Study on Performance of Geotextile Reinforced soils Using Triaxial Compression Test

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Abstract. The usage of geosynthetic materials as a ground improvement technique has gained widespread approval due to its quality of construction, simplicity and time- saving parameter. This study focuses on the use of geosynthetic geotextile as a reinforcement material for increasing strength properties of soils. This paper presents results of unconsolidated- undrained triaxial compression tests for investigating the behavior and failure mechanism of geotextile reinforced soils such as clay and red soil. The influence of varying number and locations of geotextile with varying confining pressures were studied. The test results shows that shear strength and deformation resistance of reinforced soils significantly increased with the number and location of geotextile layers.

Keywords: Geotextile, Triaxial test, Reinforced soil, Shear strength.

1 Introduction

Economically and environmentally acceptable geotechnical structures are increasing demand nowadays. But construction of such structures, some limitations are faced due to the high cost and problems caused during the extraction of aggregates. If the soil is weak in shear then shallow foundation cannot be in that areas and deep foundations are adopted. The cost of construction of a deep foundation is considerably expensive, thus it is to be stabilized the weak soil. The usage of locally available cohesive soils can be a solution to this problem, but it may not have to meet the specified geotechnical requirements (Hima H et.al. 2017). In such situations, some modifications can be done to the soils, like providing reinforcements such as geotextiles, geogrid, etc. Geotextile is derived from the words geo- soil and textile- fiber. This has got various functions in aiding drainage and reducing seepage pressure. The geosynthetic reinforced soil structures have several distinct advantages on conventional retaining structures because of their ductility, high tolerance to the differential settlement without structural distress, rapid method for construction, cost-effectiveness and adaptation to different site conditions (Kuo-Hsin Yang et.al. 2015). As a result, earth structures reinforced with geosynthetics are being constructed worldwide with increased frequency even in permanent and critical applications. The effectiveness of reinforcing element embedded in the soil is governed by various factors such as tensile strength, The adherence between the reinforcement and surrounding soil and the amount of extension exhibited by reinforcing element (Nguyen, M. D et.al. 2013). For structures along with long service- life requirements, fine-grained soil is not recommended due to the low frictional resistance, which increases the required length of reinforcement, loss of adhesion under large strain.

2 Experimental program

The unconsolidated- undrained triaxial tests were conducted to evaluate the effect of woven geotextile layers on the mechanical behavior of soils. The test variables were confining pressures and number and locations of woven geotextile layers.

2.1 Materials used

Soils. Clayey soil and red soil were used for this study. The clayey soil was collected from poochinnipadam, Mukundapuram taluk of Thrissur Dist and red soil was from Thejus Engineering college campus, Kunnamkulam taluk of Thrissur Dist, Kerala. The geotechnical properties of clay and red soil are given in Table 1. The clay and red soil were classified as high plastic clay (CH) and intermediate plastic clay (CI) respectively by IS plasticity chart.

Table 1. Geotechnical properties of soils

Properties	Results	
	Clay	Red soil
Specific gravity	2.76	2.71
Gravel size particles (%)	5	0
Sand size particles (%)	12	41
Fine size particles (%)	83	59
Liquid limit (%)	52	48
Plastic limit (%)	25	22
Shrinkage limit (%)	16	18
Plasticity index (%)	27	26
Soil classification system	CH	CI
Optimum moisture content (%)	18	16
Maximum dry density (kN/m^2)	16.1	16.8
Undrained cohesion (kN/m^2)	31	26
Angle of internal friction (^{o})	17	21

Geotextile. A commercially available geotextile was used for this work of which woven geotextile is made up of polyester with multi filament yarn. It was collected from V. M Polytex private limited at Kanjikode, Palakkad district, Kerala. The mechanical properties of woven geotextile obtained from manufactures manual are shown in Table. 2. Grab tensile strength test was used to determine the tensile strength and elongation.

Table 2. Mechanical properties of woven geotextile

(V. M Polytex private limited, Kanjikode)

Properties		Values
Fabric size (m)		2.5
Tensile strength (kN/m^2)	Warp	20
	Weft	20
Elongation (%)	Warp	24
	Weft	25
Weight (kN/m^2)		17.5
Mesh (No. per m)	Warp	394
	Weft	394
Colour		Milk white

(a) Clayey soil (b) Red soil (c) Woven geotextile

Fig. 1. Materials used for the study

2.2 Specimen preparation

The collected natural clayey soil and red soil in the form of a wet condition placed in an oven for 24 hours and then crushed into dry powder form in a mortar pan. The light compaction tests were conducted to determine the optimum moisture content and maximum dry density of two samples.

To ensure the maturing period, the measured quantities of soil samples mixed at their corresponding optimum moisture content are covered in a plastic bag and is placed in a sealed desiccator for two days. The cylindrical soil specimens with 0.039m diameter and 0.078m height were prepared. The diameter of the geotextile layer was taken as 0.03m. For unreinforced soil, the sample was filled in layers and compacted by using a standard compaction approach, so as to attained the maximum dry density obtained from the compaction test. For reinforced soil, the samples were filled in several layers keeping the same density of unreinforced specimens. After compaction of each layer, the surface was scarified prior to placing of geotextile layer to ensure favorable interface bond between soil and overlying materials. This process was repeated up to the brim of split mould. Fig. 2 represents the diagram showing the location of geotextile layers and fig. 3 shows the preparation of reinforced soil specimen with one layer of geotextile. Where geotextile was placed at the center of specimen and compacted to same density obtained for unreinforced specimens.

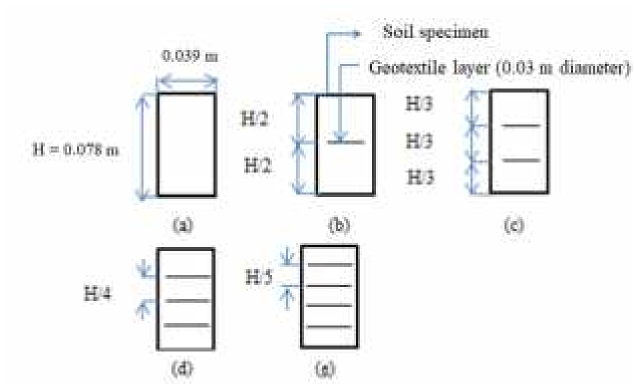

Fig. 2. Arrangement of geotextiles in reinforced soil (a) Plane soil (b) soil with one-layer geotextile (c) soil with two-layer geotextile (d) soil with three-layer geotextile (e) soil with four-layer geotextile

Fig. 3. Sample preparation with one layer of geotextile layer

2.3 Testing program

A total of 15 UU triaxial tests were performed on unreinforced and reinforced soils undergo different confining pressure (50, 100, 150 kPa) with varying numbers and locations of geotextiles (one, two, three and four layers). Tests were conducted on both clay and red soil. The specimens were as compacted conditions mounted on triaxial cell. The desired three-dimensional system was achieved by an initial application of confining pressure through water. While this confining pressure was kept constant throughout the test, axial loading was increased gradually at the rate of 1.2 mm per minute. The loading was continued until strain level of reinforced specimen reached 20 %. This strain is known as strain at failure. Finally, reproducibility and consistency of test results were examined carefully by conducting few tests on reinforced samples under initial density and water content.

3 Results and discussions

3.1 Failure type

Fig. 4 shows photos of deformed failure specimens after tests. In unreinforced samples, failure was observed as bulging failure at the center of the specimen. In reinforced samples, bulging occurred between two adjacent geotextile layers and at soil geotextile interface, necking was observed. As the number of geotextile layers increased, the bulging gets reduced. Thereby deformation become comparatively less.

(a) (b) (c) (d) (e)

Fig. 4. Failure observed after loading with and without geotextile (a) specimen before loading (b) specimen without geotextile (c) specimen with one-layer geotextile (d) specimen with two-layer geotextile (e) with three-layer geotextile

3.2 Stress strain behavior

Fig. 5 to fig. 7 represents stress strain behavior of unreinforced and reinforced clay with varying confining pressure and table 3 represents the summary of deviator stress at failure (σ_d) determined from stress strain curves. The reinforced soil specimens reached peak strength at specified confining pressure than that of unreinforced soil specimens. The deviator stress at failure increased as the number of geotextile layers up to three and confining pressure were increased. There was no considerable improvement in reinforced clay with one layer of geotextile specimen. In four layer specimen, it was comparatively smaller than three layer specimen, which is due to the decreased confining effect of soil around the geotextile layers and smaller reinforcement spacing. Axial strain at failure also increased as the number of geotextile layers and confining pressures were increased. Therefore optimum strength was obtained in three-layer geotextile specimen on both clay and red soil.

Fig. 8 to fig. 10 represents stress strain behavior of unreinforced and reinforced red soil. It was similar to that of reinforced clay except that considerable improvement in deviator stress at failure was observed in reinforced red soil with one layer of geotextile specimens compared to plane soil.

Table 3. Deviator stress at failure on both soils

Configuration		Strain at failure (%)	Deviator stress at failure (kPa)					
			Confining pressure (kPa)					
			50		100		150	
			Clay	Red soil	Clay	Red soil	Clay	Red soil
Unreinforced soil		10	96	236	217	372	238	443
Reinforced with geotextie layers	One	12	122	660	238	747	290	1206
	Two	13	524	720	590	1141	637	1398
	Three	14	635	1300	745	1667	843	2250
	Four	14	630	1291	738	1650	837	2245

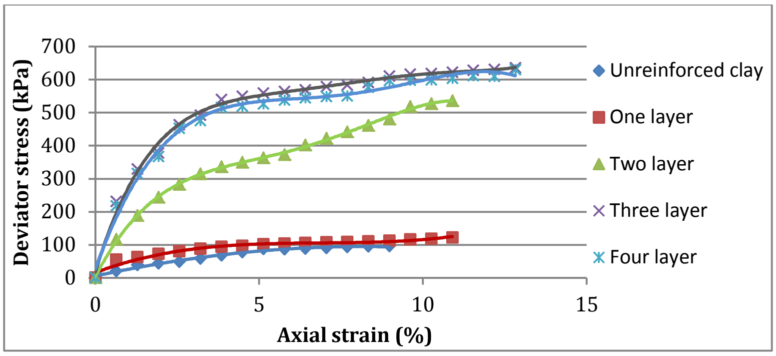

Fig. 5. Stress strain curve of clay on 50 kPa

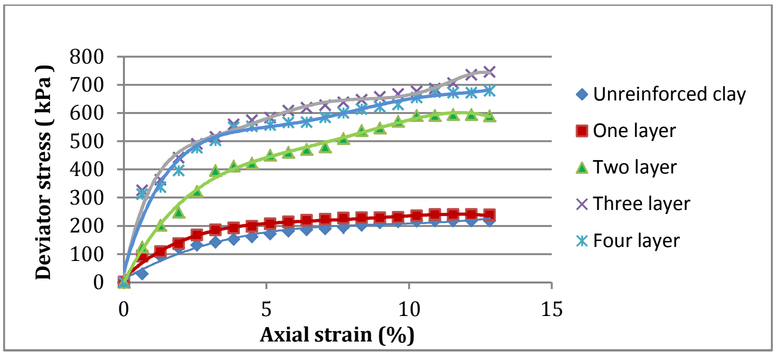

Fig. 6. Stress strain curve of clay on 100 kPa

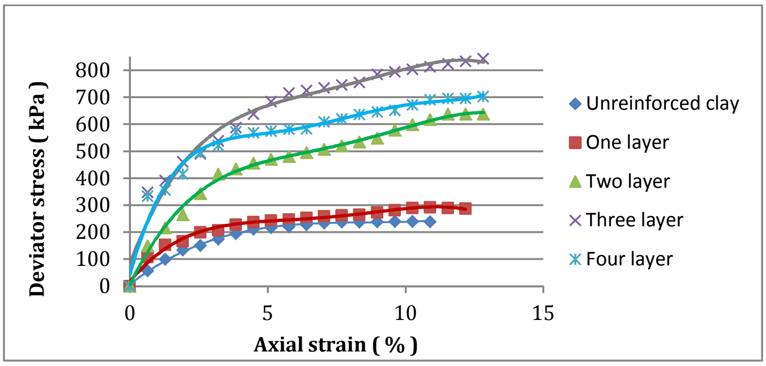

Fig. 7. Stress strain curve of clay on 150 kPa

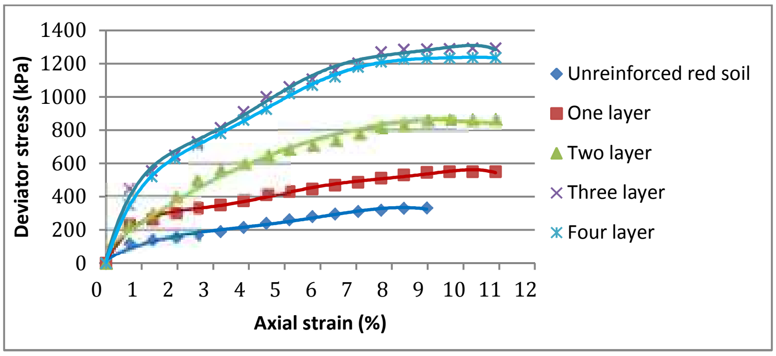

Fig. 8. Stress strain curve of red soil on 50 kPa

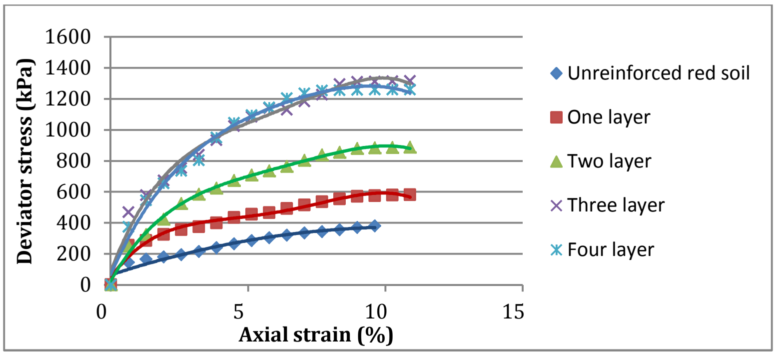

Fig. 9. Stress strain curve of red soil on 100 kPa

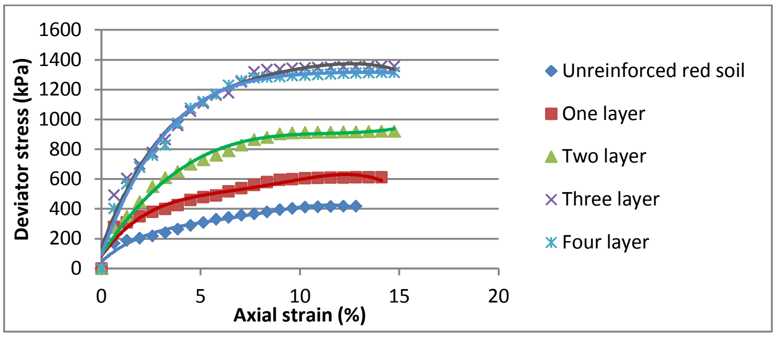

Fig. 10. Stress strain curve of red soil on 150 kPa

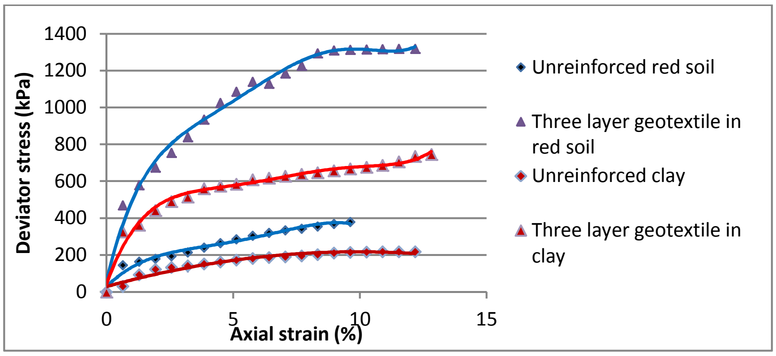

Fig. 11. Comparison of stress strain behavior of clay and red soil on 100 kPa

Fig. 11 represents the comparison of stress strain behavior of both clay and red soil at confining pressure of 100 kPa. The deviator stress was higher in red soil than that of clay and percentage of strength improvement of red soil in three layer was higher as compared to clay under the same confining pressure.

3.3 Modified failure envelope

Fig. 12 and fig. 13 presents modified failure envelopes of clay and red soil. As number of geotextile layer increased, the failure envelope of reinforced specimen shifted upward. Because of weak geotextile interaction and large reinforcement spacing, the single layer geotextile was very close to unreinforced clay. But in red soil specimens, there was a considerable improvement in single layer specimen when compared to unreinforced soil due to comparatively good soil geotextile interaction.

Table 4 presents shear parameters determined from modified failure envelopes. It was increased as the number of geotextile layers up to three. The undrained cohesion was increased because of development of pseudo cohesion on confining soil layers from geotextile layers and angle of internal friction also increased due to the increased passive resistance as the confining pressure were increased (Fabin, K et.al. 1983; Kuo-Hsin Yang et.al. 2015; Nguyen, M. D et.al. 2013). The development of pseudo cohesion was very less for small reinforcement spacing. The shear parameters of four-layer geotextile specimen were less than that of three-layer geotextile specimen.

Table 4. Shear characteristics for both clay and red soil

Parameters		Undrained cohesion (kPa)		Angle of internal friction (^{o})	
		Clay	Red soil	Clay	Red soil
Unreinforced soil		31	26	17	21
Reinforced with geotextile layers	One	38	29	21	24
	Two	47	33	29	27
	Three	58	41	33	30
	Four	55	38	30	28

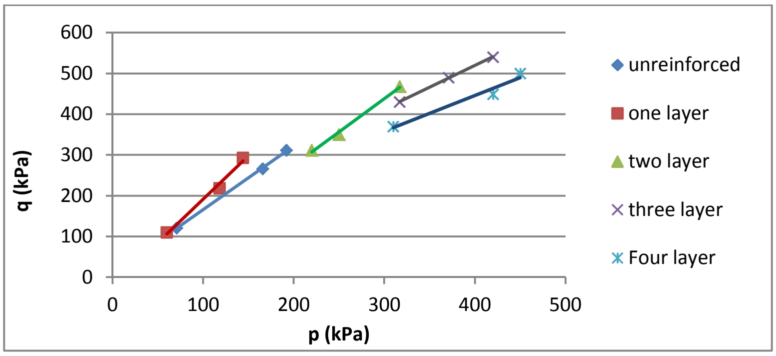

Fig. 12. Modified failure envelope of clay

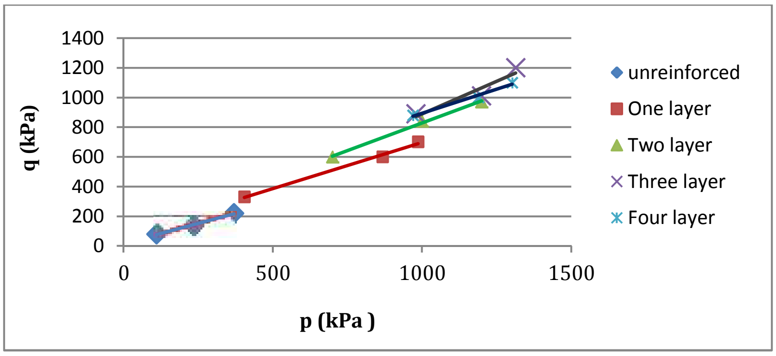

Fig. 13. Modified failure envelope of red soil

3.4 Strength improvement

Table 5 presents the strength improvement of reinforced soil samples at specified confining pressure of 50 kPa. The strength improvement was expressed as improvement factor. It was obtained by dividing deviator stress of reinforced soil specimen to that of unreinforced soil specimen.The strength was increased as the number of geotextile layers up to three. After that strength was decreased due to the weak confining effect of soil around geotextile layers. In two-layer geotextile clay specimens, the strength improvement was five times of unreinforced clay. But in the case of red soil, five times improvement was obtained in three-layer geotextile specimens

Table 5. Strength improvement for clay and red soil

Configuration		Improvement factor	
		Clay	Red soil
Reinforced soil with geotextile layers	One	1.27	2.70
	Two	5.40	3.10
	Three	6.61	5.50
	Four	6.56	5.46

4 Conclusions

A series of UU triaxial compression tests were performed to investigate the stress strain behavior and failure mechanisms of reinforced clay and red soil specimens with woven geotextiles.The main goals of this work were to evaluate the effect of woven geotextile reinforcement layers on the strength improvement of clay and red soil. The conclusions of this study can be summarized as follows.

- The reinforced soil specimens exhibit ductile behavior compared to unreinforced specimens. Reinforced red soil specimen failed same as the reinforced clay but bulging observed was less compared to clay specimens.

- The bulging of both reinforced soil samples reduced as the number of geotextile layers, thereby deformation resistance significantly increased.
- The maximum deviator stress at failure occurred in red soil than clay for the same condition.
- Both reinforced clay and red soil specimens enhanced peak strength.The peak shear strength increased as the number of geotextile layers up to three layers. In four layers, peak shear strength decreased than three layers.
- The Axial strain at failure increased as the number of geotextile layers. The axial strain at failure for unreinforced and reinforced soil was obtained as 11 % and 14 % respectively.
- The undrained cohesion and angle of internal friction were increased as the number of geotextile layers. But while testing the specimen with four layers, shear parameters decreased compared with three layers.
- The shear parameters increased because of development of psuedo cohesion and increase of passive resistance.
- When comparing both soils, the higher strength improvement was obtained in clay than red soil.
- In reinforced clay, two-layer geotextile is more preferred for geotechnical structures due to adequate strength.
- In reinforced red soil, the three-layer geotextile is preferred due to adequate strength when three layers are provided than two layers

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