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Water Content Effect on Shear Strength Parameters in Coir Fiber Reinforced Pilani Soil

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Abstract: Recently, much work has been done on strength deformation behaviour of fiber reinforced soil and it has been established beyond doubt that addition of fiber in soil improves the overall engineering performance of soil. Fiber reinforced soil is effective in all types of soils (i.e. sand, silt and clay). Use of natural fibers in civil engineering construction practice is often advantageous as they are cheap, locally available, biodegradable, and ecofriendly. Among the available natural fibers (jute, coir, bamboo, etc.), coir is produced in large quantities in South Asian countries, such as India, Ceylon, Indonesia, Philippines, etc. and has better mechanical properties, such as tensile strength. In this paper, results on the cohesion and angle of internal friction behavior (obtained from direct shear testing) of local soil reinforced with coir fibers are presented at varied water contents. Soil sample reinforced with randomly distributed coir fibers of 2.5cm length and 2.85mm to 0.64mm average diameter range (measured using screw gauge) were made for direct shear testing at 0.5% fiber content. Testing was done at four different water contents. The results show that cohesion increased and angle of internal friction decreased with increase in water content. Unreinforced in-situ local soil has negligible cohesion and angle of internal friction around 28^0 under similar direct shear testing conditions. Practical significance of the study has also been discussed.

Keywords: *Fiber reinforced soil, randomly distributed, Coir fiber, Cohesion, Angle of internal friction, Direct shear testing, Water content.*

Introduction:

Soil has been used as a construction material from time immortal. Being poor in mechanical properties, it has been putting challenges to civil engineers to improve its properties depending upon the requirement which varies from site to site. Recently, much work has been done on strength deformation behaviour of fiber reinforced soil and it has been established beyond doubt that addition of fiber in soil improves the overall engineering performance of soil. Among the notable properties improved are greater extensibility, small loss of post peak strength, isotropy in strength and absence of planes of weakness. Fiber reinforced soil has been used in many countries in the recent past and further research is in progress for many hidden aspects of it. Fiber reinforced soil is effective in all types of soils (i.e. sand, silt and clay). Use of natural material such as Jute, coir, sisal and bamboo, as reinforcing materials in soil is prevalent for a long time and they are abundantly used in many countries like India, Philippines, Bangladesh etc. The main advantages of these materials are they are locally available and are very cheap. They are biodegradable and hence do not create disposal problem in environment. Processing of these materials into a usable form is an employment generation activity in rural areas of these countries. If these materials are used effectively, the rural economy can get uplift and also the cost of construction can be reduced, if the material use leads to beneficial effects in engineering construction. Studies have also shown that durability of natural fiber added can be improved using coating of fiber with Phenol and Bitumen [Sivakumar Babu and Vasudevan (2008)].

Shear strength is a term used in soil mechanics to describe the magnitude of the shear stress that a soil can sustain. The shear resistance of soil is a result of friction and interlocking of particles, as well as possibly cementation or bonding at particle contacts. Due to interlocking, particulate soil material may expand or contract in volume as it is subject to shear strains. The shear strength of soil depends on the effective stress, the drainage conditions, density of the particles, the rate of strain, and the direction of the strain.

The safety of any geotechnical construction is dependent on the strength of the soil. If the soil fails, the structure founded on it can collapse. Understanding shear strength is the basis to analyze soil stability problems like lateral pressure on earth retaining structures, slope stability and bearing capacity of foundations.

Soil derives its shear strength from two sources: cohesion between particles (stress independent component) and frictional resistance between particles (stress dependent component, measured in terms of angle of internal friction). Direct shear testing is oldest shear testing used to find out cohesion and angle of internal friction. Technique is very useful for freely draining soils, and local soil is of this type. Addition of coir fiber (of given length and diameter) in randomly distributed form in soil affects its cohesion and angle of internal friction value, both in the presence as well as in the absence of pore water. In the present paper, locally available coir fiber (of given length and diameter) was randomly distributed and mixed in oven dry local soil at 0.5% fiber content. This fiber intermixed local dry soil was subjected to direct shear testing at four different water contents to observe the cohesion and angle of internal friction variation under these conditions.

Literature Review:

Gray and Ohashi (1983) conducted a series of direct shear tests on dry sand reinforced with different synthetic, natural and metallic fibers to evaluate the effect of parameters, such as fiber orientation, fiber content, fiber area ratios, and fiber stiffness on the shear strength. Based on the test results, Gray and Ohashi (1983) concluded that an increase in shear strength is directly proportional to the fiber area ratios.

Lekha (2004) and Vishnudas et al. (2006) have presented a few case studies of construction and performance monitoring of coir geotextile reinforced bunds and suggested that the use of coir is a cost effective ecohydrological measure compared to stone-pitching and other stabilization measures used in the protection of slopes and bunds in rural areas. Sivakumar Babu and Vasudevan (2008) studied the strength and stiffness response of soil reinforced with coir-fiber. Based on the experimental results they found that stress-strain behaviour of soil is improved by inclusion of coir-fiber in the soil. They also observed that stiffness modulus of reinforced soil increases considerably which can reduce the immediate settlement of soil significantly.

Experimental Investigation:

Local soil used in the present study was collected from ground surface using core cutter technique. Its bulk density and in-situ water content was found to be 1.76gm/cc and 8.63% respectively. This soil was oven dried. 400gm oven dry soil was used for experimentation. In this oven dry soil, 2gm locally available coir fiber (of 2.5cm length and 2.85mm to 0.64mm average diameter range) was randomly mixed and distributed giving a fiber content of 0.5%. 0ml, 20ml, 34.52ml and 60ml water was added in this coir fiber intermixed oven dry soil in four different direct shear testing experiments. Water content thus used during direct shear testing was 0%, 5%, 8.63% and 15%. Direct shear testing at these water contents of coir fiber mixed (randomly distributed) local soil was conducted in usual manner. Testing was done under fully drained conditions. Results of these direct shear testing on coir fiber reinforced local soil (randomly distributed) have been summarized in Table 1. They are also plotted in Fig 1 and Fig 2.

Table 1: *Direct Shear Test Results on Coir Fiber Reinforced Local Soil*

Normal stress (kg/cm^2)	Failure shear stress (kg/cm^2) (0% water content)	Failure shear stress (kg/cm^2) (5% water content)	Failure shear stress (kg/cm^2) (8.63% water content)	Failure shear stress (kg/cm^2) (15% water content)
0.069	0.11049	0.11663	0.129	0.1473
0.098	0.135	0.14119	0.147	0.1596
0.138	0.1596	0.165745	0.171	0.184162
0.2083	0.21485	0.20871	0.2087	0.220994

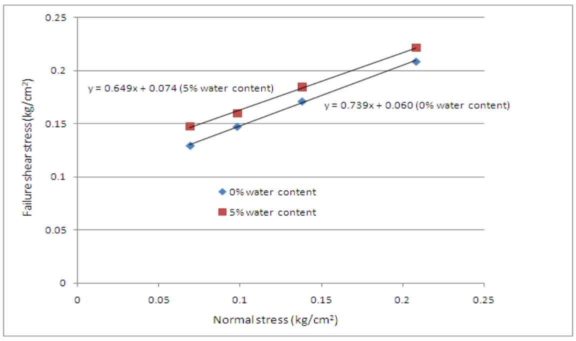

Figure 1: *Direct Shear Test Results on Coir Fiber Reinforced Local Soil*

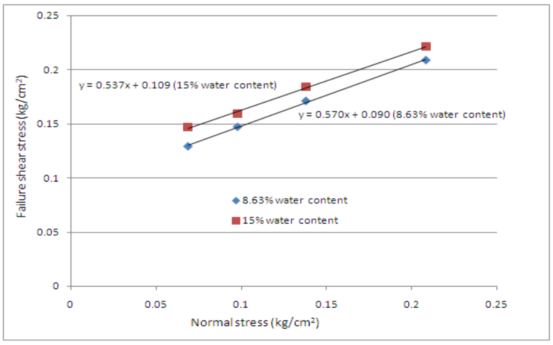

Figure 2: *Direct Shear Test Results on Coir Fiber Reinforced Local Soil*

Cohesion and angle of internal friction value variation (from analysis of Figures 1 & 2) with water content of coir fiber reinforced local soil used in present study has been shown in Table 2. It is also plotted in Figures 3 & 4 respectively.

Table 2: *Cohesion and Angle of Internal Friction Variation at Tested Water Contents*

Tested water content	Cohesion (Kg/cm^2)	Angle of internal friction
0%	0.06	36.46
5%	0.074	32.98
8.63%	0.09	29.68
15%	0.109	28.23

Discussion on Experimental Results:

In-situ experimental soil of present study has negligible cohesion. Its angle of internal friction is around 28^0 [Kumar et al. (2013)]. From the results of present study, it is clear that when local in-situ experimental soil is reinforced with randomly distributed coir fibers used in present study, it results in shear strength gain. At higher and lower than in-situ water contents used in present study also, in-situ soil reinforced with randomly distributed coir fibers used in study has substantial shear strength. Since shear strength of soil has lot of geotechnical applications, results of present experimental study has great significance in the context of local Pilani soil. Testing in present study was limited to only one coir fiber content and one coir fiber length, but shear strength gain was observed. Consequently, other coir fiber contents and other coir fiber lengths can also be tried at different water contents to observe their effect on the shear strength of in-situ local soil. These all will have geotechnical significance in the context of local soil.

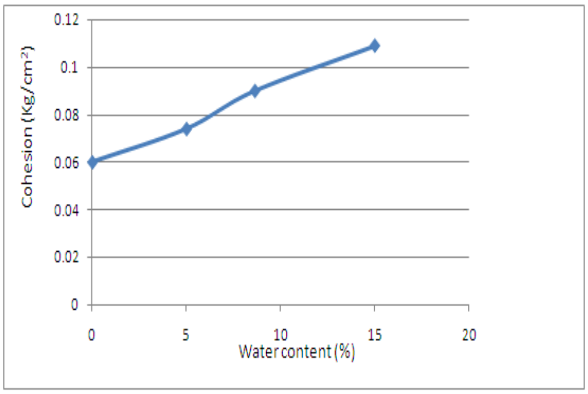

Figure 3: *Cohesion Variation of Tested Coir Fiber Reinforced Soil with Water Content*

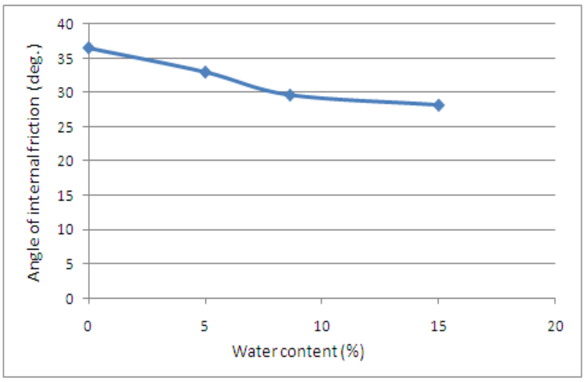

Figure 4: *Angle of Internal Friction Variation of Tested Coir Fiber Reinforced Soil with Water Content*

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