants finally gets shelter at the vulnerable places in the city. Among the migrants', women and children are prominent in numbers and faces challenges to cope up with the new livelihood and living environment. Women are vulnerable than men as evident from cases of natural disasters as women's socio-economic vulnerabilities by directly impacting on their families' food security and water consumption that are directly related to their health and wellbeing. This paper focus on the challenges of hazards been faced by the migrant women in urban context. In depth study was conducted in four areas of Dhaka city to understand migrant women's vulnerabilities to urban hazards and their strategies to cope with the situation. A case study approach was adopted comprising both primary and secondary data. Data collection methods include FGDs, in-depth interviews of women and observation of their daily activities. Further, key informant interviews with national level experts, government officials and developments workers to explore diverse perspectives. The study concluded that disaster vulnerability of the migrant women has increased exponentially being the forced resident in the city. This finding indicates that it requires comprehensive rethinking of Disaster Risk Management and Women Vulnerability to break this vicious cycle.

Introduction

About 55% of the world's population is residing in Urban Areas as trend of urbanization is growing up every year (UN DESA, 2018). People are drawn to cities as they are recognized to be centers of economic activity, opportunity and innovation. Over the years' urban areas, particularly the cities have become the center of attraction for the influx of large number of migrants from the country-sides. Bangladesh is the home of 160 million people shares about 36% of the people living in urban areas and the capital Dhaka is the home of 17.4 million people with 1418 new faces to city every day (Dhaka Tribune, 2018). Among them a large number of climate refugees is emerging in Bangladesh, due to the climate change impacts. Sea level rise is one of these, which appears a great threat for the coastal population. The BCCSAP (2009, p. 14) suspects that if sea levels rise more than the current trend then "six to eight million people could be displaced by 2050 and would have to be resettled". The United Nations predicts that a three feet sea level rise in the next 50 years would lead to the disappearance of a quarter of Bangladesh's coastline and 30 million Bangladeshis would be displaced from their homes and land (as cited in Dastagir, 2015).

Background: Urbanization and Disaster Risk

Towns and Cities in developing countries are growing fast and in many regions faster than expected. The pace of urbanization and population growth is such that both the proportion and absolute numbers of the world's population residing in urban areas will increase, with the equivalent of the total current global population living in cities by 2050. The locations of cities remain a key variable in their overall exposure and vulnerability to disasters. Many cities are located and growing in places that are by their nature exposed to natural hazards and crises, such as the deltas, coasts and river basins. Additionally, many urban centres are located along earthquake fault lines. Clearly, place remains an important aspect of their overall hazard and risk profile. The BCCSAP (2009) warns that Bangladesh is going to face an 'urgent and pressing problem' due to rapid and unplanned urbanization. In particular, the urban poor who live in slum dwellings are the most affected.

Climate Change and in Country Migration

Rural-urban migration as an adaptation strategy of climate change affected populations, in the context of the increasing trend of population flow from rural areas to urban centres. Several studies show that in recent decades, rural populations have adopted migration to cities in search of new ways to earn a living

[1] *Assistant Professor and Chairperson, Department of Sociology, East West University, Dhaka, Bangladesh-1212 Email: mtanjeela@ewubd.edu)*

as a strategy for coping with climate-related events (Displacement Solutions, 2012; Gray and Mueller, 2012). According to Penning-Rowsell, Sultana and Thompson (2012), migration to cities is the last option for climate displaced populations, as is the case of Bangladesh. Another study by the Association for Climate Refugees (ACR, 2012) claims that in Bangladesh a total of 6.5 million people have already been displaced and almost half of them have been displaced by tidal floods and river-bank erosion who moved to city areas. A recent report by Hasan (2015) claims that approximately 350,000 people migrate to Dhaka city from all over the country annually, driven by climate change incidents and a hope for better employment opportunities.

Women are More Vulnerable to Climate Change and Disaster

Climate change affects a wide range of communities in Bangladesh, for instance people living in coastal zones, settlers on unstable slopes and climate refugees in urban slums. Their livelihood is threatened, they are displaced and their lives are endangered due to adverse impacts of climate change. However, among the varied climate victims, women are more vulnerable than men as is evident from the history of climate-induced disasters in the country. For example, the death toll of women was five times higher than that of men in a cyclone in 1991 (Pender, 2008, p. 37). Penning, Sultana and Thompson (2012, p. 4) also claimed disaster-induced casualties are higher among women, with elderly women the most vulnerable in Bangladesh. Several studies found that during disasters and in post-disaster periods women become more vulnerable than men in terms of health, nutrition, personal safety and household responsibilities (Nasrin, 2012; Dankelman, 2008). Hence, in Bangladesh climate change increases women's socio-economic vulnerability by directly impacting on their families' food security, water consumption and traditional livelihood.

Methodology: A Case Study on Four Slums of Dhaka city

This study has focused on the vulnerability and their coping strategies of migrant women living in the slums of Dhaka city. To achieve the targeted objectives the case study method is adopted and study is qualitative in nature. The study was conducted in four slums: Begunbari, Khilgaon, Mohammadpur and Mohakhali covering different parts of Dhaka city. Sixty questionnaire interviews with migrated women and 4 focus group discussions (FGDs) with both male female participants were conducted for this study. In addition, 5 KI interviews were taken from the experts of this specific field.

Findings: Reasons for Increasing Vulnerability

Gender-differentiated roles and responsibilities as well gender norms and gender power relations place women differently to men in any disaster or environmental degradation. Therefore, climate change or environmental problems cannot be a gender-neutral phenomenon. This study finds that due to different types of environmental problems which includes *river bank erosion, flood, cyclone-Aila, crop failure,* which translated into *loss of livelihood, food and water crisis, economic problems and unemployment* pushed the respondents to migrate in Dhaka city. They considered moving to Dhaka city is better option as city offers diverse informal employment opportunities. Nevertheless, they fall in again urban disasters trap such as fire, flood and water logging where the situation of women is even more difficult and vulnerable than men. Being migrants, these urban slum women need to adjust to the new socio-economic environment and thus they are overburdened with different responsibilities. To fulfill the responsibilities, they need engage themselves in unfamiliar and inexperienced activities. Thus, they have to reshape their traditional gender roles and identities which sometimes put them in more vulnerabilities. Some respondents informed that they were victim of violence and sexual or economical exploitation and polygamy. One migrant woman (30 years old) from Mohammadpur slum states that:

> "I came to Dhaka 7 years back with my husband and two children. I one of my neighbors brought me to an apartment for working as a housemaid. Since I was not used to do these kinds of household activities so whenever I did any mistake, I was scrolled by family members and I never got full salary in any month due to my wrong doings. Next, I started working in a male mess and where I was physically harassed".

In addition, adult females suffer from illnesses related to reproductive health due to poor nutrition and unhygienic living conditions. They even do not to seek medical assistance, in particular for issues related to their reproductive health due to lack of money, information and mobility. Thus, their health issues particularly, reproductive right is always ignored and unattained. Another respondent (25 years old) from Mohakhali slum who moved to Dhaka city recently informs her situation:

> "I left my village in this monsoon so am new resident of this area and do not know where to go for " meyeli rog" (gynecological disease). It is also shame to share such types of problems to anyone. Moreover, we do not have enough money to spend for treatment or buying medicine. I heard some NGO Apa (female NGO workers) come from them we can take help but yet I did not meet anyone".

Access to safe drinking water and proper sanitation system is another major problem for urban slum women, which is one of the major obstacles for their health wellbeing. They have to face long queue for collecting water for household uses and same for using common toilets in the slum. With the limited water they have to maintain all water related household activities such as cooking, washing, cleaning and drinking. Thus, they become again the water manager at their home similar as their rural lives which create both physical and mental pressure for them.

In addition, unsafe workplace makes women differently vulnerable than their men counterpart. Most of the young female slum dwellers work in RMG factories where fire is common hazard that they need to face regular basis. During the FGD at Begunbari slum the respondents informed their vulnerable situation this way:

> We live within the fire in both our living place and work place. Our slum burnt more than three times during last 4 years. You will not find any one here who have not experience of fire hazard in their garments. Women are more vulnerable because they cannot get out of the factory as quickly as man because of their attires and physical condition. One girl from our slum died during Tazreen garment fire incident and several were injured.

Thus, social, economic and cultural factors always influence the gendered experiences of disaster both in rural and urban context. Attributed gender roles, the gender division of labor, and male dependency make women vulnerable in a different way to men. Thus, poverty and gender inequality appear to be important factors in shaping vulnerability within affected communities where patriarchy is a dominant social factor.

Discussions and Conclusions

In Bangladesh, gender power relations shape women's duties and responsibilities, and their access to, and control over assets and information both in rural and urban areas. Moreover, women's mobility and potentiality are also restricted due to several socio-cultural factors which impact adversely on every sphere of women's lives and livelihood. All these factors create new vulnerabilities for urban migrant women. Therefore, the poor and marginalized groups, particularly women face more difficulties in any vulnerable socio-economic condition. They have to confront a 'double dilemma' since their lives are directly affected by climate change and they had fewer options and capacity to adapt in villages, so migrate to Dhaka city has become the last resort for them which even could not provide social safety for them. The study highlights the impacts of climate change on both urban and rural realms and how they are closely interconnected. Population migration, rapid urbanization and poverty concentration are extending the risks of climate change impacts particularly on women. Hence, this requires better adaptation planning to improve adaptive capacities of slum dwellers.

References

ACR (Association for Climate Refugees). 2012. "Climate 'Refugees' in Bangladesh — Answering the Basics: The Where, How, Who and How Many?"

BCCSAP (Bangladesh Climate Change Strategy and Action Plan). 2009. Ministry of Environment and Forest, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh, xviiii–76.

Dastagir, R., (2015). Modeling Recent Climate Change Induced Extreme Events in Bangladesh: A Review. *Weather and Climate Extreme*, 7, 49–60

Dankelman, I. (2008b). Gender, Climate Change and Human Security: Lessons from Bangladesh, Ghana and Senegal. This chapter is excerpted from WEDO's study, Gender, Climate Change and Human Security Commissioned by the Greek chairmanship (2007–2008) of the Human Security Network. The report includes three country specific case studies prepared by WEDO partners; the countries are Bangladesh, Senegal and Ghana

Amin. A. M. (2018). Dhaka remains the world's most densely populated city. Dhaka Tribune, 14th October, 2018

Displacement Solutions. (2012). Climate Displacement in Bangladesh: The need for Urgent Housing, Land and Property (HLP) Rights Solutions. Geneva, Switzerland.

Gray, C.L. and Mueller, V. (2012). Natural Disasters and Population Mobility in Bangladesh. *PNAS*, 109(16), 6000–6005.

Hasan, M. (2015). Bangladesh's Climate Change Migrants. *IRIN*, November 13.

Nasreen, M. (2012). "Women and Girls: Vulnerable or Resilient? Institute of Disaster Management and Vulnerability Studies", University of Dhaka, Bangladesh.

Pender, J. (2008). What is Climate Change? And How it Will Affect Bangladesh? A Briefing Paper. Church of Bangladesh Social Development Programme, Dhaka.

Penning-Rowsell, E., Sultana, P. and Thompson, P. (2012). The 'Last Resort'? Population Movement in Response to Climate-Related Hazards in Bangladesh. *Environmental Science & Policy,* 27, 1–16.

UNDESA (2018). "The 2018 Revision of World Urbanization Prospects", Population Division of the UN Department of Economic and Social Affairs.

INDIGENOUS DISASTER RESILIENCE: AN OBSERVATION OF BAWM HOUSES, BANDARBAN, CHITTAGONG

Shwe Wai Ching[1] and Romana Haque Suravi[2]

ABSTRACT

Chittagong Hill tracts are affected by natural disasters like earthquake and landslide, causing severe casualty and loss of property. The tribal inhabitants are tackling this hazard with age old construction technique gained from everyday experiences and without any theoretical knowledge. This article delves into the vernacular architecture of the hill tracts to find the indigenous disaster resistant non-engineered and engineered construction techniques through observing the *Bawm* traditional *Machang* houses of Bandarban. This article attempted to present these resilient features and construction techniques; and encourage the integration of local learning and proper theory. This research will provide valuable resources for future researches to overcome the untreated part of the disaster resilience through adapting the indigenous knowledge.

Disasters in the Hill tracts

The Chittagong Hill Tracts is situated in the south-east region of Bangladesh consisting of the three districts of Rangamati, Khagrachhari and Bandarban. Bangladesh is surrounded by the regions of high seismicity. According to Professor Bruce Bolt of University of California at Berkeley, large magnitude earthquakes generated in four tectonic zones can affect Bangladesh. It is also the site of the Dauki Fault system along with numerous subsurface active faults and a flexure zone called Hinge Zone These weak regions are believed to provide the necessary zones for movements within the basin area. All thanks to the particular climatic and topographical features, Bandarban is vulnerable to earthquake and landslides.

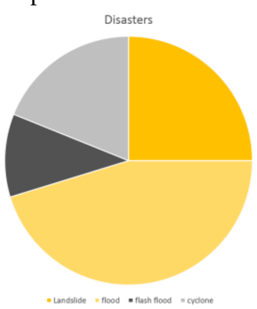


Figure 1. Disaster frequency in Bandarban.

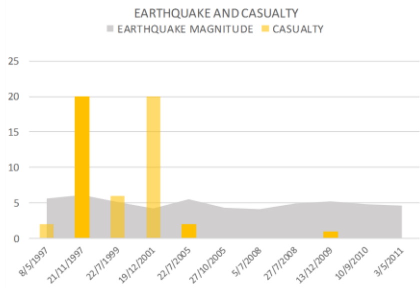


Figure 2. Earthquake and casualty.

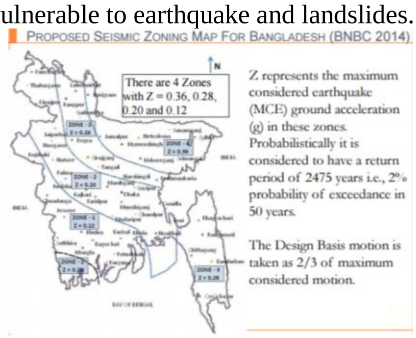


Figure 3. Earthquake zones in Bangladesh.

The serenity of Bandarban is disturbed due to recurring natural disasters like earthquake and landslides, leaving behind massive casualty and property damage as the after effect. In the recent years the casualty rate in this area due to these disasters has become alarming. But it is a matter of great hope that the indigenous house construction technic has been playing a very interesting role in depleting the casualty rate.

The main objective of this paper is to have an observatory look into the construction technic of the ethnic group to understand the potential of the vernacular architecture in the disaster management and to present them to the literary society as a manual to use them as tools in disaster resilient architecture.

Methodology

This research adopted the method of site surveying and documenting the observations through photographs. To understand the construction process better, the authors conducted a thorough

[1]*Lecturer, Dept. of Architecture, State University, Dhaka-1205, Bangladesh*
[2]*Master's Student, Dept. of Architecture, BUET, Dhaka-1000, Bangladesh*
Email of Corresponding Authors – shwewai.ching@gmail.com , romana1001009@gmail.com

questionnaire survey and first-hand observation which has been endorsed with extensive literature review.

Understanding the Site

This research observed the *bawm* houses of Faruk para, a small village in Bandarban district as the site for field survey. The population of the particular village is 640. The weather of this region is characterized by tropical monsoon climate with mean annual rainfall of nearly 2540 mm in the north and east and 2540 mm to 3810 mm in the south and west. This village is elevated 1150 feet above the sea level. The hill soils (*dystric cambisols*) are mainly yellowish brown to reddish brown loams which grade into broken shale or sandstones as well as mottled sand at a variable depth. The soils are strongly acidic.

Figure 4. Site section of Faruk para and survey photographs.

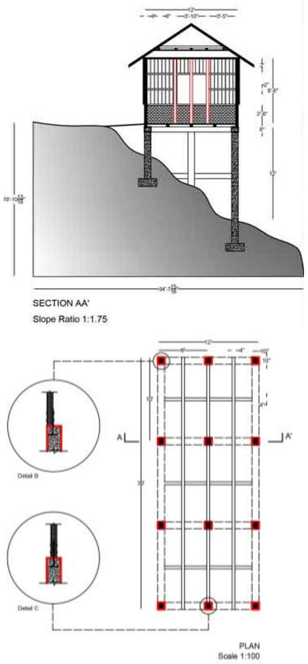
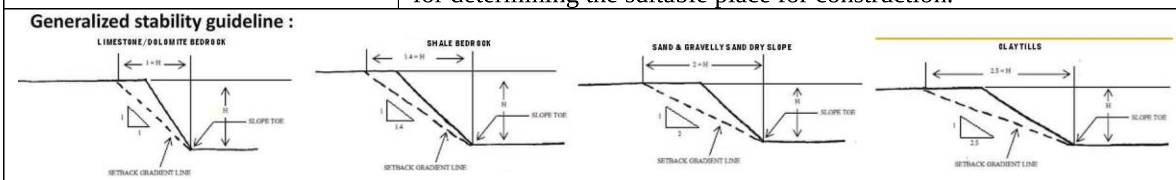
Bawm Houses

The vernacular houses of *Faruk* para are stilted *Machang* houses, mostly made of wood and bamboo stilts as the support for the elevated floor. The flooring materials are mostly wood. In the recent years combination of wood and concrete is used at an increased rate. These houses have great similarities with the Indian Rural stilted houses, mostly Lushai houses (Mizoram) and Tang Ghar (Tripura) (Lala, Gopalakrishnan and Kumar, 2017).

Table 1. Types of Bawm houses

Lushai type houses Wood or bamboo stilt, sometimes with bracings Wooden floor Wooden or bamboo walls	
Tang Ghar Branched wooden or bamboo stilt Wooden floor Walls made of bamboo	

Indigenous Technique in Disaster Resilience

Earthquake	
Bamboo and wooden poles as stilt 	Bamboo has good seismic performance properties. They are lighter in weight and ductile. The lightness of buildings lessens the inertial load that the walls must support, making building's resistance to the ground movement relatively small. Bamboo is highly flexible tensile material. During an earthquake, the building continues to be supplied with energy. If the intensity of the earthquake is low, this energy is absorbed partly by internal damping in the materials and partly as elastic energy. In heavy earthquakes, these two means of absorbing energy do not suffice, and the building will not survive the earthquake unless its structural system can absorb energy through plastic deformation.
	Wood is capable of load transferring through small cross-sectional area, which is a characteristic of the *bawm* houses. Wood-frame construction is substantially lighter than other types of construction and has a high strength-to-weight ratio. As a result, properly designed and built wood-frame structures perform well during seismic activity. Wood-frame buildings can flex, absorbing and dissipate energy when subjected to sudden earthquake forces. Similarly, sheathing and finishes attached to wood joists ad studs provide redundant load paths for earthquake forces. These numerous small connections and load paths dissipate seismic forces (Mukhopadhyay, 2008).
Wooden flooring and walls 	Wood is used as a substitute for concrete by local people traditionally as it crack easily during the tremor. Elasticity of wood is better than that of concrete. An earthquake's lateral forces tend to distort building walls, causing them to rack. Shear walls in wood construction provide necessary racking resistance. The stiffness and resistance of walls can be augmented in areas prone to strong earthquakes by increasing the thickness of structural panels, stud size, and number or size of nails. Securely connecting a structure's walls, floors and roof framing make it a single, solid unit, which is critical to withstanding earthquake forces. All structural elements must be anchored to the building's foundation to resist racking, sliding and overturning during an earthquake. Standard connections and tie-downs manufactured for high-load designs make this quite simple.
Affordability and availability	Bamboo and wood are cheaper than other modern construction materials. According to Sarkar (2006), material cost accounts for 70 to 80 percent of the housing construction cost, and this cost should be optimized by choosing appropriate materials.
Landslide	
Materials and Design	Lightweight materials like wood and bamboo are used to avoid overloading the soil. Small cross-sectional area also greatly helps in mitigating pressure on the ground. The stilts are used to mitigate the pressure of water and liquid soil coming down the slope.
Slope Analysis	Before construction begins the indigenous people conduct a slope analysis for determining the suitable place for construction.
	

Recommendations

Low cost local building material (bamboo or brick) should be encouraged for better quality performance during earthquake tremor. Modification of the available material and construction technique might be required for making them strong enough to resist significant amount of forces. Bamboo and wood are lighter, flexible and ductile materials. Therefore, they can be used effectively for seismic resistant construction. They can be used in constructing frame, partitions, and hence can be effective earthquake resisting members. Similarly, Ferro-cement, rice straw, rice husk, and potter like materials are also other less expensive materials.

Local non-engineered structures should be modified and adopted in the disaster resistant construction by making them safer and; to make them safer; non-engineered structures should be constructed earthquake proof just by applying earthquake resistant components during construction. Providing at least three bands at plinth, at lintel and at roof level to resist lateral forces; proving vertical joints to resist vertical forces; and making joints of wall stronger with stitches on any buildings no matter what kinds of building material, be it bamboo, wood or concrete, can be strong enough to resist significant amount of vertical as well as lateral force. This can save loss of property and life.

Local level workers should be trained and community awareness should be developed about the disaster resistant construction process. Easy applicable thumb rule for constructing earthquake proof non-engineered structures should be prepared. Implementing the building Code and bylaws incorporating all those earthquake resistant components for the construction of buildings is another vital part. Government should be more aware to ensure safety of their citizens.

Conclusions

Indigenous construction techniques are the result of long accumulated knowledge perfected to achieve the best outcome. In resilient architecture these knowledges are precious treasure. The construction technique of *Bawm* houses and their small but significant techniques like using locally available materials and site appropriate construction techniques (stilt houses and slope adapted construction) can be a good example in any sustainable construction. In conclusion, it is appropriate to assume that resilient and sustainable construction is possible only through understanding the nature of site and adopting local material and construction technique.

References

Karsh, E. (2014) “Wood-frame construction advantageous in areas prone to seismic activity”, *CIVIL + STRUCTURAL ENGINEER*, https://csengineermag.com/article/wood-frame-construction-advantageous-in-areas-prone-to-seismic-activity/

Mukhopadhyay, P. (2008) “Role of bamboo in seismic architecture”, *Indian Architect & Builder magazine* https://www.researchgate.net/publication/276409292_Role_of_bamboo_in_seismic_architecture

Sarkar, R. (2006). Post-Earthquake Housing Construction Using Low Cost Building Material. http://conf.ncree.org.tw/Proceedings/i0951012/data/pdf%5C4ICEE-0275.pdf

Lala, S. Gopalakrishnan, N. and Kumar, N. (2017) “A Comparative Study on the Seismic Performance of the Different Types of Bamboo Stilt Houses of North-east India”, *4th National Conference on Innovations in Indian Science, Engineering & Technology with a focus on "RURAL HOUSING"*, https://www.researchgate.net/publication/317661736_A_Comparative_Study_on_the_Seismic_Performance_of_the_Different_Types_of_Bamboo_Stilt_Houses_of_North-east_India

Sponsored By

Fresh CEMENT
HIGH PERFORMANCE CEMENT

In Association With

CONCORD