Shear Strength Parameters of BC Soil Admixed with Different Length of Coir Fiber

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Abstract: **- Use of natural fibers as soil reinforcement is gaining much attention by geotechnical engineers as it has inherent advantage with regard to its availability, cost and does not pose environmental hazard on the long run. Natural fibers when used as a soil reinforcement is found to increase peak compressive strength, shear strength, and ductility of the soil. In the present experimental study, undrained triaxial tests were conducted on black cotton soil (BC Soil) mixed with coir fibers and the effect of lime treatment and length of the fibers on peak deviator stress and shear parameters were studied. The results of the experimental investigation found that coir fiber as reinforcement to BC soil causes significant increase in peak deviator stress. Increase in length of coir fiber increases cohesion and angle of internal friction. When the length of the fiber exceeds 20mm, mixing difficulty to obtain a uniform soil-fiber mixture causes marginal decrease in shear parameters.**

Keywords—coir fibers; peak shear stress, angle of internal frictionr,cohesion.

1. INTRODUCTION

"Black cotton soil," cover an area of more than 200,000 square miles and constitute about 20% of the total area. Since the soils are expansive in nature, the problems of construction increase due to low shear strength, high compressibility, high swelling potential.

Reinforcing soil with natural fibers are used frequently with the attention of increasing peak compressive strength, shear strength, and ductility and reducing post peak strength loss. The main advantages of using short fibers over planar reinforcement are: *absence of potential plane of weakness, feasibility of application within a limited space compared with the use of planar reinforcement such as geotextiles and significant cost savings because of the availability of fibers at lower cost and no need for a specific design*. Among natural fibers, fibers obtained from coir in proven to be most durable when used in soils because of it having high lignin content. Hence the use of coir fibers in black cotton soil is examined in this context. Coir is abundantly available in most parts of south and costal India, Sri Lanka, Philippines, Indonesia, Malaysia, Brazil, and others [1]. Considerable information on the properties of coir fibers compared to other natural fibers is its *high initial strength, stiffness, and hydraulic* properties. Direct shear tests were carried out [2] on dry sand reinforced with fibers to evaluate the effect of different parameters on shear strength. A series of triaxial compression tests on sand reinforced with continuous, oriented fabric layers and also with randomly distributed discrete fibers. Unconfined compression test were conducted on sandy clay soil [3] to study the effect of fiber inclusion on unconfined compressive strength at different water contents. Mechanical properties of kaolinte-fiber soil composite [4] were evaluated by conducting a series of unconfined compression and splitting tension test. The effect of fiber content that can be added varied significantly. In one of the study, it was varied from 0.05 to 0.25% [5] while in other study[6] it was varied upto 2.0% .Applications of synthetic and natural fibers were studied [7,8,9,10,11,12] using randomly distributed fiber (RDCF) and found that the RDCF increases the shear and compressive strength along with improvement in ductility of clayey soils.

Since fiber to soil particle interaction is significantly affected by length of extensible fibers in soil, the objective of present study is to explore the influence of length of fiber on shear strength characterization fiber reinforced Black cotton soil (BC soil). The results have been analyzed in terms of effect of length of fiber and conclusions have been drawn.

2. EXPERIMENTAL WORK

2.1 Material Used

Black cotton soil (BC soil) was collected from Davangere Dist., Karnataka state, India by an open excavation from a depth of 1 meter below natural ground level. Black cotton soil was air dried and pulverized in a ball mill after separating the pebbles. The pulverized soil which is passing through 300 micron BIS sieve was used in the present investigation. The physical properties of the collected BC soil are as shown in Table 1.

Coir fibers cut into various lengths were used as a natural reinforcing material. Coir fibers, brownish in color, were obtained from the local small scale factory in Gubbi, Karnataka, India.

Table 1. Properties of black cotton soil

Properties	Values
Liquid Limit, *LL* (%)	67
Plastic Limit, PL(%)	22
Shrinkage Limit, SL(%)	11
Specific gravity, G	2.62
Silt + clay size (%)	79
Sand size (%)	21

2.2 Test procedure

Proctor compaction test on BC soil as per BIS 2720 part VII (1980) were conducted to obtain the maximum dry density (MDD) and Optimum Moisture Content (OMC). Fig. 1 shows the compaction curve for BC soil used in the present study. The BC soil was admixed with coir fibers and compacted to 97% of MDD with water content corresponding to OMC obtained from the compaction test.

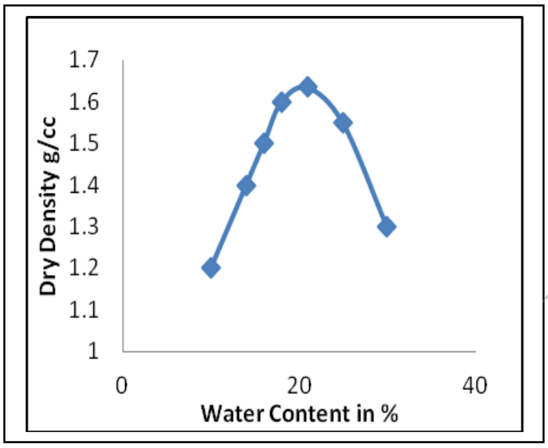

Fig. 1 Compaction curves of black cotton soil.

3. RESULTS AND DISCUSSIONS

3.1 Effect of Length of Fiber on Deviator Stress.

Fiber-reinforced soil samples were prepared by mixing BC soil and different percentage of coir fibers on dry weight basis using maximum dry density and water content corresponding to OMC obtained from compaction test. Fibers were mixed with wet soil randomly, place in the mould and compacted to get 97% of the desired density.

Different percentage of coir fibers were added to BC soil and tested in triaxial compression testing machine. Parameters such as percentage of reinforcement and length of coir-fibers were considered for investigation. Samples were prepared by adding coir fibers at different percentage and with different length viz., 10mm 20mm and 30mm. Undrained triaxial tests were conducted in a standard tri-axial apparatus, with and without coir fibers, to study the improvement in the shear strength parameters of black cotton soil. Size of soil specimen used was 38 mm diameter and 76 mm high. Sufficient care was taken so that coir fiber distribution was uniform thought the mixed soil. Tests were conducted for fiber contents of 0.5%, 1.0%, 1.5%, 2.0%, 2.5% and 3.0% by dry weight of soil, The specimens were subjected to three levels of confining pressures (σ_3 of 100kPa, 200kPa, and 300kPa). The tests were repeated by mixing BC soil with fiber Lengths 10mm, 20mm, and 30mm. Deviator stress was applied up to 15% axial strain level or up to the failure of specimen which ever occurred earlier. Figures 2 to 4 shows typical stress-strain curves for black cotton soil reinforced with coir fibers having different lengths of 10 mm, 20mm and 30mm, sheared at a confining pressure of 100 kPa, 200kPa and 300kPa. It can be seen from these typical plots, that the effect of addition of fibers increases peak deviator stress. The peak deviator stress increases with increase in fiber content only up to a specified percentage of fiber content, for all length of fibers used.

The improvements of the deviator stress is attributed to the reduction of void ratio in the coir fiber reinforced soil due to confining stress and contribution of pull out resistance in the form of frictional effect of induced cohesion parameters.

It was seen from figures 2 to 4 for a given length of the fiber and fiber content, and at constant confining pressure, increase in length of the fiber increases peak deviator stress. It was also noted that, mixing of coir fibers beyond a fiber content of 2% was found to form lumps, which may have contributed to reduction in peak deviator stress beyond the fiber content of 2%.

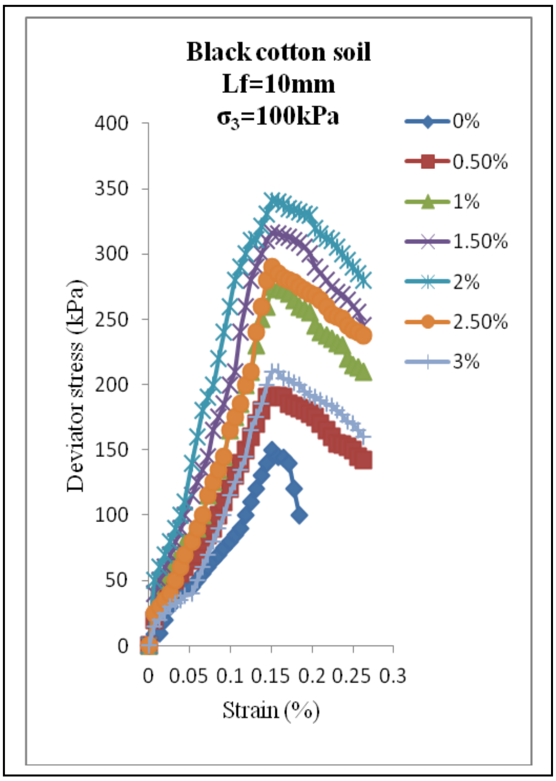

Fig. 2 Stress vs. strain curves for black cotton soil + coir fiber with different percentage (σ_3= 100 kPa, Length of fiber L_f=10mm)

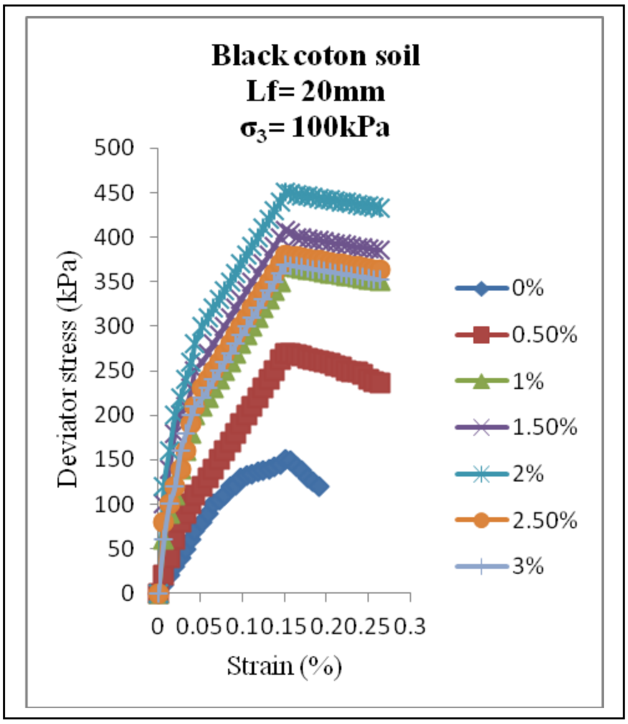

Fig. 3 Stress vs. strain curves for black cotton soil + coir fiber with different percentage (σ_3= 100 kPa, Lf=20mm)

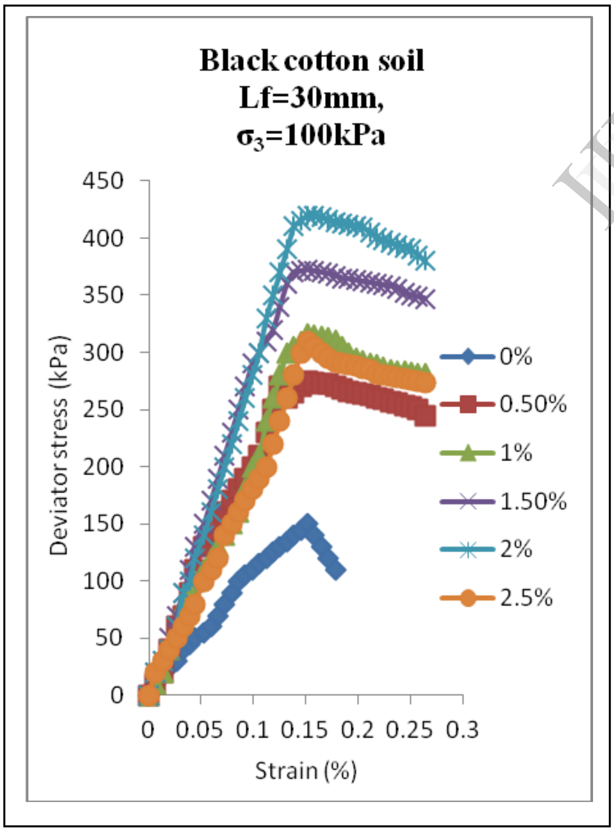

Fig.4. Stress vs. strain curves for black cotton soil + coir fiber with different percentage (σ_3= 100 kPa, Lf=30mm)

3.2 Effect of Fibers on Shear Strength Parameters

Shear parameters were determined from modified failure envelope. Fig. 5 show modified failure envelopes obtained for BC soil admixed with coir fiber. It can be seen that modified failure envelopes of soil with different fiber contents are parallel to each other. Using the modified failure envelopes the shear parameters such as cohesion (c) and angle of internal friction (Φ) were calculated.

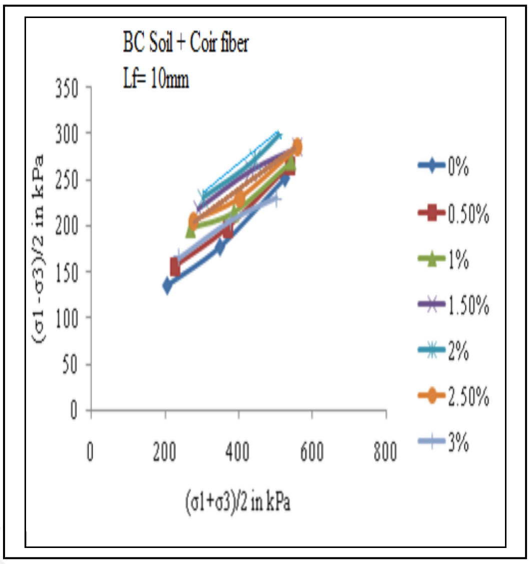

Fig.5. Modified failure envelope for BC soil admixed wirth Coir Fiber

Fig. 6 shows the variation of cohesion with fiber content for different length of fiber for BC soil admixed with coir fiber. It can be seen that, increase in length of the fiber increases cohesion. However, when length of the fiber becomes large than 20mm, there is marginal decrease in cohesion. This is attributed to the fact that, increase in length beyond 20mm of coir fiber induces difficulty in uniform mixing with the formation of soil lumps

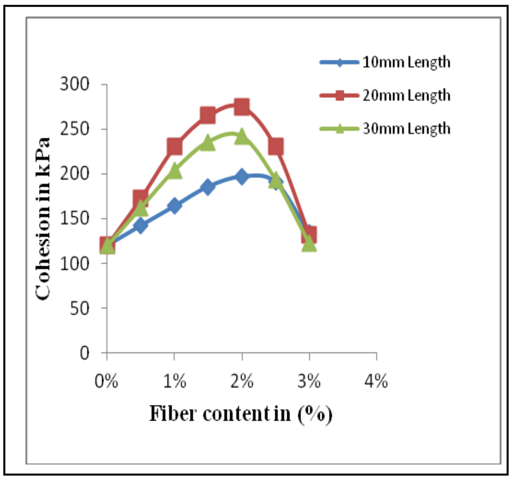

Fig.6 Cohesion values for Black cotton soil + different percent of coir fiber with different lengths

Table 3 shows variation of angle of internal friction (ø) obtained for different fiber content and fiber length. Increase in fiber content increases ø for BC soil. It can be seen that increase in length increases ø up to coir fiber length of 20mm. Beyond 20mm length, the ø value decrease marginally. This is attributed to obtaining lack of uniform mix due to mixing difficulty, when length of fiber increases beyond 20mm.

Table 3. Variation of Φ for BC soil + coir fiber

Black cotton soil + coir fiber			
Length	**10mm**	**20mm**	**30mm**
coir%	ø	ø	ø
0%	4.00	4.00	4.00
0.50%	7.96	5.54	5.54
1%	8.14	7.96	6.1
1.50%	8.74	9.14	6.66
2%	9.34	9.57	7.8
2.50%	9.14	9.27	5.54
3%	8.8	6.08	6.03

4. CONCLUSIONS

On the basis of present experimental investigation the following conclusions are drawn:

i. The peak shear stress increases with increase in percentage of fiber content for BC soil which was found to be about 2% for the BC soil used in the present study. The strength of expansive BC soil is thus improved by the inclusion of coir fibers

ii. Fiber content beyond 2% poses mixing difficulty as soil lumps are formed during mixing. This has led to decrease in peak shear strength with addition of fiber content beyond 2%.Hence, there exists a speific fiber content to get optimum strength benefits.

iii. Increase in length of fiber increase peak deviator stress for a given percentage of fiber content. However when the length of fiber exceeds 20mm, there is marginal reduction in peak deviator stress.

iv. Marginal reduction in cohesion occurs when the length of fiber becomes larger than 20mm for BC soil. Similar trends have been observed with regard to angle of internal friction where in increase in the length of coir fiber beyond 20mm length decreases the angle of internal friction marginally.

v. Thus, when the averasge length of fibers distributed randomely in soil varies from 10mm to 20mm, the optimum benefit with regard to increase in shear parameters such as cohesion and angle of internal friction can be obtained.

REFERENCES

1. Rao, G.V. Balan, K (2000). "*Coir Geotextile Emergint Trends.*" Alappuzha, Kerala India: Kerala State Coir Corporation Ltd.
2. Gray, D.H., Ohashi, H. (1983). "*Mechanics of fiber reinforcement in sand''*. Journal of Geotech. Eng. 109(3): 335-353.
3. Gray,D.H., Al-Refeai, T. (1986). "*Behaviour of fabric-versus fiber-reinforced sand". Journal* of Geotech. Eng. 112(8): 804-820.
4. Freitag D.R (1986). "*Soil randomly reinforced with fibesr"*. Jouranl of Geotech. Eng.112(8): 823-826.
5. Cai, Y., Shi, B., Ng, C. W. W., and Tang, C. (2006). " *Effect of polypropylene fiber and lime admixture on engineering properties of clayey soil*." J.Eng.Geo., 87(3-4), 230-240.
6. Kumar, A., Balajit, S. W., and Mohan,J. (2006). "*Compressive strength of fiber reinforced highly compressible clay*." J. Construct. Building Mater., 20(10), 1063-1068.
7. Nataraj,M.S and McManish, K.L. (1997). " *Strength and deformation properties of soils reinforced with fibrillated fibers*." J. Geosynth. Int., 4(1), 65-79.
8. Nagu P.S, Chandrakaran . S and Sankar. N. (2008), *"Behaviour of lime stabilized clayey soil reinforced with Nylon fibers*", Proc.8th Int.Conf.on. Geotechnical and Highway Engineering, Geotropic, Kual Lumpar, Malaysia, May.
9. Ramesh , H.N. Manoj Krishna , K.V and Mamatha , H.V. (2010), "*Compaction and Strength behaviour of lime-coir fiber treated Black cotton soil*". Int. J of Geomechanicas and Engineering, **2**, 19-28.
10. Venkatappa Rao, G.,Dutta.R.K., and Ujwala,D. (2005), "*Strength characteristics of Sand Reinforced with coir fibre and coir Geotextiles*"Electronic Jou. of Geotechnical *Engineering*,USA,Vol.10/G, http://www.ejge.co.in.
11. Haeri. S. M., Noorzad. R.,Oskoorouchi. A. M(2000), "*Effect of geotextile reinforcement on the mechanical behaviour of sand*", Jou. Of Geotextiles and Geomembranes,Vol.18, pp385-402.
12. Girish, M.S and Ramanatha Ayyar (2000) "*Improvement of durability of coir geotextiles*". Proc. of the Indian Geotextiles Conference, Bombay,India, 309–310.