THE OPTIMUM LOCATION OF REINFORCEMENT EMBANKMENT USING 3D PLAXIS SOFTWARE

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ABSTRACT

Geo synthetics reinforcement in geotechnical layers are used to increase stiffness, separation, filtration, drainage, and protection of soil. The target of this study is to find the optimum geo synthetic reinforcement depth of embankment using (PLAXIS 3D) software. A series of plane strain models are used to simulate reinforcement sand slopes under surface loading (footing).

The analysis shows that settlement behavior of embankment improved by include geo synthetic reinforcement layer as interface at the appropriate location in the fill slope. It is founded that placing reinforcement as (0.5) times the width of the footing is the best position to reduce maximum settlement of geo synthetic reinforcement slop embankment.

Key words: Geo synthetics, Embankment, Reinforcement, PLAXIS 3D.


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1. INTRODUCTION

In recent years, many structures are constructed on the slope embankment, such as buildings and roads on hilly regions. The bearing capacity of sloped embankment will be reduced and settlement increase as comparing with the loading on horizontal embankment, high tension strength of geo synthetic material are used in the field to stabilize embankments or existing slopes to sustain traffic loading or heavy structures. An understanding of the behavior of loaded reinforced slope with a surface footing is of practical importance to geotechnical engineers.

The main purposes of this investigation are to examine some salient aspects that influence on the performance of a strip footing loading on a granular slope by including a single layer of geo grid or geotextile reinforcement.

Many researches such as Selvadurai and Gnanendran (1989), K.M. Lee and V.R. Manjunath (2000), study the mechanisms of geo synthetic reinforcement of the slope embankment.
Finite element analysis using (3D-Plaxis) software is used in this research, different models are carried out to investigate the settlement of a plane strain rigid footing on slope embankment and verified with experimental data.

2. MODELING USING FINITE ELEMENT MESH AND BOUNDARY CONDITIONS

Experimental work done by Lee and Manjunath (2000) on embankment was chosen to verify finite model in this study. This model include two type of soils, natural and geo grid reinforcement soils, different geo grid locations at different depth (U/B=0.25, 0.5, 0.75, 1) from surface is used, when U is the embedment depth of geo grid reinforcement and B is the width of footing, the dimensions of embankment, 1800mm long (x-direction), 900mm wide (y-direction), 1000mm height(z-direction), the footing (surface load) width 100mm with long 900mm place at distance 100mm from edge of embankment (De/B=1), and for embankment slope using (2H: 1V),as shown in Figures (1) and (2).

![Figure 1](image1)
**Figure 1** Numerical model of embankment by 3D Plaxis software program

![Figure 2](image2)
**Figure 2** Side view of embankment

According to model dimension, medium mesh generation was created and refined at the embankment model and the reinforcement geo synthetic to allow short phase time phase to attain greater accuracy in the beginning of plastic analysis. The mesh consists of over (6708) elements (10-node tetrahedrons) with over (10394) nodes with average element size nearly (0.01554m) as shown in the Figure (3).
3. CONSTITUTIVE MODELS AND MATERIAL PARAMETERS

Hardening model of soil was used to simulate the sand slope embankment soil material. Plastic analysis was conducted to simulate an embankment. These constitutive models were verified with experimental data of Lee and Manjunath (2000). Parameters for the benchmark case are listed in Table (1) which is the same parameters that adopted in this research.

Geo synthetics reinforcement is used to enhance load carrying capacity and reduces vertical deformation. Linear elastic model is selected to simulate behavior geo grid model. Two interfaces were product for each geo grid, the first outside the geo grid (positive interface) between geo grid and soil upward the geo grid carrying the soil properties, and the second one inside the geo grid (negative interface) between geo grid and soil underneath the geo grid carrying this soil property. Interfaces are composed of 12-node elements, six pairs of nodes, compatible with the 6-noded triangular sides of the soil (Brinkgreve et al., 2013).

Table 1 Material parameters for the numerical analyses (K.M. Lee and V.R. Manjunath 2000)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Sand top layer</th>
<th>Sand bottom layer</th>
<th>Geogrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsaturated unit weight, $\gamma_{	ext{unsat}}$ (KN/m³)</td>
<td>18.2</td>
<td>18.2</td>
<td></td>
</tr>
<tr>
<td>Saturated unit weight, $\gamma_{	ext{sat}}$ (KN/m³)</td>
<td>21.02</td>
<td>21.02</td>
<td></td>
</tr>
<tr>
<td>Material model</td>
<td>Hardening soil</td>
<td>Hardening soil</td>
<td></td>
</tr>
<tr>
<td>Drainage type</td>
<td>Drained</td>
<td>Drained</td>
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</tr>
<tr>
<td>$E_{50\text{ ref}}$ (KPa)</td>
<td>35 000</td>
<td>60 000</td>
<td></td>
</tr>
<tr>
<td>$E_{	ext{eqd ref}}$ (KPa)</td>
<td>35 000</td>
<td>60 000</td>
<td></td>
</tr>
<tr>
<td>$E_{ur\text{ ref}}$ (KPa)</td>
<td>105 000</td>
<td>180 000</td>
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<tr>
<td>Power in stiffness laws, $m$</td>
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<tr>
<td>Unloading–reloading Poisson’s ratio $\nu$</td>
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<td>0.3</td>
<td></td>
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<tr>
<td>Cohesion, $C$ (KN/m²)</td>
<td>1</td>
<td>1</td>
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<td>Friction angle, $\phi$ (°)</td>
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<td>38</td>
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<tr>
<td>Angle of dilatancy, $\Psi$ (°)</td>
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<td>10</td>
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<tr>
<td>Interface reduction factor, $R_{\text{inter}}$</td>
<td>0.75</td>
<td>1</td>
<td></td>
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<tr>
<td>Axial stiffness, $EA$ (KN/m)</td>
<td></td>
<td></td>
<td>68</td>
</tr>
</tbody>
</table>
4. NUMERICAL ANALYSIS PROCEDURE
The numerical modeling consisted of four steps, the first step was initial geostatic equilibrium, the second steps was modeling the embankment depend on dimension of model and material parameters as shown in Table 1, the third steps mesh generation, the last step was modeling surface loading pressure (10, 20, 30, 40, 50 and 60) kpa of footing at the top of embankment. In case of modeling untreated embankment, modeling treated embankment with reinforcement and interface element phase was added. Plastic calculation type was used in all steps.

5. RESULT AND ANALYSIS
Figures (4), (5), (6) and (7) are represented the verification of numerical and experimental results, and the percentage of this different at loading pressure (40kpa) is (15.27%, 51.50% 59.20% and 27.28%) for un reinforcement embankment, reinforce at (U=0.25B), reinforce at (U=0.5B) and reinforce at (U=0.1B), respectively. It can be noticed good agreement obtained between numerical and experimental results.

Figure 4 Results of loading pressure versus vertical deformation of untreated embankment

Figure 5 Results of loading pressure versus vertical deformation of treated embankment with reinforcement at (U=0.25B)
Different locations of geo grid in the embankment (U=0.25B, 0.5B, 0.75B and 1B) are trailed to use in this study, to find optimum position. Figure (8) explain this result with different location of geo grid reinforcement, and the percentage of reduce in vertical deformation at loading pressure (40 kpa) (20.15%, 27.68%, 27.68% and 16.32%) for reinforcement embankment at (U=0.25B, 0.5B, 0.75B and 1B) respectively, as compare with un reinforcement embankment, as shown in Figure (9). It can be seen from these results the optimum embedment depth at (U=0.5B), because the less deformation obtained at the surface. The output of vertical deformations using 3D Plaxis software are illustrated in Figures (10),(11),(12),(13) and (14).
Figure 8 The relationship between vertical deformation and loading

Figure 9 The relationship between vertical deformation and location of geogrid

Figure 10 The vertical deformation of reinforcement embankment at loading pressure (40 kpa)
The Optimum Location of Reinforcement Embankment using 3D PLAXIS Software

**Figure 11** The vertical deformation of reinforcement embankment with reinforcement at (0.25B) for loading pressure (40 kpa)

**Figure 12** The vertical deformation of reinforcement embankment with reinforcement at (0.5B) for loading pressure (40 kpa)

**Figure 13** The vertical deformation of reinforcement embankment with reinforcement at (0.75B) for loading pressure (40 kpa)

**Figure 14** The vertical deformation of reinforcement embankment with reinforcement at (1B) for loading pressure (40 kpa)
6. CONCLUSION

- 3D Plaxis software can be used to simulate numerical behavior of reinforced embankment.
- Good agreement obtained when compare between numerical and experimental results.
- The maximum reduction of vertical deformation (27.68 %) obtained when geogrid reinforcement depth is placed as 0.5 width of footing.

REFERENCE


