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Laboratory analysis for coconut coir fiber to improve compressibility characteristics of cohesive nature soil

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Abstract — An efficient and dependable method for enhancing the strength and stability of soils is soil reinforcement. Numerous studies have looked at how randomly oriented discrete inclusions (such as fibres, mesh components and waste materials like plastic strips and tyre pieces) affect highly compressible clayey soils.. In many parts of southern and coastal India, coir, a naturally biodegradable material, is used for construction. In the majority of these experiments, the Small samples were put through the triaxial test, C.B.R., unconfined compression and direct shear tests. The current work focuses on the effect of coir on bearing capacity and settling of footings employing parameters using laboratory model tests on highly compressible clayey soil reinforced with randomly dispersed coir fibre. such as the thickness of the reinforced layer with 0.25%, 0.5%, 0.75%, and 1.0% of coir. The capacity of the structure is increased by the inclusion of a reinforced layer made of coconut coir. The provision of a coir-reinforced layer, which was shown to be an economical technique among many types of bearing capacity improvement techniques, generally demonstrates that it decreases settlement and enhances bearing capacity.

Keywords — ***Coconut coir, bearing capacity, Settlement, Renewable source, CBR value***

1. INTRODUCTION

During building infrastructure development, waste materials are frequently recycled to improve the soil's bearing and settling qualities. One of the main reasons for soil shear failure is the high compressibility of clayey soil. When soft soil is used for building construction, other ground-improvement methods, such as soil stabilization and soil reinforcing, are used. The majority of the immediately accessible soil is weak or has poor tensile strength, but it has acceptable compressive strength and adequate shear strength. Many scientists have focused their studies on the creation of new materials like these through the creation of composites in an effort to overcome the problem. Few studies have employed the triaxial test to examine the shear strength of expansive soil mixed with fibres, despite the fact that many studies have been undertaken to evaluate the influence of randomly mixed fibres in soil. The direct shear test was used by Kar et al. [15] and Das et al. [9] to examine the shear strength of sandy soils. Expansive soil supplemented with coconut fibres has undergone several mechanical property tests. Peter carried out the triaxial and CBR experiments [10], Narendra et al. noticed the expansive soil's UCS [18], Himanshu et al. performed triaxial testing on clay soils [19], and Lal et al. performed a triaxial test on sandy soil. Due to the normal behavior of soil, settlements, fissures, and other structural problems result. It is essential to remove the current weak soil and replace it with a non-expanding soil in order to stabilise the weak soil and improve its properties. Expanding soils typically have undesirable engineering characteristics.

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Due to their propensity for having low shear strengths and further losing them after being wet or experiencing other physical disturbances, improving the soil is strengthened, or its properties are stabilized. It is an old and traditional concept to use natural fibres to strengthen soil.

As a result, soils with randomly distributed fibre reinforcement have recently become more popular in geotechnical engineering. In order to continue development and protect natural resources for future generations, waste product implementation should be promoted. Natural fibres are widely available and can be easily obtained in many tropical areas. India is home to a wide variety of natural waste products, including coir, rice husk, sisal, jute, oil palm, and others. The features of soils need to be enhanced with a focus on cost-effectiveness because they make suitable reinforcement materials. This work has examined certain soil stabilization methods, wherein the strength of the soil-coir mixture grows as the proportion of coir fibre increases.

2. PROPOSED METHODOLOGY FOR SOIL STABILIZATION

The portion of the mature coconut that is discarded is its fibrous outer shell, or "husk," which is referred to as the coconut. Lignin, tannin, cellulose, pectin, and other water-soluble substances make up the majority of the fibres, which typically have a length of 50 to 350 mm. Coconut fibre, sometimes known as coir, is a type of hard structural fibre. It is a substantial commercial product made from coconut husk.

The coir fibre maintains its curl as if it was continuously waved and is robust enough to retain a twist without breaking. Long bristle fibres, which are then a waste in the coir fibre industry, are separated from shorter mattress fibres. So that it may be appropriately disposed of and employed in the stabilization of soil, this waste coir fibre can be utilized. The incorporation of fibre in the soil has a substantial impact on the engineering behavior of soil-coir mixes. The polypropylene fibres significantly reduced the consolidation and settlement of the clay soil. The amount of fibre was shown to be more significant and effective than the length of the fibres, which had minimal impact on this soil feature. As a result, the fibre has an extremely long lifespan, possessing an infield service life of 4 to 10 years when wet coir still has a significant amount of tensile strength. It has a low toughness but a significantly higher elongation

It was discovered that when the soil's fibre content rose, so did its CBR value. The CBR value likewise increased as length and diameter increased. Therefore, the focus was on the impact of coir on the bearing capacity and settlement of the footing with parameters like the thickness of the reinforced layer with 0.25%, 0.5%, 0.75%, and 1.0% of coir using laboratory model tests on square footings supported on highly compressible clayey soil reinforced with randomly distributed coir fibre. A further finding was that coconut husk ash is good for improving lateritic soils with low CBR values but ineffective for soils with high liquid limits. Later research from several experiments demonstrated the impact of treated coir fibres on the clay's unconfined compressive strength. The results indicate that the clay with fibre reinforcement could resist bigger strains and that the unconfined compressive strength gain was greater. The following are the justifications for using coconut coir fibres:

- It is an environmentally friendly, renewable resource.
- The fibre is plentiful, naturally non-toxic, biodegradable, low density, and relatively affordable.
- In addition to being rich in micronutrients, fibre has a great capacity to hold the water.

3. SOIL STABILIZATION USING COCONUT COIR FIBRE

A. Physical properties of coir fibre:-

From the above study it is evident that coconut coir fibre may be effectively use in elevate the soil properties. For this the engineering properties of the said material is found out from literature survey. The study takes into account the physical characteristics of the fibre from coconuts which are shown in Table 1. (Tenacity, Breaking Elongation, and Rigidity of Modulus Source: Ravi Shankar et al, 2012)

Table 1- Coconut coir fiber's physical attributes

Coir fibre size in inches	7-9
Density (g/cc)	1.50
Coir fibre Tenacity(g/Tex)	8.8
Breaking Elongation	36%
Measurement in mm	0.1 to 0.5
Rigidity of Modulus	1.8924 dyne/cm^2

Figure 1- Coconut coir fibre sample for experiment

B. Characteristics of soil sample:-

Before we can determine the impact of mixing coconut coir fibre with soil, we must first collect a sample of the soil for the various experiments. Sampling is the first stage in all laboratory testing, thus it requires the same level of care and consideration as every other test.

The soil sample is first undergone for all the necessary tests that will help determining the strength of the soil, and other properties as well. After adding the coir i.e., the reinforcement, we will again perform all these tests and compare the results. Adding coir should increase the performance of the soil. Soil properties are evaluated in laboratory and different soil characteristics are shown below.

The moisture content of the soil in percentage

Weigh of container, W_1 = 21.26 gm

Weight of container + wet soil, W_2 = 51.26 gm

Weight of container + oven dry soil, W_3 = 46.26 gm

So, water content, $w = \frac{(W_2-W_1)-(W_3-W_1)}{W_3-W_1}*100$

$$\frac{(51.26-21.26)-(46.26-21.26)}{46.26-21.26}*100 = 20\%$$

Now from the Figure 2,

D_{10} = 0.29

D_{30} = 0.62

D_{60} = 0.79

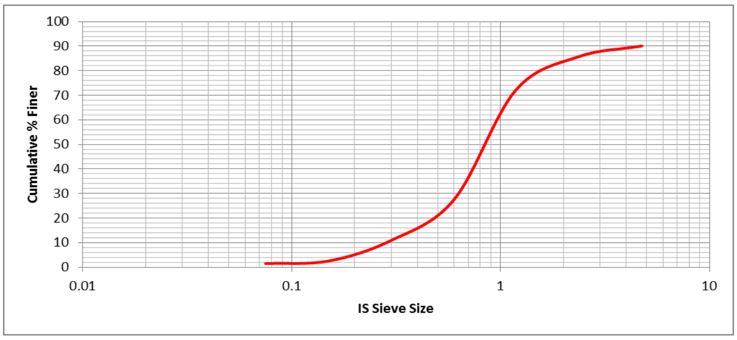

Figure 2: IS Sieve size vs Cumulative % finer Graph

We can determine the (C_C) Coefficient of Curvature value = $(D_{30})^2 / D_{60}*D_{10}$ = 1.6778

And (C_U) Coefficient of Uniformity value = D_{60} / D_{10} = 2.7241

Table 3: Specific Gravity test results

Sl no	Mass of the pycnometer (M_1) gm	Mass of the pycnometer + mass of dry soil (M_2) gm	Mass of the pycnometer + mass of distilled water (M_4)	(M_2-M_1+ mass of distilled water) = M_3	M_2-M_1	(M_4-M_1) - (M_3-M_1)	Sp. gravity
1.	641	1016	1761	1537	375	151	2.48
2.	642	962	1724	1522	320	118	2.71
3.	645	965	1721.5	1508	320	106.5	3

Minimum value of Sp. Gravity (G) = (2.48+2.71+3)/3 = 2.73

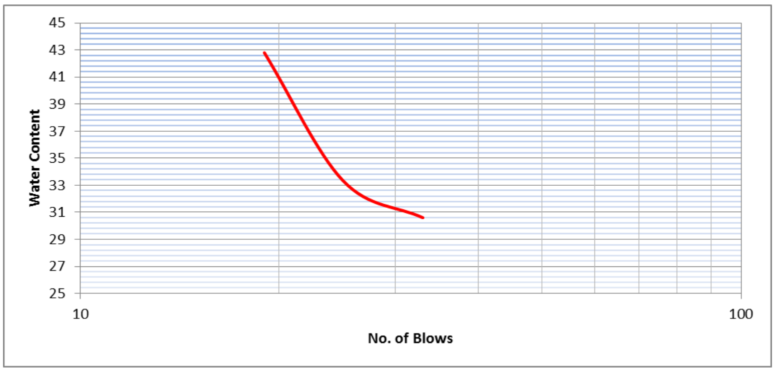

Figure.3: Liquid Limit Test Graph

Now from the Figure 3 liquid limit test,

$P_I = L_L - P_L$ = 36-7.99 =28.08 %

From plasticity chart using equation of A line

$P_L = 0.73(L_L - 30) = 4.38$

Hence, from this we can say the soil is Clayey Soil.

$L_L = 36\%$

The soil is therefore moderately compressible.

C. Calculation of CBR:-

In order to compare soil with and without coconut fibre, the maximum dry density and ideal moisture content were calculated.

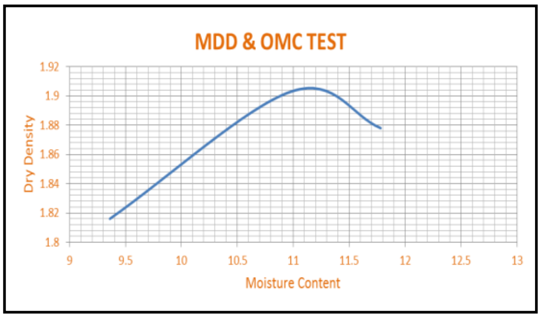

Fig 4: MDD & OMC Test Graph without Coconut Coir

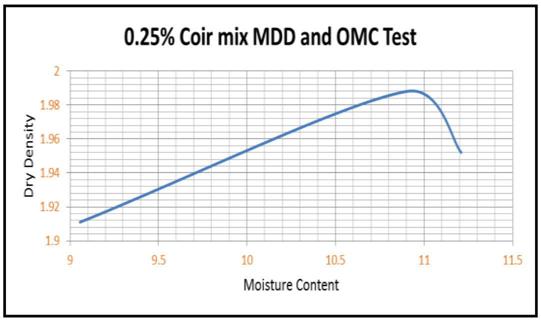

Fig 5: MDD & OMC Test at 0.25% result Graph

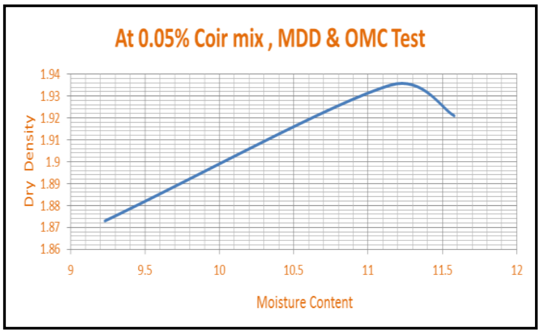

Fig 6: MDD & OMC Test at 0.05% result Graph

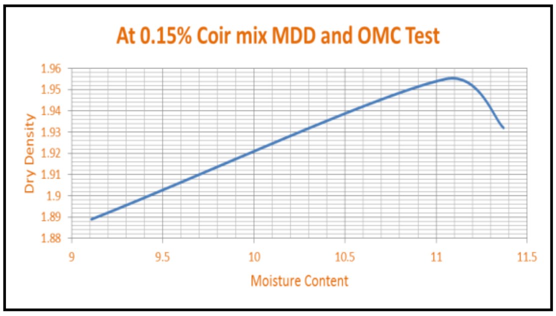

Fig 7: MDD & OMC Test at 0.15% result Graph

From the fig-4, MDD is 1.905 and OMC is 11.2%

4. RESULT AND DISCUSSION

A. Comparison of the test results after mixing the coconut coir fibre:-

Maximum Dry density and Optimum moisture content for reinforced and unreinforced soil

Before mixing the coir fibre MDD is 1.905 and OMC is 11.2%.

After mixing the coir fibre the test results are:

Optimum moisture content (OMC) and maximum dry density (MDD) of the soil after mixing of coconut coir

For 0.05% fibre mix OMC is 11.15% and MDD is 1.935

For 0.15% fibre mix OMC is 11.05% and MDD is 1.955

For 0.25% fibre mix OMC is 10.90% and MDD is 1.988

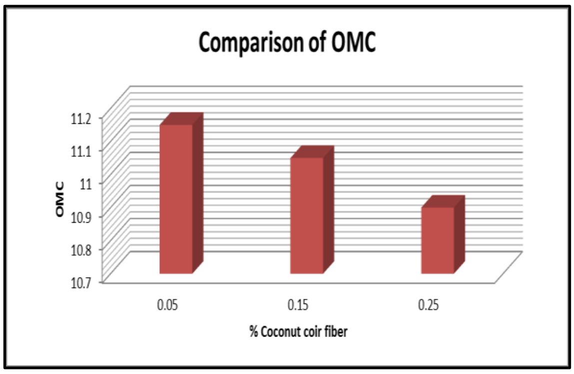

Fig 11: Comparison of OMC before and after mixing coconut coir fibre

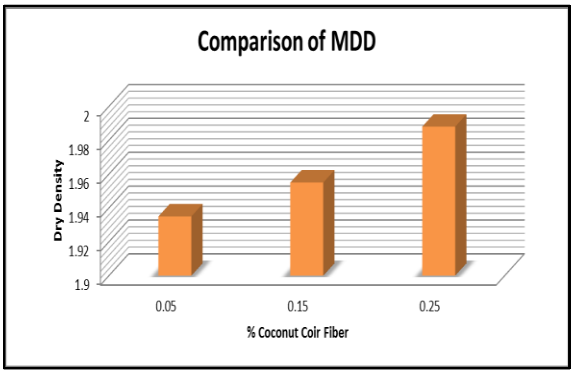

Fig 12: Comparison of MDD before and after mixing coconut coir fibr

B. Comparison of soil with and without reinforcement using the California Bearing Ratio(CBR) test:-

Table 4: Unreinforced soil

Penetration of plunger (mm)	Load dial reading division	Load (Kg)	CBR %
2.5	23	37.95	2.77
5	34	56.1	2.7299

Table 5: When 0.05% coconut coir reinforcement is done

Penetration of plunger (mm)	Load dial reading division	Load (Kg)	CBR %
2.5	27	44.55	3.2518
5	39	64.35	3.131387

Table 6: When 0.15% coconut coir reinforcement is done

Penetration of plunger (mm)	Load dial reading division	Load (Kg)	CBR %
2.5	28	46.2	3.372263
5	40	66	3.211679

Table 7: When 0.25 % coconut coir reinforcement is done

Penetration of plunger (mm)	Load dial reading division	Load (Kg)	CBR %
2.5	32	52.8	3.854015
5	45	74.25	3.613139

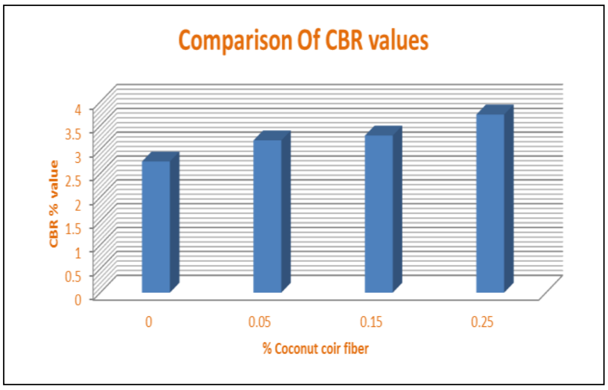

Fig 13: Comparison of CBR values before and after mixing coconut coir fibre

5. CONCLUSION

The findings of the present investigation are quite positive. And the following key conclusions may be drawn:

- Coir fibre is a waste product that can be used to stabilize clay soil.

- As the percentage of coir fibre in the soil-coir mixture rises, so does its strength.As the percentage of fibre in the soil-coir mix increases, so do the CBR and UCS values.
- Increasing the proportion of coir fibre increases the strength of the soil core mix.
- When 0.5% of coir is added to the soil, both Unconfined Compressive Strength and California bearing ratio values improve the most.

The optimal proportion for materials with the highest soaking CBR value has been found to be 0.5% of coir fibre in soil. Therefore, clay soil can be stabilized economically by using this ratio.

Acknowledgement: The research is based upon the civil departmental soil mechanics laboratory work supported by Dr. B. C. Roy Engineering College, Durgapur.

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