Effect of Stress on Safety Factor

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ABSTRACT: An embankment of steep slope is more advantageous due to the desire to increase land usage and decrease in site development costs. Steep slopes are not stable and have more chances of failure. Hence, such slopes are to be made stable and safe by providing geotextile as a reinforcing material. On using a geotextile as a reinforcing material the factor of safety is increased. Geotextile is placed as a reinforcing material at different locations through the entire depth of an embankment. The factor of safety changes as the position of geotextile is changed through the depth of an embankment. When these embankments are loaded and checked for the factor of safety after failure it decreases. A comparison is made in different factor of safety of different cases of loading of an embankment at different slip surfaces.

Keywords: Embankments, Factor of safety, Geotextiles, Reinforcement, stress

Introduction

In experimental investigations, a model embankment was constructed of designed dimensions and load was applied till its failure. Later the embankments were reinforced using geotextiles both woven and non woven, at different positions through the depth of the embankment and tested. Therefore, a comparison can be drawn for the embankments constructed with and without geotextiles.

After the experimental investigations, Factor of safety for the embankment with geotextile at different positions without loading is determined using geostudio software. Later, the factor safety is calculated using Bishop’s method of analysis for the embankment with geotextile at different positions, in addition to stress obtained while loading is determined. A comparison is made between the factor safety determined using software and by Bishop’s method of analysis.

Identification of critical slip surface

Location of critical slip surface is necessary to find most stress affected surface in the embankment. Critical slip surface can be identified by using geostudio software or by calculation of factor safety for different slip circles by using bishop’s method. An embankment with 1:1 slope is designed with the required dimensions in geostudio software by following steps.

1) First, dimensions are set according to the requirements, and number of slices required is defined.
2) Page size selected and grid pattern is enabled.
3) Region of embankment is drawn selecting the ‘draw region’ option in the menu.
4) After drawing the region of an embankment soil properties are given selecting ‘material properties’ option from the menu.
5) Later slip surface area is selected at required ranges.
6) If reinforcement is to be provided then it is also drawn from menu and its properties are also defined immediately.
7) And then the model is solved and then factor of safety for the critical slip surface is identified.
8) If needed each slice can be studied according to the requirement of the model problem.
Critical slip surface for an embankment without geotextile

Fig. 1 Most critical slip surface for an embankment without geotextile

Factor of safety = 1.36

Different slip surfaces are identified with different factor of safety. The above diagram shows most critical slip surface with least factor of safety i.e. = 1.36.

Different types of failures like slope failure, toe failure and base failures are seen and their factor of safeties are tabulated below.

Table 1 factor of safeties for different slope failures

<table>
<thead>
<tr>
<th>Type of failure</th>
<th>Factor of safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope failure</td>
<td>1.37</td>
</tr>
<tr>
<td>Toe failure</td>
<td>1.49</td>
</tr>
<tr>
<td>Base failure</td>
<td>1.830</td>
</tr>
<tr>
<td>Critical slip failure</td>
<td>1.36</td>
</tr>
</tbody>
</table>

Fig. 2 Slope failure

Factor of safety = 1.37

The above figure shows a slope failure in an embankment, where a failure or slide of soil mass has occurred in the slope of an embankment.

Fig. 3 Toe failure

Factor of safety = 1.49

The above figure shows a failure of toe of an embankment. Where failure or slide of soil mass has takes place from the top surface of an embankment to the toe of an embankment.

Fig. 4 Base failure

Factor of safety = 1.830

The above figure shows a failure of base of an embankment. Where failure or slide of soil mass has takes place from the top surface of an embankment to the toe and to the base of an embankment.

Critical slip surface of an embankment with geotextile at H/3 from top surface

The above figure shows a slope failure in an embankment, where a failure or slide of soil mass has occurred in the slope of an embankment.
Fig. 5 Slip surface failure of embankment with geotextile at H/3 distances from top

Factor of Safety = 1.9534

Critical slip surface of an embankment with geotextile at h/2 from top surface

Fig. 6 slip surface failure of embankment with geotextile at H/2 distances from top

Factor of Safety = 1.6578

Critical slip surface of an embankment with geotextile at 2h/3 from top surface

Fig. 7 slip surface failure of embankment with geotextile at 2H/3 distances from top

Factor of Safety = 1.532

Critical slip surface of an embankment with geotextile at h/3 and h/2 from top surface

Fig. 8 Slip surface failure of embankment with geotextile at H/3 and H/2 distances from top

Factor of Safety = 1.9938

Critical slip surface of an embankment with geotextile at h/2 and 2h/3 from top surface

Fig. 9 Slip surface failure of embankment with geotextile at H/2 and 2H/3 distances from top

Factor of Safety = 1.6934

Table 2 Factor of safeties for different positions of geotextiles

<table>
<thead>
<tr>
<th>CASES</th>
<th>FACTOR OF SAFETY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embankment without geotextile</td>
<td>1.36</td>
</tr>
<tr>
<td>Embankment with geotextile at H/3</td>
<td>1.95</td>
</tr>
<tr>
<td>Embankment with geotextile at H/2</td>
<td>1.65</td>
</tr>
<tr>
<td>Embankment with geotextile at 2H/3</td>
<td>1.53</td>
</tr>
<tr>
<td>Embankment with geotextile at H/3 and H/2</td>
<td>1.99</td>
</tr>
<tr>
<td>Embankment with geotextile at H/2 and 2H/3</td>
<td>1.69</td>
</tr>
</tbody>
</table>
Here, it can be noticed that the embankment with geotextile has a higher factor of safety than the embankment without geotextile. The factor of safety further increases when geotextile is placed towards the top surface of an embankment. It further increases when two layers of geotextiles are used in an embankment. This implies that when geotextile is used the load carrying capacity of an embankment is improved to a great extent. The slope failure occurs above the layer of geotextile. Therefore, the geotextile is to be effectively placed towards the top surface of an embankment.

**Effect of stress on factor of safety**

Factor of safety is determined by using geostudio software. After testing of embankment under the applied load, factor of safety is again calculated using Bishop’s method of analysis for the critical slip surface. The applied stress adds on to the weight component of the critical slip surface. The critical slip surface is drawn on the graph for Bishop’s method of analysis. Based on that factor of safety is determined by adding stress on the weight component of the critical slip surface by using the following equation.

\[
Fs = \sum \frac{1}{m\alpha} \left[ cb + (w - ub) \tan \phi \right] / \Sigma \sin \alpha
\]

\[
m\alpha = \cos \alpha + \sin \alpha \tan \phi / \text{FOS}
\]

Where FOS = factor of safety

\[
c = \text{cohesion}
\]

\[
w = \text{weight of the slice}
\]

\[
b = \text{width of slice}
\]

\[
\phi = \text{angle of friction}
\]

**Safety factor for unreinforced embankment for different cases**

1. **Critical slip surface**

   i) Factor of safety before application of surcharge = 1.36

   ii) Factor of safety after application of surcharge = 0.71

2. ** Slip surface from the edge of the loading plate**

   **I. Unreinforced embankment**

   i) Factor of safety before application of surcharge = 1.03

   ii) Factor of safety after application of surcharge = 0.63

3. **Slip surface below the loading plate**

   i) Factor of safety before application of surcharge = 1.00

   ii) Factor of safety after application of surcharge = 0.92
II. Safety factor for an embankment with geotextile at 2H/3 distance from top surface for different cases

1. Critical slip surface
   i) Factor of safety before application of surcharge = 1.53
   ii) Factor of safety after application of surcharge = 0.82

2. Slip surface from the edge of the loading plate
   i) Factor of safety before application of surcharge = 1.01
   ii) Factor of safety after application of surcharge = 0.91

3. Slip surface below the loading plate
   i) Factor of safety before application of surcharge = 1.04
   ii) Factor of safety after application of surcharge = 0.95

III. Safety Factor for an embankment with geotextile at H/3 distance from top surface for different cases

1. Critical slip surface
   i) Factor of safety before application of surcharge = 1.95
   ii) Factor of safety after application of surcharge = 0.98

2. Slip surface from the edge of the loading plate
   i) Factor of safety before application of surcharge = 1.41
   ii) Factor of safety after application of surcharge = 0.96
3. Slip surface below the loading plate
   i) Factor of safety before application of surcharge = 1.32
   ii) Factor of safety after application of surcharge = 0.95

Conclusions: From the above cases it is observed that, when the stress is added to the weight component, factor of safety is decreased. This is same for all the cases of embankment. The reduction of factor of safety is in lesser amount when a geotextile is placed at H/3 distance from the top surface. Whereas when a geotextile is placed at H/2 and 2H/3 distance from the top surface the factor of safety is decreased to a larger extent. This is because when geotextile is placed at H/3 distance from top the failure of an embankment or the critical slip surface is very small, as the load carrying capacity is more in this case and the tensile strength of the geotextile is utilized effectively. Therefore the chance for failure of an embankment is very less in this case when compared to that of the other cases.

REFERENCES

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