An investigation on stabilization of laterite soil using coconut coir fibres

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Abstract. Laterite soils are highly permeable and make the foundation unsuitable construction. Foundation is a significant structural element which play a key role in safety and stability of structure and it has to be strong enough to support the overlying and underlying structures. This research focuses on stabilizing the laterite soil adding coconut coirs fibres at varying percentages viz., 0.25%, 0.5%, 0.75%, and 1%, which are extracted from coconuts serving as natural fibre for stabilization of soil. The tests such as liquid limit, plastic limit, plasticity index, optimum moisture content, maximum dry density, unconfined compressive strength, and soaked & unsoaked California Bearing Ratio tests were conducted on soil specimens made with varying percentages of coconut coir. It was noted that at 0% addition of coconut coir fibre maximum liquid and plastic limits were obtained and with every increase in the coir content the plasticity index, unconfined compressive strength and California Bearing Ratio strengths were increased. On the other hand, the dry density of all the specimens showed almost equal range of density content and the moisture content was decreased with increase in the coconut coir content. Overall, it was found that stabilization of laterite soil using coconut coir as natural fibres is a cost-effective and eco-friendly approach to improve the properties of soil.
Key words: Laterite soil, Soil stabilization, Coconut coir fibre

1. Introduction

Now a days population increase and rapid industrial development, having sufficient knowledge and information about the methods of improving the current surface soils for use in various construction projects is an essential issue for a geotechnical engineer. Soil improvement is very essential and possible practical ways. It is also economically viable to improve the soil resisting capacity, strength, soil permeability and also control soil erosion [1]. There are a number of different stabilization techniques to choose from, and the best one must be considered based on its specific requirement. In recent years, using industrial by-products for soil stabilization has become more popular as a means of ensuring that regional soils satisfy site-specific needs [2]. Fibers like polypropylene fibers, coconut coir etc. help to give soil particles more stability [3-9]. Lateritic soil, which is common in coastal areas of southern India, has a porous structure and requires stabilization when the intended use is special and requires more strength and durability. The goal of this study is to use coconut coir fibers to stabilize laterite soil.

2. Methodology

Laterite soil was collected from the place Miyapur, Hyderabad. The laterite soil was tested in the laboratory and sequence of procedure for each test is described below. Coconut coir is used as natural fibre for stabilization of soil. The coconut coir fibre is a natural fibre, ecofriendly. Whereas the other type of made chemical fibres cause harm to environment. Coir fibre is used as it is an eco-composite, tough and sturdy, resistant to fungus and decay, has lower thermal conductivity and bulk density. This soil stabilization technique. Soil stabilization is important in sloped structures. The major deposits of laterite soil in India are mainly found in southern and eastern India, and marine areas in such areas the laterite soil stabilization is more helpful. Properties of laterite soil are listed in Tables 1 and 2.

Table 1. Chemical properties of laterite soil.

Chemicals	Values (%)
SiO_2	33.55
Al_2O_3	22.31
Fe_2O_3	19.40
K_2O	16.71
CO_2	3.65
MgO	2.07
SO_3	1.98
P_2O_5	0.11

Table 2. Physical properties of laterite soil.

Property	Values (%)
pH	4.86
Specific Gravity	2.73
Surface area	57.89 m^2/g
LL	53%
PL	31%
PI	22%
MDD	1.35 mg/m^3
OMC	33.4%

The laterite soil has some disadvantages the most problems with shallow lateritic soils are low effective soil volume, poor nutrient status and water holding capacity. To improve the properties of laterite soil coconut coir is used for the laterite soil stabilization. The major disadvantages of laterite soil are nutrition values are very less and it will not hold water in its pores i.e., high permeability.

Coconut coir fibre is a hard structural fibre and it is a crucial commercial product obtained from the husk of coconut. There are two types of fibres are available, depending upon method of extraction of coir from husks. The husks obtained from ripe are brown coir in colour and primarily used for brushes, floor mats and white coir is obtained from shortly harvested coconut before they ripen.

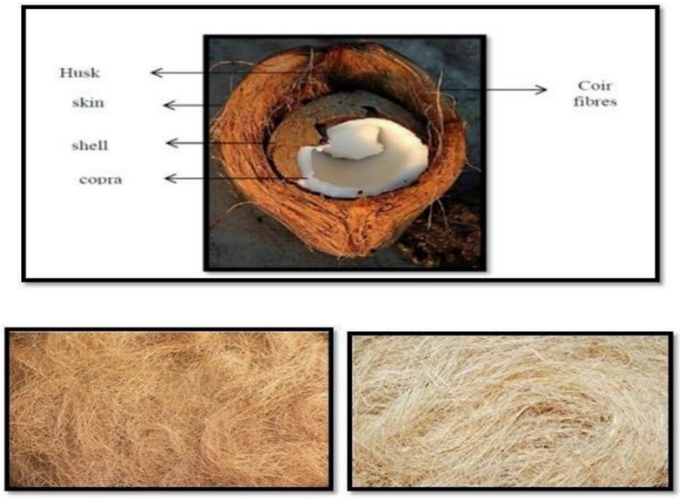

Figure 1. Types of coir fibre.

The coconut coir fibre consists of cellulose, hemicellulose formed sugar chains, lignin, pectin and some water-soluble contents are present. The types of coir fibers are shown in Figure 1 and their chemical and physical composition are listed in Tables 3 and 4.

Table 3. Chemical composition.

Content	Percentage
Lignin	45.84
Cellulose	43.44
Hemi cellulose	0.25
Pectin and related compounds	3.00
Water soluble	5.25

Table 4. Physical properties.

Property	Values (%)
Length (mm)	15 – 280
Density (g/ cc)	1.15 – l.40
Breaking elongation (%)	29.04
Diameter (mm)	0.1 -0.5
Specific gravity	1.15
Young's modulus (GN/m^2)	4.5
Tenacity (g/tex)	10.0

2.1. Compaction test

The compaction test conducted on laterite soil, for the test 1300gm of soil was used with and water is sprinkled to meet water content in soil near to 5 percent less than OMC. Compaction mould setup (Figure 2) is prepared and filled with soil in three layers for each layer 25 blows are given to obtain maximum compaction. After this step apparatus setup is removed and sample is tested for determining the moisture content. This procedure is continued for different water percentages, with help of graph optimum moisture content can be calculated.

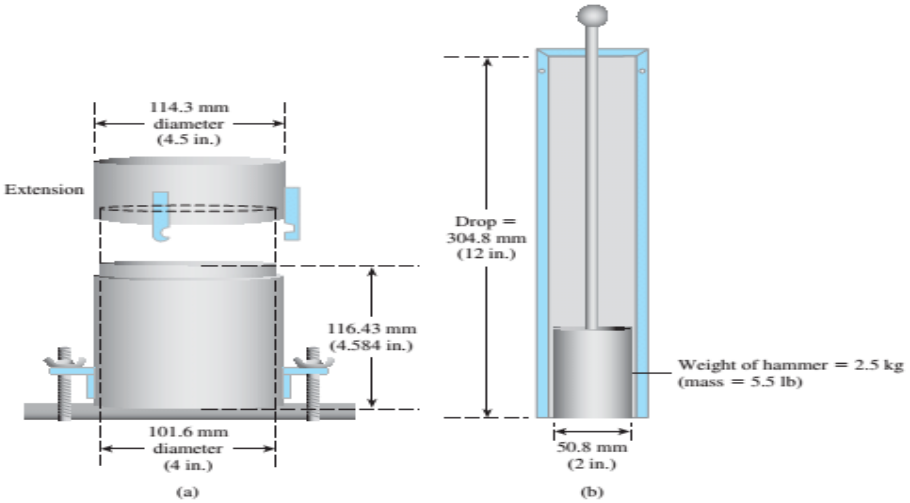

Figure 2. Compaction tools.

2.2. Liquid limit test

To conduct liquid limit, test a soil sample was taken and mixed with distilled water, prepared a uniform paste. Using Casagrande's liquid limit apparatus (Figure 3) and grooving tools (Figure 4) the liquid limit was determined based on number blows as per IS: 2720 (Part 5) – 1985 (Re-affirmed 2015) [10].

Figure 3. Liquid limit apparatus.

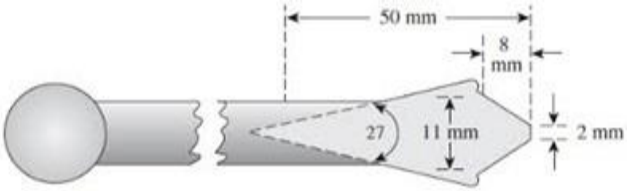

Figure 4. Grooving tools.

2.3. Plastic limit test

The plastic limit test – take 120 gms of soil oven dried sample of size less than 425 μ. This sample is thoroughly mixed with water and using plastic limit test procedure shown in Figure 5, we will find the appropriate water content.

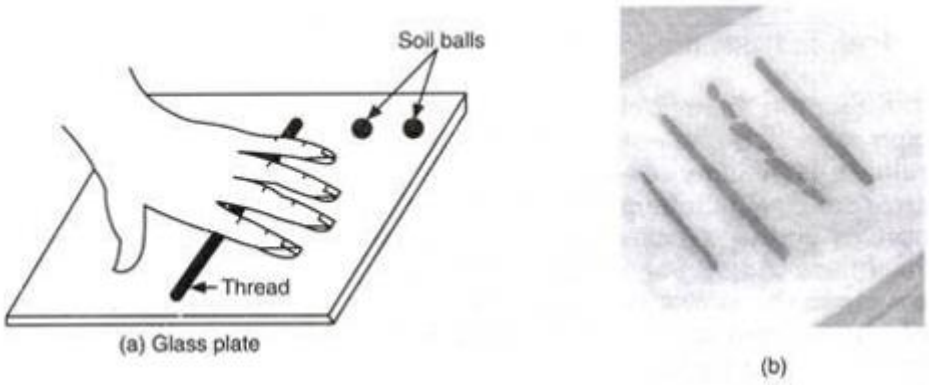

Figure 5. Plastic limit apparatus.

2.4. Unconfined compressive strength test

The unconfined compressive strength of soil, a sample of soil is taken sprinkled with required water content. A specimen is prepared with different percentages of coir fibre as per standard dimensions and allowed for testing as per IS: 2720 (Part 10) – 1991 (Re-affirmed 2006) [11] and deflection vs load results were noted down after testing in test setup shown in Figure 6.

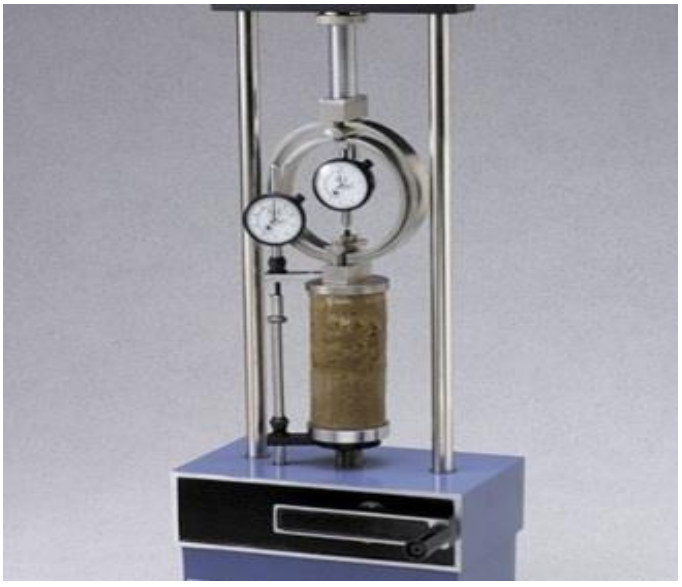

Figure 6. Unconfined compressive strength test apparatus.

2.5. California bearing ratio test

To conduct bearing ratio test 5000 grams of soil is used, required quantity of water is added and sample is prepared as per standards by giving required number of blows for each layer for compaction. The sample tested and load is applied using CBR testing machine shown in Figure 7 as per IS: 2720 (Part 16) – 1987 (Re-affirmed 2002) [12] and results were noted.

Figure 7. California bearing ratio (CBR) test.

3. Results and discussion

The laterite soil was tested to evaluate different properties of it, with 0%, 0.25%, 0.5%, 0.75%, 1% adding of coconut fibre with laterite soil and the results were tabulated below.

3.1. Plastic limit test

The soil was tested for plastic limit values at different percentages of coconut coir fibre 0%, 0.25%, 0.50%, 0.75% and 1% respectively. The results are shown in Table 5 and Figure 8.

Table 5. Plastic limit.

Coconut coir fibre (%)	Plastic Limit (%)
0%	25.5
0.25%	23.2
0.50%	21.0
0.75%	18.6
1%	16.4

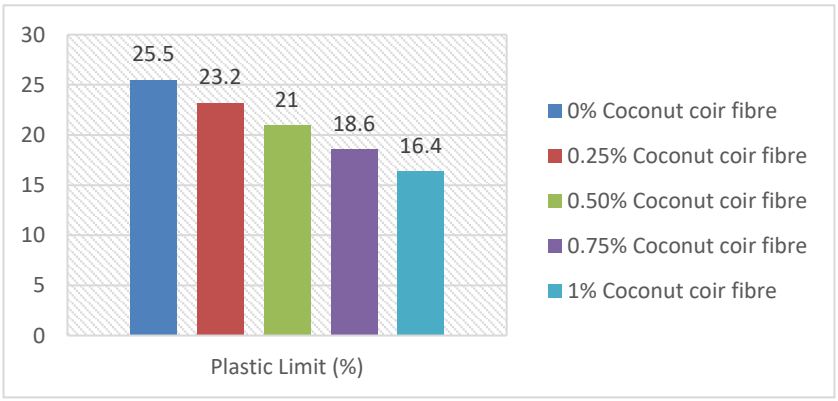

Figure 8. Plastic limit results.

For plastic test maximum plastic limit value was observed at 0% coconut coir fibre which was 25.5% and the minimum plastic limit value was recorded at 1% of coconut coir fibre replacement which was 16.4%.

3.2. Liquid limit test

The soil was tested for liquid limit values at different percentages of coconut coir fibre 0%, 0.25%, 0.50%, 0.75% and 1% respectively. The results are tabulated shown in Table 6 and Figure 9.

Table 6. Liquid limit.

Coconut coir fibre (%)	Liquid Limit (%)
0%	47
0.25%	46.2
0.50%	44.6
0.75%	43.5
1%	42.0

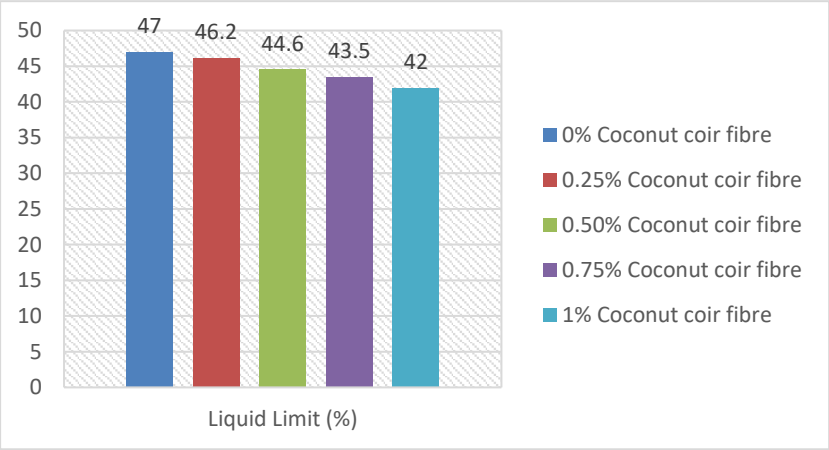

Figure 9. Liquid limit.

In liquid limit test at 0% coconut coir fibre, liquid limit of the laterite soil was 47% which is the maximum liquid limit value and the minimum liquid limit was recorded at 1% of coconut coir fibre which was 42%.

3.3. Plasticity Index

The soil was tested for plastic and liquid limit values at different replacement % of coir fibre 0%, 0.25%, 0.50%, 0.75% and 1% respectively. The values of plasticity index values are shown in Table 7 and Figure 10.

Table 7. Plasticity index.

Coconut coir fibre (%)	Plasticity Index (Liquid Limit-Plastic Limit) (%)
0%	21.5
0.25%	23
0.50%	23.6
0.75%	24.9
1%	25.6

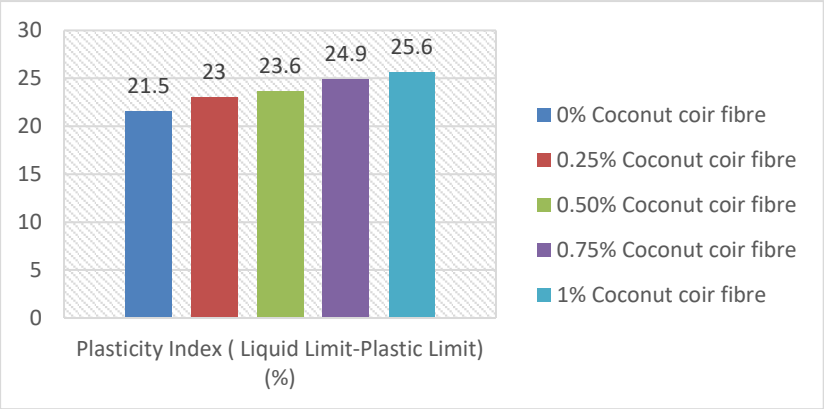

Figure 10. Plasticity index.

In the plasticity index the maximum value was recorded at 1% of coconut coir fibre replacement which was 25.6% and the minimum plasticity index value is recorded at 0% coconut coir fibre replacement which was 21.5%.

3.4. Optimum moisture content and maximum dry density

The compaction test was conducted on soil at different percentages of coconut fibres and maximum dry density values are noted down and shown in Table 8 and Figure 11 and Figure 12.

Table 8. Optimum moisture content and maximum dry density.

Coconut coir fibre (%)	Maximum Dry Density	Optimum Moisture Content
0 %	1.84	13
0.25%	1.86	12.8
0.50%	1.875	12.45
0.75%	1.88	12.15
1%	1.89	11.95

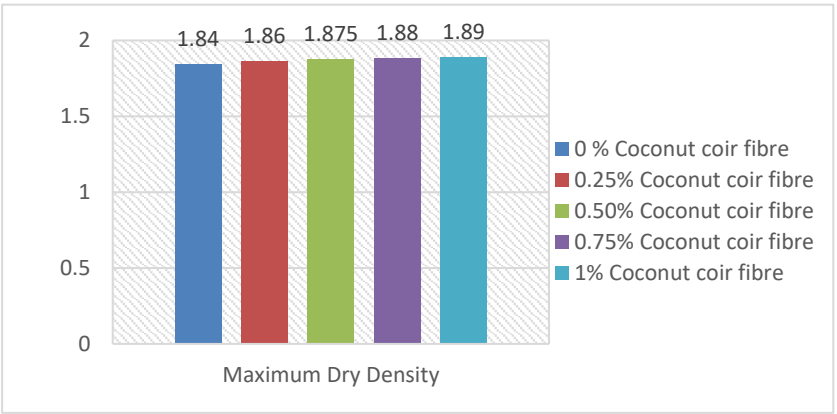

Figure 11. Maximum dry density.

The maximum value of dry density was recorded at 1% of coconut coir fibre replacement which was 1.89 and the minimum dry density value is recorded at 0% coconut coir fibre replacement which was 1.84.

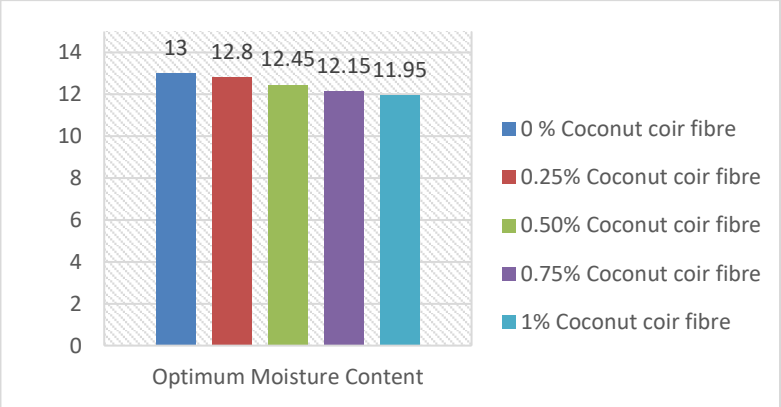

Figure 12. Optimum moisture content.

The moisture content values are decreasing with increase of coconut coir fibre replacement. At 0% replacement of coconut coir fibre the moisture content values are observed as 13, whereas for 1% replacement moisture content value is observed as 11.95.

3.5. Unconfined compressive strength

the soil was tested for unconfined compressive strength values at different percentages of coconut fibres and results are shown in Table 9 and Figure 13.

Table 9. Plasticity index.

Coir Fibre (%)	Strength (kg/cm2)
0%	0.335
0.25%	0.352
0.50%	0.363
0.75%	0.374
1%	0.428

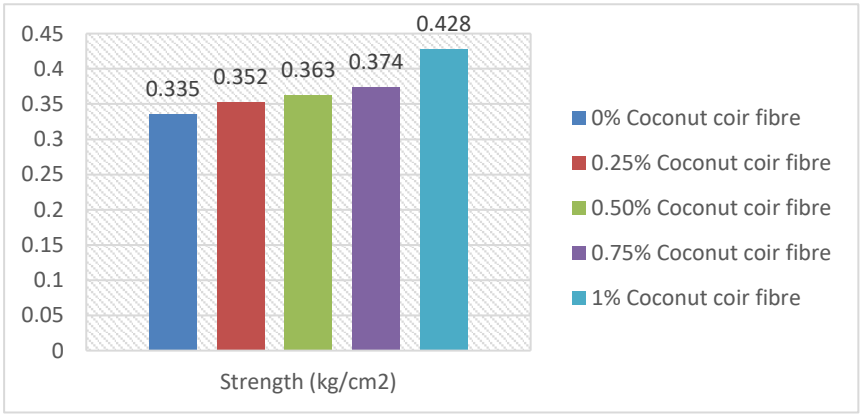

Figure 13. Unconfined compressive strength.

In unconfined compressive strength test, the maximum stress was recorded at 1% of coconut coir fibre which was 42.8kn/m2 and the minimum stress was recorded at 0% of coconut coir fibre replacement which was 35.2kn/m2.

3.6. California bearing ratio test - Soaked

The soil was tested for California bearing ratio at different percentages of soaked coconut fibres and results are shown in Table 10 and Figure 14.

Table 10. Soaked California bearing ratio.

Coir fibre %	CBR %
0%	5%
0.25%	6.1%
0.50%	7.3%
0.75%	8.2%
1%	9.7%

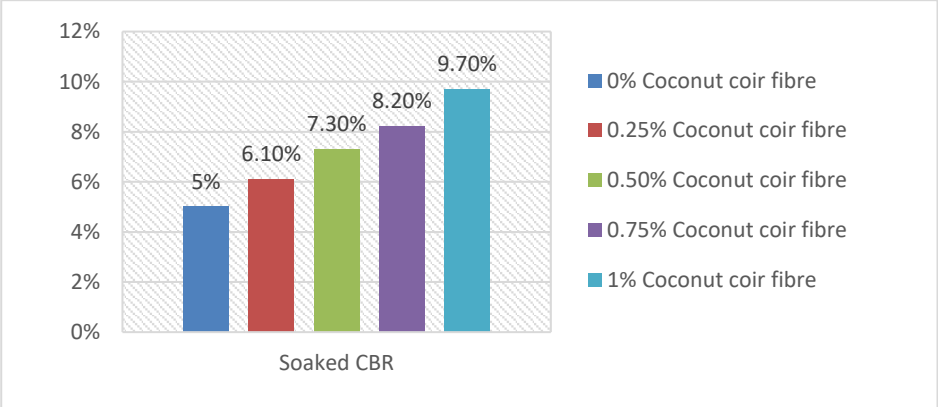

Figure 14. Soaked California bearing ratio.

In Soaked California bearing ratio test the maximum CBR% value was recorded at 1% coconut coir fibre replacement which was 9.7% and the minimum value was recorded at 0% of coconut coir fibre replacement which was 5%.

3.7. California bearing ratio test - Unsoaked

The California bearing ratio test was conducted at different percentages of un-soaked coconut fibres and results are shown in Table 11 and Figure 15.

Table 11. Unsoaked California bearing ratio.

Coir fibre %	CBR %
0%	14%
0.25%	15.6%
0.50%	16.7%
0.75%	17.8%
1%	19.1%

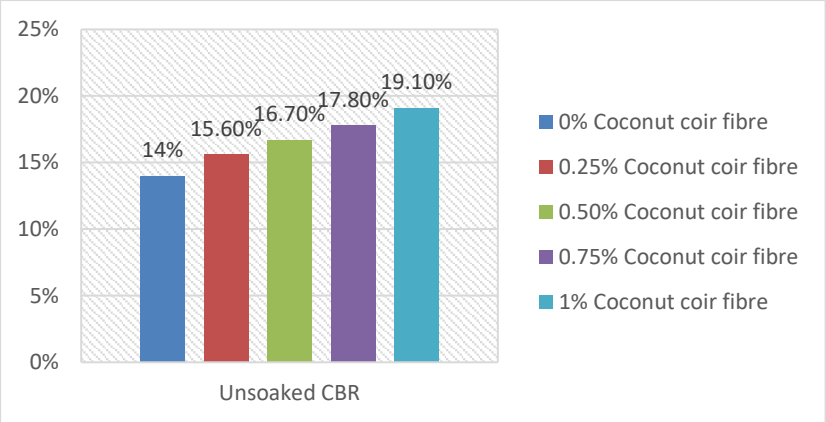

Figure 15. Unsoaked California bearing ratio.

In Unsoaked California bearing ratio test the maximum CBR% value was recorded at 1% coconut coir fibre replacement which was 19.1% and the minimum value was recorded at 0% of coconut coir fibre replacement which was 14%.

4. Conclusion

The tests such as liquid limit, plastic limit, plasticity index, optimum moisture content, maximum dry density, unconfined compressive strength, and soaked & unsoaked California Bearing Ratio tests were conducted on soil specimens made with varying percentages of coconut coir.

1. In compaction test, the maximum dry density was observed 1.89 for 1% coconut coir fibre addition. The OMC value is decreased to 11.95 at 1% coconut coir fibre.
2. The liquid limit value is maximum 47%, without adding coconut coir fibres and at 1% coconut coir fibre addition the liquid limit value is decreases to 42%. The decrease in liquid limit is due adding coconut coir.
3. The plastic limit value is decreased from 25.5-16.4% at 1% adding of coconut coir, this decrease is observed as the coconut coirs have observed the water content. The plasticity index was observed as 25.6% at 1% adding of coconut coir fibres.
4. By adding 1% coconut coir fibres the unconfined compressive strength value was observed as 42.8, there is an increase in the strength as fibres added are taking over the load acting on laterite soil.
5. In California bearing ratio (Soaked) test the maximum CBR% value was recorded at 1% coconut coir fibre replacement which was 9.7% and the minimum value was recorded at 0% of coconut coir fibre replacement which was 5%. California bearing ratio-soaked test observed a result of 9.7 at 1 % fibre addition where as in unsoaked test the value was 19.1. The addition of unsoaked fibres is giving effective results.

5. Scope of Further Study

Coir fibre is the waste material obtained from the husk of coconut fruit and can be used for civil engineering constructions. Stone dust, fly ash and rice husk etc. other additives can be used in mix with Coir fibre to improve strength of soil. Coating of coir fibre can be done to increase the life of fibre. A study on compressibility and consolidation characteristics of soil mixed with coir fibre is suggested and aspects of bearing capacity also warrant further investigation. We've found no higher study papers on the laterite soil with coconut coir during our whole research so we expect our paper would help as a base for further studies or researches on this topic.

References

[1] Marto, A., Latifi, N., & Sohaei, H. (2013). Stabilization of laterite soil using GKS soil stabilizer. Electronic Journal of Geotechnical Engineering, 18(18), 521-532.
[2] Noolu, V., Paluri, Y., Chavali, R. V. P., Reddy, B., & Thunuguntla, C. S. (2021). Evaluation of a clayey soil stabilized by calcium carbide residue as pavement subgrade. Transportation Infrastructure Geotechnology, 1-14.
[3] Chowdary, B., Ramanamurty, V., & Pillai, R. J. (2020). Fiber reinforced geopolymer treated soft clay–An innovative and sustainable alternative for soil stabilization. Materials Today: Proceedings, 32, 777-781.
[4] Dasaka, S. M., & Sumesh, K. S. (2011). Effect of coir fiber on the stress–strain behavior of a reconstituted fine-grained soil. Journal of Natural Fibers, 8(3), 189-204.
[5] Subramani, T., & Udayakumar, D. (2016). Experimental study on stabilization of clay soil using coir fibre. International Journal of Application or Innovation in Engineering Management Decision, 5, 192-204.
[6] Tiwari, A., & Mahiyar, H. K. (2014). Experimental study on stabilization of black cotton soil by fly ash, coconut coir fiber and crushed glass. International Journal of Emerging Technology and Advanced Engineering, 4(11), 330-333.
[7] Upadhyay, P., & Singh, Y. (2017). Soil Stabilization Using Naural Fiber Coir. Int. Res. J. Eng. Technol., 4(12), 1808-1812.
[8] Ayininuola, G. M., & Oladotun, P. O. (2016). Geotechnical properties of coconut coir fiber soil mixture. Journal of Civil Engineering Research, 26(4), 79-85.
[9] Shankar, A. R., & Priyanka, B. A. (2021). Experimental Studies on Lateritic Soil Stabilized with Cement, Coir and Aggregate. In Problematic Soils and Geoenvironmental Concerns (pp. 751-763). Springer, Singapore.
[10] IS: 2720 (Part 5) – 1985 (Re-affirmed 2015) Methods of Test for Soils: Laboratory Determination of Liquid and Plastic Limit.
[11] IS: 2720 (Part 10) – 1991 (Re-affirmed 2006) Methods of Test for Soils: Determination of Unconfined Compressive Strength
[12] IS: 2720 (Part 16) – 1987 (Re-affirmed 2002) Methods of Test for Soils: Laboratory Determination of California Bearing Ratio (CBR).