Assessment of Geotextile Reinforced Embankment on Soft Clay Soil

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Abstract

Results of parametric study to investigate the applicability of finite element method for analyzing reinforced embankment on soft soil are investigated in this paper. The effect of number of geotextile layers, slope inclination, geotextile modulus and geotextile effective length on the behavior of reinforced silty sand embankment on soft clay is determined. Results reveal that use of geotextile between bed and foundation can decrease displacements. Decreasing the slope and height of embankment, crest width and increasing geotextile modulus can decrease displacements. The optimum place for geotextile layer is between bed and embankment. If the geotextile layer covers the bottom of embankment completely it will cause the least displacements.

1. Introduction

Soil can resist pressure and shear forces very well, but it is not able to tolerate tensile forces. Reinforced soil is composite material that contains components that can easily stand tensile forces. Nowadays reinforcing materials is widely used to overcome technical problems. Reinforced soil is used in stabilizing embankment (slope), fill dams, retaining walls, foundation and in-situ slope for increasing the shear resistance of soil layer in different earth structures.

Geosynthetics recognized as synthetic materials are used in soil [1]. The specific families of Geosynthetics are the following: Geotextiles, Geogrids, Geomembranes and Geocomposites. When synthetic fibers are made into a flexible, porous fabric by standard weaving machinery or are matted together in woven and nonwoven manner, the product known as "Geotextile". Geogrids are plastics formed into a very open netlike configuration. Geotextiles and Geogrids are used usually as reinforcing material for soil improvement [1]. These reinforcing materials are not susceptible to corrosion, have relatively low stiffness and flexible enough to tolerate large deformation. These factors make them to be superior to steel reinforcing materials in soils. As use of geotextile in reinforcing embankment is growing, this paper is an attempt to investigate the applicability of finite element method for analyzing reinforced embankment on under laying soft soil.

2. Geosynthetics and their applications

Geosynthetics are produced using different types of polymer fiber namely: polypropylene, polyester etc.. Use of Geosynthetics is growing in civil engineering activities. Their applications are namely: i) Separation ii) Reinforcement iii) Filtration iv) Drainage v)Sealing [1].

3. Modeling and analysis

Initial step for analyzing the model, is to create the geometry of the model. The geometry characteristics such as embankment height, slope and crest width. The other geometry which should be defined is under laying soil profile such as Thickness of the soft layer. The second step is to provide the material properties of the embankment and the under laying soil. For present investigation the main model with 5m height, 10m crest width, 1:1.5(V:H) slope and is placed on a soft clayey layer of 4m thickness. As the model is symmetric with respect to center line, half of the embankment is modeled in analysis (Figure 1). The PLAXIS 2D software version 7.2 is employed for performing the analyses.

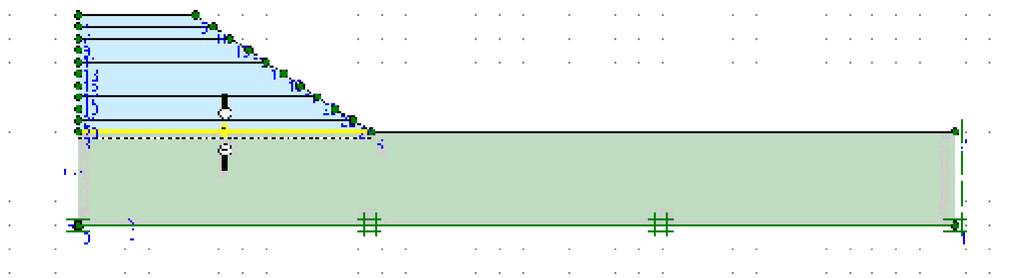

Figure 1 Geometry of the main model

The embankment is divided to layers of 0.5m thickness. For stage construction analysis to simulate the actual conditions of geotextile layers (being used to reinforce the embankment), the construction period of 3 days is considered for each layer. After full construction of the embankment, the model is analyzed for consolidation in one year periods and then analyzed for pore water pressure of 1kN/m².

4. Material properties

Because under laying layer is soft and clayey, the consolidation and time relative behavior of this soft layer must be considered in analyses of the model. The soft soil creep (S.S.C) concept as an advanced type of modeling for the first time is incorporated in Plaxis ver7.2 is used for soft under laying layer. The material properties used for the model are presented in the following tables (Table 1 and 2):

Table 1 Material properties of embankment

Specification	γ (dry)	γ (wet)	Kx	Ky	υ	E	C	∅	psi
Units	KN/m^3	KN/m^3	m/day	m/day		KN/m^2	KN/m^2	degree	
Embankment	19.2	19.2	864	864	.33	6130	10	38	9

Drainage condition= Drained; R(inter)= 9 (Used in analysis)

Table 2 Material properties of under laying layer

Specificat ion-	γ (dry)	γ (wet)	Kx	Ky	υ	C	Ø	psi	λ	Kappa
Units	KN/m^3	KN/m^3	m/day	m/day		KN/m^2	degree	degree		
Subsoil	16	18.5	.0001728	.0000864	.15	20	23	0	.13	.026

Drainage condition= Undrained : R(inter)= 9 ; μ =.006 (Used in analysis)

A layer of geotextile is modeled between the embankment and the under laying soft layer. In Plaxis the geotextile is introduced to software as a tensile element and named as "EA". In software structural element is selected for presence of geotextile layer. In this model EA is considered 2500 KN/m. The interface element is used to model interaction of soil-geotextile layer. This ratio is defined as R in Plaxis software. R stands for shear resistance of soil and reinforcing material, R=0.9 is considered by using pullout test reported by Bargado [2].

5. Assessment of effect of geotextile layers

To assess the effect of presence of number of geotextile layers, initially three types of embankments are modeled without geotextile. In second step, one layer of geotextile is introduced between the embankment and the under laying soft soil. For last step of analyses, three layers of geotextile are considered and they are placed one between the embankment base and the soft layer and remaining two others in the body of embankment at level of 2m and 4m above the base respectively.

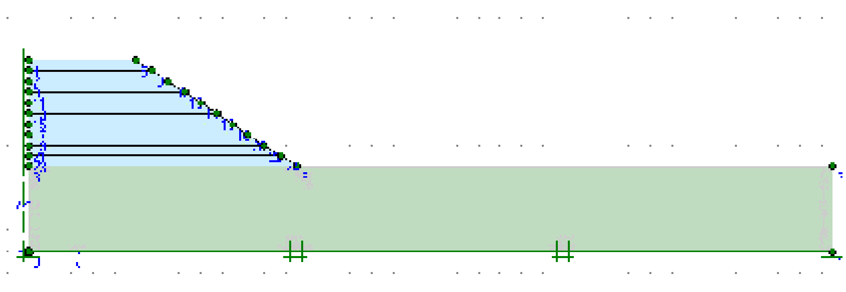

Figure 2 Model of embankment with no layer of geotextile and under laying soft layer

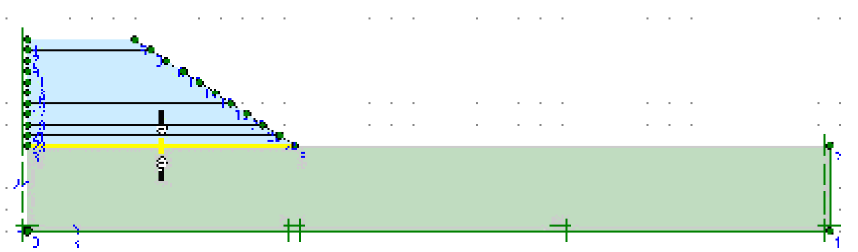

Figure 3 Model of embankment with one layer of geotextile and under laying soft layer

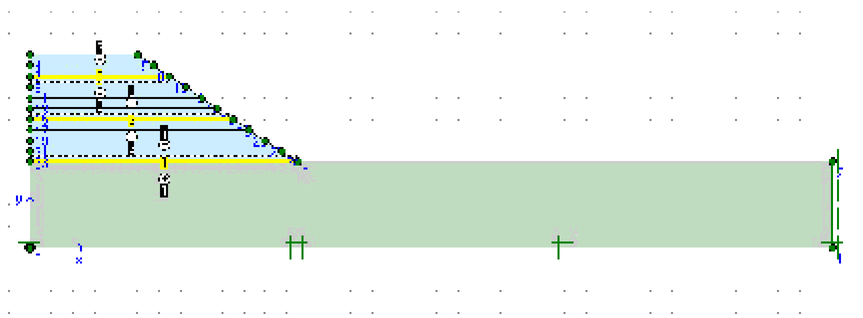

Figure 4 Model of embankment with Three layers of geotextile and under laying soft layer

Table 3 shows results of the maximum horizontal and vertical displacements obtained on analyzing three models of embankment. As can be observed from Table 3, as number (no.) of geotextile layer increases displacements decreases.

Table 3 Maximum horizontal and vertical displacements for three embankment models

No. of geotextile layer	Horizontal displacement(cm)	Vertical displacement(cm)
No geotextile layer	37	85.57
One layer of geotextile layer	25.59	77.81
Three layer of geotextile layer	24.11	76.45

Assessments of displacement results show the following conclusions:
i) The highest horizontal displacement occurs near the embankment toe and geotextile layer can decrease this amount about 30 percent. ii) Increasing the stiffness of geotextile will decrease displacements. iii) Increasing number of geotextile layers leads to 1.6 percent reduction in vertical settlements and 4 percent reduction in horizontal displacements.

6. Assessment of effect of embankment slope

Four different models with: 1to1, 1to1.5, 1to2, 1to3 slopes are modeled. Table 4 presents displacement results obtained for embankment with different slopes.

Table 4 Values of horizontal and vertical displacements for embankment with different slopes

Embankment slope	Horizontal displacement(cm)	Vertical displacement(cm)
1 to1	25.96	77.3
1to1.5	25.59	77.81
1 to2	22.44	76.51
1to3	19.02	74.58

The following conclusions can be drawn: i) The maximum vertical displacement occur at center line of embankment and values of displacement will decrease about 3.5 percent by reduction of embankment slope from 1:1 to 1:3. ii) The maximum horizontal displacement occur near to embankment slope at toe section of the embankment and values of displacement will decrease about 26.7 percent by reduction of embankment slope from 1:1 to 1:3. iii) Changing the embankment slope from 1:1.5 to 1:1 doesn't have any effect on values of displacement. This happens because of reinforcement existence.

7. Assessment of effect of geotextile stiffness

Considering the availability of different products of Geosynthetics in market, the assessment is done by considering "EA" parameter with different values. For this part of assessment, initially the stiffness of EA=2500kN/m and considering all other parameters for the three models to be similar is selected and the analysis is performed. In second series of analysis, the value of EA=1250kN/m half value of EA considered in initial step is used. In last step EA=5000kN/m is used for three embankment models. Results obtained from analysis are presented in Table 5.

Table 5 Horizontal and vertical displacements using geotextile with different stiffness values

Geotextile stiffness, EA (KN/m)	Horizontal displacement(cm)	Vertical displacement(cm)
1250	30.9	82.17
2500	25.59	77.81
5000	21.72	73.38

Assessments of displacement results show the following conclusions:

i) The maximum vertical displacement occur at center line of embankment and its value decrease about 10.6 percent with increasing geotextile stiffness from 1250 kN/m to 5000kN/m. ii) The maximum horizontal displacement occur near to embankment slope at toe section of the embankment and with increasing geotextile EA from value of 1250 (KN/m) to 500 (KN/m) the displacement value decrease by 29.7 percent. iii) Higher the stiffness of geotextile, higher ability to resist tensile forces. The reason that can be given is, when the stiffness of geotextile increases the difference between strain in top and bottom of the geotextile layer become larger and so, larger tensile force is generated in reinforcement.

8. Assessment of effective length of geotextile layer

For this purpose, embankment models with different geotextile length namely: continuous length (Covering whole width of embankment), 4m and 8m length starting from embankment toe and are placed in either sides of embankment are used. The results obtained from analyses are presented in Table 6.

Table 6 Horizontal and vertical displacements using different geotextile effective length

Effective Geotextile length	Horizontal displacement(cm)	Vertical displacement(cm)
4 m	37.15	88.17
8 m	36.6	75
continuous	25.59	77.81

The following results are drawn:

i) The maximum vertical displacement occur at center line of embankment and its value decrease by 7 percent as geotextile length increase from 32 percent of continuous length to full continuous length. ii) The maximum horizontal displacement occur near to embankment slope at toe section of the embankment and with increasing length of geotextile layer from 64 percent of continuous length to full continuous length, the displacement decrease by 31 percent.

9. Conclusions

1. Using one layer of geotextile between the embankment base and the under laying soft layer decrease vertical and horizontal displacement.
2. As decreasing horizontal displacements of embankment has important role in stability of embankment, the best place for installing geotextile layer is between the embankment base and under laying soft layer.
3. We can use a geotextile with high stiffness when it is required to construct a high embankment or an embankment with steeper slope on soft soil.

10. References

[1] KOERNER, R.M., Designing with Geosynthetics, Prentice-Hall, Englewood Cliffs, New Jersey, (1986), 424 pp.

[2] BERGADO, D.T. and PHAM V LONG, A Case Study of Geotextile Reinforced Embankment on soft Ground, School of engineering, Asia Institute of Engineering, Bangkok, ,(2002).