Geosynthetics, J. Kuwano & J. Koseki (eds)
© 2006 Millpress, Rotterdam, ISBN 90 5966 044 7

Behaviour of sand reinforced with coir fibres

Damarashetty, U.
Department of Civil Engineering, Indian Institute of Technology, New Delhi – 110016, India, u_damarashetty@yahoo.com

Rao, G.V.
Department of Civil Engineering, Indian Institute of Technology, New Delhi – 110016, India, gvrao@civil.iitd.ernet.in

Dutta, R.K.
Department of Civil Engineering, National Institute of Technology, Hamirpur – 177005, Himachal Pradesh, India, rkd@recham.ernet.in

Keywords: sand, coir fibres, ground improvement, behaviour

ABSTRACT: Laboratory triaxial compression tests were carried out in order to determine the behaviour of sand reinforced with coir fibres. The mechanical behaviour of the composite material was investigated through varying four confining pressures, 2 types of coir fibres in a random arrangement with percentage varying from 0.5% to 1%. Tests were performed on 100 mm diameter and 200 mm high specimens. The results indicated that inclusion of coir fibres improves the performance of sand specimens.

1 INTRODUCTION

Coir is the fibre which surrounds the bare shell of a coconut protecting the kernel. Depending on the process of extracting the fibres from the husk, coir is classified into two varieties, viz., “White Coir” and “Brown Coir”. White Coir is produced from husks of mature green coconuts by subjecting the husk to a retting process of 6 to 8 months in sea water, followed by beating of the rutted husks with mallet against a log by manual labour for thrashing out the pith. On the other hand brown coir is produced from dry/semi-dry coconut husks by mechanical process. The length of these fibres vary and can be as much as 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).

The paper presents the results of drained triaxial tests carried out on Yamuna sand reinforced with two types of coir fibres in random arrangement for their possible use in ground improvement.

2 EXPERIMENTAL WORK

2.1 *Sand*

The investigation was carried out on locally available Yamuna sand, which is fine-grained uniformlygraded sand. It had a specific gravity of 2.67.

2.2 *Coir fibres*

Two types of coir fibres were selected for this study. They are designated as Type A1 (fibre length varying from 150-199 mm) and Type A2 (fibre length less than 100 mm). These fibres were later cut into lengths of 25 mm and their properties are reported by Banerjee et al. 2002.

2.3 *Admixture used*

The composition of the admixture chosen had a fibre content varying from 0.5 to 1% for Type A1 and Type A2 coir fibres.

2.4 *Experimental procedure*

The required percentage of the coir fibres was first uniformly mixed with the sand in dry condition. The sand was then soaked. Saturated specimens of 100 mm dia and 200 mm high were then prepared and drained triaxial tests were conducted as per Bishop and Henkel, 1962 at confining pressures ranging from 24.5 to 196 kPa using a deformation rate of 0.66 mm/min. The density of sand specimen was maintained at 16 kN/m^3.

3 RESULTS AND DISCUSSION

3.1 *Stress-strain behaviour*

Figure 1 presents the stress-strain behaviour of sand. It can be generally seen from this figure that with an increase in confining pressure, the peak stress increases and corresponding axial strain also marginally

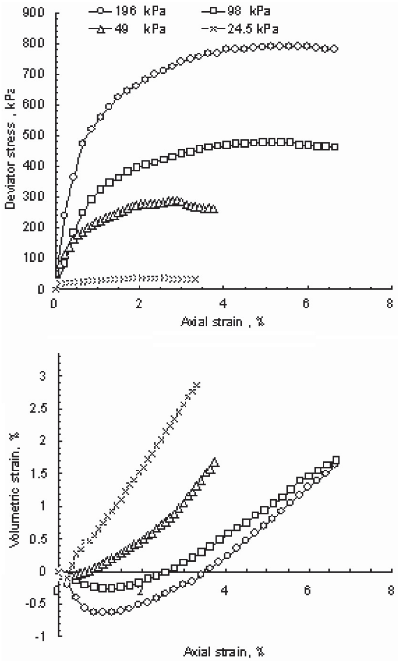

Figure 1. Stress-strain-volume change curves for sand.

increases. For example, sand at $\sigma_3 = 49$ kPa exhibits a peak stress of 289.8 kPa and a failure strain of 2.9%, whereas these values at $\sigma_3 = 196$ kPa are 790.7 kPa and 5.6% respectively.

Typical stress-strain curves for sand reinforced with 0.5% Type A1 and 1% Type A2 coir fibres at different confining pressure are shown in Figs. 2-3. Figs. 1-3 indicate that the behaviour of sand and reinforced sand is similar at different confining pressures. Fig 4 shows the improvement in performance of sand specimen when the fibre content is increased from 0.5% to 1% for both the types of fibres.

3.2 *Strength ratios*

The values of strength ratio (the ratio of the strength of a reinforced specimen to that of an unreinforced specimen) under different confining pressures are given in Table 1. From the table the following can be observed.

Table 1. Strength ratios at different confining pressures.

Fibre type	% fibre	Strength ratios at confining pressure of (kPa)			
		24.5	49	98	196
A1	0.5	6.18	1.64	1.50	1.18
A1	1.0	25.33	2.25	2.25	1.75
A2	0.5	7.91	1.84	1.45	1.24
A2	1.0	12.34	2.81	2.03	1.66

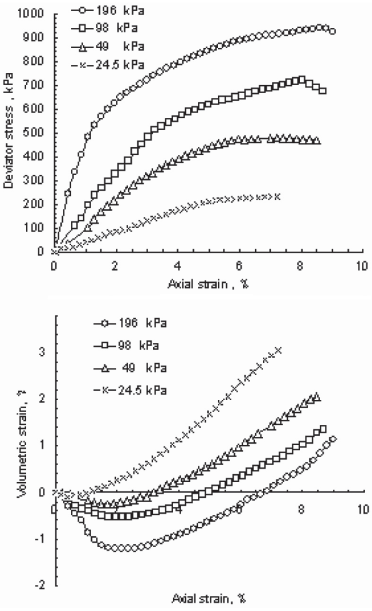

Figure 2 Stress-strain-volume change curves for sand reinforced with 0.5% coir fibres of Type A1.

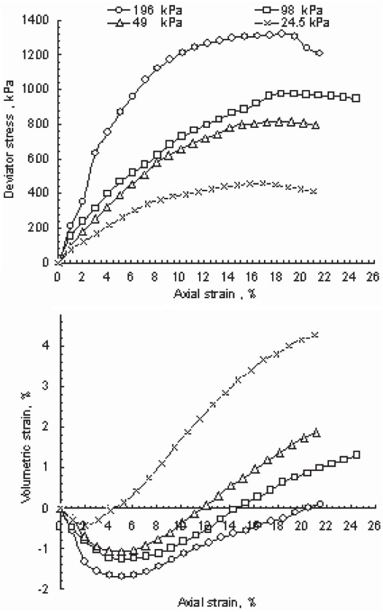

Figure 3. Stress-strain-volume change curves for sand reinforced with 1% coir fibres of Type A2.

1. For Type A1 fibre at $\sigma_3 = 24.5$ kPa, the strength ratio was 618% for 0.5% fibre content, and 2533% for 1% fibre content. On the other hand, at $\sigma_3 =$ 196 kPa, the increase in strength was only from

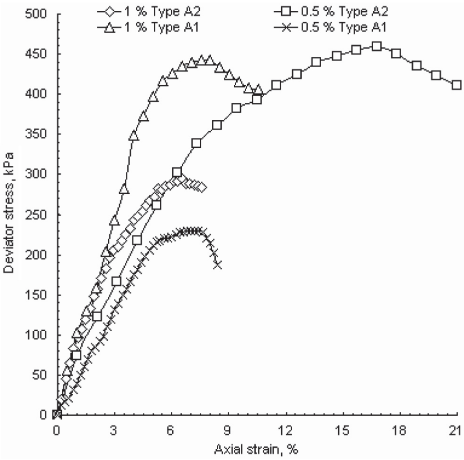

Figure 4. Stress-strain curves for sand reinforced with coir fibres of Type A1 and Type A2 at $\sigma_3 = 24.5$ kPa.

18% to 75% when the fibre content increased from 0.5 to 1%.

2. For Type A2 fibre at $\sigma_3 = 24.5$ kPa, the increase in strength was 791% for 0.5% fibre content, and 1234% for 1% chip content. On the other hand, at $\sigma_3 = 196$ kPa, the increase in strength was only from 24% to 66% when the fibre content increased from 0.5 to 1%.

3.3 *Volumetric strain*

The variations of volumetric strain versus axial strain for both unreinforced and sand reinforced with Type A1 and Type A2 were also presented in Figs 1-3. A study of these figures indicate that:

1. As expected during the initial shear, the volume of unreinforced and reinforced sand decreases slightly (the positive sign of volumetric strain indicates dilatancy). With further shearing, the behaviour is reversed and the specimens show a increase in volume, while, increase in confining pressure limits the volumetric expansion of both unreinforced and reinforced sand.
2. The tendency of samples to dilate is restricted by the fibres. As reported by many researchers (for example Duncan and Dunlop, 1968), dilation occurs mainly in the center of the specimens. At the top or bottom of the sample, the cap and the base restrain lateral deformation and dilation. It is also believed that fibre restrain lateral deformation. Consequently, it is evident that fibre effectively restricts the dilation of the samples.

3.4 *Strength characteristics*

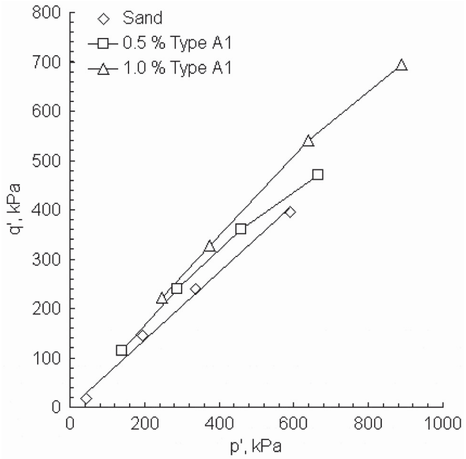

Figure 5. p'-q' plot for the sand reinforced with Type A1 fibres.

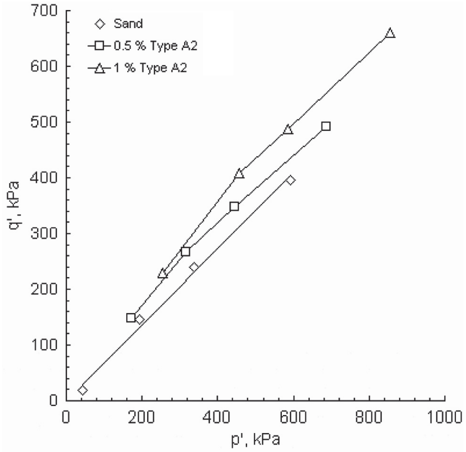

Figure 6. p'-q' plot for the sand reinforced with Type A2 fibres.

Typical p′-q′ plots are depicted in Figs. 5 and 6, which show the bilinear behaviour of the failure envelope for the reinforced case. Similar behaviour is observed for all other cases studied. The strength parameters obtained are tabulated in Table 2. From these figures and table it is evident that: The p′-q′ plot for the unreinforced sand is linear in the entire range of confining pressure giving values of $\phi' = 43°$ and $c' = 0.0$.

Table 2. Strength parameters for reinforced sand.

Fibre type	% fibre	σ_3, σ_{crit}		$\sigma_3 > \sigma_{crit}$	
		c′ (kPa)	φ′	c′ (kPa)	φ′
Sand		0	43°	0	43°
A1	0.5	0	56°	88	38°
A1	1.0	0	62°	95	45°
A2	0.5	0	58°	97	37°
A2	1.0	0	64°	152	39°

The p′-q′ plots for the reinforced sand exhibit a bilinear behaviour. In general behaviour upto around confining pressure of 49 kPa, is an increase in ϕ′ and beyond this critical pressure (Confining pressure corresponding to the break in failure envelope) the value of ϕ′ is generally equal to that of the unreinforced sand but there is an increase in the value of c′. As expected, the values of c′ or ϕ′ increase with percentage fibre content. For instance, for 0.5% of Type A1 fibre the value of ϕ′ increases from 43° to 56°, upto a confining pressure of 49 kPa, beyond which the value of ϕ′ = 38° and c′ = 88 kPa. Similarly for 0.5% of Type A2 fibre, the value of ϕ′ increases from 43° to 58° upto the confining pressure of 49 kPa, beyond which the value of ϕ′ = 37° and c′ = 97 kPa.

3.5 *Hyperbolic stress-strain relationship*

Many researchers have found the validity of hyperbolic stress strain relationship (Konder and Zelasko, 1963) for various kinds of soils and rocks under various test conditions. To assess the validity of hyperbolic stress – strain relationship for coir fibres sand mixtures, the present experimental results alongwith predicted strength at different confining pressures using hyperbolic model are shown in Figs 7 and 8 respectively. Figs. 7 and 8 clearly indicate that there is good agreement between the experimental and predicted strength.

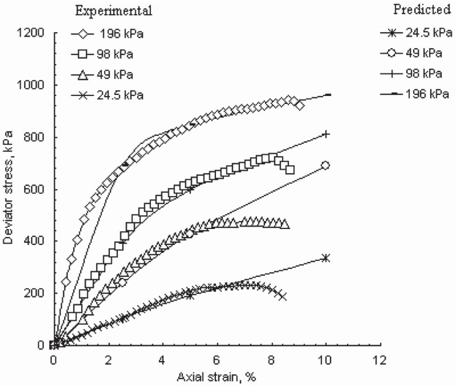

Figure 7. Results from triaxial compression tests on sand reinforced with 0.5% coir fibres of Type A1 and Hyperbolic stress-strain relationship at four confining pressures.

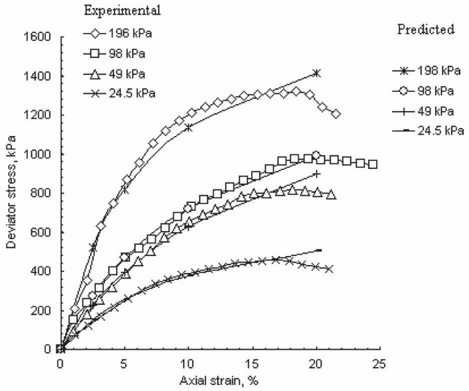

Figure 8. Results from triaxial compression tests on sand reinforced with 1.0% coir fibres of Type A2 and Hyperbolic stress-strain relationship at four confining pressures.

4 CONCLUSION

From the triaxial behaviour of sand reinforced with coir fibres, it may be concluded that addition of coir fibres upto 1 % increases the value of ϕ′ from 43° to 62° for Type A1 and 43° to 64° for Type A2 reinforced sand respectively upto a critical confining pressure of 49 kPa. However, beyond critical pressure the value of c′ increased from 0 to 95 and 152 kPa respectively for Type A1 and A2 reinforced sand. Considering that coir has a longer life compared to other natural fibres like jute that degrade much faster, it is possible to use this material for ground improvement.

REFERENCES

Banerjee, P.K., Chattopadhyay, R. and Guha, A. (2002). “Investigations into homogeneity of coir fibres”, Indian journal of fibre and textile research, vol. 27, pp. 111-116.

Bishop, A.W. and Henkal, D.J. (1962), “The Measurement of Soil Properties in the Triaxial Test”, Edward Arnold Publishers Ltd., London.

Duncan, J.M and Dunlop, P. (1968). The significance of cap and base restraint. Proc ASCE Journal of soil Mechanics and Foundations, Vol 112, No. 8, pp. 804-820.

Konder, R.L and Zelasko, J.S (1963). A hyperbolic stress-strain formulation for sands. Proc. 2nd PanAm Conf. SMFE, pp 289-324.