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Unconfined Compressive Strength of Geotextile Sheets Reinforced Soil

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Abstract: Soil reinforcement is a good alternative for improving the performance of a weak soil. Application of geosynthetic as a soil reinforcement has gained wide popularity in the last two decades. Various studies on reinforced sand and unconfined compressive strength of clay are available in literature but only few studies have been conducted in c-φ soil. In present study, a series of experiments have been conducted in the laboratory to determine the effect of reinforcement on unconfined compressive strength of a c-φ soil. A series of unconfined compressive tests are performed on soil with inclusion of reinforcement and without reinforcement. Woven and non-woven geotextiles are used as reinforcing media and incorporated in soil sample in layers. Soil samples of 38 mm diameter and 76 mm height are used in study. The numbers of layers varied from zero to three. In case of soil without geotextiles, failure plane is observed between lower bottom and center of sample. In case of two layer woven and non- woven geotextile, the failure plane was observed above the level of geotextile. Peak strength of reinforced soil increases with a considerable amount due to inclusion of woven reinforcement compared to non-woven reinforcement. More are the number of layers of woven geotextile, more is the strength of the soil observed. Though, the effect of number of layers is negligible in case of non-woven geotextile.

Keywords: *Geotextile, Compressive strength, Reinforcement, Clayey sand, Unconfined, Layers*

1. Introduction

Construction and utilization of loose and low shear strength soils is a very challenging work for a civil and geotechnical engineers as they cannot sustain loads, and can either fail in shear or fail by excessive settlement (Lambe & Whitman, 1969[1]). Population is increasing with very high rate and favorable lands are available in limited amount so engineers have to use unfavorable land or low strength ground for construction purpose. Performance of this soil can be improved before construction work will start. A wide variety of improvement methods and techniques are listed in literature and these method comprise of hydraulic modification, physical and chemical stabilization, mechanical modification, and modification by inclusions and confinement (Raj, 2005[2]).

Selection of a particular type of ground improvement method is a bit difficult task for a geotechnical engineer as soil properties use to vary with time and loading history and various other phenomenon. The selection of a most suitable ground improvement method depends on the economical consideration, soil characteristics, durability of material involved, seepage conditions loading type, geological structure, degree of modification required, available time, availability of equipment effectiveness of technique and local availability of material. Reinforcing come under inclusion category ground improvement and reinforcing materials can be either made from either metal or geosynthetic.

Geotextiles are common reinforcing material made up of textile material and can perform other secondary function such as filtration and drainage apart from reinforcement to overcome various problem. Considering deformability of soil, geotextile are having more compatibility compared to other stiff reinforcing material (Tuna & Altun, 2012[3]). In case of nonwoven geotextiles, fibers are arranged at randomly and they form a planner structure whereas woven geotextiles are manufactured by weaving techniques and fibers are arranged into sets of two perpendicular threads. Geotextile improves the ductility of soil in addition to strength of soil and same time it decrease the loss of post peak strength of granular soil. Performance of geotextile reinforced soil depends on the properties of soil, characteristic and type of geotextiles, arrangement of geotextiles, percentage of geotextiles and loading condition (Shukla & Yin, 2006[4]).

Various new construction and design methods have been emerged in the field of ground improvement using geosynthetic and this has made possible for engineers to construct and develop. The combination of improved materials and design methods has made possible engineers to face challenges and to build structures under unfavorable and impossible site condition that would be unthinkable in the past. In case of randomly oriented fibers, the reinforcing effect is contributed by coiling of fibers around soil particles and friction whereas in case of horizontally placed geosynthetic, this effect comes from the interlocking and friction that occurs between the geosynthetic and soil (Broms, 1977[5]). Reinforcing effects in soil-geotextiles system is mostly contributed from tensile strength. Friction force develops between soil and geotextile is mainly responsible for transferring of stresses from soil to geotextile. Maximum mobilization of strength of geotextile is possible only at sufficient deformation of geotextiles at which maximum amount of tensile stress in develop in geotextiles (Latha & Murthy, 2006[6]). In the last two decades use of geotextiles as reinforcement has gained wide popularity in ground improvement work as they are easily available in market at low cost, environmentally friendly and easy in application. Credit of this development is goes to Henry Vidal for introducing modern form of reinforcement (Jones, 1985 [7]).

2. Literature Review

Performance and reliability and of reinforced soil has already been evaluated and discussed in literature. (Portelinha et al., 2012[8]; Koerner, 2000[9]; Holtz, 2001 [10]; Mirzababaei et al., 2013[11]; Fannin and Sigurdsson, 1996[12]).

Various studies have been conducted in the laboratory using unconfined compression tests, triaxial compression tests and direct shear tests and it has been found that the reinforcement of soil by discrete fibers causes an increase in the strength of soil and reduction in the post peak loss of strength. (Al Refeai, 1991[13]; Maher and Ho, 1994 [14]; Yetimoglu and Salbas, 2003[15]; Tang et al., 2007[16]; Chegenizadeh and Nikraz, 2011[17]).

Ramaswamy and Aziz (1989)[18] conducted unconfined compression tests on compacted soil samples of diameter of 100 mm and 200 mm length. All the samples were compacted at OMC of 25% and two layered reinforcement was used in testing. The tests revealed that UCS of soil was increased due to incorporation of jute geotextiles. Ghavami et al. (1999) [19] used natural fibers (coconut fibre and sisal) for reinforcing the soil and found that the natural fibers enhanced the ductility and the strength of soil. Akbulut et al. (2007)[20] found that the increase in scrap tyre rubber content resulted in an increasing UCS value and after it reached an optimum amount there was a reduction in strength of reinforced soil. This optimum amount and length of reinforcement were found to be 2% and 10 mm respectively. Hu et al. (2009)[21] conducted tests on GRS samples reinforced with non-woven geotextiles and concluded that the UCS of reinforced soil increased with decrease in reinforcement spacing and increase in relative density of soil. Due to reinforcement, composite soil exhibits a flexible and ductile failure. Amin chegenizadeh and Hamid Nikraz (2012)[22] conducted a series of UCS tests and concluded that fiber content, type of fiber and length of fiber have significant effect on the performance of reinforced soil. Fiber content and length of fiber cause an increase in the strength of soil by a considerable amount. Plastic fiber is more effective than natural fiber. Jafari & Ashari (2012)[23] performed unconfined compressive strength tests on soil samples reinforced with tyre cord. Incorporation of tyre cord in soil increased the UCS value and its reinforcing effect was enhanced with an increase in freeze-thaw cycle. Mirzababaei et al. (2013)[24] used carpet waste fibers as reinforcing material and evaluated the unconfined compression strength for clays. It was revealed that the UCS of clay was predominantly affected by the initial dry unit weight of soil and it increased with increase in initial density of clay. The failure pattern for 5% fiber reinforced soil samples were observed as barrel-shaped whereas unreinforced soil samples exhibited classical failure pattern. Reinforcement causes a change in the failure pattern of soil from brittle failure to ductile failure, thus revealing that the reinforcement has increased the flexural strength of soil. Carpet waste fibers also cause a reduction in post peak strength loss. Bera (2013)[25] determined the UCS of virgin soil, pond ash, pond ash mixed soil and reinforced mixed soil. UCS of soil decreased with addition of pond ash in soil samples whereas the jute geotextiles lead to an increase in UCS of mixed soil.

Literature is full of studies conducted on granular and cohesive soil separately with reinforcing material, but only few studies have been conducted on reinforced, well graded c-φ soil using triaxial test. In some cases, clay has been used with some other additive and waste material. This article presents the results of series of unconfined compressive strength tests conducted in laboratory on well graded c-φ soil with and without reinforcements. Woven and non-woven geotextiles are used in layers and the effect of number of layers and type of geotextiles on uncompressive strength of soil is evaluated.

3. Material and Apparatus used in Study

3.1. Soil Material

Soil used in present study are consist of sandy clay, and collected from Domehar district of Himachal Pradesh, India. Index properties of soil are shown in tabular form in table1. Stress-strain relationship and Grain size distribution of soil are shown in figure 1 and figure 2 respectively.

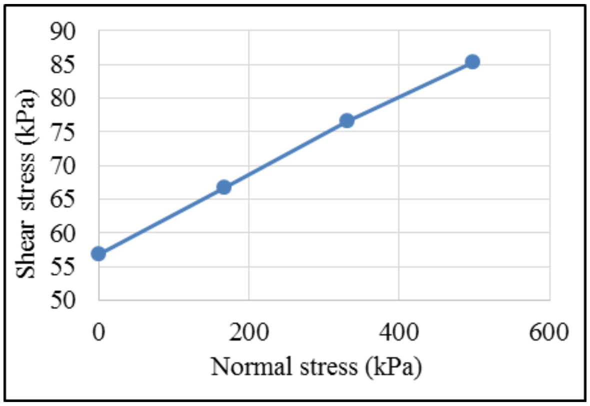

Figure 1: *Stress-strain relationship for soil*

Table 1: *Soil Properties*

Properties	Value
Effective size	0.019 mm
Uniformity Coefficient	14.21
Coefficient of Curvature	1.949
Liquid limit	41.80%
Plastic limit	21.85%.
Cohesion	52.88 kPa
Angle of friction	8.90
OMC	17.1%
Max. Dry Density	1.73

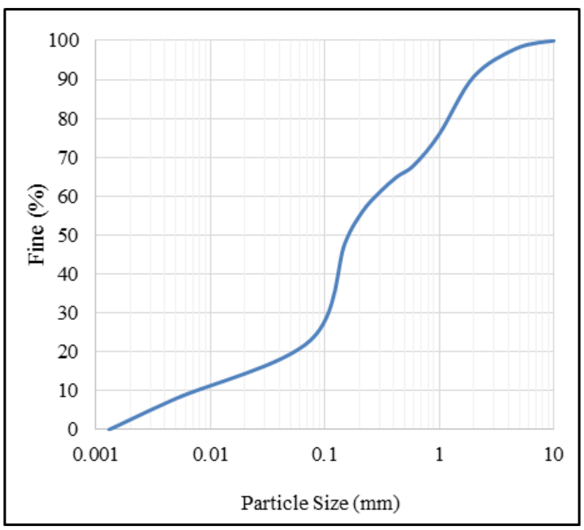

Figure 2: *Grain size distribution curve of soil*

3.2. Geotextile

The geotextiles used in present study were bought from Virendera Textiles, Noida, Uttar Pradesh. Woven and non-woven geotextiles having thickness 240 GSM and 120 GSM respectively. Figure 3 shows the nonwoven geotextiles and woven geotextiles used in present study and their properties are shown in table 2 and table 3 respectively. The fabrics of geotextiles are having resistant to most of chemicals and other microorganism found in various type of soil. Fabric are short term resistant to UV radiations and stable with in a pH range of 2 to 13.

(a)

(b)

Figure 3: *Geotextiles used in study; (a) Non-Woven Geotextiles (b) Woven Geotextiles*

***Table 2**:* *Properties of nonwoven geotextiles*

Properties	Values
Mass Per Unit Area	120 g/m²
Thickness	120 GSM
Tensile Strength CD	4.0 KN/m
Elongation	80 %
Grab Tensile Strength CD	.30 kN
CBR Puncture Strength	640 N
Apparent Opening size (AOS)	90 Microns

Table 3: Properties of woven geotextiles

Property	Value
Tensile Strength	42 KN/m
Elongation at Break	28 %
Trapezoid rear strength	520 N
Puncture strength	620 N
Water Permeability	9.5
Apparent opening	0.075 mm
Weight of Fabric	240 GSM

3.3. Apparatus for unconfined compressive strength

Reinforcement on stress-strain relationship for geotextile-reinforced clayey sand. All test specimens of triaxial test are having diameter of 38mm and 76 mm high. Apparatus used in study is shown in Fig 4.

Figure 4: Unconfined compressive strength test

4. Experimental Program and Procedure

Soil samples were collected from Domehar district of Himachal Pradesh. First of all, field density, water content and other index properties were determined in laboratory. The specific gravity, water content, grain size distribution and compaction parameters curve of the soils samples were determined as per IS: 2720 (Part III :(1980)[26], IS : 2720 (Part II) -1973[27], IS : 2720 (Part IV)-1975[28] and IS: 2720 (Part VII)—1980[29] respectively.

The specimens for determination of UCS were prepared in laboratory with the help of a metallic split mould having a detachable collar. This mould is having diameter of 38mm and height 76 mm. Detachable collar is attached at the end of mould and it remains orthogonal with the vertical axis of mould. Reinforcement was first cut into circular shape of 37mm diameter and placed in the mould in layers. Height of each divisions has been varied for all different configurations throughout the testing as shown in figure 5. Geotextiles were placed parallel to the horizontal surface. After placing the geotextile in the mould, samples were compacted with help of a taming rod. Various trials were made to fix the initial height of placing the reinforcement in mould, so that after compaction the geosynthetic layer reaches the required position. After obtaining the suitable position for geotextiles, samples were prepared and then tested for the unconfined compressive strength to evaluate the effect of different type of geosynthetics. More detail of sample preparation is given in Bera et al. (2009) [30].

Unconfined compressive strength tests, with and without inclusion of reinforcement were performed in the laboratory as per Indian standards.

Geotextiles used in layers and placing arrangement is shown in fig 5.All test were conducted with woven and nonwoven geotextiles as parallel spaced sheet reinforcements. Unconfined compressive strength tests of soils samples are determined by as per IS: 1943, Part X: 1981[31].

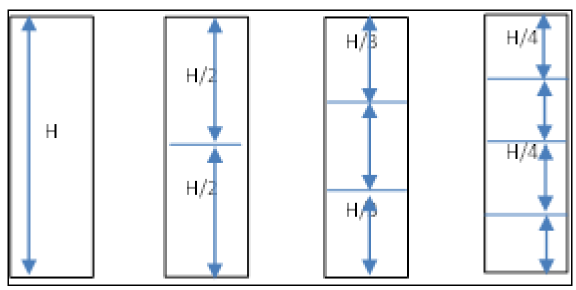

Figure 5: Geotextile arrangement used in tests

5. Results and Discussion

A series of unconfined compressive strength are performed in soil with and without reinforcement. In case of soil without geotextiles, failure plane was observed between a distances of 1.5 cm to 3.5 cm from the base of sample.

5.1. Effect on peak strength

In case of two layer woven and non- woven geotextile, the failure planes were bserved above the top of geotextile. Some typical graphs are shown in figure 6 and figure 7 for non-woven and woven geotextiles respectively. The observation made in laboratory test is presented in tabular form in table 4. Peak strength of and percentage axial strain have been increased to a considerable amount with the inclusion of woven reinforcement compared to non-woven reinforcement. More the number of layers of woven geotextile, more the strength of soil. The stress–strain behavior of reinforced soil is consistent with several past studies [Haeri et al., 2000[32], Moghaddas & Asakereh, 2007[33], Wu& Hong, 2008[34]). Effect of number of layers on peak strength is very predominant in case of woven geotextiles as compared to non-woven geotextiles as shown in figure 8. Soil reinforced with woven geotextiles exhibits more ductile and flexible failure as compared to non-woven geotextiles.

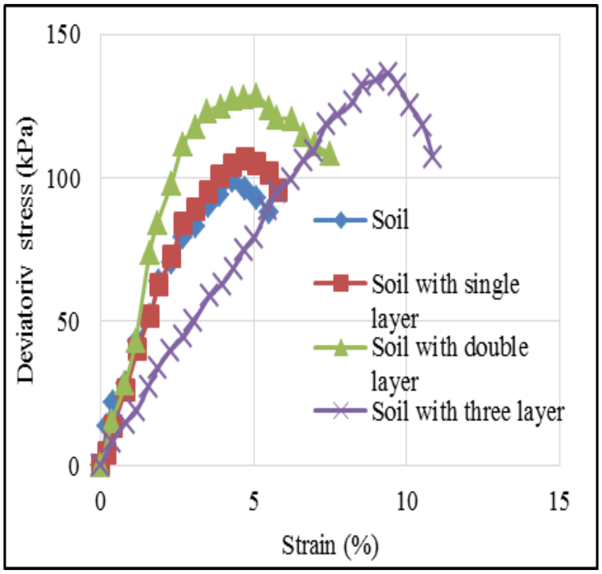

Figure 6: *Stress-strain relation for non-woven reinforced soil*

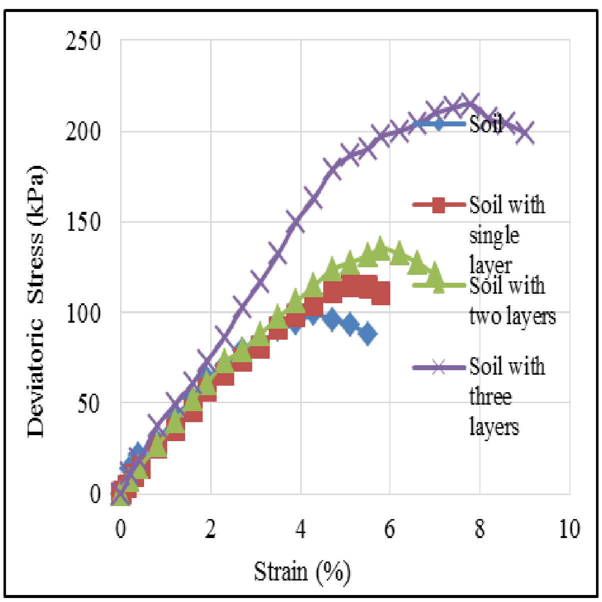

Figure 7: *Stress-strain relation for woven reinforced soil*

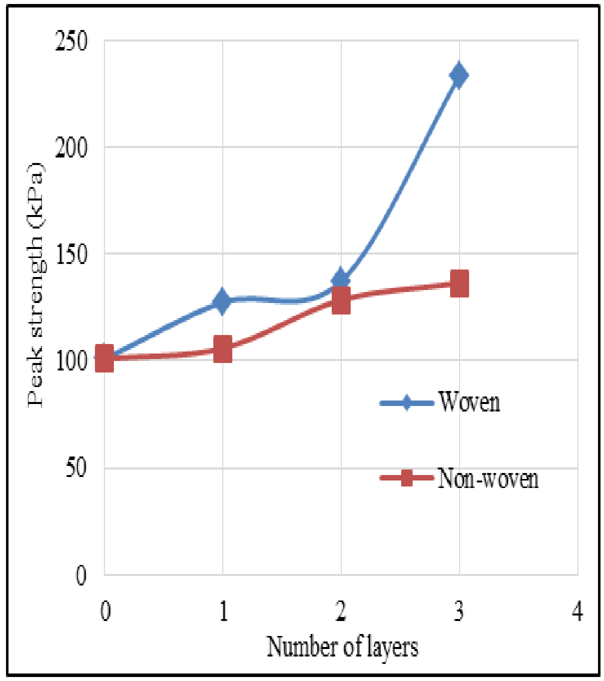

Figure 8: *Effect of number of layers on peak strength*

Table 4: *Effect of reinforcement on unconfined compressive strength test*

Test Type Test	Peak strength (kPa)	Change (%)
Soil without geotextile	101.00	-
Soil with single woven geotextile kept in between the failure plane	127.48	26.2
Soil with double layer woven geotextile	137.35	36.0
Soil with triple layer woven geotextile kept in between the failure plane	233.39	131. 0
Soil with single non-woven Geotextile	105.98	5.92
Soil with double layer non-woven geotextile	128.57	27.30
Soil with three layer non - woven geotextile	136.40	35.04

5.2. Failure pattern for different configuration and type of geosynthetic

Peak strength is more for woven type of geotextiles. From carefully observing all four figures, it can be easily analyzed that in case non-woven geotextiles reinforcement, soil samples shows clear cracks and failure surface. The failure plane has reached at the top of soil sample and can be observed in opposite face of soil sample as well. In case of woven geotextiles the cracks are on the external surface only. Soil sample fail completely in case of non-woven geotextiles.

Figure 9: *Failure with Woven Geotextile when kept in between the failure plane*

Figure 10: *Failure with Non-Woven Geotextile when kept in between the failure plane*

6. Conclusions

All the laboratory tests were conducted as per Indian standard code. Woven type geotextiles are more effective compared to non-woven geotextiles to improve the peak shear strength of soil. With increase in number of layers, unconfined compressive strength increases for woven geotextiles. Nonwoven geotextiles causes some increase in the unconfined compressive strength, but effect of the number of layers is negligible as compared to woven geotextiles. Soil reinforced with woven geotextiles exhibits more ductility and flexible behaviour as compared to non-woven geotextiles.

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