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REINFORCING SAND WITH COIR FIBRE

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ABSTRACT

In order to utilise coir fibre, which is abundantly available in coastal India as an inexpensive material, in foundation beds, an investigation is taken up. Drained triaxial tests were performed on specimens of sand reinforced with coir fibres (25 mm and 50 mm long) upto 1%. The results are very encouraging in that the behaviour is similar to that observed in synthetic fibres and meshes. Considering that coir has a longer life compared to other natural fibres which degrade much faster, it is possible to use this method in rural housing for foundations.

INTRODUCTION

Fibre reinforcement of soils is an age-old technique used in the past for making unburnt clay bricks (reinforced with straw) and typified by the stabilising root systems of soil reinforcement to prevent erosion.

Many studies have been reported on the improvement of properties of soil reinforced with strips, fabrics, polymeric mesh elements, synthetic fibres etc. It is clear that addition of randomly distributed discrete inclusions to soils contribute to the increase in strength as well as stiffness. In view of the extensive availability of coir fibres in the coastal areas of India, it is planned to investigate their efficacy for possible use in foundation improvement, as buildings in these areas are invariably on soft clays.

LITERATURE REVIEW

Broms (1976) was perhaps the first to report the strength improvement of soils reinforced with geotextiles in triaxial testing. Since then many researchers reported studies on

i) the use of woven and non-woven fabrics as reinforcing elements (geotextiles, geogrids/geomeshes etc. as sheets or discs),

ii) the use of fills other than selected granular fills currently used,

iii) the use of randomly distributed elements such as polymeric mesh elements (Andrawes et al. 1986, Venkatappa Rao et al. 1994), metallic fibres (Fatani et al. 1991), synthetic fibres (Gray and Ohashi, 1983), shredded waste tyres (Foose et al. 1996), strips of reclaimed HDPE (Benson and Khire, 1993) or the Texsol system (Leflaive, 1988) in which a single mono-filament is spun or injected in a random pattern simultaneously with the deposition of a given sand.

Venkatappa Rao et al. (1987, 1994) reported investigations on two granular materials with three types of geosynthetics, viz. a non-woven geotextile, an woven geotextile and a geomesh in a disc form through triaxial testing. In addition, the influence of randomly distributed polymeric mesh elements (geomesh) (30 x 30mm and 50 x 50mm) was studied in detail. Using these results, computations were carried out to estimate the influence of geomeshes on the bearing capacity and settlement behaviour of different reinforced beds on clayey soils for several foundations (square). It was brought out that the increase in bearing capacity, depending on the ratio of thickness of reinforced bed to the width of the foundation can be more than 2.5 times.

Reinforcing Sand with Randomly Oriented Fibres

In fibre reinforced soil, the fibres are mixed with the soil to produce a relatively homogenous and isotropic material in order that the physical and mechanical properties are consistent. [This ought to be differentiated from oriented sheet/disc reinforcement which will produce an anisotropic effect]. However, the mechanism of reinforcement is yet to be thoroughly understood. The confining stress causes the friction between fibre and the soil particles to develop, thereby not allowing the particles to slide, resulting in tensioning the fibres. This could be causing an apparent confining effect at micro-level and in view of the randomly oriented and well distributed fibres, is expected to result in a reinforced soil mass to behave like a dense soil or over-consolidated soil.

COIR FIBRE

Coir is the fibre which surrounds the bare shell of a coconut protecting the kernel. India produces annually 175,000 t of coir fibre which is 66% of the world production. Whereas this is an industry estimate, it is familiar to those living in the coastal belt, that this fibrous material is usually thrown out as waste, at best it is used as fuel. At the same time, the coastal regions in which coconut trees grow in plenty, have soft clayey soil as the foundation soil, making foundation construction expensive. Through this investigation it is planned to investigate the extent of improvement one gets in granular material with the coir fibre as random inclusion. If found suitable, this can be used as a method of soil improvement in rural areas as an inexpensive technique.

Properties of Coir Fibre

The length of the fibre varies and can be as much 150 mm or more and the diameter is in the range of 0.1 to 0.8 mm. The coarser fibres are usually very stiff whereas the fine ones are softer. The strength of the fibre is in the range of 15 g/tex. Chemically about 50% of coir fibre is cellulose and around 45% is lignin, which is said to make it durable, say, compared to jute (another natural fibre) which with 14% lignin can decay much faster. When in soil, below water table/or continuously saturated (i.e. not subjected to drying and wetting) the strength loss in 3 months could be over 20%. More details on the durability characteristics of coir yarns are presented in Balan and Venkatappa Rao (1996).

EXPERIMENTAL WORK

Granular Material Used

Yamuna sand, a locally available fine grained, uniformly graded sand, was used in this investigation ($C_u = 2.29$, $C_c = 1.30$). The density of the specimens for triaxial testing was 14.0 kN/m^3 with a $D_r = 53\%$.

Triaxial Testing

Drained triaxial tests were conducted on 200 mm high and 100 mm diameter specimens reinforced with randomly distributed coir fibre. Out of the coir fibres of varying length, pieces were cut to either 25 mm or 50 mm. Specimens were tested at confining pressures 24.5, 49.0, 196.0, 392.4 kPa using 0.1, 0.3, 0.5 or 1.0 percent by dry weight of soil. Neither longer fibre could be used nor the percentage could be increased beyond 1% due to segregation and difficulties in mixing.

The desired quantity of coir fibre of chosen length, after air drying and conditioning at constant temperature of 20±1°C, and humidity 90% RH is hand mixed with the sand. Subsequently sufficient quantity of distilled water is added and kept for 24 hours to saturate. The test procedure adopted is the same as that recommended by Bishop and Henkel (1957) for a conventional consolidated drained triaxial compression test, at a strain rate of 0.25% per minute.

TEST RESULTS

Triaxial stress-strain curves for unreinforced sand are presented in Fig. 1. The results with 25 mm and 50 mm long fibres, with 1% fibre content are shown in Figs. 2 and 3 respectively. From these figures, it is evident that the strength increases with reinforcement and more so with the length of the fibre. For example, at a cell pressure of 196 kPa, the unreinforced specimen has a maximum deviatoric stress of 758 kPa at an axial strain of 7.5%, the reinforced specimens with 25 mm and 50 mm long fibres yielded a strength of 1190 kPa and 1766 kPa at failure strains of 12% and 21% respectively. This is depicted in Fig. 4. Though not plotted, there was dilatant behaviour during shearing, similar to dense sand or over-consolidated clay. Similar trend may be noticed from Fig. 5, which presents results obtained at 49 kPa. Another important aspect to be noted is that the modulus or stiffness of the specimens increases with reinforcement.

The p-q plots for the different triaxial series are plotted in Figs. 6 and 7. Table 1 summarises the strength parameters. For instance, the sand with a ϕ' of 41.40 (and c'=0), improved to ϕ' = 62^0 and c'=0 with 1% coir fibre of 25 mm length. They further improve to ϕ'= 41.4° and c' = 210 kPa for 50 mm long coir. Also noticed is that beyond a critical confining pressure σ_{crit}, the c' and ϕ' change possibly due to the compression of coir fibres. This pressure is in the range of 49 kPa, beyond which the slope of the p-q line reduces, causing a decrease in ϕ' and increase in c', as tabulated in Table 1.

It may also be noticed that in general reinforcement does not effect the ϕ' as much as it effects the value of cohesion. This is in conformity with those observed by other researchers and also the previous work done at IIT Delhi.

Also evident from the stress-strain curves shown in Figs. 4 to 5 is that the improvement is more significant at lower confining pressure than at higher pressures.

Bouazza (1997) reported results of triaxial tests conducted on uniform sand reinforced with 0.5 mm diameter, 20 mm long polyamide fibres for confining pressures upto 400 kPa. With 1% fibre reinforcement, it was found that ϕ' increased to 49° from 39° whereas c' remained the same as zero below the critical confining pressure, which was in the range of 100-200 kPa.

Table 1 : Summary of Triaxial Test Results

Reinforcement	$\sigma_3 \quad \sigma_{crit}$		$\sigma_3 > \sigma_{crit}$	
	c' (kPa)	ϕ'	c' (kPa)	ϕ'
Nil	0	41.4	0	41.4
Coir Fibre - 25mm long				
0.3%	0	54.0	44	37.0
0.5%	0	57.0	68	41.5
1.0%	0	62.0	135	45.5
Coir Fibre - 50mm long				
1.0%	210	44.4	434	32.0

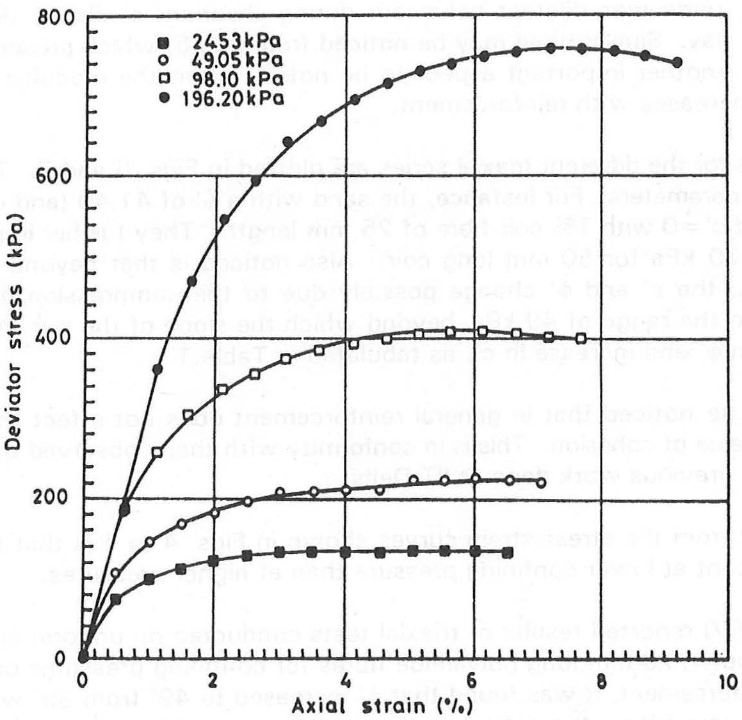

Fig. 1 Stress-Strain curves for triaxial tests on sand

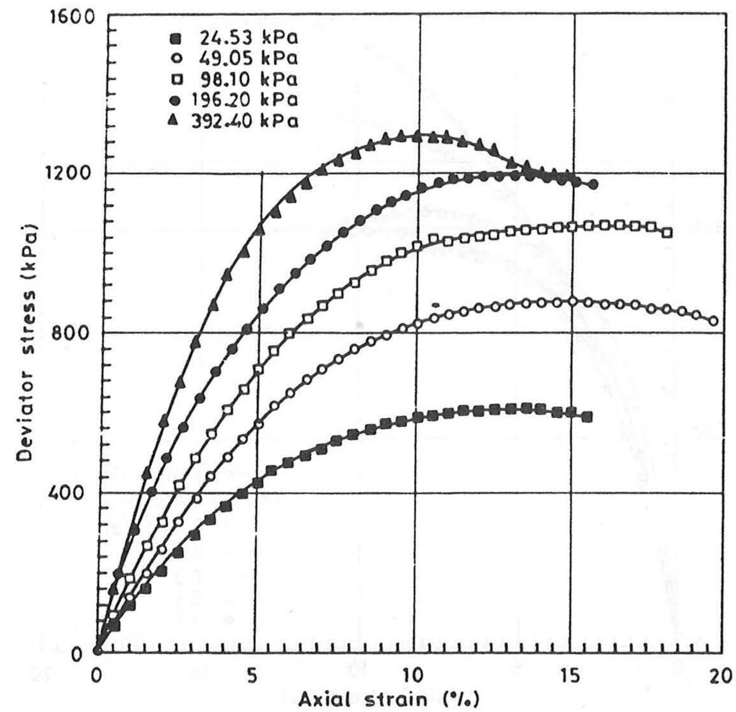

Fig.2 Stress-Strain curves for triaxial tests on sand reinforced with 1% coir fibre (25mm long)

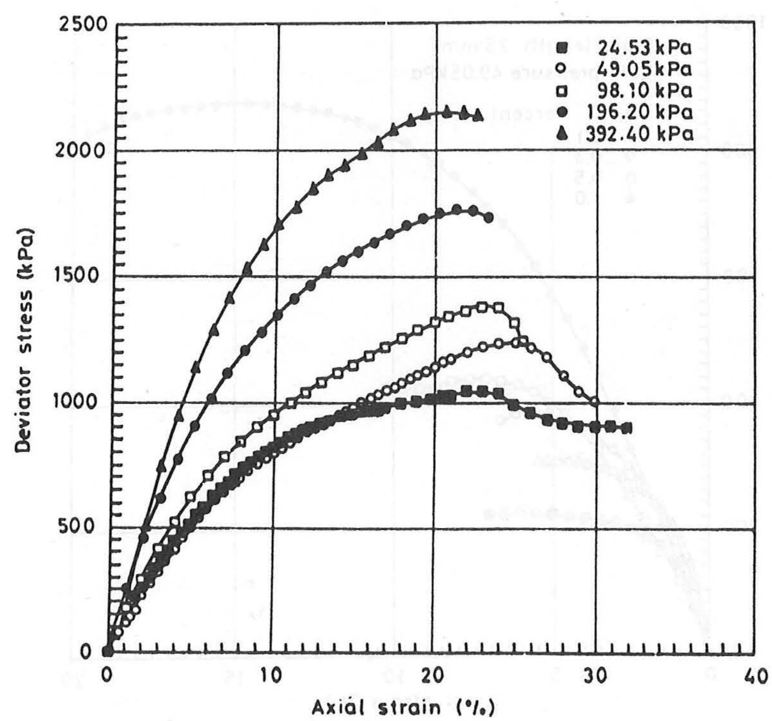

Fig. 3 Stress-Strain curves for triaxial tests on sand reinforced with 1% coir fibre (50mm long)

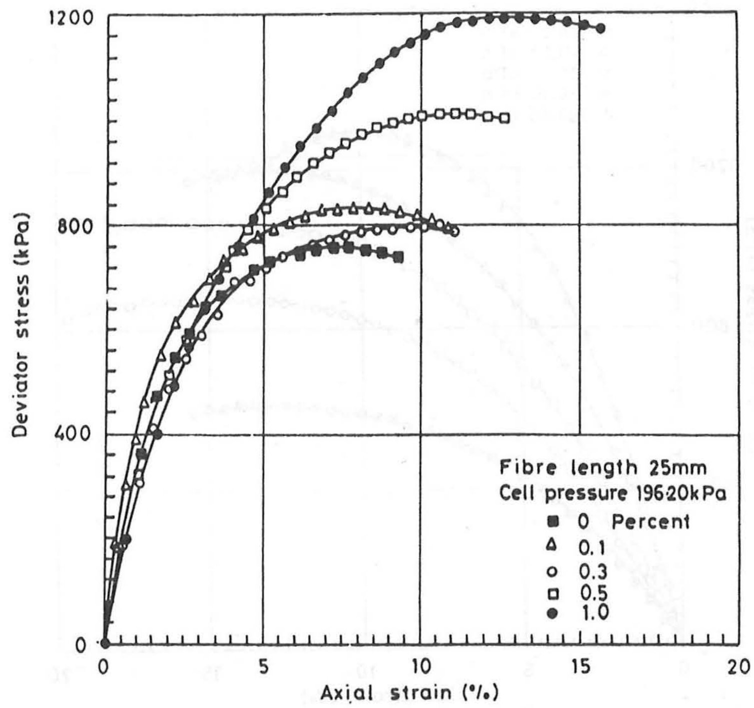

Fig. 4 Stress-Strain curves for triaxial tests on reinforced sand at a confining pressure of 196.2 kPa

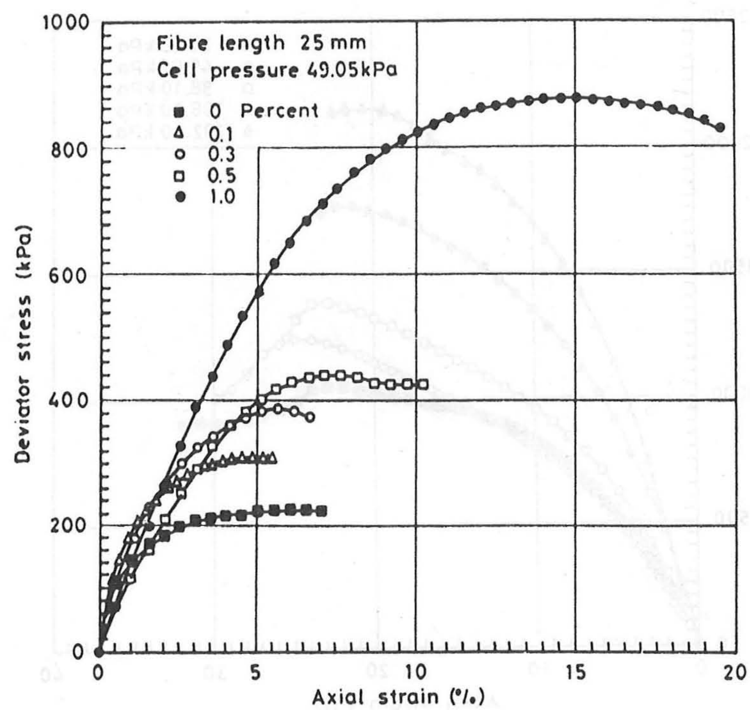

Fig. 5 Stress-Strain curves for triaxial tests on reinforced sand at a confining pressure of 49kPa

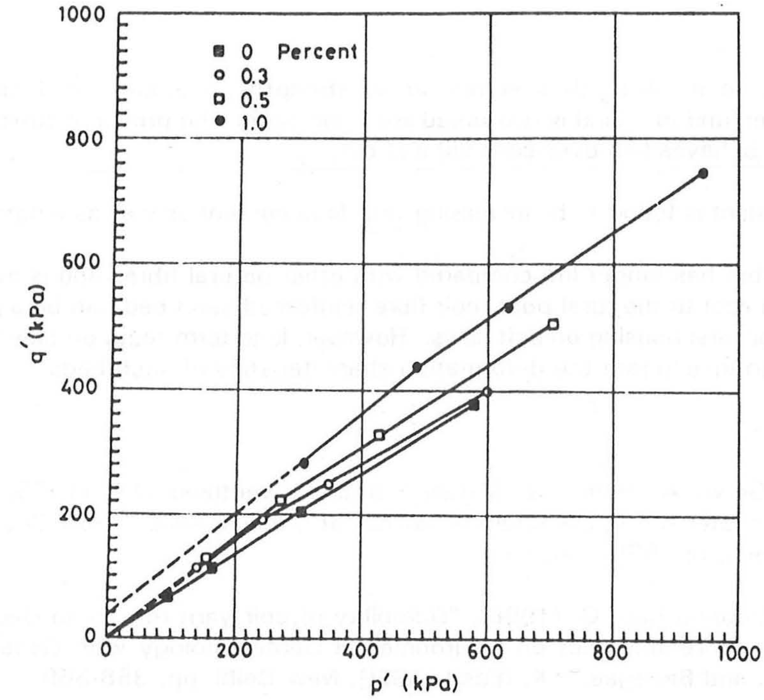

Fig. 6 p-q plots for reinforced sand with 25 mm long coir fibre

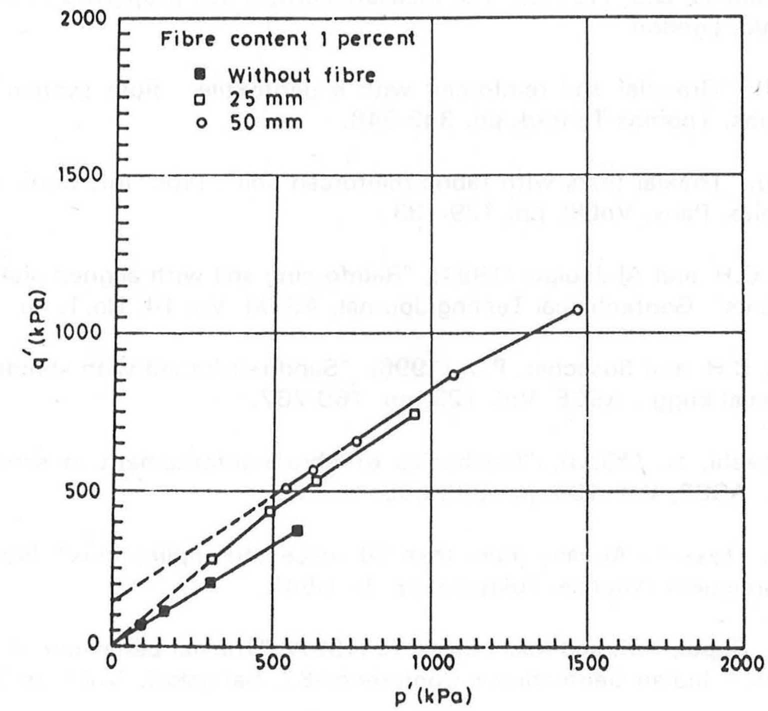

Fig. 7 p-q plots for reinforced sand with 25 mm and 50mm long coir fibre (1%)

CONCLUSIONS

1. Significant gain in strength/effective stress strength parameters and stiffness is observed when uniform sand is reinforced with coir fibre. The principal stress p-q plot isbilinear. It behaves like over-consolidated clay.

2. The improvement is found to be increasing with fibre content as well as length of fibre.

3. As the coir fibre has longer life compared with other natural fibres and is available at practically no cost to the rural poor, coir fibre reinforced sand bed can be a promising foundation for rural housing on soft clays. However, long-term tests on clay beds may be required to investigate the deformation characteristics of such beds.

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