Effect of Surface Treatment on Settlement of Randomly Distributed Coir Fiber Reinforced Sand

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Abstract **- Use of natural materials and developing a by-product that are most beneficial for use in construction industry generates employment in rural areas. Though use of natural materials such as coir fibers is well established, there extent of use in construction field is limited by the fact that these are biodegradable materials. In this context, the objective the present study is to surface treat the coir fibers, making it hydrophobic. Model footing tests using these surface treated randomly distributed coir reinforced sand bed was conducted. The results indicate that the surface treatment of coir products is beneficial in increasing the strength of reinforced soil when compared with untreated coir fibers.**

Keywords- **model footing, surface treatment, settlement reduction factor(SRF), coir fiber.**

I. INTRODUCTION

Foundations or substructures that need to transfer load from superstructure over poor sub-soil conditions need special attention by structural engineers. In such cases, one has to suggest a type of substructure that may prove to be uneconomical. Inclusion of reinforcement to strengthen sub-soil may prove to be a viable alternative, in which shallow foundations can be designed with safety. In the past three decades, reinforced soil foundations (RSF) have been widely used in various geotechnical engineering applications. Reinforcement in the past and extensive investigations were concentrated towards performance of synthetic reinforcements, which were found to function satisfactorily in most adverse soil conditions. However, because of their non-biodegradability, it was found to pose environmental and ground pollutions on the long run. Availability of natural plant based reinforcement materials, in subsequent stages, made engineers to explore the possibility of them being used as reinforcements in soils. In countries where the availability and cost of the synthetic reinforcing materials are a major constraining factor and where natural materials are available in plenty, the potential of natural materials for use as soil reinforcing elements is worth examining. Amongst the naturally occurring materials, coir which is the processed husk of ripe coconuts is reputed to be the strongest and most durable. In countries where the availability and cost of the synthetic reinforcing materials are a major constraining factor and where natural materials are available in plenty, the potential of natural materials for use as soil reinforcing elements is worth examining. Amongst the naturally occurring materials, coir which is the processed husk of ripe coconuts is reputed to be the strongest and most durable. Coir is a cheap and abundant waste material in India, Indonesia, Brazil, and Sri Lanka and in some other Asian countries where coconuts are grown and subsequently processed. Unlike synthetic reinforcing materials, coir is bio degradable. However, due to its high lignin content (about 40-46%), degradation of coir takes place much more slowly than that in the case of other naturally occurring materials. Also it has acceptable strength properties and it does not pose much environmental problems on its long run. However the main drawbacks with regards to the use of these materials are its poor compatibility between soil and reinforcement matrix. Lignin, pactin and other impurities within the coir fiber are considered harmful for its adhesion with the matrix during the composite fabrication. Hence in order to increase and to have better interaction between reinforcement and soil, suitable surface treatment is proposed to be introduced to modify the surface characteristics of coir mat which enhance its non-bio degradability as well as frictional interaction between soil and reinforcement. Several investigations have been carried out [1-7] with regard to the bearing capacity of fiber type of reinforcements and have indicated that both synthetic and natural materials when used as reinforcement in soils are beneficial in reducing the settlement of reinforced soil. In all these investigations, it has been observed that the layout and configuration of reinforcement play a vital role in bearing capacity improvement rather than the tensile strength of the material. In contrast randomly distributed fiber form of reinforced soils exhibit some advantages. The objective present study thus is to understand the performance of randomly distributed treated fiber type of reinforcement. For this study, the locally available coir based materials have been used as reinforcement.

II. MATERIALS

A. Sand Used

Sand a naturally occurring granular material composed of finely divided rock and mineral particles was used which was extracted from Bangalore. Properties of sand used in the present experimental study are as shown in Table I.

B. Coir Fiber Used

Coir fiber used in the present study were obtained from coir industry, Gubbi, Tumkur district, Karnataka, India. Typical properties of coir are as shown in Table II.

C. Stone Dust Used

Stone dust/particles passing 75 micron IS sieve which a waste product is during processing of cutting granite and a Shabad stone was used. The specific gravity of stone dust used is 2.62.

D. Chemicals Used

Chemicals such as sodium hydroxide, Ethanol, Benzene and water based epoxy resin were used to modify the surface characteristics of coir fibers.

Table I
Properties of Sand Used

Coefficient of uniformity, (C_u)	4.48
Coefficient of curvature, C_c	0.96
Specific gravity, G	2.66
Maximum density of sand, γ_d(max.), kN/m^3	16.7
Minimum density of sand, γ_d(min.), kN/m^3	14
Classification of Sand	SP

Table II
Typical Properties of Coir Fibers

Young's modulus	4000-5000Mpa
Tensile strength	140-150mpa
Elongation index	15-17.3%
Thermal conductivity	0.047W/m K
Density	1.15-1.33 Kg/m3
water absorption	10%
Total water soluble	26%
Pectin soluble in water	14.25%
Hemi celluloses	8.50%
Lignin	29.23%
Cellulose	23.81%

E. Surface Modification

As per the review of literature [8], alkali treated coir fibers using sodium hydroxide of 4% concentration is found to reduce water absorption of coir fibers by 70%. In addition, to make the coir fiber hydrophobic, it was also coated with water based epoxy resin. Such a coating was found to make the surface of coir fibers smooth. Hence, the epoxy coated coir fibers was sprayed with liberal doses of stone dust powder, which sticks to the surface randomly. This enhances the frictional characteristics of surface of coir, which is essential for interaction between reinforcement and soil. The treatment of coir fibers were done in stages: (i) The fibers were first scoured with detergent solution (2%) at 70°C for one hour and washed with distilled water and dried in vacuum oven at 70°C. (ii) Fibers are then immersed in a 1:2 mixture of Ethanol and Benzene for 72 hours to dewax the sample followed by washing with distilled water and air drying. (iii) Next the fibers were treated with 6% concentrated NaOH solution for 3 hours at 100°C with occasional shaking followed by washing with distilled water to obtain alkali treated fibers. (iv) Further with these treated fiber materials, fibers of length 20mm were cut. (v)Further these 20mm length fibers were sprayed with a water based epoxy resin [with 1(base):1(hardener):2(water)], which is available in the market with the name Dr.Fixit Damp guard and were air dried for 6-8 hours. (vi)Epoxy coated fibers were immediately sprinkled with stone dust passing 75µ and were air dried for 6-8 hours.

III. METHODOLOGY FOR LOAD TESTING

The load tests on model footings resting on unreinforced sand and reinforced sand were conducted in a load frame that can apply load at a continuous rate of 1.25mm/minute. Sand beds were prepared in a cylindrical steel tank of diameter 300mm and height 350 mm. The model footing used for the tests was circular in shape and is of 50 mm diameter and is of sufficient thickness to withstand bending stress.Fig.1 shows the typical layout of the reinforced sand bed adopted in the model tests.

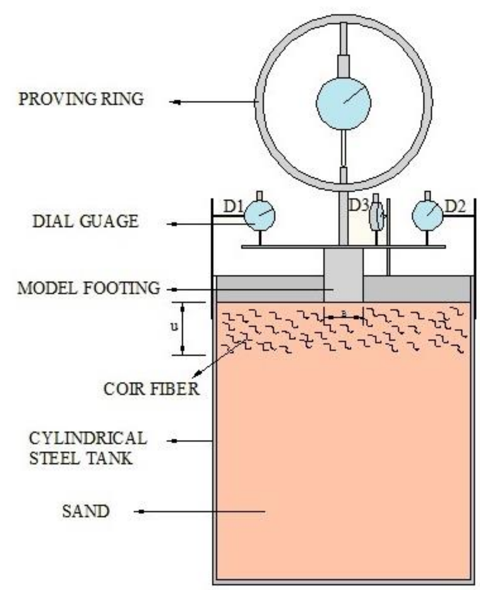

Fig.1 Typical layout of Reinforced sand

Sand bed was prepared up to the height of 30cm by compaction in three layers and a relative density of 80% was maintained for all the tests. Treated fibers of average length 20mm were randomly reinforced for the required depth. The depth of randomly distributed treated fiber reinforced sand from the bottom of the footing is measured as u, and model footing tests for various depth of reinforcement to width of footing ratio(u/B) 0.6, 0.3, 1.0 and 2.0 were conducted.

Tests with reinforced sand beds were carried out by placing randomly distributed treated fiber at the predetermined depths while preparing the sand beds. After preparing the bed, surface was levelled and the footing was placed exactly at the centre to avoid eccentric loading. The footing was loaded and the load was applied at the rate of 1.25mm/min, measuring the corresponding footing settlements through the dial gauges D1, D2 and D3.Average of the three readings were considered as final settlement for a given load intensity. Model footings resting on unreinforced sand bed were also conducted to compare the results in terms of settlement reduction factor(SRF). Table III shows the different parameters considered in this experimental study. Experiments were repeated with randomly distributed untreated coir fiber reinforced sand using the same parameters for comparison purpose.

Table III
Parameters Considered in the Experimental Study

Type of reinforcement	u/B ratio	Depth of reinforcement u(mm)
Unreinforced	-	-
Untreated fibre of 20mm average length	0.3,0.6,1,2	15,30,50,100
Treated fibre of 20mm average length	0.3,0.6,1,2	15,30,50,100

IV. Results and Discussions

To evaluate the performance of model footings under randomly disributed coir fiber reinforcement placed at various u/B ratio of 0.3, 0.6, 1 and 2 settlement reduction factor(SRF) was evaluated which is defined as $SRF=(S_o-S_r)/S_o*100$. Where S_o is settlement of unreinforced sand at specified S/B and S_r is corresponding settlement of reinforced sand.

Normalized stress was calculated as the ratio between pressure corresponding to specified S/B ratio and corresponding peak stress.Variations between SRF versus normalized stress were plotted to acess the performance of model footings for settlement. Fig.2 shows such a variation for model footings resting on randomly disributed coir fiber reinforced sand. It can be seen that there is significant increse in SRF with increase in depth of fiber reinforced zone i.e u/B ratio. Hence settlement of footings on fiber reinforced sand is dependent on depth of fiber reinforced zone. SRF obtained corresponding to u/B=0.6 is significant for all values of normalized stress, indicating u/B=0.6 becomes optimum depth of fiber reinforced zone from consideration of both bearing capacity and settlement.Table IV shows tabulated values of normalized stress and corresponding settlement reduction factor for untreated randomly distributed coir fiber reinforced sand.

Table IV
Tabulated values of normalized stress and corresponding settlement reduction factor for untreated randomly distributed coir fiber reinforced sand.

Series	U/B	Normalized Stress		
		s/B=2.5%	s/B=5%	Peak Stress
Unreinforced	-	0.285189	0.71288	1
S1 :0.2%	0.3	0.283843	0.803753	1
S2:0.2%	0.6	0.310262	0.694159	1
S3:0.2%	1	0.184143	0.445271	1
S4:0.2%	2	0.141691	0.461816	1
Series	U/B	SRF Corresponding to		
		s/B=2.5%	s/B=5%	Peak Stress
Unreinforced	-	-	-	-
S1 :0.2%	0.3	19.21804	27.99778	45.01649
S2:0.2%	0.6	55.99216	49.51702	58.06361
S3:0.2%	1	34.90221	33.16112	47.43353
S4:0.2%	2	-0.997	14.30663	35.53221

Fig.2 shows a comparitive variation between untreated and treated randomly distributed coir fiber reinforced sand. It can be seen that u/B=0.6, the SRF obtained for randomly distributed treated coir fiber reinforced sand is significantly larger than that obtained for randomly distributed untreated coir fiber reinforced sand. Thus the effect of surface treatement increases the interfacial interaction between particles and reinforcement and hence is very effective in reducing the settlement of model footings.Thus the effect of surface treatment for coir fibers can be considered beneficial in effectively increasing bearing capacity and consequently causing a reduction in settlement.Table V shows tabulated values of normalized stress and corresponding settlement reduction factor for surface treated randomly distributed coir fiber reinforced sand.

Table V
Tabulated Values of Normalized Stress and Corresponding Settlement Reduction Factor for Surface Treated Randomly Distributed Coir Fiber reinforced sand.

Series	U/B	Normalized Stress		
		s/B=2.5%	s/B=5%	Peak Stress
Unreinforced	-	0.285189	0.71288	1
S1 :0.2%	0.3	0.582784	0.97826	1
S2:0.2%	0.6	0.512179	0.85964	1
S3:0.2%	1	0.345457	0.69828	1
S4:0.2%	2	0.25221	0.64012	1
Series	U/B	SRF Corresponding to		
		s/B=2.5%	s/B=5%	Peak Stress
Unreinforced	-	-	-	-
S1 :0.2%	0.3	73.23847	64.6334	68.0189
S2:0.2%	0.6	78.39615	72.6850	75.9252
S3:0.2%	1	65.06434	59.4418	68.6625
S4:0.2%	2	13.68499	45.3775	61.7629

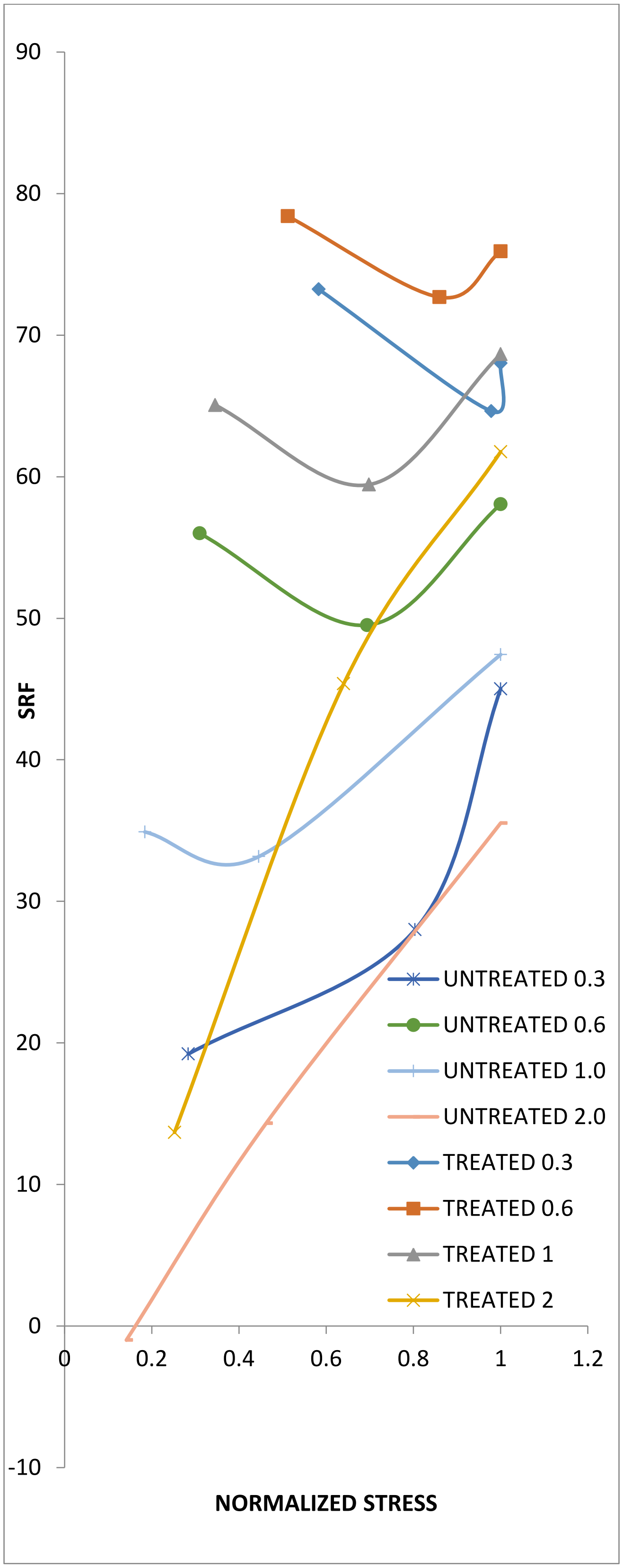

Fig. 2 SRF vs Normalized settlement for untreated and surface treated Randomly Distributed Coir Fiber reinforced sand at different u/B ratios.

The negative values in a certain case is due to the fact that the settlement of reinforced sand being greater than that of unreinforced sand. The reason for this trend is attributed to the fact that, when a settlement exceeds a certain percentage nearer to the failure stress(or peak stress), mobilization of shear strength of soil leads to greater settlement as sudden collapse occurs when sand fails in general shear mode.

V. CONCLUSIONS

On the basis of present experimental study, the following conclusions have been drawn:

1. Surface treatment of coir products make them hydrophobic and a more beneficial by product for soil reinforcement.
2. It can be seen that there is significant increse in SRF with increase in depth of fiber reinforced zone i.e u/B ratio. Hence settlement of footings on fiber reinforced sand is dependent on depth of fiber reinforced zone. SRF obtained corresponding to u/B=0.6 is significant for all values of normalized stress, indicating u/B=0.6 becomes optimum depth of fiber reinforced zone from consideration of both bearing capacity and settlement. This indicates that surface treatment of coir products is more beneficial when used as reinforcement from consideration of settlement of model footings. The effect of surface treatment thus increases interfacial interaction between particles and reinforcement, which is very effective in decreasing the settlement.

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