Soil Reinforcement using Cocopeat

Nitin Goyal, Naman Singhal, Rahul Singh Shekhawat, Nitesh Kumar, M. Bharathi
Department of Civil Engineering, Swami Keshvanand Institute of Technology, Management & Gramothan, Jaipur, Rajasthan-302017, India
Email: **bharathi.m@skit.ac.in**
Received 14.03.2024 **received in revised form** 03.06.2024, **accepted** 07.06.2024
DOI: 10.47904/IJSKIT.14.1.2024.24-27

***Abstract*- Various laboratory and field tests are conducted to acquire essential engineering characteristics of soil for the purpose of design. The characteristics of soil are crucial factors in the planning and construction of foundations and structures for retaining earth. The outcomes of laboratory examinations carried out on soil specimens obtained from three diverse areas of Rajasthan are presented herein. Efforts were made to enhance the soil's shear strength property by utilizing a natural fiber. Cocopeat is one such natural fiber that is commonly used in soil stabilization. The present study investigates and reports the impact of two varying percentages of cocopeat on the soil's strength. It is found that the soil reinforced with cocopeat has achieved improved angle of internal friction values.**

Keywords **– Natural fiber, cocopeat, shear strength, soil reinforcement.**

1. INTRODUCTION

Soil investigation is an important part of any construction project. With the increasing globalization and urbanization, the piece of land available for any infrastructure project is decreasing. The construction fraternity faces a lot of challenges dealing with the limited availability of land for any project. One of those challenges is dealing with the poor properties of soil. Soil basically comprises gravel, sand, silt, and clay. For any building, it is necessary for the soil to have adequate engineering properties. In case the soil does not have adequate strength, there are methods adopted to improve the strength, popularly known as “ground improvement techniques.” Soil reinforcement is one such technique used to improve the strength of the soil.

There are various methods to reinforce soil, such as stone columns, micro-piles, soil nailing, and reinforced earth. In soil reinforcement, natural and synthetic fibers are used to improve the strength of the soil. Soil reinforcement is largely used to improve the engineering characteristics of soil.

Both natural and synthetic fibers have demonstrated successful applications in soil reinforcement over time [1, 2]. These fibers are either oriented distributed or randomly distributed in soil mass to prepare the fiber-reinforced soil. When the fibers are oriented in a particular pattern, either vertical, horizontal or in both directions, it is known as oriented distributed, whereas the latter does not follow any particular pattern. Natural fibers such as bamboo, jute, coir, palm, sugar cane bagasse, water hyacinth, rice husk, sisal, etc., have been used in soil reinforcement applications [1, 2]. In the present study, the selected natural fiber, i.e., cocopeat, has been randomly mixed with soil mass and examined for improvement in strength.

2. LITERATURE REVIEW

The combination of coir fiber, fly ash, and cement demonstrated a notable enhancement in the shear strength (SS) of clayey sand, as reported by Praveen and Kurre [3]. Himanshu et al. [4] found the optimum fiber content to be 0.75% of the dry weight of the soil (clay of low plasticity). They reported that California Bearing Ratio (CBR) values and the unconfined compressive strength (UCS) significantly improved at the optimum fiber content. It was interesting to note from Himanshu et al. [4] that the cohesion value kept increasing with the increase in fiber content till it reached 0.75% and then started decreasing, whereas the angle of internal friction, ϕ kept on increasing with the increase in fiber content. Chaple and Dhatrak conducted a study [5] investigating the influence of coir fiber on both the bearing capacity and settlement of footings. Their findings suggest that reinforcing the soil with coir fiber to a depth equal to 0.25 times the width of the footing is effective in achieving the maximum ultimate bearing capacity. They noted that a concentration of 0.5% of coir in the reinforced soil was sufficient for this enhancement. Kumar et al. [6] reported the optimum percentage of coir fiber reinforcement to be 0.5% in soil (clay with low plasticity). The CBR value increased by three times and the maximum dry density (MDD) increased by four percent and the UCS increased roughly around eighty percent. Das et al. [7] reported an increase of 21% in SS when sandy soil was reinforced with coconut fibers. Upadhyay and Singh [8] reported noticeable improvement in SS of soil from Najafgarh and Noida when reinforced with coir fiber.

3. OBJECTIVES

The major aims of the present investigation are outlined as follows:

• To assess the index and engineering characteristics of soil samples from three diverse areas of Rajasthan.
• To use a natural fiber, in this study, cocopeat and evaluate its effect on the SS of soil.

4. EXPERIMENTAL INVESTIGATION

For soil sample collection, three different parts of Rajasthan, i.e., Jaipur, Sikar, and Jhunjhunu, were selected. Soil sample no. 1 was collected near Akshay Patra, Jagatpura, Jaipur (26.48'5.551"N, 75.51'42.224"E); sample no. 2 was collected from Hanuman Pura, Khatoo, Sikar (27.23'4.733"N, 75.25'36.375"E) and sample no. 3 was collected from Udawas, Jhunjhunu (28.05'10.5"N, 75.25'36.375"E). Basic index and engineering properties tests were conducted on all three collected samples. Tests like sieve analysis of soil [9], specific gravity [10], consistency limits [11] (i.e., liquid limit (LL) and plastic limit (PL)), standard proctor [12], and direct shear (DS) tests [13] were conducted on all three soil samples. All the results obtained from these tests have been presented in section 3.

5. FINDINGS AND DISCUSSION

The outcomes of various laboratory examinations conducted are reported in this section in detail. The soil having the least SS among the three soil samples was reinforced with cocopeat fibers and checked for improvement in SS.

Table 1: Sieve Analysis of Soil Samples

Sieve Size (mm)	Percentage Passing		
	Sample 1	Sample 2	Sample 3
4.75	100	99.8	100
2	83.8	99.6	99.8
1	77.8	99.4	99.6
0.6	74.8	99.2	99.2
0.425	68.4	98.8	97.4
0.3	65.4	98.4	96.8
0.15	24.2	29.2	11.2
0.075	4.8	3.4	2

Table 2: Results of Sieve Analysis

Coefficient	Sample 1	Sample 2	Sample 3
Uniformity coefficient, C_u	2.81	1.97	1.437
Coefficient of Curvature, C_c	2.11	1.31	0.832

The data provided in Table 2 illustrates the outcomes of the sieve analysis. This information reveals that uniformity coefficient (C_u) value is less than four for all three soil samples. When C_c is between one and three, and C_u is greater than six, then the soil can be classified as well-graded sand. In this study, all soil samples fall under the classification of poorly graded sand (SP) [14]. The specific gravity of soil samples 1, 2, and 3 were 2.60, 2.64, and 2.65, respectively.

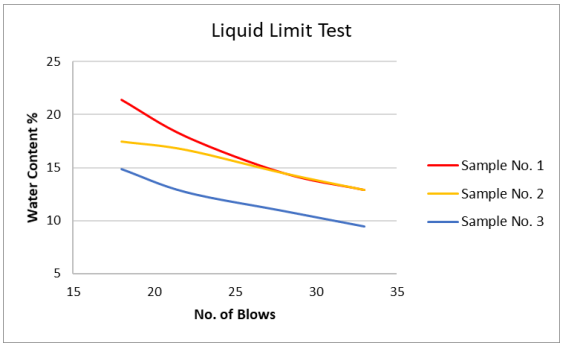

Figure 1: LL of different soil samples

The results of LL tests are presented in Fig.1. The LL is considered as the water content [15] corresponding to 25 blows. Thus, the LL obtained for samples 1, 2, and 3 is 16.2 %, 15.5 % and 11.60 % respectively. Since all three soil samples are poorly graded sand, the authors could not perform PL test as it could not be converted into a thread of diameter 3mm.

Figure 2 displays the results of the compaction test conducted on all three soil samples. At the peak of the curve lies the maximum dry density (MDD), with the water content corresponding to this apex indicating the optimal moisture content (OMC). These values obtained for the soil samples considered in the present study are reported in Table 2.

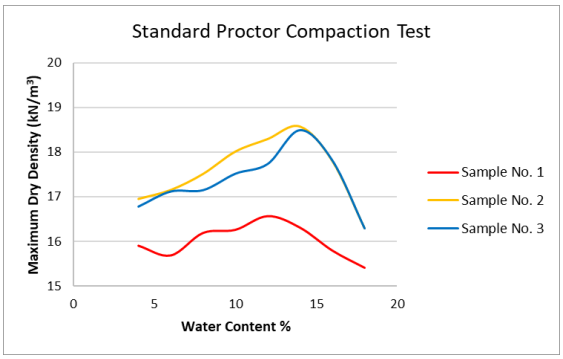

Figure 2: MDD of different soil samples

Table 3: Results of Standard Proctor Test

Sample No.	OMC (%)	MDD (kN/m^3)
1	12	16.57
2	14	18.57
3	14	18.50

An important engineering parameter of soil often reported in geotechnical reports is its SS parameter. Given all three soils under consideration exhibit poor grading characteristics, a DS test has been undertaken to ascertain their SS parameters. DS tests

[7] are carried out for three different normal stress conditions, i.e., 50, 100, and 150 kN/m^2. The shear stress values corresponding to these normal stress values are obtained and reported as presented in Fig. 3.

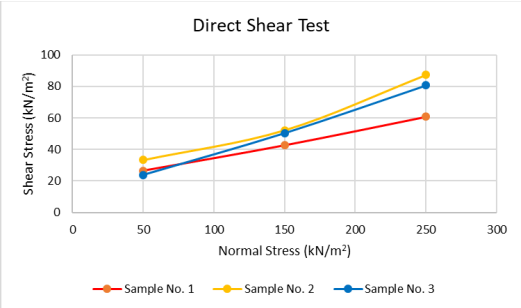

Figure 3: SS of different soil samples

The SS parameters c and ϕ can be obtained from these results. The inclination of the plot from the horizontal will give the value of ϕ whereas its intercept on the vertical axis will give the value of c. Since the soil is poorly graded sand, the c value of the soil will be zero, and the ϕ values are obtained using the equation of a straight line with the intercept of zero for each soil sample in Fig. 3.

Table 4: Results of the DS Test

Sample No.	Equation	R^2	ϕ (°)
1	y = 0.2622 x	0.6306	14.69
2	y = 0.3583 x	0.8396	19.71
3	y = 0.3306 x	0.9654	18.29

3.1 Effect of Cocopeat on SS of soil

It can be observed from Figs. 2 and 3 and Table 4 that among all the three soil samples, sample no. 1 has the least MDD and ϕ. Efforts were made to enhance the SS parameters of soil sample no. 1 with the addition of cocopeat. Compared to the soil, coco peat retains much more water and releases it slowly. A fine powder made from the husks of coconuts is ground into cocopeat.

The density of cocopeat is very low, and hence, literature reported that the addition of 0.5 to 2% of cocopeat by weight of the soil mass will help in significant improvement of the SS parameters of the soil. Thus, in the present study, two different ratios (0.5% and 1%) of cocopeat have been added to soil samples and tested for improvement in SS.

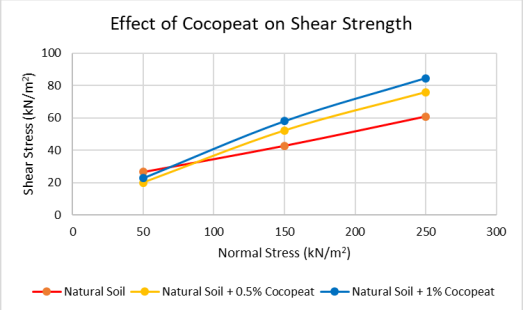

Figure 4: Effect of cocopeat

Table 5: Results of DS Test on Reinforced Soil

Sample	Equation	R^2	ϕ (°)
Natural Soil	y = 0.2622 x	0.6306	14.69
Natural Soil + 0.5% Cocopeat	y = 0.3181 x	0.9688	17.65
Natural Soil + 1% Cocopeat	y = 0.354 x	0.9658	19.49

It can be observed from the results of the present study that ϕ value of the soil improved with the increase in the amount of cocopeat.

6. CONCLUSIONS

The conclusions drawn from the present experimental study are as follows:

- With the addition of natural fiber, cocopeat the ϕ value of the soil was found to improve.
- When 0.5% cocopeat was added to the soil, the value of ϕ increased from 14.69° to 17.65°.
- Further on increasing the cocopeat content to 1%, the ϕ value increased to 19.49° from 14.69°.
- 1% replacement of cocopeat yields a higher value of ϕ. Thus, 1% replacement can be considered as the optimum value for further improvement of soil sample 1 (collected from site near Akshay Patra, Jagatpura, Jaipur).

7. FUTURE SCOPE OF WORK

All the three soil samples obtained for this experimental study were poorly graded sand (SP). This study can be further extended on different types of soil especially on soils with significant silt and clay content to understand the effectiveness of cocopeat reinforcement on these soil types as well.

REFERENCES

[1] Gowthaman S, Nakashima K and Kawasaki S (2018), A State-of-the-Art Review on Soil Reinforcement Technology using Natural Plant Fiber Materials: Past Findings, Present Trends and Future Directions, Materials, 11(4). doi: 10.3390/ma11040553

[2] Sayyed MH, Mohammad S, Sayyed MA and Ali Z (2012), A Simple Review of Soil Reinforcement by using Natural and Synthetic Fibers, Construction and Building Materials, 30, pp. 100-116. doi: 10.1016/j.conbuildmat.2011.11.045

[3] Praveen GV and Kurre P (2021), Influence of Coir Fiber Reinforcement on Shear Strength Parameters of Cement Modified Marginal Soil Mixed with Fly Ash, Materials Today: Proceedings, 39 (1), pp. 504-507. doi: 10.1016/j.matpr.2020.08.238

[4] Himanshu B, Jauhari N and Varshney H (2017), Performance and Analysis of Coir Fibre as Soil Reinforcement, International Journal for Research in Applied Science & Engineering Technology, 5 (11), pp. 67-72. doi: 10.22214/ijraset.2017.11009

[5] Chaple PM and Dhatrak AI (2013), Performance of Coir fiber Reinforced Clayey Soil, International Journal of Engineering and Science, 2 (4), pp. 54-64. https://www.theijes.com/papers/v2-i4/part.%20(5)/J0245054064.pdf

[6] Kumar U, Pandey V and Malviya PR (2022), Stabilization of Soil using Coir Fiber, International Research Journal of Engineering and Technology, 9 (2), pp. 50-54. https://www.irjet.net/archives/V9/i2/IRJET-V9I208.pdf

[7] Das D, Kaundinya D, Sarkar R and Deb B (2016), Shear Strength Improvement of Sandy Soil using Coconut Fibre, International Journal of Civil Engineering and Technology, 7 (3), pp. 297-305. https://iaeme.com/MasterAdmin/Journal_uploads/IJCIET/VOLUME_7_ISSUE_3/IJCIET_07_03_029.pdf

[8] Upadhyay P and Singh Y (2017), Soil Stabilization using Natural Fiber Coir, International Research Journal of Engineering and Technology, 4(12), pp. 1808-1812. https://www.irjet.net/archives/V4/i12/IRJET-V4I12332.pdf

[9] BIS (1985a) IS 2720-4: Methods of test for soils, Part 4: Grain size analysis, Bureau of Indian Standards, New Delhi, India.

[10] BIS (1980) IS 2720-3-1: Methods of test for soils, Part 3: Determination of specific gravity, Section 1: Fine grained soil, Bureau of Indian Standards, New Delhi, India.

[11] BIS (1985b) IS 2720-5: Methods of test for soils, Part 5: Determination of liquid and plastic limit, Bureau of Indian Standards, New Delhi, India.

[12] BIS (1980) IS 2720-7: Methods of test for soils, Part 7: Determination of water content-dry density relation using light compaction, Bureau of Indian Standards, New Delhi, India.

[13] BIS (1986) IS 2720-13: Methods of test for soils, Part 13: Direct shear test, Bureau of Indian Standards, New Delhi, India.

[14] BIS (1970) IS 1498: Classification and identification of soils for general engineering purposes, Bureau of Indian Standards, New Delhi, India.

[15] BIS (1973) IS 2720-2: Methods of test for soils, Part 2: Determination of water content, Bureau of Indian Standards, New Delhi, India.

LIST OF ABBREVIATIONS

SS: Shear Strength; CBR: California Bearing Ratio; UCS: Unconfined Compressive Strength; MDD: Maximum Dry Density; LL: Liquid Limit; PL: Plastic Limit; DS: Direct Shear; SP: Poorly Graded Sand; OMC: Optimal Moisture Content.

ACKNOWLEDGEMENT

We express our sincere gratitude for the assistance provided by Mr. Suresh Kumar Yadav, Senior Technical Assistant in conducting this experimental study efficiently.