STRENGTH BEHAVIOUR OF SAND REINFORCED WITH GLASS FIBRES

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ABSTRACT

Construction of roads and other civil engineering structures on a loose or soft soil is risky due to its high compressibility, low shear strength, and high permeability. In such situations, it is general practice to modify the soil properties by blending with different materials such as lime, cement and fly ash or by reinforcing the soil. Soil reinforcement has been carried out since many decades due to its ease in application, good performance and cost effectiveness. It is implemented by embedding different types of reinforcing elements such as metal strips, nailing, geosynthetics and fibres inside the soil mass. In the present study, a series of triaxial tests has been carried out to investigate the strength behaviour of a poorly graded fine sand which has been reinforced with glass fibres. The influence of fibre content and relative density has been studied.

***Key words*:** Soil modification, sand, glass fibres, strength

1. INTRODUCTION

The presence of plant roots is a natural means of incorporating randomly oriented fibre inclusions in the soils. The plant fibres improve the strength of the soils and the stability of natural slopes [1]**.** This concept and principle was first developed by Henri Vidal in 1969 by which he demonstrated that the introduction of reinforcing elements in a soil mass increases the shear resistance of the medium.

One of the main advantages of randomly distributed fibres is the maintenance of strength isotropy and absence of potential failure plane that can develop parallel to oriented reinforcement. A wide range of reinforcement has been used to improve soil performance. Increasing the soil strength has caused increased interest in identifying new available resources for reinforcement. Short discrete fibres made of polymeric or natural material have also been used to improve the shear strength of soil [2].

A number of laboratory experimental studies have been carried out on soils mixed with artificial and natural fibres. Shewbridge and Sitar [3] carried out tests on soils in which the fibres were oriented in particular directions. Many other investigators have conducted tests with the fibres oriented randomly in the soils [4], [5], [6]. Several field studies on test sections have been reported to validate the performance of fibre-reinforced soils. Santoni and Webster [7] concluded that the technique showed great potential for military airfield and road applications and that a 203 mm thick sand-fibre layer was sufficient to support substantial amounts of military truck traffic. Tingle et al. [8] concluded from full-scale field tests that fibre-stabilized sands were a viable alternative to traditional road construction materials for temporary or low-volume roads.

The objective of this study is to investigate the strength behaviour of fine sand reinforced with glass fibres, particularly the effect of fibre content and relative density.

2. EXPERIMENTAL PROGRAM

2.1. Materials

The sand was procured from the nearby bank of Brahmaputra River. The physical properties of the Brahmaputra sand are tabulated in Table 1, and the grain size distribution is shown in Figure 1. According to Unified Soil Classification System, the sand is classified as poorly graded sand (SP). Synthetic glass fibres of 20 mm length (Figure 2) were obtained from a local supplier.

2.2. Methods

For preparing test specimens, first the required amounts of sand and fibres were mixed together in a dry state. To prevent the segregation of fibres during mixing, a minimum amount of water (6%

by dry weight of sand) was then added. All mixing was done by hand and proper care was taken to prepare a homogeneous mix. The compacted specimens were of 38 mm in diameter and 76 mm in length. Four fibre contents (1%, 2%, 3% and 4%) by dry weight of sand were used with three different relative densities (50%, 65% and 82%) of the sand.

Table 1: Physical properties of Brahmaputra sand

Property/Grain sizes	Value
Specific gravity, G_s	2.67
Gravel (> 4.75 mm)	Nil
Coarse sand (2 – 4.75 mm)	1.18%
Medium sand (0.425 – 2 mm)	16.1%
Fine sand (0.075 – 0.425 mm)	81.2%
Uniformity coefficient, C_u	1.68
Coefficient of curvature, C_c	0.024
Soil classification	SP

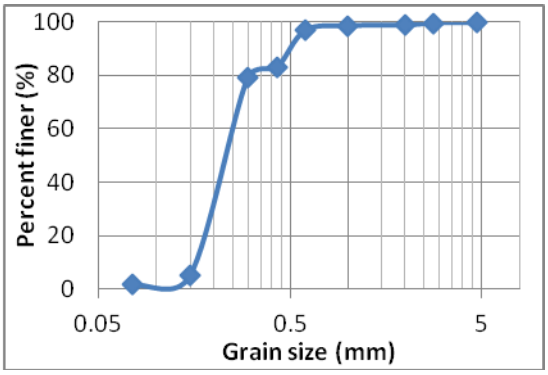

Figure 1: Grain size distribution of Brahmaputra sand

Figure 2: Glass fibres

The designations used for the specimens are: BS for Brahmaputra sand, F for glass fibres, and BS+F for sand-fibre mixes, respectively. In the mix designation, the fibre content by weight is indicated by the numeral prefixed before the symbol F. For example, 2%F indicates that 2% by weight is fibre content and the remaining is soil.

Consolidated drained triaxial tests were conducted as per the procedure of Indian Standards [9]. The tests were performed under confining pressures of 100, 200, 300 and 400 kPa at a strain rate of 1.2 mm/min, with the load and deformation readings recorded up to 20% strain.

3. RESULTS AND DISCUSSION

The results are presented in the form of both deviatoric stress vs. axial strain plots and p-q plots.

3.1. Effect of Fibre Content

Figures 3 & 4 show the stress-strain response of the mixes at 50% relative density for different confining pressures. The plots indicate that for the same confining pressure, the deviatoric stress at failure increases with fibre content whereas the stiffness increases notably only at high fibre contents. The improved behaviour of reinforced sand is on account of sand-fibre interfacial friction and apparent cohesion induced due to moistening of the sand-fibre mix. As the fibre content increases, the contribution of the interfacial friction becomes larger.

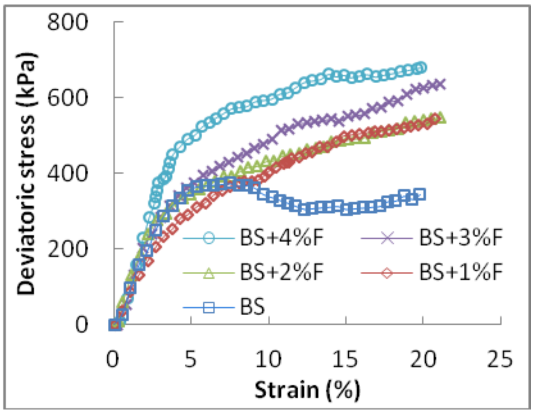

Figure 3: Deviatoric stress vs. axial strain plots for various BS+F mixes at 50% relative density (100 kPa confining pressure)

Moreover, due to sand-fibre interlocking, stress is transferred from sand to the fibres leading to the mobilization of tensile strength of fibres which in turn imparts this resisting force to the sand.

Furthermore, reinforced sand does not exhibit any specific peak indicating the ductile behaviour of sand-fibre mixes.

With increasing confining pressure, the strength and stiffness are observed to increase. This is mainly due to increase in lateral support and the subsequent greater mobilisation of apparent cohesion. Similar trends of the influence of confining pressure have been observed at the other two relative densities of 65% and 82%.

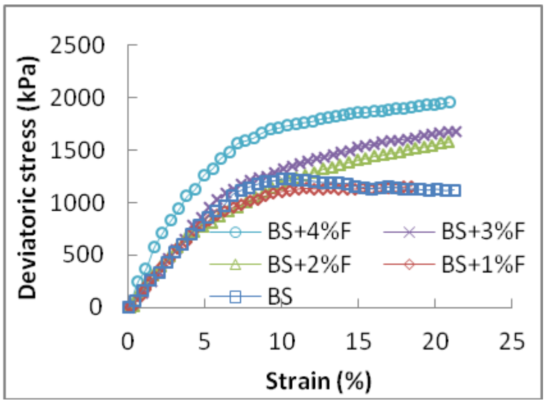

Figure 4: Deviatoric stress vs. axial strain plots for various BS+F mixes at 50% relative density (300 kPa confining pressure)

3.2. Effect of relative density

Figures 5 & 6 plot the stress-strain response of the BS+1%F and BS+4%F mixes at different relative densities tested under 400 kPa confining pressure.

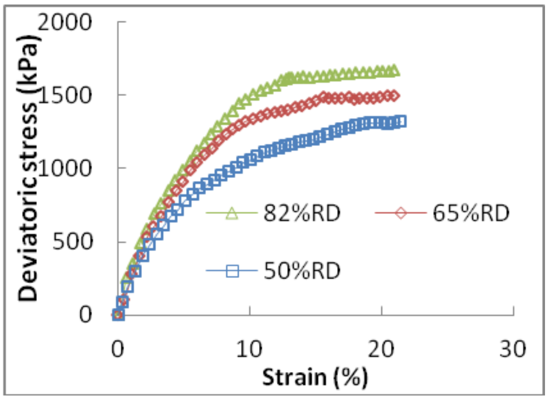

Figure 5: Deviatoric stress vs. axial strain plots for various BS+1%F mixes at different relative densities (400 kPa confining pressure)

The plots indicate that for the same confining pressure and fibre content, both failure deviatoric stress and stiffness increase with increase in relative density. At a higher relative density, the particles arrange themselves in a denser packing which leads to the increased strength and stiffness.

Figures 7 to 9 show the p-q plots of the reinforced sand with different fibre contents (1 to 4%) at 50%, 65%, and 82% relative density, respectively. The values of cohesion and angle of internal friction obtained from these plots are tabulated in Table 2.

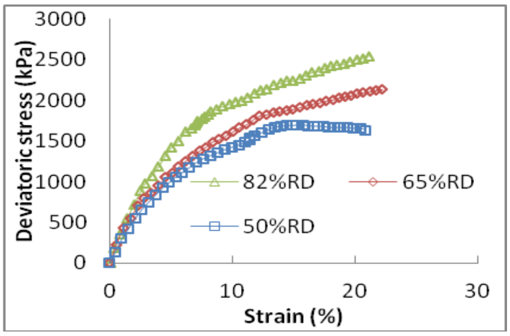

Figure 6: Deviatoric stress vs. axial strain plots for various BS+4%F mixes at different relative densities (400 kPa confining pressure)

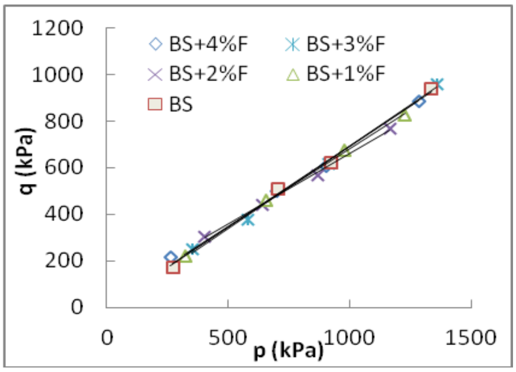

Figure 7: p-q plots for various BS+F mixes at 50% relative density

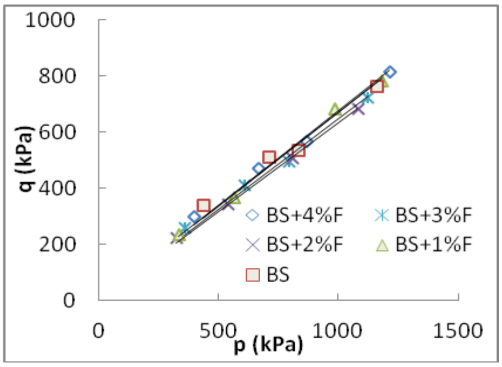

Figure 8: p-q plots for various BS+F mixes at 65% relative density

The results have shown variation of shear strength parameters with percentage of fibres and relative density. It is noted that at the same relative density, higher fibre content leads to an increase in both cohesion and internal angle of friction. This is attributed to the sand-fibre interfacial friction, mobilisation of tensile resistance, and apparent cohesion.

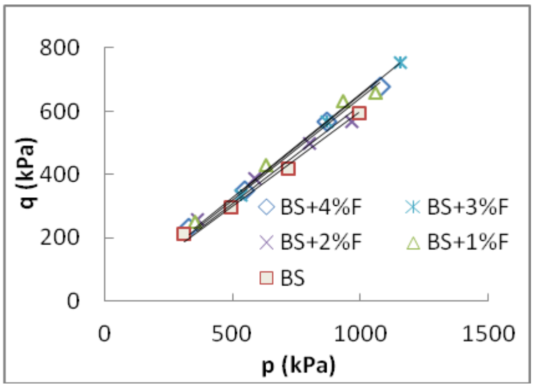

Figure 9: p-q plots for various BS+F mixes at 82% relative density

Table 2: Shear strength parameters of different mixes

Relative Density	Mix	C (kPa)	φ (degree)
50%	BS	0.17	34.1
	BS+1%F	0.19	36.9
	BS+2%F	0.21	38.2
	BS+3%F	0.25	39.1
	BS+4%F	0.29	39.8
65%	BS	0.19	36.1
	BS+1%F	0.22	36.8
	BS+2%F	0.25	37.3
	BS+3%F	0.30	38.5
	BS+4%F	0.31	39.1
82%	BS	0.18	39.5
	BS+1%F	0.24	42.2
	BS+2%F	0.68	42.9
	BS+3%F	0.68	43.4
	BS+4%F	0.70	43.6

4. CONCLUSIONS

The stress-strain response of the fine sand modified by the addition of glass fibres has been studied. The behaviour of the sand noted to change into a ductile one. The addition of fibres to the sand specimens results in substantial increases in the measured values of the cohesion and friction angle. The findings of this study have practical significance as a ground improvement technique, with respect to the use in subgrade, embankment and other applications.

5. REFERENCES

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