ANALYSIS OF EMBANKMENT REINFORCED WITH DIFFERENT MATERIALS

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ABSTRACT

Building embankments over soft soil in Civil Engineering poses several challenges. Soft soils have low bearing capacity and high compressibility, making them susceptible to settlement and deformation under load. Reinforcement helps in enhancing the stability and strength of embankments and reducing the risk of settlement-related issues. It also minimizes the potential for differential settlement, which can cause uneven stress on structures and lead to structural damage over time.Various materials are employed for reinforcing soil in Civil Engineering projects. Geosynthetics, including geotextiles, geogrids, and geocells, are commonly used reinforcing materials. The selection of the appropriate material depends on factors such as type of soil, project requirements, and engineering considerations. In this study geotextile, coir mat and waste plastic sheet are used as reinforcing materials. The stability of embankment reinforced with geotextile, waste plastic sheet, and coir mat in terms of number of layers and ideal depth for placement of reinforcement were analysed by the use of Plaxis 2D which is a finite element software. The performance of each materials in reinforcing the embankment over soft soil are analysed and compared in this study.

Keywords :- Building embankments; Finite element analysis; Material Selection

1. INTRODUCTION

The engineering challenges associated with soft soil have induced the exploration of innovative solutions to enhance stability in embankment construction. Soft soils are characterized by low shear strength and high compressibility, often leads to settlement issues and reduced stability in conventional embankment structures. In response to these challenges, reinforced embankments over soft soils have emerged as a viable solution, leveraging the benefits of geotechnical reinforcement materials.

Geotextiles as a reliable reinforcement option plays a pivotal role in enhancing soil characteristics, offering functions such as separation, filtration, stabilization, water conservation, and drainage. Geotextiles are typically fabricated from polymers such as polyester or polypropylene, and they come in various types, including woven and non-woven variants. Woven geotextiles consist of interlocking fabric strands, providing reinforcement precisely where it is needed. Woven geotextiles exhibit robustness and can withstand considerable thickness, rendering them suitable for tasks requiring separation and reinforcement. The use of coir mat, a natural biocomposite derived from coconut fibers, is becoming more and more popular in the field of geotechnical engineering. This research explores the potential of coir mat as a reinforcing element for embankments. Coir mat, with its inherent tensile strength and frictional properties, offers an eco-friendly alternative for enhancing the stability of embankments. One of the emerging approach for innovative and cost-effective methods for embankment reinforcement involves the utilization of waste plastic sheet as a reinforcing material. Waste plastic sheets, offer a potential solution by transforming plastic waste into plastic sheets. The inherent strength and flexibility of waste plastic sheet, when appropriately integrated into embankments, could provide a method to enhance stability of embankment. This study specifically focuses on the performance of woven geotextiles, coir mat, and waste plastic sheet as reinforcement material in embankment design, employing PLAXIS 2D for finite element analysis.

Many researchers studied the behaviour of reinforced embankments to evaluate the effect of various parameters. Siavoshnia et al. (2010) revealed that use of geotextile between bed and foundation can decrease displacements. and reported that optimum place for geotextile layer is between bed and embankment. Kasim et al. (2013) aims to determine best spacing of geotextile on embankments constructed on soft ground and reported that the best spacing of geotextile is less than 1m from the top. To determine the effectiveness of coir fiber and coir geotextile mats under the static and dynamic loading condition Harinder et al. (2022) conducted experiments and concluded that the coir geotextile mats is more effective in reducing settlement, permanent deformation/rut and it can also improved the performance of the roads with a lower cost of maintenance.

Boobalan et al. (2023) focuses on stabilization of the soil, improvement of the shear strength, and enhancement of the bearing capacity by employing waste plastic sheet at different depths (H, H/2 and H/3) and reported that the plastic sheet placed at the depth of H/2 within the soil sample exhibited superior bearing capacity properties. Lakshmi & Lakshmi (2023) has made an attempt to utilize woven Geotextiles and non-woven Geotextiles as reinforcement within soil to enhance the strength of subgrade soil and revealed that the ideal depth of location of woven and non woven geotextile is H/5 and 3H/ 5 from the top, for coarse-grained soil with high fines and low fines content respectively. The use of glass fibers as discrete random reinforcement in expansive subgrade soil to improve its strength for pavement application is investigated by Rabab et al. (2021) . Their test results showed that the inclusion of glass fibers in subgrade soil significantly increases the strength value and decreases the free swell values. They also reported that a significant decrease in pavement thickness can be achieved by the inclusion of glass fibers in subgrade stabilization. Cuelho and Perkins (2017) aimed to evaluate the performance of various geosynthetic reinforcement products in stabilizing weak subgrades for transportation applications. Through a series of controlled laboratory tests and regression analyses, they found that junction stiffness was a key indicator of performance under the given conditions. This study aims to analysis stability of an embankment reinforced with geotextiles, coir mat and waste plastic sheet by varying the geometric parameters like slope of the embankment, depth of placement and nmber of layers of reinforcing materials.

2. EMBANKMENT MODELLING AND ANALYSIS

The embankment model (Fig 1) was developed using the software Plaxis 2D. A 3 m embankments was modelled and analysed in this study. The fill and the entire soil material were modeled as Mohr Coulomb.Table 1 summarizes soil properties used in the PLAXIS modeling. A surcharge of 8.34 kN/m has been used for modelling the traffic load. Fine mesh is generated. Fig 1 shows the finite element models developed in Plaxis 2D. The tensile strength of geotextiles, coir mat and waste plastic sheet are taken as 1000 kN/m, 16.5 kN/m and 18200 kN/m respectively.

Table 1 Soil Parameters

Material	γ_{unsat} (kN/m³)	γ_{sat} (kN/m³)	E(kN/m)	c (kN/m²)	Φ (°)	Ψ (°)
Fill	18	19	50000	1	33	3
Clay1	16	17.5	2000	33	1	0
Clay2	16	17.5	2000	12	1	0
Clay3	16	17.5	2000	47	1	0
Clay4	16	17.5	2000	118	1	0
Clay5	16	17.5	2000	163	1	0

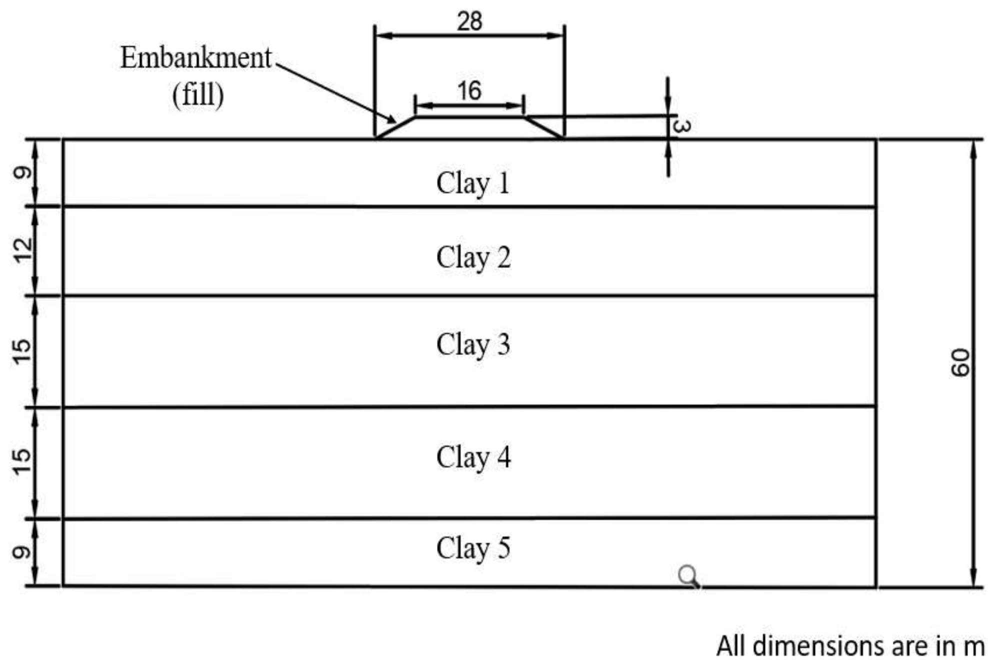

Fig 1 Geometry Model

In this study slope of the embankment, depth of placement and number of layers of reinforcing materials were varied and the stability of the embankment was analysed. Inorder to determine the effect of slope on the stability of un reinforced embankment, three different slopes 1:2, 1:1.5, 1:1 were analysed and stability was studied. To determine the ideal location for placing reinforcing materials (geotextiles, coir mat, waste plastic sheet), embankment stability was analysed with reinforcing materials were placed at depths H/3, 2H/3, and H distance from the top of the embankment where, H is the height of the embankment (Fig 2). To find the effect of multiple layer geotextiles on embankment stability, analysis were carried out on embankments with 1 layer, 2 layer, and 3 layer of geotextiles. The analysis results are discussed below.

3. RESULT AND DISCUSSION

Design of geotextile reinforced embankment is performed by determining the factor of safety. Generally, a value of 1.5 for the factor of safety with respect to strength is acceptable for the design of a stable slope. Iniyially the stability of road embankment without any reinforcement was analyzed for different slopes. Table 2 shows the results of the analysis. From the table, it is clear that, decreasing the angle of slope of embankment decreases horizontal movement of embankment. The factor of safety (FOS) serves as a critical indicator of embankment stability. A value exceeding 1.5 signifies a stable slope, whereas a value below 1.5 suggests an unstable condition. The embankment with the slope 1:2 is stable having a factor of safety of 1.68. The embankment with the slope 1:1.5 is stable having a factor of safety of 1.30. The embankment with the slope 1:1 is unstable having a factor of safety of 0.90. Hence, in this study considering the limited availability of land for the road construction, the model with 1:2 embankment slope was selected. It offers a steeper inclination, potentially reducing land required or material requirements, and its FOS can further be increased by providing reinforcements.

Table 2 Result of slope stability analysis

Slope of embankment	Factor of safety (FOS)	Horizontal displacement (m)	Vertical displacement (m)
1:2	1.682	0.01639	0.07818
1:1.5	1.286	0.03430	0.1013
1:1	0.905	0.06282	0.1413

Table 3 shows the factor of safety and horizontal displacement obtained from Plaxis 2D by placing the three reinforcing materials at different depths of the embankment. From the table it is evident that for any reinforcing material, the ideal location is between the base soil and the embankment as the factor of safety is high and displacement is considerably low. While placing the geotextile in between the base soil and embankment, there produce a much better factor of safety of 1.622 and a minimal displacement of 1.939 cm, for coir mat the factor of safety of 1.612 and a minimal displacement of 1.940 cm and for waste plastic sheet it is 1.683 and 1.938 repectively. It is evident from the result that the ideal location for placing the reinforcement material is between the base soil and the embankment as the factor of safety is high and displacement is considerably low. Of the three reinforcing materials used aste plastic sheets shows the better result. It may be due the better tensile strength of plastic sheet.

Table 3 Results of analysis for ideal location of reinforcing materials

Reinforcing material	Depthof placing Reinforcing material	Factor of Safety (FOS)	Horizontal Displacement (m)
Geotextiles	H/3	1.460	0.01948
	2H/3	1.376	0.01950
	H	1.622	0.01939
Coirmat	H/3	1.457	0.01941
	2H/3	1.385	0.01945
	H	1.612	0.01940
Waste plastic sheet	H/3	1.454	0.01949
	2H/3	1.381	0.01950
	H	1.683	0.01938

To find the effect of multiple layer geotextiles on embankment stability, analysis were carried out on embankments with 1 layer, 2 layer, and 3 layer of geotextiles. For the analysis. the tensile strength of geotextiles assigned was 1000 kN/m and slope of the embankment 1:2 was used.

The layer of geotextiles was placed in between base soil and embankment, in one layer case. The geotextiles was then splaced in two layer. One layer of geotextiles was placed in between base soil and embankment and the other layer is placed at a depth 2H/3 from top of the embankment. To determine the effect of 3 layer of geotextiles, they are then placed at three different depths in the embankment, one at a distance of H/3, another at a disctance of 2H/3 and the third layer at H distance from the top. Table 4 shows the factor of safety and horizontal displacement obtained from Plaxis 2D by placing multilayers of geotextiles at different depths of the embankment. From the table it is evident that as the number of layers of geotextiles increases, the stability also increases. The factor of safety reaches a maximum value of 1.747, while the horizontal displacement is minimized to 1.934 cm, by using three layers of geotextile with a spacing of 1m. In order to find the effect of multiple layer waste plastic sheet on embankment stability, analysis were carried out on embankments with 1 layer, 2 layer, and 3 layer of waste plastic sheet. For the analysis the tensile strength of waste plastic sheet assigned was 18200 kN/m and slope of the embankment 1:2 was used. The waste plastic sheet was placed in one layer, two layers and in 3 layers as in the case of geotextile explained earlier and the same was repeated for coirmat. Table 5 shows the factor of safety and horizontal displacement obtained from Plaxis 2D by placing multilayers of waste plastic sheet and coirmat at different depths of the embankment. The result of applying multilayer of waste plastic sheet on embankment shows that as the number of layers of waste plastic sheet increases, the stability also increases. When three layers of plastic sheet with a spacing of 1m is used the factorof safety reaches a maximum value of 2.128, while the horizontal displacement is minimized to 1.932 cm.

Table 4 Results of analysis for the effect of no. of layers of reinforcing materials

Reinforcing material	No. of layers	Factor of Safety (FOS)	Horizontal Displacement (m)
Geotextiles	1	1.622	0.01939
	2	1.685	0.01936
	3	1.747	0.01934
Coirmat	1	1.457	0.01939
	2	1.597	0.01936
	3	1.660	0.01932
Waste plastic sheet	1	1.683	0.01938
	2	1.686	0.01933
	3	2.128	0.01932

4. CONCLUSIONS

The primary objectives of this work was to identify the most suitable reinforcement material for an embankment constructed on soft soil, where the reinforcing materials used were geotextiles, coir mat and waste plastic sheet. This assessment involved identifying best slope for un reinforced embankment, ideal depth for placing these reinforcing materials and suitability of using multilayers of reinforcing materials.

The results revealed that the best slope for n reinforced embankment is 1:2 with a factor of safety of 1.628. The study demonstrated that all three materials (geotextile, coir mat, and waste plasticsheets) improved embankment stability even when employed in a single layer. Three layers of waste plastic sheets exhibited the highest factor of safety (2.128) and the lowest horizontal displacement (1.932 cm) among the evaluated options. However, the analysis revealed that waste plastic sheets offered the most significant enhancement in factor of safety and reduction in horizontal displacement when implemented in a three-layer configuration.

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