SLOPE STABILITY ANALYSIS OF AN EARTHEN EMBANKMENT FOR DIFFERENT GEOMETRIC AND WATER LEVEL CONDITIONS BOTH FOR COHESION-LESS AND COHESIVE SUBSOIL

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ABSTRACT

Soil properties, geometric figures, subsoil properties and water level conditions these are some of the factors on which the stability of the soil depends. In this thesis, stability analysis has been done for an earthen embankment considering those factors. Embankment soil properties have been assumed fixed in this study. The analysis has been done for different heights and slope angles both for cohesion less and cohesive subsoil. Three water level conditions have been considered such as high flood level, low flood level and rapid drawdown condition. For cohesion less subsoil, the subsoil has been divided into three layers containing different unit weights, friction angles and zero cohesion. Then the factor of safety has been determined for different heights (6m, 7m, 8m and 9m) and slope angles (26.57, 30.26, 33.69 and 36.87 degree) and different water level conditions through SLOPE/W. For cohesive subsoil, same procedure has been followed to determine the factor of safety for those heights and slope angles and water level conditions. The friction angles have been assumed zero for cohesive subsoil. The change of factor of safety with the change of heights, slope angles, water level conditions have been shown through graph plotting. The comparison of stability between cohesion-less and cohesive subsoil has been shown in a table for different heights, slope angles and water level conditions. For checking the suitability of the geometry, minimum factor of safety has been taken as 1.25. For cohesion-less subsoil, 6m height (26.57 degree) produces factor of safety greater than 1.25 for all water level conditions. So, the maximum allowable height for cohesion-less subsoil is 6m. For cohesive subsoil, The height 8m (slope angle 33.69 degree) produces enough safety for all water level conditions and also ensures less costly construction. So, the maximum allowable height is 8m for cohesive subsoil.

Keywords: Angle, cohesion, factor of safety, height, rapid drawdown, slope stability

Introduction

Slope stability of an earthen embankment depends much on its soil parameters, subsoil conditions, water level conditions and geometry of the embankment slope. Slope stability decreases with the increase of height and slope angle of embankment slope. Weights of manmade structures constructed on or near slopes tend to increase destabilizing forces and slope stability.

Slope Stability Analysis through SLOPE/W

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Subsoil Properties

For analyzing purpose, it needs to assume the parameters of the subsoil of the embankment. Here the soil is divided into the different layers. Then 16, 17, and 18 unit weight in KN/m^3 and friction angle of value 30, 32 and 35 are assumed respectively. And for cohesion-less subsoil the value of cohesion is 0. Similarly for cohesive subsoil for three different layers 18, 19 and 20 KN/m^3 unit weight and 38, 40 and 42 KPa cohesion are assumed respectively. And for this soil the value of friction angle is 0 degree. Slope stability has been analyzed for different geometric conditions. Table 3 shows the different heights, slope and slope angles for which slope stability analysis has been done. For different layer height (7m, 8m, and 9m) the Geometry of embankment was selected the slope angle 30, 33.69 and 36.87 respectively. The analysis of slope stability has been done for three conditions such as high flood level, low flood level and rapid drawdown. For analysis, here three Flow Conditions are considered. They are: - High Flood level, Low flood level and Rapid drawdown. In case of factor of safety generally, minimum factor of safety for an earthen embankment is 1.2~1.3. Here, minimum factor of safety has been taken as 1.25 considering both safety and cost.

Findings

Variation of Slope Stability with Water Flow Condition for Same height

Analysis shows that the factor of safety is maximum for high flood condition, minimum for rapid drawdown condition and medium for low flood condition for 7m height embankment, which has been shown through graph plotting in the figures 1 and figure 2.

![Figure 1. Slope Stability Of Cohesionless Soil for Different Water Level Conditions for 7m Height](image1)

![Figure 2. Slope Stability Of Cohesionless Soil for Different Water Level Conditions for 7m Height](image2)

Variation of Slope Stability with Slope Angle

The factor of safety decreases with the increase of slope angle for high flood condition. The following Figure 3 and figure 4 show the change of factor of safety with the change of slope angle for both cohesion-less subsoil and cohesive subsoil through graph plotting.
Variation of Slope Stability with Water Flow Condition for Same Slope Angle

Analysis shows that the factor of safety is maximum for high flood condition, minimum for rapid drawdown condition and medium for low flood condition for 30.26 degree slope angle which has been shown through graph plotting in the following figures 5 and figure 6 for Cohesionless and Cohesive soil respectively.

Variation of Slope Stability with Subsoil Properties

Factor of safety changes with the change of subsoil properties. Analysis shows that the factor of safety of earthen embankment for cohesive subsoil is greater than the factor of safety for cohesion-less subsoil for same height and same water level condition except for 8m and 9m height for low flood condition. 8m and 9m height produce more factor of safety for cohesion-less subsoil than cohesive subsoil. The comparison between cohesive and cohesion-less subsoil is given in the table.
Table 1. Comparison of Slope Stability for Cohesion less and Cohesive Subsoil

<table>
<thead>
<tr>
<th>Height (m)</th>
<th>Slope Angle (B) degree</th>
<th>Flow condition</th>
<th>Factor of safety for Cohesion-less soil</th>
<th>Factor of safety for cohesive</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>30.26</td>
<td>High Flood Level</td>
<td>2.187</td>
<td>2.887</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low Flood Level</td>
<td>1.637</td>
<td>1.684</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rapid Drawdown</td>
<td>1.072</td>
<td>1.587</td>
</tr>
<tr>
<td>8</td>
<td>33.69</td>
<td>High Flood Level</td>
<td>1.881</td>
<td>2.368</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low Flood Level</td>
<td>1.532</td>
<td>1.494</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rapid Drawdown</td>
<td>0.977</td>
<td>1.407</td>
</tr>
<tr>
<td>9</td>
<td>36.87</td>
<td>High Flood Level</td>
<td>1.669</td>
<td>2.009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low Flood Level</td>
<td>1.433</td>
<td>1.317</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rapid Drawdown</td>
<td>0.906</td>
<td>1.248</td>
</tr>
</tbody>
</table>

Conclusions

There are many earthen embankments in Bangladesh. These embankments are very important for the people of those areas because these embankments save them from flooding and failure of these causes huge flooding and immense damage. So, huge research should be done about the failure of the earthen embankments in Bangladesh. In Bangladesh, there are many earthen embankments which are not safe against failure. Many embankments are not being well designed. Even proper designed embankments fail sometimes under unexpected environment and water level conditions. In this research, embankment stability has been analyzed for different heights, slope angles, water level conditions and subsoil properties through SLOPE/W.

Analysis shows that factor of safety decreases with the increase of height and slope angle. Considering water level condition factor of safety is the highest for high flood condition, low flood condition produces less factor of safety than high flood condition and rapid drawdown condition produces the lowest factor of safety. The analysis also shows that cohesive subsoil produces better stability than the cohesion less subsoil except for 8m and 9m heights under low flood condition. From the research, for cohesion-less subsoil, 6m height (Slope angle 26.57 degree) produces enough factor of safety (>1.25). Therefore, the maximum allowable height for the cohesion-less subsoil is 6m (Slope angle 26.57 degree). But for cohesive subsoil, 8m height (Slope angle 33.69 degree) produces enough factor of safety (>1.25) and minimum construction cost. Therefore, the maximum allowable height for the cohesive subsoil is 8m (Slope angle 33.69 degree).

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