

Research Article

INVESTIGATION OF THE APPLICATION OF GEOSYNTHETICS ON THE SETTLEMENT OF EMBANKMENTS OVER SOFT SOILS

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ABSTRACT

One of the major challenges in road construction projects is the design and construction of roads over soft and weak soil subgrades. One of the methods to improve the load-bearing capacity of weak foundation soils is reinforcement using synthetic fibers and polymers. Among the most widely used of these polymers is the family of geosynthetics. In this paper, the effect of using geosynthetics to improve the performance of embankments constructed over soft subgrades is investigated. One of the objectives of this study is to introduce the FLAC software as a suitable tool for designing embankments over soft soils. Using the finite difference method and the FLAC software, the settlement of the Urmia–Tabriz Road embankment constructed over soft soil was analyzed, both with and without the use of geotextile reinforcement. The settlement values of different layers of the subgrade and embankment were calculated. The results of the analysis show that the settlement values obtained for the unreinforced embankment are in close agreement with the actual field measurements. Furthermore, the results indicate that the use of geotextile reduces settlement by up to 60% compared to the case without geotextile.

INTRODUCTION

From the past to the present, civil engineers have faced the challenge of constructing structures and roads on soft foundations and subgrades. Until about 30 years ago, engineers tended to avoid building structures on such soils. However, with the rapid advancement of science and the expansion of engineering knowledge, appropriate solutions for constructing such structures have been proposed by geotechnical engineers. The main characteristics of soft soils include high compressibility and low shear strength, which lead to long-term deformations and stability problems in embankments constructed over them. These deformations manifest as settlement in roads built on such embankments, and the repair and rehabilitation of these roads involve very high costs. Therefore, providing an economical and feasible method for constructing embankments on soft soils is essential. Various methods have been proposed for embankment construction on soft ground, each with its own advantages and disadvantages. These methods include benching and slope flattening, staged construction, installation of vertical drains, complete excavation and replacement, pile-supported embankments, and the use of geosynthetics. In recent years, the use of geosynthetics has become widespread. When placed between the subgrade and embankment, or within embankment layers over weak soils, they enhance the load-bearing capacity of the soil ^[5,6,8,9]. Analyzing the performance of reinforced embankments during the service life is one of the issues engineers face. Today, numerical methods and computers with high computational capabilities play a significant role in assisting engineers in this field.

Case Study

Numerous roads in the country have been constructed over soft subgrades and have experienced settlement problems. Among them are roads built in West Azerbaijan Province around Lake Urmia [1]. The Urmia–Mahabad, Urmia–Tabriz, and Qarah Zia al-Din–Maku roads are examples of such cases. The problematic sections of these roads are typically located in areas with ponding and accumulation of surface water during rainy seasons. After construction, since all three roads were built on soft, muddy, or peat subgrades, they exhibited considerable settlement over an average period of about four years. These road sections, typically ranging from approximately 50 to 150 meters in length, have been repeatedly overlaid with significant amounts of asphalt to restore them to the design grade. According to calculations, the weight of the added asphalt ranges between 400 and 600 tons. This additional load induces excessive stress, accelerates consolidation, and consequently leads to continued settlement. For this study, the Urmia–Tabriz road has been selected, and the settlement of the embankment constructed over its soft subgrade is analyzed. Figure 1 illustrates the condition of the subgrade layers, based on geotechnical investigations conducted by the General Directorate of Roads and Transportation of West Azerbaijan Province. According to [Figure 1](#), a layer of organic soil (peat) is located near the ground surface, underlain by silty clay layers forming the remaining strata. The primary causes of settlement appear to be the presence of the organic soil layer, a high groundwater table, and underlying silty clay layers.

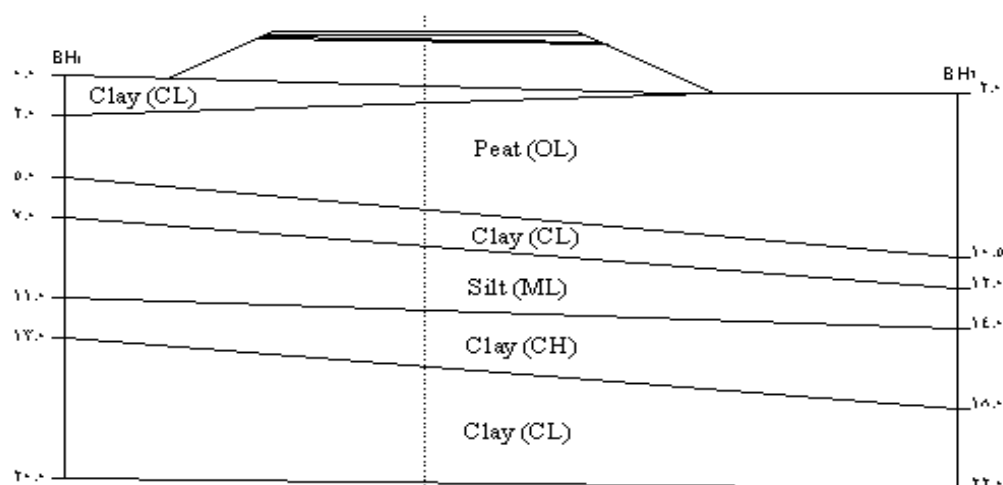


Figure 1: Cross-section of the embankment and its subgrade

METHOD

In this study, the amount of soil settlement of the Urmia-Tabriz Road in the section that is placed on a loose substrate is compared once without the use of geotextiles and once reinforced with geotextiles to investigate the effect of using geotextiles on reducing settlement. The finite difference method in the FLAC program has been used in the modeling and analysis of settlement. The Mohr-Coulomb model has been used to describe the behavior of the materials [3].

Modeling

As mentioned, FLAC finite difference software was used for the analysis [7]. First, the grid lines of the stratification model were introduced to the software according to [Figure 2](#). After introducing the initial conditions such as applying soil weight, the clamping conditions that include the restriction of movement in the horizontal direction for the right and left sides of the grid and the embankment edge and the restriction of movement in the vertical direction for the points located at the bottom of the grid, and the conditions related to the characteristics of water flow were introduced in the model [4]. First, the initial analysis was carried out under the effect of the weight of the model and then the material properties of the layers were introduced to the software according to [Table 1](#). In this study, the model was first analyzed under its own weight without considering the loadings. Considering that the road in question has two lanes, two loads of 2.8 tons are applied to the entire road. By converting this load to a uniform spread load, we will have a load equal to 12 kPa across the width of the road. This load was applied statically to the model. At this stage, it is first applied to the model assuming that the embankment is 2.4 meters high and an asphalt layer is applied. The model is then allowed to settle for 4 years under the existing conditions. After four years, the analysis continues assuming road pavement repair and the addition of a loading equivalent to 50 cm of asphalt.

Table 1: Material properties of the embankment and subgrade

Soil Name	Cohesion C(Pa)	Soil specific gravity Φ	Soil specific gravity $\gamma(\text{kN/m}^3)$	Soil modulus of elasticity $E(\text{N/m}^2)$	Soil expansion angle in degrees ν	Soil expansion angle in degrees ψ
Embankment	1000	34	2100	5e7	0.35	0
Clay (CL(1))	1000	22	1580	2e7	0.3	0
Peat (OL)	5000	30	1508	1e7	0.3	0
Clay (CL2)	10000	20	1580	2e7	0.3	0
Silt (ML)	3000	22	1366	3e7	0.3	0
Clay (CH)	12000	14	1284	7e7	0.35	0
Clay (CL3)	14000	24	1131	1.5e7	0.35	0

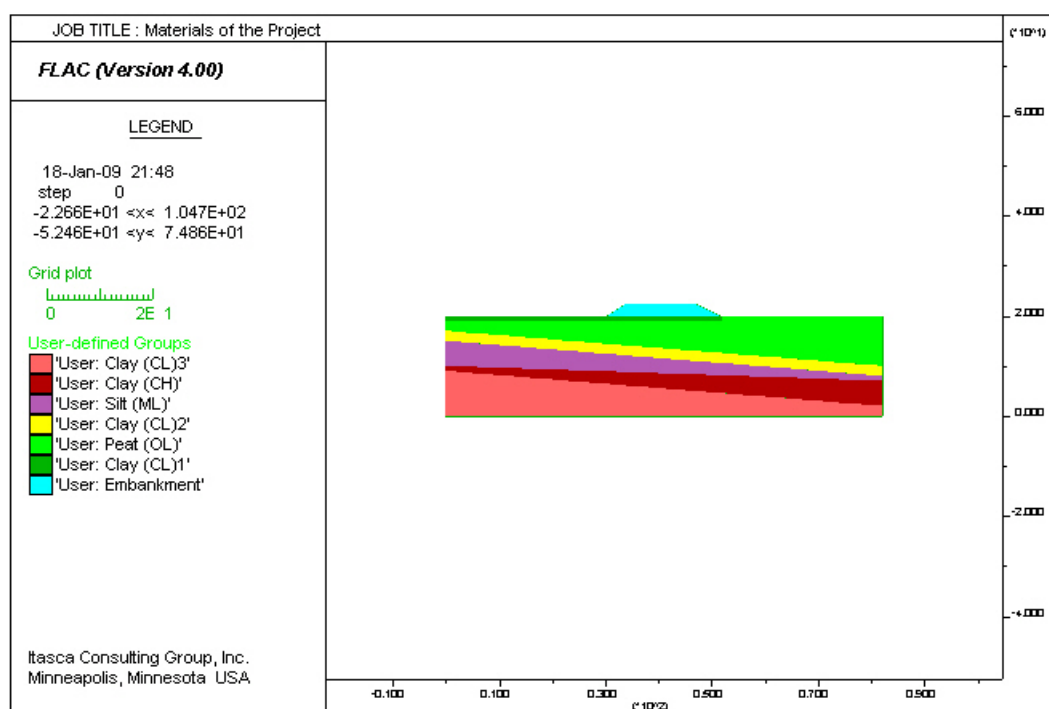


Figure 2: Stratification of the embankment and natural ground

ANALYSIS RESULTS

Figures 3 and 4 show the results of the analysis of the settlement of the embankment over time and under the influence of the weight of the earth and the applied loads for the case of unreinforced geotextile and reinforced geotextile, respectively. By comparing both figures, it is observed that the settlement of the earth in the case without geotextile is greater than that in the case of reinforced geotextile, and the stability of the embankment is at risk. Figure 5 shows the cumulative settlement of the different layers of the embankment bed for the two cases of

unreinforced and reinforced geotextile, in which the vertical axis shows the total settlement of the layers of the bed of the desired layer. The sudden increase in settlement in the third layer is related to the type of soil in the third layer, which is peat. As can be seen in the figure, the settlement of the embankment in the unreinforced condition is about 0.71704 meters, which is almost equal to the actual amount of settlement observed in the embankment of the Tabriz-Urumiah road in the analyzed section. In comparison, the total settlement of the embankment in the reinforced condition has decreased to about 0.2915 meters, which indicates the significant effect of reinforcing the embankment to control the settlement of the roads constructed in these areas. In this analysis, the results have shown that when geotextiles are used in the embankment, the pore water stresses and pressures are also reduced to a considerable extent, which reduces the settlement of the layers.

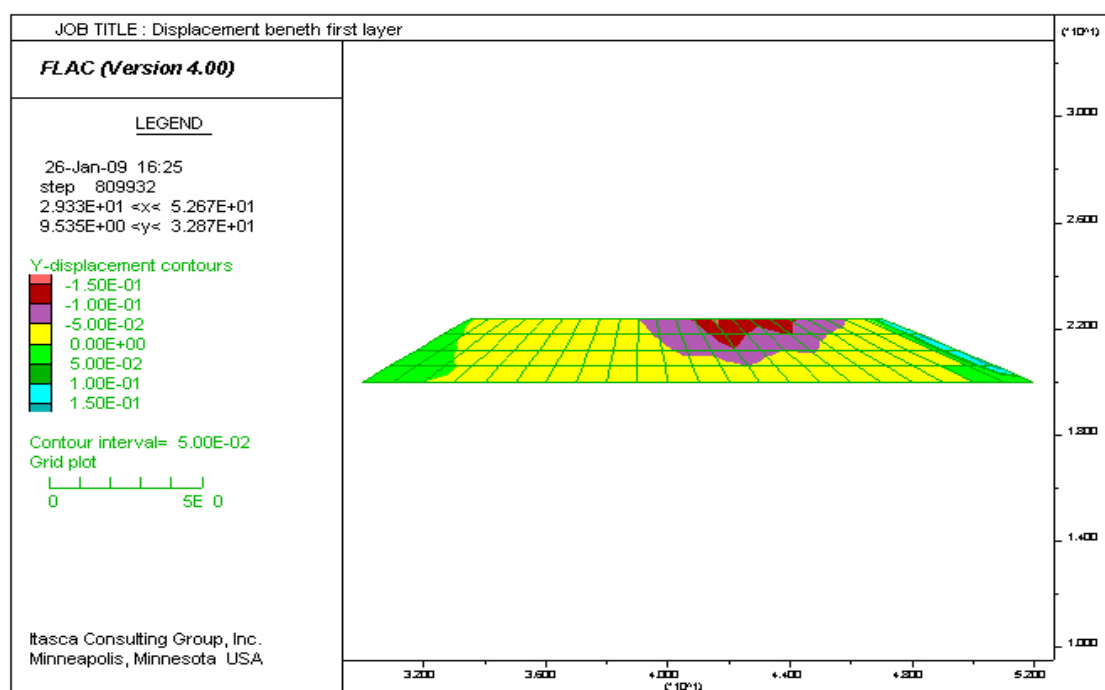


Figure 3: Settlement of the embankment in the unreinforced condition

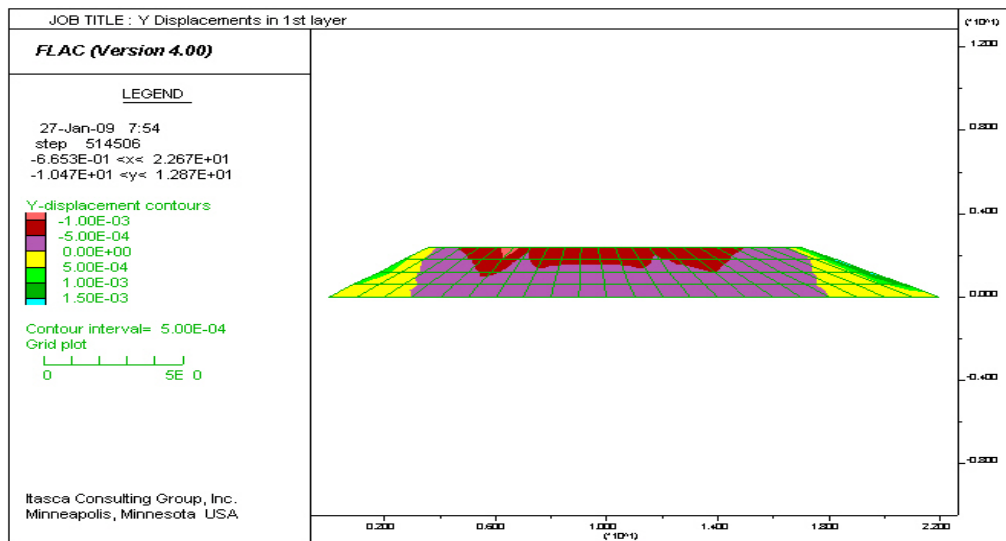


Figure 4: Settlement in the reinforced condition

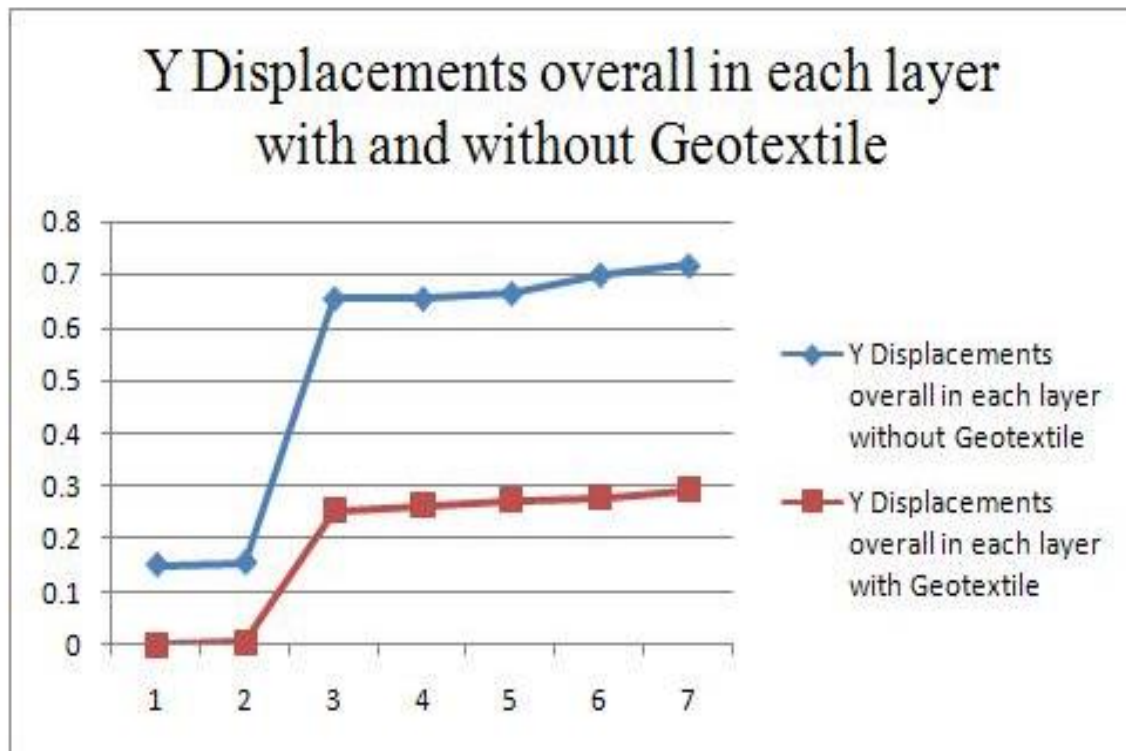


Figure 5: Cumulative settlement of layers in unreinforced and reinforced conditions

CONCLUSION

Based on the above discussion, the results can be summarized as follows:

- Reinforcing the embankment with geotextile leads to a significant reduction in vertical settlement compared to the unreinforced condition. The reduction in settlement is related to several factors, including decreased stresses, reduced pore water pressure, and reduced vertical and horizontal displacements. For the embankment analyzed in this study, settlement decreased by approximately 60% with the use of geotextile.
- Comparison between the results obtained from the FLAC software and actual field settlements indicates that this software is effective and reliable for analyzing road embankment settlement.
- The reinforcing performance varies across different layers. This performance depends on factors such as proximity to applied loads, layer thickness, material type, and other conditions. In this study, the greatest reinforcement effect was observed in the first layer.

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