Load Settlement Characteristics of Model Footings Resting on Surface Treated Coir Fiber Reinforced BC Soil Overlying Loose Stratum

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Abstract: In nature there are situations where in foundation had to be placed over loose soil deposits. In such cases, deep foundations are recommended which increases cost of the structure. Black cotton soils, because of its high swelling and shrinkage characteristics, have been a challenge to geotechnical engineers, increasing the strength of Clayey soil which is formed introducing randomly distributed fibers results in comparatively more homogeneous soil mixture and is one of the popular methods of soil stabilization. In the present study, model footing resting on BC soil reinforced with optimum percentage of treated and untreated coir fiber underlain by loose soil deposit was conducted to study its influence on bearing capacity and settlement. Loose soil deposit has been simulated by compacting sawdust in prefabricated steel tank. BC soil reinforced with optimum percentage of treated and untreated coir fibers has been compacted over loose sawdust and load settlement characteristics were determined at various D/B ratio of 1, 2, 3 and for different sized model footings. The results indicated that settlement of model footings is significantly small at lower D/B = 1 and 2 ratios. Bearing capacity of BC soil is also found to be significantly affected by fiber reinforcement.

Key words: Black cotton soil, model footing, treated coir fiber, bearing capacity factor, RDF.

1. Introduction

The significant purpose of a foundation is the appropriate transmission of the loads coming on superstructure to the soil in a way such that the soil is neither overstressed nor undergoes deformations which would cause undesirable settlements. BC (black cotton) soil is a highly problematic soil which has medium to high compressibility due to its high swelling and compressibility characteristics. Design and construction of any infrastructure on a BC soil is a challenging task for engineers and in some cases even resulting in the collapse of the structures. Reinforcing soil with natural fibers is 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 are 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

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different parameters on shear strength. Unconfined compression tests 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 kaolinite-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 studies, it was varied from 0.05 to 0.25% [5] while in other study [6] it was varied up to 2.0%. Applications of synthetic and natural fibers were studied [7-12] using RDCF (randomly distributed fiber) and found that the RDCF increases the shear and compressive strength along with improvement in ductility of clayey soils.

In the present study, the effects of coir fiber reinforced sand underlain by loose soil on the bearing capacity and settlement were studied by conducting load settlement tests on model footing resting on coir fiber reinforced BC soil.

2. Materials Used

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 425 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 20 to 30 mm lengths were used as a natural reinforcing material, and were obtained from the local small scale factory in Gubbi, Karnataka, India.

Table 1 Properties of black cotton soil.

Properties	Values
Liquid Limit, LL (%)	65
Plastic Limit, PL (%)	21
Shrinkage Limit, SL (%)	10.85
Specific gravity, G	2.62
Silt + clay size (%)	79
Sand size (%)	21

Treated coir fiber is used as an effective natural geo-synthetic reinforcing material. Fibers are chemically treated to make it waterproof and to induce friction on its surface.

Chemicals like sodium hydroxide, Ethanol, Benzene and water based epoxy resin were used to modify the surface characteristics of coir mat. The method of surface treatment of coir mat has been explained in detail in the earlier paper [13].

Saw dust is used to simulate loose stratum that is made to underlain fiber reinforced BC soil which for practicality. Several trails are conducted by compacting the saw dust and the density of the compacted soil dust was determined and the density was found to be 0.52 g/cc. This density is constantly maintained throughout the current investigational experiment.

3. Methodology

3.1 Proctor Compaction Test

Proctor compaction test on BC soil as per BIS 2720 part VII (1980) was conducted to obtain the MDD (maximum dry density) 1.59 g/cc and OMC (optimum moisture content) 20%. The BC soil was compacted using the OMC to obtain MDD and placed above the sawdust stratum to have different D/B ratios, where D is depth of BC soil stratum and B is breadth of footing.

The bed of sawdust was hand compacted so as to achieve a density of 0.52 g/cc. Reinforced BC soil layer with coir fibers of average length 20-30 mm and admixed at 0.2% by dry weight of coir fibers w₂ as used and compared its performance with unreinforced BC soil layer. Both the layers were prepared to overlay sawdust stratum in a steel tank of base dimension 300 mm × 300 mm and a height of 380 mm. By using a lubricating gel, sidewalls of the steel tank were made smooth to reduce boundary effects.

The layer of reinforced or unreinforced BC soil was prepared separately for a pre determined depths (1 B, 2 B, 4 B) and then it is placed on saw dust layer which resembles weak soil stratum below BC soil.

3.2 Model Footings Used

After the preparation of BC soil bed, the surface is leveled and the model footing of size 70 mm, 50 mm and 30 mm is placed exactly at the centre of load cell to avoid eccentricity in loading. An indentation was made on the footing top at its centre to accommodate ball bearing on which vertical load is applied for the footing. The load is applied by load cell on the model footing resting on black cotton soil overlaying loose stratum and black cotton soil is reinforced with treated coir fiber to improve its bearing capacity. Fig. 1 shows schematic diagram of set up used in the present investigation.

The load was applied in smaller increments; each load increment is maintained constant until the footing settlement is stabilized. The applied load vs. settlement characteristics for different depths of footing are noted down. The settlement is measured by using dial gauges attached to the tank.

4. Results and Discussions

The results of the load settlement tests using model

footings were plotted as load versus settlement for various configurations used in the experimental study. Fig. 2 shows typical plot of variation load-settlement for all the footing sizes and for all D/B ratios used in the present study.

The loads corresponding to 5 mm and 10 mm settlement of model footings were obtained from these plots. Tables 2 and 3 show the summarized values of load in kN obtained for all the model footings resting on BC soil with different D/B ratios corresponding to 5 mm and 10 mm footing settlement respectively for both fiber reinforced and unreinforced BC soil. The BCR was thus calculated as the ratio of load in kN obtained for fiber reinforced BC soil to load in kN for unreinforced BC soil obtained at the same settlement of 5 mm and 10 mm respectively.

Figs. 3 and 4 show variation of BCR obtained at different D/B ratios and for different model footing widths used in the present study. It can be observed that the load carrying capacity of fiber reinforced BC soil is significantly larger than that of the unreinforced BC soil for same settlements. It can be seen that BCR value is greater than 1 for all the cases of fiber reinforced BC

Fig. 1 Schematic set up.

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Fig. 2 Typical variation of load-settlement for different footing sizes and for different D/B ratios.

Table 2 BCR values for different widths of model footings and for different D/B ratios corresponding to 5 mm settlement.

Footing size (m)	Load (KN) BC soil + TCF			Load (KN) BC soil - URF			BCR value		
	D/B ratio			D/B ratio			D/B ratio		
	1	2	4	1	2	4	1	2	4
0.07	0.24	0.26	0.27	0.12	0.12	0.13	2.25	2.16	2.11
0.05	0.18	0.20	0.20	0.06	0.08	0.10	3	2.5	2
0.03	0.15	0.16	0.16	0.04	0.06	0.08	3.75	2.67	2

Table 3 BCR values for different widths of model footings and for different D/B ratios corresponding to 10 mm settlement.

Footing size (m)	Load (KN) BC soil + TCF			Load (KN) BC soil - URF			BCR value		
	D/B ratio			D/B ratio			D/B ratio		
	1	2	4	1	2	4	1	2	4
0.07	0.36	0.38	0.39	0.17	0.225	0.23	2.11	1.68	1.69
0.05	0.29	0.315	0.32	0.125	0.15	0.17	2.32	2.1	1.88
0.03	0.235	0.265	0.265	0.09	0.11	0.15	2.611	2.4	1.76

soil indicating that the introduction of treated coir fiber as a reinforcing material increases the load carrying capacity of BC soil.

The minimum BCR value from different specified settlements was found to be 1.32 and the maximum is 3.75. Hence on an average 1.5 to 3 times the increase in strength because of the reinforcement of treated coir fiber in BC soil is observed.

Further, as the width of footing increases the load

carrying capacity increases for the same settlement. Higher BCR value is observed for the footing of smaller dimension. The test results also indicate that increase in the depth of BC soil over loose stratum decreases BCR—indicating the decrease in the influence of loose stratum on bearing capacity of BC soil as shear failure zone may lie entirely in BC soil stratum and hence bearing capacity is predominantly influenced BC soil alone.

Fig. 3 BCR with D/B ratio corresponding to footing settlement of 5 mm.

Fig. 4 BCR with D/B ratio corresponding to footing settlement of 10 mm.

5. Conclusions

Based on the preset experimental study the following major conclusions are drawn:

- For specified settlements (5 mm and 10 mm) of footings, load carried by fiber reinforced BC soil layer is significantly larger than unreinforced BC soil layer for all reinforcing depths of $D = 1B, 2B$ and $4B$.
- The minimum BCR value from different specified settlements was found to be 1.32 and the maximum is 3.75. Hence, on an average 1.5 to 3 times the increase in strength because of the reinforcement of treated coir

fiber in BC soil is observed.

- As the width of footing increases, the load carrying capacity increases for the same settlement. However, higher BCR value is observed for the footing of size of smaller dimension.
- Maximum improvement in bearing capacity of coir fiber reinforced BC soil occurs when the depth of BC soil stratum over loose stratum is maintained at ratio $D/B = 1$.
- The test results indicate that increase in the depth of BC soil over loose stratum decreases BCR—indicating the decrease in the influence of loose

stratum on bearing capacity of BC soil as shear failure zone may lie entirely in BC soil stratum.

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