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IMPROVING FLEXIBLE PAVEMENT PERFORMANCE THROUGH THE APPLICATION OF GEOTEXTILES

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ABSTRACT

The construction of highway pavements on soft soils faces several challenges that can impact their performance and longevity. Such as it may result in consolidation, settlement, frost, heave, moisture susceptibility, lateral spreading, increased rutting and deformation etc. Typically, various technical techniques are used to either replace or stabilize the weak subgrade soil, or it is reinforced with various natural and geosynthetic fiber types. The goal of the current study was to determine if Typar SF-37, Typar SF-56, Needle Punched, and Fiber Glass Geogrid Composite geotextiles could be applicable in any given situation for the improvement of flexible pavement performance on relative strength and support capability of soil as a function of CBR-value and resistance to axial loading as a function of uniaxial compressive strength (UCS). Although the basic functions of these geosynthetic materials are different; however, the present research was focused on their effect on relative strength and resistance to axial loading. The objectives of the present study were to identify the appropriate position of the placement of geosynthetics in the subgrade, relative improvement in the subgrade performance. According to the test results, adding geosynthetics at 0.2H (the depth of the sample obtained from the top) and 0.5H (the depth of the specimen from the top) correspondingly significantly increased the CBR and UCS values. The Geosynthetics TYPAR SF-37 and Fiber Glass Geogrid Composite Geotextiles have shown better results. From the experimental results it may be concluded that the relative strength and support capability as a function of the CBR value of weak subgrade soil was improved from 1.5 to 2.0 times by reinforcing the clayey soil with geosynthetics and a significant increase in unconfined compressive strength was also noted.

Keywords: Geosynthetics, CBR, Unconfined compressive strength, Lifecycle Cost analysis.

1. INTRODUCTION

The construction of highway pavements on soft soils faces several challenges that can impact their performance and longevity [1-3]. Such as it may result in consolidation, settlement, frost, heave, moisture susceptibility, lateral spreading, increased rutting and deformation etc. This may also make the road construction uneconomical [4, 5]. Geotextiles and Geogrid may play a vital role in the enhancement of flexible pavement performance by improving various engineering properties such as drainage, separation, filtration, reinforcement, confinement and life longevity. These reinforcing elements have been in use in many countries since decades [6] and there has been continuously increasing trend in the use of geosynthetic materials for the sustainable development of civil engineering infrastructures. Such as Nagrale, Sawant [7], Iliescu and Ratiu [8] and many others used geogrid reinforcement to improve the CBR values of subgrade soil from 2.9 to 9.4 and 4.15 to 6.83 percent respectively. In general, the synthetic geotextiles have been successfully applied as subgrade reinforcement to increase the load-carrying capacity of the reinforced soil subgrade system and thereby reducing the overall thickness of the road pavement [9, 10].In terms of placement position of geosynthetics in the pavement system variety of recommendations can be found in the literature [11-13]. In addition to preventing intermixing, the GT separation layer among the soft subgrade and gravel layer contact raises the CBR values. [14, 15]. Subgrade soil was improved by Soil-Fabric-Aggregate (SFA) system using geotextile layers [16]. The present research exclusively emphasized to investigate the potential application of Typar SF-37 Geotextile, Typar SF-56 Geotextile, Needle Punched Geotextile and Fiber Glass Geogrid Composite Geotextile for the improvement of flexible pavement performance on relative strength and support capability of soil as a function of CBR-value and resistance to axial loading as a function of uniaxial compressive strength (UCS). Although the basic functions of these geosynthetic materials are different; however, the present research was focused on their effect on relative strength and resistance to axial loading. The objectives of the investigation were to identify the appropriate position of the placement of geosynthetics in the subgrade, relative improvement in the subgrade performance.

2. MATERIALS

Clayey soil was used as the basic material for this investigation, and different geosynthetics were used to reinforce the clayey soil.

2.1 CLAYEY SOIL

The base material clayey soil was used. The image of the soil in stock was in the form of clay lumps as shown in Figure 1 for visual observations. To prepare the specimens, a mallet hammer was used to break apart the lumps of clay. The ASTM D6913-04, ASTM D1140 and ASTM D4318 specifications applied on the selected clayey soil. The properties of the base material were measured and are given in Table 1.

Figure 1.Clay lumps in the stock

Table 1. Index properties of Soil

Soil Properties	**Values**	**Soil Properties**	**Values**
Liquid Limit (%)	37.0	Sand (%)	3.0
Plastic Limit (%)	21.67	Mean Grain Size (mm)	0.0061
Plasticity Index	15.33	The coefficient of Uniformity (C_u)	2.78
Specific Gravity	2.73	The coefficient of Curvature (C_c)	150.32
Clay (%)	73.0	OMC (%)	10.25
Silt (%)	24.0	MDD (lb./ft^3)	122.3

2.2 Geosynthetics

Potential uses of Fiber Glass Geogrid Composite Geotextile, Needle Punched Geotextile, Typar SF-37, and Typar SF-56 Geotextile in the context of improving flexible pavement are examined in this study.

2.2.1 Typar SF-37 Geotextile

Typar SF-37 Geotextile can work as a separator and filter. Placed between subgrade soil and pavement layers, Typar SF-37 helps prevent the mixing of different soil layers, thus preventing the loss of bearing capacity due to intermixing. It serves as a filter to keep the base course's intended gradation intact by preventing tiny particles from the subgrade from migrating into the substance.

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2.2.2 Typar SF-56 Geotextile

The Typar SF-56 Geotextile can mainly work as reinforcement. SF-56 can be used to offer reinforcement in areas where there is a likelihood of tensile stress, such as under heavy traffic loads. It reduces the chance of rutting and deformation by helping to distribute the weight across a larger region.

2.2.3 Needle Punched Geotextile

The fundamental purpose of needle-punched geotextile is to offer drainage provision. Needle-punched geotextiles can be employed for their drainage properties soil. Improved drainage helps in maintaining the stability of the pavement structure.

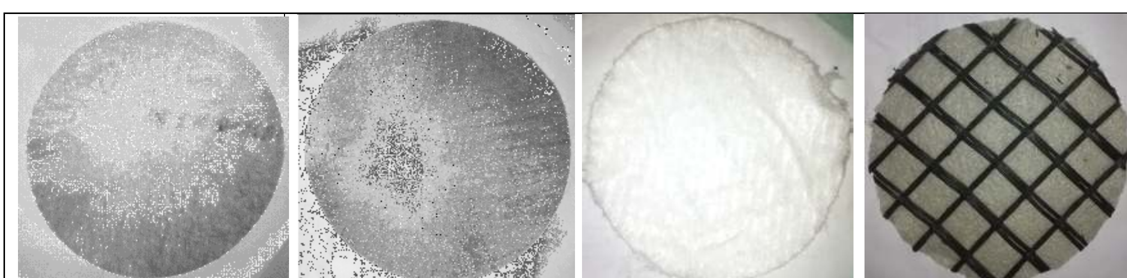
2.2.4 Fiber Glass Geogrid Composite Geotextile

Fiberglass provides reinforcement. The Fiberglass Geogrid component in the composite enhances the tensile strength of the geotextile. This reinforcement is beneficial in preventing the development of cracks and improving the overall structural integrity of the pavement.

Table 2 lists the specific engineering attributes and features of geosynthetics. Figure 2 displays the geosynthetics' visual perspective.

Table 2. Characteristics of several geosynthetic varieties

S. No.	**Geosynthetics**	**Weight/ Area**	**Tensile Strength**	**Grab strength**	**Puncture CBR**	**Tear strength**
	Units	g/m^2	kN/m	N	N	N
	Standards	EN ISO 9864	ASTM D4595	ASTM D4632	EN ISO 12236	ASTM D4533
1	Typar SF-37 Geotextile	125	8.5	725	1200	320
2	Typar SF-56 Geotextile	190	13.1	1100	1850	460
3	Needle Punched Geotextile	140	10.1	1100	1720	500
4	Fiberglass Geogrid	210	18	1500	1800	600



TYPAR SF-37	TYPAR SF-56	Needle punched	Fiberglass Geogrid Composite

Figure 2. Types of Geotextile used in this study

3. METHODOLOGY

The methodology adopted in this study for achieving the targeted parameters of the soil was CBR and Unconfined compression strength tests (UCS).

3.1 UNSOAKED CBR TESTS

A Series of unsoaked CBR tests were done on clayey soil sample without geosynthetics and with geosynthetic as per the ASTM D1557 and ASTM D1883-16. The samples with geosynthetics were prepared and compacted by placing the geosynthetics in different layers shown in Table 3. The Figure 3 provides details and a schematic depiction of the CBR mold preparation and layering.

Table 3. Layer arrangement within the mold

S. No.	Layers/Level	Height (%)
1	1st Level	0.2H
2	2nd level	0.4H
3	3rd level	0.6H
4	4th level	0.8H

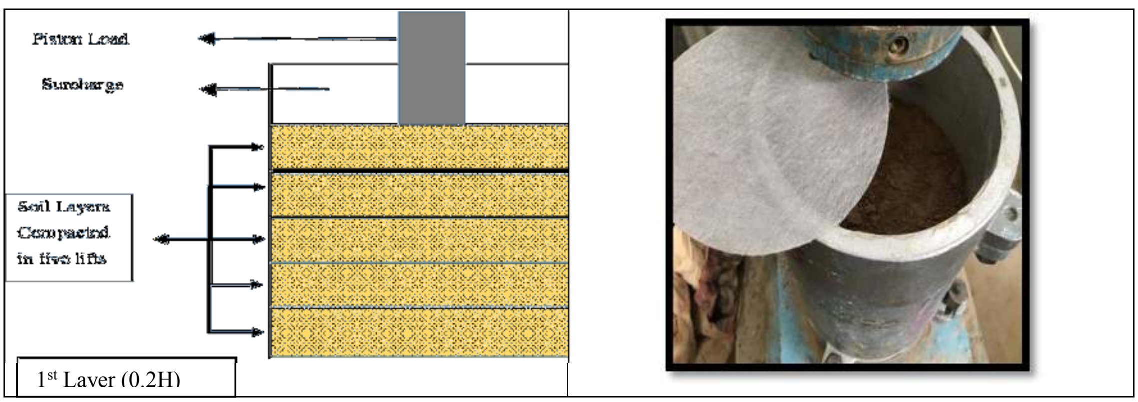


Figure 3. Placing geosynthetics sample in the mould

3.2 Unconfined Compression Strength (UCS) tests

A series of UCS were carried out on cylindrical specimens prepared in a cylindrical mould compacted at its MDD and OMC in five layers as per ASTM D2166 standards. The compacted specimens of reinforced and unreinforced clayey soils with different types of geosynthetics were placed. The stress-strain readings were recorded through dial gauges and loading of the sample continued up until failure as it schematically shown in figure 4.

Figure 4. Reinforced clayey soil sample for UCS test with 1st layer of geosynthetics at 0.2H

4. RESULTS AND DISCUSSIONS

4.1 EFFECT OF GEOSYNTHETICS ON CBR VALUES

The results showed that the presence of any of the selected four geosynthetics has shown satisfactory performance in terms of CBR values and improvement in the load-bearing capacity as shown in table 4. The CBR values were improved by geosynthetics at different ratios due to variations in its production quality as shown in figure 5.

Table 4. Overall improvement in CBR values

S. No.	Geosynthetics	CBR (%)	Improvement ratio
1	Clayey soil (without Geotextile)	8.3	1.00
2	Typar SF65	10.18	1.25
3	Needle Punched Geotextile	10.94	1.32
4	Fiber Glass Geogrid Composite Geotextile	12.45	1.60
5	Typar SF37	13.58	1.70

The CBR values of the four geosynthetics varied depending on where they were applied in the CBR specimens. The CBR values have been enhanced by geosynthetics, and the higher CBR value increase was examined at 0.2H depths, with the effect diminishing towards the specimen's bottom. In comparison to the other two forms of geosynthetics, Typar SF37 and Fiber Glass Geogrid composite geotextiles have demonstrated superior performance in terms of CBR values and load-bearing capacity (stresses).

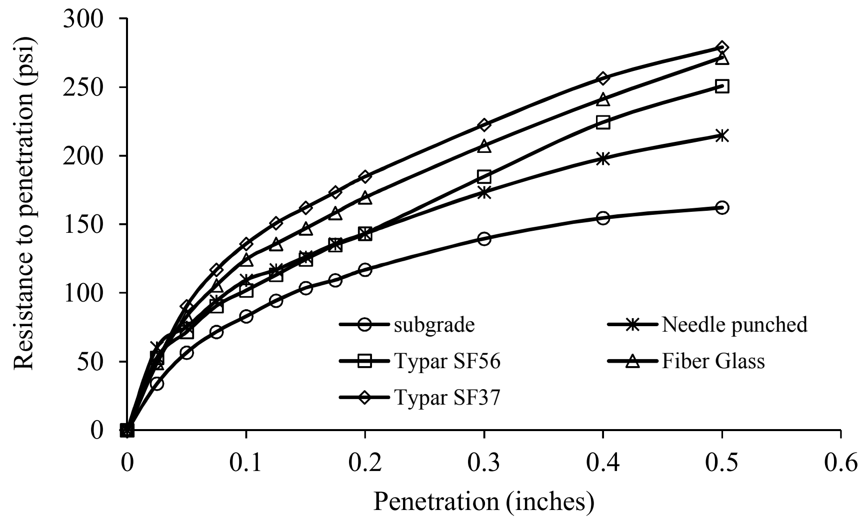


Figure 5. Geosynthetics performance curve with respect to penetrations and stresses

4.2 The effect on UCS values

The overall performance of all four geosynthetics can be investigated through given analyzed data and curves in the previous section and it can easily be observed that the selected four geosynthetics have shown satisfactory performance in terms of UCS values and improvement in stress-strain are shown in table 5.

Table 5. Overall improvement in UCS qu (kPa) values

S. No.	Geosynthetics	UCS q_u (kPa)	Axial strain (%)
1	Clay (No Geotextile)	414	5.06
2	Typar SF37	471	4.81
3	Typar SF65	463	4.81
4	Fibre Glass Geogrid Composite Geotextile	490	4.55
5	Needle Punched Geotextile	455	4.81

Different UCS values were obtained by applying each of the four geosynthetics in different places within the UCS sample. The UCS values have been enhanced by geosynthetics, and the effect has diminished toward the top and bottom of the specimen. The higher increment in UCS values in terms of stress-strain was examined at 0.5H depths. Fiber Glass Geogrid and Typar SF37 composite geotextiles have outperformed the other two forms of geosynthetics in terms of stress and strain values. Their combined performances and stress-strain curves are given in Figure 6.

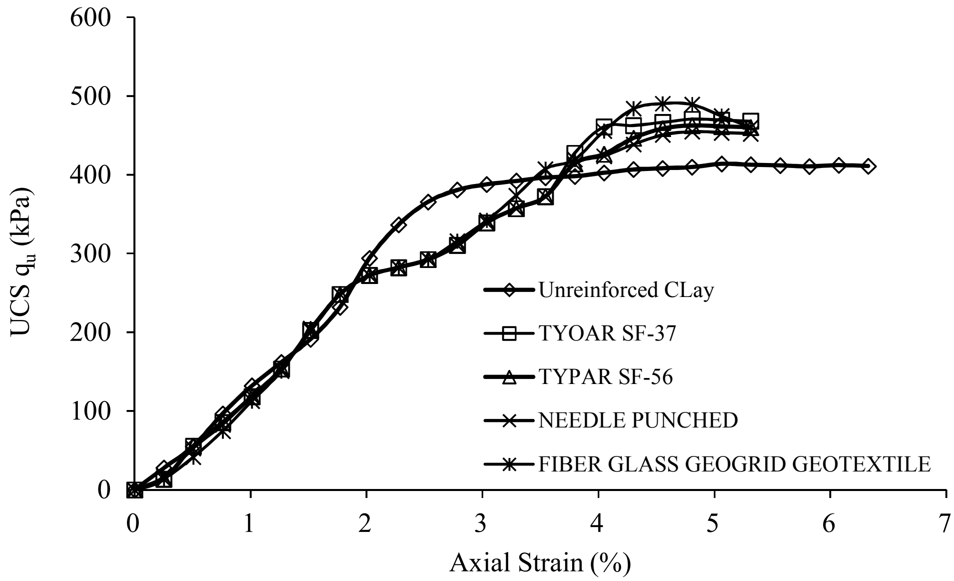


Figure 6. The Comparative curve of all types of geosynthetics in terms of stress-strain.

5. CONCLUSIONS

Following a thorough review of the experimental data, the following findings were reached:

1. From the results it may be concluded that at 0.2H from the top the CBR value would be the highest. Higher the depth of placement lower would be the effect on the CBR-value. On the other and the UCS-value was found to be highest while placing the geosynthetics in the middle (0.5H) range of the layer. Placing geosynthetic above or below the middle resulted to a gradual decrease in its performance against axial loading.
2. The CBR-value increased from 1.5 to 2.0 times as compared to unreinforced soil.
3. The relative improvement in the soil strength through Typar SF-37 and Fiber Glass Geogrid composite geotextile found to be better than other types of geosynthetics.
4. The placement of different type of geosynthetics in different layers is important to study because it may not give the desired results when not placed at the exact location.

REFERENCES

1. Brown, S.F. *Achievements and challenges in asphalt pavement engineering*. in *Proc. of 8th Int. Conf. on Asphalt Pavements, Seattle*. 1997.
2. Kamal, I. and Y. Bas, *Materials and technologies in road pavements-an overview.* Materials Today: Proceedings, 2021. **42**: p. 2660-2667.
3. Thoke, A.E. and P.L. Naktode, *A Review About Pavements: Soil Type, Challenges and Solution.*

International Research Journal of Engineering and Technology (IRJET), 2021. **08**(07): p. 3751-3756.

4. Nagrale, P., P. Sawant, and S. Pusadkar. *Laboratory investigation of reinforced sub grade soils*. in *Proceedings of the Indian Geotechnical Conference, Mumbai, India*. 2010. IIT Bombay.
5. Singh, P. and K. Gill, *CBR improvement of clayey soil with geo-grid reinforcement.* International Journal of Emerging Technology Advanced Engineering, 2012. **2**(6): p. 315-318.
6. Saran, S., *Reinforced soil and its engineering applications*. 2010: IK International Pvt Ltd.
7. Nagrale, P., P. Sawant, and S. Pusadkar. *Laboratory investigation of reinforced subgrade soils*. in *Proceedings of the Indian Geotechnical Conference, Mumbai, India*. 2010.
8. Iliescu, M. and I. Ratiu, *Soft soil geogrid reinforcement impact on bearing capacity values.* Acta Technica Napocensis: Civil Engineering & Architecture, 2012. **55**(3): p. 286-290.
9. Khan, A. and M. Rahman. *Road subgrade reinforcement using jute geotextiles*. in *Proceedings of Bangladesh Geotechnical Conference*. 2009.
10. Babu, G.S. and S.K. Chouksey, *Stress–strain response of plastic waste mixed soil.* Waste Management, 2011. **31**(3): p. 481-488.
11. Zornberg, J.G. *Advances in the use of geosynthetics in pavement design*. in *Second National Conference on Geosynthetics*. 2011. India Institute of Technology Madras.
12. Perkins, S., *Mechanical response of geosynthetic-reinforced flexible pavements.* Geosynthetics international, 1999. **6**(5): p. 347-382.
13. Perkins, S., et al., *Geosynthetic reinforcement for pavement systems: US perspectives*, in *International Perspectives on Soil Reinforcement Applications*. 2005. p. 1-13.

14. Chakravarthi, V. and B. Jyotshna, *Efficacy of overlying coarse aggregate and geosynthetic separator on CBR value for soft subgrade of varying plasticity-a lab study*. International Journal of Research in Engineering Technology, 2013. **2**(12): p. 749-755.

15. Dembicki, E. and J. Alenowicz, *Influence of geotextile on bearing capacity of two-layer subsoil.* Construction Building Materials, 1990. **4**(1): p. 49-52.

16. Abduljauwad, S.N., et al., *Influence of geotextiles on performance of saline sebkha soils.* Journal of geotechnical engineering, 1994. **120**(11): p. 1939-1960.