SOIL STABILIZATION USING NATURAL FIBER COIR

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Abstract *– Soil having poor bearing and shearing strength need stabilization to make it suitable for construction purpose. In this study coir (extracted from coconut) is used as natural fiber for stabilization of soil. Stabilization using natural fiber is a cost-effective and eco-friendly approach to improve properties of soil. Chemical-based or synthetic fibers harm our environment so; the use of natural fiber is an initiative to maintain balance in nature. This study reveals around the reinforcement of soil by coir fiber and the comparison between engineering properties before and after stabilization. The study is carried out to evaluate the effects of coir fiber on shear strength of soil by carrying out direct shear test and unconfined compression test on two different soils samples. Disturbed samples are collected from two different construction sites at Najafgarh and Noida respectively. In laboratory, testing of liquid limit, specific gravity along with grain size distribution is carried out for the classification of soil. For different percentage of coir fiber the Proctor Compaction test was carried out. Further at optimum moisture content (OMC), direct shear test and unconfined compression test are carried out for different fractions of coir fiber. The experimental results with and without coir fiber reinforcement are compared to obtain optimum quantity of fiber reinforcement (% of soil sample) required to stabilize a weak soil along with the inference about effect on bearing capacity and shear strength.*

Key Words:* *Coir, Reinforcement, fibers, OMC, shear strength, bearing capacity.

1. INTRODUCTION

The foundation is very important in field of civil engineering to support and resist loads of entire structure. Therefore, a foundation should be strong enough to increase the service life of any structure. The foundation of structure directly depends on to the soil. So, it is mandatory to have proper knowledge about the physical and chemical properties of soil; and factors which affect their behavior. Some soils are not suitable for foundation work so these soils are stabilized to achieve the required properties needed for the construction work. The need of enhancing soil properties had came in light at the beginning of ancient constructions. In ancient times, Romans utilized various methods to improve soil strength etc. Some of these methods were so effective that their construction in buildings and roads still exist. In India, the era of soil stabilization began in early 1970's. Shortage of petroleum and aggregates forced the engineers to look for other means to reinforce soil instead of replacing the poor soil at the site. Lack of obsolete methods and engineering techniques, soil stabilization lost favor. In the modern era, the increase in the demand for infrastructure and resources, soil stabilization has started to take a new shape. Various researches are carried out on soil stabilization techniques and it is emerging as a popular and cost-effective method to improve soil properties.

Soil reinforced with fibers behaves as a composite material in which fibers improves the strength of soil. Shear stresses in the soil enhance tensile resistance in the fibers, which in turn provides greater strength to the soil. The use of fibers in soil is similar to the behavior of plant roots which contributes to the stability of soil by adding strength to the near-surface soils in which the effective stress is low. Therefore, laboratory and some in situ test results have led to positive conclusions proving the potential use of fibers for the reinforcement of soil mass. The concept of fiber reinforcement was developed in ancient times, more than 5000 years ago when ancient civilizations used straw and hay to reinforce mud blocks. However, short natural and synthetic fiber soil composites have recently gathered attention in the field of geotechnical engineering. The primary purpose of reinforcing soil mass is to improve its stability in order to increase its strength to resist deformations and shear failure. As it was mentioned, soil reinforcement is a procedure where natural or synthesized additives are used to improve the properties of soils. In present time, several reinforcement techniques are available for stabilizing problematic soils.

Here, in this study, soil stabilization has been done with the help of randomly distributed coir fibers obtained from outer shell of coconut (waste material). The objective of this study is to focus on improvement of the shear strength parameters.

2. ADVANTAGES

The study of stabilizing or reinforcing soil with coir fiber helps to predict an idea of its workability and the durability. The workability of soil depends on load bearing capacity and shear strength. Soil gradation is also important to keep in mind while working with soils. The soils may be classified as well-graded which is stable as it has less number of voids or uniformly graded which is partially stable but has more voids. In case of weak soils it is very expensive and inappropriate to replace the entire soil and hence, there is a need of soil stabilization. The study deals with an economical technique to stabilize soil both in terms of cost and energy. This technique can be used to the soil in slopes to provide more stability. It prevents soil erosion or formation of dust in dry and arid weather. The main aim of this study is to utilize coir fiber as a soil stabilizing material that will hold under the design use conditions and for the designed life of the engineering project.

3. METHODOLOGY

3.1 Materials Used

3.1.1 Coir Fiber (coir)

These fibers are biodegradable and environmentally friendly. It has the greatest tearing strength among all natural fibers and retains this property in wet conditions. Therefore, coconut fiber is selected as the reinforcement material for this study. Coir is biodegradable and it takes approximately 20 years to decompose above ground.

3.1.2 Soil Sample

(i) Soil sample 1 (Najafgarh)

(ii) Soil sample 2 (Noida sec. 23)

All the soil samples are compacted at their respective maximum dry density (MDD) and optimum moisture content (OMC), corresponding to the standard proctor compaction tests.

The percentages of fiber reinforcement taken in this study are 0, 0.5, 0.1, and 1.5 of soil sample. Firstly, the sample without fibers is air-dried and mixed with an amount of water depending on the OMC of the soil. Secondly, the sample which has to be reinforced is air dried and then mixed with the adopted content of fibers in small increments by hand, and then the required water was added.

3.2 Experiments Performed and Results

The Atterberg limits for the two samples were carried out by performing the tests in laboratory. The specific gravity of soil is measured with the help of a volumetric flask in a very simple experimental setup where the weight of the soil divided by the weight of equal volume of water. The liquid limit test was carried out by casagrande's tool or groove method with 25 blows. Plastic limit for samples is determined by rolling out soil till its diameter reaches approximately 3 mm and it was repeated until soil crumbles. Plasticity index (Ip) was also calculated with the help of liquid limit and plastic limit.

Table 1 Atterberg Limits of Soil Samples

Properties	Sample 1	Sample 2
Specific Gravity	2.73	2.25
Liquid Limit (W_l)	28.90	43.49
Plastic Limit (W_p)	22.58	19.56
Plasticity Index (I_p)	6.32	24.35
Uniformity Coefficient	9.368	4.547

Uniformity Coefficient is measured with the help of results obtained from sieve analysis test. The curve of particle size distribution was plotted and D10 and D60 are determined. The ratio of, D10 and D60 gives the uniformity coefficient (C_u).

3.2.1 Proctor Compaction Test

This experiment was performed to obtain a relationship between the dry density of the soil and the moisture content of the soil. The experimental setup consists of a cylindrical metal mould, detachable base plate, collar, and hammer (2.5Kg). Compaction process helped in increasing the bulk density by driving out the air from the voids. The concept used in the experiment is that for any compactive effort, the dry density depends upon the moisture content in the soil. The maximum dry density (MDD) is achieved when the soil is compacted at relatively high moisture content and almost all the air is driven out, this moisture content is called optimum moisture content (OMC). The data obtained from experiment helped in plotting the curve with water content as the abscissa and dry density as the ordinate. From this curve, the OMC and MDD were obtained.

Table 2 Summary of results obtained from Proctor Test

Soil Sample	Mass of Soil	Fiber Content (%) of soil mass	Optimum Moisture Content (%)	Maximum Dry Density (gm/cc)
Sample 1	Without Fiber	-	10.0	1.89
	With Fiber	0.5	11.0	1.89
		1.0	11.0	1.93
		1.5	11.6	1.83
Sample 2	Without Fiber	-	8.7	1.90
	With Fiber	0.5	9.3	1.86
		1.0	13.0	1.82
		1.5	13.5	1.80

3.2.2 Direct shear test

Direct shear test is used to find out the soil shear strength parameters such as cohesion (c) and the angle of internal friction (φ). The shear strength is one of the most important factors because workability of structure depends on the soil shearing resistance. The test was conducted by putting the soil at OMC and MDD inside the shear box which is made up of two independent parts. A constant normal load (ς) is applied to obtain one value of c and φ. Horizontal load (shearing load) was increased at a constant rate and applied till the failure point was reached. This load when divided with the area gives the shear strength 'τ' for that particular normal load. The equation for shear strength is given as: $\tau = c + \sigma * \tan(\varphi)$. After repeating the experiment for different normal loads (ς) we obtained a plot which was a straight line with slope equal to angle of internal friction (φ) and intercept equal to the cohesion (c). Direct shear test is the easiest and the quickest way to determine the shear strength parameters of a soil sample.

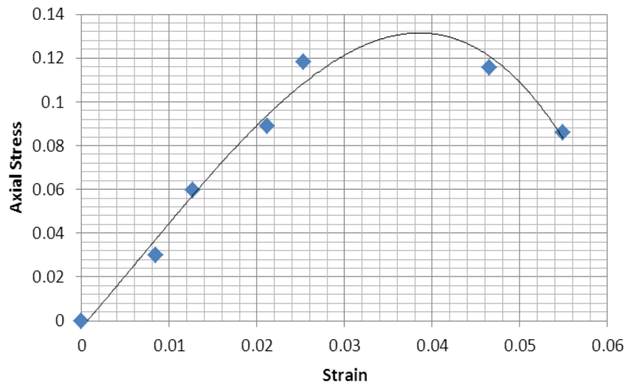
Table 3 Direct Shear Test Results

Soil Sample	Mass of Soil	Fiber Content (%) of soil mass	Cohesion (Kg/cm²)	Angle of internal friction (φ)
Sample 1	Without Fiber	-	0.325	47.72⁰
	With Fiber	0.5	0.357	48.11⁰
		1.0	0.374	48.25⁰
		1.5	0.388	48.48⁰
Sample 2	Without Fiber	-	0.351	27.82⁰
	With Fiber	0.5	0.473	29.02⁰
		1.0	0.504	29.95⁰
		1.5	0.537	23⁰

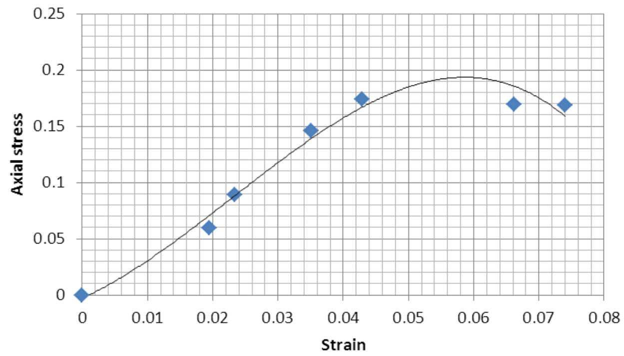
3.2.3 Unconfined Compression Test

This test is usually performed on clayey soil to get their sensitivity values. It is used rapidly to assess clay consistency in field. The test helps in quickly evaluate the undrain cohesion. An undisturbed cylindrical specimen of dimensions 38 Diameter and 76 mm length was used in the test. In this study, both sample 1 and sample 2 possess negligible UCS which can't be determined despite of repetitive efforts. The graph of stress versus strain plotted with the help of results obtained.

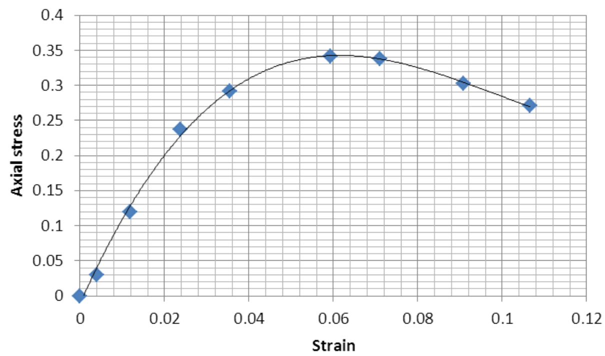
Sample 1 (0.5% fiber), UCS=0.132



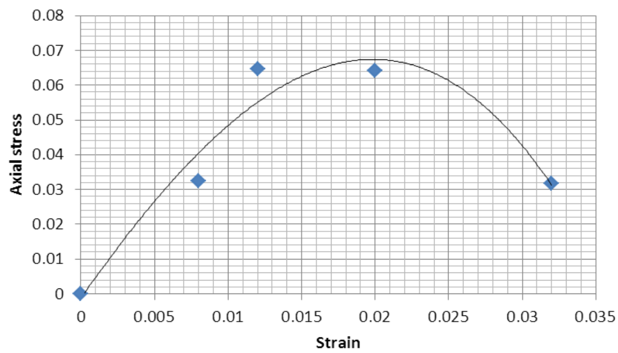
Sample 1 (1.0%fibre), UCS=0.192



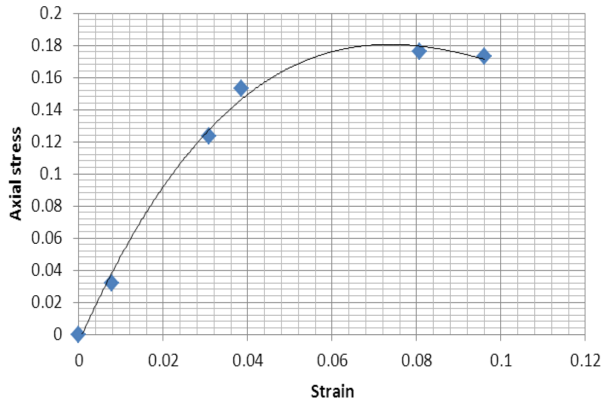
Sample 1 (1.5% fiber), UCS=0.36



Sample 2 (0.5% fiber), UCS=0.0675



Sample 2 (1.0% fiber), UCS=0.18



Sample 2 (1.5% fiber), UCS=0.2675

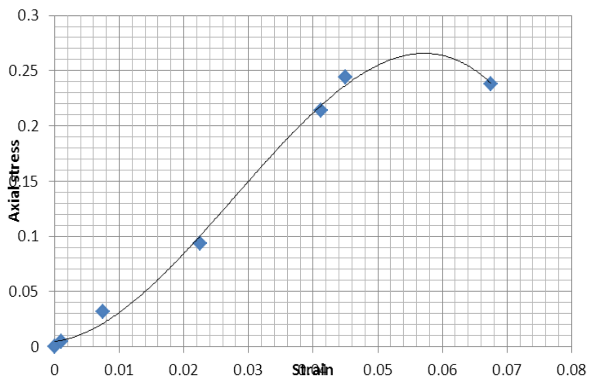


Table 4 Unconfined Compression Test Results

Soil Sample	Fiber Content (%) of soil mass	UCS
Sample 1 (Najafgarh)	0.0	0.750
	0.5	0.132
	1.0	0.192
	1.5	0.360
Sample 2 (Noida)	0.0	0.010
	0.5	0.067
	1.0	0.180
	1.5	0.267

4. CONCLUSION

On the basis of present experimental study, the following conclusions are drawn:

- The results obtained from direct shear test shows that the soil sample 1, with fiber reinforcement of 0.5%, 1.0% and 1.5%, the increase in cohesion was found to be 10%, 4.8% and 3.73% respectively and the increase in the internal angle of friction (φ) was found to be 0.8%, 0.31% and 0. 47% respectively. Since the net increase in the values of c and φ were observed to be 19.6%, from 0.325 kg/cm^2 to 0.3887 kg/cm^2 and 1.59%, with angle of friction from 47.72^0 to 48.483^0 respectively. It can be concluded that for such a soil, randomly distributed Coir fiber reinforcement is not recommended.

- The results from the UCS test for soil sample 1 were also similar for reinforcements with fiber content of 0.5%, 1.0% and 1.5%. The increases in unconfined compressive strength from the initial value are 11.68%, 1.26% and 0.62% respectively. This increment is not substantial and applying it on soils similar to soil sample 1 is not effective.

- The shear strength parameters of soil sample 2 determined by direct shear test illustrates that the increase in the value of cohesion for fiber reinforcement of 0.5%, 1.0% and 1.5% are 34.7%, 6.09% and 7.07% respectively. The increase in the internal angle of friction (φ) was found to be 0.8%, 0.31% and 0.47% respectively. Thus, a net increase in the values of c and φ were observed to be 53%, from 0.3513 kg/cm^2 to 0.5375 kg/cm^2 and 15.02%, with angle of friction 27.82^0 to 32^0 degrees. Therefore, the use of Coir fiber as reinforcement for soils like soil sample 2 is recommended.

- On comparing the results from UCS test of soil sample 2, it is found that the values of unconfined compressive strength show a net increment of 49.8% from 0.0692 MPa to 0.1037 MPa. This also supports the previous conclusion that use of Coir fibers for reinforcing soils like soil sample 2 is recommended.

- Overall it can be concluded that reinforcing soil with fibers can be considered as good ground improvement technique especially in engineering projects on weak soils where it can act as a substitute to deep/raft foundations, reducing the cost of project.

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