Behaviour of Square Model Footing on Sand Reinforced with Woven Coir Geotextiles

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Abstract: This paper presents the results of laboratory model tests carried out on square footings supported on woven coir geotextile reinforced sand beds. The influence of various parameters such as depth of reinforcement, length and number of layers of reinforcement were studied. On the whole, the results indicate that up to four fold increase in strength and about eighty percent reduction in settlement can be obtained by providing two or more layers of reinforcement. The optimum value for depth of reinforcement was found to be 0.25 times the width of foundation. It was also found out that bearing capacity does not proportionately increase with length and number of layers of reinforcement. There exist an optimum layout of placement of geotextile.

Keywords: Coir geotextile, Depth of reinforcement, Number of layers, Bearing capacity, Reinforcement length.

Introduction

Geosynthetic applications are widely used as soil reinforcement and is a proven alternative to conventional ground improvement technique under appropriate conditions. These synthetic materials and products generally have a long life, but are costly and may create environmental problems in the future. 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 pro-cessed husk of ripe coconuts, is reputed to be the strongest and most durable.

Research on the use of coir as a soil-reinforcing material started in the 1990s. Triaxial shear tests carried out on sand reinforced with discrete, randomly oriented coir fibers of different lengths and fiber contents indicated that coir has great potential as a soil- reinforcing material in field applications [8]. Reference [9] conducted a series of triaxial compression tests on sand reinforced with randomly oriented coir fibers and evaluated the strength and stiffness response of the reinforced soil system. This paper reports a series of laboratory test results of plate load test on sand bed reinforced by woven coir geotextiles. The objectives of the study were to investigate the effects of depth, length and number of layers of reinforcement on pressure versus settlement behaviour of sand bed.

Literature Review

The use of coir as a reinforcement material has been studied by researchers [6-12]. Review of various literatures shows that the use of woven coir geotextiles in reinforcing shallow foundations are rare.

Reference [9] Conducted studies on a strip footing on sand which was reinforced with randomly distributed coir fiber and mesh elements. Results indicated an increase in ultimate bearing capacity values. Larger mesh size elements produced better performance compared to other inclusions.

Reference [8] conducted a series of triaxial shear tests on sand reinforced with discrete, randomly oriented coir fibers and indicated the potential of coir as an efficient reinforcing material.

Reference [6] conducted a series of laboratory model tests were conducted on square footing resting on loose sand reinforced with braided coir rope. The test results indicated a substantial reduction in normalized settlement with the introduction of braided coir rope. Three layers of braided coir rope reinforcement yielded optimal performance.

Materials and Methodology

Materials used in the study

The test soil used in the study was dry sand whose particle size distribution characteristics are shown in Fig.1.The basic and index properties of sand, determined according to ASTM standards are summarized in Table 1. The tests were done at 60%

relative density. Woven coir geotextiles were used as reinforcement in the present study. The physical properties of coir geotextiles according Indian standards are given in Table 2.

Table 1. Properties of sand used in the study

Properties	Value
Specific Gravity	2.63
D_{10} (mm)	0.32
D_{30} (mm)	0.48
D_{60} (mm)	0.82
C_u	2.56
C_c	0.88
I.S Classification	SP
Maximum Dry density (g/cc)	1.69
Minimum Dry density (g/cc)	1.46
Angle of Internal Friction at 60 % relative density	38.5^0

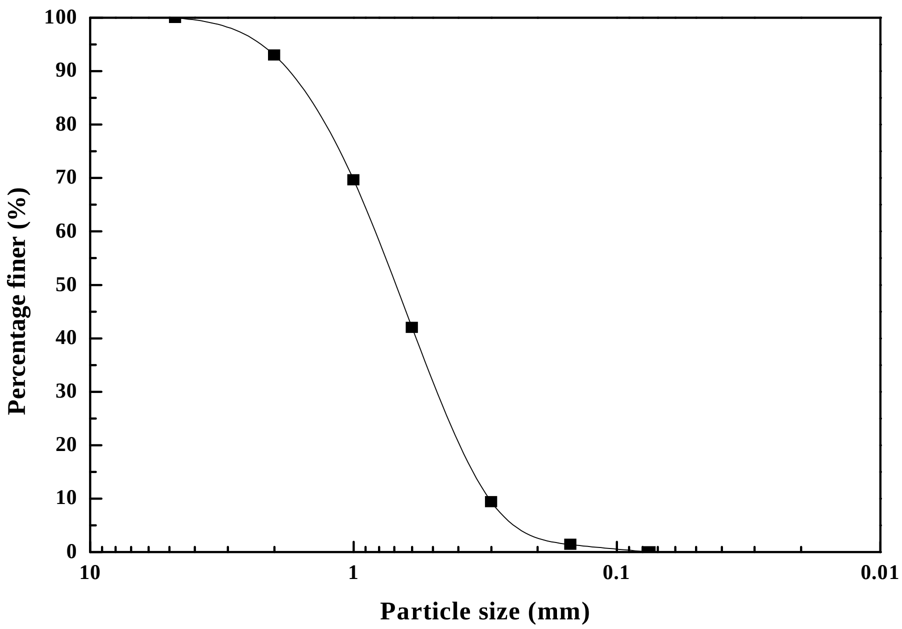

Fig.1. Particle size distribution characteristics of sand used in the study

Table 2. Properties of woven coir geotextile used in the study

Properties	Value
Mass per unit area	720 g/ m^2
Ultimate Load & Failure strain (Warp direction)	15 KN/m & 25%
Ultimate Load & Failure strain (Weft Direction)	9 KN/m & 8%
Aperture size (mmxmm)	5x12
Thickness	6mm

Methodology

For conducting model tests, sand was poured in to the test tank using a raining technique [1-3]. The height of fall to achieve the desired relative density was determined prior by conducting a series of trials with different heights of fall. The relative density achieved was confirmed by collecting samples in small cans of known volume placed at different locations in the test tank and determining the density of sand at the time of filling. After preparing the bed, the surface was leveled, and the footing was placed exactly at the center of the loading jack to avoid eccentric loading. The footing was loaded by a hand-operated hydraulic jack supported against a reaction frame. A recess was made in the footing plate at its center to accommodate a ball bearing, through which vertical loads were applied to the footing. A precalibrated proving ring was used to measure the load transferred to the footing. The load was applied in small increments. Each load increment was maintained constant until the footing settlement was stabilized. Two displacement dial gauges were positioned on either side of the footing by means of magnetic bases attached to the steel section of the tank. Average of the two displacement dial gauges were recorded [1-3]. The arrangement of the test series is shown in Fig.2.The objectives of the test series were to study the influence of depth, length and number of layers of reinforcement on the overall performance of the foundation. Test series were conducted by varying the number of layers (N), depth of reinforcement layer from the top of footing (u), and length of reinforcement layer (L).

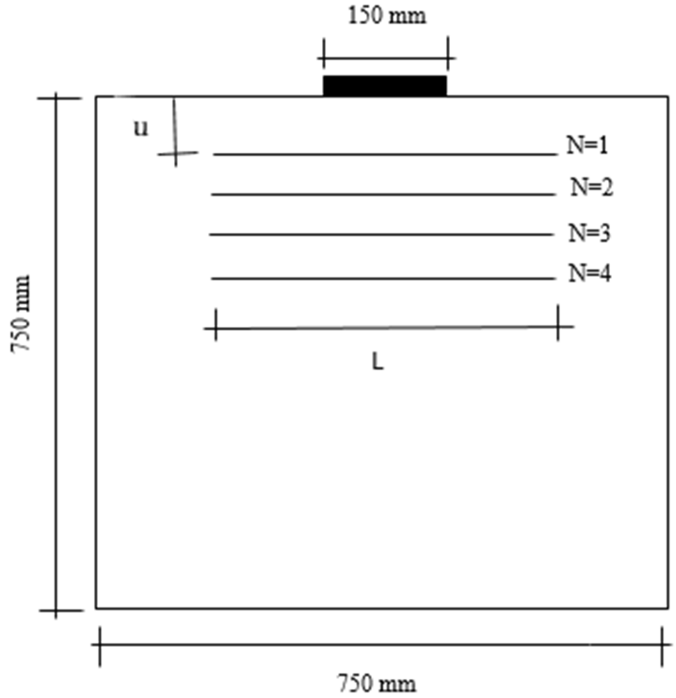

Fig. 2. Arrangement of geotextile reinforcement

Results and Discussion

Effect of depth of reinforcement

Fig.3 (a) shows the load settlement behavior of footing underlain by woven coir geotextile reinforced sand bed. For comparison result obtained from non-reinforced sand bed is also presented. The performance improvement for foundation at various depth of reinforcement is shown in figure 3(b). A non-dimensional term improvement factor is introduced to quantify the performance improvement [1-6]. Improvement factor is the ratio of footing pressure with reinforcement at a given settlement to the pressure on the unreinforced soil at the same settlement. It can be seen from Fig. 3(a) that pressure versus settlement behavior of woven coir geotextile reinforced foundation is better than that of unreinforced case. This is mainly due to the interface frictional resistance between sand and coir geotextile. Improvement factor versus u/B shows that bearing capacity of the footing increases up to a depth of 0.25 times the width of footing, there after it decreases because the reinforcement will be located out of the most effective zone. Here the improvement factor is taken for a settlement of 25 mm, which is considered threshold settlement for foundations. Maximum beneficial effect was obtained in this study by placing the woven coir geotextile reinforcement at a depth of 0.25 times the width of footing. It is also seen that placing the geotextile beyond 0.5 times the width of foundation, soil behavior is similar to unreinforced case.

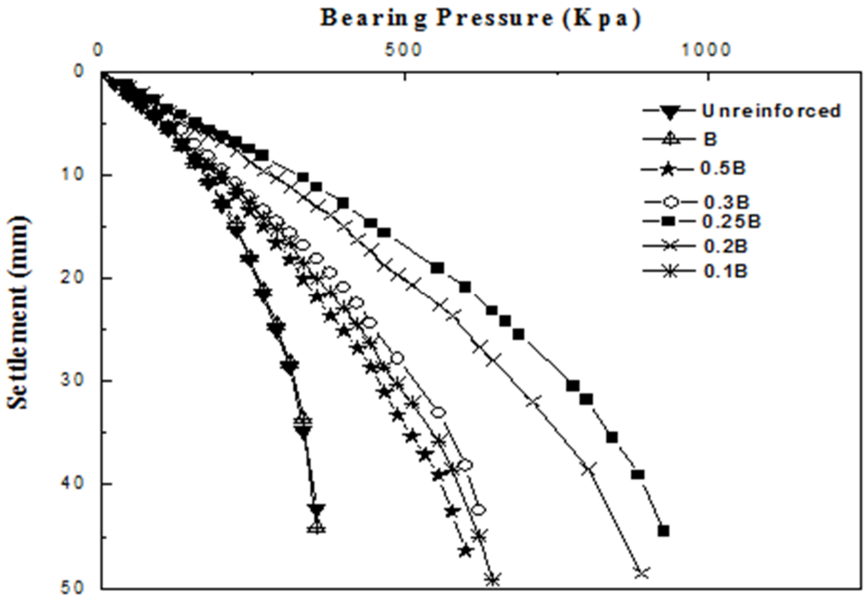

Fig.3 (a). Variation of applied bearing pressure with footing settlement for various depth of reinforcement

Effect of number of layers of reinforcement

Fig.4 (a) shows the applied pressure versus settlement behavior for various number of reinforcement layers (N). It can be seen that with increase in number of layers of coir reinforcement, the bearing capacity increases appreciably. However with an increase in number of layers above three, there is not much bearing capacity improvement. A settlement reduction factor is introduced by which improvement by reduction of settlement can be quantified. Settlement reduction factor = $(S_0\text{-}Sr)/S_0$, where S_0 is the settlement of non-reinforced sand bed at a given pressure and Sr is the settlement of sand reinforced with coir geotextile at the same pressure [6]. Fig. 4(c) shows the variation of Settlement reduction factor with improvement factor for different layers of reinforcement. Here in this case settlement reduction factor and improvement factor for different number of layers of reinforcement is taken for a normalized settlement (Settlement / width of foundation) of 30% of the non-reinforced sand bed [6]. It is seen that about 80% reduction in settlement and about four fold increase in bearing capacity can be obtained by providing two or more layers of reinforcement. It is also seen that beyond 3 layers there is not much improvement which may be due to the reinforcement layer positioned out of the effective zone.

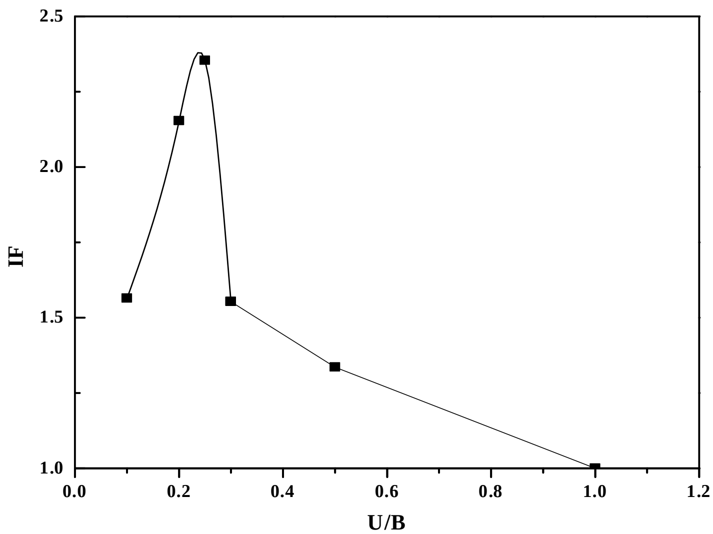

Fig.3 (b). Variation of Improvement factor with u/B

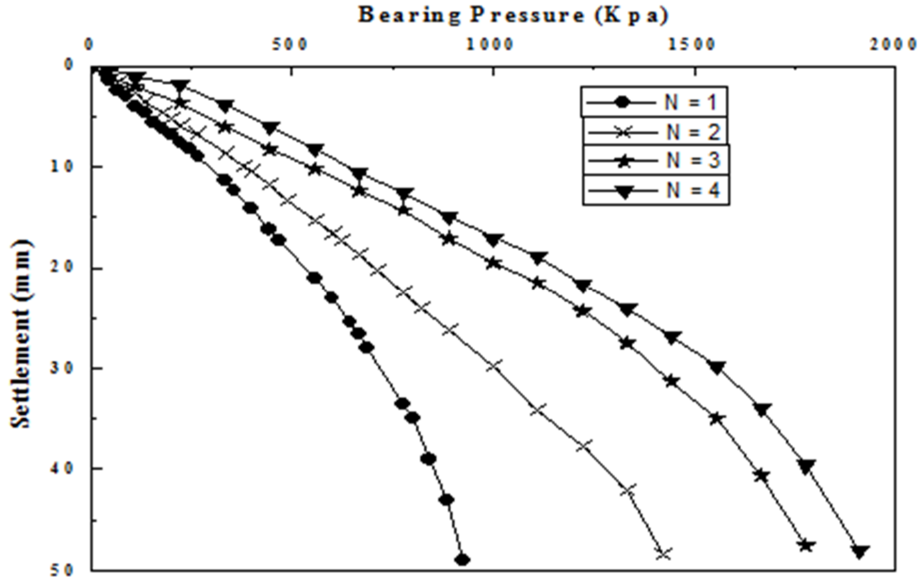

Fig.4 (a). Variation of applied bearing pressure with footing settlement for different layers of reinforcement

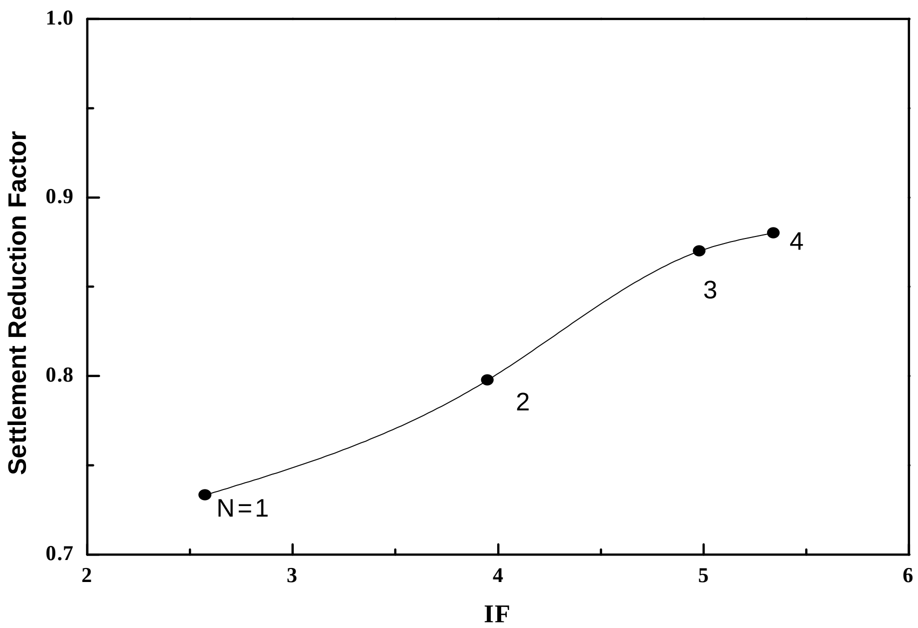

Fig.5 (a). Variation of settlement reduction factor with IF for different layers of reinforcement

Effect of length of reinforcement

Fig.5 (a) depicts the variation of applied pressure versus the settlement for different L/B ratios of reinforcement kept at optimum depth of 0.25B. Fig.5 (b) shows the variation of Improvement factor with normalized settlement values at different L/B ratios. From these figures it is clearly seen that improvement is not appreciable with increase in length. However providing a greater length will be beneficial regarding shear failure point of view.

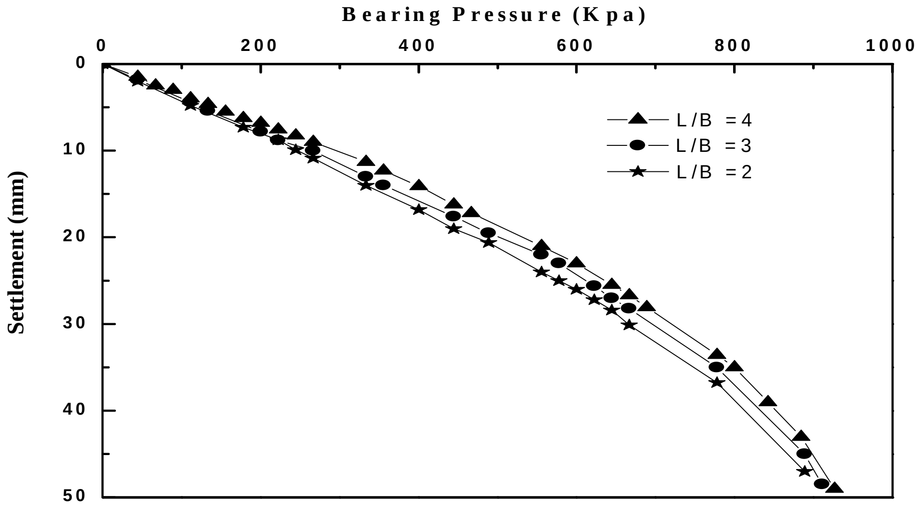

Fig.5 (a).Variation of applied pressure with footing settlement for different L/B ratio

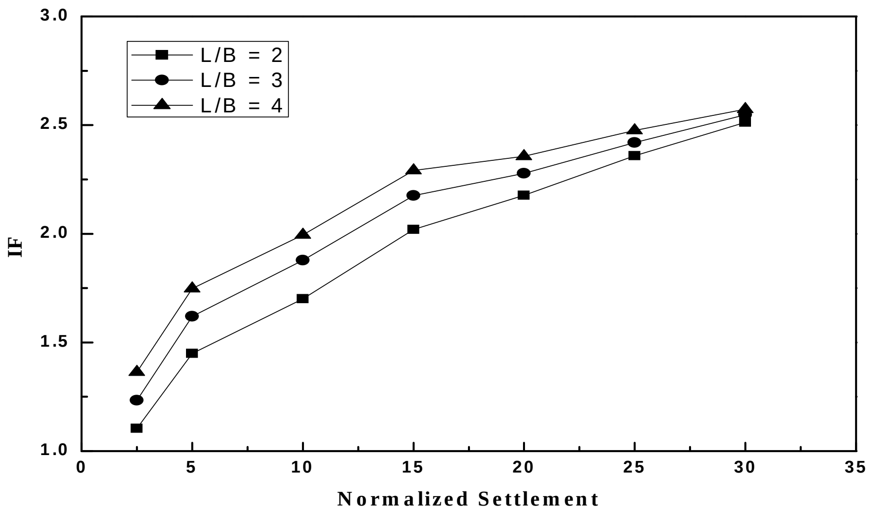

Fig.5 (b). Variation of Improvement factor with Normalized settlement for various L/B ratios

Conclusions

The use of natural fibres for erosion control and improvement of surficial stability of embankments is practiced in the state of Kerala in India, and this paper attempts to explain the degree of improvement obtained in terms of strength and stiffness by using this material. The Various parameters that were studied are length, depth and number of layers of reinforcement. Based on the results obtained the following conclusions can be obtained.

1) Provision of coir geotextile reinforcement significantly increases the load carrying capacity and reduces the footing settlement.
2) Optimum depth of the topmost layer of reinforcement is 0.25 times the width of foundation.
3) About 80% reduction in footing settlement and four fold increase in bearing capacity can be obtained by providing two or more layers of reinforcement.
4) The performance of foundation with increase in length is not appreciable, however a larger length will be beneficial regarding shear failure point of view.
5) However extensive research on large scale field tests is essential before actually applying them in the field.

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