Laboratory Evaluation of Interaction Between Geotextile Reinforcement and Cement Modified Murrum Soil Using Unconfined Compressive Strength Tests

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Abstract. The term 'primary construction material' refers to soil. Most of the time, it shows poor engineering qualities. In this regard, numerous researchers are conducting numerous experiments to advance novel concepts and consequently recommend new approaches to enhance soil qualities. Many studies are still being conducted today to make these soils appropriate for various kinds of construction projects. Mechanically Stabilized Earth (MSE) technique has gained universal acceptance for variety of applications such as retaining walls, embankments, mountainous roads, support systems for mining roofs, pipeline supports, area foundations, landscaping and hydraulic structures. The technique in its simplest sense consists of introducing reinforcement in a free draining frictional soil as backfill material. This results in a composite material that is resistant to both static and dynamic loads owing to the formation of interfacial frictional resistive forces in between the soil and reinforcement. Several experimental research works were done on Granular soils, whereas studies on cohesive soils have seen comparatively few. In practical applications, the mechanical characteristics of reinforced clayey soil, particularly with regard to shear strength phenomena, have become of highest relevance. Studies pertaining to geotextile reinforced cohesive soils are very limited. This study compares the performance of woven and non-woven geotextile, two distinct geosynthetic reinforcement materials. The primary goal is to investigate how reinforcement interacts with murrum soil. Testing for unconfined compressive strength was done in a lab study. In order to conduct the experiment, big size cylindrical soil samples were used. The experimental investigation may provide a likely solution to the topic of how two distinct geosynthetic reinforcement techniques may be compared with regard to interaction and shear parameters.

Keywords: Mechanically Stabilized Earth · Woven Geotextile · Non–woven Geotextile · Murrum · Unconfined Compressive Strength

1 Introduction

Henry Vidal came up with the concept of 'Reinforced Soil' for the first time in 1966. In the construction sector, it is seen as a cost-effective solution. The most common and widely use generic name of the 'Reinforced Earth' is 'Mechanically Stabilized Earth'.

B. Raj et al. (Eds.): ICETE 2023, AER 223, pp. 305–313, 2023.
https://doi.org/10.2991/978-94-6463-252-1_34

Mechanically Stabilized Earth (MSE) is an instant hit with researchers and field engineers alike for temporary as well as permanent construction and well appreciated for its simple mechanism and economy in cost and construction time. Also, with the introduction of novel reinforcing materials, utilization and applications of MSE technique in the field of civil engineering have increased. Since its early stages of development, the scarcity for suitable soil as backfill materials is reported by various investigators [6]. By incorporating reinforcing materials into the direction plane of tensile strains, the performance of such soils can be greatly enhanced. Attempts have been made to use the murrum soil (marginal backfill soils which are said to be inferior in engineering properties) which is available at the work sites by adopting soil modification by adding cementitious materials, electro kinetic methods or by mechanical methods particularly pre–stressing the entire composite material. The poor drainage characteristics of murrum soils are being offset by introducing internal drainage. The drainage property can be increased by provision of geotextile. In this work, an effort is done to examine the shear strength behavior of geotextile-reinforced murrum soil without and with cement modification, and to compare these results to those of reinforced sand. The intention of cement modification is to counteract the negative effects of fines and their plasticity without damaging the murrum soil's flexibility. The fundamental mechanisms of reinforced soil have been studied by various investigators. There exists still some speculation regarding the behavior of this material under varied test conditions and materials used. The addition and mixing of carpet waste fibers with clay soils that have been added to their maximum dry density (MDD) can significantly enhance the unconfined compression strength (UCS). Testing revealed a decrease in post-peak strength loss and a switch from brittle to ductile failure behavior [5, 7]. Many soil enhancement techniques, including soil replacement, dynamic compaction, lime/cement columns, stone columns, and fiber-based soil reinforcements, have been implemented [2, 3]. Other researcher [1] conducted a series of unconfined compression tests to investigate the influence of key parameters on the behavior of geotextile-reinforced clayey soil. For this purpose, characteristics such as geotextile type (nonwoven, woven), water content, loading rate, and number of geotextile layers were examined [4]. Moreover, most of the previous investigations were carried out using sand. The possible behavioral changes with regard to plain and cement modified murrum soils in reinforced earth are studied in this paper. The shear strength behavior is studied both under uniaxial and triaxial test conditions. To evaluate the shear strength characteristics, UCS experiments with 100 mm diameter samples (big samples) were conducted. The stress-strain behavior and shear parameters for several sample combinations are shown. This experiment is conducted to examine the effect of reinforcement on the stress-strain behavior of murrum soils. The testing is intended to investigate the effect of cement modification on the shear strength parameters of unreinforced and geotextile reinforced murrum soil.

2 Materials Employed

The characteristics of the materials used in this study are discussed briefly and listed below.

Table 1. Properties of Murrum

Property		Murrum Soil
Specific Gravity (G)		2.40
Grain size distribution in percentage	Clay Silt Sand Gravel	16 24 56 04
Atterberg limits	Liquid limit (%) Plastic limit (%) Shrinkage limit (%)	36 18 15
Soil Classification (as per IS Code)		SC
Compaction properties	OMC (%) MDD (g/cc)	16.6 1.75
Shear strength parameters (CD condition)	c' (kPa) $Ø'$	51 39
Coeff. of permeability (k) in cm/sec		2.90 × 10-6

2.1 Murrum

In this work, murrum soil is classified as Clayey Sand (SC) and was used to replicate a marginal soil. Table 1 displays the characteristics of murrum.

2.2 Reinforcing Material

Specifications and material properties of the two types of geosynthetic reinforcing materials employed in this investigation are provided in Table 2.

Figure 1 shows the geosynthetic reinforcements used in the study were cut into circular of diameter 9.5 with lateral area spreading over 280 cm^2.

Table 2. Material Properties of Geosynthetic Reinforcing Materials

Type	Description
Fibertex G– 100, Non Woven Geotextile	Material: Polypropylene Thickness: 0.75 mm under 2 kPa Grab Tensile Strength: 4 kN/m
PD 381, Woven Geotextile	Material: Polypropylene Thickness: 0.50 mm under 2 kPa Grab Tensile Strength: 12 kN/m

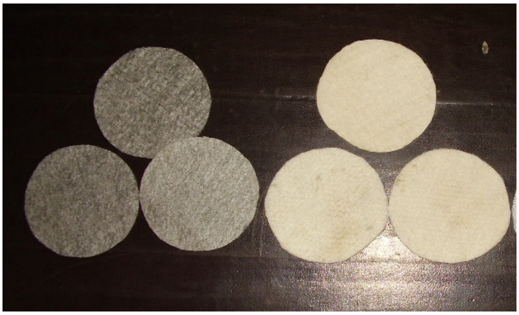

Fig. 1. Fibertex G – 100 and PD 381 geotextile cut into circular discs used for the study

Fig. 2. Unconfined compressive strength test set up

3 Experimental Procedure and Test Setup

In the present UCS tests, the specimen is subjected to an axial compression without any confining pressure. During this test, the length of the specimen decreases with subsequent increase in its lateral dimension. The unconfined compressive strength test apparatus is shown in Fig. 2. The pre calculated quantity soil is compacted into a mould of 100 mm diameter and 200 mm height (Fig. 3) to the desired maximum dry density at optimum moisture content. The specimen is placed on the base plate of compression testing machine. The upper plate is adjusted to make just in contact with the specimen. The initial readings on dial gauge and proving ring are set to zero. The compression load is applied at the axial strain rate of 0.5 to 2% per minute.

In this test, plain samples and samples embedded with 2 layers of either non-woven or woven geotextile as reinforcement on each testing were used. Cement content of 2% was used to modify the murrum soil making it into non–plastic. The same type of tests was repeated by admixing 5% cement content.

4 Testing Methodology

The predetermined weight of murrum soil was compacted in three layers with a 2 kg hand rammer forming into the cylindrical soil specimens (Fig. 4). Care is taken to obtain of uniform density for each soil sample. During the compaction stage the reinforcement of one type was placed on the leveled surface of soil at an interval of H/3, where H being the height of the cylindrical specimen.

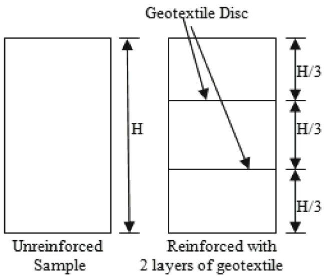

Fig. 3. Geotextile arrangements for UCS tests

Fig. 4. Prepared cylindrical soil specimens of desired density for UCS testing.

5 Results and Discussion

Experimentation was planned to investigate the effect of reinforcement on murrum soil embedded with two types of geosynthetic reinforcing materials such as non–woven geotextile and woven geotextile. At each time of testing single type of geotextile was used. These geotextile reinforcing materials are intended to improve the strength of murrum soil. The graphical representative curve between compressive stress as ordinate versus axial strain as abscissa is plotted to determine unconfined compressive strength. The results of UCS testing are presented in Table 3.

Table 3. Compressive strength of murrum soil

Soil Combination	Unconfined Compressive Strength (kPa)	
	Fibertex G - 100	PD 381
Murrum soil	58	58
Murrum soil + 2 Layers	121	140
Murrum soil + 2% cement	206	238
Murrum soil + 5% cement	302	314
Murrum soil + 2% cement + 2 Layers	296	325
Murrum soil + 5% cement + 2 Layers	322	341

During the UCS testing, plain murrum soil samples exhibited the shear failure (Figs. 5 and 6). Compared to unreinforced soil, it has a lower breaking strength and higher consistent performance. At the end of the deformation, there is a progressive failure. The angle between the failure surface and the horizontal surface is measured (Fig. 5). The UCS of plain murrum soil at its OMC & MDD is raised by approximately 50 to 60 percent when embedded with two layers of non–woven and woven geotextile reinforcement, respectively. The samples were failed under bulging without rupture of the reinforcement as shown in Fig. 7. About the mechanism of geotextile-reinforced murrum soil, the interfacial frictional force between geotextile-soil particles in horizontal plane influences the soil strength. The gain in strength could be attributed to the added confinement due to the interfacial friction resistance between the soil and geotextile. This induced frictional resistance could provide the restriction for soil particles for lateral movement during increase in vertical loading.

It can be observed from testing (Fig. 8) that the introduction of 2% cement to plain soil at OMC imparted a strength gain of about 4 to 5 times. Splitting failure pattern is observed in case of cement modified murrum soil. This type of failure could be due to conversion of murrum soil (clayey sand) in to non–plastic upon cement modification. Upon reinforcing by 2 layers of geotextile in case of cement modified soil samples (Fig. 9), the strength is further increased approximately 6 to 7 times with respect to Fibertex G–100 and PD 381. In case of 5% cement modified murrum soil; the strength is increased by 6 times compared to plain murrum soil (Table 3).

Upon reinforcing with 2 layers of geotextile of this 5% cement modified murrum soil, the strength is further increased again only by 6 times. It is to be noted that at

Fig. 5. Shear failure pattern in case of failed samples of plain murrum soil

Fig. 6. Shear failure pattern in case of failed samples of plain murrum soil

Fig. 7. Bulging failure pattern of reinforced plain murrum soil sample

Fig. 8. Splitting failure in case of 2% cement modified murrum sample

higher cement contents, the degree of strength contribution by geotextile reinforcement is insignificant compared to that at lower cement content. This testing is repeated twice to confirm this finding and it is understood that at higher cement content with flexible geotextile reinforcement, the material could not gain the proportionate strength due to the cracking of rigid/semi-rigid soil-cement much before the strain required to mobilize the strength of geotextile. Hence, under field conditions, it is to be kept in mind that the flexibility of reinforced soil is to be maintained while attempts are made to overcome/offset the ill–effects of fines and their plasticity. Under this set of testing, all the samples have shown distinct shear failure with fabric rupture as shown in Figs. 10 and 11. Since, Fibertex G – 100 has low grab tensile strength, the rupture of the fabric has been observed.

Murrum soil reinforced with geotextile alone could not derive significant benefit under uniaxial compression. Upon 2% cement modification, the soil has become more workable and has shown distinct shear failure under unconfined condition indicating its reducing susceptibility. A multi–fold improvement in strength gain is observed for reinforced cement modified murrum soil compared to its plain soil condition indicating that, if the ill–effects of fines and plasticity of murrum soil are overcome by cement modification. The sudden post peak failure of murrum soil is modified to progressive failure when they are reinforced with geotextile. Bulging failure is observed in reinforced

Fig. 9. Failed murrum soil samples with 2 layers of geotextile (Fibertex G–100 and PD 381)

Fig. 10. Rupture of geotextile layer in case of 5% cement modified reinforced samples

Fig. 11. Rupture of geotextile discs in case of soil samples modified with 5% cement content

plain murrum soil where as upon cement modification, initial surface cracking followed by distinct internal shear failure is observed without affecting the flexibility of the soil particles. At higher cement content of about 5%, the benefit of geotextile reinforcement is insignificant compared to that at 2% cement content, which indicates that the cement content used should not convert the soil into rigid material, in which the flexible geotextile reinforcement is placed.

6 Conclusion

The objective of this laboratory work was to examine the effect of non–woven & woven geosynthetic reinforcing materials on the enhancement of the strength of reinforced murrum soil. Modification by using 2% cement could convert the plastic natured murrum soil into non–plastic. The plasticity exhibited by finer soil particles present in the murrum soil has been nullified by cement modification. The cement modification is adopted in this testing just to make the plastic soil in to non–plastic, not for the purpose of induction of strength. Murrum soil reinforced with geotextile alone could not derive significant benefit under uniaxial compression. Upon 2% cement modification, the soil has become more workable and has shown distinct shear failure under unconfined condition indicating its reducing susceptibility. A multifold improvement in strength gain is observed for reinforced cement modified murrum soil compared to its plain soil condition indicating that, if the ill–effects of fines and plasticity of murrum soil are overcome by cement modification. The sudden post peak failure of murrum soil is modified to progressive failure when they are reinforced with geotextile. Bulging failure is observed in reinforced plain murrum soil where as upon cement modification, initial surface cracking followed by distinct internal shear failure is observed without affecting the flexibility of the soil particles. At higher cement content of about 5%, the benefit of geotextile reinforcement is decreased compared to that at 2% cement content, which indicates that the cement content used should not convert the soil into rigid material, in which the flexible geotextile reinforcement is placed. At a higher percentage of cement content, the strength gain is solely due to the effect of cement by making the soil sample stiffer. Due to this stiffness geotextile could not able to derive the action of generated interfacial frictional forces.

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