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Behavior of Soil Reinforcements in Slopes

M. Inanc Onur[1*], Mustafa Tuncan[1], Burak Evirgen[1] Bertan Ozdemir[1]and Ahmet Tuncan[1]

[1]Anadolu University, Eskisehir, TURKEY.

mionur@anadolu.edu.tr, mtuncan@anadolu.edu.tr, burakevirgen@anadolu.edu.tr, eftal.bozdemir@gmail.com atuncan@anadolu.edu.tr

Abstract

In geotechnical and transportation engineering, especially road constructions in cuts and deep excavation problems are solved by using different supporting excavation methods. Soil reinforcements are chosen due to easy and economic application. In this study, behavior of supported slopes with geotextiles and geogrids were analyzed by performing experiments on slope models in the laboratory. In the experiments, a static loading was applied to find failure surface and deformations for each case. Additionally, slopes were designed by using Plaxis program. At the end of the study, experimental and analytic models were compared and also behavior of models were presented.

Keywords: Soil reinforcements, geotextiles, geogrids, Plaxis 2D

1 Introduction

Retaining structures are constructed at nearly every highway, road and railway projects and used against for slopes and embankments. Retaining structures are classified under two main groups. These are permanent structures such as retaining walls, reinforced earth structures, anchored walls and temporary structures such as sheet pile walls and braced cuts. Retaining walls are mostly preferable elements among them and there are three types such as cantilever, gravity and counterfort (Das, 1984). Retaining walls constructed by using reinforced concrete so construction of retaining walls needs money and time. On the other hand, weak subsoil conditions and slope heights increase the cost. Therefore alternative methods such as reinforced earth structures are used especially last 50 years. Reinforced earth structure is also known as Mechanically Stabilized Earth Wall and is a specific reinforced soil system. Geotextiles and geogrids are flexible polymeric materials and used as reinforcing elements. An example of reinforced earth structure is given in Figure 1.

Geotextiles are used with soils because of providing tensile strength. And other advantages of using geotextile is also given (Brooms, 1977). The analysis, design and construction of reinforced soil walls

[*] Corresponding author. Tel.: +90-2223213550. fax: +90-2223239501. E-mail address: mionur@anadolu.edu.tr

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with geosynthetics are investigated (Bathurst, 1994). A manual on mechanically stabilized earth walls for design and construction process of these structures are prepared (Elias, 1994). The bearing capacity of shallow foundation with geogrids are studied (Yildiz, 2005). And also, finite element analysis were performed by using the PLAXIS program. Benefits of geogrids are evaluated and modeled by using ABAQUS software (Gu, 2011).


Figure 1. An example of reinforced soil structure

The design progresses of geotextile and geogrid walls are as follows: Firstly, internal stability analysis are calculated to determine spacing, length and overlap distance. Then external stability analysis against overturning, sliding and foundation failure are found. And finally, wall facing details and external drainage are analyzed. Rankine earth pressure theory is generally used for earth pressure calculations. Designing reinforced soil systems need much more knowledge. Possible stability failures are given in Figure 2.

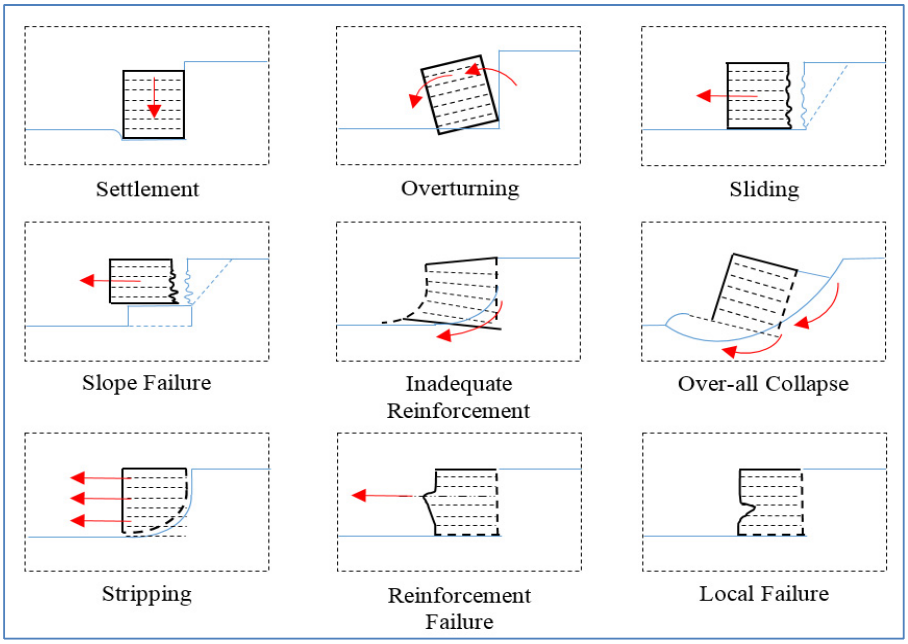

Figure 2. Some possible failures (Das, 1994)

In this study, behavior of supported slopes with geotextiles and geogrids were analyzed by performing experiments on slope models in laboratory. In the experiments a static loading was applied to find failure surface and deformations for each case (Ozdemir, 2015). Additionally, models were analyzed by using Plaxis program. At the end of the study, experimental and analytic models were compared and also stress and strain behaviors of models were presented.

2 Experimental Study

In this study, a model box was developed in the laboratory for creating slopes with geotextile and geogrid members according to the theoretical calculations. After designing box model, vertical loads were applied to the system and all dimensions scaling with 4/100 ratio. The model has 20 cm in height, 50 cm in width and 90^o angle of slope shown in Figure 3. After placing the reinforcements, the soil was compacted by using standard compaction energy. Loading frame, having 10 tons capacity, was adapted on top of the box to apply static load vertically on the slope. Dial gages were placed in both vertical and horizontal directions to measure the displacements.

Figure 3. Model box

After placing reinforcements, granular fill material was compacted. Granular fill material contains 72.3 % sand, 23.1 % silt and 4.6 % clay and the grain size distribution curve is given in Figure 4. Specific gravity of this material is 2.67. Mechanical properties of the reinforcements are given in Table 1. They are taken from Geoplas inc. Ankara, Turkey and the firm is a reinforcement supplier for many highway projects. Geotextile reinforcements were placed 20 mm intervals and geogrid was placed 16 mm intervals in the vertical direction.

In this study, Plaxis 2D program was performed for model analysis. Plaxis is a commercially available finite element program which is used commonly in geotechnical engineering for the deformation and stability analysis. The software can make numerical solutions based on the finite element method (Brinkgreve & Vermeer, 1998). The software can solve the problems with 2D or 3D analysis by separate modules.

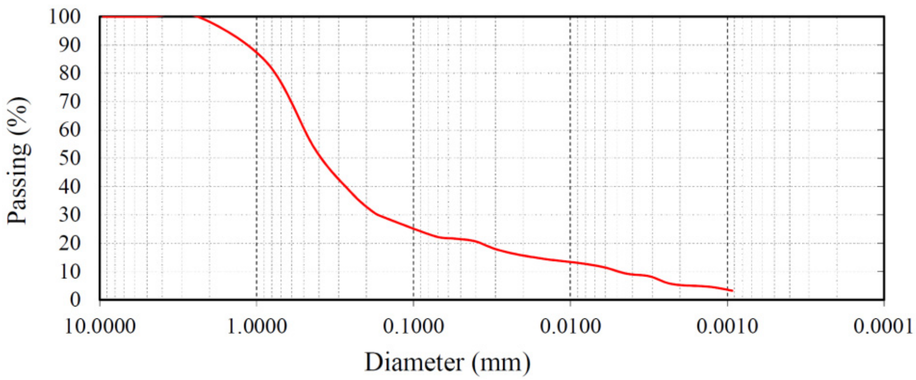

Figure 4. Grain size distribution curve

	Geotextile	Geogrid
Unit Weight	200 gr/m^2	260 gr/m^2
Tension Strength	7.5-11 kPa	40-50 kPa
Thickness (mm)	1.2	1.6

Table 1. Mechanical properties of reinforcements

2.1 Application with Geogrid

In this case, geogrids having 4 cm rib spacing were used. Theoretical calculations were done then the length and spacing of geogrids were determined according to maximum lateral earth pressure. Firstly, the laboratory experiments were performed and then model was analyzed by using Plaxis program. Maximum load was 3300 kg. Maximum stress of slopes with geogrid reinforcements was about 8.7 kg/cm^2. Stress level showed that slope with geogrid reinforcement did not carry that load. And also slope with geogrid reinforcement gave deformation in vertical direction. Maximum vertical and horizontal deformations of the slope were 22 mm and 7.0 mm, respectively. Laboratory model and Plaxis model of the slope with geogrid reinforcement are given in Figure 5 and 6, respectively.


Figure 5. Laboratory model for geogrid reinforcement

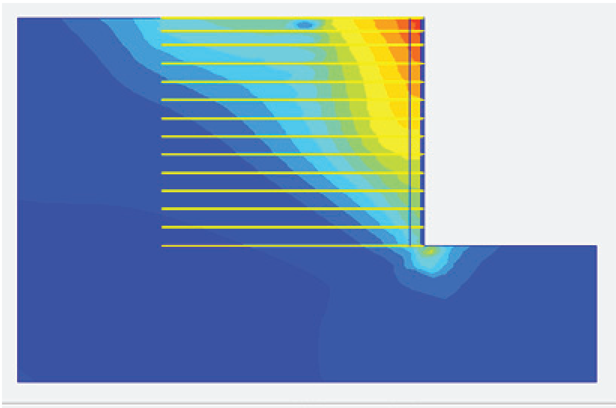

Figure 6. Plaxis model for geogrid reinforcement

2.2 Application with Geotextile

In this case, geotextiles having 1.6 cm thickness were used. After making theoretical calculations, the length and spacing of geotextiles were determined according to maximum lateral earth pressure. Firstly, the lab experiments were performed and then model analyses was done by using Plaxis program. Maximum load was 2600 kg. Maximum stress of slopes with geotextile reinforcements was about 6.6 kg/cm^2. Stress level showed that slope with geotextile reinforcement did not carry that load. And also slope with geotextile reinforcement gave deformation in vertical direction. Maximum vertical and horizontal deformations of the slope were 28 mm and 9.0 mm, respectively. Laboratory model is given in Figure 7.

Figure 7. Laboratory model for geotextile reinforcement

3 Results

In this study, slopes with geotextile and slopes with geogrid were constructed in the laboratory with scale and their deformations under static loading were determined. Results obtained from this study are given below and also results of Plaxis analysis are compared with laboratory experiments.

Slopes with geogrid and geotextile reinforcements were failed under the stress of 8.7 kg/cm^2 and 6.6 kg/cm^2 respectively. Slope with geogrid and geotextile reinforcements were deformed horizontally 9.0 mm and 7.0 mm, respectively. It can be seen from Table 2 that Plaxis program gives a little bit higher values compare to the laboratory model.

	Plaxis Deformation (mm)	Laboratory Model Deformation (mm)
Geogrid Reinforcement	8.50	7.00
Geotextile Reinforcement	14.00	9.00

Table 2. Deformations of models

4 Conclusions

In geotechnical and transportation engineering, excavation problems are solved by using different supporting excavation methods. Economic feasibility, fast construction, high resistance to earthquake loads and aesthetic appearance are the main reasons for the preference of reinforced earth structures. In this study, behavior of supported slopes with geotextiles and geogrids were analyzed by performing experiments on slope models in the laboratory and Plaxis program. Results show that, geogrid members give less deformations and higher strength comparing with geotextile members. Additionally, Plaxis program gives approximately similar values with laboratory models.

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