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Effects of Coconut Coir Fiber Reinforcement on the Shear Strength of Soil

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Abstract—*Soil reinforcement technique is one of the most popular techniques used for improvement of poor soils. Metal strips, synthetic geotextiles, geogrid sheets, natural geotextiles, randomly distributed synthetic and natural fibers are being used as reinforcing materials to soil. Further, soil reinforcement causes significant improvement in tensile strength, shear strength, bearing capacity, as well as economy. The use of coconut fiber, which is now most often considered as waste, as a resource to produce farm building material to substitute wood product, offers many advantages. They are moth-proof, resistant to fungi and rot, provide excellent insulation against temperature and sound, not easily combustible, flame-retardant, unaffected by moisture and dampness, tough and durable, resilient, springs back to shape even after constant use, totally static free and easy to clean. The main objective of this paper is to investigate the use of waste coconut coir fiber as a soil reinforcement material and to evaluate its effects on the shear strength of soil. A series of direct shear tests are conducted in the laboratory for sands with and without coconut fiber and the results obtained are compared for the original soil sample and the soil sample reinforced with coconut coir fiber and inferences are drawn towards the usability and effectiveness of coconut coir fiber reinforcement as a cost effective approach.*

1. INTRODUCTION

For any land-based structure, the foundation is very important and has to be strong to support the entire structure. In order for the foundation to be strong, the soil around it plays a very critical role. So, to work with soils, we need to have proper knowledge about their properties and factors which affect their behaviour. Construction of building and other civil engineering structures on weak or soft soil is highly risky because such soil is susceptible to differential settlements, poor shear strength, and high compressibility. Various soil improvement techniques have been used to enhance the engineering properties of soil. The process of soil reinforcement helps to achieve the required properties in a soil needed for the construction work. Soil reinforcement by fiber material is considered an effective ground improvement method because of its cost effectiveness, easy adaptability, and reproducibility.

Coconut fiber finds applications in slope stabilization in railway cutting and embankments, protection of water courses, reinforcement of temporary walls and rural unpaved roads, providing a sub base layer in road pavements, land reclamation and filtration in road drains, Containment of soil and concrete as temporary seeding etc, highway cut and fill slopes, control of gully erosion and shallow mass waste.

2. EXPERIMENTAL INVESTIGATIONS

Soil classification by sieve analysis as per Indian Standard Soil Classification System (ISSCS)

The grain size distribution obtained from the test results of the sieve analysis is shown in Fig. 1.

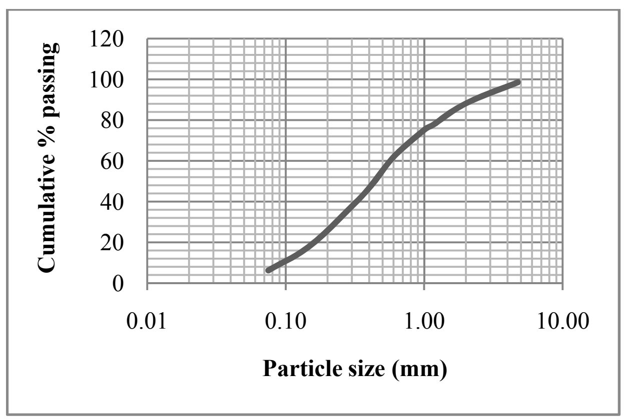

Fig. 1: Grain size distribution

From the curve, we have,
D_{10} = 0.092 mm
D_{30} = 0.250 mm
D_{60} = 0.600 mm
Hence, the coefficient of uniformity, $C_u = D_{60}/D_{10} = 0.6/0.092 = 6.522$
And, the coefficient of curvature, $C_c = D_{30}^2/(D_{10} \times D_{60}) = (0.25)^2/(0.092 \times 0.6) = 1.132$
For a soil to be well-graded C_c must lie between 1 and 3 and in addition to this, C_u must be greater than 4 for gravels and greater than 6 for sands.

Since in the present case, C_c lies between 1 and 3 and C_u is greater than 6, the soil is classified as well-graded sand (SW).

Determination of the maximum dry density (MDD) and the corresponding optimum moisture content (OMC) of the soil by light compaction test

A graph is plotted with water content as abscissa and dry density as ordinate, as shown in Fig. 2.

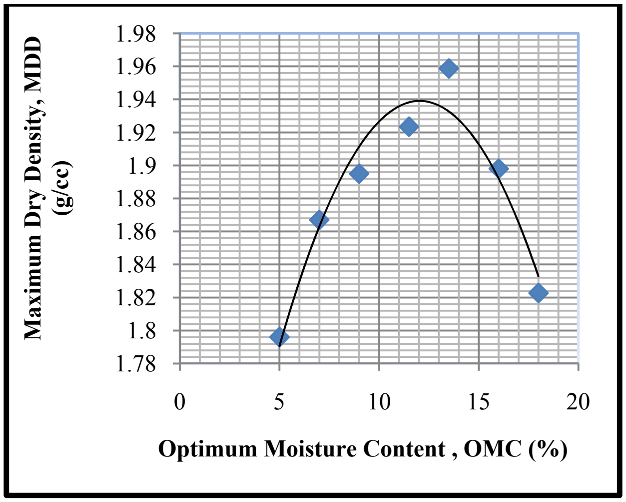

Fig. 2: Compaction curve

From graph, we have,
Optimum moisture content (OMC) = 12%
Maximum dry density (MDD) = 1.94 g/cc

Determination of the shear strength of the original soil sample and reinforced soil samples by direct shear test

i. Thickness of the sample: 2 cm
ii. Area of cross section: 6 cm x 6 cm= 36 cm^2
iii. Rate of shearing: 1.25 mm/min.
iv. Volume of the sample: (6x6x2) cm^3= 72 cm^3
v. Proving Ring Constant: 0.025 kN/Divisions

For the direct shear test, we take a dry density lower than the maximum dry density, MDD (1.94 g/cc). We take 1.6g/cc for the direct shear test.

Therefore,

Weight of the soil sample taken = Density of soil sample x Volume of soil sample
= 1.6 g/cc x 72 cc
= 115.2 g

1.1.1. Unreinforced soil

The shear stress (kg/cm^2) values for unreinforced soil at different normal stress (kg/cm^2) values are shown in Table 1.

Table 1: Shear stress (kg/cm^2) values for unreinforced soil at different normal stress (kg/cm^2) values

NORMAL STRESS (kg/cm^2)	SHEAR LOAD (kN)	SHEAR LOAD (kg)	SHEAR STRESS (kg/cm^2)
0.0	0.113	11.531	0.320
0.5	0.280	28.571	0.794
1.0	0.395	40.306	1.120
1.5	0.452	46.122	1.281

The Mohr-Coulomb failure envelope for unreinforced soil is shown in Fig. 3

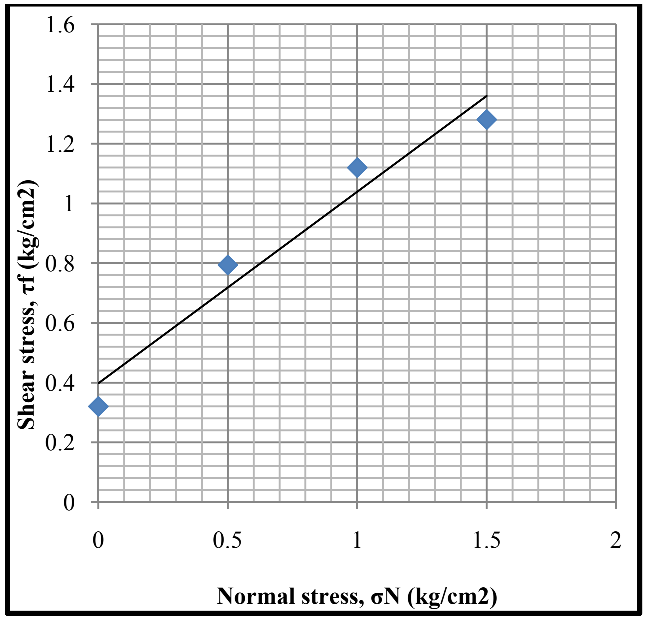

Fig. 3: Mohr-Coulomb Failure Envelope for unreinforced soil

Angle of internal friction, $\varphi = 32°$
Cohesion, C = 0.4kg/cm^2

1.1.2. Reinforcement = 0.25%

The shear stress (kg/cm^2) values for 0.25% reinforcement at different normal stress (kg/cm^2) values are shown in Table 2.

Table 2: Shear stress (kg/cm^2) values for 0.25% reinforcement at different normal stress (kg/cm^2) values

NORMAL STRESS (kg/cm^2)	SHEAR LOAD (kN)	SHEAR LOAD (kg)	SHEAR STRESS (kg/cm^2)
0.0	0.114	11.633	0.323
0.5	0.315	32.143	0.893
1.0	0.375	38.265	1.063
1.5	0.510	52.040	1.445

The Mohr-Coulomb failure envelope with 0.25% reinforcement is shown in Fig. 4

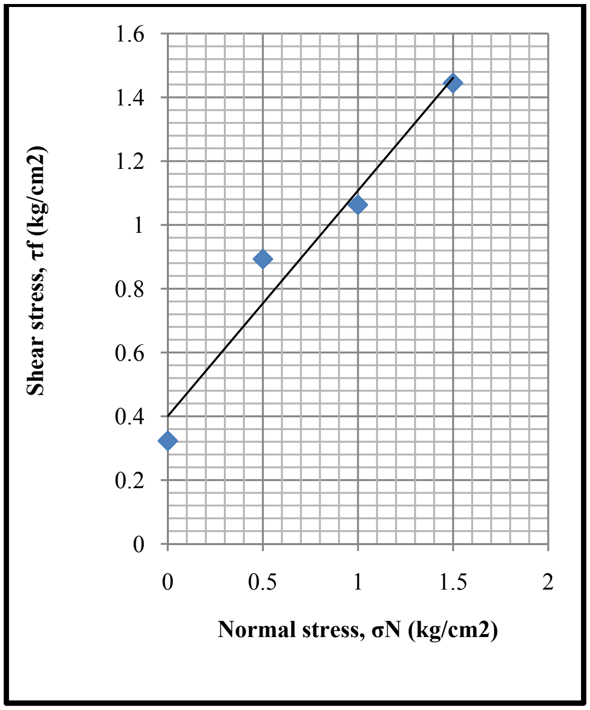

Fig. 4: Mohr-Coulomb Failure Envelope with 0.25% reinforcement

Angle of internal friction, φ = 32.75°
Cohesion, c = 0.43 kg/cm^2

1.1.3. Reinforcement = 0.5%

The shear stress (kg/cm^2) values for 0.5% reinforcement at different normal stress (kg/cm^2) values are shown in Table 3.

Table 3: Shear stress (kg/cm^2) values for 0.5% reinforcement at different normal stress (kg/cm^2) values

NORMAL STRESS (kg/cm^2)	SHEAR LOAD (kN)	SHEAR LOAD (kg)	SHEAR STRESS (kg/cm^2)
0.0	0.120	12.245	0.340
0.5	0.3275	33.418	0.928
1.0	0.375	38.265	1.063
1.5	0.560	57.143	1.587

The Mohr-Coulomb failure envelope with 0.5% reinforcement is shown in Fig. 5.

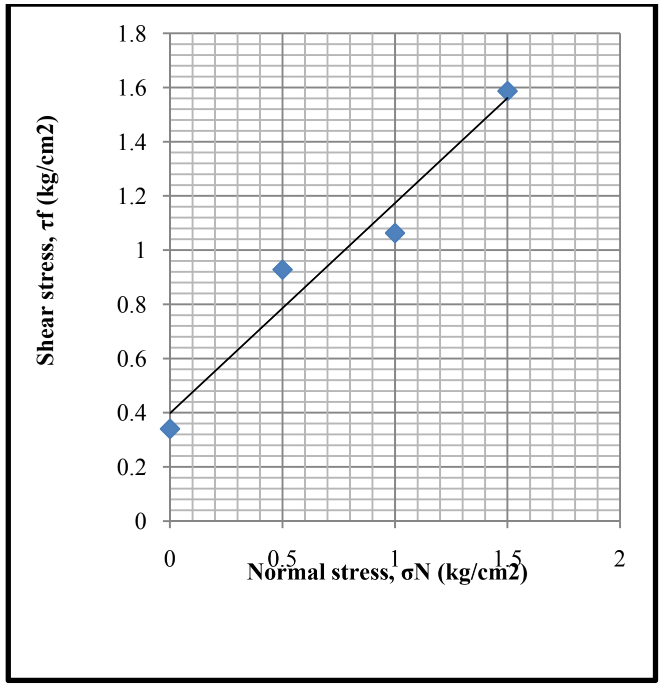

Fig. 5: Mohr-Coulomb Failure Envelope with 0.5% reinforcement

Angle of internal friction, φ = 33°
Cohesion, c = 0.44 kg/cm^2

1.1.4. Reinforcement = 0.75%

The shear stress (kg/cm^2) values for 0.75% reinforcement at different normal stress (kg/cm^2) values are shown in Table 4.

Table 4: Shear stress (kg/cm^2) values for 0.75% reinforcement at different normal stress (kg/cm^2) values

NORMAL STRESS (kg/cm^2)	SHEAR LOAD (kN)	SHEAR LOAD (kg)	SHEAR STRESS (kg/cm^2)
0.0	0.190	19.388	0.538
0.5	0.240	24.490	0.680
1.0	0.494	50.408	1.400
1.5	0.550	56.122	1.559

The Mohr-Coulomb failure envelope with 0.75% reinforcement is shown in Fig. 6

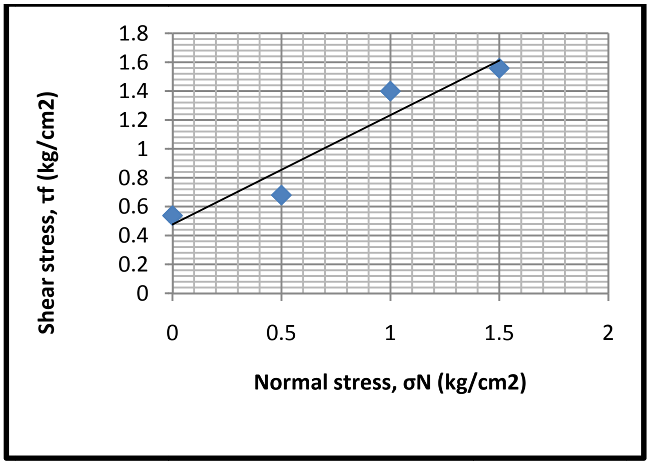

Fig. 6 Mohr-Coulomb Failure Envelope with 0.75% reinforcement

Angle of internal friction, φ = 33.5°
Cohesion, c = 0.45kg/cm^2

1.1.5. Reinforcement = 1%

The shear stress (kg/cm^2) values for 1% reinforcement at different normal stress (kg/cm^2) values are shown in Table 5.

Table 5: Shearstress (kg/cm^2) values for 1% reinforcement at different normal stress (kg/cm^2) values

NORMAL STRESS (kg/cm^2)	SHEAR LOAD (kN)	SHEAR LOAD (kg)	SHEAR STRESS (kg/cm^2)
0.0	0.205	20.918	0.581
0.5	0.251	25.612	0.711
1.0	0.425	43.367	1.205
1.5	0.480	48.980	1.360

The Mohr-Coulomb failure envelope with 1% reinforcement is shown in Fig. 7.

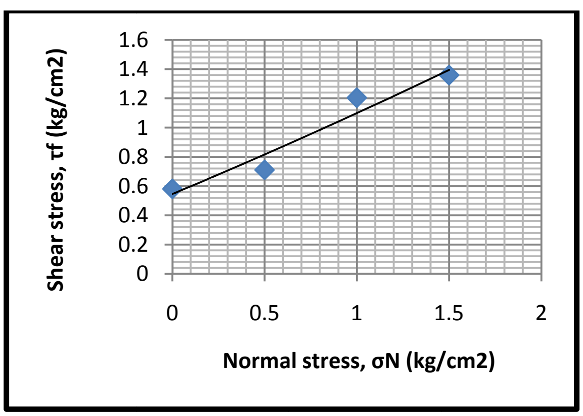

Fig. 7: Mohr-Coulomb Failure Envelope with 1% reinforcement

Angle of internal friction, φ = 34°
Cohesion, c = 0.46 kg/cm^2

3. EXPERIMENTAL RESULTS

The variation of maximum shear load (kg) with the percent of coir fiber (%) is shown in Fig. 8.

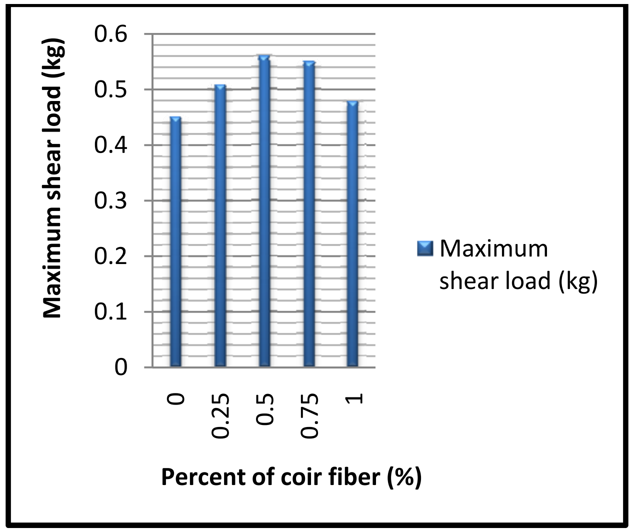

Fig. 8: Variation of maximum shear load (kg) with the percent of coir fiber (%)

The variation of failure lateral strain (%) with the percent of coir fiber (%) is shown in Fig. 9

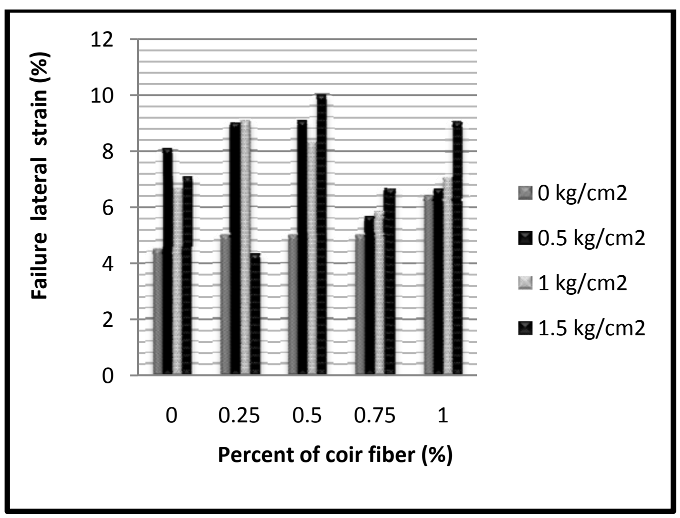

Fig. 9 Variation of failure lateral strain (%) with the percent of coir fiber (%)

The values of angle of internal friction, Φ and cohesion, c (kg/cm^2) for different values of reinforcement are shown in Table 6.

Table 6: Values of angle of internal friction, Φ and cohesion, c (kg/cm^2) for different values of reinforcement

Percent of coir fiber (%)	Angle of internal friction, Φ	Cohesion, c (kg/cm^2)
0	32°	0.40
0.25	32.75°	0.43
0.50	33°	0.44
0.75	33.5°	0.45
1.00	34°	0.46

4. CONCLUSIONS

The conclusions drawn from the test results and discussions are as follows:

- ❖ Among all the considered percentages of coir fiber, the maximum value of shear load (kg) is obtained on addition of 0.5% of coir fiber.

- ❖ The variations of failure lateral strain (%) with the percent of coir fiber added, for a particular value of applied normal stress are as follows:
  - For a zero value of applied normal stress, there is not much variation in the failure lateral strain (%) with the percent of coir fiber added.
  - For 0.5 kg/cm^2 applied normal stress, the maximum failure lateral strain (%) occurs on addition of 0.5% of coir fiber.
  - For 1 kg/cm^2 applied normal stress, the maximum failure lateral strain (%) occurs on addition of 0.25% of coir fiber.
    - For 1.5 kg/cm^2 applied normal stress, the maximum failure lateral strain (%) occurs on addition of 0.5% of coir fiber.

Therefore, 0.5% can be considered to be the optimum percentage of coir fiber to be added to soil to improve its shear strength, among all the percentages that we have considered in our project.

- ❖ The angle of internal friction, Φ increases with the increase in the percent of coir fiber.
- ❖ The cohesion, c (kg/cm^2) tends to increase with the increase in the percent of coir fiber.

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