Effect of Surface Treatment on Settlement of Coir Mat Reinforced Sand

Sachin Patil

Assistant Professor in Civil Engineering Department,
Rao Bahadur Y Mahabaleshwarappa Engineering College, Ballari-583104, India

***Abstract:* - Employment in rural areas is generated when by-product from the natural materials is used in construction industry. The extent of usage of coir fibres in construction industry is restricted by the fact that it is biodegradable. Though use of natural materials such as coir fibers is well established. In this view, the objective the present study is to surface treat the coir mats, making it hydrophobic. Model footing tests using model footing of 50mm diameter resting on Surface treated coir mat of different opening size were 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 mats.**

***Keywords:* model footing, surface treatment, settlement reduction factor(SRF), coir mat, coir fiber**

I. INTRODUCTION

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, 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 mat 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 to grid or mat form of reinforced soils exhibit some advantages. The objective present study thus is to understand the performance of mat type of reinforcement. For this study, the locally available coir based materials have been used as reinforcement.

II. MATERIALS

2.1 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 1

2.2 Coir Mat Used

Coir mat used in the present study were prepared from coir obtained from coir industry, Gubbi, Tumkur district, Karnataka, India. Typical properties of coir are as shown in Table 2.

2.3 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.

2.4 Chemicals Used

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

Table1: Properties of Sand Used

Properties of sand	
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

Table2: Typical Properties of Coir Fibers

Properties of coir	
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%

2.5 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. (iii) Further with these treated fiber materials, mats of diameter 28cm with mat openings of size 10x10 mm,20x20 mm and 30x 30 mm were prepared. (iv)Further these mats 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. (v)Epoxy coated fiber mats 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.

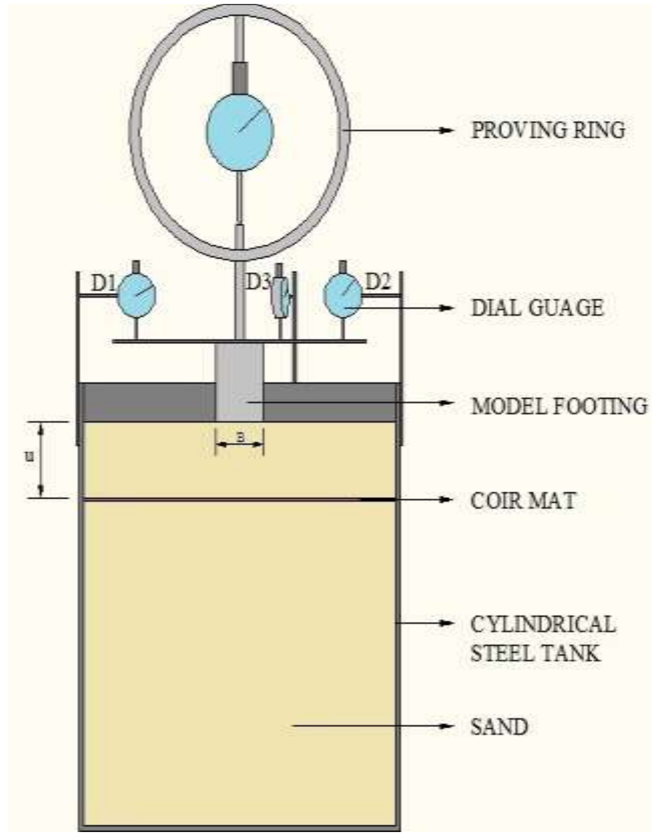

Fig.1: Typical layout of Reinforced sand

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 coir mats of opening 10x10 mm, 20x20 mm and 30x 30 mm and of diameter slightly less than the inner diameter of tank, to avoid side friction, were used and placed at specific depths while preparing the sand bed for each model test. The depth of layer of reinforcement in case of treated mat 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 the coir mat 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 3 shows the different parameters considered in this experimental study. Experiments were repeated with untreated coir mat using the same parameters for comparison purpose.

Table 3: Parameters Considered in the Experimental Study

Type of reinforcement	u/B ratio	Depth of reinforcement, u(mm)
Unreinforced	-	-
10mmx10mm treated and untreated mat	0.3,0.6,1	15,30,50
20mmx20mm treated and untreated mat	0.3,0.6,1	15,30,50
30mmx30mm treated and untreated mat	0.3,0.6,1	15,30,50

IV. RESULTS AND DISCUSSIONS

To evaluate the performance of model footings under coir mat reinforcement placed at various u/B ratio of 0.3, 0.6 and 1.0, 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. Figure 2 shows such a variation for model footings resting on reinforced sand with different u/B ratios and different size of mat openings. In majority of the cases, SRF increases with increase in normalized stress. Further, with decrease in mat opening size, there is significant increase in SRF for a given u/B ratio. Further, with increase in u/B ratio, there is decrese in SRF, indicating that when mat reinforcement is placed at shallow depth, the settlement of the model footings also decreases significantly. Increase in the mat opening size, also increases settlement.

Table 4 shows tabulated values of normalized stress and corresponding settlement reduction factor for untreated coir mat.

Table 4: Tabulated values of normalized stress and corresponding settlement reduction factor for untreated coir mat.

Series	U/B	Normalized Stress			SRF Corresponding to		
		2.50%	5%	Peak	S/B=2.5%	S/B=5%	Peak Stress
Unreinforced	-	0.285189	0.71288	1	-	-	-
S1: 10x10	0.3	0.178372	0.520068	1	53.07546	58.45872	68.80272338
	0.6	0.232696	0.647064	1	46.25644	42.48649	57.57541995
	1	0.421853	0.893206	1	43.91242	31.8514	44.61496144
S2: 20x20	0.3	0.32198	0.711113	1	75.95017	70.2194	75.07807891
	0.6	0.300784	0.640025	1	37.71176	17.39637	37.7531899
	1	0.25878	0.806589	1	-13.258	1.212277	100
S3: 30x30	0.3	0.131169	0.418517	1	10.16558	25.47048	43.37640442
	0.6	0.172765	0.573829	1	-6.19792	11.47501	33.92567592
	1	0.653532	0.952215	1	-139.894	100	100

Figure 2 shows a comparitive variation between untreated and treated coir mats. It can be seen that for a given coir mat opening and at u/B=0.3, the SRF obtained for treated coir mat is significantly larger than that obtained for untreated coir mat. 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 mat can be considered beneficial in effectively increasing bearing capacity and consequently causing a reduction in settlement.

Table 5 shows tabulated values of normalized stress and corresponding settlement reduction factor for surface treated coir mat and surface treated coir fiber.

Table 5: Tabulated values of normalized stress and corresponding settlement reduction factor for surface treated coir mat.

Series	U/B	Normalized Stress			SRF Corresponding to		
		2.50%	5%	Peak	S/B=2.5%	S/B=5%	Peak Stress
Unreinforced	-	0.285189	0.71288	1	-	-	-
S1: 10x10	0.3	0.164374	0.509785	1	51.0545	57.12393	68.13904199
	0.6	0.239015	0.645231	1	49.00686	43.52433	58.20415864
	1	0.417528	0.843939	1	94.02745	39.8514	49.16915865

S2: 20x20	0.3	0.311828	0.707723	1	77.30495	70.89892	75.23881036
	0.6	0.276758	0.574824	1	57.41176	20.93483	41.84167073
	1	0.261006	0.667825	1	-1.58333	9.84561	-57.5121418
S3: 30x30	0.3	0.137974	0.543758	1	15.54902	37.80492	57.73947741
	0.6	0.180179	0.583936	1	-1.30381	16.66714	35.74312371
	1	0.550885	0.861757	1	-61.8794	100	100
S4:0.2%	2	0.25221	0.640122	1	13.68499	45.37757	61.7629179

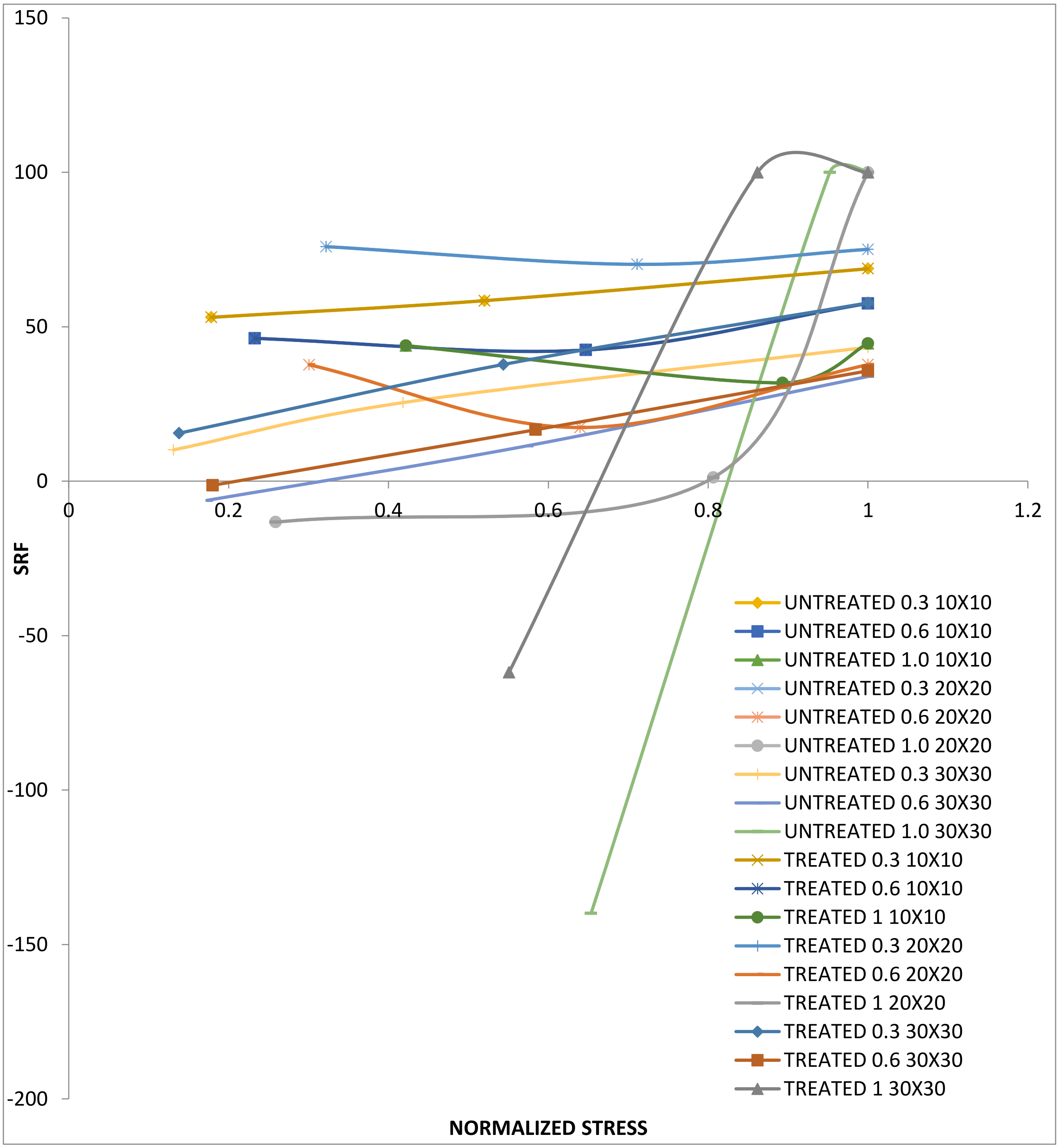

Fig 2: SRF vs Normalized settlement for untreated and surface treated coir mats at different u/B ratios.

The negative values in certain cases are 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. The SRF obtained for a given mat opening which over surface treated were significantly higher, particularly at peak stress, when compared with untreated coir mat. 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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