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WHY BANGLADESH?

Lal Udagedara[1]

Keynote Address by **Mr. Lal Udagedara**, who presents a powerful picture in which he will take the audience through the development, the numbers, and the opportunities of Bangladesh to remain a world leader in garment production. In his address, Mr. Lal will emphasize the importance of structural integrity, fire safety, and electrical safety, and share his vision on what needs to be done to achieve this goal.

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SAFETY IN RMG SECTOR: PERFORMANCE AND PROGRESS OF DIFE AFTER RANA PLAZA

Tasnim Tarannum[1] and Mehedi Ahmed Ansary[2]

ABSTRACT

On 24 April, 2013, the factory building of Rana Plaza collapsed with a death toll of 1,129 lives and injury of approximately 2,500 workers. In response to this deadly collapse, government of Bangladesh upgraded the Chief Inspector of Factories and Establishment office to Department of the Inspection for Factories and Establishments (DIFE) in 15 January, 2014 with increased manpower, stronger leadership and improved infrastructure. Since then, DIFE is taking several initiatives regarding workplace safety in Ready-Made Garment (RMG) sector, including factory inspection, training and capacity building of labor inspectorates, and expansion of district offices. This article explores the safety-related activities undertaken by DIFE and reviews progress of the initiatives in five years after Rana Plaza. In the long run, the challenge is to maintain the momentum and upscale the operations of DIFE for ensuring compliance in RMG sector.

Keywords: Rana Plaza, DIFE, Workplace Safety, Bangladesh RMG Sector, Remediation, Factory Inspection.

1. Introduction

Safety has become an issue of major concern with the increase of population and rapid industrialization. According to ILO, every year 317 million accidents and more than 2.3 million deaths occur in workplaces worldwide as a result of occupational accidents. Substandard occupational safety practices can be attributed to an annual economic burden of 4 percent of global Gross Domestic Product (GDP) (ILO, 2017). Research works have already recognized the significance of safety interventions in order to ensure workplace safety and decrease injury rates (Ashford, 1976; Smitha *et.al*., 2001; Locke *et.al*., 2007; Cohen, 2013).

Most countries address occupational safety in two forms- through the establishment of safety association and formulation of safety laws and regulations. In USA, the establishment of the Occupational Health and Safety Association (OSHA) lead to the reduction of work-related deaths and injuries by more than 65 percent (OSHA, 2016). In 1919, following the end of First World War, International Labor Organization (ILO) was established as a result of growing labor and social movements. Japan adopted Industrial Safety and Health Law (ISHL) in 1972 which sharply decreased the number of work-related deaths in the country (Reich and Frumkin, 1988). China, being the fifth largest trading nation in the world, experiences industrial hazards frequently. Chinese government adopted the Work Safety Law (2002) which focuses on factory-wise safety management system, training aspects and routine inspection of production activities (Walker, 2015). European Union (EU) directives set minimum requirements to ensure safety and health at workplaces and the Member States must comply with these standards through the implementation of national legislations. ILO works in coordination with the governments, employers and representatives of 187-member states in order to ensure safe and decent work for both men and women (ILO, 2017). Bangladesh has been an active member state of the ILO since 22 June, 1972 and has ratified 35 ILO Conventions including seven fundamental conventions (ILO, 2017).

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Working condition in RMG factories in Bangladesh has been low as most factories do not comply with the existing labor laws and international labor standards (Ahamed, 2012). Ready Made Garments (RMG) sector is the largest exporting industry of Bangladesh which experienced phenomenal growth during the last 25 years. This sector contributes for 75% of foreign currency earning and 13% of GDP growth of Bangladesh (Firoz, 2011). Despite its phenomenal success in terms of remittance earning and employment generation, this sector experienced some worst industrial accidents in the history. One of the deadliest accidents include the fire incident at Tazreen Fashions of Ashulia, Dhaka in November 24, 2012, which resulted in the deaths of 111 workers and injuries of more than 300 workers (Chowdhury and Tanim, 2016). Since the Tazreen Fashions Factory fire, at least 142 RMG factory fire accidents occurred up to April, 2017 leading to the death of 1,148 workers (Solidarity Center, 2017). The collapse of Rana Plaza in 2013 is considered to be one of the deadliest accidental structural failures in history which created a worldwide concern for workplace safety in Bangladesh (ILO, 2016). The building collapsed on 24 April, 2013 due to poor structural condition, with a death toll of 1,129 lives and approximately 2,500 injured (Alam and Hossain, 2013; Butler and Hammadi, 2013). Lack of compliance to the workplaces safety issues is considered to be largely responsible for its collapse (Ansary and Barua, 2015).

Despite the tremendous growth of RMG sector in Bangladesh, the capacity of regulatory bodies, especially the labor inspectorate was not growing in the same pace. Department of Inspection for Factories and Establishments (DIFE) was established in 1972 to implement the labor laws of the country. But with its limited manpower, infrastructure and logistic support, DIFE was falling behind to meet the needs of huge number of factories and commercial establishments (GoB, 2016). Major industrial accidents like Rana Plaza collapse and Tazreen fire reflected the need for a complete renovation of the labor inspection system of Bangladesh (GoB, 2015). In this background, DIFE undergone an extensive upgrade in 2014. This paper explores the initiatives taken after Rana Plaza collapse with special focus on workplace safety. The purpose of this paper is to provide an update of the progression made by DIFE after its initiation in 2014, including the next steps for ensuring workplace safety in Bangladesh. The objectives of this article are- (1) to summarize the workplace initiatives and administrative reform that has been done so far by DIFE to determine how far the occupational safety agenda has progressed since 2014; (2) to identify the gaps in the system and outline the next steps for moving forward in order to make DIFE achieve its vision and objectives from the perspective of workplace safety in RMG sector.

2. Background of Department of Inspection for Factory and Establishments (DIFE)

2.1. Formation of DIFE: In 2010, the service sector was accounted for the largest share of employment (35.4%) within the non-agricultural sector, followed by the manufacturing industry (12.4%) (Labor Force Survey, 2010). According to Economic Census (2013), the total number of economic units was 3,708,144 in 2010 which increased to 8,075,704 in 2013 (BBS, 2013). This rapid expansion of manufacturing and service industry led to an increase in the number of factories and the number of workers engaged in the sector. Although the Chief Inspector of Factory and Establishments office was playing a vital role in ensuring legal rights, safe and hygienic work place for the huge number of working people, existing manpower, infrastructure and logistic support were poor compared to the total number of factories, and commercial establishments.

After the tragic incident of Rana Plaza collapse, the need for fundamental changes related to safety, inspection and compliance became crucial in order to safeguard the lives of four million garments workers and retain the confidence of global buyers (ILO, 2015). This resulted in several national and international commitments and initiatives directed towards reforming the RMG sector of Bangladesh and improving workplace safety in garments factories. Some of the major initiatives include National Tripartite Plan of Action on Fire Safety and Structural Integrity, European Union Sustainability Compact and United States Trade Representative (USTR) Plan of Action. Many of these initiatives had influence in shaping the roles and responsibilities of DIFE.

In this context, the government of Bangladesh took an initiative to upgrade the directorate into a "department" with greater operational and management authority. Ministry of Labor and Employment issued the government order of upgradation of Chief Inspector of Factories and Establishment office to Department of the Inspection for Factories and Establishments (DIFE) in 15 January, 2014 sanctioning 679 new staff positions and 392 new inspectors. The post of Chief Inspector (Deputy Secretary) was upgraded to Inspector General (Additional Secretary) to provide DIFE with stronger leadership. Besides, the number of district offices were increased from 7 to 23, and budget allocation for DIFE was increased more than three-fold in FY 2013-14 and 2015-16 as shown in Figure 1 (GoB, 2016).

The adopted vision of DIFE is to ensure a better working environment for workers. In the old structure, there was little inter-agency cooperation by the DIFE office (GoB, 2015). But now DIFE collaborates with various government and private agencies along with international organizations like ILO to facilitate the policy, planning, measures and directions to enhance safety in RMG sector (GoB, 2016).

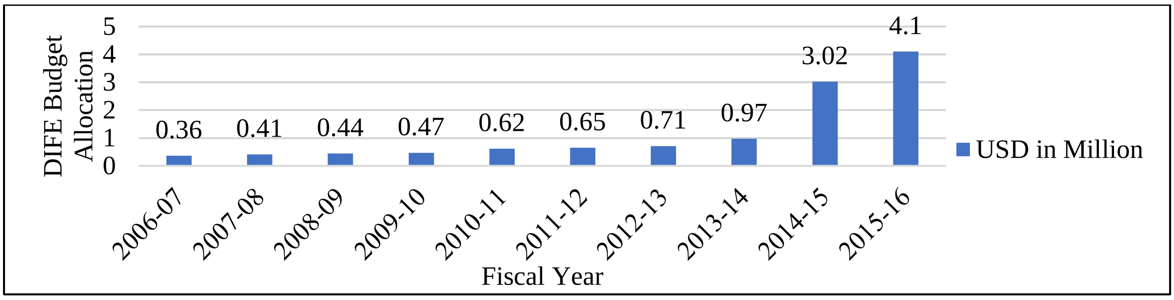

Figure 1. Budget allocation for DIFE from FY 2006-2016 (Source: GoB, 2016)

2.2. Organizational Framework of DIFE: The official headquarter of DIFE is located at Kawran Bazar, BFDC Bhaban, Dhaka which is supervised by the Inspector General (Additional Secretary). The organogram of DIFE headquarter is shown in Figure 2. Apart from the headquarter, there are 23 district offices located all over Bangladesh, each of which are chaired by one Deputy Inspector General (DIG). Government of Bangladesh has already taken an initiative to expand the existing number of district offices. A development project named as "Modernization and Strengthening of DIFE and Establishment of 5 Zonal and 4 Regional offices" has been undertaken in Gazipur, Narayanganj, Kushtia, Faridpur, Comilla, Barisal, Mymensingh, Maulvibazar and Rangpur in January, 2013.

The Safety Section of DIFE, operating under the supervision of one DIG and two Assistant Inspector Generals (AIG), coordinates the activities of Review Panel and Remediation Coordination Cell (RCC) and performs other functions such as factory assessment, approval of Corrective Action Plan (CAP), and review of factory compliance reports. Health Section of DIFE is responsible for ensuring safe workplaces, identification of work-related diseases, protection of occupational health and maternity benefits. The General Section prepares inspection plan, supervises the inspection activities and resolves labor disputes. The Law Sub-Section under Administrative and Development Section manages and takes necessary initiatives to resolve the ongoing cases related to Ministry and Department. The responsibility of Statistics and Research Sub-Section is to collect and preserve the list of factories and establishments all over the country. According to this Sub-Section, the number of registered factories and establishments is 26,953, among which 4,667 are RMG factories. The Information and Public Relation Sub-Section works on raising awareness among workers and employers through different programmes, television documentaries, social media and strives to protect information right. Lastly, the Accounts Sub-Section is responsible for budget preparation of the department including maintenance cost, procurement of equipment etc. With the assistance of ILO, the library of DIFE has been upgraded into a resource center along with infrastructural development. Apart from these four divisions, the district offices have an additional division named as Shops and Establishments Section (GoB, 2015-16). In order to mobilize the activities of different divisions of DIFE, 18 working committees have been formed within 2016 period. The committees include Database and Website Management Committee, Social

Media Admin Panel, Crisis Management Committee, Monitoring, Training, Inspection Reporting, Transparency and Accountability, LI Policy, Helpline Management Committee etc. DIFE has also formed an Occupational Safety and Health Unit consisting of 26 members which is headed by the Inspector General (CPD, 2016).

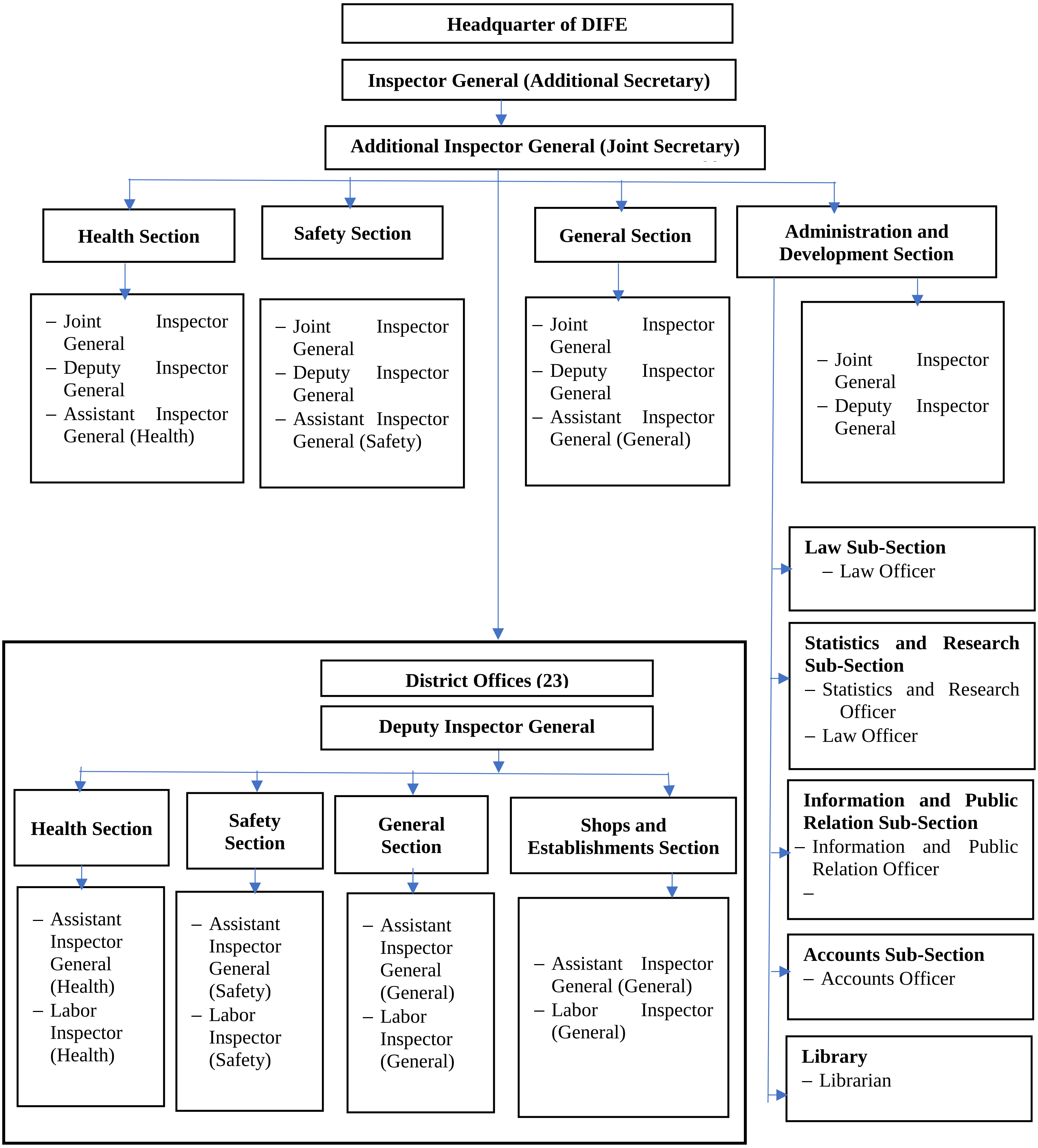

Figure 2. Organizational framework of DIFE headquarter (Source: DIFE, 2017)

3. Activities and Progress of DIFE for Improving Safety in RMG

3.1. Inspection of Factories: Factory inspection, being an essential part of labor administration system, can assist national authorities to identify the loopholes in the application of national labor laws (ILO, 2017). Regular labor inspection has been prioritized in countries like USA, Japan, and in EU, where the inspectors have formal police power and regular, programmed workplace inspections are carried out annually (OSHA, 2015). In Bangladesh, Apart from National Initiatives (NI), Accord and Alliance comprised of European and North American retailers are also conducting inspection of their enlisted factories. So far, Accord has completed 80% and the Alliance completed 90% of the inspection and remediation (The Daily Star, 2018). As seen from Figure 3, preliminary assessment of 3,780 factories has been conducted by three initiatives up to September, 2015.

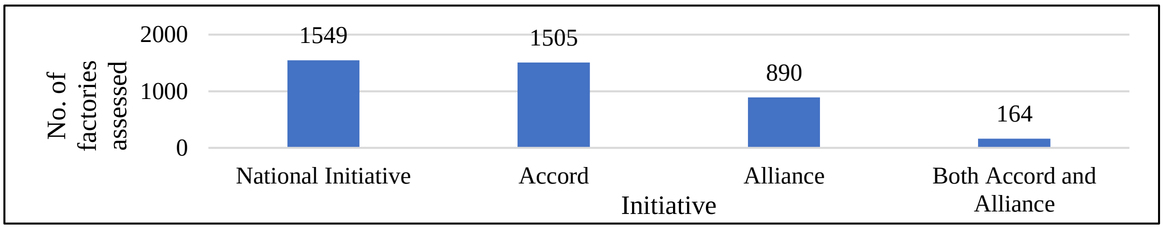

Figure 3. Preliminary assessment of factories by three initiatives up to Sept., 2015 (Source: DIFE, 2018)

Review Panel is responsible for visiting the factories in question, reviewing the evidence and making decision regarding the future operation of the factory. It is chaired by the Inspector General of DIFE and has the authority to close down factories according to labor laws. Till December, 2017, out of 145 factories that have been referred to Review Panel, 37 factories have been closed, 36 factories have been partially closed and 66 factories have been allowed to operate with some recommendations. Under NI, a total of 147 factories are asked to initiate Detailed Engineering Assessments (DEA) and primarily 13 engineering firms have been appointed to perform DEA (ILO, 2018). Table 1 shows the actions taken by Review Panel until December, 2017.

Table 1. Factories referred to Review Panel and actions taken (as of December, 2017)

Decision	**NI**		**Accord**		**Alliance**		**Total**	
	No. of factories	No. of buildings	No. of factories	No. of buildings	No. of factories	No. of buildings	No. of factories	No. of buildings
Referred to review panel	42	18	47	23	56	27	145	68
Partially closed	16	7	8	5	12	5	36	17
Closed	3	3	26	10	8	5	37	18
Allowed operation	23	8	12	7	31	12	66	27
Pending decision	0	0	1	1	5	5	6	6

(Source: DIFE, 2017)

3.2. Initiation of Remediation Coordination Cell (RCC): After the expiry of the tenure of Accord and Alliance in 2018, two new bodies named as "transitional Accord" and "Safety Monitoring Organization" will act as safety supervisors in RMG sector (The Daily Star, 2018). An organized national framework is needed to oversee the workplace safety issues, monitor progress in enhancing safety and manage the remediation process for garment factories. In this background, the Remediation Coordination Cell (RCC) has been launched in 15 May, 2017 with the plan of creating a long-term, coordinated approach for factory inspection and safety progress monitoring (ILO, 2017). The core body of RCC is supported by five government organizations including DIFE, Fire Service and Civil Defense (FSCD), RAJUK/ Chittagong Development Authority, Public Works Department and Chief Electrical Inspector's Department. Three officers from each organization monitor remediation activities at field level and core body meeting is held on every two months. Up to February, 2018, five core body meetings have been held and one factory has been visited on 12 February, 2018 (DIFE, 2018).

3.3. Formulation of Task Force: Three task forces have been formulated for structural, electrical and fire under RCC. Task force is comprised of IG, DIFE as Convener, and representatives from FSCD, RAJUK/CDA and BUET as members. These taskforces monitor the progress of Corrective Action Plan (CAP) and Detail Engineering Assessment (DEA) in national initiative factories. Total 28 task force meetings have been held until 13 February, 2018 with 19 meetings for structural, 8 meetings for fire and 1 meeting for electrical. Table 2 lists the decisions made on task force meeting.

Table 2. Decisions made on Task Force meeting (up to 13 February, 2018)

Task force	Total DEA required	Number of DEA/CAP submitted	Number of DEA/ CAP reviewed
Structural	147	59	40
Fire	745	15	08
Electrical	745	20	01

(Data Source: DIFE, 2018)

The manual for the preparation of CAP has already been devised and uploaded in DIFE website. A number of DIFE inspectors are also being trained on CAP development (GoB, 2016). Up to January, 2018, all NI factories have prepared their CAPs based on the findings of inspection reports (ILO, 2018). Progress of CAP up to February, 2018 has been shown in Figure 4, which denotes that progress in fire CAP is comparatively lower than that of structural and electrical CAPs. Total progress is also higher for owned buildings (33%) compared to the rented buildings (19%).

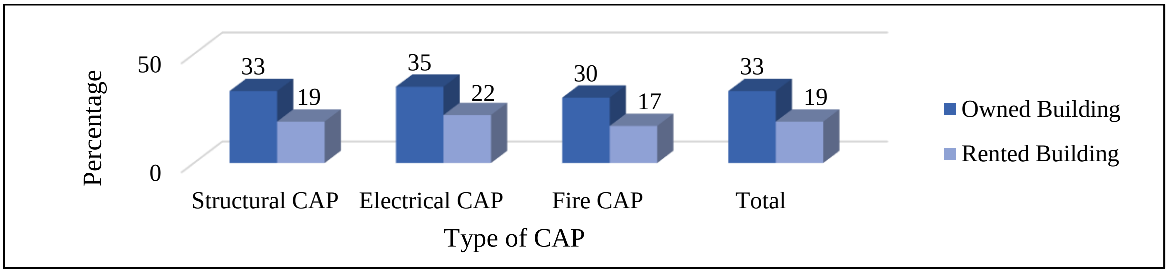

Figure 4. Progress of CAP among NI factories (Data Source: DIFE, February, 2018)

3.4. Approval of Factory Layout: The Labor Law stipulates that factory layouts shall be approved by DIFE. In order to get approval, the factory authority needs to submit necessary documents such as copies of layout, trade license, soil test report, load bearing capacity certificate, structural design prepared by any recognized engineer/engineering agency, building construction certificate and approved building design by local authority to the Deputy Inspector General (DIG). DIG will assign inspectors to submit the inspection report and may approve the design after reviewing the report. The process of registration and issuing of license of factories and establishments is quite similar to the factory layout approval process (DIFE, 2017).

3.5. Recruitment and Qualification of Labor Inspectors: Government has increased manpower from 314 to 993, out of which 575 are inspectors and 284 inspectors are working in DIFE (CPD, 2016). In 2017, the number of inspectors has been increased up to 330 (DIFE Interview, 2017). In order to ensure the effectiveness of inspection services, the recruitment process of AIG (Assistant Inspector General) and LI (Labor Inspector) is done through Bangladesh Civil Service (BCS) examination. For the AIG (safety and general section), minimum educational requirement is B.Sc. in engineering and the AIG under health section must be a doctor. In case of the LIs, minimum graduation is required in any field of science (DIFE interview, 2017).

3.6. Training and Capacity Building of the Labor Inspectors: As part of the reform of DIFE, ILO is working closely with DIFE to improve the capacity of labor inspectors (ILO, 2016). A comprehensive series of capacity building activities, ranging from basic training of newly recruited labor inspectorates to specific training focused on labor law, fire safety assessment etc. have been taking place since January, 2014. DIFE has collaborated with a wide range of partners to provide training including ILO, GIZ, FSCD, BUET and BGMEA (GoB, 2015). The three-and-a-half-year long ILO programme on "Improving Working Conditions in the Ready-Made Garment Sector" launched in October, 2013 is working with an aim of significantly improving the capacity of inspection system in Bangladesh. Training courses under this programme covered a wide range of subjects, including accident investigation, labor inspection strategies, international labor standards, Bangladesh Labor Laws, labor-market related policies and programmes etc. to improve the professional skills of the labor inspectors.

3.7. Preparation of District Database: DIFE has taken initiatives to prepare a database containing the list of factories in different districts of the country. Already this list has been prepared for 23 among 64 districts. Figure 5 shows the type of factories in different districts according to the database. In the database, the factories have been classified into more than 100 types of sectors. These sectors have been categorized into 13 broad categories and represented in Figure 5. From the figure it can be seen that, most of the factories fall under garments and textiles category in all six districts, with the highest percentage belonging to Narsingdi (98.71%) followed by Dhaka (75.10%).

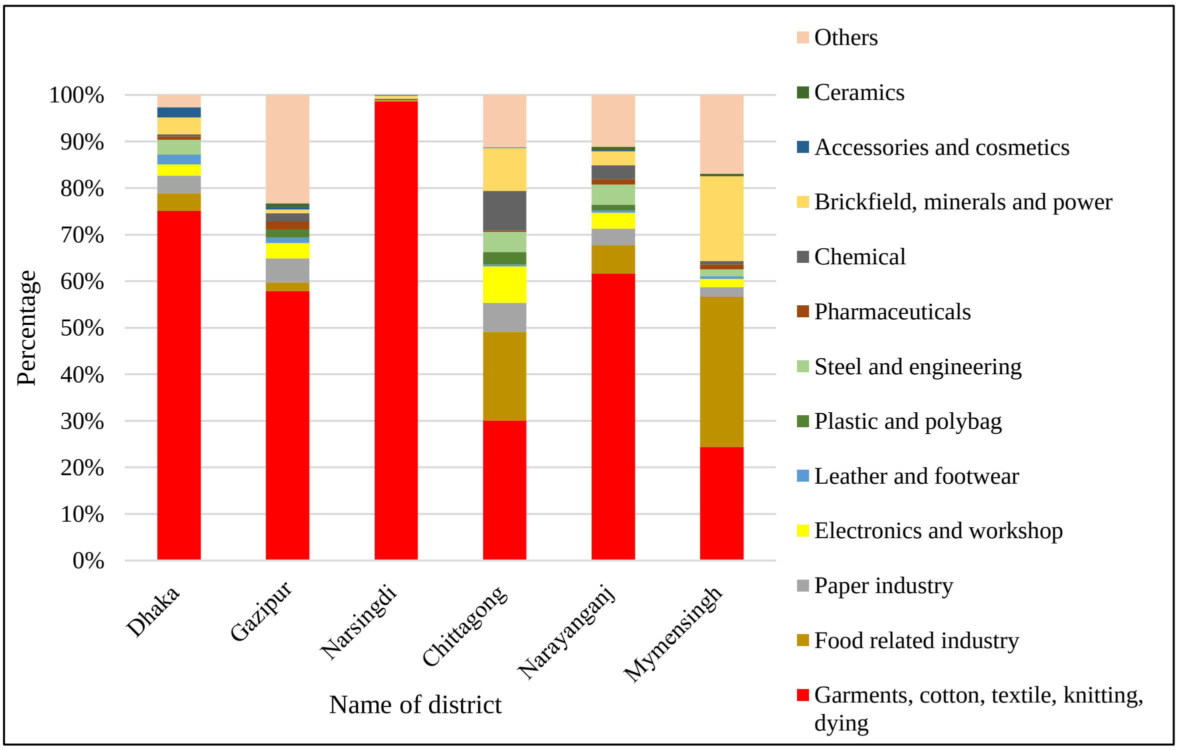

Figure 5. Distribution of factories according to type of sector in different districts
(Prepared by Author, Data Source: DIFE, 2017)

3.8. Ensuring Transparency, Accountability and Workers' Participation: The launch of DIFE website and a publicly accessible data base containing the basic information of 4,808 RMG factories can be remarked as a step forwards towards ensuring transparency (ILO, 2014). According to DIFE, already 2,961 assessment summary reports have been published in the website among which 1,707 reports are prepared by NI, 712 by Accord and 542 by Alliance (DIFE, 2017). But the database is often inaccessible due to technical issues and requires necessary upgrade to be effective. The planned establishment of an accountability unit within DIFE is another major step. Any decision regarding the closing of factories are taken in the presence of stakeholders from BGMEA, BKMEA, BUET and other organizations in order to ensure impartiality. With the assistance of ILO, DIFE has launched a toll-free helpline number for the RMG workers in March, 2015. Through the number, anyone can complain to the government with a view to improving the working conditions which will be addressed by concerned authorities. DIFE has also established an email account to receive complaints or grievances of workers (GoB, 2015).

4. Factory Verification: Are Factories Closed by DIFE Really Closed?

DIFE closes down factories that fail to improve the remediation by the deadline. Then hardly any assessment is done to verify whether those factories are still operating. In order to determine the current status of the closed factories, a survey has been conducted among 37 factories covering 10 areas of Dhaka- Gulshan, Jatrabari, Malibagh, Mirpur, Motijheel, Old Dhaka, Tejgaon, Mohammadpur, Dhanmondi and Badda under the supervision of authors. Interestingly, almost 49% of the "closed" factories are still running. Among them, 83% factories are operating with a new unit name whereas the rest are working with their original names. As seen from Figure 6, the number of factories that are still operational are high in Mirpur, Jatrbabari, Tejgaon, and Mohammadpur.

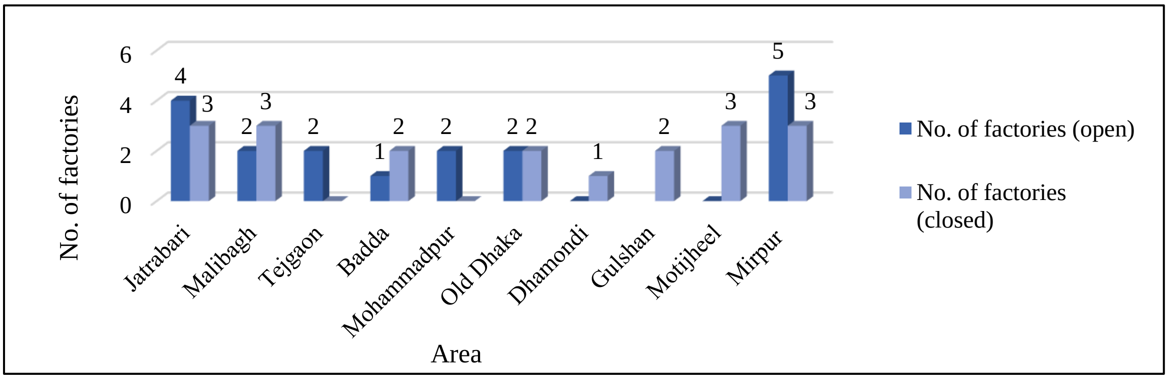

Figure 6. Area wise comparison of running and closed factories in Dhaka among factories closed by DIFE (Data Source: Field Survey, 2018)

5. Challenges and Way Forward

Despite the steady improvements being made and the number of measures taken to improve occupational safety in Bangladesh RMG sector, there is a huge workload on DIFE to deliver concrete and reportable results within a short period of time (GoB, 2015). Major challenges faced by DIFE include the lengthy recruitment process of the inspectors, lack of professional training institutes, lack of adequate labor inspectors, procurement of equipment, lack of monitoring activities and coordination among different stakeholders. Database management and regular update of database is another key challenge for DIFE. There is no dedicated member or staff at DIFE responsible for the data collection, compilation and upgradation process. Currently the data compilation and record-keeping take place based on a paper-based system which has certain limitations. Technological upgradation, procurement of new computers, and more recruitment of staff in the Statistics Cell are required for the establishment of a more modernized and efficient system of data collection and management. In order to make visible progress and facilitate inspection process, priority should be given towards increasing the number of labor inspectors. According to BBS, district offices must be established in 64 districts in order to cover 80 lakh economic units of the country. Therefore, more district offices are needed to be established to conduct inspection in a systematic manner. Overall, DIFE holds substantial potential in creating a safe workplace in RMG industries of Bangladesh. More attention is required in the field of manpower, capacity building, technical advancement and monitoring of closed factories to properly execute the national and international commitments directed towards safety compliance.

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ORGANISATIONAL LEARNING ACCRUED THROUGH 'ACCORD' AND 'ALLIANCE' LED INITIATIVES: CAN WE TAKE THE LESSON FOR THE FUTURE?

Khondaker Golam Moazzem[1]

1. Introduction

The formation of 'Accord' and 'Alliance' in 2013 and their activities for workplace safety in the RMG sector afterwards are the important organizational learning for Bangladesh. For the first time, stakeholders of the RMG value chain have experienced with new form of compliance assurance – first, brands/retailers/buyers and international trade unions have directly involved in ensuring workplace safety at the manufacturers' end; second, local entrepreneurs have experienced with requirement of high level of safety standards and their maintenance at their own factories; third, local public agencies appreciated the gaps in monitoring and enforcement mechanism that they follow and requirement of improvement of their process; fourth, workers of RMG enterprises able to understand the safety related issues and concerns and how to respond in case of emergencies in the factories. Such organizational learning in Bangladesh's RMG industry have encouraged global brands/buyers to replicate those in other apparel manufacturing countries. The key issue is - how to institutionalize of such learning with a view to develop an effective monitoring and inspection mechanism in the future.

After five years of operation, both the initiatives have entered into a transitional phase as the initiatives of Accord and Alliance are going to end in 2018. Given the remediation works remain in factories, both Accord and Alliance will extend their timeline to complete their works; however, Accord is willing to extend their operation beyond limited time period but Alliance is not willing to extend their contracts after that. During 2017, a new body has been formed under the Directorate of Inspection of Factory Establishments (DIFE) of the Ministry of Labour and Employment (MoLE) with a view to oversee the progress of remediation related activities initially those factories under the National Initiatives and gradually other factories including those under Accord and Alliance. Creation of RCC is very important in order to take over the charge by public agency; at the same time, this set up is expected to deliver the services maintaining the quality and standards. The point is – how quickly the newly formed RCC could accumulate the organizational learnings accrued through Accord and Alliance and will be able to deliver the expected level of services and thereby become an effective monitoring agency in Bangladesh?

2. Major Institutional Learnings Accrued through Accord and Alliance led Initiatives

During the last five years, a number of uniqueness have been revealed through the private sector led initiatives of Accord and Alliance. These include, among others, formation of the private entities with the participation of major brands, retailers, buyers and international trade unions for monitoring safety standards of a major sourcing country, harmonizing the national rules and regulations concerning workplace safety of Bangladesh within a short time, setting up standard operating procedure (SOP) for monitoring and inspection and review and following up of remediation works of factories on a timely basis. The safety concerns of backward linkage activities of the RMG enterprises (such as textiles, accessories etc.) had been excluded from these monitoring and inspection which also need to be taken into due consideration.
Besides, both the initiatives have prepared corrective action plans (CAP) for each of the factories based on the problems identified in the factories and made those public through their websites.

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The progress of remediation related works of each factory has also been made public. Both the initiatives made timely review of remediation related works and based on the progress gave necessary pressure to factories for timely completion of their remaining works; in extreme cases where factories unable to comply with target level of remediation works, business ties with those factories have been cancelled. On the other hand, factories successfully completed the remediation related works received 'Letter of Recognition' from the private initiatives.

It is fact that the process of work followed by private initiatives has to get positive node (though informal in nature) from the stakeholders particularly that of employers, which was not so smooth all the time. The first work of Accord and Alliance was to consolidate national rules and regulations related to fire, electrical and building integrity. Based on the national rules and regulations including Bangladesh National Building Code Act, Bangladesh Labour Act 2006 and other national rules, a comprehensive document was prepared. In case of insufficiency in local rules, both Accord and Alliance took support from international rules/guidelines which further strengthen the overall safety standards. However, those inclusion in the operational guideline was not so welcome by the entrepreneurs because of requirement of huge additional investment in order to comply with the new standards. However, ultimately entrepreneurs accepted those new standards and did necessary investment for improvement of compliance standard.

Both the initiatives follow almost similar types of standard operating procedures for inspecting factories such as inspection checklists, standard level of compliance of different safety measures, testing requirements, timeline for remediation, reporting of problems, public reporting of non-compliance, review mechanism, notice period, level of warning and cancellation of contractual ties in case of non-compliance etc. Entrepreneurs were initially quite apprehensive about public reporting of non-compliance of their respective factories which might have adverse effect on their reputation; however, such reputational risk of public reporting did not happen, rather employers benefitted through reporting of their compliance related information. Most importantly, such public reporting of state of compliance of inspected factories has ensured transparency about the initiatives and made the concerned stakeholders more accountable.

According to the last available report of Accord and Alliance, a significant part of problems has been remediated by the factories. In case of Accord inspected factories, 85.4% of electrical, 76.4% of fire related and 65.4% of structural problems have been addressed while the respective shares in case of Alliance inspected factories are 89%, 85% and 78% respectively. In both cases, factories are relatively slow in remediating structural problems because of difficulty in addressing their concerns. Besides, Accord and Alliance have taken initiatives to better aware workers about the safety standards of factories by setting up safety committees at the enterprise levels as well as introducing hotline for workers. Those initiatives contributed a strong supplementary role in addressing the safety concerns at the factories.

3. Institutionalisation of Organization Learnings of 'Accord' and 'Alliance'

Such detailed organisational learnings through the initiatives of Accord and Alliance has strong elements to be institutionalised with a view to make them sustainable. Theoretically, organisational learning is a cyclical process through which knowledge that is learned on an individual or group level is objectified on the organisational level, institutionalized and embedded in the organisational memory (Wiseman, 2007). There is a 4-I Framework of organisational learning (developed by Crossan, Lane and White, 1999) which identifies four main processes including 'intuiting', 'interpreting', 'integrating' and 'institutionalising'. Figure 1 presents different steps of organsiaitonal learning and role of stakeholders in different steps.

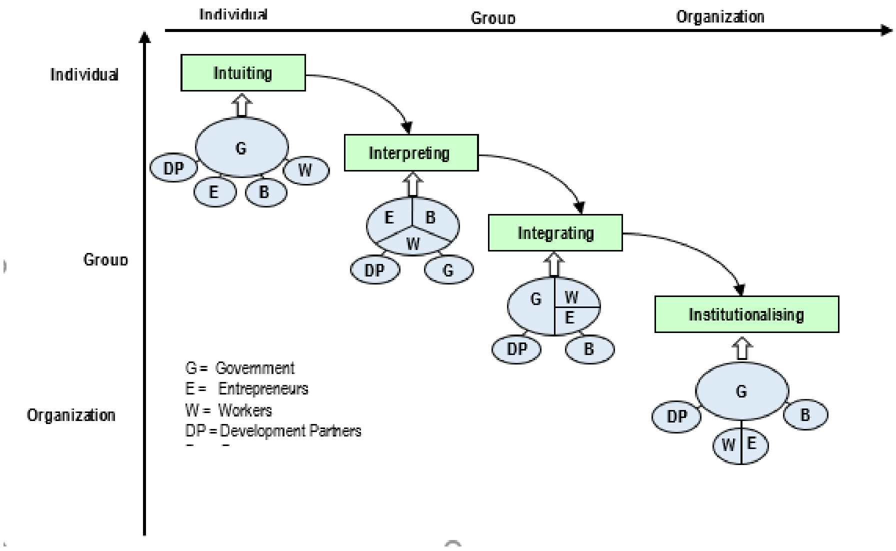

Figure 1. Steps of Organisational Learning and Roles of Stakeholders

Analysis of the activities of Accord and Alliance reveal that their completed works resemble the first two phases of institutionalization such as 'initiation' and 'interpretation'. The third phase of this process, i.e. 'integration' needs to be initiated which will be followed by the final phase i.e. 'institutionalization'. With the end of the initial commitment period of Accord and Alliance and thereafter, initiation of the work of Remediation Coordination Cell (RCC) under the DIFE of the MoLE, the process of integration has been started. This specialized cell will work in the transition phase and meet the requirement. The objective of this Cell initially would be to monitor and inspect and review the progress of remediation related activities of factories earlier inspected under National Initiatives. The Cell will gradually take over the responsibility of factories under Accord and Alliance led initiatives and ultimately take charge of inspection related activities of all industrial enterprises in Bangladesh.

In this context, a number of issues need to be taken into due consideration with regard to the capacity of the public agency to inspect and monitor factories as par the standard set by private initiatives: a) Is there adequate technical, human resource, organizational capacity to monitor, inspect and review and ensure compliance at global standard by public agency? b) Are buyers/brands accept the inspection reports to be prepared by the local agencies and continue their businesses with local suppliers? c) Should the private agencies (such as Accord or other private agencies) be involved in facilitating the monitoring works of the Public agencies; what kinds of arrangements would work well in this regard? d) In case of a transition period, what should be the arrangement between public and private agencies in dealing with current and future safety concerns of RMG factories?

4. The Arrangement for Transition Period

The ultimate objective should be to strengthen the monitoring and inspection capacity of public agencies. Given the limited capacity in terms of human resources, technical issues and database management, public agencies need to be get ready under a targeted timeline with specific objectives and action plans. The RCC has been formed with the long-term objective to inspect factories maintaining global standards. Hence RCC needs to be equipped with competent human resources, technologies, skills, logistics, testing facilities, adequate resources and database management system. Despite strengthening RCC, it is not technically feasible to monitor and inspect all factories by this lone agency as this would require large scale investment in RCC. Considering the level of competency available at the private sector, it would be better to undertake their services under the arrangement of public-private partnership (PPP) where public agency will be in charge of overall supervision of the monitoring process and private agencies to be accredited by the public agency will undertake monitoring and inspection related works. Such an arrangement will ensure quick monitoring, better reporting and more transparency. Besides, it is important to integrate the brands and buyers in the process of compliance assurance. The ultimate objective is to ensure workers' safety and security initially to export-oriented sectors and gradually to other sectors and risky activities.

FIRE SAFETY IN THE READY-MADE GARMENT INDUSTRY IN BANGLADESH, FIVE YEARS AFTER RANA PLAZA

J.W.F. Wiersma[1]

ABSTRACT

On November 22, 2012 a fire broke out in the Tazreen Fashion Ltd. Garment factory in the Ashulia District, Dhaka, Bangladesh, killing 112 people. In response to this deadly fire, A National Tripartite Plan of Action (NTPA) was agreed between government, employers and workers in March 2013, to improve fire safety in the Ready-Made Garment (RMG) industry in Bangladesh. After the collapse of the Rana Plaza building, only five months later on April 24, 2013, this NTPA was extended, to include structural integrity. Since then, a host of activities have been carried out to improve fire safety in the garment industry. In the immediate aftermath of Rana Plaza, the Bangladesh Accord on Fire and Building Safety (Accord) and the Alliance for Bangladesh Worker Safety (Alliance) were established. As part of their activities, the current regulation and standards were revised and harmonised, and all exporting RMG factories producing for brands and retailers that were signatories of the Accord, or member brands of the Alliance, were inspected on structural, electrical and fire safety, using the revised standards. Following the inspections, remediation programs were set up by the Accord and the Alliance, to monitor the progress of factories in remediation, and support them to achieve the appropriate quality of remediation work. Exporting factories that were not inspected by these two initiatives have been inspected by BUET and several international consultant firms under the National Tripartite Committee (NTC). Recently, a Remediation Coordination Cell (RCC) has been established under the National Initiative (NI), to monitor progress of remediation on fire safety for these factories. With regard to fire safety, important shortcomings were identified throughout the industry, following from outdated regulation and lack of a proper inspection regime. This paper examines what improvements the RMG industry has been able to achieve since 2013, and what challenges still remain. An impressive progress has been made in improving factories on fire safety, under a strict regimes of Accord and Alliance. However, not all factories are covered under these initiatives, and the remaining factories show far less progress. Governance by the competent authorites is still under development and there still is a severe lack of knowledge in fire safety engineering capability. The total number of fires in factories decreases slowly. To make improvements in the industry sustainable, and to extend them to the whole RMG value chain, will take a careful process, that will need several more years.

1. Background

Factory fires are a recurrent problem in the garment industry in Bangladesh. At least 33 major fire incidents at garment factories occurred between 1990 and 2012, claiming more than 450 lives (BILS, 2015). The deadliest fire in this series was that at Tazreen Fashions Ltd. in Ashulia, in the Dhaka district, on November 22, 2012, where at least 112 workers lost their lives and many more were injured (MoLE, 2013b). The tragedy made headlines in the international press (Bajaj, 2012; Burke & Hammadi, 2012) and on TV (BBC, 2012; CNN, 2012), highlighting to the world the dangers facing garment workers in Bangladesh that were producing cheap clothes for the high streets in Europe, the USA and elsewhere.

2. Response to the Fires

In response to this fire and previous ones, the National Tripartite Plan of Action (NTPA) was agreed between government, employers and workers in March 2013, with the objective to improve fire safety in the Ready-Made Garment (RMG) industry in Bangladesh (MoLE, 2013b). Only five months after the fire at Tazreen factory, on April 24, 2013 the Rana Plaza building collapsed in Savar, in the Dhaka district, due to severe structural deficiencies resulting from a series of violations in building construction (Ansary & Barua, 2015).

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1135 People were killed in the collapse or died later in hospital of their injuries, and many more were injured, leaving hundreds of people permanently disabled (BILS, 2013). This makes Rana Plaza the deadliest accidental structural failure in modern human history. After the Rana Plaza disaster, the National Tripartite Plan of Action was extended to also include structural integrity (MoLE, 2013a).

Since then, a host of activities have been carried out to improve fire safety in the garment industry. In the immediate aftermath of the Rana Plaza building collapse, the Bangladesh Accord on Fire and Building Safety (Accord) was signed on May 15, 2013. The Accord is a five-year independent, legally binding agreement between global brands and retailers and trade unions designed to build a safe and healthy Bangladeshi RMG Industry[2]. A few months later, on July 10, 2013, the Alliance for Bangladesh Worker Safety (Alliance) was established. The Alliance also constitutes a five-year legally binding agreement to improve worker safety and contribute to the long-term viability of this important Bangladesh industry[3]. Members of the Alliance are 29 North-American companies.

3. Inspection of Factories

An important element of the activities of the initiatives was the independent assessment of the structural integrity, fire safety, and electrical safety of all RMG factories, active in the export. Accord an Alliance were responsible for the inspection of factories producing for their signatory and member brands. Initial inspections were conducted by international engineering firms contracted by the Accord and Alliance. Factories were inspected against the Accord and Alliance Building Standards, which are largely based on the Bangladesh National Building Code and the product of discussions facilitated by the ILO between the Accord, the National Tripartite Plan of Action, and the Alliance (Accord, 2013; Alliance, 2013). Assessment of the remaining factories fell under the responsibility of the NTC. Under the NTPA, the Guidelines for Assessment of Fire and Electrical Safety of Existing RMG Factory Buildings in Bangladesh were developed (NTPA, 2013). Comparison of Accord and Alliance Standards, and the NTC Guidelines to the prevailing regulation in Bangladesh is the topic of one of the other studies in this symposium (Barua, Wiersma, & Ansary, 2018b). The Standards and Guidelines were used to inspect all exporting RMG factories. Inspections were initially conducted by Bangladesh University of Engineering and Technology (BUET), later inspections were conducted by international engineering firms.

In total 4127 factories were inspected, 1819 by the Accord (Accord, 2018); 759 factories were inspected by the Alliance (Alliance, 2016); 1549 factories were inspected under the NI (DIFE, 2018). There is overlap in the numbers of inspected factories, some factories have been inspected by more than one programme, while other factories have had different programmes inspect different aspects (structural, electrical or fire safety). According to the DIFE, who keeps an online database[4], the total number of inspected factories is 3780 (up to September 2015) (DIFE, 2018). Factories working for the local market and factories that only work as a subcontractor were not submitted to an inspection. According to a report by NYU-Stern in 2015 many of these factories produce for export through their sub-contracting activities. The report estimates the real number of exporting factories to be over 7000, divided between direct and indirect sourcing. (Labowitz and Baumann-Pauly, 2015).

Inspection reports for Accord and Alliance factories are available online[5,6], and provide a wealth of information on the state of fire safety in the RMG in Bangladesh since 2013; for the results of the initial inspections as well as for the progress made since then. For NTC factories, only summary reports are available

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[2] *http://bangladeshaccord.org/about/*
[3] *http://www.bangladeshworkersafety.org/files/Alliance-Action-Plan-Package-FINAL.pdf*
[4] *http://database.dife.gov.bd/reports/safety-assessment-reports*
[5] *http://accord.fairfactories.org/ffcweb/Web/ManageSuppliers/InspectionReportsEnglish.aspx*
[6] *http://www.bangladeshworkersafety.org/factory/reports-caps*

on the website of the Department of Inspection for Factories and Establishments (DIFE) of the Ministry of Labour and Employment (MoLE), but these reports too give a good understanding of the fire safety in the factories[7].

For a quick overview the, Accord publishes Quarterly Aggregate reports, describing the remediation progress at the factories covered by the Accord[8]. According to the Accord reports, the original inspections uncovered 33.397 issues on fire safety[9], and 10.930 more issues in follow-up inspections[10], an average of more than 24 issues per factory[11]. The numbers for the other programmes can be expected to be comparable. Most findings reported are common to many factories:

- 97% of Accord factories lacked safe means of egress. Lockable/collapsible gates, storage blocking exits and inadequate egress lighting were the most common hazards.
- Exit stair openings, the fire pump rooms, warehouses and storages were the most common areas identified in factories as lacking a proper fire separation.
- 91% of factories required an adequate fire detection & alarm system. (Accord, 2018).

4. Remediation Process and Progress

Remediating the deficiencies in the factories, uncovered by the inspections, is a monumental challenge. The serious, widespread, high risks with regard to fire safety throughout the industry made very clear that the RMG industry in Bangladesh had no grasp on fire safety and lacked basic understanding of the fundamentals of modern fire safety engineering and management.[12]

As a first step in the remediation process, factory owners had to develop a Corrective Action Plan (CAP) detailing remedial actions with clear timelines and a financial plan, as well as the progress on the remediation, as far as they have been verified by Accord and Alliance. CAP's are available online on the Accord[13] and Alliance[14] websites, alongside the inspection reports. Accord and Alliance have setup organisations and trained engineers as case-handlers to provide technical guidance to factories, and to monitor the progress made by factories, through conducting verification visits, where corrective actions are verified. To comply with the strict Standards of Accord and Alliance, most fire safety equipment has to be imported from abroad. There was (and to a large extend still is today) no industry in Bangladesh available of producing the fire safety equipment certified to the required international standards.

For factories not falling under Accord and Alliance supervision, a Remediation Coordination Cell (RCC) has been established in 2017 under the National Initiative (NI) The RCC will oversee the remediation of 1293 non Accord and Alliance factories (ILO, 2017). It is planned that most remediation will have been completed

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[7] *http://database.dife.gov.bd – not online at days of writing.*
[8] *http://bangladeshaccord.org/progress/*
[9] *Number of issues based on published Corrective Action Plans (CAPs) only*
[10] *New issues arise when new factories are listed by Accord signatories, or when new issues are discovered in follow-up inspections.*
[11] *The findings cover a wide range of issues, and are not categorised according to risk, or costs of remediation. Issues range from* "Storage was located in the egress path.*" to* "The exit stairs are not separated from work areas, and other spaces on each floor by fire rated construction. This was reflected throughout the building on all floors.*" to* "The fire alarm system is antiquated, not a listed system, and does not provide alarm and notification features consistent with acceptable standards.*"*
[12] *This lack of knowledge stretched far beyond the RMG industry. The government oversight was largely reactive, and much less aimed at prevention of or early control of fire incidents. Also, there was no proper education in the fields of fire engineering and management or safety engineering and management in Bangladesh.*
[13] *http://accord.fairfactories.org/ffcweb/Web/ManageSuppliers/InspectionReportsEnglish.aspx*
[14] *http://www.bangladeshworkersafety.org/factory/reports-caps*

in 2018. It is unlikely that this target will be met though, since the activities of this RCC with regards to remediation of fire safety in the factories so far have been limited.

Looking at the progress of the Accord and Alliance programmes as reported in their progress reports, the results after five years are impressive. The last published report on the Alliance website is the Annual report 2017 (Alliance, 2017). According to this report, as of November 10, 2017, the Alliance has 658 active factories. 234 Factories have achieved substantial completion of their Corrective Action Plans. Remediation of 85 % of all items has been completed, including 80% of high-priority items (ibid, p.3), including 85% of issues relating to fire safety (ibid, p.5). The Accord shows equally impressive results on progress. The latest update on progress and remediation (April 2018) shows the steady progress in remediation since March 2015[15]. In April 2018, 84% of issues identified during initial inspections has been remediated. For the findings on fire safety out of 33.584 initial findings 74% has been corrected, 8% is pending verification, and 18% is in progress. For the findings on fire safety out of 11.687 findings from follow-up inspections 62% has been corrected, 13% is pending verification, and 26% is in progress.

The progress on remediation of the remaining factories (i.e. factories under the NI) is unknown. Despite several requests for information over a period of six months to the competent authorities, the author has until April 2018 not received any information on the progress of factories falling under the RCC.

5. Suspension, Termination, and Closure of Factories

Factories that do not follow through on the remediation process can be suspended (Alliance) or terminated (Accord) for reasons of workplace safety. Accord signatories and Alliance members have committed to only "work with factories that ensure a safe working environment". Factories that fall behind too far in the remediation process, or otherwise do not fully participate in the programme can be suspended, and eventually terminated, after an escalation procedure. Accord signatory companies and Alliance members are required to terminate business with these supplier's factories. Both procedures and a list of terminated factories can be found online. At the date of writing the Alliance list of terminated businesses contains 151 factories, the list of Accord contains 93 suppliers with each one or more production locations[16.17].

Suspension and termination by Accord and Alliance does not mean that factories have to stop producing al together. It merely indicates that signatories of Accord and Members of Alliance cannot source from the factory. The factory can still produce for buyers that are not part of these programmes, or work as a subcontractor. Supervision of these factories becomes the responsibility of the NI.

A large of number of factories have closed their doors in the past years, due to a range of circumstances. According to the figures of the DiFE, out of 1549 factories falling under the NI, 531 have closed, while another 68 have relocated (DIFE, 2018). The Alliance website mentions another 14 factories, closed for different reasons[18]. The RMG market is very competitive internationally and buyers are always looking globally for the lowest cost of production. The RMG is a dynamic, global marketplace, so there is a constant pressure on margins. Not all factories can maintain their business, and subsequently close their factories, temporarily, or permanently. This may be account for a number of the closures. Another reason for closing factories is that factories are moving to new locations, to newer and often larger buildings. Often the costs of remediation of the old building is a factor in speeding up the process of moving to a new location. It is unclear what happens to the buildings where factories had been located after the factories relocate. It is assumed that other factories take over the location, sometimes also exporting factories, sometimes only producing for the

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15 http://bangladeshaccord.org/progress/
16 http://www.bangladeshworkersafety.org/factory/suspended-factories
17 http://bangladeshaccord.org/terminated-suppliers/
18 http://www.bangladeshworkersafety.org/factory/suspended-factories

local market or subcontracting. This form of "downscaling" clearly does not improve overall safety, since the same fire risks are now the responsibility of another company, only working under another name.

Not all factory closure is voluntary. As part of the activities under the NTC, A review panel along with a review mechanism was also established in 2013, to handle urgent safety issues in garment factories, under all initiatives, Accord, Alliance and NI (Ansary and Barua, 2015). The activities of this review panel with regard to structural safety have until 2015 led to the partial closure of 17 factories (divided over 10 buildings), and the complete closure of 29 factories (divided over 12 buildings), affecting in total 16.623 workers (Ansary and Barua, 2015). Considering the gravity of the findings of the inspections, one could expect at least an equal number, if not many more, factories would have been closed immediately due to the high fire safety risks. However, this has not occurred. There is no public information available, showing that any of the factories has been closed for high risks on fire safety. The rationale for this reluctance to close factories, is the economical and social unrest caused by closure, that would have been generated when a large number of factories would have to close their business, and workers would lose their jobs. Of course not using the ultimate sanction on factories does in no effect release factory owners from the duty to remediate the fire safety risks.

6. Fire Incidents Since Tazreen Fashion Fire

The success of the interventions in Bangladesh cannot be measured by the amount of remedial action taken as described above alone. The real success depends on the question if the number of fires and their severity has decreased. Until 2013, factory fires with casualties were frequent, but largely unreported (Burke, 2013). Data on factory fires are collected by NGO's from public sources, including newspapers and the internet.
A report compiled by the American Center for International Labor, AFL-CIO presents the fire incidents since the fire at Tazreen Fashion up to April 2017 (Solidarity Center, 2017). This list has been updated with the latest incidents and scrutinized. For this study incidents that are not fire-related (i.e. boiler explosions, collapse) are excluded, while fires in garment-related facilities, such as warehouses and textile mills are included, since they are part of the garment value chain. The results are presented in *Figures 1* and *2*.

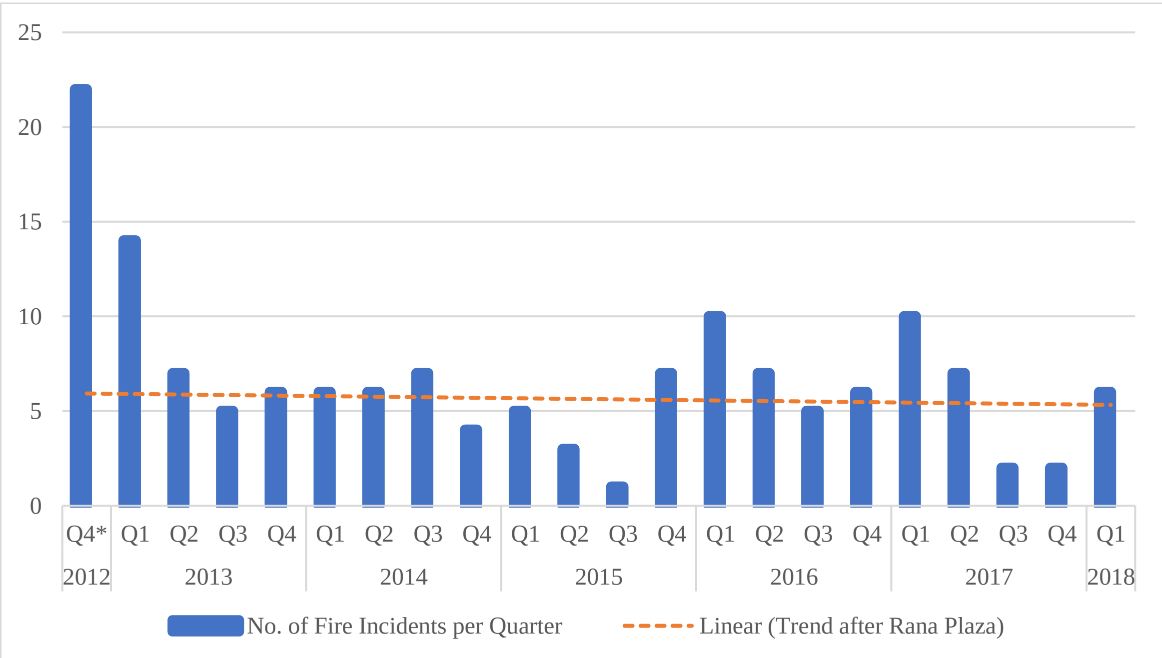

Figure 1: Total of fire incidents in the garment industry in Bangladesh since Tazreen Fire (adapted from solidarity center, 2017)

Figure 1 shows the number of fire incidents per Quarter year since Tazreen Fashion fire until present (April 2018)[19], with a linear trend line for the period after Rana Plaza. The trend in *Figure 1* is downwards, but to a very small extent (y = -0,03x + 5,96, R^2 = 0,0051). This indicates that the total number of fires is decreasing very slowly. *Figure 2* shows the number of fire incidents per Quarter year since Tazreen Fashion fire until present (April 2018)[20] in which at least one person was injured or died, with a linear trend line. The downward trend in *Figure 2* is more pronounced (y = -0,16x + 4,27, R^2 = 0,2908), indicating that the number of serious fires is decreasing at a higher rate than the overall number of fires. The careful conclusion of *Figures 1* and *2* is, that the number of fire incidents decreases slowly, and the remaining fires also decrease in gravity, but that it is too early to become complacent. Extra efforts to bring down the number of fire incidents are still needed.

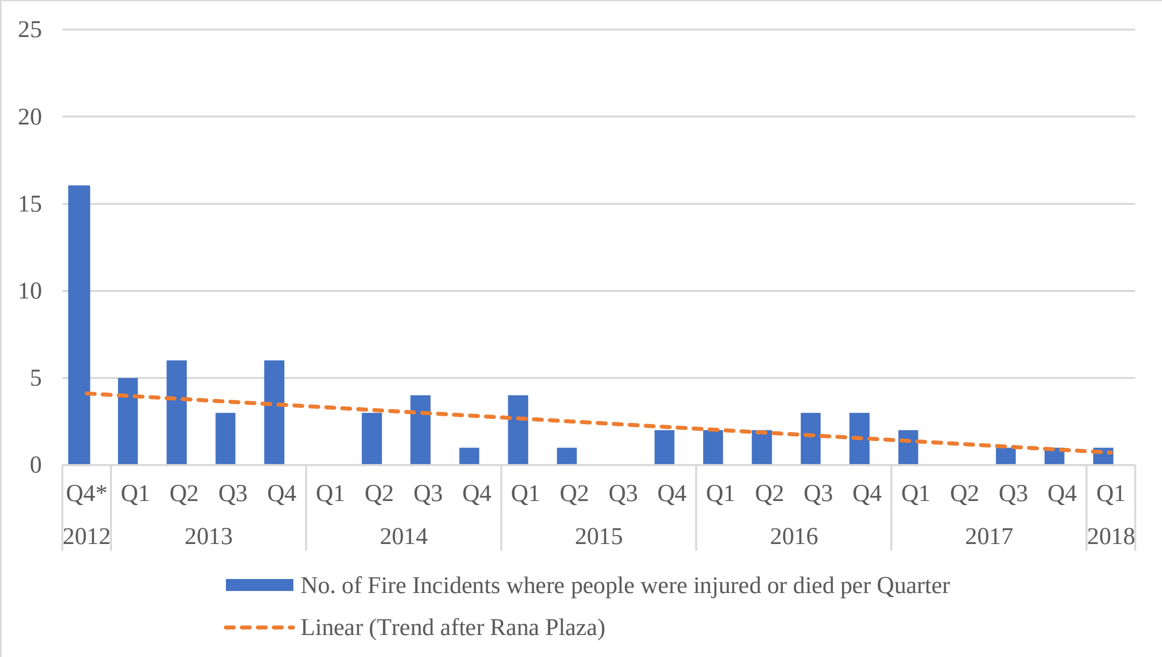

Figure 2 Fire incidents with one or more victims (injured or dead) in the Garment industry in Bangladesh since Tazreen Fire (Adapted from Solidarity Center, 2017)

7. Field Observations: Factory Visits

Over the past six months (October 2017 - April 2018), attempts have been made to complement the study of documents with field observations. A request was made to the DIFE to organise visits to 10-15 factories, with a broad variety: under different programmes; rented and factory-owned buildings; industrial and commercial buildings; large and small factories, etc. In the period from October 2018 until April 2018, three visits were conducted with support from the DIFE, who selected the factories, and accompanied the researcher during the visits.

The researcher – i.e. the author of this paper - is not a certified fire safety engineer or inspector but has visited many RMG factories in Bangladesh with inspectors and auditors over the past five years, to monitor progress with regard to safety. The visits were explicitly announced not to be inspections and were not directly focussing on (non-)compliance issues.

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[19] *Fire incidents for Q4* of 2012 shows only partial results, the counting starts after 22 November 2012*
[20] *Idem.*

To stay away from the compliance discussion, a functional approach was taken. Construction separation and compartmentation are well established structural fire safety engineering concepts, that are very relevant in preventing the spread of fire and smoke, and in creating safe routes of egress for workers in case of fire. However, in the RMG industry of Bangladesh before 2013 these concepts were not commonly applied. RMG factories in Bangladesh could basically be considered one large fire compartment, without separation between floor. In many factories, stairs were functionally more considered as a channel to supply the factory floors with fresh air, than as safe path of egress, which needed to be shielded off. As a result, the initial inspection reports of Accord, Alliance, and NI show that nearly all RMG factories lack proper separation constructions and fire doors. For this study, separation and compartmentation were used as a case to illustrate the progress and the challenges of the RMG industry.

All three factories visited were in the process of remediation, none of the factories had completed their remediation under Accord or Alliance. All three factories had major issues with regard to fire separation. Even when fire doors had been installed, they often were unfunctional. This was sometimes achieved by installation of sub-standard material or incorrect installation, sometimes by carrying out structural remediation after the installation of fire doors – which annihilated the effect of the fire doors, sometimes by keeping fire doors open - for fresh air or transportation of materials and finished products -, with help of bricks of rope, because closed doors were hindering the operation of garment production. Moreover holes in walls or floors could be observed, due to new or old electric installation work or modification of factory layout, that were not filled up. Factory managers seemed keen to comply with the requirements from Accord, or DIFE, without considering or understanding the underlying principles.

It adds up to the conclusion that although remediation measures are being taken, and remediation is underway from a compliance perspective, the functional requirements of compartimentation and separation are not being achieved in the factories, or even aimed for. None of the issues uncovered here would ever be accepted by Accord inspectors, so these factories would not be cleared, but factory management seemed unworried working under these conditions, and factories were also able to show BGMEA, or FSCD fire licenses, given them the impression that it was safe to operate. Inspections that they have endured in 2013-2015 with a subsequent lack of proper follow up in the years thereafter, may have given factory owners of high risk factories the false suggestion that their factories are somehow “safe enough”, since they are allowed to operate, and receive licenses to do so.

8. Other Observations

Since 2013, factories supplying to Accord and Alliance brands have had to follow a rigorous scheme of inspection and remediation. At the same time, factories that do not fall under these programmes have for the larger part of the past five years, been allowed to operate under pre-2013 conditions – conditions that everybody agrees are very sub-standard with regard to fire safety. This has widened what a recent NYU-Stern report calls the *bifurcation of the industry*. “An elite segment of suppliers can afford to make improvements and continues to enjoy relationships with international brands and retailers. Much of the rest of the industry either cannot or will not make expenditures to enhance safety and, as a result, workers in this segment remain at risk.” (Barrett, Baumann-Pauly, and Gu, 2018).

Large part of the sub-standard factories are housed in converted commercial buildings, on the upper floors of buildings with shops on the ground floor and lower levels. Often these factories are housed in buildings that they do not own, and buidling owners do not take responsibility for the safety of the factory and it’s workers. Even though they often do allow factory owners to carry out remedial activities, factory owners have to make these improvements at their own expenses. Moreover, since factory owners only occupy part of the building, it is very difficult to implement a safe solution. These buildings were not designed for industrial use, and several have been closed for lacking structural integrety. With regard to fire safety the risks of these buildings may be even larger than the issues of strucural interity. The factory lay-out is often inherently unsuitable for the evacuation of large numbers of workers in case of fire, because of complex lay-out, limited egress routes, sometimes leading into the building, not to the outside. In the past exits were closed and locked with gates, a practise that has reduced since the Tazreen Fashion fire. Physical removal of the gates is a requirement in the new standards, but is not implemented everywhere.

Over the past five years, many of these factories have closed their doors. However, a number of these factories still operate today. Sometimes they do so under the same name, sometimes under a different name. Sometimes these factories have switched from export to local market. A comprehensive overview of this segment is absent.

The case made in (Barua, Wiersma, and Ansary, 2018a) about factories that should be taken out of production immediately due to their imminent risks with regard to structural integrety, can equally strong be made about fire safety, except in this case the factories that pose the highest risks (the “rotten apples”) have not even been properly identified.

9. Discussion of Next Steps

Without a shadow of a doubt, a lot has been achieved over the past five years to improve fire safety in the RMG in Bangladesh. However, it is by far too early to state the at present the RMG is safe with regard to fire safety. A lot of remedial work still needs to be conducted. The model that has been developed by Accord and Alliance for the remediation process appears to be functioning well in getting the necessary remediation implemented up to a good level. Continuing inspections of Accord discover new issues, that may have been missed in earlier stages, or that have developed since the last inspection. Remediation of these issues is implemented with the same rigour.

After completion of the initial CAP, the factory is not finished with “the safety issue”, but merely ready to start working safely. Continuous attention to safety remains a prominent requirement for factories – Always. Factories need to learn to set up an internal system for the management of safety, as well as a system for maintaining the safety related installations – just as they must have for production related equipment. Without such systems a very quick relapse to the old situation is to be expected.

Under the Accord an Alliance programmes, capacity has been build of organisations and trained engineers that have a proven record of properly inspecting factories and supporting remediation up to a high level. However, the foreign-run programs will not continue forever. At some point in time, the Bangladeshi government will inherit responsibility for all factories and workers. It is important that the competent authorities in the Bangladesh governement develop equally strong organisations, with equally strong procedures. Activities are underway in developing this capacity under the RMGP programme of ILO (ILO, 2017), but there are major challenges in achieving that (Tarannum and Ansary, 2018). IIn that context, it seems wise to keep the Accord ongoing, until the government has a proven track record that they can achieve the same solid results.

Transparancy is a very powerful tool for improving safety. It allows benchmarking between suppliers of garment production, and offers Civil Society information to hold stakeholders accountable. The Accord and Alliance website offer a wealth of information on the safety progress of factories. The Dife website is a good start, but the information is limited, and the website is often unavailable. Transparacny on the side of the Accord and Alliance put a spotlight on the intransparancy that is still present in other parts of the production chain. It is difficult to get complete, reliable information on the progress outside Accord and Alliance. Especially information on factories that are not officially exporting is very hard to find. Attempts have been made to collect this information, such as a study by NYU-Stern in 2015 (Labowitz and Baumann-Pauly, 2015), suggesting that there are thousands of factories and other production facilites in the garment chain, that have not been inspected. Efforts to increase transparancy in the garment supply chain, such as the recent meeting "Transparancy in Apparels"[21] should be fully embraced.

The capacity developments that are required to achieve a sustainable improvement of fire safety demand a large effort from educational institutions, to educate engineers and managers capable of accomplishing the transformation. Until now, no education programs have been implemented to achieve this capacity building. Certificate courses and other short courses have been developed, but no comprehensive programs. Without strong emphasis on developing and delivering necessary education on fire safety engineering, and safety management, to name just a few, the results of the programmes to improve the safety in the factories will prove to be unsustainable.

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ON THE GUIDELINES FOR ELECTRICAL SAFETY AUDITS IN RMG INDUSTRY OF BANGLADESH

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ABSTRACT

An aftermath of the catastrophic incidence of fire in Tazreen Fashions in 2012 and building collapse at Rana Plaza in 2013 is the introduction of a number of international and national initiatives in order to ameliorate the fire, electrical, and structural safety scenarios in the Ready-Made Garment (RMG) industry of Bangladesh. These initiatives include international organizations such as the ACCORD on Fire and Building Safety in Bangladesh and the ALLIANCE for Bangladesh Workers Safety, and the National Initiative under the National Tripartite Plan of Action (NTPA) on Fire Safety and Structural Integrity. Ensuring electrical safety is essential not only to prevent electrical shocks or accidents and subsequent injuries and deaths, but also to reduce the number of fire incidents by a great extent. According to the Fire Service and Civil Defense Authority (FSCDA) of Bangladesh, the majority (about 75%) of the past events of fire accidents in the RMG factories in Bangladesh originated from electrical issues, e.g., loose connections, electrical arcing, flashing of static charges, and short-circuits. In order to ensure and enhance electrical safety in the existing RMG factories and thereby to improve the overall fire safety measures, the organizations mentioned above developed their own guidelines to perform electrical safety audits and remediation of identified electrical problems in the RMG industry. These guidelines are mostly based on the Bangladesh National Building Code (BNBC) 2006. In some contexts, they have also incorporated relevant internationally renowned standards, such as the National Fire Protection Association (NFPA) 70 or NFPA 70E. This paper aims to review these guidelines to identify their dissimilarities, limitations, overemphasized issues and scope of improvement. This is necessary to suggest suitable changes for the harmonization and improvement of these guidelines, facilitating remediation, and enhancing electrical safety management in the RMG industry, while also to take into account the upcoming BNBC. This is important to sustain the process of inspection and remediation as in near future the activities of all the three initiatives will presumably be carried out under a single and independent entity.

1. Introduction

The Ready-made Garment (RMG) industry has long been the main driving force of the export economy of Bangladesh accounting for about 81% of its overall export. It is also one of the largest employers in the country, engaging 4 million workers in 4,482 factories (BGMEA, 2018). Over the years, occasional fire incidents have been a major plight of the industry (ILO, 2017, Wadud et.al. 2014, Hossain 2016). In November 2012, a devastating fire occurred in Tazreen Fashions; 129 lives perished while 200 people got severely injured. This was followed by the catastrophic building collapse at Rana Plaza in April 2013, causing more than 1100 deaths and similar number of injuries (Solidarity, 2017). Although the industry had been suffering from fire and other accidents before and had a poor safety record since its nascent, these two major incidents drew the attention of the world, national and international stakeholders. As these catastrophes occurred mostly due to non-compliance regarding fire, electrical and structural issues on one hand and lack of supervision and control by the enforcing agencies on the other (ILO, 2017). A number of international and national initiatives were taken to ameliorate the fire, electrical and structural problems in the RMG industry. These include ACCORD on Fire and Building Safety in Bangladesh, the ALLIANCE for Bangladesh Workers Safety, and the National Initiative under the National Tripartite Plan of Action (NTPA) on Fire

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Safety and Structural Integrity. The ACCORD and ALLIANCE are the platforms formed by groups of mainly European and USA-based clothing brands, respectively. On the other hand, the NTPA involves the Government of Bangladesh and stakeholders from RMG factories and labor organizations (ILO, 2017).

Among the three major issues, the electrical ones cause electrical shocks and accidents in the factories which can result in injuries leading to prolonged disability on occasions and fatalities. At the same time, it is also a major cause of fire and explosion worldwide (Daéid, 2004). As for the RMG industry in Bangladesh, electrical safety issues are responsible for most of the fires, about 75% according to the Fire Service and Civil Defense Authority (FSCDA) of Bangladesh. Many of these fires occur due to loose connections, arcing and flashover and short circuits (Sundaram et.al., 2016 and Haque et.al., 2017). It is interesting to note that unlike the well-circulated electrical short-circuit, the main reasons for electrical fires are loose connections and in-line arcing (Babrauskas, 2008). In terms its ability to cause fire, short-circuits rank below in-line arcing followed by miscellaneous events such as misuse of appliances, use of extension cords, lightning protection etc. It is of utmost importance that electrical problems are minimized in the RMG industry as it will reduce not only electrical accidents, but also electrical fires. The ACCORD, ALLIANCE and NTPA have developed their own guidelines to identify electrical issues in the garment factories, build the required corrective action plans and mobilize and supervise remediation. The Guidelines are mostly based on the Bangladesh National Building Code (BNBC) 2006 and in some respects well-known international standards such as the NFPA 70 and NFPA 70E. Using the Guidelines, the ACCORD and ALLIANCE have made a considerable progress in indentifying and remediating electrical problems. Under ACCORD as of January 2018, 65,266 electrical items have been found of which more than 85% have been rectified (ACCORD, 2018). As of 2017, more than 600 factories have been inspected under ALLIANCE wherein about 90% of the electrical errors are remediated (ALLIANCE, 2017). Under the umbrella of NTPA, 1549 factories have been inspected for identifying electrical issues with only a few factories being remediated. Note that the ALLIANCE and ACCORD will leave the field soon and presumably the process will continue under an independent body afterwards (ALLIANCE, 2017). It is necessary to review the Guidelines to identify their limitations and scope of possible improvement so that the process of inspection and remediation becomes harmonized, stronger and more sustainable. The present paper aims at finding the dissimilarities, limitations and overemphasized issues among the existing guidelines and suggests necessary assimilations and changes to harmonize and improve while taking into account the upcoming BNBC. The latter is important since electrical safety inspections beyond ALLIANCE and ACCORD should conform to the upcoming version of BNBC (based on BNBC 2015 draft).

2. Comparison of the Guidelines of ACCORD, ALLIANCE and NTPA

In this Section, the Guidelines mentioned above have been compared. During the comparison, the Guidelines of ACCORD and ALIANCE are compared together against that of NTPA because the first two are almost similar. We will refer to the former as A-A and the latter as NTPA in subsequent discussions. The comparison reveals three different types of issues: (i) Requirements in NTPA but not in A-A (Table 1), (ii) Requirements in A-A but not in NTPA (Table 2), (iii) Requirements in A-A and NTPA that are different (Table 3). Note that the electrical items in Tables 1 and 2 have similar requirements in most part and only the additional requirements as in NTPA or A-A are shown. If the additional requirement improves electrical safety considerably, it is termed as a major issue otherwise will be termed as moderate or minor issues. Similarly, if the differences in Table 3 reduce risk of electrical accidents and fires significantly, it is denoted as a major issue and moderate or minor otherwise. For the various electrical safety items, comments are also provided on the corresponding requirements regarding their affect on reducing electrical and fire hazards. The draft version of the upcoming BNBC, referred to as BNBC 2015, is also considered in the comments. It is seen from the tables that in most of the cases the differences or additional requirements do not significantly increase the risk of electrical accidents and/or fire, and hence are considered as moderate/minor issues. On the other hand, there are several major issues meaning that the absence of corresponding additional requirements (for example the requirements for *the Inspection and Testing* item in A-A) can reduce the risk of electrical accidents and fire, and hence must be included in NTPA. However, the lone major issue in Table 1 is considerably substantiated in A-A by the requirement of *Layout and Installation Drawings*. As for the moderate issues, the harmonization of the corresponding additional requirements for the guidelines will bolster their capacity to identify electrical problems and facilitate remediation to reduce electrical accidents and electrical fire. For the minor issues, the guidelines can be kept as it is since the differences are expected to affect the risk of electrical accidents and fire insignificantly. It is also observed that the comments as well as the overall requirements of the various guidelines are, in general, conform to the BNBC 2015. BNBC recommends the use of a spare circuit-breaker for *Electrical Connections*, not found in either NTPA or A-A, and hence can incorporated in them. The requirements of A-A for the *Conductors* is also provided in BNBC 2015 and thus should be included in NTPA.

Table 1. Requirements mentioned in NTPA but not in Accord-Alliance (A-A)

Items	Additional Requirements	Comments
Electrical Wiring and Cabling: Electrical Connections	Use of looping wiring, join box and importantly provision for 20% spare capacity and a spare circuit in branch circuits (Clause 4.4.1)	* Useful to reduce risk of overloading and subsequent electrical fire. BNBC 2015 additionally mentions a spare circuit-breaker. *Moderate issue
EQUIPMENT AND ACCESSORIES: Energy Meters	(Clause 4.7.5)	*Minor issue
Inspection of the Installation: Inspection of Substation Installations	Installation in accordance with the approved drawings; (Clause 4.16.7.1)	*Major issue

Table 2. Requirements mentioned in Accord-Alliance (A-A) but not in NTPA

Items	Additional Requirements	Comments
Electrical Wiring and Cabling: Lighting Fittings	Independent support of lighting fixtures from the building structure with seismic bracing as required (Clause 10.3.6)	*Reduces risk of electrical fire *Moderate issue
Electrical Wiring and Cabling: Layout and Installation Drawings	For existing buildings, maintaining an appropriate Single Line Diagram (SLD) reflecting as built conditions (Clause 10.3.7)	*Useful for identifying electrical problems. *Moderate issue
Electrical Wiring and Cabling : Conductor and Cables: Conductors	Identification of Live, Neutral and Earth through the use of colored insulation or colored plastic vinyl tape (Clause 10.3.8.1)	*Important for electrical safety *Moderate issue *also provided in BNBC 2015
Electrical Wiring and Cabling: Sub-distribution Boards	Legible identification of every circuit with its location and specific purpose or use; provision for circuit directory on the panel door (Clause 10.3.9.1)	*Important for electrical safety *Moderate issue

Items	Additional Requirements	Comments
Electrical Service Shaft and Bus Duct: Bus Duct	Vermin and damp-proof components of a bus duct and using fire stops in all openings (Clause 10.4.2)	*Important for reducing risk of electric shock and arcing *Moderate issue
Electrical Substation: Substation Location	Sufficient access and working space of at least 1.07 m (3ft 6in) in substations around the equipment (Clause 10.5.2)	*Important for electrical safety *Moderate issue
Main Switch, Switchboards and Metal Clad Switchgear: Main Switch, Switchboards and location of distribution boards	Distance of 1 m (39 in.) in front of the switchboards and switchgear and distribution panels.(Clause 10.7.1 and Clause 10.7.3)	*Important for electrical safety *Moderate issue
Standby Power: Generator Room	At least 1.07 m(3ft 6in) space on all sides of the generator (Clause 10.8.4)	*Important for electrical safety *Moderate issue
ILLUMINATION OF EXIT SIGNS AND MEANS OF ESCAPE: Exit Signs	**E**mergency power or battery backup Lighting for exit signs; verification of the power at least once per year. Battery-operated signs being tested monthly, and for a minimum 90 min once per year (Clause 10.12.1)	*Minor issue *The requirements on inspection and testing are not given in BNBC 2015
ILLUMINATION OF EXIT SIGNS AND MEANS OF ESCAPE: Means of egress	**E**mergency power or battery backup Lighting for exit signs; verification of the power at least once per year. Battery-operated signs being tested monthly, and for a minimum 30 min once per year (Clause 10.12.2)	*Minor issue
Battery Systems (standby or emergency power)	Battery systems installed, tested and maintained as per NFPA 111. (Clause 10.12.3)	*overemphasized requirement as one can follow BNBC *Minor issue
Generators (standby or emergency power)	Generators installed, tested, and maintained in accordance with NFPA 110.(Clause 10.12.4)	*overemphasized requirement as one can follow BNBC *Minor issue
INSPECTION AND TESTING: Periodic Inspection and Testing	Periodic inspection and testing program complying the requirements of NFPA 70E (clause 10.13.2.1**)**. For existing construction, thermographic inspection of electrical equipment being on a tri-annual basis and in accordance with ASTME1934 (Clause 10.13.2.2)	*Important for reducing electrical fires and electrical accidents. *Major issue
INSPECTION AND TESTING: Insulation Resistance Tests	For existing construction, test made on all electrical equipment on a 5 year cycle and as per Clause 10.13.4.1 (Clause 10.13.4)	
INSPECTION AND TESTING: Earth Resistance Test	For existing construction, on a 5 year cycle and as per Clause 10.13.5.1 (Clause 10.13.5)	*Important ensuring electrical safety. *Major issue
Electrical Inspections	Preserving Records of initial testing and subsequent testing onsite (Clause 10.13.8)	*Minor issue

Items	Additional Requirements	Comments
Naked lights	Not allowed in storage areas or in any area where the Inspector of the Factories Rules (1.6.3.7) Part 53 disallows. Posting of signs in Bengali and English, indicating this prohibition at all entrances to these areas. Mandatory Lighting in storage areas. (Clause 10.15)	*important for electrical safety and reducing risk of electrical fire *Major issue
Electrical Safety Program	Development of an Electrical Safety Program as per NFPA70E for operation and maintenance personnel (Clause 10.16)	*Moderate issue

Table 4 provides a set of recommendations that should be incorporated in the Guidelines. Mandatory use of the Cu conductors will drastically reduce the problem of loose connections and overloading. Employing RCCBs in watery premises is necessary as unbalance 3-phase supply is common in Bangladesh that can easily lead to earth leakage currents and any inadvertent operation can cause fatality. On the other hand, use of AFCI is common in USA and can be introduced in our factories as it would extinguish in-line arcing and hence suppress incipient electric fire. Provision for accepting new technology for LPS is suggested as otherwise factory owners could be deprived off possible alternative method with greater efficiency and reduced cost. The suggestions can also be incorporated in the upcoming BNBC for its improvement and ensure conformity of the guidelines with the BNBC.

Table 3. Differing Requirements in A-A and NTPA

Items	Requirements	Comments
Electrical Wiring and Cabling: Wiring	A-A: Underground cables through GI or PVC pipes and laid in earth trenches of 600 mm (24 in,) (Clause 10.3.2) NTPA: …. trenches of sufficient depth (Clause 4.4.2)	*Minor issue
Electrical Wiring and Cabling: External Influences	A-A: 900mm (36 in.) distance from external heat (Clause 10.3.4.2); NTPA: Sufficiently far (Clause 4.4.4.2)	*Minor issue
Main Switch, Switchboards	NTPA: allows open type switchboards only in dry and ventilated locations and far away from storage batteries or chemical fumes.(Clause 4.8.1); A-A: Open type switchboards are not allowed. (Clause 10.7.1)	*Moderate issue

Table 4. Suggested Recommendations for inclusion in the Guidelines

Items	Recommendations	Comments
Wiring	Use of Cu cable should be mandatory for LV (low voltage) application. Use of Aluminum cable should be discouraged. Fire resistant (FR) cables with 3-hours fire rating shall be used for emergency communication and	BNBC 2015 suggests the use of PVC insulated cables with Cu conductors. However, it does not mention the use of FR or flame retardant cables although it is important for inhibiting flame propagation, fire detection and suppression, and effective evacuation.

Switchgear	Residual Current Circuit-Breaker (RCCB) should be used in all outlets at premises with proximity to water, such as kitchen, washrooms, washbasin, boiler room, washing plant, water treatment plant etc.	BNBC 2015 recommends the use of RCCB in MDBs only. However, it is mentioned in NFPA 70 E and important for reducing risk of electrical shock and electrocution.
Switchgear	Arc Fault Circuit Interrupter (AFCI) is recommended in all MDBs and substations.	Mentioned in NFPA 70 (not in BNBC 2006/2015) and will be useful for suppressing arcing, thus reducing the risk of electrical fire.
Lightning Protection System (LPS)	Use of newly introduced technology not mentioned in the BNBC or other standards can be accommodated upon scientific evaluation/assessment by established research or testing labs or universities.	New technology may be more effective. Too much emphasis on available technology while rejecting the new one without scientific validation can be counter-productive.

3. Conclusions

Enhancing electrical safety in the RMG industry is essential to reduce electrical accidents and fires, thereby saving numerous lives and properties. In this regard, the initiatives of ACCORD, ALLIANCE and NTPA have contributed, so far, significantly through inspections and remediation in a large number of factories, performed under their respective Guidelines. A comparative analysis of the Guidelines has been carried out in the present paper to identify their limitations and areas of improvement. A number of moderate and minor issues have been identified and a few major issues have been determined. Suggestions have been provided for assimilations and changes to incorporate these issues in various guidelines and render improvement. However, the impact of the guidelines on reducing risks of electrical accidents and fire should be analyzed and compared with related data from stakeholders such as FSCDA and Department of Inspections for Factories and Establishments (DIFE). Fire risk indices have been developed incorporating structural and management parameters (Wadud, 2017); however, a risk index reflecting the current level of electrical safety in the RMG industry is still lacking.

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BOILER SAFETY IN THE READY-MADE GARMENTS (RMG) SECTOR OF BANGLADESH: AN ASSESSMENT OF THE EXISTING SCENARIO

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ABSTRACT

The necessity to seriously focus on boiler safety in Bangladesh is underscored by the recurring tragic incidents in the form of boiler explosion that have occurred in Bangladesh in recent years. The present study attempts to examine the current scenario of boiler safety in Bangladesh, to determine the principal reasons behind the boiler accidents occurring in the industry, especially in the RMG sector, and to outline the mitigating measures that are being implemented to overcome the existing barriers in ensuring boiler safety. With an aim to obtain a proper overview of the overall boiler picture in Bangladesh, the available information on all the licensed industrial boilers in Bangladesh, more than five thousands of them, has been gathered and extensively analyzed. The existing industrial boiler scenario has been constructed by classifying the boilers according to their size and capacity, geographic location and the type of industry that own them. It is found that about 60% of the industrial boilers in Bangladesh are used in the RMG industry and they also bear a significant share of the boiler accidents. After a careful review and analysis of the reported boiler incidents a number of issues have been identified as the major reasons behind the boiler related incidents. These include the failure to establish an effective occupational safety and health (OSH) management culture in the industries, lack of preventive routine inspection and maintenance, shortage of adequately skilled boiler operators/technical personnel, and the miscellaneous limitations of the overseeing authority. The study finally highlights the various steps that are being undertaken, in the wake of such incidents, to improve the boiler safety in the RMG sector.

Keywords: Boiler Safety, RMG, Multifabs, Risk Assessment.

1. Introduction

The importance of Ready-made Garments (RMG) sector in the socio-economic development of Bangladesh cannot be overstated. Currently, more than 80% of Bangladesh's total earning from export is generated by the RMG sector, which amounted to about $28.09 billion USD in the fiscal year 2015-16. In this period, Bangladesh also became the second largest garments exporter in the world (The Daily Star, February 2, 2016). Throughout the last two decades, the RMG sector has significantly contributed in the mitigation of country's unemployment problem by employing about 4.2 million workers (Salvai, 2017). However, industrial health and safety issues have been a burning issue for the RMG factories in Bangladesh. The RMG sector in Bangladesh has been plagued by a number of structural collapses of the factory buildings, deadly fire incidents and fatal boiler accidents in the recent years. Only a few hundred of the country's 4500 textile factories have been certified as safe (The Daily Mail, July 5, 2017). The infamous Rana Plaza collapse occurred in April 2013, which claimed the lives of more than 1,100 workers and injured 2,500 more- thus making it the worst industrial accident in the recent times.

A boiler is a highly pressurized vessel containing an internal or external furnace which poses two different kinds of hazards- fire hazard and explosion hazard. Boiler explosion, a failure of the normal boiler operation that can cause severe damage to infrastructure as well as loss of human lives, can result from a number of factors. In most cases, boiler explosion occurs when the steam pressure inside the vessel increases beyond a critical limit. It also presents a fire hazard as the packaged boilers used in the industries contain a furnace

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inside where fuel is burnt to produce steam. With the expansion of the RMG industry in Bangladesh, numbers of boiler installations are augmented rapidly as boilers are an essential feature of these industries. And since boiler poses both fire and explosion hazard, ensuring the safety of these boilers is a massive concern for Bangladesh.

It is a commonly accepted fact that the issue of ensuring occupational safety and health (OSH) does not get a very high priority in the developing countries (Diugwu, 2012; Umeokafor, 2014). So it should not come as a surprise that the RMG industries of Bangladesh rank poorly in ensuring occupational safety and health. Lack of awareness about the danger of unsafe boiler operation, limited technical skill of the boiler operators and technicians, erroneous boiler design, poorly maintained and inspected boilers, inadequacy of the pertinent authorities *etc.* are some of the obstacles in warranting safe operation of boilers in these industries.

Boiler explosions in the industrial buildings have killed more than 100 people in the last five years (The Daily Star, July 6, 2017). However, attention and initiatives to ensure workplace safety in the RMG sector was mostly focused on fire safety as fire is the greater hazard in clothing factories all over the world. However, two deadly incidents in the last two years in two factories, Multifabs Ltd. and Tampaco Foils Ltd., have seriously raised the issue of addressing the problem of boiler safety in Bangladesh. In September 2016, a tragic accident due to the cause of boiler explosion at Tampaco Foils Ltd., a packaging company, led to the death of 42 people, serious injuries of more than 40 people (DW, October 9, 2016). At least 10 people were killed and 50 more people were injured in another boiler explosion in July 2017 at the premises of Multifabs Ltd., an apparel factory at Gazipur, Bangladesh (Bangladesh ACCORD, July 5, 2017).

In order to realize an acceptable level of it is important to learn from accidents (Stemn, 2018). However, in spite of these above-mentioned two fatal boiler incidents and few others in the recent times, the issue of boiler safety in RMG sector is not receiving enough attention in Bangladesh. No published work on the topic of boiler safety in Bangladesh could be located in the open literature. For this paper, an attempt has been made to conduct a comprehensive study on the overall scenario of boiler safety in Bangladesh. The analysis is based on data collected from the regulatory and enforcing authority overseeing boiler operation, feedback from participants in boiler safety workshops, who are working in the RMG sector as boiler operators and maintenance technicians, academic and newspaper articles, and reports from international and national organizations. The key reasons and issues for the boiler incidents in Bangladesh are examined, followed by an overview and analysis of the recent developments and initiatives that are underway as remedial measures.

2. The Boiler Scenario in Bangladesh

With an objective to obtain an overview of the existing boilers in Bangladesh, we attempted to analyze the information available on the boilers currently in use in industrial and other sectors of Bangladesh. It was found that there is a considerable lack of information and analysis regarding the number, capacity, location, type, age, condition, and other relevant information on the existing boilers in Bangladesh. Most of the information on the existing boilers in Bangladesh was collected from the Office of the Chief Inspector of Boilers, the regulating and enforcing agency that oversees the boiler licensing, inspection, and operation of boilers in Bangladesh. However, it was found during the collection of data that the department records very limited information in the inventory on a boiler when it provides license to a new boiler. The data provided by the department was also highly scattered as the boiler department does not contain any systematic categorization or arrangement of the information according to the boiler specification, service life, or the location and type of industry where the boilers will be installed.

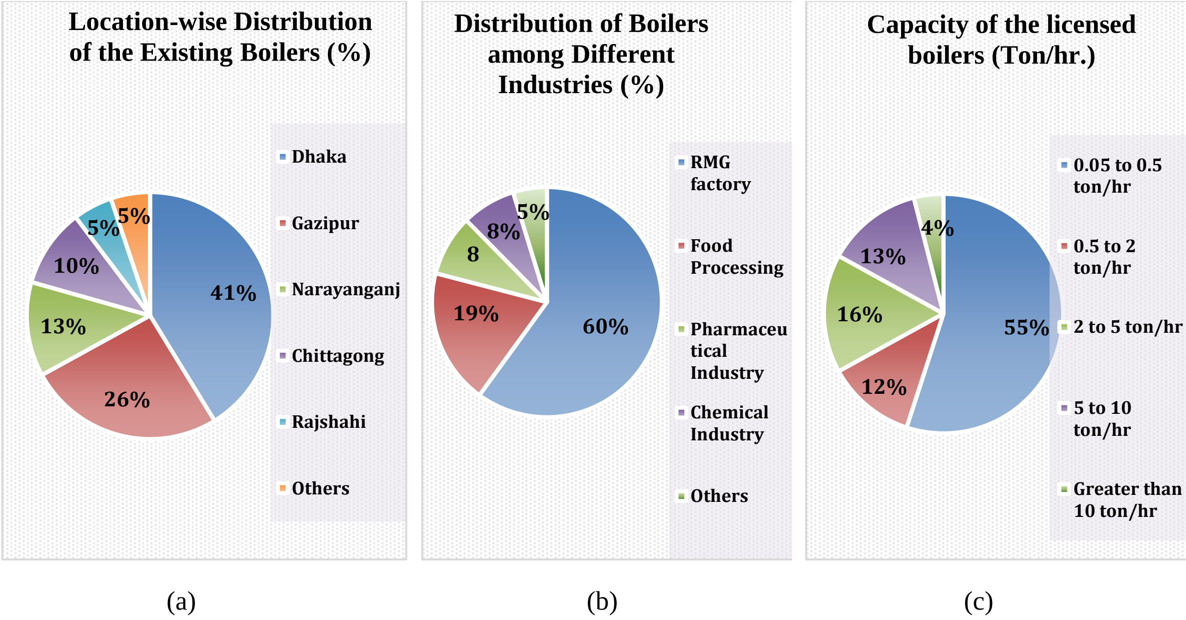

Figure 1. Distribution of all the licensed boilers in Bangladesh according to (a) location (b) Industry type and (c) capacity. About 80% of all the boilers are being used in factories located in the districts of Dhaka, Gazipur, and Narayanganj. RMG sector owns the majority of the boilers, about 60%.

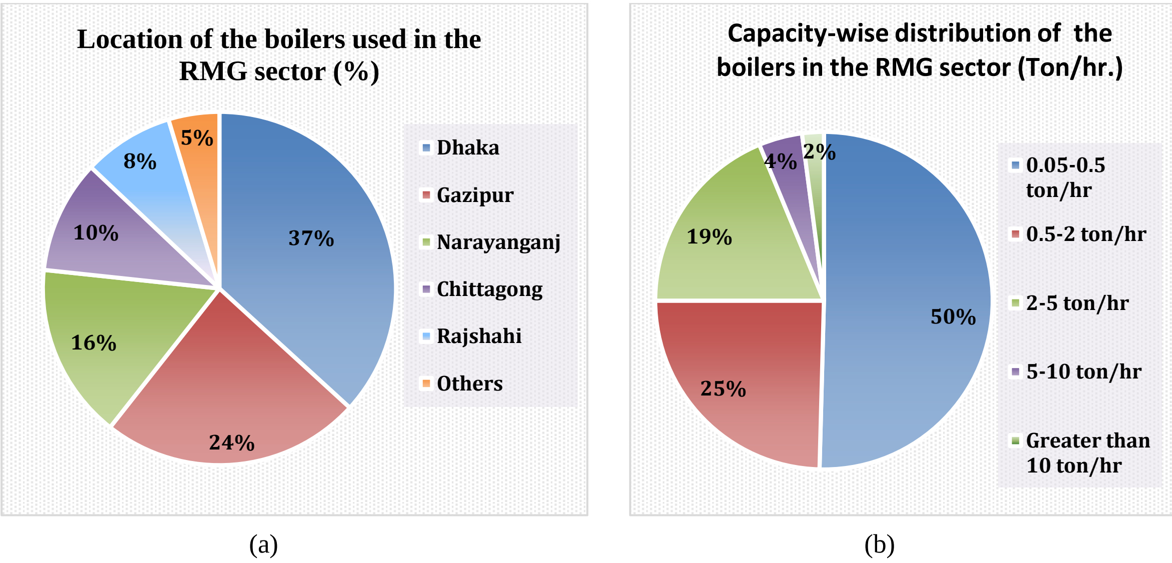

Figure 2. The a) location and b) capacity of all the licensed boilers used in the RMG sector of Bangladesh are shown. The majority of these boilers (more than three-fourth) are installed in RMG factories which are located in the three most industrialized districts of the country. About half of these boilers are small capacity boilers, having a steam generation capacity of 0.5 Ton/hr. or less.

It was found that there are more than 5000 licensed boilers in Bangladesh at present, the majority of which are imported with a small share of locally fabricated licensed boilers. As mentioned before, the data available on these licensed boilers was found to be incomplete, especially very limited data is available on the working pressure, capacity and the number of years these boilers are in operation. However, with the information in hand, we have analyzed the data and tried to establish a picture of the overall boiler scenario in terms of their location, capacity, the type of industry where the boilers are being used, especially analyzing the data in more detail for the RMG industry.

Table 1. Year-wise information on licensed boilers and boiler operators in Bangladesh

Fiscal year	Number of boilers permitted to operate	Number of new registered boilers	Number of certified locally manufactured boilers	Number of examinee for the boiler operator licensing exam
2016-17	5039	697	323	1041
2015-16	5035	578	263	997
2014-15	4450	415	181	1233
2013-14	3954	337	116	409
2012-13	3668	328	124	834
2011-12	3900	343	111	776

The category-wise distribution of all the licensed boilers in Bangladesh in terms of location, industry-type, and capacity are presented in Figure 1. It is found that 80% of the existing boilers i.e., about 4000 boilers are located in three cities- Dhaka, Gazipur, and Narayanganj, where the concentration of different types of industries is highest in the country. The rest of the boilers are located in different industries around the country. It can also be seen that RMG sector is by far the largest user of boilers in Bangladesh and about 60% of the boilers (about 3000 boilers) are used in different RMG factories. The food processing sector and the pharmaceutical sector are the next large shareholders, employing about 20% and 8% of the total boilers. However, majority of the boilers used in Bangladesh are small boilers, with a steam generation capacity of 0.5 Ton/hr. or less.

The information available on all the boilers used in the RMG sector was further analyzed and was categorized in terms of their location and capacity [Figure 2]. Since the major portion of the RMG factories are located in the middle part of the country, specifically Dhaka, Gazipur and Narayanganj, it was no surprise that about 77% of the boilers are located in this region. About half of the boilers used in the RMG sector were found to be small, with a steam generation capacity of 0.5 Ton/hr. or less. About 25% of the boilers used in this sector, about 750 in number, are of fairly large capacity (2 Ton/hr. or more).

The year-wise distribution of the total number of boilers for the last seven years, the number of new boilers (local and imported) that received license to operate, the number of operators receiving license are shown in Table 1. From this Table we can see that with the rapid industrialization of the country, the number of new boilers getting permit to operate has increased almost in the last three years and the total number of licensed boilers in the country has increased over 27% over the same period. Although the data on the number of people taking the boiler operator licensing exam are shown here, information on the number of new licensed boiler operator being added to the workforce and total number of certified boiler operators in the country were not available.

3. Identifying the Reasons

The factors that can affect the safe operation of boilers are many and include the relevant legislations, safety awareness of the management and supervision, training and technical competence of the operators, regularity of maintenance, inspection, and testing, the design, operating conditions, control and safety systems of the boiler itself. To ensure the safe operation of boilers, all of the above-mentioned factors need to be in place and need to be addressed at all times. Failure to warrant any one of the factors can render the boiler operation unsafe, resulting in catastrophic consequences. The underlying reasons behind the boiler incidents in Bangladesh are a complex mix of these many factors.

- **Legislations:** Boiler systems are usually required to comply with different local or international health and safety regulations. The objectives of these legislations are to ensure safe operation and maintenance of all new and existing boilers. Bangladesh lacks in appropriate documentation, legislation and surveillance related to safe boiler practices and requirements of a safe boiler room. From the point of view of risk assessment, boilers pose two different kinds of threats. Being a high pressure vessel equipped with an internal or external furnace, boilers present both a fire hazard and an explosion hazard to the occupancy at the same time. The local legislations to ensure workplace safety, to prevent such hazards, and germane to the installation and operation of boilers are '*The Bangladesh Labour Act, 2006'*, '*The Boiler Act, 1923'* and *'Bangladesh National Building Code, 2006'*. *The boiler Act* of 1923 deals mostly with the certification and license of the boilers and boiler operators and does not offer any guideline on boiler maintenance or operation. While the *Bangladesh National Building Code (BNBC)* outlines many technical requirements on boiler installation, requirements of the room or building housing a boiler, it does not differentiate between power (high pressure) boilers and heating (low pressure) boilers, contains inconsistent requirements for different types of occupancies, and offer very little specific direction in regards to the boiler log book, means of egress, and ventilation requirement of the boiler room. None of these legislatures provide any detailed guideline on the testing, inspection and maintenance requirements for boiler operation.

- **Inadequacy of Regulatory and Enforcing Authority:** The substantial shortage of manpower in the office of the Boiler Inspector of Bangladesh, which oversees the certification and licensing of the boilers and operators, and is in charge of ensuring inspection of all the licensed boilers is a major reason in the poor supervision and consequent boiler incidents. Lack of effective communication and cooperation among related different agencies of the government, such as *Department of Inspection of factories and Establishment* and *Office of the Boiler Inspector*, might also play a significant role in worsening the situation. At present, there are only six boiler inspectors available to the authority to monitor the nearly 6000 licensed boilers in the country and this scarcity pushes each inspector to examine 50 to 80 boilers a month, eventually leading to a sub-par supervision (Dhaka Tribune, July 5, 2017). Furthermore, it was shown in our analysis in the previous section that about 60% of all the boilers in Bangladesh are owned by the RMG factories and about 80% of these RMG factories are located within three districts- Dhaka, Narayanganj, and Gazipur. There are only 3 designated boiler inspectors in charge of these districts who are also in charge of few other districts as well. This means that they have to inspect and provide new and renewal license for more than 2400 boilers owned by RMG factories located in these areas, in addition to their other responsibilities. Although the Boiler Act mandates routine inspection of boilers in every six months for the renewal of license, adequate inspection of the boilers in these areas appear impossible.

- **Sub-standard Occupational Health and Safety Culture:** The not-so-strong occupational safety and health awareness in the industrial sector, absence of a strong safety ethics, and a lack of specific direction in the prevailing laws on boiler operation result in a poor culture of testing, maintenance and inspection of boilers. There is lack of understanding on the boiler owners' part that the owner or user of a boiler is ultimately responsible for ensuring that the boiler system complies with all the relevant health and safety regulations. The necessity of carrying out an appropriate risk assessment, detailing the likelihood and possible sources of danger, the operational risks, capability of the control and safety measures, level of supervision and maintenance, is not properly prioritized. The relevant legislations also offer little direction on the required frequency of the inspection and maintenance activities. For example, the requirement of keeping a properly documented and updated boiler log-book and preserving it in the boiler room is not imposed in the existing legislations. However, boiler log-book is usually considered to be one of the most effective ways to monitor the condition of a boiler. A majority of the boiler incidents can be attributed to the poor maintenance and irregular inspection of the boiler system.

- **Lack of Skilled Boiler Operator and Maintenance Personnel:** There is a considerable lack of skilled boiler operators and maintenance personnel in Bangladesh. The boiler operators should be competent and adequately trained to carry out all the duties for the daily safe operation of the boiler system. Similarly, the maintenance personnel should have sufficient experience and technical knowledge to be able to carry out the required tasks. It is the duty of boiler owners or employers to ensure that all such personnel receive adequate training on the boiler systems on which they work. Unfortunately, there are very few opportunities and training providers in Bangladesh to obtain the required training on boiler systems. Furthermore, the seriously under-staffed office of the boiler inspectorate, which is also in charge of holding the boiler operator licensing tests, can arrange the exams only a few times a year. As a result, the number of new boiler operators getting license is considerably lower than the requirement. Every now and then the RMG industries choose to continue the boiler operation with poorly skilled/unskilled boiler operators, which often acts as a central cause behind the boiler incidents. It can be mentioned here that the mistake made by the unskilled boiler operator(s), which caused the pressure to build up inside the boiler above the safe level, was identified as one of the main reasons behind the tragic boiler incident at the Multifabs Limited [Dhaka Tribune, July 12, 2017].

After exploring the pattern of reported accidents in detail by reviewing and analyzing the accident reports on the recent major boiler incidents, it is found that the above-mentioned factors have also been identified more or less as the primary reasons in those incidents as well. Survivors of the massive boiler explosion at Multifabs Ltd. in 2017 blamed the lack of safety measures and the negligence of the operators which took away 13 workers' lives. Later on, the investigation committee reported that the explosion was caused by excessive pressure in the boiler as the delivery valve was kept closed due to the malfunctioning of safety devices. The injured workers complained that the boiler had been beeping warning signal continuously for several days before the day of the incident, yet the owners were indifferent to the necessary maintenance, modification or replacement of the boiler. Also the boiler, aged more than 15 years, was being operated even after 2 weeks of its date of expiration (The Daily mail, July 5, 2017). *ACCORD on Fire and Building Safety in Bangladesh, a*n international coalition formed after Rana Plaza tragedy, identified the broken pressure gauge, negligence of operators, absence of the required fire rated construction of the boiler room as the major reasons behind the catastrophic incident of Multifabs Ltd. (REUTERS, July 4, 2017). In the case of the boiler incident at Tampaco Foils Limited at Tongi in 2016, it was reported that the unauthorized boiler and booster machines were being operated without any safety measures, leading to the accident.

4. Recent Developments and Remedial Initiatives Undertaken to Promote Boiler Safety

The fatalities of the recent boiler explosions once again demonstrated how serious the problem of poorly operated, maintained and irregularly inspected boilers in the RMG sector in Bangladesh can be. The good news is, a number of initiatives have been taken or are being undertaken by the Government of Bangladesh, Bangladesh Garment Manufacturers and Exporters Association (BGMEA), Bangladesh Knitwear Manufacturers and Exporters Association (BKMEA), the *Accord* and *Alliance* signatory brands, and other concerned authorities to improve the workplace safety and worker safety in the RMG sector in Bangladesh. Although the major emphasis has been allocated on fire safety for obvious reasons, boiler safety is also being addressed in the recent times. These initiatives can be broadly divided into the following categories -

- New regulations or agreement/treaty on the workplace safety
- Greater emphasis on safety monitoring and inspection
- Strengthening the regulatory and enforcing authority
- Safety training and workshops

'The Bangladesh Labour Act 2006' has gone through a substantial amendment in 2013, and a number of provisions have been introduced to improve the workplace safety and reduce occupational hazard. One

notable amendment among those was that the labour inspectorate has been given the responsibilities of inspecting workplace health and safety situation with a jurisdiction to conduct on-the-spot inspections in any factory. Collaborating with International Labor Organization (ILO), Bangladesh government has already adopted National Tripartite Action Plan for building and fire safety (NTAB) in conducting building assessment (structural integrity, fire and electrical safety). Moreover, in order to ensure a more dynamic and regular boiler inspection, the Ministry of Industries of Bangladesh Government has proposed to increase the staff number of the Boiler Inspector's Office by 235 and has also declared its plan to set up five more inspection offices in Gazipur, Mymensingh, Narayanganj, Khulna & Rangpur (Dhaka Tribune, July 5, 2017).

The Rana Plaza building collapse in April 2013, which claimed the lives of more than 1,100 garments workers, was a crucial turning point in addressing the workplace safety issue in the RMG sector in Bangladesh. Immediately after the Rana Plaza tragedy, the first Bangladesh Accord on Fire and Building Safety and Alliance for worker safety in Bangladesh were signed to ensure a safe and healthy environment in RMG sector of Bangladesh. According to Accord, approximately 81% of identified safety hazards found in Accord inspections have been fixed, while 84% non-compliance (NC) issues inspected by Alliance have been solved. Less than 2% factories were found to be at risk of violating workers' safety among 2200 factories inspected by both Accord & Alliance and those factories have already been shut down (Dhaka Tribune, October 29, 2017). Alliance has completed safety training in 34 factories and has claimed to provide the training for 1.2 million workers to enable workers for a better workplace (Mausumi, 2016). However, as mentioned before, both Accord and Alliance did not include boiler inspection, maintenance and safety in their first phase.

On 29 June 2017, the global trade unions IndustriALL and UNI, announced a new three-year post-2018 renewal of the Accord agreement at the OECD Global Forum on Responsible Business contact in Paris. IndustriALL and UNI were signatories to the new Accord, while major non-governmental organizations working in the global garment industry such as 'Clean Clothes Campaign' and the 'Worker Rights Consortium' were the witness signatories (Dhaka Tribune, 12 July 2017). Majority of the international retailer brands engaged with thousands of Bangladeshi RMG factories, have signed the agreement. The new three year agreement is expected to extend its building safety inspections to ensure that the safety improvements realized in the first Accord are followed up and to address any new problem, such as the one of boiler hazard.

After the boiler incident at Multifabs Ltd. in July, 2017, the Accord declared in a statement that although their inspectors addressed the issue of a proper fire separation of the boiler room at that factory, they did not address the potential issue of the boiler *explosion*. Boilers were covered only from point of view of the confinement of the possible fire hazard in the boiler room by fire-rated construction under the inspections of Accord at that time. In light of the above incident, Accord further stated that they were considering the possibility whether they can expand their inspection regime to include the boilers in a factory (Dhaka Tribune, 12 July 2017). The Alliance for worker safety also does not cover the inspection and regulation for the safety of boilers.

BGMEA has been involved in enforcing the safety measures among its member RMG factories and is trying to raise awareness among the workers. They have formed a variety of monitoring cells which are following up on the activities undertaken by its member units to improve worker safety. In association with the ILO, the garments and knit manufacturer's association, BGMEA and BKMEA have been arranging a series of training workshops on occupational safety and health for its workers and employees from April 2015, providing instructions on different aspects of occupational safety. BGMEA has hired 175 staff members with expertise in the occupational health issues, who have so far trained more than 8000 supervisors working in the RMG sector with an intention that the supervisors will follow that up with the workers in the factories. (The Daily Prothom Alo, April 17, 2017). Another project, organized by the ILO, titled "Building a Culture of Occupational Safety and Health in the RMG sector" provided training to 8000 mid-level managers and 750,000 workers of 585 enterprises in the RMG sector in three phases - training trainers, training mid-level managers, and information session for workers (Salvai, 2017). The leading technical institutions of the country, such as the Bangladesh University of Engineering and Technology (BUET) are also organizing series of training workshops on boiler operation, maintenance and safety for the operators, technicians, engineers, and supervisors working in the RMG and other industrial sectors in the country (DCE, BUET, 2018).

5. Conclusion

Boiler safety has become a crucial issue in the RMG sector in Bangladesh in the recent years. In the present study, an attempt has been made to examine the existing scenario of boiler safety in Bangladesh, to identify and analyze the principal factors behind the boiler accidents occurring in the industrial sector, especially in the RMG sector, and to discuss the recent development and initiatives undertaken to overcome the existing barriers in ensuring boiler safety. In order to obtain a comprehensive assessment of the boiler safety scenario in the country, the data on the existing licensed boilers in Bangladesh were collected and analyzed. It was found that nearly 3000 boilers, which is about 60% of the total number of boilers in Bangladesh, are used in the RMG industries with majority (80%) of these industries being located within Dhaka along with two of its neighboring districts- Gazipur and Narayanganj. The factors responsible for the poor boiler safety culture and consequently the boiler accidents have been identified after a comprehensive study on the of boiler safety scenario and analyzing the data and feedback collected from people working in the RMG sector, and careful analysis of the published reports. It is found that a number of initiatives and remedial measures have been undertaken by various government and non-government agencies to improve boiler safety in Bangladesh and developments have been achieved - which bode well for the workers in the RMG industries. The authors expect to continue the present study to work further on establishing a comprehensive and systematic database on the licensed boilers in Bangladesh in order to achieve a more accurate assessment of the boiler safety scenario in Bangladesh.

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CAN RANA PLAZA HAPPEN AGAIN IN BANGLADESH?

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ABSTRACT

Workplace safety has been a great concern in RMG sector in Bangladesh. Due to non-compliance with safety issues, accidents are general phenomena in this sector. Among many of the devastating accidents happened in this sector the collapse of Rana Plaza in 24 April, 2013 is one of the one of the deadliest industrial disasters in the world. After this accident, different diversified national and international initiatives have been taken to improve workplace safety condition in this sector. This paper aims to reveal whether such initiatives could truly ensure workplace safety or can accidents like Rana Plaza collapse happen again. This study found that, the factory building assessment initiative has reached to its target. But there are some further issues which still remained unaddressed. They are: still now there are factories which have not been included in the process due to unwillingness of the factory owners and incomplete list of factories, limited capacity in terms of human resources, technical issues and database management, uncertainty about continuation of the remediation work after termination of international support, huge amount of money required by the factory owners for remediation work, and finally and most importantly lack of cooperation and false information provided by the factory owners during inspection. If these issues cannot be addressed immediately then undoubtedly, Rana Plaza can happen again in Bangladesh.

1. Introduction

The Ready-Made Garment (RMG) industry in Bangladesh has been facing challenges to ensure workplace safety and better working conditions for the millions of garment workers. One of the deadliest fire accidents in RMG sector Bangladesh is Tazreen Fashion fire on November 24, 2012, which resulted in death of 112 workers. Since Tazreen Fashion Factory fire to 22 April 2017, about 133 fire incidents have occurred in the sector leading to at least 38 deaths and 815 injuries (Solidarity Center, 2017). In 2005, the building of Spectrum factory collapsed causing death of 64 garment workers and injury of 80. In 2006, 22 workers died due to collapse of the Phoenix Garments building. In 2012 due to partial collapse of Siams Superior Ltd. factory building in Chittagong Export Processing Zone (CEPZ), five workers received minor injuries. In February 2013, factory building of Envoy Garments Ltd. in Ashulia, Dhaka at least 100 garment workers were injured in a stampede triggered by a false fire alarm and consequent collapse of stair railing. Just months after this accident, Rana Plaza collapsed on 24 April 2013. All these accidents represent poor workplace safety condition in Bangladesh RMG factories. After Rana Plaza accident different diversified national and international initiatives have been taken to improve workplace safety condition in this sector. Five years after the accident the question is now whether these initiatives could truly succeed to ensure workplace safety or can accidents like Rana Plaza collapse happen again.

2. Ins and outs of Rana Plaza collapse

The factory building of Rana Plaza was located in Savar, Dhaka. It housed five garment factories employing around 5,000 people, more than 300 shops, and a bank. It was a 9-storied industrial building with a single basement. Local Municipality (Savar) gave permission to the owner of Rana Plaza to construct a five storey commercial building with one basement in 2005. Though the foundation of the building was for five storey, later the owner was allowed to extend the building up to nine storey without considering the structural design. Moreover, the building was converted from commercial to industrial use, and power generators were placed at the higher floors. As a result of such violations in building construction, on 23

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April 2013, a day prior to the fateful day, cracks developed on some pillars and on few floors of the building following a jolt. After inspection, industrial police requested the building authorities to close the building and to suspend operations of the factories on that day. However, the building owner and top-management of the garment factories ignored the warning and forced the workers to work in the next morning on 24th April, 2013. As a consequence, the collapse resulted in the high death toll of 1,134 and more than 2500 people were badly injured at the end of the rescue operation on 14 May 2013. It was the most fatal industrial accident in RMG sector in Bangladesh, and one of the deadliest industrial disasters in the world, which was the result of the reluctant attitude of the stakeholders towards the compliance issues. This tragic accident received global attention and brought forward diverse issues concerning millions of stakeholders in the RMG sector of Bangladesh (Ansary & Barua, 2015).

3. Initiatives after Rana Plaza collapse

Considering the potential of RMG industry in Bangladesh, several and diverse national and international commitments and initiatives resulted as part of the reform and restructuring of the RMG sector after Rana Plaza accident. The National Tripartite Plan of Action (NTPA) on Fire Safety was first outlined on March 2013 after Tazreen Fashion fire accident. Upon NTPA, tripartite partners (GoB, RMG workers, and RMG employers) signed a Joint Statement on May, 2013.Afterwards, without altering the content, the NTPA on Fire Safety was merged with the Joint Statement to form the NTPA on Fire Safety and Structural Integrity in the RMG Sector of Bangladesh in July 2013. It included 25 commitments divided into three categories: legislation and policy, administration, and practical activities. To ensure and monitor its implementation the National Tripartite Committee (NTC) was established at the same time under NTPA commitment. The committee is chaired by Labour Secretary and includes Government agencies, employers (Bangladesh Employer's Federation (BEF), Bangladesh Garment Manufactures & Exporters Association (BGMEA) and Bangladesh Knitwear Manufacturers & Exporters Association (BKMEA)), and trade unions. Based on NTPA, the EU, GoB and ILO issued an agreement of time-bound actions, "The Sustainability Compact: Compact for Continuous Improvements in Labour Rights and Factory Safety in the Ready-Made Garment and Knitwear Industry in Bangladesh" in July 2013 to promote improved labour standards and responsible business conduct in the RMG and knitwear industry in Bangladesh. A total of twenty-nine activities were listed in the EU Sustainability Compact. In addition, the United States Trade Representative (USTR) requested GoB to implement a sixteen-point action plan within one year in order to reinstate Bangladesh's GSP status in the US market. The USTR Action Plan endorsed the EU Sustainability Compact particularly for trade union related activities (Moazzem & Islam, 2015).

In addition to these initiatives, two different factory inspection programmes were established to make work place safer in Bangladesh where ILO fulfils the role of neutral chair. They are: the Bangladesh Accord on Fire and Building Safety in Bangladesh (the Accord), and the Alliance for Bangladesh (the Alliance). The Accord was initiated by over 190 apparel companies from over 20 countries in Europe, North America, Asia and Australia; two global trade unions, IndustriALL and UNI Global; and eight Bangladeshi trade unions on May 15th 2013. It is a five-year independent and legally binding agreement designed to build a safe and healthy Bangladeshi RMG Industry (Bangladesh Accord, 2015). The Alliance officially launched its local operation in Dhaka on December 9, 2013, which is also a five-year independent and legally binding agreement initiated by a group of North American apparel companies and retailers and brands (26 North American retailers and brands) to develop and launch the Bangladesh Worker Safety Initiative (Alliance for Bangladesh, 2013).

The targets and objectives of these initiatives are the same and they share some common courses of action aiming at improvement of workplace safety to safeguard the lives of over four million RMG workers and to retain the confidence of global buyers following the Rana Plaza accident (Barua & Ansary, 2017; Moazzem & Islam, 2015). Among the common actions considered in these initiatives, improving fire, electrical and structural safety of RMG factory buildings is significant to ensure a safe working environment.

4. Actions regarding structural safety of RMG factory buildings

Considering work-place safety as one of the most important challenges to sustain RMG industry in Bangladesh, actions regarding structural, fire and electrical safety assessment of all active export-oriented RMG factories were addressed in all the action plans. The supporting actions included upgrading and strengthening of the Chief Inspector of Factories and Establishment office to a "department", recruitment of additional labour, fire and building inspectors, arrangement of training programs to increase capacity of the inspectors, development of plan in consultation with the ILO to conduct effective inspections, initiation of remedial actions or close or relocate factories as appropriate, and creation of a publicly accessible database of all RMG/knitwear factories as a platform for reporting labour, fire and building inspections. All of these actions are either fully or partially completed (Barua & Ansary, 2017).

Bangladesh University of Engineering and Technology (BUET) and two private engineering firms TUV SUD Bangladesh (Pvt.) Ltd and Veritas Engineering & Consultant on behalf of the NTC, the Accord, and the Alliance are responsible for conducting the assessments of the structural integrity and fire safety of RMG factory buildings. A Review Panel along with a review mechanism was established under DIFE to handle urgent safety issues in garment factories. Finally, in November 2013, assessments of the structural integrity and fire safety of RMG factory buildings officially commenced, led by engineers from BUET. The BGMEA and BKMEA agreed to share necessary documents related to factory design and layout with the Committee to facilitate a smooth assessment process.

To undertake the structural assessment of factory buildings with common approach, Guidelines for Assessment of Structural Integrity and Fire and Safety including harmonized standards were developed by the technical experts (structural engineers, fire safety experts, etc.) from the BUET on behalf of the NTC, the Accord, and the Alliance in 2013 (NTPA, 2013). In 2014, Accord and Alliance consolidated national rules and regulation related to fire and electrical, and building integrity (Bangladesh National Building Code Act, Bangladesh Labour Act 2006, and others) and prepared a comprehensive document. In case of insufficiency in local rules, the initiatives took support from international rules/guideline which further strengthened overall safety standards.

A Remediation Coordination Cell (RCC)was formed in 2017 comprising of four teams to take over charge in transition phase be public agency. The teams include: the core body, field monitoring committee (to monitor remediation activities in field level), task force, and case handler and co-case handler. The activities of the cell include oversee the progress of remediation related activities (of factories initially under national initiative and later other factories under Accord and Alliance) and Detailed Engineering Assessment (DEA). The safety assessment and remediation process for the factory buildings under national initiative is composed of six main steps.

- Firstly, preliminary assessment reports are prepared after each preliminary inspection including the findings and required recommendations for the building owner and users according to the assessment results. Whether DEA recommended or not is also included in the assessment report. Issues triggering DEA are: concerns with structural issues, i.e. extensions, lateral system, flat plate punching capacity and slender columns, and state of documentation and approvals.
- Secondly, if any factory is assessed as vulnerable, then they are referred to the review panel to order the closure and evacuation of the factories until undertaking additional strength testing or taking immediate remedial measures. Assessment alone is not enough to ensure a safe working environment for all in the sector. The weak factory buildings are required to be strengthened to ensure resilience. So, after inspection of each factory, the inspection reports are shared with factory owners, the active brands and worker representatives. Then factory owner and the brands are tasked to develop a detail Corrective Action Plan (CAP) as per recommendation and to submit for approval with a clear timeline and a financial plan. Additionally, they propose firm for DEA (from the DEA firms short-listed by the DIFE Task Force) within a maximum of two weeks.

- Thirdly, the outline of the CAP is approved within two weeks through joint meeting between Factory Technical Team and the Initial Assessment Team.
- Fourthly, the approved firm conducts DEA and prepares report containing detail remediation scheme within six to twelve weeks and submit it for review and comments by the DIFE Task Force. DEA of the buildings involve soil investigation, other non-destructive tests and 3D building modeling. Fifthly, the DIFE Task Force review the DEA along with remediation scheme and send comments to the factory owner within two weeks after receiving the DEA report.
- Fifthly, after revision of DEA and remediation scheme by the approved firm, it is submitted to DIFE Task Force for final approval within maximum two weeks.
- Finally, after approval of CAP, remediation work is initiated under supervision of RCC. After successful completion of remediation work approved by the task force, safety clearance certificate is provided to the factory to continue business as usual. If the factory owners do not start remediation work after 3rd escalation then DIFE or BGMEA would take legal action to cancel license of the factory.

5. Progress of inspection initiative

As per DIFE website, assessment of 3582 RMG factories have been completed till March 2016, including NTC 1549, Accord 1204, Alliance 656, and common by Accord and Alliance 164 (DIFE, 2016). A total 150 factories were referred to Review Panel, out of which 39 factories were closed, 42 factories were partially closed, and 69 factories were allowed to operate, whereas decisions for five factories are pending. Among 1549 factories assessed under NTC, 24 are highly vulnerable (open 12, closed 10 and relocated 2), 219 are moderately vulnerable, 560 are low vulnerable, 449 are structurally safe, 282 are vulnerable for fire and electrical issues and owners of 15 factories did not allow to enter and assess their factories. Among these factories 745 factories are under follow-up.

Till January 2018, 83% overall remediation works have been carried out in garment factories under the Accord. Among these factories, a total of 138 factories have completed initial remediation works (Bangladesh Accord, 2018). Furthermore, till November 2017, 85% overall remediation works have been carried out in garment factories under the Alliance. Among these factories, a total of 234 factories have completed initial remediation works (Alliance for Bangladesh, 2018). The assessment reports and CAPs for the factories under Accord and Alliance have been made public through their websites. Both initiatives made timely review of remediation activities and based on the progress put necessary pressure for timely completion of remaining works. In extreme cases where the factories were unable to comply, business ties with those factories ended. On the other hand, factories which successfully completed the remediation works received “letter of recognition” from the initiatives. In contrast, 33% and 19% remediation works have been carried out in garment factories under NTC in case of owned and rented factories respectively. Factories which successfully completed the remediation works or are found to be okay after the DEA, received a “Business As Usual Certificate” from DIFE.

6. Way forward

The assessment initiative has reached its target. Yet there also are factories that have not been included in the process due to unwillingness of the factory owners, and incomplete and improper list of factories provided by BGMEA and BKMEA. Moreover, there remain a number of factories which are not member of any organizations such as BGMEA and BKMEA. So, the list of factories needs to be updated and verified including the remaining factories to ensure quick completion of the assessment. Additionally, the safety concerns of backward linkage activities of RMG enterprises (e.g. textiles, accessories, etc.) had been excluded from monitoring and inspection which also need to be taken into consideration.

Due to limited capacity in terms of human resources, technical issues and database management, the process of remediation under national initiative is getting hampered. Additionally, due to non-co-operation of rented/ shared building owners, remediation works cannot be progressed.

The assessment initiatives for workplace safety in the Bangladesh RMG sector have led to important organizational learning for Bangladesh as well as for other apparel manufacturing countries. Furthermore, both the initiatives of Accord and Alliance have entered into a transition phase after five years' operation which are going to end in 2018. Considering the status of remediation works of the remaining factories under this initiative, both the initiatives will extend their timeline to complete the works. Accord is willing to extend their operation beyond the limited time frame but Alliance is not willing to extend their contract. So, the key issue is now to institutionalize this learning to develop and continue an effective monitoring and inspection mechanism in the future even after completion of the assessments.

Another challenge is the huge amount of money required by the factory owners, which are insolvent but willing to remedy factory safety. For that purpose, the RMG factory owners have requested for the establishment of long-term loan instruments. In response to such request, different organizations, e.g., International Finance Corporation (IFC) US, Agence Française de Dévelopment (AFD), the Accord, the Alliance, and Japan International Cooperation Agency (JICA) provided loans to the local banks. These banks will disseminate the loans to the factory owners to improve their structural, electrical and fire safety infrastructure. The GoB has vowed to set up a specialized bank for the garment industry to provide easy loans. Though it is potentially an effective initiative, but the challenge lies in the fact that these financial supports are not sufficient compared to the requirement. Although the lenders have provided Bangladesh Bank (BB) with almost zero percentage interest, BB and other private Banks while disbursing the fund (around 300 million USD) to the RMG factories are asking an interest rate of 7 to 9%. Also, Public Works Department (PWD) under Bangladesh Government is entrusted to find out the deficiency of those RMG factories, which is hindering the process of fund disbursement. So far, only two RMG factories have received fund from this source.

7. Can RANA Plaza Happen Again?

From the above discussion it can be said that even though the assessment initiative has largely reached its target of inspection and remediation of factories, there is still a long way forward to reach the goal of workplace safety in Bangladesh RMG factories. In addition to these limitations, there are many cases where factory owners are doing wrong deeds to get positive report from the assessment. We have one recent experience with a factory during training of the DIFE inspectors regarding factory assessment and follow up. This particular factory located at Dhaka has been assessed under National initiative in December 2013. Basically, there are two buildings under the factory: one is a 6-storied and the other is an 8-storied building having a basement. Two factories namely AL and PR are located there. The ground floor of the two buildings are housing several shops and go-downs, the basement of the 8-storied building has been used as the fabric store for one of the factories (factory A). This factory is occupying both buildings up to 3rd floor (connected internally) and up to 5th floor of the 6-storied building, while the other factory (factory B) is occupying 4th to 7th floor of the 8-storied building. In early 2015, factory A moved under Accord. While applying for the Accord, they have only used the 8-storied building which has larger columns and smaller spans and can be considered safe. The 6-storied building which has smaller columns and larger cantilevers is not fully safe but has not been assessed under Accord. During a recent visit to the factory, the DIFE inspectors have found several cracks in the top floor beams of the 6-storied factory, which we have had already observed during our 2013 visit and for which we required the factory to make remediation. The owner of factory A has intentionally kept the 6-storied building outside the Accord assessment. So, as a result, the safe 8-storied building has been assessed and certified by Accord, while the 6-storied building under the same factory has never been assessed by Accord. But when DIFE inspectors were checking the factories, the owners told them that the whole factory is under Accord and has been fully assessed.

This is just a case among many. If these conditions cannot be taken care of then it is sure that Rana Plaza can happen again.

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RELIABLE MEASUREMENT OF IN-SITU CONCRETE STRENGTH AND IMPLICATIONS IN BUILDING SAFETY ASSESSMENT

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ABSTRACT

The tragic event of Rana Plaza was primarily caused by the structural failure of the building. Building safety assessment hence constituted a major part of the subsequent efforts to ensure workers' safety in garment factories in Bangladesh. A fundamental challenge faced in assessing structural safety of garment factory buildings has been to estimate the in-situ material properties of the structures, particularly that of the concrete. Although international codes and standards have provisions for different non-destructive testing methods for concrete strength assessment, due to their inherent uncertainties, the only method accepted by the National Tri-Partite Plan of Action (NTPA) guidelines is the semi-destructive method of core testing. However, in most of the cases, due to small sizes of columns and beams, diameters of the collected cores were less than that recommended by the standard testing method ASTM C42. Smaller diameter cores yield unreliable assessment of core strengths with large variations in results. A number of factors related to the condition of the cores, even if they are properly collected, influence the test results. Effects of these conditions are supposed to be incorporated in the test results through some correction factors as mentioned in ACI 214. However, many available core test reports did not properly mention these conditions. The effective concrete strengths for the structures are estimated following ACI 562, according to which greater variations of test results yield smaller effective strengths; in some cases even smaller than the least result obtained from the individual tests. In the present paper, core strength results of 59 buildings, assessed by the lAlliance for Bangladesh Worker Safety, were analysed in relation to age and height of the buildings. For most of the buildings the evaluated effective core strengths were much below the values usually assumed during the design process. Now, the question arises whether the low effective strength is a consequence of poor quality of construction alone or is a reflection of unreliable method of testing too. For the buildings analysed in this paper, it is found that the inadequacies, determined during assessment, which required major retrofitting of structures are more correlated to poor concrete strength than to the age or height of the buildings. This betrays the necessity of revisiting policies addressing quality control in core collection and methods of estimating the effective strength from test results. The authors suggest that the organizations assessing the factory buildings should require the technical personnel involved in collection of cores participate in orientation or training on proper procedures of the test method. The testing laboratories should also be dictated to mention all the required information regarding conditions of a core. As inherent uncertainties of the core test are, however, unavoidable, the approach towards determination of effective strength should be more pragmatic one than the most stringent ones available in the standards.

1. Introduction

Awareness to structural safety of factory buildings had been almost non-existent among the stake holders of manufacturing industries in Bangladesh before 2013. Rana Plaza collapse of 24 April 2013 was a stark awakening for the entire nation, exposing terrible systemic weaknesses of the country's construction sector. None had any idea how many 'Rana Plazas' are there in the country about to come down with hundreds of workers under slightest of perturbations. International Labour Organization (ILO), foreign brands (through the Accord, Alliance and others) and Bangladesh Government (through Department of Inspection for Factories and Establishments, DIFE) undertook a huge task of seeking an answer to the question by assessing the buildings of all member factories of Bangladesh Garment Manufacturers and Exporters

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Association (BGMEA) and Bangladesh Knitwear Manufacturers and Exporters Association (BKMEA) (Ansary and Barua, 2015). These assessing entities have been following different methodologies of structural assessment. Bangladesh Government along with the representatives of workers' and employers' associations drafted the National Tripartite Plan of Action (NTPA) (Khan and Wichterich, 2015). Structural assessment methodologies outlined by the NTPA, Accord and Alliance have basically two tiers. The first tier comprises of a preliminary or visual inspection of the structure where the vertical load bearing capacity of the structure is assessed for a minimum live load and a standard minimum material strength. The buildings which do not have a minimum factor of safety are then further evaluated through a Detail Engineering Assessment (DEA). For the DEA, a qualified engineer has to prepare a computer model of the structure to simulate its behaviour against different load combinations and check the design of individual structural components of the building. For this purpose the engineer needs to have an idea about strengths of the building materials. Majority of the garment factories in Bangladesh are housed in reinforced concrete buildings. However, all most in all cases, except very recent ones, there is no record of concrete strength test during construction of the buildings. Thus determination of in-situ concrete strength from the existing buildings becomes necessary.

There are a number of non-destructive testing (NDT) methods suggested in the standards (ACI 437R, 2003). Due to the inherent limitations of the NDT methods, as discussed in the next section, NTPA, Accord and Alliance guidelines recommend core testing method as the only acceptable method for in-situ concrete strength evaluation. Despite the fact that the core testing is much more reliable compared to other tests, it has its own limitations. Many of the limitations may be considered in the evaluation of the concrete through application of some correction factors (ACI 214.4, 2003). However, some limitations may be very difficult to overcome in practical situations like smaller diameter core or incorrect direction of loading during test (Tuncan et al., 2008; Yip and Tam, 1988). The practical problems in collecting cores and their implication in structural safety assessment is discussed here.

2. In-Situ Concrete Strength Tests

The compressive strength of concrete is the most significant concrete property with regard to the strength evaluation of concrete structures. In-place concrete strength is a function of several factors, including the concrete mixture proportions, curing conditions, degree of consolidation, and deterioration over time etc. As it is one of the most important parameters, determination of in place concrete strength needs critical engineering judgment. To assess the existing condition of a reinforced concrete building we need to find the in-situ strength of concrete. There are a number of test methods available to determine the in-place compressive strength or to determine relative concrete strength within different locations of the structure. The common feature of in-place tests is that instead of directly measuring the concrete compressive strength, they measure some other property that has some empirical relation with the compressive strength.

Rebound number: In this test a hammer rebounds from the concrete surface and the distance is measured on a scale numbered from 10-100 which is known as rebound number (ASTM C 805). The rebound distance depends on how much of the initial hammer energy is absorbed by the interaction of concrete and plunger, located perpendicular to concrete surface. If the rebound number is low that means more energy has been absorbed. There is good correlation between gain in compressive strength and the increase in rebound number for a given concrete mixture. This test is a simple and economical method for quickly obtaining information about the near-surface concrete properties of a structural members but this may not be representative of the rebound values of interior concrete. Moreover, due to increase in moisture content the rebound number increases. So, tests on dry surface can't predict the property of the interior moist concrete.

Probe Penetration: This test involves the use of a special powder-actuated gun to drive a hardened steel rod into the surface of a concrete member. The penetration of the probe into the concrete is taken as an indicator of concrete strength (ASTM C 803/C). The aggregate and mortar are crushed as the probe penetrates into the concrete, so the strength of aggregate and mortar effects the penetration depth. This test method is not sensitive to surface conditions as the probe penetrates into the concrete unlike the rebound number. But this analysis is more complex. Another limitation of this test is, the relationship between probe penetration and compressive strength has been validated only at a specific power level and probe type.

Pulse Velocity: In this test procedure where the time required for a pulse of ultrasonic energy to travel through a concrete member is measured. Dividing the distance between two surfaces where the transmitting and receiving transducers are located by this travel time the pulse velocity is obtained (ASTM C 597). The pulse velocity is inversely proportional to the mass density of the concrete and proportional to the square root of the elastic modulus. This elastic modulus varies approximately in proportion to square root of compressive strength. So there is very little change of pulse velocity even if there is large changes in compressive strength due to the maturation of concrete. Though there are good correlations between the velocity and compressive strength, this is not usually used as a proper measure of in-place concrete strength. There are factors such as moisture content, alignment of reinforcement along the travel path of pulse etc. which can easily cause misinterpretations of results.

Pullout Test: The pullout test measures the load required to pull an embedded metal insert out of a concrete member. To assess the early age in place strength the inserts are cast into the concrete during construction. Another procedure according to ASTM C 900, deals with post installed inserts that can be used in existing construction. The test produces a well-defined failure in the concrete and measures a static strength property. There is, however, no consensus on which strength property is measured and so a strength relationship should be developed between compressive strength and pullout strength (Stone and Carino, 1983). The relationship is valid only for the particular test configuration and concrete materials used in the correlation testing. Compared with other in-place tests, strength relationships for the pullout test are least affected by details of the concrete proportions. The strength relationship, however, depends on aggregate density and maximum aggregate size (ASTM 437R).

However, there are currently no in-place tests that provide direct measurements of compressive strength of concrete in an existing structure. In-place or nondestructive tests are commonly used in conjunction with tests of drilled cores. If in place strength test are conducted, strength relations need to be developed the correlates compressive strength and test measurements by testing core samples that have been drilled from areas adjacent to the in-place test location. Therefore, in place testing can reduce the number of cores taken but can’t eliminate the need for drilling cores from the building. So eventually we need to get rely on the semi-destructive core testing to obtain in-situ concrete compressive strength.

3. Core test process: Uncertainties and Problems

Strength interpretations should always be made by, or with the assistance of, an investigator experienced in concrete technology. The factors that contribute to the scatter of core strength test results include systematic variation of in-place strength along a member, random variation of concrete strength both within one batch and among batches, low test results attributable to flawed test specimens or improper test procedures, Effects of the size, aspect ratio, and moisture condition of the test specimen on the measured strengths and importantly additional uncertainty attributable to the testing that is present even for tests carried out in strict accordance with standardized testing procedures

This section primarily depicts the uncertainties and the practical problems that are associated with core testing and determination of compressive strength of concrete.

3.1 Uncertainties

The overall uncertainty of the estimated in-place strengths is a combination of the sampling uncertainty and the uncertainty caused by the strength correction factors. The measured strength of a core depends partly on factors that include the ratio of length to diameter of the specimen, the diameter, the moisture condition at the time of testing, the presence of reinforcement or other inclusions, and the direction of coring.

Specimens with small l/d fail at greater loads because the steel loading platens of the testing machine restrain lateral expansion throughout the length of the specimen more effectively and so provide confinement (Newman and Lachance 1964; Ottosen 1984). The end effect is largely eliminated in standard concrete compression test specimens, which have a length to diameter ratio of two.

An analysis of strength data from 1080 cores tested by various investigators indicated that the strength of a 50 mm (2 in.) diameter core was on average 6% less than the strength of a 100 mm (4 in.) diameter core (Bartlett and MacGregor 1994d).

In practice it is often difficult to obtain a 50 mm (2 in.) diameter specimen that is not affected by the drilling process or does not contain a small defect that will markedly affect the result. If correction factors are required to convert the strength of 50 mm (2 in.) diameter cores to the strength of equivalent 100 or 150 mm (4 or 6 in.) diameter cores, the investigator should derive them directly using a few cores of each diameter obtained from the structure in question.

Soaking causes the concrete at the surface of the specimen to swell, and restraint of this swelling by the interior region causes self-equilibrated stresses that reduce the measured compressive strength (Popovics 1986).

Cores drilled in the direction of placement and compaction (which would be loaded in a direction perpendicular to the horizontal plane of concrete as placed, according to ASTM C 42/C 42M) can be stronger than cores drilled normal to this direction because bleed water can collect underneath coarse aggregate.

3.2 Practical Problems

Figure 1 depicts some practical reasons for which core test produces low compressive strength of the drilled concrete core. In case of columns we can observe that the direction of test load is not the same as the direction of the actual loading in the structure. Again even though we avoid reinforcements in cores, the cores are drilled from places which are very close to the existing reinforcements of the column. This proximity of the reinforcement to the drilled bit causes excessive vibrations which eventually affects the strength results of the cores. In beams (figure b) the cores are usually drilled from the tension zone. Hairline cracks are already generated due to flexure in the tension zone of the beam. So, when the loading in the compression test is applied parallel to the cracks as shown in the figure, the sample fails at a lower stress due to having the crack lines as predetermined failure lines.

4. Determination of Effective Strength

As per ACI code 214 .4R-03, the in-place strength of the concrete at the location from which a core test specimen was extracted can be computed using the equation

$$f_c = F_{l/d} F_{dia} F_{mc} F_d F_{core} \tag{1}$$

where f_c is the equivalent in-place strength; f_{core} is the core strength; and strength correction factors $F_{l/d}$, F_{dia}, and F_{mc} account for the effects of the length-to-diameter ratio, diameter, and moisture condition of the core, respectively. Factor F_d accounts for the effect of damage sustained during drilling including microcracking and undulations at the drilled surface and cutting through coarse-aggregate particles. Again this value is used to calculate the equivalent compressive strength of the concrete.

$$f_{ceq} = 0.9 f_c \left[1 - 1.28 \sqrt{\frac{(k_c V)^2}{n} + 0.0015} \right] \tag{2}$$

where, f_c is the average core strength, as modified to account for the diameter and moisture condition of the core; V is the coefficient of variation of the core strengths; n is the number of cores taken; and k_c is the coefficient of variation modification factor.

With this process, the value of the final equivalent compressive strength of concrete seems to be a value which is much smaller than the initial value of the core strength, and even in case where the sample size is small (approximately) the final value is smaller than the minimum of all the values of the sample. A sample calculation of the process is shown in Table 1. Here, it can be seen that the final result (2496.5 psi) is smaller than all four values of initial core tests in the first column. So, this process of determining concrete strength seems to be unduly conservative.

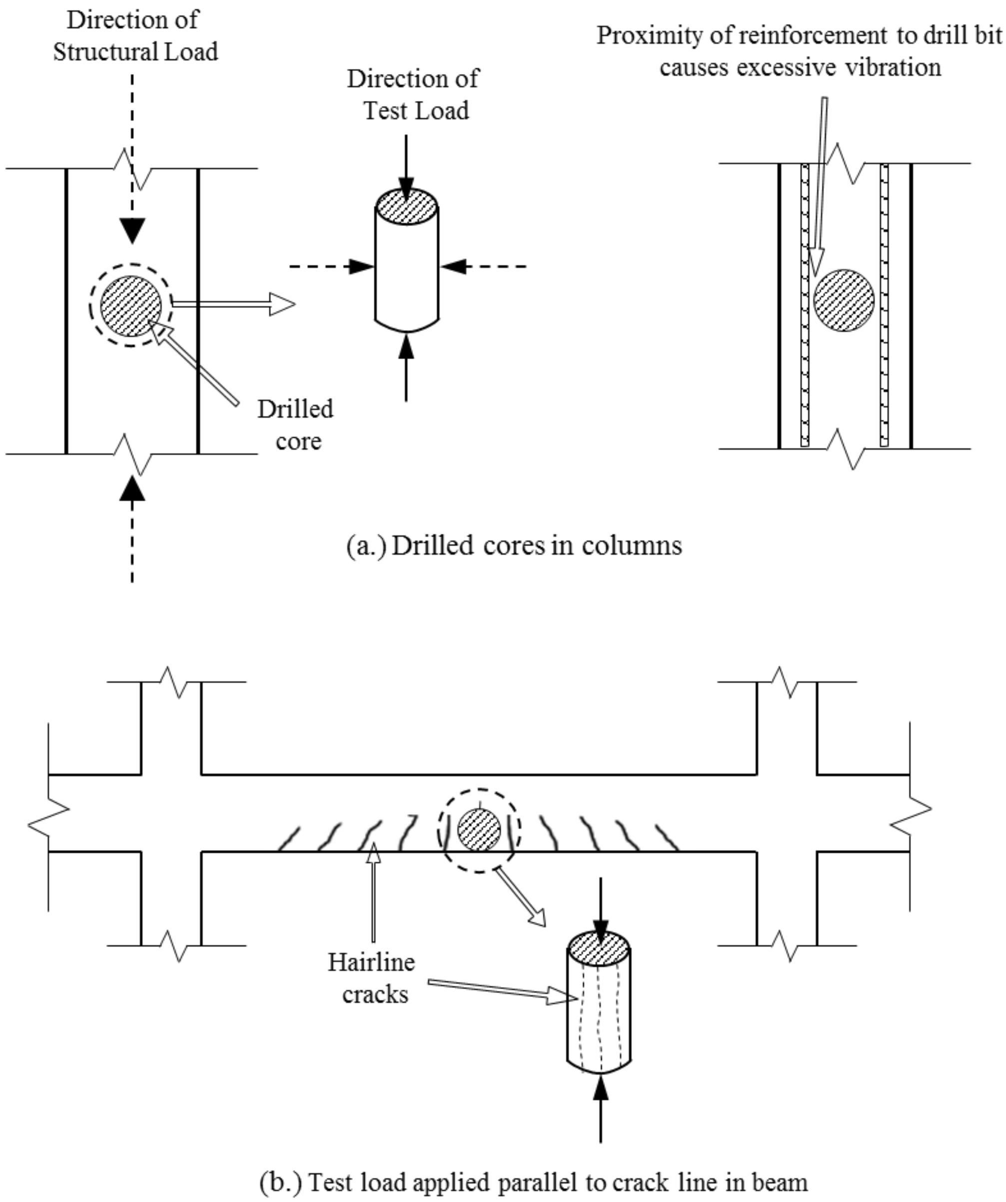

Figure 1. Some practical problems in core collection.

Table 1. Sample calculation

Core test results (psi)	**Modified Core test results (psi)**	**Average (psi)**	**Number of sample**	**Standard deviation**	**Coefficient of variation**	**Equivalent Concrete strength according to ACI 562 sec. 6.4.3 (psi)**
3010	3219.315	3219.32	4	507.63	0.16	2496.50
2710	2898.453					
3680	3935.907					
2640	2823.586					

5. Core Strength and Structural Adequacy

Core testing is the most direct method of determining the in-situ compressive strength of concrete in both new structure and existing structures. But as mention in the previous sections the uncertainties associated with the core test have some implications on the overall interpretations regarding the evaluation of structural capacity. In order to understand the relationship between the compressive strength, obtained from the core test and the retrofitting requirement of reinforced concrete buildings a set of 59 buildings has been studied in this paper. The study aimed to observe the relationship among the degree of retrofitting, age of the building, story height and most importantly the equivalent compressive strength.

5.1 Degree of Retrofitting and Equivalent Compressive Strength

The equivalent compressive strength has been calculated by following the provisions of ACI 562. Among the 59 buildings, there were three categories of buildings. They have been classified depending on the degree of retrofitting required e.g. major, minor and no retrofitting. The compressive strength has varied between 1000 psi to 4500 psi. From the analysis it has been found that the majority of the buildings which need major retrofitting have very low equivalent compressive strength. As the compressive strength increases the percentage of buildings requiring major retrofitting declines and buildings with minor or no retrofitting increase. Figure 2 shows this trend.

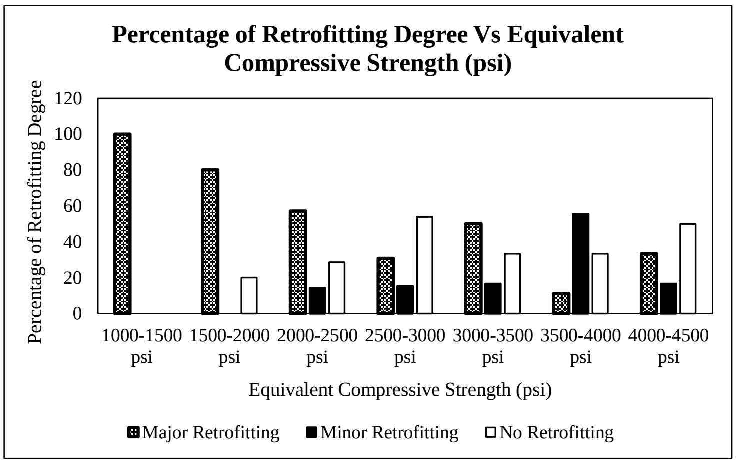

Figure 1. Percentage of Retrofitting Degree Vs Equivalent Compressive Strength (psi)

Here we can see, at a strength level of 1000 psi-1500 psi all the buildings require major retrofitting. On the other hand, only 33% of buildings with a strength of 4000 psi to 4500 psi require major retrofitting. From this it can be said that the low compressive strength obtained from the core test is one of the major deciding factors regarding the retrofitting requirement of structures.

5.2 Degree of Retrofitting and Age of the Building

In the data set the age of the buildings has varied from two to thirty three years. The newly constructed ones, with an age of less than five years, almost require no retrofitting. As the age increases the percentage requirement of major retrofitting increases more or less. Most buildings e.g. 22 among 60, fall within the age group of 10 to 15 years, Among these almost 46% require major retrofitting and the percentage for minor or no retrofitting in is 27% each. The maximum percentage of buildings, which require major retrofitting are the oldest ones with an age of 20 to 30 plus years. Figure 2 summarizes this. It can be said that there is also some dependency between the age and degree of retrofitting.

5.3 Age and Equivalent Compressive Strength of Building

From the data set it is observed that the buildings with a compressive strength of 1000 psi to 1500 psi need major retrofitting. 60% of them are more than 20 years old. Remaining 40% has an age of 10 to 15 years.

Yet they require major retrofitting due to the low compressive strength. So the governing factor is the low compressive strength, not the age. The argument could be strongly supported if we had old buildings with higher compressive strength, e.g. 3000-4500 psi which did not need any retrofitting. But we lack this kind of data. Among the 21 buildings within this compressive strength range only two are older than 20 years. Though one of them do not require such retrofitting. We need more such data to establish that the compressive strength is the more important factor here. Figure 3 shows that the higher the age of the building the lower is the compressive strength.

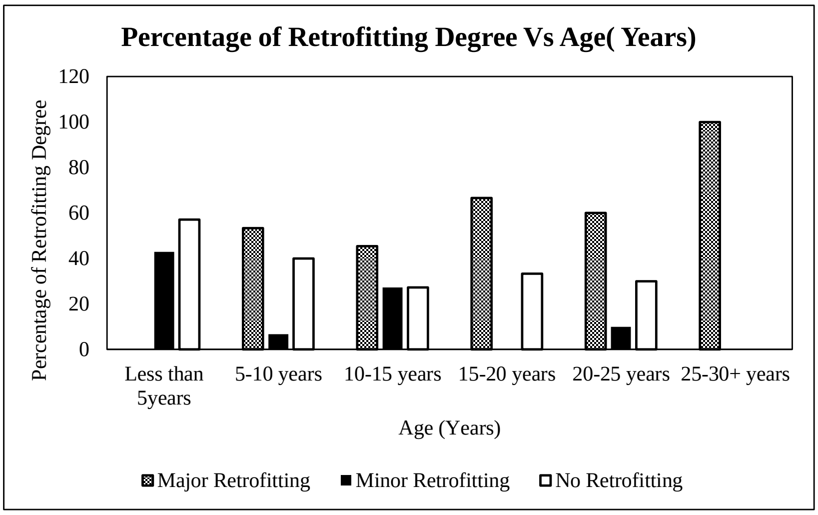

Figure 2. Percentage of Retrofitting Vs Age (Years)

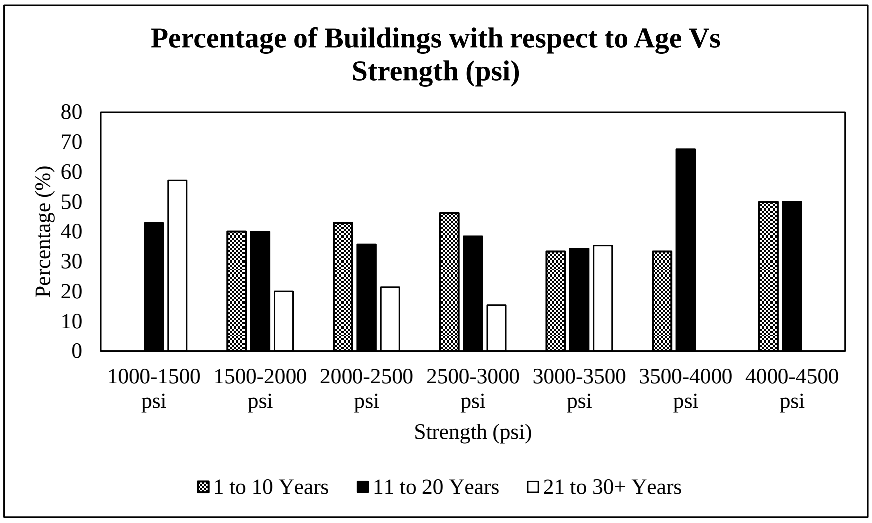

Figure 3. Percentage of Buildings with Respect to Age Vs Compressive Strength (psi)

5.4 Degree of Retrofitting and Height of the Building

The height of the building does not have any particular effect on the degree of retrofitting. 0, 1 and 2 degree of retrofitting means major, minor and no retrofitting respectively. Figure 4 shows that buildings of the same height, e.g. having same number of stories, may require major, minor and even no retrofitting. It depends on the age and more importantly on the compressive strength of the building.

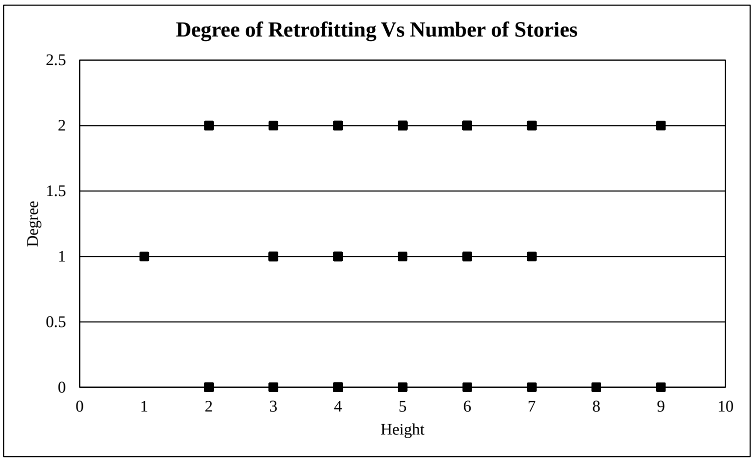

Figure 4. Degree of Retrofitting Vs Number of Stories

6. Conclusions

Structural safety assessment is of paramount importance for the future of garments industry in Bangladesh. Safer structures will not only ensure workers' safety, it will as well increase international buyers' confidence. However, incorrect assessment due to wrong data from the field may either result in unsafe structure or may cause unnecessary burden on the industry due to over conservative assessment. Core test data is the crux to the reasonable implementation of the structural safety assessment. From the discussion of the present paper it is apparent that requirement of retrofitting depends on the in-situ concrete strength. However, there are issues regarding core testing which need to be addressed. Firstly, there are possibilities of faulty collection cores that may result in low strength. To address this problem, the authors suggest that the technical people involved in collecting cores should be properly trained so that they can appreciate the delicate technical issues of core testing.

Secondly, from the core test reports of the 59 buildings studied in this paper, it is obvious that in many reports there is not enough information relating the test conditions of the cores. This fact also raises the concern if the testing laboratories are actually following the standard practices of core testing. For quality control of core testing the authors recommend that the monitoring authorities should inspect the laboratories on a regular basis so that adherence to standards are ensured. The testing laboratories should also be dictated to provide the information about the conditions of the core as required by the standards.

Finally, as it appears that due to faulty collection of core or smaller diameter of core or due to inappropriate test condition in the laboratory, core test results may be much lower than the actual concrete strength. This fact is also apparent from cases of 15 to 20 year old structures without any sign of distress require extensive retrofitting due to very poor concrete strength. With this presumption, the authors also suggest that instead of following very strict requirement of ACI 562 for determination of effective strength, we may consider a more pragmatic approach. For example, ASCE 41 (2013) uses a concept of expected strength which is less stringent for existing structures. Moreover, strength reduction factors are also relaxed for existing structures according to ASCE 41. The authors suggest that this issue be revisited and a discussion is held among the stakeholders to come up with a rational approach for the advantage of the industry without compromising safety of workers.

Acknowledgments

The authors wish to gratefully acknowledge the Alliance for Bangladesh Workers Safety for providing data of the 59 unnamed factories for the study.

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WORKPLACE SAFETY: EMPOWERING WORKERS CAN MAKE A DIFFERENCE

S. S. U. Ahmmed[1]

ABSTRACT

Two reasons are attributed main for Rana Plaza crisis i.e, i) faulty building structure and ii) lack of participation/choice by the workers. The main focus in this article is on this second main reason. Despite known risks and denial by workers, they were forced to work during the crisis day. There was no trade union in the workplace. Despite having risk workers could not say no to hazardous work which is a right to them. Although emergency exit was there it was totally blocked. All these prove that structural development itself is not enough to ensure safety of workplace. Workers participation, training, complain mechanisms are essential ingredients in this. This is what later on influenced government to initiate safety committee in the industrial settings. This article deals with this empowering aspect of workers to ensure safety in workplace.

Main Body

Workers' right to form trade unions and collective bargaining is guaranteed by our Constitution and Bangladesh Labour Law-2006. Bangladesh has been a member State of the ILO since 22 June 1972, and has ratified 35 ILO Conventions, including 7 fundamental conventions like Freedom of Association (87) and Collective Bargaining (98).

Bangladesh RMG sector, having 4,221 establishments (DIFE, 2018) and 3.4 million workers (BBS, 2016-2017), employers' hostile attitude did not allow workers to form Trade Unions and the Participation Committee, even though it has been obligatory for the employers by Law. Provision of safety committee was also absent in the Labour Law earlier. As a result, there was a lack of structure where workers can share their concerns & issues.

On 23rd of April 2013 when the building crack in Rana Plaza was identified, workers were evacuated. But the next day, the workers were forced to enter the building and according to various inquiry reports, the gate was locked which was absolutely against Law. This negligence & reluctance caused the huge casualty that day.

In order to bring change to this scenario, immediate national & International concerns were;

- Respect to workers' right to association and bargaining,
- Formation of Safety Committee, Participation Committee and other legally prescribed structure,
- Ensure workers' right to participate and
- Respect workers' right to raise their concern and say no to risky works & working conditions.

It was also part of the tripartite commitment agreed & signed by Government, Trade Unions and Employers' Association, and ILO as witness signatory.

Afterwards, massive change in Labour Law have been brought and as a part, formation of safety committee with participation of workers has been made mandatory. A total of 909 safety committees have been formed

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so far up-to February 2018 (DIFE, 2018) in RMG factories. The main role of factory based safety committee is to ensure safe working environment in the factory. The responsibilities are as follows;

- To make, implement and monitor the policies regarding OSH related issues,
- To make checklists for the assessment of risks and hazards in the factory,
- To inform the management about the risks and danger,
- To arrange various types of safety related training for the worker etc.

A number of Participation Committees have also been formed, one of the mandate of which is to improve Occupational Health & Safety-OHS & workplace situation at factories. Even though, progress in overall situation is rather slow, as the only mechanism to empower workers is being organized through trade union.

Focusing on ways forward, we need to put emphasis on the following areas of actions among others;

- Accelerating process of formation of safety committee,
- Providing trainings to the safety committee members,
- Arranging periodic meeting of committee members,
- Making implementation of committee's recommendations mandatory and exceptions to be punishable,
- Forming multi-stakeholder task force for monitoring & supervision (including Fire Brigade officials, Chemical expert, boiler expert, building & structure expert etc.),
- Ensuring transparency, on both policy & implementation end
- Most importantly, ensuring workers' right to say no against dangerous forms of work through Law.

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COMPUTER MODELLING OF FIRE SAFETY PERFORMANCE OF A READY-MADE GARMENTS (RMG) BUILDING IN BANGLADESH

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ABSTRACT

In the present study, fire safety analysis of a multistoried RMG building is performed by coupling results from fire growth and smoke propagation modelling and evacuation modelling software. The different smoke propagation and evacuation scenarios are selected to resemble some typical and often overlooked unsafe workplace practices observed in the RMG sector in Bangladesh. Occupant evacuation from a seven-storied RMG building is simulated for these fire scenarios and the effects of smoke temperature, visibility, CO concentration, occupant behavioral features, obstructed/unobstructed evacuation routes, exit condition are analyzed in terms of the required safe evacuation time. The fire-smoke production and spread is simulated by using PyroSim, and the occupant evacuation is modelled using Pathfinder. The simulated results are compared with the critical time for evacuation obtained from the fire modelling and also with the actual fire-drill data in hand for a number of such RMG buildings having similar geometry and size. For the same fire growth scenario and fuel load, it is observed that when there is no fire barrier in place near the stairway (fully or partially open fire doors), different areas of the building become untenable very quickly. For the evacuation scenario with obstructions in the egress pathways and reduction in the number of available exits, an open fire door to the source of the fire increases the required evacuation time by 41% compared to when the fire door is closed. Moreover, if all the unsafe practices are considered at the same time (open fire door, obstructed egress route and reduced number of exits), about 141 occupants get trapped and fail to evacuate safely due to the reduced visibility through the smoke in the egress route. Findings of this study can be useful in assessing and enhancing safe evacuation of the occupants in RMG buildings of Bangladesh.

Keywords: PyroSim, Pathfinder, FDS, Fire safety, Fire modelling, Evacuation, RMG.

1. Introduction

Ready-made garment factories in Bangladesh have experienced repeated fires and building collapses in the last 10 years, resulting in more than 1,600 deaths and hundreds of disabling injuries (Brown, 2015). Therefore, the necessity to address this problem and work towards a solution to avoid these deadly incidents has become more profound than ever. Since fire can originate from various changes in the environmental conditions, behavior of fuels and combustion chemistry, computer simulations can help in the analysis of these conditions and to realize the proper safety measures. Performance-based fire growth and smoke propagation models coupled with egress models to simulate the occupant evacuation process can be very useful in the evaluation of fire safety performance of a building.

Different computational tools such as computational fluid dynamics (CFD) and large eddy simulation (LES) have been used to model fires growth and smoke spread with sufficient accuracy. Fire dynamics simulator (FDS) is a widely used simulation tool in the study of fire processes and hazards. PyroSim is a CFD tool based on FDS with the capability of simulating fire scenarios and optimized for low-speed, thermally-driven flow. PyroSim has been used to study the effects different fire scenarios in a cinema hall fire, simulate fire in a high speed train for different ignition scenarios (Glasa, 2013; Liang, 2014). A number of evacuation modelling software has been used by the researchers with a varying degree of ability to accommodate psychological aspect of human behavior during evacuation process. Pathfinder is a continuous egress modeling software that adopts two ways to simulate the evacuation process: the steering model and the

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Society of Fire Protection Engineers (SFPE) model. PyroSim has been used with Pathfinder to evaluate safe evacuation condition and egress timing from a supermarket building model subjected to fire (Dong, 2015). In a recent study, PyroSim was used to assess the critical situation in the second floor of a two storied dormitory building, where the fire incurred in a room attached to corridor in the top floor (Long, 2017).

Only one previous work could be found in the open literature on the modeling of fire and smoke in RMG buildings in Bangladesh in spite of its tremendous importance and necessity (Khandoker, 2017). In this study, the propagation of fire and smoke in the event of fire and subsequent evacuation of the occupants has been modelled for a 7-storied RMG building in Bangladesh. The objectives of the present study are to conduct a fire risk assessment of a model RMG building for some typical and often overlooked unsafe workplace practices observed in the RMG sector in Bangladesh. The geometric characteristics of the building have been modelled by selecting typically available features from some of the better RMG buildings in the country. Pyrosim is used to model the fire growth and smoke propagation. The fire scenario considered is the ignition of nylon stacks stored in one of the storage areas on the ground floor. The fire dynamics and the characterization of the fuel properties are according to the SFPE and related guidelines (Hurley, 2016). The evacuation process of the occupants of the RMG building is modelled using Pathfinder. The effects of fire separation, obstructed egress path, number of exit routes, and various behavioral aspects of the occupants on the evacuation process have been examined.

2. Building Geometry and Simulation Methodology

To analyze the fire hazard and the consequences, a 7 storied RMG building was taken into consideration where Nylon stacks acted as the prime source of fire. Simultaneously, a quantitative investigation has been carried on which aims to scrutinize human behavior under certain conditions. The corresponding reaction for Nylon was determined from the SFPE handbook to establish the composition of carbon, oxygen, nitrogen, and hydrogen. Necessary devices were placed to ascertain the variations of the aforementioned parameters under different conditions. Under different cases the amount of Nylon working as the fire source or fuel was varied for different ventilation conditions. The t-square model was used to verify the effect of heat release rate with respect to the change of time.

The simulation was performed considering a building geometry whose features closely resembled the *'ideal layout'* of a RMG factory in Bangladesh (Figure 1). The area of each floor was 73000 ft^2 and the total occupant number in the building was 5381. The occupant density and number of occupants in each floor was selected depending on the type of work done on that floor. The total occupant numbers, ratio of male-female workers were decided by collecting data from a number of RMG factories in Bangladesh. The overall ratio for male-female for the whole factory is taken as 30:70. The workforce in RMG all over Bangladesh mainly consists of adults in the age between 18 to 40 years. Hence, the walking and evacuation speed of individuals during evacuation were selected accordingly considering this age group for both genders (Wong, 2006).

Pathfinder was used to model the evacuation process. Pathfinder embeds partial behavior which covers the implicit or explicit variables to simulate the behavioral factors associated with the evacuation process. As mentioned before, Pathfinder contains two methods to simulate the evacuation process: the steering model and the Society of Fire Protection Engineers (SFPE) model. In this study, steering mode was used, because it is more dependent on collision avoidance and occupant interaction for the final answer and often gives answer more similar to the experimental data than the SFPE mode. For modeling the evacuation, 2nd generation Flow/Hydraulic model has been used (Gwynne, 2008).

The evaluation of safety of the occupants has been based upon ASET/RSET analysis. The Available Safe Egress Time (ASET) is the amount of time that elapses between fire ignition and the development of untenable conditions. While, the Required Safety Egress Time (RSET) is the time that is required by the last individual to exit the building. Typically, in a RMG building, there are smoke detectors and fire alarm, hence the time required of detection and notifying the occupant can be considered to be negligible. Hence, the overall RSET was considered to be dependent broadly on pre evacuation and evacuation time. A pre-evacuation time was also considered and a normal distribution of the pre evacuation time was set with a maximum delay of 40s, minimum delay of 15s, and an average delay of 27.5s in this study (Shields, 2000).

Pathfinder takes into consideration people-people, people-fire and people-structure interactions. It comprises of five core interacting submodules: OCCUPANTS, MOVEMENT, BEHAVIOUR, TOXICITY, and HAZARD sub-models. The OCCUPANTS sub-model describes an individual as a collection of attributes and variables such as gender, shoulder width, height and maximum unhindered walking speed. The body dimension of typical Bangladeshi male were set considering the normal distribution for the population from the anthropometry data of Bangladeshi individual (Talapatra, 2016; Khadem, 2014), as shown in Table 1.

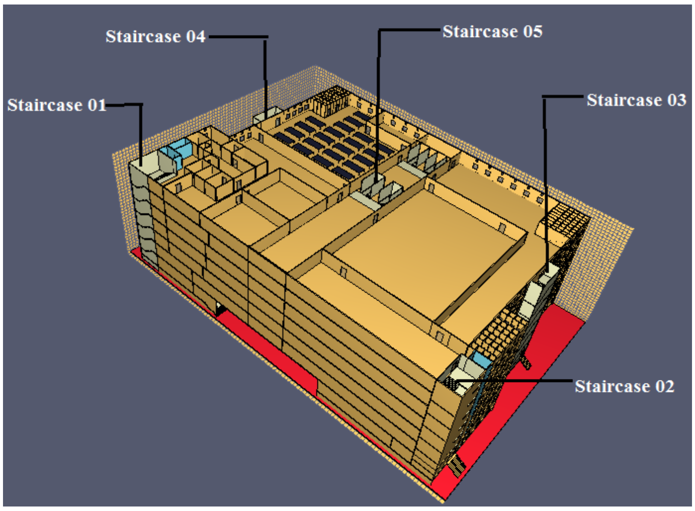
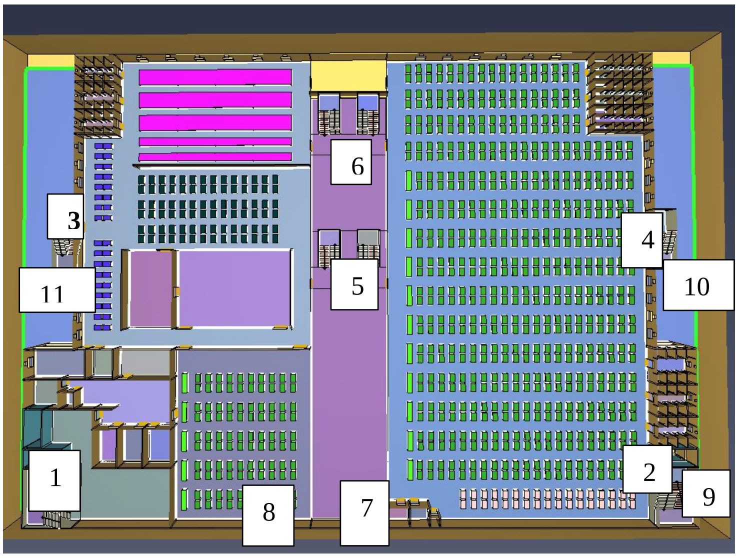


Figure 1. 3D view of the RM building model whose geometric features resembled those of existing 'ideal' RMG buildings



1. Staircase 1
2. Staircase 2
3. Staircase 3
4. Staircase 4
5. Staircase 5
6. Staircase 6
7. Exit number 1
8. Exit number 2
9. Exit number 3
10. Exit number 4
11. Exit number 5

Figure 2. Layout of the RMG building showing the location of staircases and exits.

Table 1. Anthropometry data for Bangladeshi male and female (Talapatra, 2016; Khadem, 2014).

Gender	Dimension	Minimum(in)	Maximum(in)	Mean(in)	Std. deviation
Male	Shoulder breadth (Bideltoid)	13.685	19.307	16.496	0.937
	H Height	59.82	72.22	66.02	2.067
Female	Shoulder breadth (Bideltoid)	14.328	20.1	16.925	1.5
	Height	57.3	64.7	60.32	1.2

Table 2. Detail of walking speed in emergency considered for Bangladeshi young male and female.

Gender	Maximum speed (m/s)	Minimum speed (m/s)	Mean speed (m/s)	Std. Deviation
Male	4.25	2.95	3.68	0.41
Female	3.15	2.92	3.04	0.09

The MOVEMENT sub-model takes the maximum, minimum and mean speed for an individual occupant profile along with the standard deviation. For the present analysis, the maximum walking speed of an individual under emergency situation is considered. The data for standard deviation of the speed along with mean, maximum and minimum values that has been considered is shown in Table 2. Since the maximum walking speed in largely dependent on age and health condition of the occupant, the experimental data Wong *et al.* (2006) was selected as it resembles the given demographic of the RMG workers fairly closely. For movement through smoke, Jin's model has been used (Jin, 2002), which relates light extinction coefficient to walking speed.

Since fire drills are arranged regularly at RMG in Bangladesh, the occupants can be considered to know the distance to different exits and are aware about the exit path that should be used to exit the building quickly. Because of this, in our simulation, the occupants were allowed to make independent decision based on the existing scenario of congestion in different areas and distance to each exit. The threshold value for temperature tolerance by human, the minimum visibility for movement through smoke for fire-trained individuals, the effect of the reduction of visibility on occupant's way-finding ability were included following the appropriate standards available in the literature (Jin, 2002; Isobe, 2004).

For the occupants to evacuate safely, the parameters that should remain below a certain limit during a fire incident are temperature, carbon monoxide (CO) concentration, and visibility. Therefore, these parameters were measured at different locations of the geometry in order to determine the tenability. Devices were set up at every floor, adjacent staircases and corridors at heights corresponding to male height, female height and crawling height. The critical concentration of CO was taken as 3000 ppm. These standards have been established as the decision criteria of tenability in the present work.

3. Results and Discussion

3.1 Fire and Smoke Propagation Scenario

In order to analyze the fire growth and smoke propagation, four different simulations scenarios were simulated considering the variation of fuel load and fire compartmentation, as shown in Table 3. The different fire scenarios had the same fuel load of nylon stacks in one of the storage areas on the ground floor, only the fire barrier conditions were varied by keeping the fire door partially/full open or closed. This was done to examine the effect of the keeping the doors open on the fire and smoke propagation.

Table 3: Various fire scenarios considered

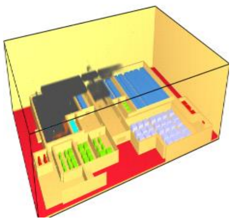
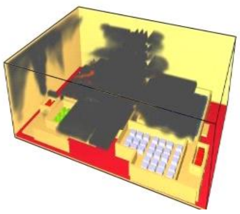
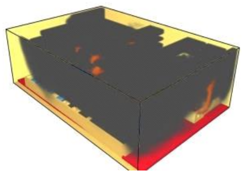
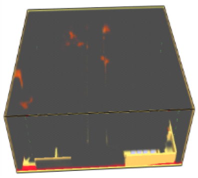
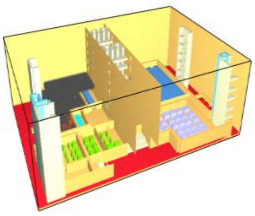
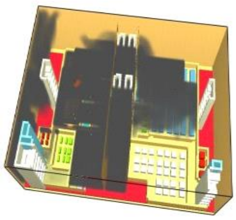
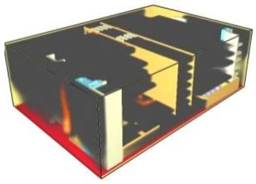
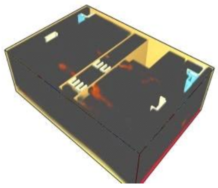
Scenario designation	Characteristics
A	Long, continuous stacks of finished goods/raw materials which act as fuel load having average width of 10 ft. and separated by 5 feet. All the fire doors are open.
B	Fuel load same as case A, fire doors are partially open.
C	Fuel load same as case A, the doors are closed.

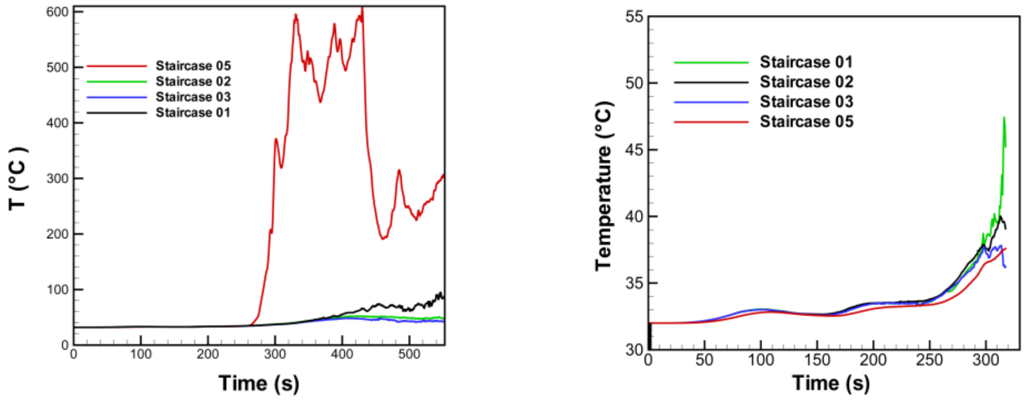
3.2 Propagation of Fire and Smoke for Different Fire Separation Scenario and Tenability Analysis

The propagation of smoke in the building for same fuel load and different fire separation conditions are shown in Table 4. For the fire scenario A (open door), the whole building geometry was found to be covered by a layer of smoke within 450 seconds of the initiation of fire. For scenario B (partially open door), the smoke took about 10% more time than scenario A to spread through the whole building. However, fire scenario C exhibited completely different state of smoke propagation, when compared to other cases. Due to tight compartmentation achieved by closing all the doors, smoke could not spread through the central hallway and spread towards the right portion of the geometry. The drop in visibility was higher for occupants residing in the left portion of the building, while people could continue to safely evacuate from the right side of the building even after 5 minutes.

There are four general staircases and two emergency staircases in this building that can be used by occupants during evacuation. Two central stairways are situated in the middle of the building and are connected to the hallway that leads to the central exit. Occupants are more likely to use these two sets of staircases for general purpose in their daily routine. However, in the event of a fire scenario with open doors, the central staircases and adjacent hallway becomes untenable very rapidly, as shown in Figure 4.

Table 4: Comparison of smoke spread throughout the building at the same time periods after the initiation of fire for the three different fire scenarios considered in this study

Fire scenario	Time (s)			
	120	270	390	510
A	 (a)	 (b)	 (c)	 (d)
B	 (e)	 (f)	 (g)	 (h)



(a) (b)

Figure 4. The variation of temperature with time in different staircases on the third floor for (a) fire scenario A, and (b) fire scenario C

The central staircases crossed the limit of tenable temperature after 4 minutes 20 seconds for fire scenario A. This can be attributed to the fact that smoke rapidly traveled upwards through stairway shaft and adjacent hallway before encompassing the whole floor. From Figure 4(a), it can be seen that the temperature in the central stairways went as high as 400 °C within 5 minutes after the ignition. In comparison, it can be seen from Figure 5(b) that the temperature reached a maximum value of 47ºC at staircase-01when there was an effective compartmentation (closed door).

The corridor on the ground floor reached the tenability limit of temperature at around 200 seconds for Case A. However, for other fire scenarios, it was the first floor corridor that reached the tenability limit first. Within 5 minutes 40 seconds, visibility in corridors of all floors dropped significantly when the doors were open. An important pattern that was observed in our simulation was that the corridor in first floor always reached a hazardous state before other floors. Similar patterns were reported in case of the dormitory fire by Long (2017). According to their findings, floors above the fire source were more seriously influenced by smoke.

3.3 The Different Evacuation Scenarios

Table 6. The state of evacuation for different fire separation and egress conditions

	Evacuation Scenario Designation	Egress Route	Exit Condition	Egress Condition	RSET	No. of Occupants Trapped
Without Fire	Scenario 1	Free	All Open	Ideal	5min 14 sec	0
Open fire door	Scenario 2	Free	All Open	Ideal	5 min 44 sec	0
	Scenario 3	50% Blocked	All Open	Non-Ideal	6 min 20 sec	0
	Scenario 4	50% Blocked	2 Closed	Worst	8 min 08 sec	141
Closed fire door	Scenario 5	Free	All Open	Ideal	5 min 23 sec	0
	Scenario 6	50% Blocked	2 Closed	Worst	5 min 46 sec	0

Different evacuation scenarios were modelled for the same fire-condition by considering different egress conditions and exit numbers. Separate cases considering the blockage of movement pathways and condition of the exits during evacuation were included since these two factors significantly modify the movement of occupants. The different evacuation conditions were rated from ideal to non-ideal to worst, depending on the amount obstruction and unsafe practice modelled (Figure 5). In order to assess the effect of exit doors and blockage of hallway for a specific fire condition, evacuation simulations were performed assuming all the exits to be open and no blockage in the hallway, staircase and near door (ideal condition), as shown in Figure 5(a). Simulations were conducted for the same fire condition with 50% blockage in the hallway, staircase and near door (due to storage of cartons, boxes, materials), and for another condition considering similar obstruction on the pathways and 2 out of the 6 exits to be blocked (hence termed as the 'worst' condition).

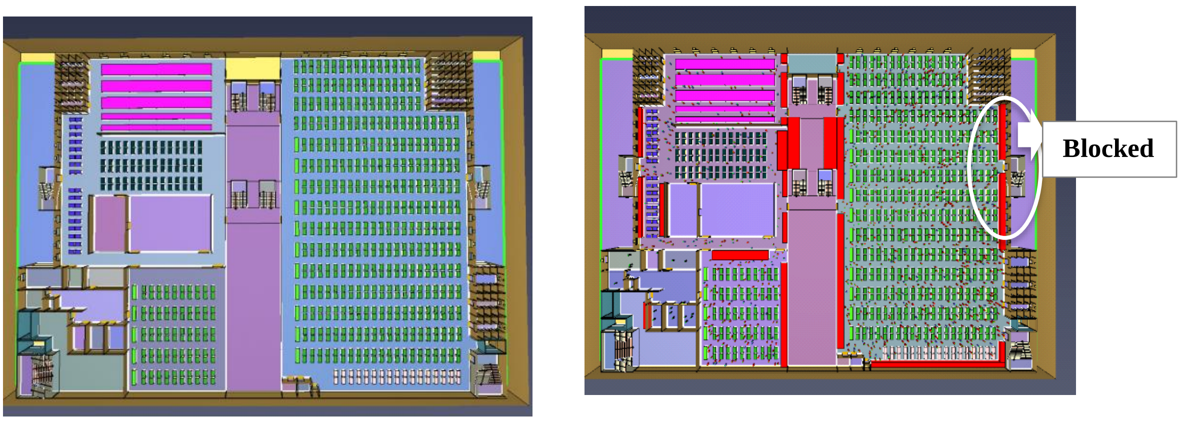
3.4 Validation of the Evacuation Modeling

In order to validate the evacuation modelling, the first case was simulated where the time required for all the occupants to exit the building without the occurrence of any fire was determined. The data for the required evacuation time for actual unannounced fire drill conducted at different RMG factories having geometry and occupant number closely resembling the RMG building model considered here was collected and averaged. The evacuation time obtained from our simulation for the case without fire was compared with this collected data. From the collected fire drill data, the average evacuation time was found to be about 300s. The evacuation time obtained in our simulation for the same scenario was 314s. Since the difference of our simulated value with respect to the actual time required was less than 5%, it was determined that within the limits of the accuracy of the approximations made, the results are in close agreement. Hence, this setting is utilized for simulating the remaining fire scenarios.

3.5 Comparison among Various Evacuation Scenarios

- **For Closed Fire Doors (Evacuation Scenario No. 5 and 6)**

The closed fire doors surrounding the fire source caused containment of the smoke in the ground floor for a period of time before it began to escape through the windows. Smoke entered the first floor from the window on the left side of the building directly above the fire source. The smoke then begins to spread from the first floor to the central corridor. For evacuation scenario 5 (ideal condition), the time required for evacuation is 5 minute 23 seconds, almost the same time as in the case of evacuation without any fire. The occupants exit the building from all the staircases, with the staircase no. 2 being used by most. The occupants did not have to face any sorts of obstruction along the way and since the smoke propagated more slowly in this case, the



(a) (b)

Figure 5. Layout of 2nd floor in a) Evacuation Scenario 1, and b) Evacuation Scenario 2 and 3;

visibility and temperature remained well inside the threshold value throughout the whole time. For evacuation scenario 6 (worst condition), the time required for evacuation was 5 minute 46 seconds when the doors were closed. The required evacuation time was only 10% higher than the case when there was no fire in the building.

- **When the Fire Doors are Open (Evacuation Scenario 2, 3 and 4)**

After the ignition of the fire source in the ground floor, the smoke began to spread from the window of the ground floor and entered the left side of the first floor through the windows. The smoke was found to spread rapidly causing quick reduction in visibility within the first 90s in the room opening to the corridor of the central staircase in first floor. It propagated upwards to the staircase no. 6, causing decline in visibility below the threshold limit (4 m for trained individual) inside the staircase no. 6 on all the floors within 210s. Among the six staircases inside the building, staircase no. 6 became untenable first. Hence the occupants trying to exit the building were forced to take other routes leading to the remaining staircase for exiting the building. For evacuation scenario 3, because of the obstructions present in the way of movement of the occupants, the flow rate of occupants towards an exit was greatly affected. This led to an increase in safe evacuation time from the ‘ideal’ condition (without any obstruction in the egress path) by about 10%.

For evacuation scenario 4, which depicts the ‘worst’ evacuation scenario (open fire door, obstructed egress pathways, reduced number of exits), the load on the remaining four staircases were increased. As a result of this, the congestion in the remaining staircase caused evacuation time to increase. Moreover, after 200s, due to the propagation of smoke through the staircase no. 5, the visibility inside the staircase falls below threshold which renders it useless as shown in Figure 7. This causes the occupants using this staircase during that time to be trapped as shown in Figure. 6. On the other hand, smoke is seen to cover the rooms to the left of central corridor of the first floor after 184s as shown in Figure 6. In addition to that the visibility in rooms to the right of the central corridor in the first floor falls below 4 m after 214s (Figure 7). As a result, the occupants who have reached the first floor (141 occupants) while they are moving through the corridor get trapped. The required evacuation time increased by about 42% compared to the when there was no obstruction in the hallway and all the exits were open. However, it should be noted that the estimate of even this high number of casualty is a conservative one because of Pathfinder’s limited ability to alter occupant’s movement speed and decision making when facing smoke.

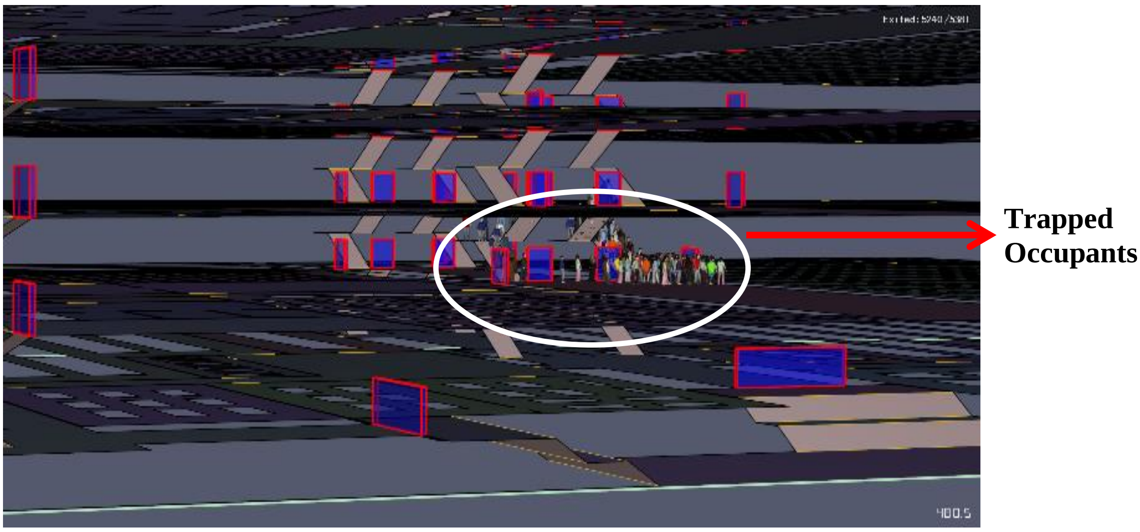


Figure 6. Trapped occupants in the staircase no. 5 and the central corridor of the first floor for Evacuation scenario 4; where the fire doors are open, the egress paths are obstructed and two exits are closed.

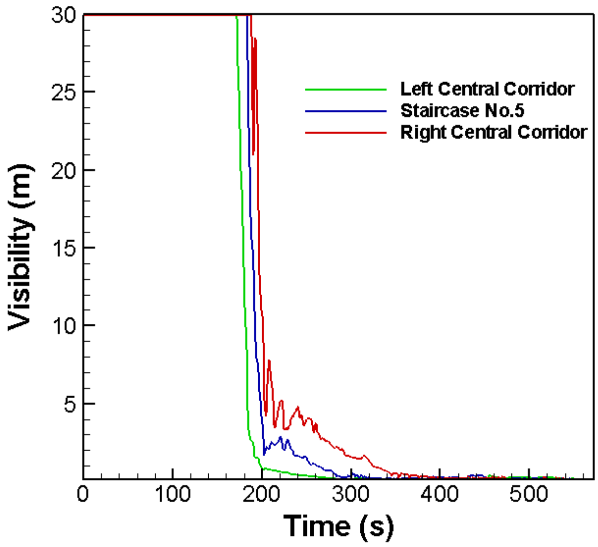


Figure 7. Visibility in rooms to the left and right of central corridor on first floor and Staircase no.5 for Evacuation scenario 4. Visibility in these areas falls below the threshold value, rendering them useless.

It should be noted here that the required evacuation time was 5 min 46 s for the worst condition when the door to the fire source was closed. Therefore, for the same amount of obstruction in the egress path and same number of exits, keeping the fire doors closed reduced the required evacuation time by about 41%. This finding clearly demonstrates the tremendous importance of maintaining a fire and smoke barrier, in this case, keeping the fire doors closed, to improve the fire safety of the building.

4. Conclusion

A coupled simulation study, CFD modelling for fire growth and smoke propagation, and evacuation modelling of the occupants, was conducted to evaluate the fire safety performance of a multistoried RMG building in Bangladesh. The effect of fire separation, obstruction in the egress pathways, and the number of exit routes on the evacuation process and occupant safety was analyzed.

For the same fire growth scenario and fuel load, it was observed that when there was no fire and smoke barrier to the stairways (fully or partially open fire doors), different areas of the building became untenable very quickly due to high CO concentration or air temperature. The visibility also reduced significantly for some of the exit paths and stairways, rendering them unusable for evacuation. The rapid smoke propagation resulting from the unsuppressed fire due to the open fire door increased the required safe evacuation time by about 41% compared to the same fire scenario with the door closed. When all the unsafe practices were considered at the same time (open door, obstructed egress path and reduced number of exits), it was found that 141 occupants got trapped and failed to evacuate safely due to the reduced visibility through the smoke in the egress route. For the same smoke propagation and exit condition, the movement of the occupants towards an exit was greatly affected by the obstructions in the egress routes, leading to an increase in the evacuation time from by about 10%. The significance of this study lies in the fact that it brings to attention the importance of fire safety assessment of RMG buildings by demonstrating the possible devastating consequences of some of the typical and often overlooked workplace practices observed in the RMG sector of Bangladesh.

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DO WOMEN AND MEN HAVE DIFFERENT PERCEPTIONS ON HAZARDS IN THE WORKPLACE?

A study at eight export-oriented garment manufacturers in Bangladesh

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ABSTRACT

Women make up a large part of the workforce in the garment and textile industry. This study examines if there are gender differences in the perceived hazards in the workplace. The study uses the data collected through a survey of 414 randomly selected production workers in eight garment factories in Bangladesh, to identify differences in hazard perceptions between women and men. Electrical safety, clear evacuation routes and verbal abuse are among the top five priorities for both women and men. Women more likely to perceive high workload/long working hours, tripping and cracks on the wall as serious hazards, while men tend to believe that food hygiene and electrical hazards are important.

1. Introduction

Women's participation in the garment manufacturing industry has largely contributed to the Bangladesh economy. Globally women as well as men are exposed to hazards in their workplace. Studies in different industries in the EU have shown that women are more vulnerable to occupational hazards than their male counterparts (Belin, 2011; Campos-Serna, Ronda-Pérez, Artazcoz, & Moen, 2013; Lu, 2007). It is the responsibility of employers to control hazards and provide a safe and healthy environment for workers. To do this effectively, employers need to involve workers, both women and men, because they often have the best understanding of the root causes of hazards and insights into how they can be controlled. The Department of Inspections for Factories and Establishments of Bangladesh has published a guideline on Safety Committees as part of the Occupational Safety and Health kit (DIFE, 2016). The Guideline explicitly points out that gender aspects need to be considered.

Workplace hazard is defined by the International Labour Organization as "the potential to cause harm – which can include substances or machines, methods of work or other aspects of organization" (Alli, 2008). Employees' perception of safety and hazards at work is linked to overall safety climate and safety performance of an organization. (Griffin & Neal, 2000; Kouabenan, Ngueutsa, & Mbaye, 2015). Understanding hazard perceptions is an inevitable step in order to design activities aiming at behavioural change of individuals and organizations.

This study aims to find out whether or not there are gender differences in hazard perception between women and men in the context of Bangladesh export-oriented garment industry.

2. Method

Eight garment factories participated in this study, and another two factories participated in testing the questionnaire initially. The factory managers were approached either by their buyers or by the research team directly to voluntarily join the study. All factories in the study are producing for export. The original

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questionnaire was mainly open-ended questions, which ask workers to identify five hazards that they are exposed to. Prior to the survey, the questionnaire was tested among a group of unionised workers in the office of their union. The workers were asked to fill in the questionnaire and afterwards discuss the results with the research team. The team adapted the questionnaire and tested it again at two smaller factories as a pilot.

During the pilot, the research team realised that workers were reluctant to identify risks as asked in the open-ended questions. Many workers refused to fill in the questionnaire and told the research team that their factories were perfect. Half of the workers were able to identify one or two hazards, while only three persons out of the 138 respondents identified four hazards. Therefore, the research team decided to change the questionnaire to a structured questionnaire. The open question asking for hazards was replaced with a list of 19 hazards that respondents could choose from. These 19 hazards were developed based on the answers given by 10 unionised workers and the 138 non-unionsied workers in the pilot factories. The question asked workers to imagine themselves as an auditor. They need to decide five most concerning hazards when they inspect a factory and find 19 hazards on occupational health and safety. The question stressed that they were asked to give their own opinion rather than give the ‘correct answer’. The workers could also decide to add one or more hazards if they felt relevant.
Four hundred and twenty workers at the eight garment factories were chosen to fill in a structured questionnaire. Due to low literacy level of some workers, the help of worker interviewers was provided when necessary. Stratified sampling was used to select samples. All employees in a factory were partitioned into groups based on the floor they were working.

In total fourteen questions were asked in the questionnaire. Besides demographical data, the questionnaire also collected data on workers’ participation in unions, committees, safety trainings and fire drills. The final question was the 19 hazards list. The questionnaire was designed to encourage workers to identify hazards based on their own perception without being afraid of retaliation. It measured the perception of the workers towards certain hazards, rather than the exposure to these hazards. In order not to disrupt production of factories, the questionnaire was designed to be short and as straightforward as possible. This is also more suitable for the group of workers who received lower education.

3. Results

The results from the survey were analyzed in R. The Pearson’s Chi-squared test with Yate’s continuity correction was used to test if the difference between two groups was significant.

3.1 Characteristics of the Respondents

The survey had reached 420 respondents, who were all production workers. In total 98.6% of the questionnaires (414 questionnaires) were complete and analyzed in this paper. 211 interviewed workers were female and 203 were male. The data showed that women and men were of similar age (24.2 for women and 25.9 for men.) and had spent similar years of their career in the industry 5.0 years and 5.8 years respectively. Education level of women seemed to be lower than that of men. About half (50%) of female workers did not finish junior high education - grade 8, while 28% of male workers did not finish grade 8. Out of the 20 workers who reported that they had never been to school, 16 were women. Women’s job positions seemed to have less variety than men’s. Majority of all interviewed women (77%) worked in two departments: sewing (57%) and finishing (19%). About the same proportion of men (74%) distributed their jobs in these departments: sewing (29%), cutting (18%), knitting (11%), quality control (10%), and finishing (8%).

None of the workers claimed that they were member of a union. Both women (20.9%) and men (25.6%) participated in committees relevant to safety. Safety trainings were given equally to both women and men. The percentage of women (79%) who had received at least one training in the last year is nearly the same as the percentage of men (78%). Among all workers who have received a training, 78% have received it from safety officers or safety committees of their own company.

3.2 Differences of Men And Women In Perception Of OSH Hazards

Overall women and men perceived OSH hazards differently. There were more female than male workers who perceived 'extremely high workload or long hours', 'tripping over stairs or over objects on the floor' and 'crack on the wall' as most concerned hazards if found in a factory. More men compared to their female colleagues found 'unhygienic food and water' and 'tangled or uncovered power cables/broken power distribution board' most concerning. *Table 1* lists the hazards and the differences in perception between women and men as observed in this study.

Table 1. The differences between women and men in hazard perception

	Female N=211	**Male N=203**	**Difference**	**X-squared**	**p -value**
Unhygienic food and water	32%	43%	-11%	4.99	0.03*
Extremely high workload or long hours	18%	7%	11%	9.88	0.00*
Tangled or uncovered power cables, Broken power distribution board	53%	64%	-10%	4.24	0.04*
Tripping over stairs or over objects on the floor	43%	33%	10%	4.07	0.04*
Crack on the wall	35%	26%	9%	3.93	0.04*
Machines without safety guards	31%	24%	8%	2.65	0.10
Not enough fire-fighting equipment	29%	37%	-8%	2.34	0.13
Water boiler, power generator or other big machine is not maintained regularly	23%	29%	-6%	1.55	0.21
No safety protection during pregnancy	35%	30%	5%	0.99	0.32
Blocked evacuation route, Locked factory gates	45%	49%	-4%	0.45	0.50
Personal protective equipment is not used properly	13%	16%	-3%	0.52	0.47
The factory is too dusty	15%	17%	-3%	0.33	0.57
Broken machines	15%	13%	2%	0.30	0.58
Transporting in the dark from work to home	12%	10%	2%	0.23	0.63
Chemicals not being handled properly	9%	10%	-1%	0.09	0.77
Inappropriate storage of inflammable materials	6%	7%	-1%	0.09	0.76
Some jobs requiring maintaining same position for a long time	12%	11%	1%	0.03	0.87
The factory is too hot or too noisy	32%	33%	-1%	0.00	0.95
Abusive language was used towards workers	41%	42%	-1%	0.00	0.97

*The cutoff for significance is p<0.05, which is marked with an asterisk (*).*

Subsequently the overall data was separated into two subsets for further analysis: 1) workers who have reported to have had at least one safety training; and 2) workers who have not had any safety training. A small number of workers (2%) did not remember whether they have had any safety training. They were not included in either of the subsets. Regarding 'unhygienic food and water', 'extremely high workload or long hours' and 'tangled or uncovered power cables, broken power distribution board', differences between women and men are observed in both subgroups, though not all differences are statistically significant.

It is notable that the difference between women and men is much smaller in the subgroup of people with a safety training, when it comes to their opinions on 'tripping over stairs or over objects on the floor'. There is a significant difference between women and men in the group without training, but the difference is not obvious in the group with training. This is probably because more men who have received a safety training consider tripping as a serious hazard than those without a training. This is confirmed when comparing the group of male workers who have participated in safety training and those who have not (See Table 2).

Table 2. Largest differences between women and men in two subsets: workers who had safety training and workers who did not have safety training

	Without training		Difference	p-value	With training		Difference	p-value
	F N=44	M N=45			F N=167	M N=158		
Unhygienic food and water	32%	51%	-19%	0.10	32%	41%	-9%	0.13
Extremely high workload or long hours	20%	4%	16%	0.05*	17%	8%	9%	0.02*
Tangled or uncovered power cables, broken power distribution board	45%	56%	-11%	0.46	55%	66%	-11%	0.06
Tripping over stairs or over objects on the floor	34%	11%	23%	0.02*	46%	39%	6%	0.30
Crack on the wall	20%	22%	-2%	1.00	39%	27%	12%	0.02*

*The cutoff for significance is p<0.05, which is marked with an asterisk (*).*

'Crack on the wall' is considered as a serious hazard by similar percentage of men and women without training. But significantly more women consider it as a serious hazard if they have had a safety training. More women who have had a training choose 'Crack on the wall' as a hazard that needs immediate action compared to those who have not had a training (See Table 2)

Table 3. Largest differences observed between workers who participated in a safety training and those who did not

Women	**Without training N=44**	**With training N=167**	**Difference**	**p-value**
The factory is too dusty	32%	10%	-22%	0.00*
Not enough fire-fighting equipment	14%	34%	20%	0.02*
Crack on the wall	20%	39%	18%	0.04*
Transporting in the dark from work to home	25%	9%	-16%	0.01*
Tripping over stairs or over objects on the floor	34%	46%	11%	0.23
Men	**Without training N=45**	**With training N=158**	**Difference**	**p-value**
Tripping over stairs or over objects on the floor	11%	39%	28%	0.00*
No safety protection during pregnancy	42%	26%	-16%	0.04*
Not enough fire-fighting equipment	24%	41%	16%	0.07
The factory is too hot or too noisy	44%	29%	-15%	0.08
Some jobs requiring maintaining same position for a long time	22%	8%	-14%	0.02*

*The cutoff for significance is $p<0.05$, which is marked with an asterisk (*).*

As demonstrated in Table 3, between women who experienced safety training and women without the experience, the biggest differences lie in the opinions towards five hazards: 'the factory is too dusty'($p<0.05$), 'not enough fire-fighting equipment'($p<0.05$), 'crack on the wall'($p<0.05$), 'transporting in the dark from work to home'($p<0.05$) and 'tripping over stairs or over objects on the floor'($p>0.05$). Women who have had a training tend to consider two hazards less threatening: dusty factory and going home in the dark. Between two groups of men – those who have had safety trainings and those who have not, the differences are the biggest in 'tripping over stairs or over objects on the floor' ($p<0.05$), 'not enough fire-fighting equipment'($p>0.05$), 'the factory is too hot or too noisy'($p>0.05$) and 'some jobs requiring maintaining same position for a long time'($p<0.05$). It seems that men with safety training tend to consider no pregnancy protection, temperature/noise and musculoskeletal hazards less important compared to men without training.

3.3 Similarities of Men And Women In Perception Of OSH Hazards

The data also showed that women and men are very similar in their opinion on prioritizing two hazards to be controlled: 'abusive language was used towards workers' and 'the factory is too noisy or too hot'. Nearly same proportion of women and men chose these two hazards as hazards for immediate remediation. Table 4 presents the similarities between women and men's opinion on prioritizing these two hazards in two subgroups.

Table 4. Two hazards which same proportion of women and men chose

		Without training		**Difference**	**p-value**	**With training**		**Difference**	**p-value**
		F N=44	**M N=45**			**F N=167**	**M N=158**		
04	Abusive language was used towards workers	39%	42%	-4%	0.90	42%	42%	0%	1.00
14	The factory is too hot or too noisy	36%	44%	-8%	0.58	31%	29%	1%	0.87

A high percentage of women (39-42%) and men (42%) overall believed that 'abusive language was used towards workers'. It is observed that the percentage of men who considered this hazard as serious and needs immediate remediation is positively related to the percentage of women working in the department. The correlation coefficient is 0.60. Figure 1 shows the linear relationship.

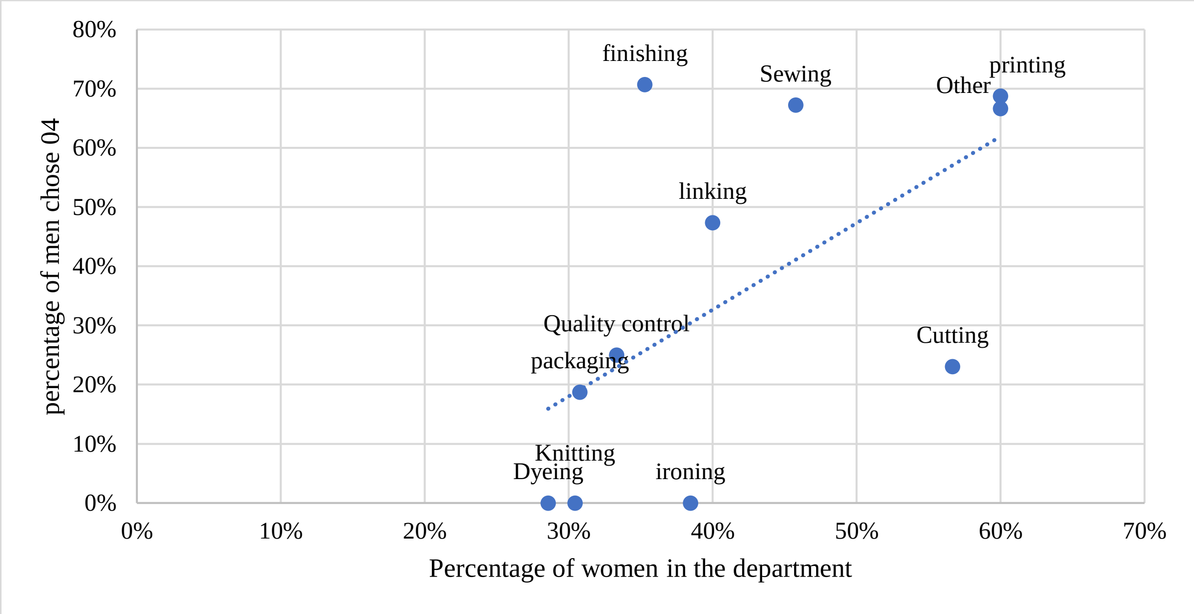

Figure 1. Percentage of men chose 'abusive language was used towards workers' vs. percentage of women working in the department

4. Conclusion and Discussion

4.1 Overall women and men differ in their opinion towards prioritising hazards for control. Women are more concerned about high workload/long hours, tripping and cracks on the wall, while men are more concerned about food/water hygiene and electrical safety such as uncovered cables. Food poisoning is found to be one of the most common health hazards reported by workers according to a study in the Bangladesh garment industry (Talapatra & Rahman, 2016). In our study both men (43%) and women (32%) find it a serious hazard, but more men seem to be concerned than women. This is not consistent with previous studies conducted in Western countries on gender differences in food risk perception, where men usually care less about natural (such as bacterial) or technological (such as pesticide) risks (Bieberstein, 2013; Malam, Prior, Phillips, & O'Driscoll, 2014).

Majority of both women and men concern about electrical safety, which is a well recognised hazard in the garment industry. Many companies in Bangladesh have been working on addressing electrical safety. This study shows that men are far more concerned about electrical safety than women. A reason for that may be that men work in different departments where they are exposed more to electrical risks, while women mostly work in sewing and finishing department.

Only a small proportion of women and men believe that high workload should be a priority to be addressed. It concerns women plenty more than men. Findings from other studies also show that women frequently suffer from stress and persistent fatigue as a result of work overload (Javed & Yaqoob, 2011: Campos-Serna et al., 2013; Javed & Yaqoob, 2011; Lu, 2007).

About 10% more women (43%) than their male counterparts (33%) consider tripping and falling as a major hazard. A paper summarising previous studies found that woman's incidence rate of falling is either the same or higher than man's (Chang, Leclercq, Lockhart, & Haslam, 2016). The same paper also points out that falling is associated with footwear. In Bangladesh most workers work in the factories on bare foot. Our study and previous studies have not investigated on the relation between gender and footwear among Bangladesh garment workers. But lack of proper footwear probably contributes to a good number of both women and men concerning about tripping.

It is not clear why significantly more women than men consider 'crack on the wall' a serious hazard. When comparing the group of women with safety training and without safety training, one could conclude that women who have joined a training also tend to choose this hazard. This implies that women probably learn knowledge about building safety during trainings. As mentioned earlier, since we do not know the contents of the training, this consideration needs further study.

In all subgroups analysed in this study, 'Tangled or uncovered power cables, broken power distribution board' and 'blocked evacuation route, locked factory gates' are identified for both men and women as the most concerning hazards. These two hazards are also among the most recognised fire hazards in the Bangladesh garment industry. This shows that many workers have gained basic knowledge on OSH.

4.2 There is a difference between women who have received a safety training and those who have not. The same is observed between the two groups of male workers. Women who have not received safety training are more concerned about dust in the factory and travelling home in the dark than those who have received a training. Probably women who have received training learn more about safety and they decide that other hazards or risks can cause more harm. A high percentage of men (42%) who have not received training believe that safety protection during pregnancy is important, while much less of those who have had a training (26%) consider it a priority. While sufficient fire-fighting equipment, preventing tripping and structural safety of buildings are important safety measures, it is striking that much less male workers who have been trained find safety protection during pregnancy a priority. Although no conclusion can be made regarding the impact of training, it is vital to integrate gender in trainings, especially those that are conducted by safety officers in factories. Women do have a different focus on safety from men. They detect different things, which can help cover a wider range of issues. Involving women in hazard prevention and designing safety training is essential.

4.3 Verbal abuse is one of the most widely spread workplace violence(International Labour Office, 2016). Both men and women chose verbal abuse in their top five priorities in this study. We also found that the percentage of men who chose to verbal abuse as a priority to address is correlated to the percentage of women working in the same department. This could imply that men are more likely to be victims of verbal abuse when they work in an environment with more women, or men as bystanders are more likely to feel sympathy for female colleagues being affected by verbal abuse. In any case, it is in the interest of employers to consider violence and harassment as a major OSH hazard and include it in company OSH policies.

4.4 There are limitations of this study. First of all, the choices of hazards in the questionnaire were mainly based on suggestions provided by workers. We might have missed some common hazards in the garment industry. Some of the hazards in the questionnaire could be considered as risks, such as lack of fire-fighting equipment, personal protective equipment is not used properly or transporting in the dark from work to home. This may have a different effect on different workers. Secondly, workers have participated in various safety training. It was not possible to track the contents of training each of them has had, hence the impact of trainings is unknown. Since 78% of the respondents who have had a safety training have participated one organised by safety officers in their own companies, we could guess that training provided by factories plays the biggest role in the study. Thirdly, we did not randomise the order of the hazard choices in the questionnaire. The order of choices often influences the decision of the respondents (Hogarth & Einhorn, 1992) (Krosnick & Alwin, 1987). However, considering that this study is looking at the differences between men and women, and order effect affects both of them equally, there might be limited influence in the result, unless order effect affects the way women and men make choices differently. We have not found any study that discussed gender aspect of order effect. This area needs more research.

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FIRE EVACUATION SAFETY IN BANGLADESH READY MADE GARMENT (RMG) FACTORIES: A COMPARISON OF STANDARDS AND NON-COMPLIANCE ISSUES OF MEANS OF ESCAPE

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ABSTRACT

Ready Made Garment (RMG) industry is one of the most important export-oriented sectors in Bangladesh. Despite its contribution and prospects, occupational safety has been ignored in this sector which resulted in different accidents in this sector. Among others, fire accident is most frequent in this sector. Several initiatives have been taken since 2013 after the Tazreen Fashion fire accident to combat such situation. Among them, an assessment of factory buildings for fire safety is one of the most significant which is been done through one national initiative National Tripartite Plan of Action (NTPA) and two international initiatives the Accord and the Alliance. Though these three assessment initiatives/programs are all for the same purpose, there are differences in the fire safety standards based on which compliance or non-compliance is decided under a different program. They include Accord and Alliance standards (2014), NTPA guideline (2013), BNBC (1993), and BNBC (2018 Draft). This study aims to find out and understand the differences among the standards and the non-compliance issues related to means of escape for safe fire evacuation in Bangladesh RMG sector. From this study, it has been found that among these standards, Accord and Alliance (2014) provides most superior standards compared to others. In case of compliance issue, factory buildings do not comply with BNBC (1993) standard. Thus, automatically they remain non-compliant to Accord and Alliance (2014). The findings of this study will enable policymakers to understand the differences among the standards based on which the factory buildings have been assessed as well as the non-compliant fire evacuation safety issues in RMG factories in Bangladesh related to means of egress.

1. Introduction

Workplace safety is very important to ensure business sustainability and thus to survive in the global competitive market (Jilcha & Kitaw, 2017; Jilcha, Kitaw, & Beshah, 2016). The working efficiency of an employee dominantly relies on how they believe that safety is to be valued in the organization (Griffin & Neal, 2000). Safety performance motivates them to work harder and work with efficiency and to take ownership of responsibility for safety performance (O'Dea & Flin, 2001). Due to non-compliance with workplace safety, occupational hazards lead to permanent disabilities, death and economic loss every year in different industries all over the world (Dağdeviren & Yüksel, 2008; Jaiswal, 2012). Among different occupational hazards, fire is one of the major concerns for ready-made garments industries. There are four keys to fire safety: Fire prevention, early warning of the fire, containment of the fire, and safe exits (Bangladesh Accord, 2014b). Among them, safe exits or evacuation can be ensured by providing proper means of egress, which reduces the impact of uncontrolled fire (Hall & Watts, 2008; Sekizawa, 2005). Thus, compliant means of egress is one of the most important components to ensure safe fire evacuation.

In Bangladesh, Ready Made Garment (RMG) industry is one of the most important export-oriented sectors (F. Z. Ahmed, Greenleaf, & Sacks, 2014; J. U. Ahmed & Hossain, 2009; Ansary & Barua, 2015; Wadud, Huda, & Ahmed, 2014). Apart from its contribution in export earnings, it is also an important player in the economy in terms of employment generation, poverty alleviation and empowering of women (Haider, 2007; Khosla, 2009; Rahman & Hossain, 2010). Though it is one of the most important sectors of Bangladesh, the safety issues are not up to a standard yet (Ahamed, 2013; Clean Clothes Campaign, 2012; Muhammad, 2011). Such lack of workplace safety has resulted in different occupational disasters in RMG factories in Bangladesh (J.

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U. Ahmed & Hossain, 2009). One of the most deadly fire accidents in this sector is Tazreen Fashion fire on November 24, 2012, which resulted in the death of 112 workers. Since Tazreen Fashion Factory fire to 22 April 2017, about 133 fire incidents have occurred in the sector leading to at least 38 deaths and 815 injuries (Solidarity Center, 2017). These tragic accidents received global attention and brought forward diverse issues concerning millions of workers, employers, brands, and consumers.
To improve workplace safety and thus reduce fire accidents in Bangladesh RMG sector several initiatives have been taken since 2013 after the Tazreen Fashion fire accident. Among them, National Tripartite Plan of Action (NTPA) on Fire Safety was first outlined in March 2013. After Rana Plaza collapse, it was converted to form the NTPA on Fire Safety and Structural Integrity in the RMG Sector of Bangladesh in July 2013 (Barua & Ansary, 2017). One of the most significant activities outlined in the plan was to assess the fire safety of all active export-oriented RMG and knitwear factories and initiate remedial actions accordingly. As part of this plan, the National Tripartite Committee (NTC) agreed on an initial assessment of buildings housing RMG factories. Additionally, two different factory inspection programmes were established: the Accord on Fire and Building Safety in Bangladesh (the Accord), and the Alliance for Bangladesh Worker Safety (the Alliance), where ILO assumed the role of the neutral chair(Alliance for Bangladesh, 2013; Bangladesh Accord, 2015). Bangladesh University of Engineering and Technology (BUET) and two private engineering firms TUV SUD Bangladesh (Pvt.) Ltd and Veritas Engineering & Consultant on behalf of NTC were responsible for conducting the assessments.

Though these three assessment initiatives/programs are all for the RMG factories, there are differences in the fire safety standards based on which compliance or non-compliance is decided under different programs. In practice, factory buildings are obliged to follow Bangladesh National Building Code (BNBC) of 1993 (BNBC, 1993) to ensure fire safety. The original 1993 BNBC is in the process to be amended in which some standards for fire safety has been upgraded (BNBC, 2018). On the other hand, to carry out the assessment with a common approach, *Guidelines for Assessment of Structural Integrity and Fire and Safety* was developed in 2013 under NTPA which is again one step ahead of both the BNBC standards (NTPA, 2013). Likewise in 2014, the Accord and the Alliance developed their assessment guide with similar standards which is again superior to previously stated standards (Alliance for Bangladesh, 2014; Bangladesh Accord, 2014a). Thus, a difference in consideration for standards can be observed. Such situations may create confusion among the factory owners regarding which standards to follow. Additionally, after assessment under three programs, comparison of assessment results of the factory buildings to understand non-compliance issues are difficult. Such comparison may also create meaningless outcomes due to the difference in standards.

Several studies were carried out on Bangladesh RMG industry. Barua and Ansary (2017); Samaddar (2016); Ansary and Barua (2015); Tania and Sultana (2014); Akhter, Salahuddin, Iqbal, Malek, and Jahan (2010); J. U. Ahmed and Hossain (2009); and Mahmud and Kabeer (2003) studied different workplace safety issues in Bangladesh garment industry. Wadud et al. (2014) developed fire risk index (FRI) for soft parameters (management practices) in Bangladesh garment industry. Ahmad and Kamruzzaman (2015) analyzed the availability of fire-fighting equipment in selected knitting garment factories in Bangladesh. Wadud and Huda (2017) developed fire risk index (FRI), considering hard (structural) and soft (management practices) parameters for the Bangladesh garment industry. None of these studies compared the standards and analyzed non-compliance issues related to fire safety in Bangladesh RMG factories.
In this background, objectives of this research are: firstly, to compare different standards of means of escape for RMG factories to ensure safe fire evacuation, and secondly, to find out the non-compliance issues of means of escape in the factories with respect to different standards. This research will enable to find out and understand the differences among the standards and the non-compliance issues related to means of escape for safe fire evacuation in Bangladesh RMG sector.

2. Methodology

2.1 Comparison of Standards Related to Means of Escape for Fire Safety in Bangladesh

To understand difference among the standards related to means of escape, four standards were compared: Accord and Alliance 2014 (Part 6: Means of Egress), NTPA 2013 (Section 2.9: Means of Escape), BNBC 1993 (Part 4: Chapter 3: Means of Escape), and BNBC 2018 (Draft) (Part 4: Chapter 3: Means of Egress). To maintain a systematic comparison, the arrangement of Accord and Alliance standards was followed where 115 standards were organized under twenty-one broad headings. They are: fire separation of means of egress; walking surfaces in means of egress; impediments to means of egress; reliability; occupant load; egress width; number of exits and means of egress; arrangement of exits or means of egress; doors; stairway; ramps, corridors and ramped aisle; signs; sign illumination; egress illumination; handrails and guards; travel distance; exit enclosure; smokeproof enclosure; exit passageway; exit termination; and exit discharge. After comparison, the standards were organized in a tabular format. In cases where the variation of standards could be observed, they were represented according to their superiority where a higher standard is represented by most superior and lower standard represent less superior.

2.2 Analysis of Non-Compliance Issues Related to Means of Escape for Fire Safety

Until March 2016, assessment of 3582 RMG factories have been completed (NTC 1549, Accord 1204, Alliance 656, and common by Accord and Alliance 164) (DIFE, 2016). As these assessments have been done under national and international initiatives, so for the purpose of this study these assessed reports have been considered. Again, considering detailing of assessment reports, factories assessed by Alliance have been utilized. In the website of Alliance, assessment reports are available (Alliance for Bangladesh, 2018). Among 656 assessed factories, 500 factories are active. Therefore, these active factories have been considered for this analysis. From this set 217 factories have been selected for this study. The factories have been selected through random stratified sampling method considering four quarters each from 2013 to 2017, e.g. January to March, April to June, July to September, and October to December, assuming 95 percent confidence level and 5 percent confidence interval, Fire assessment reports of these selected factories have been collected from the website of Alliance.

The reports were analyzed based on the findings from the comparison of standards. The focus of the analysis was whether the factories comply with both standards and if not with which standards they do not comply with. Additionally, the basic information of the factories including factory name, location, number of storey, ownership status, year of construction and occupancy, were also been collected from reports. After that, the analysis findings were input in SPSS 21 and the data were analyzed through descriptive statistics.
For the convenience of discussion, all the broadheads have been divided into two groups. They are: condition of means of egress components (including fire separation of means of egress; egress width; doors; stairway; ramps, corridors, ramped aisle; handrails and guards; exit passageway; exit termination; and exit discharge), and condition of means of egress (including number of exits and means of egress; arrangement of exits or means of egress; travel distance; exit enclosure; smoke proof enclosure; walking surfaces in means of egress; impediments to means of egress; reliability; egress illumination; occupant load; signs; and sign illumination).

3. Results and Discussion

3.1 Description of the Dataset

Among the factories considered in this research, about 73 percent are located in Dhaka (Mirpur, Gazipur, Narayanganj, Tongi, Ashulia, Dhaka Export Processing Zone, and other areas in Dhaka), and rest are located in Chittagong (Nasirabad Industrial Area, Chittagong Export Processing Zone, Karnaphuli Export Processing Zone, different industrial areas, and other areas in Chittagong). Among them about 82 percent are owned and rest are rented. Figure 1 shows the percentage of factory buildings considered in this research with respect to their year of construction.

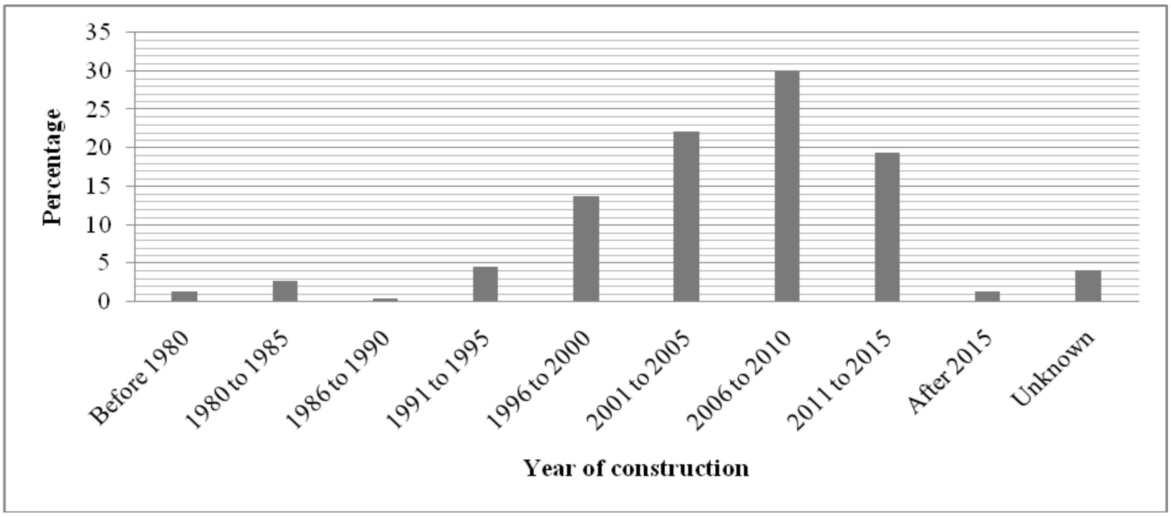

Figure 1. Percentage of factory buildings with respect to their year of construction

From the figure, it can be observed that most of the assessed buildings have been constructed in the period of 2001 to 2015, which are mostly new constructions. Figure 2 shows the percentage of factory buildings considered in this research with respect to their number of storeys, which shows that most of the buildings are six storied.

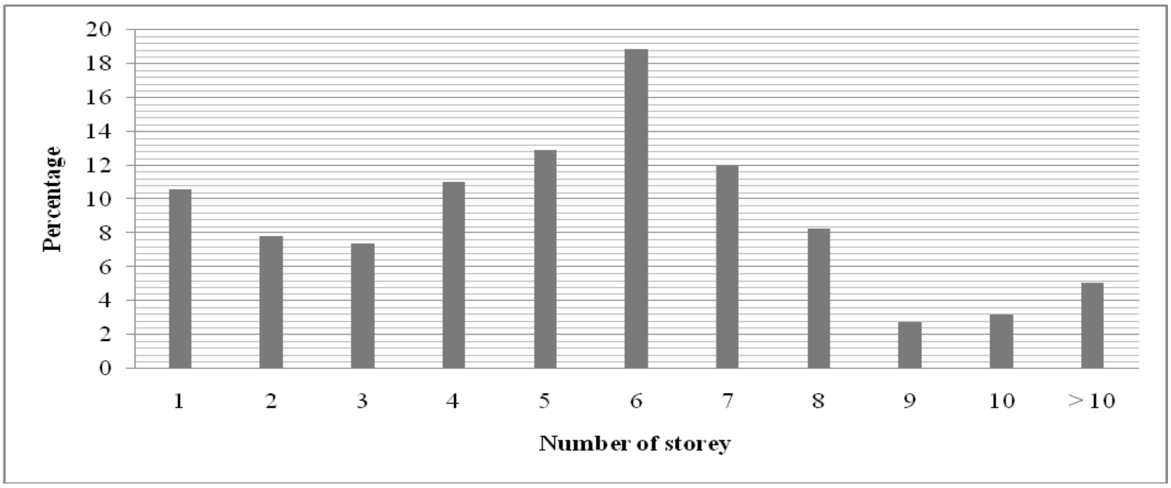

Figure 2. Percentage of factory buildings with respect to their number of storey

3.2 Means of Egress for Fire and its Components: Comparison of Standards

In BNBC (1993), the way of means of egress is defined to consist of three parts, e.g. the exit access, the exit, and the exit discharge, which is consistent with other standards. As in BNBC (1993), the components of exit should include "…*a) A doorway, corridor or passage leading to an exterior or interior staircase, smoke proof and fireproof enclosure, ramp, balcony, fire escape or combination thereof, having direct access to the street, the roof of a building or any designated refuge area which affords safety from fire or smoke from the area of incidence; b) A horizontal exit from the affected building to an adjoining building or an area of refuge at the* *same level which provides safety from fire and smoke from the area of incidence and the areas communicating therewith*…". This is confirmed in Accord and Alliance (2014) as well as in NTPA (2013). In BNBC (draft 2018), the words have just been rephrased keeping the main idea same. Furthermore, in BNBC (1993), it is stated that lifts, escalators and moving walks shall not be regarded as components of means of escape (confirmed by other standards). In addition to these, in NTPA (2013) the roof of the building is prohibited to be designated as a refuge area, whereas in some contexts of fire incidents roof of a building can use as a component. Thus, from review of the definition of means of egress in different standards, it can be said that the BNBC (1993) is been considered as the basis by other standards but Accord and Alliance (2014) provide a definition in simple phases whereas, in BNBC (draft 2018), it is more elaborate and defined.

From the comparison and analysis of standards it could be observed that among 115 standards, 37 standards of BNBC (1993) are followed by other standards (about 27% of all standards). BNBC (draft 2018) provides 11 superior standards than others. NTPA (2013) specifies 11 standards higher than others which are also followed by Accord and Alliance (2014). But most significantly, Accord and Alliance (2014) provide 56 standards which are superior to others (about 48% of all standards). Thus it can be said that among four standards compared, most of the standards for means of egress for fire are superior in Accord and Alliance (2014).

3.3 Non-Compliance: The Components of Means of Egress for Fire

3.3.1 Exit and Assembly Doors

As an exit component or opening on to the means of egress, doors should have minimum fire separation rating. In case of a door as an exit component, Accord and Alliance (2014) provide higher, 2 hour standard, than NTPA (2013), which specifies one-hour fire rating for all fire doors. Among analyzed factory buildings, 126 buildings do not comply with this standard of Accord and Alliance (2014). For door assemblies opening on to the means of egress, BNBC (1993) specified standard is followed by other standards which are at least 20 minutes fire resistance. Among analyzed factory buildings, 29 buildings do not comply with this standard.
For total capacity and a minimum width of new exit doors, BNBC (1993) specified standards are followed by other standards. But in case of the minimum width of existing exit doors, NTPA (2013) provides higher standard compared to Accord and Alliance (2014) "*...For existing RMG buildings a performance-based determination of the width of the doorway shall be adopted, but in no case, the width of the doorway shall be less than 0.9m...*". But considering limitation for reconstruction Accord and Alliance (2014) standard is more suitable.

Also for minimum height, allowable door type, space outside the doorway, doors in the smokeproof enclosure, BNBC (1993) specified standards are followed by other standards. Space outside: A space of width not less than the width of the doorway shall be maintained immediately outside the doorway. Space shall be at the same level as that of the floor the door serves. In case of prohibited door type, BNBC (1993) specified standard is followed by other standards with slight modification in Accord and Alliance (2014). About 144 buildings do not comply with these standards.

In case of swing direction, BNBC (1993) states that "*...Doors shall not swing out over stairs or ramps...*", which is approved by other standards. But for allowable swing direction Accord and Alliance (2014) and BNBC (draft 2018) provide the same standard where the direction is more explained in later one.

All of the standards comply that all doors should be openable in the direction of egress. Accord and Alliance (2014) provide a superior standard for impediments to means of egress stating that "...No locks or other devices shall be installed on a means of egress component that would prevent any occupant from having safe egress from the building or structure...", where BNBC (1993) states this condition addressing lock with detachable key. But which kind of locking features are prohibited and lock type have been more clearly defined in Accord and Alliance (2014) which includes hasps, locks, slide bolts, and other locking devices. NTPA (2013) states that locks of any of the doors should be unlocked during the operational hour and should be checked regularly which is also supported by Accord and Alliance (2014). About 62 percent buildings have these types of locking features available in the doors but they were open during the operation period.

Conditions for re-entry provision for stair doors have been specified only in Accord and Alliance (2014) which is very important to ensure safe fire evacuation considering from where the fire would generate or spread. About 28 percent building do not have required re-entry provisions.

3.3.2 Stairway

Exit stairway shall be protected by a smokeproof enclosure serving occupants located more than 23 m above the ground as per BNBC (1993) which is also supported by BNBC (draft 2018). But all the stairways are required to keep free from smoke for safe fire evacuation. Thus NTPA (2013) stated that "*...all exit stairways serving occupants located above the ground floor shall be smoke proof with fire-resistant walls and door...*", which is supported by Accord and Alliance (2014). For exterior stairway, BNBC (draft 2018) only stated that "*...exterior stair shall be separated from the building interior by fire resistive assemblies or walls and are constructed by noncombustible materials and free from smoke accumulation...*". Whereas, Accord and Alliance (2014) specify fire-resisting enclosure rating and its extension based on a number of the storey which the stair connects.

For total capacity, BNBC (1993) specified standards are followed by other standards. In case of the width of new stair and landing width BNBC (1993) provides a standard which is followed by others except for BNBC (draft 2018), where the former standard is superior to later. Accord and Alliance (2014) also state that, if existing landings less than the stair width, the overall available capacity of the stair shall be reduced. But in case of the minimum width of existing stairways, NTPA (2013) provides compatible standard considering its limitation for reconstruction specifying "*...For existing RMG buildings a performance-based determination of the width of the staircase shall be adopted, but in no case, the width of the staircase shall be less than 0.9m...*". This standard is also supported by Accord and Alliance (2014).
Maximum riser height specified in BNBC (1993) is supported by both NTPA (2013) and BNBC (draft 2018). But considering ease of evacuation, Accord and Alliance (2014) provide lower height which is superior to the former. In case of minimum tread, BNBC (1993) standard is supported by others. In case of allowable difference of any riser height or tread depth, BNBC (draft 2018) provides superior standard than Accord and Alliance (2014) with less tolerance.

BNBC (draft 2018) also specifies that "*...An exit stairway shall not be built around a lift shaft unless both of them are located in a smokeproof enclosure and made of a material with fire resistance rating required for the type of construction of smokeproof enclosure...*". It also specifies that in windowless staircases mechanical ventilation shall be installed. These standards are not mentioned in any other standards.

A similar standard for height of new handrails for stair is provided by Accord and Alliance (2014) and BNBC (draft 2018). But for the height of existing handrails for stair, only Accord and Alliance (2014) formulated standard. BNBC (1993) specifies that handrails shall be provided on both sides of each stairway which is followed by Accord and Alliance (2014) and NTPA (2013). It is also superior to that of BNBC (draft 2018) because here requirement of the inner handrail is defined by the width of the stair which is not appropriate for the emergency condition. About 56 percent buildings do not have a handrail on both sides. Conditions for the requirement of intermediate handrails for stair is similar for BNBC (1993) and BNBC (draft 2018), which is also followed by other standards.

To ensure proper functionality of the stairways during a fire evacuation, BNBC (1993) states that all the exit stairways should be accessible, which is supported by other standards. Additionally, Accord and Alliance

(2014) state that interior exit stairways shall terminate at an exit discharge or an exit passageway, which has not been maintained in about 25 percent buildings.

In case of the exterior stairway, BNBC (1993) states that there shall not be considered as a means of exit unless they lead directly to the ground, which is supported by other standards. But BNBC (draft 2018) adds to this that, they shall also be separated from the building interior by fire resistive assemblies or walls and shall be constructed by noncombustible materials and free from smoke accumulation. Among 217 buildings, 47 do not comply with these standards.

3.3.3 Ramps, Corridor, Aisles and Ramped Aisles

For separation of exit access corridors, though BNBC (1993) provides higher standard specifying one-hour fire rating wall for all the cases (accepted by other standards), Accord and Alliance (2014) provide more specific standard depending on occupant load and availability of automatic sprinkler system. BNBC (draft 2018) states that exit corridors shall not be designed or used as components to supply or return air.

Only Accord and Alliance (2014) provides a standard for a minimum width of aisles which has not been complied in almost 20 percent factory buildings. For the total capacity of all these exit components, BNBC (1993) specified standards are followed by other standards. Only BNBC (draft 2018) provides a standard for the length of these components. BNBC (1993) specified that width shall not be reduced in any part, which is followed by other standards. Minimum width of these components is similar for Accord and Alliance (2014), BNBC (1993) and BNBC (draft 2018), which is also followed by NTPA (2013). BNBC (1993) specifies width based on occupancy load which is more specific though it is less superior to others.

The allowable slope for the ramp is superior in Accord and Alliance (2014) as it allows lower slope. Only Accord and Alliance (2014) provides a standard for slope for existing ramp. Only BNBC (draft 2018) states that "*...Landing shall be at least as wide as the ramps and shall be placed at the bottom, at intermediate levels where required, and at the top of all ramps...*". Accord and Alliance (2014) specify that handrails shall be provided on both sides of each ramp which is superior to other standards. Only Accord and Alliance (2014) states that ramps shall terminate at an exit discharge or an exit passageway.

3.3.4 Exit Passageway

Only Accord and Alliance (2014) states that exit passageways shall meet the same rating requirement as the exit that is being served, shall be considered an extension of the stairs and shall not be used for any other purpose. Around 46 factory buildings do not comply with this standard. Accord and Alliance (2014) and BNBC (draft 2018) states similar standard for exit passageway termination stating that they shall terminate at an exit discharge.

3.3.5 Exit Discharge

Statement of BNBC (1993) and Accord and Alliance (2014) are similar for termination of exit discharge, which is also supported by other standards. Accord and Alliance (2014) state other standards for exit discharge regarding re-entry provision, fire separation, opening condition and conditions for interior building exit discharge.

3.4 Non-compliance: The condition of means of egress for fire

3.4.1 General conditions

Accord and Alliance (2014) provide superior general fire separation standard based on a number of storey. It also provides standards for opening and penetration into and from exit enclosure. It also specifies that the capacity of the means of egress shall not be reduced along the path of travel.

3.4.2 Number and arrangement of exits

BNBC (1993) provides standard for a minimum number of staircases and number of means of egress from any floor, story or portion thereof based on the number of storey and occupant load which is followed by other standards with slight modification in Accord and Alliance (2014) and BNBC (draft 2018) for single exit condition. Minimum requirement of exit is defined by NTPA (2013) which is followed by Accord and Alliance (2014). For more than one exits, their arrangement is important to ensure access to all the occupants. Though BNBC (1993) specified a standard for the arrangement of exits is followed by NTPA (2013) and BNBC (draft 2018), Accord and Alliance (2014) provide more detailed and specified standard considering the condition whether there is automatic sprinkler system or not.

3.4.3 Distance

Travel distance means straight line distance between the remotest point of an area of the incident and the entrance point of a separated area shall be measured and termed as a travel distance as per BNBC (draft 2018). NTPA (2013) and BNBC (draft 2018) provides a similar and superior standard for maximum travel distance based on the availability of automatic fire detection system, portable fire extinguishers, and standpipe system, which is followed by Accord and Alliance (2014). On the other hand, Accord and Alliance (2014) provide a standard for the maximum length of the common path of travel considering the condition whether there is automatic sprinkler system or not. BNBC (1993) provides a superior standard for the maximum length of the dead-end corridor.

3.4.4 Walking surface

Accord and Alliance (2014) and BNBC (draft 2018) provides a similar standard for levels of walking surfaces and changes in level (condition to use ramp or step). Accord and Alliance (2014) provide a higher standard for changes in elevation with lower allowable change. According to this standard, about 20 percent factory buildings are non-compliant. BNBC (draft 2018) provides a standard for steps in walking surface. Accord and Alliance (2014) provide a superior standard for slip resistance stating that walking surfaces, including stairway treads, shall be uniformly slipping resistant. Accord and Alliance (2014) state that changes in slope or elevation shall be marked.

3.4.5 Reliability

All the standards of BNBC (1993) regarding reliability are addressed by other standards. According to these standards, about 22 percent buildings are non-compliant because egress path in these buildings is obstructed and interfered by alternate uses. In addition to these standards, Accord and Alliance (2014) provide standard about visibility obstruction and BNBC (draft 2018) provides a standard for accessibility of the exits. All paths of egress shall be provided with illumination as per Accord and Alliance (2014), which has not been maintained in 26 percent buildings. Moreover, according to this standard, all occupiable roofs shall be provided with parapets or guards with a minimum mentioned height, which has not been provided in around 21 percent buildings.

3.4.6 Occupancy load

In case of minimum space requirement for each occupant, NTPA (2013) provides a superior standard, whereas Accord and Alliance (2014) allow an increase of occupant load if all other means of egress requirements for that higher occupant load are met. It also mentions that occupant load should be posted at appropriate locations in the building, which does not comply in almost 70 percent factory buildings.

3.4.7 Marking and signage

All the standards of BNBC (1993) regarding marking and signpost and sign illumination are addressed by other standards. About 40 percent factory buildings do not have required markings and signpost. About 57 percent buildings do not have stair designation sign whereas 47 percent buildings do not have floor designation sign. In addition to these standards, BNBC (draft 2018) states that presence and location of steps or ramps in the walkways shall be readily apparent. Accord and Alliance (2014) state that floor entrance from the stair, stair name and floor name and door location shall be provided accordingly. According to Accord and Alliance (2014), signs should be provided with appropriate language (English and Bengali) and graphics. Moreover, according to this standard, all lighted exit signs shall be provided with either battery backup or emergency power to keep them continuously illuminated, which has not been complied in 26 percent buildings.

4. Conclusion

From the above discussion, it can be observed that BNBC (1993) standard has been considered as the basis for other standards. This standard is not in line with modern fire safety concepts. Therefore, it was considered an insufficient basis for the inspections that were carried out in the wake of the fire at Tazreen Fashion. Thus, NTPA (2013) and Accord and Alliance (2014) added ungraded standards. BNBC standard has also been improved and in some cases upgraded in BNBC (draft 2018). But among these standards, Accord and Alliance (2014) provide most superior standards compared to others. The difference among the standards is alarming. The reason is that the final findings of the factory buildings are compared at national level considering all factories under all initiatives together. Such comparison may remain inconsistent because some factory buildings may have been identified safe under one initiate considering a certain fire safety issue and in contrary in the same condition for the same safety issue other factory building may have been identified non-compliant under another initiative.

In case of compliance issue, factory buildings do not comply with BNBC (1993) standard. Thus, automatically they remain non-compliant to Accord and Alliance (2014). The most important non-compliance issues observed in means of egresses in the factory buildings are: noncompliant fire resistance of exit doors with improper type and locking features, non-compliant exterior stair, handrail not provided in both sides of stairways, improper termination of stairways and exit passageways, slippery walking surface, obstructed egress path hampering continuity, lack of proper illumination in egress path, unprotected rooftop, absence of occupancy load posting, and insufficient marking and signage with insufficient illumination.

The findings of this study will enable policymakers to understand the differences among the standards based on which the factory buildings have been assessed. This will encourage them to take initiative to work together to make a single and efficient standard for all. Additionally, the non-compliant fire evacuation safety issues in RMG factories in Bangladesh related to means of egress that have been identified in this study will help policymakers to understand the issues which have been mostly ignored by the factory owners. This will help them to take necessary initiatives to ensure compliance in regard to these issues.

In this research only means of escape component of fire safety has been considered. Moreover, this research could not consider the whole document of the standards. So if there are some standards mentioned in other chapters of the considered standards, then they have not been considered here. In future, this study will be extended to other portions of the standards related to fire safety considering other components. After that, a complete scenario can be established. Further analysis is required to analyze the components of means of egress.

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