Shear Strength Behaviour of Bamboo Fiber Reinforced Soil

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Abstract - *Bamboo is recognized as a potential natural reinforcing material for improvement and stabilization of soil. Arunachal Pradesh contributes about 40% of the bamboo species available in India. In the present study the shear strength behaviour of a bamboo fiber reinforced soil is investigated. Direct shear tests are performed on the unreinforced and reinforced soil with different percentage of bamboo fiber. The study reveals the increase in the shear strength parameters of the soil with increase in the percentage of fiber upto an optimum amount. Two different length of the fiber are considered in the study and shear strength parameters are also increased with the increase in the length of the fiber.*

Key Words: **Soil improvement; Bamboo fiber; fiber-reinforced soil; Direct shear test, Shear strength.**

1. INTRODUCTION

Due to urbanization and industrialization, soil improvement and stabilization has been an area of major concern in the field of construction. In particular, improvement in sub grade in the construction of highway has always been an active area of study. The behaviour of soil reinforced with natural fibers has gained wide acceptance over the last decades and it has been established that fiber reinforced soil greatly improves the overall engineering performance of soil [5,6,8,10,11,12].

2. REVIEW OF LITERATURE

Different types of fibers are used as reinforcing material to improve the mechanical properties of soil. The choice of a particular type of reinforcing material should be made by considering the material to be (i) cost efficient, (ii) easily available, (ii) nonhazardous and (iv) there is significant increase in engineering properties of soil after its addition. In this regards, the use of natural fiber can be considered to be advantageous. Because natural fibers are cheap, locally available, biodegradable and Eco-friendly.

Bamboo, a perennial grass, is one of the fastest growing grasses, which belongs to family of poaceae/graminae. It exists abundantly in tropical, subtropical and temperate zones of the world and India is the second largest bamboo growing country with an account of 130 species. It is reported that north east region of India has 89 species, out of which Arunachal Pradesh alone contribute 40% of it. Studies have shown that bamboo posses high tensile and compressive strength and also can be used as a potential material for reinforcement in soil as well as in concrete[1,3].

Different investigators studied the laboratory performance of soil reinforced with bamboo in its different shapes and sizes. Mustapha [1] studied the Unconfined Compressive Strength (UCS) and modulus of rigidity of laterite soil reinforced with bamboo plates of 34mm diameter and 3mm thickness. The surfaces of the bamboo specimens were roughened to increase the friction between soil and the specimen. Both the UCS and modulus of rigidity were found to increase with the increase in number of bamboo specimen due to the friction between the soil sample and the rough surface of the bamboo.

Prasad et. al.[4] studied the performance of gravel sub base layer reinforced with different materials in a model flexible pavement construction laid on expansive soil sub grade. The reinforcing materials used include bitumen coated bamboo mesh (BCBM), waste plastics (WP) and waste tire rubber (WTR). Cyclic load was applied by placing a circular metal plate directly on the flexible pavement and the sub grade reinforced with BCBM showed highest the load carrying capacity followed by WP and WTR stretches.

Huang et. al. [7] performed the UCS tests on soil mixed with cement and bamboo chips. The study reveals the increased strength and ductility characteristics of the soil when mixed with bamboo chips.

Marto and Othman [3] studied the potential use of bamboo as reinforcement for soft clay in embankment construction. They constructed three embankments: (a) Embankment on bamboo-geotextile composite (BGC) reinforced, (b) Embankment on High strength geotextile (HSG) reinforced and (c) Unreinforced reinforced embankment. The test results revealed that the BGC reinforced embankment experienced least settlement and lateral movement as compared to the other two embankments.

Asaduzzaman et. al. [9] studied the performance of laboratory model square footings in a bamboo reinforced soil. It was reported that the the vertical settlement of the footings was remarkably decreased with the introduction of bamboo reinforced soil. The improvement in load carrying capacity was also observed considerable in reinforced soil over the unreinforced soil.

Hegde and Sitharam [2] studied the performance of clay beds reinforced with bamboo cells and bamboo grids. The results were compared with that of clay beds reinforced with geocells and geogrids. In their study the bamboo were used to form three–dimensional cells (similar to geocells) and two-dimensional grids (similar to geogrids). It was reported that the ultimate bearing capacity of the clay bed reinforced with bamboo cell and bamboo grid was 1.3 times more than that of clay bed reinforced with geocell and geogrid. Inclusion of reinforcement substantial reduced the footing settlement and the surface deformation. The tensile strength and surface roughness of bamboo were found to be nine times and three times higher than geocell materials respectively.

Critical observation of the literature on fiber reinforced soil reveals that inclusion of fibers can improve both mechanical and engineering properties of soil. Looking at the cost and availability, the present work is aimed to carry out laboratory investigation on the use of bamboo as a potential reinforcing material for improving the behaviour of local soil of Arunachal Pradesh.

3. MATERIALS AND METHODS

The area under present study is located at Karsingsa which is 4km from North Eastern Regional Institute of Science and Technology (NERIST), Arunachal Pradesh. The soil was collected from a depth of about 0.5m from the ground surface. The Index properties of the soil were determined in the Laboratory as per IS codes and is shown in Table-1. The soil is classified to be poorly graded sand.

The shear strength parameter of the soil are determined by Direct Shear Test. All the samples of the soil (both unreinforced and reinforced) are tested at low strain rate so that the tests can simulate drained condition. The three different normal stresses applied for each set of tests are: 0.5 kg/cm^2, 1 kg/cm^2, 1.5 kg/cm^2. Figure 1 shows the normal stress (σ) versus shear stress (τ) graph for unreinforced soil.

Table -1: Index properties of the soil

Sl. No.	Description	Values
1.	Moisture content	5%
2.	Specific Gravity	2.64
3.	Coefficient of curvature	1.142
4.	Coefficient of uniformity	3.31
5.	Maximum dry density (MDD, kN/m^2)	18.68
6.	Optimum moisture content (OMC, %)	13.5

Bamboo fiber was used in this research work. Among the species of bamboo available in Arunachal Pradesh, Bambusa tulda was selected because of its high tensile strength and availability in the locality. The fiber length was taken as 20mm and 30mm. The diameter of the fiber was kept in between 1mm to 2mm. The bamboo reinforcement were mixed with the soil randomly at

different percentage. Laboratory direct shear tests are performed on the bamboo reinforced soil at different percentage of the bamboo fiber. The percentage of the bamboo fiber used for the study are 1%, 2%, 2%, 4% and 5% by weight of the soil. The water content and density of the soil was maintain as 13% and 18 kN/m² (near to OMC and MDD).

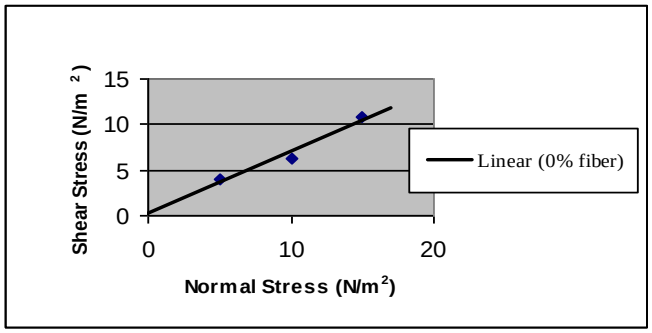

Fig -1: Failure Envelope of unreinforced soil

4. RESULTS AND DISCUSSION

The experiment results i.e. shear strength parameters (C and φ) of soil alone and the Bamboo fiber reinforced soil are studied and compared. Figure 2 and 3 compare the direct shear test results of unreinforced and reinforced soil with different percentage of bamboo fiber with 20mm and 30mm length. The values of the shear strength parameters with different percentage of fiber and length are shown in Table 2. The comparison of the failure envelops for different percentage of fiber are shown in Figure 2 and 3. It can be drawn from the results that inclusion of the fiber content in the soil increases the values of shear strength parameters.

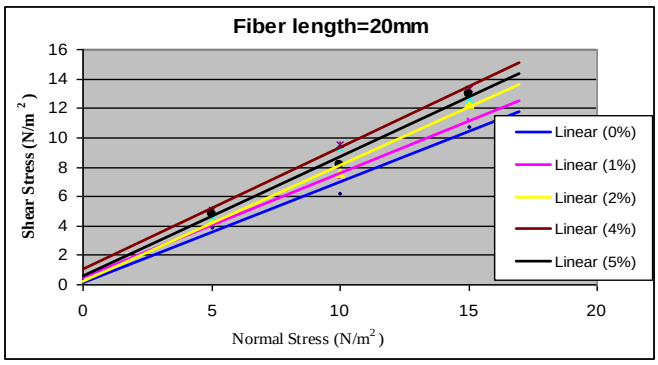

Fig -2: Failure Envelopes for different % of fiber

The increase in length of fiber also increases the shear strength parameters. It is observed that shear strength parameters start falling beyond 4% of fiber content. As only two particular length of the fiber is considered in the study, to draw a conclusion of optimum percentage of fiber with an optimum length, extensive study is to be done and can be a future scope of study.

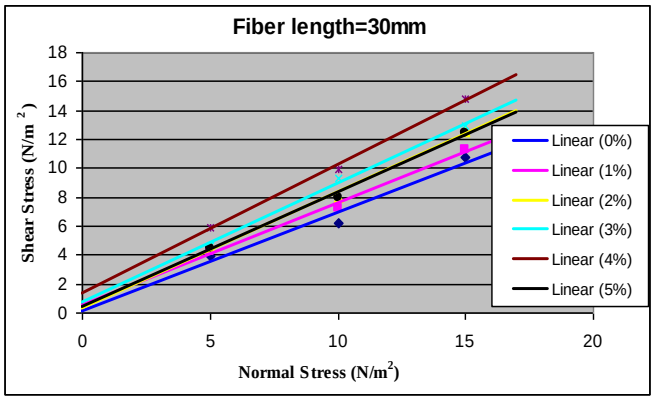

Fig -3: Failure Envelopes for different % of fiber

Table-2: Comparison of shear strength parameters

Length of Fiber	% of Fiber	Cohesion (c in kN/m^2)	Angle of friction (ϕ in degree)
20 mm	0	0.11	34.4
	1	0.488	35.65
	2	0.25	38.9
	3	0.711	39.35
	4	1.025	40.1
	5	0.53	39.4
30 mm	0	0.11	34.4
	1	0.569	35.71
	2	0.33	39.21
	3	0.77	40.0
	4	1.3	41.98
	5	0.4	38.8

5. CONCLUSIONS

The shear strength parameters of a local soil without and with bamboo fiber reinforcement are studied and compared. The fibers are distributed randomly with 5 different percentage and 2 different length. The % of fiber considered are 1%, 2%, 3%, 4% and 5%. The length of the fibers considered are 20mm and 30mm. Laboratory Direct shear tests are performed with slow strain rate to simulate drained condition during the tests. The bamboo used is a locally available species in Arunachal Pradesh. The results show that shear strength parameters of the fiber reinforced soils start raising till 4% of fiber for both the length of the fiber. The increase in the length of the fiber also causes an increase in the shear strength of the soil. To find an optimum percentage of fiber with an optimum length, extensive study is to be done and can be a future scope of study.

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