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Experimental Study of Geotextile Effect on Bearing Strength and Permeability of Sudanese Cohesive Soils

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Abstract: This paper focuses on the influences of geotextile on bearing strength and permeability properties of cohesive soils. Experimental investigation was conducted on three soils reinforced with geotextile sheets in one or more layers. The soil samples are compacted at optimum moisture content and maximum dry density in five layers with or without geotextile sheets. The California Bearing Ratio (CBR) and the permeability tests have been carried out on natural soils and soils with geotextile sheets. The experiments results have showed a significant decrease in the CBR and the permeability values of the three soils with the inclusion of geotextile sheets. The CBR values of geotextile reinforced soils have decreased by 70% for 4 layers of geotextile sheets. Also, the average reduction in the permeability of the three soils reinforced with 1-layer geotextile sheet is about 60% of the natural soils. Hence, it is concluded that provision of geotextile sheet with an activator such as lime or fly ash to increase the soil strength will be beneficial and economical option in earth dams and canal banks.

Keywords:*California Bearing Ratio, permeability,effect,geotextile.*

1. INTRODUCTION

The soil is strong in compression and weak in tension, and therefore to provide tensile strength to soil, the reinforcement of soil is necessary. The main areas where soil reinforcement may be applied are slope and embankments, foundations, retaining walls. The use of geosynthetic materials as reinforcing elements, soil structures can be built to carry tensile forces. These forces act to restrict soil movements and thus impart additional shear strength. This result in the composite soil/reinforcement system having significantly greater shear strength than the soil mass [1].

Geotextiles are the largest and most diverse group of geosynthetic materials and include all fabrics produced from polymer fibers. The geotextils are defined as permeable textiles used in conjunction with soil or rock, as an integral part of manmade projects. Every textile applied under the soil is a geotextile [2]. The main functions of geotextiles are separation, filtration, drainage material, sealing and protection and reinforcement involve interactions with the surrounding soil [3]. Depending upon the required function, they are used in open mesh form, woven form, non-woven form and knitted form.

The geotextiles are broadly classified into two categories as biodegardable and non-biodegradable. The geotextiles which are non- biodegradable are also named as geosynthetics as their basic raw material is manufactured from petroleum products.

The purpose of this study is to evaluate the effect of using geotextile on bearing strength and permeability of cohesive soils.

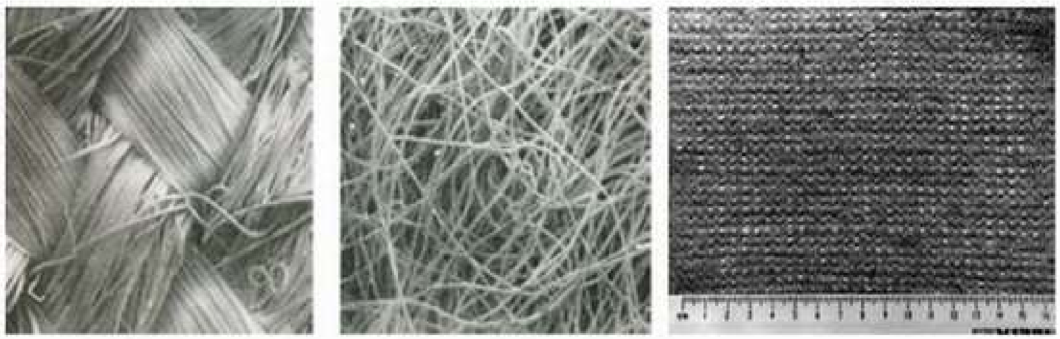
2. LITERATURE REVIEW

2.1 Geotextile Materials

Geotextiles are flexible textile fabrics that are used with foundation, soil, rock, earth, etc to increase stability and decrease wind and water erosion. Geotextiles like geonets, geogrids, geocomposites are functioning as separator, filter, drainage material, reinforcement, sealing and protection.

The reinforcement acts to prevent lateral movement because of the lateral shear stress developed. Reinforcement provided by the geotextiles and geogrids allow embankment and roads to be built over very weak soils and allows for steeper embankments to be built. Therefore the geotextiles are applied in paved roads, rail road embankment stabilization, erosion control, sport field construction. A geotextile may be made of synthetic or natural fibers [4].

Fig. 1 shows three different types of geotextiles structures (a) woven geotextiles, (b) non-woven geotextiles, and (c) knitted geotextiles.Nonwoven geotextiles are manufactured from either staple fibers or continuous filaments randomly distributed in layers onto a moving belt to form a felt-like “web”.



(a) **(b)** **(c)**

Fig.1. Different types of geotextiles structures [4]

The web then passes through a needle loom and/or other bonding machine interlocking the fibers/filaments. Nonwoven geotextiles are highly desirable for subsurface drainage and erosion control applications as well as for road stabilization over wet moisture sensitive soils.Woven geotextiles are made from weaving monofilament, multifilament, or slit film yarns. Slit film yarns can be further subdivided into flat tapes and fibrillate yarns. There are two steps in this process of making a woven geotextile, (1) manufacture of the filaments or slitting the film to create yarns; and (2) weaving the yarns to form the geotextile. A knitted geotextile is produced by interloping one or more yarns (or other elements) together with a knitting machine, instead of a weaving loom. Stitched geotextile are that in which fibers or yarns or both are interlocked/bonded by stitching or sewing [4]-[7].

2.2 Previous studies

Several researches were conducted to investigate the improvement of soil using geotextile [7] - [17].

Choudhary et al [7] carried out an experimental work to evaluate the use of jute geotextile and geogrid. CBR tests were conducted in soaked condition for both the reinforced and unreinforced soil. They founded that the CBR value of the soil increases significantly with increase in number of reinforcing layers. Also jute geotextile was observed to offer better reinforcing efficiency as compared to geogrid.

Kumar [8] studied the performance of woven and nonwoven geotextile, interfaced between soft subgrade and unbound gravel in an unpaved flexible pavement system, they observed that both woven geotextile as well as nonwoven geotextile in an unpaved road especially with soft subgrade, increases the penetration resistance and hence the CBR strength. Therefore, the performance of the unpaved road is better with the inclusion of geotextiles and improves further at larger depth of penetration.

Ghosh et al [9] carried out a study to improve the characteristics of soils using jute geotextile by prepared two different clayey soils with and without Jute geotextile. They founded the jute geotextile had significant influence on the soil properties. Shear strength, dry density, permeability and CBR values had been compared before and after lying of the jute geo-textile Hence, jute geotextile plays very effective role in the improvement of soil properties by reducing their compressibility and increasing their strength.

Philip and Charly [10] studied the effectiveness of using geotextile reinforcement placed at three different positions on granular soils at top, middle and bottom of the model. They found that the CBR values of reinforced granular soils with geotextile sheet increases. Also the shear strength property of the soil increases for the soil reinforced with geotextile sheet compared with respect to un reinforced.

Naeini [11] investigated the geotextile as a tensional material used for reinforcement of granular soils. Three samples of granular soil with different grading were selected and tested with and without reinforcement. The geotextile sheets were placed at certain depths within the sample in one and two layers. They observed that geotextile sheets increase the bearing capacity and CBR of granular soils with reinforced geotextile materials.

Singh and Bagra [12] studied the improvement in the CBR value of the soil reinforced with jute fiber when placed at different positions .The percentage of the Jute fiber by dry weight of soil was taken as 0.25%, 0.5%, 0.75% and 1%. The length of the fiber was taken as 30mm, 60mm and 90mm and two different diameters, 1mm and 2mm were considered for each fiber length. They founded that the CBR value of the soil increased with the inclusion of the jute fiber. As the Jute fiber content increases, the CBR value of the soil is further increases and this increment is substantial at fiber content of 1%.

Tapas and Baleshwar [13] investigated the influence of jute geotextile layers on compaction, deformation and strength characteristics of soils stabilized with fly ash. They founded that the dry unit weight of the soil increased with the inclusion of jute geotextile layers. The unconfined compression tests (UCS) of compacted samples with two layers of jute fabric were performed. They founded that the UCS of the soil reinforced with jute geotextiles is better than the unreinforced soil. The improvement in strength is very significant when the soil is reinforced with 4 layers of jute geotextile at equal vertical spacing between two consecutive layers.Dasgupta [14] Studied the performance and construction cost comparison of roads constructed with and without jute geotextiles. They found that construction with geotextile was less in cost compared to natural granular materials, because it contributes towards better road performance and economy by reduced road thickness and construction time added advantages.

Singh [15] carried out an experimental work to determine the strength and stiffness of soil reinforced with geotextile by conducting triaxial tests at four different position. All the soil samples were prepared at a dry density of 17.46 kN/m^3 and water content of 14.55%. They found that shear strength parameters of the soil increased due to inclusion of jute geotextile sheet in the soil.

The maximum increment in cohesion "c" and angle of friction "ϕ" values of the soil are 72% and 46% respectively for 4 layers of Jute geotextile sheets. Also the stiffness modulus of the soil increases with the increase in confining pressures. The average maximum increment in the stiffness modulus of the soil is 112% for 4 layers of jute geotextile sheets.

Masoumi et al [16] experimentally evaluated the effectiveness of one and two layers of nonwoven geotextile in the bearing capacity of the soils layers. Three types of geotextiles were placed in different depths of layers in clayey and sandy soil samples, and two sheets of geotextiles between the layers were also used.

They founded that the CBR values of geotextile (150 and 200g/m^2) type in a clayey soil indicated better response under loading conditions; however, the reverse was the case for the 300g/m^2 geotextile. Also the CBR values increased with one-layer geotextile, the maximum CBR values in clayey and sandy soils were approximately 3 and 2.6 times greater than those without reinforcement.

Kumar et al [17] studied the improvement in the strength of expansive soil measured by CBR. They observed that the CBR value of the natural sample was 2.67% and after 2-layer reinforcement of jute layer, the improvement in the CBR value 6.07% and when the jute layer reinforcement was increased to 4-layers the tremendous CBR value of 11.85% has been achieved.

3. MATERIALS AND METHODS

The objective of this study is to investigate the influence of geotextile layers on strength and permeability properties of cohesive soils. To achieve this objective, experimental work was conducted on cohesive soils to evaluate the effectiveness of one or more sheets of geotextile in bearing strength and permeability of soil layers. Laboratory tests were performed to determine the strength and permeability of soil reinforced with geotextile by conducting CBR and permeability tests at three different positions.

3.1 Materials used

a) Cohesive Soil

In this research, three soils are used for the experimental work obtained from different regions in Sudan, Almamora (S1) in Khartoum; Kafori (S2) in Khartoum North and Gadarif (S3) in Gedarif state, eastern Sudan. The basic physical and mechanical properties of these soils were determined and presented in Table 1.

Table .1: The basic properties of the soils studied

Property	S1	S2	S3
Sieve analysis			
Gravel, %	0	0	31
Sand, %	33	21	18
Silt/Clay, %	67	79	51
Atterbag's limits			
Liquid limit, %	66	55	35
Plastic limit, %	24	35	17
Plasticity index, %	42	20	18
Specific gravity	2.70	2.65	2.74
Compaction			
Max. Dry Density, KN/m^3	16.2	14.7	20.3
Optimum Moisture Content, %	18.0	22.5	12.4
Unsoaked CBR, %	23	28	36
Free swell index, %	183	103	60
Soil classification	CH	CH	CL

b) Geotextile material

Geotextile material studied is a nonwoven made of staple fibers, mechanically bonded by a needle punching process to produce a dimensionally stable network. The geotextile sheet used in this studyis supplied by Norandy Company (see Fig. 2). The properties of the geotextile are given in Table 2.

Figure 2: the geotextile sheet used in the study

Table 2: The properties of geotextile material used

Properties	**value**
Tensile strength (CD), KN/m^2	42
Tensile strength (MD), KN/m^2	22
Elongation at break (CD/MD), %	55/55
CBR puncture, N	5100
Permeability VI50,	40
Flow rate normal to the plane, $l/m^2/sec$	40
Opening size, microns	67
Thickness under 2KPa, mm	4.4
Roll Dimensions (width ×length), m	3×100
Dynamic puncture, mm	8
Mass per unit Area, g/m^2	500

3.2 Specimen Preparation and Test Procedure

The three soils were initially air dried, crushed into small sizes and pulverized. The test samples were prepared by sieving the three soils through set of sieves. The soil samples were oven dried at 105-110 °C for 24 hours. The test program constituted preparing each soil sample by proctor compaction to determine their maximum dry density (MDD) and optimum moisture content (OMC). The soil samples were subdivided and each sub-sample was prepared at MDD and OMC.

The samples were reinforced with geotextile sheets while compacting at OMC and MDD in five layers in the CBR mould. For each soil sample, three pairs of specimens were prepared for unsoaked CBR and permeability tests. For each specimen, the geotextile sheets were placed either in one position below the top layer, two positions below the 2nd and 4th layers, or four positions between the soil layers. The positions of the geotextile sheets are illustrated with simple sketches in Fig. 3. The unsoaked CBR and permeability "Falling Head Method" tests were conducted on compacted specimens with or without reinforcement. All tests were performed according to BS 1377 [18].

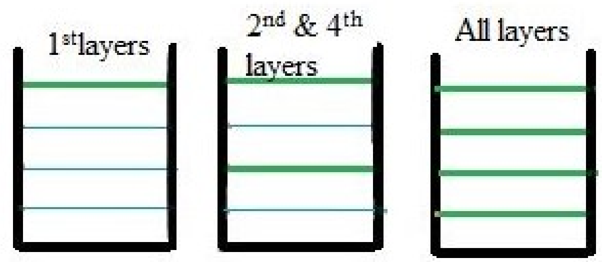


Fig.3. Simple sketches of specimens with geotextile sheets placed between soil layers

4. RESULT AND DISCUSSION

The results of the experiments are presented and discussed in this section. The CBR test results are graphically shown in Fig. 4. It was observed that the CBR values of the natural soil samples decreased after 1-layer reinforcement of geotextile sheet and when the geotextile sheet reinforcement was increased to 2-layers and 4-layers the CBR value rapidly decreased. The average reduction in CBR values of three soils is almost 62% for 4 layers of geotextile sheets.

This result agreed with the findings of Masoumi et al [16]who evaluated three nonwoven geotextile of different mass per unit area (150,200 and 300g/m^2)in a clayey soil and found that the 300g/m^2 geotextiletype showed reduction in the CBR values. In this study, the geotextile type used has a mass per unit area 500 g/cm^2, therefore the CBR value decreased by inclusion of geotextile sheets.

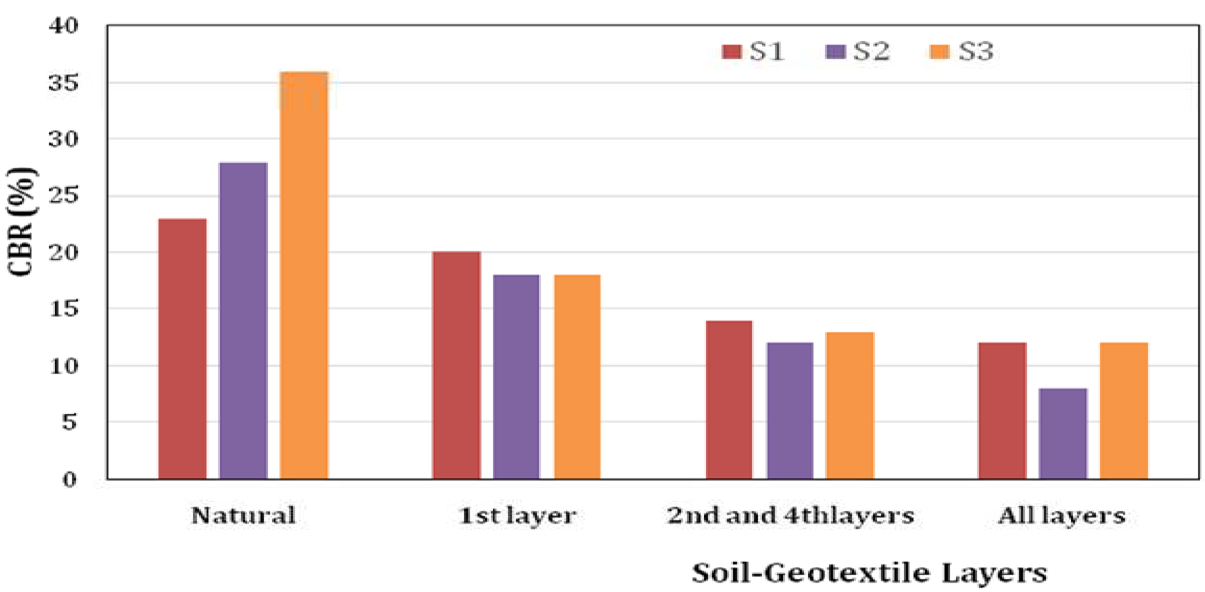


Fig.4. CBR values for natural and reinforced soils with geotextile layers

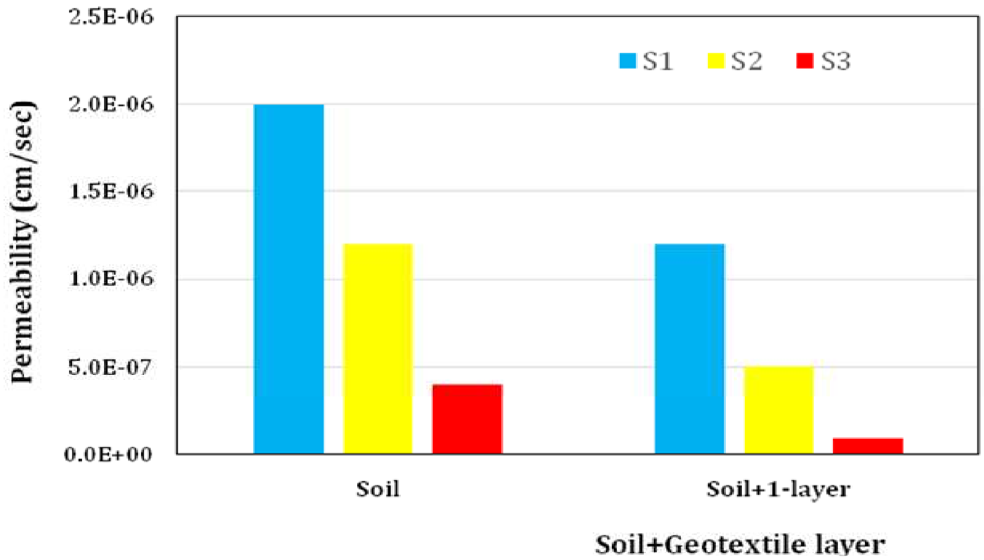


Fig.5. Permeability of natural and reinforced soils with geotextile

The permeability test results are graphically plotted in Fig. 5. It can be seen that the permeability values of the three soils decreased with inclusion of geotextile sheets in the soils. The average reduction in the permeability of the three soils is around 60% due to inclusion of 1-layer of geotextile sheet in the soils.

5. CONCLUSION

This study focused on experimental evaluation of the effect of geotextile on bearing strength and permeability of cohesion soils. Based on the experimental results obtained, the following conclusions are drawn.

- The three studied soils (S1, S2& S3) are classified as sandy Clay of high to medium plasticity (PI 42%, 20%& 18%), free swell index (183%, 103%& 60%), and bearing strength (CBR 23%, 28%& 36%). Geotextile used is a nonwoven made of staple fibers, type 500 g/m^2. The soils were reinforced with one or more layers of geotextile sheets.
- Inclusion of geotextile in cohesive soils has significant effect on the bearing strength and permeability parameters. It was found that the CBR and permeability values of the natural soils reduced when the geotextile layer reinforcement was increased to 4-layers.
- The nonwoven geotextile type of large mass per unit area, such as 300 and 500 g/cm^2 has adverse effect on soil strength.The CBR values of the soils rapidly decreased as the geotextile layer increased from 1-layer to 4-layers. The average reduction in the CBR values of the three soils is about 62% for 4 layers of geotextile sheets.
- The permeability is significantly decreased in soils reinforced with geotextile sheets. The average reduction in the permeability of the three soils is around 60% due to inclusion of 1-layer of geotextile sheet in the soils.
- Based on the research findings, it is clear that the nonwoven geotextiles,type 300 and 500 g/cm^2 need an activator to increase the soil strength and it is recommended to be used in earth dams and canal banks for seepage and erosion control applications.

REFERENCES

[1] Mirafi,(2010), “Geosynthetics for Soil Reinforcement,” Mirafi Eng. Solut. An Innovative Word, Vol. 20, No. 8, pp. 1–12.

[2] Kousik D., (2013), “Design of geosynthetic-reinforced earth using equivalent thickness concept” Indian Journal of geosynthetics, Vol. 2, No.1, pp 4-8.

[3] Gohil D. P., Solanki C. H., and Desai A. K., (2009), “Application of Geosynthetics for Ground Improvement an overview,” lambert Acad. gndec.ac.in-publishing, pp. 439–442.

[4] Zunjarrao K., (2010), “Geotextile: Soil Improvement Techniques,” D.K.T.E.S. Textile & Engineering Institute, Ichalkaranji, India, pp. 379–398.

[5] Zornberg J. G. and Gupta R., (2010), “Geosynthetics in pavements: North American contributions,” 9th Int. Conf. Geosynth. Brazil, 2010, no. 1, pp. 379–398.

[6] ShuklaS.K., (2011), “Handbook of Geosynthetics,” p. 59.

[7] singh H. and singh J.,Jha J., Gill K., (2012), “Ground Improvement and Ground Control including Waste Containment With Geosynthetics,”.

[8] Kumar R., (2012), “Effect of Geotextile on CBR Strength of Unpaved Road with Soft Subgrade,” Electron. J. Geotech. Eng., vol. 17, pp. 1355–1363.

[9] Ghosh B., Ramesh V., and Vibhuti R. B., (2014), "Improvement of Soil Characteristics Using Jute," Int. J. Sci. Eng. Technol. Res., vol. 3, no. 7, pp. 1983–1986.

[10] Philip A. S. and Charly K. K., (2016), "Study on Strength Behaviour of Soil Using Geotextile," Int. J. Engineering Res. Sci., vol. 2, no. 7, pp. 30–37.

[11] Naeini S. A., (2008), "The Effect of Geotextile and Grading on the Bearing Ratio of Granular Soils," Electron. J. Geotech. Eng., vol. 13, no. 1996, pp. 1–10.

[12] Singh H. P. and Bagra M., (2013), "Improvement in CBR Value of Soil Reinforced With Jute Fiber," Int. J. Innov. Res. Sci. Eng. Technol., vol. 2, no. 8, pp. 3447–3452.

[13] Tapas D. and Baleshwar S., (2014) "Deformation And Sterngth Characeristics of Jute Geotextile Reinforced Soil," J. Environ. Res. Dev., vol. 8, no. 4, pp. 987–995.

[14] Dasgupta T., (2014), "Soil Improvement By Using Jute Geotextile And Sand," Int. J. Sci. Eng. Technol., vol. 884, no. 3, pp. 880–884.

[15] Singh H. P., (2013), "Strength and Stiffness of Soil Reinforced with Jute Geotextile Sheets," intenatiol J. Curr. Eng. Technol., vol. 3, no. 3, pp. 1143–1146.

[16] Masoumi M. T., Kordani A. A., and Nazirizad M., (2017), "Experimental Study of Geotextile Effect on Improving Soil Bearing Capacity in Aggregate Surfaced Roads," word Acad. Eng. Technol. Int. J. Civ. Enviromental Eng., vol. 11, no. 1, pp. 43–49.

[17] Singh A. K., and Yadav R. K., (2016), "Improvement in CBR of Expansive Soil with Jute Fiber Reinforcement," Int. Research Journal of Eng. and Technol., Vol. 3, No. 11, pp. 767–771.

[18] British Standard (1990). British Standard 1377, Methods of Test for Soils for Civil Engineering Purposes. British Standard Institution, London.