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A STUDY ON THE VARIATION OF STRENGTH OF FIBER REINFORCED COHESIVE SOIL

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Abstract

Delicate silty or clayey soils are broadly appropriated worldwide and they can be improved with reinforcement as haphazardly dispersed strands of natural and synthetic types. Among the natural strands, coir and jute are created in huge amounts in South Asian nations. Polypropylene, polyester, polyethylene and glass strands are generally accessible synthetic fibers. It is important to decide the optimum fiber content and fiber length for any fiber type in the research facility preceding field applications. This paper audits the strength conduct of cohesive soils built up with coir filaments, polypropylene strands and scrap tire elastic filaments as announced from trial examination, that incorporates triaxial, direct shear and unconfined pressure tests.

Keywords: Fiber reinforcement, cohesive soil, triaxial test, direct shear test, unconfined test.

1. Introduction

The primary purpose of reinforcing a soil mass is to improve its stability by increasing its bearing capacity, and by reducing settlement and lateral deformation. Conventional reinforcing methods make use of continuous inclusions ofstrips, fabrics, and grids into the soil mass. The random inclusion of various types of fibers is a modification of the same technique, in which the fibers act to interlock soil particles and aggregates in a unitary coherent matrix. The use of natural materials, such as bamboo, jute and coir as soil reinforcing materials has been prevalent for a long time in several South Asian nations. Their main advantage is that they are locally available and are of low cost.

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Synthetic fibers such as polypropylene, polyester, polyethylene and glass fibers have also been used as reinforcing materials. The fiber-reinforced soil behaves as a composite material. When loaded, the fibers mobilize tensile resistance, which in turn imparts greater strength to the soil. Use of natural or synthetic fibers in geotechnical engineering has been in the construction of pavement layers, road and railway embankments, and retaining walls as well as in the protection of slopes. Several studies on the strength behavior of cohesive soils mixed with randomly distributed coir fibers, polypropylene fibers and scrap tire rubber fibers are available in the literature, and a review of the same is presented in this paper.

2. Strength Behaviour

Stress-Strain Response in Triaxial Tests

Sivakumar Babu and Vasudevan (2008) investigated the strength and stiffness response of coir fiber-reinforced tropical silty soil of intermediate plasticity, and reported the effect of fiber content and fiber length on the strength and stiffness characteristics of the soil. Fig. 1 presents a typical result of the stress versus strain response for various fiber contents. The results show that the deviator stress at failure increases with fiber content and occurs at about 10–18% of strain. The optimum fiber content corresponding to maximum improvement in strength is found to be 2.0-2.5%. Fig. 2 shows the effect of length of coir fibers on stress-strain response. Maximum improvement is obtained with 15 mm long fibers. To avoid the possibility of boundary effects for 30 mm long fibers, length in the range of 15–25 mm (40–65% of least lateral dimension of 38 mm) was considered to be appropriate to obtain improvement.

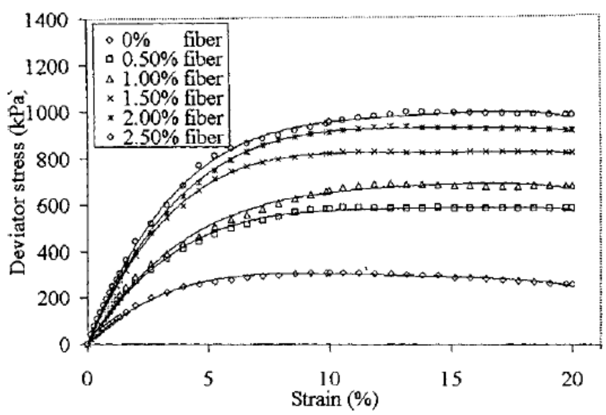

Fig. 1: Stress versus strain curves for coir fiber-reinforced soil having different fiber contents at 50 kPa confining pressure.

Maliakal and Thiyyakkandi (2013) studied the influence of randomly distributed coir fibers on the shear strength of a silty soil of high plasticity. Fig. 3 shows typical deviator stress-strain plots for unreinforced clay and coir fiber-reinforced clay with different fiber contents. It is evident that inclusion of coir fibers significantly alters the stress-strain characteristics of clay. At higher fiber contents (1 and 2%), no peak is observed until the conventional serviceability failure state of 20% strain, whereas unreinforced clay attains peak deviator stress at an axial strain of about 10–15%. Fig. 4 presents the deviator stress-strain plots for coir fiber-reinforced clay with different aspect ratios at constant fiber content. The trend of the response with varying aspect ratio is identical to that with varying fiber content as depicted in Fig. 3.

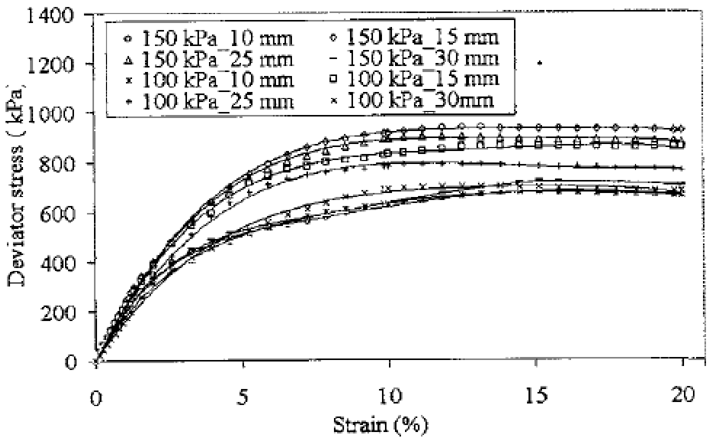

Fig. 2: Stress versus strain curves for coir fiber-reinforced soil having different fiber lengths at 150 kPa confining pressure.

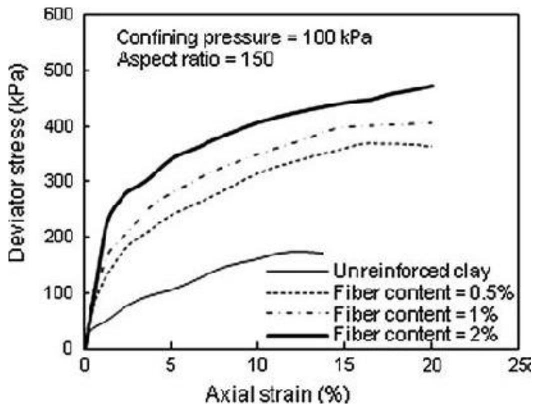

Fig. 3 Deviator stress-strain plots for fiber-reinforced clay with different fiber contents (aspect ratio = 150 and confining pressure = 100 kPa)

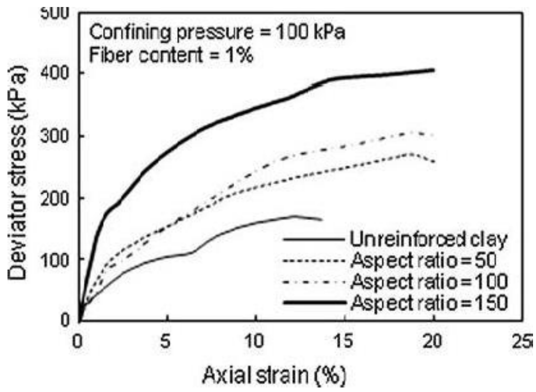

Fig. 4 Deviator stress-strain plots for fiber-reinforced clay with different aspect ratios (fiber content = 1 % and confining pressure = 100)2.2 Stress-Strain Response in Direct Shear Tests

Pradhan et al. (2012) examined the effect of random inclusion of polypropylene fibers on strength characteristics of a clayey soil of intermediate plasticity. Figs. 5 and 6 show a comparison of the shear stress to horizontal strain response of the reinforced cohesive soil with two different aspect ratios (75 and 125). It is observed that for the same fiber content and confining pressure, the shear strength increases with the increase in aspect ratio. Both peak and residual strength of reinforced soil increase with

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fiber content up to 0.4%, irrespective of the fiber length. This increase in strength is mainly due to the increase in the surface area of fiber and subsequent mobilization of tensile forces in the fibers.

Zaimoglu & Yetimoglu (2012) studied the strength behavior of a high plasticity silty soil reinforced with randomly distributed polypropylene fibers. The shear stress-horizontal displacement curves obtained for the soil samples reinforced with fiber content varying between 0.25 and 1% are shown in Fig. 7 together with those for the unreinforced sample. It is noted that reinforced samples generally exhibit ductile behavior compared to that of unreinforced soil. The shear stress-normal stress relationship is presented in Fig. 8 for each different fiber contents. It is seen that the failure envelopes are linear in shape though the shear strength angle and cohesion intercept vary with fiber content like a band saw blade showing no trends.

2.3 Stress-Strain Response in Unconfined Compression Tests

Akbulut et al. (2007) presented the modification of highly plastic clayey soils using scrap tire rubber and synthetic fibers (polyethylene and polypropylene). The effect of rubber fibers on UCS values of the soil is highlighted in Fig. 9. The UCS values of the soil–rubber fiber mixtures have a tendency to increase first to a peak value, and then decrease. According to the test results, the optimum rubber fiber length is 10 mm and the optimum rubber fiber content is 2%. Fig. 10 presents the effect of polypropylene fibers on the UCS of the soil. Both the length and content of the polypropylene fibers improve the UCS values of the reinforced samples. The maximum UCS values are obtained with 0.2% polypropylene fibers of 10 mm length.

Jiang et al. (2010) studied the engineering properties of a clayey soil of low plasticity reinforced by short discrete polypropylene fiber. The effect of fiber content, length, and diameter as well as the influence of soil aggregate size on the strength of the fiber-reinforced soil were studied. Fig. 11 shows the unconfined compression strength (UCS) versus fiber content plot for various fiber lengths.

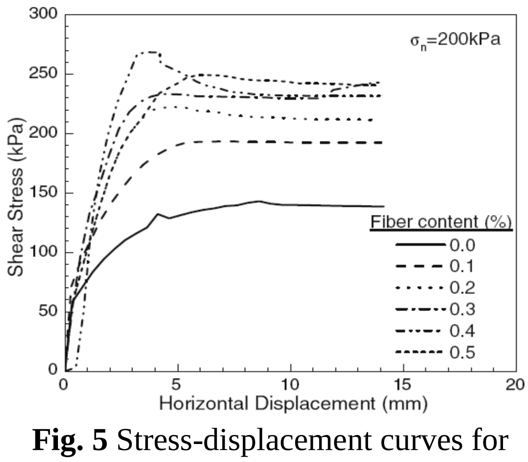

Fig. 5 Stress-displacement curves for fiber- reinforced soil from direct shear test (l/d = 75)

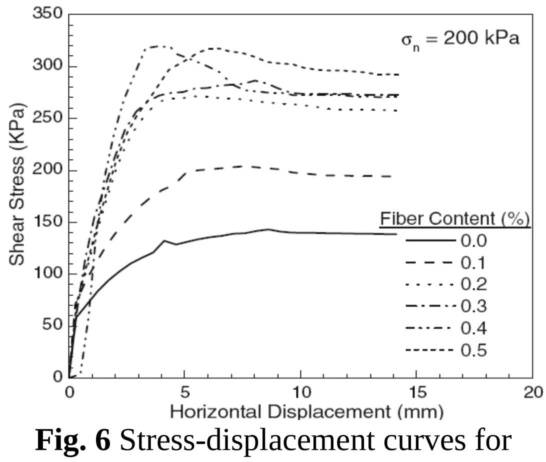

Fig. 6 Stress-displacement curves for fiber- reinforced soil from direct shear test (l/d=125)

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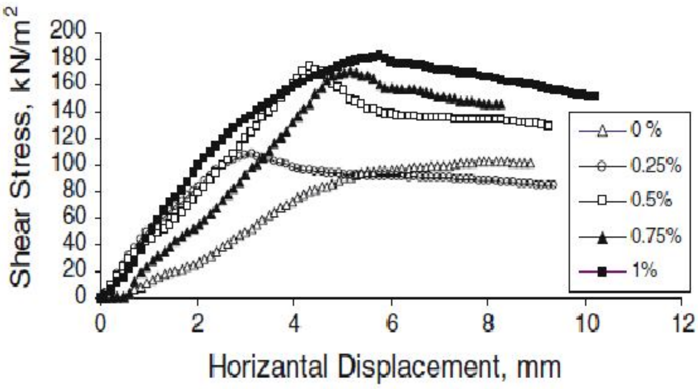

Fig. 7: Shear stress-horizontal displacement curves at vertical normal stress of 50 kPa

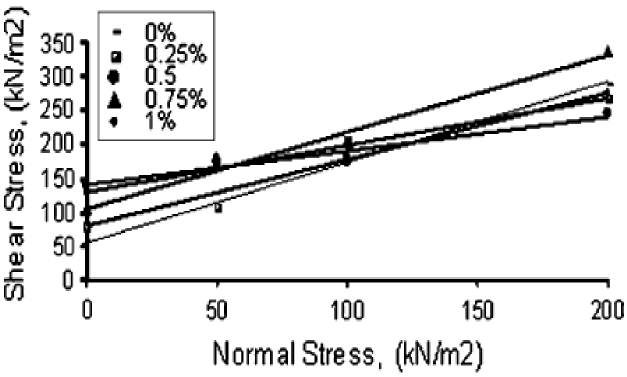

Fig. 8: Variation of shear stress with normal stress for each fiber content.

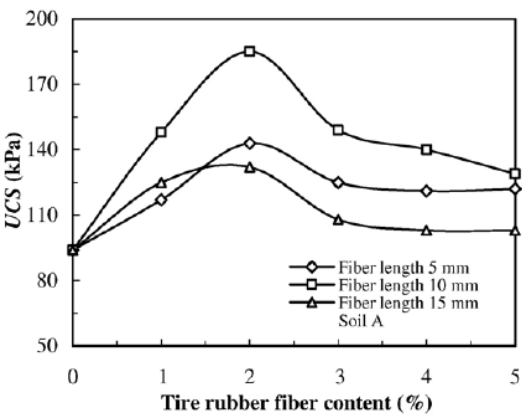

Fig. 9: Effect of scrap tire rubber fiber on UCS of samples.

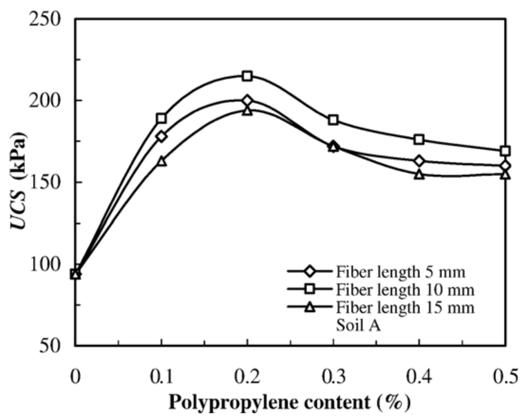

Fig. 10: Effect of polypropylene fiber on UCS of samples.

It is seen that the UCS values of fiber-reinforced samples are greater than those of unreinforced samples. It is also noted that the same trends are found in the four groups of samples differing in fiber length. With an increase in fiber content, the UCS

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experiences an initial increase followed by a decrease and the maximum value of the strength is found at the fiber content of 0.3%. Fig. 12 shows that for any fiber content studied, the UCS increases gently and then decreases rapidly with increasing fiber length and the maximum value is observed at the fiber length of 15 mm. In addition, fibers of less than 15 mm long contribute to better reinforcement effect in strength than do longer fibers greater than 15 mm.

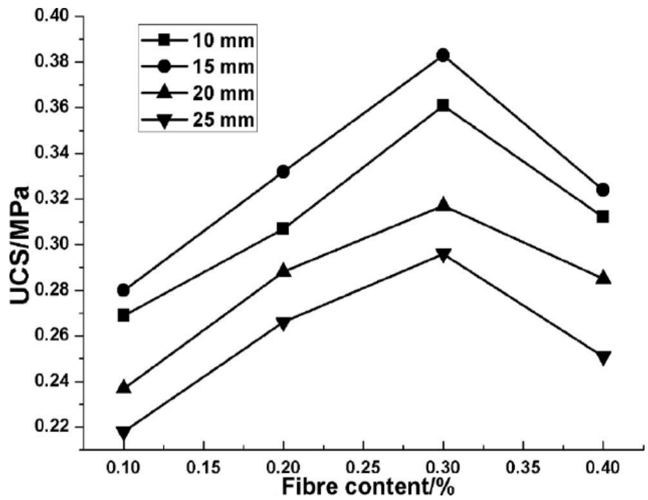

Fig. 11: Effect of fiber content on UCS of fiber-reinforced soil.

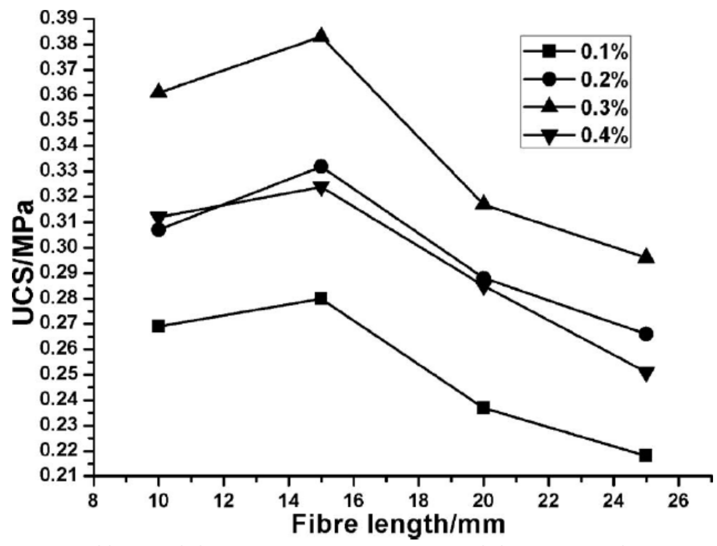

Fig. 12: Effect of fiber length on UCS of fiber-reinforced soil.

3. Conclusions

Triaxial test results indicate that the stress-strain behavior of soil is improved by incorporating coir fibers in the silty soil, and that the deviator stress at failure is increased up to 3.5 times over plain soil by fiber inclusion. The maximum increase of stress is observed when the fiber length is between 40 and 60% of the least lateral dimension of the specimen (i.e. between 15 and 25 mm for a 38 mm diameter specimen). For a constant fiber length, major principal stress at failure increases with increase in fiber content. However, the additional gain in strength is smaller when the fiber content is increased beyond 1%. At any fiber content, the strength is noted to increase with aspect ratio even up to 150.

Direct shear test results show that the shear strength of polypropylene fiber-reinforced soil increases with inclusion of fibers up to 0.4%, beyond which it decreases. For fiber length of 20 mm (l/d = 100) the increase is maximum, when compared with the unreinforced soil. The cohesion value of soil increases with increased fiber content. On the other hand, the friction angle either increases or does not change significantly with fiber content.

Unconfined compression test results indicate that the UCS of polypropylene fiber-reinforced soil is greater than those of the parent soil. With increasing fiber content, there is an initial increase followed by a decrease and the optimal fiber content is found to be in the range of 0.2-0.3%. However, for any fiber content, the optimal fiber length is observed to be about 10-15 mm. When tire rubber fibers are used, the optimum fiber length is 10 mm and the optimum fiber content is 2%.

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