

A Study on Effect of Coir Fibre on Clayey Soil

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ABSTRACT: Some of constraints faced by engineers in construction of pavements are the usage of eco-friendly materials, readily available, cheap and to maintain the standards of construction. Construction of asphalt and concrete pavements on weak soil leads to formation of cracks. In order to prevent the failure of the pavements sub grade pavement should have a sufficient load carrying capacity. Therefore a good availability of soil layer is necessary for carrying the load. Strengthening of the soil structure using coir fibre is another eco-friendly method than the usage of fly-ash, lime etc. We study on the effects of the coir fibre with the soil and the advantages it can bring into the industry in future. In this comparative study on the effect of coir fibre with 3cm as optimum length and 1.2% of CCF, on addition to soil is noted in soaked and unsoaked condition of fibre. Keeping in view about the experimental study locally available soil is collected and samples are prepared for standard proctor compaction test and soil identification tests. A comparative study on the changes occurring to the soil by adding soaked and unsoaked CCF can be identified. The composite effect of Coconut coir fiber (Natural Fibre) changes the brittle behaviour of the soil to ductile behaviour and also helps in holding the soil particles together. As a result the addition of coconut coir fiber results in increases the strength of the subgrade soil and also helps in reducing the thickness of the pavement, which promotes cheap and cost effective mode of construction. In future the reduction in the pavement thickness and the amount by which the strength improved could be found by conducting CBR test on the mix.

KEYWORDS: Coconut fiber, Eco-friendly, CBR, Standard proctor, economy.

I. INTRODUCTION

All the civil engineering structures whether small or huge, simple or complex rests on the ground surface and ultimately transfers the structure load to soil or rock. Stability of any such structure depends on the properties of the underlying soil. If we can improve the strength of existing soil by means of some ground improvement techniques utilizing the waste material generated locally, then the cost of construction can be reduced drastically. Under the traffic loads, the soil sub-base is subjected to compression in the vertical direction accompanied by tension in the lateral direction. Most of the available soil generally shows good compressive strength and sufficient shear strength but are weak in tension. Fibre reinforced soil is effective in all types of soils like sand, silt and clay. In construction of pavements, either rigid or flexible if the underlying soil (subgrade) is of good quality then the thickness of pavement becomes less thus reducing the construction cost and saving the conventional natural resources for the next generation. Deformations in subgrade due to repeated traffic loads can be avoided and strength of subgrade soil can be improved by reinforcing the soil by means of natural fibres like coconut coir, jute, bamboo, straw etc. and by synthetic fibres like polypropylene, polyester, polyethylene, glass fiber, shredded rubber tire, geo-synthetic or goe-textile etc. In this experimental study, non-woven randomly distributed coconut coir fibres (CCF) were used to reinforce the soil. CCF is produced in large quantities.

1.2 AIM

- To study the type of soil and its properties.
- To find out and study the changes in the strength of the subgrade by the addition of coir fiber.
- To find out and study the changes in the strength of the subgrade by the addition of coir fiber in water soaked condition.
- To suggest an optimum water content by the addition coir fibre in soil.
- To suggest optimum water content by the addition of coir fiber in unsoaked condition.
- To suggest optimum water content by addition of coir fibre in water soaked condition.

1.3 SCOPE

In future California bearing test can be conducted and the thickness of pavement and its component layers can be reduced which can lead to an economic type of construction. Unconfined compression test also can be conducted to know variations in the strength of soil achieved.

II. LITERATURE SURVEY

S.Muthu Lakshmi (2018) conducted an experimental study by adding coconut coir fibre for improving subgrade strength characteristics of clayey sand. Increasing percentage and length of CFC, OMC was found to increase and MDD was found to decrease. As a result, pavement thickness calculated based on soaked CBR values showed drastic reduction in thickness of up to 55% for soil with 1.2% CCF of length varying from 2cm to 3cm compared to un reinforced soil thus resulting in economical construction.

Lin-Shuang Zhao et.al (2019) studied on the physical and chemical properties of coir fibre and predicting its utilization in the soil reinforcement. The physical and chemical properties were examined and studied how they enhanced the soil reinforcement. They concluded that the usage of coir fiber is more economical than any other reinforcement work.

T.Subramani et.al (2016) His study in soil investigation shows that clay soil is one of its type a fine grained natural rock or soil material that combines one or more clay minerals with traces of metal oxides and organic matter. Depending upon the material composition clay also posses various properties. It is slow to drain, quickly to harden, and difficult to use for anything because of its finer particle size.

Shukla Devdatt et.al (2015) with his tests results he concluded that both unsoaked and soaked CBR value of soil increases with the increase in coconut coir fiber content. Soaked CBR value increases from 3.9% to 8.6% and unsoaked CBR value increases from 8.1% to 13.2% of soil mixed with 1% coconut coir fibre. Adding of coconut

coir fibre results in less thickness of pavement due to increase in CBR of mix and reduce the cost of construction and hence economy of the construction of highway will be achieved. This is due to composite effect of coconut coir fibre(natural fibre) changes the brittle behavior of the soil to ductile behaviour

III. METHODOLGY AND DISCUSSION

3.1 Experimental Analysis of Coir Fibre

Coir fiber is a natural fibre abundantly available in a cheap rate and an eco-friendly material. They are moth proof, tough and durable, unaffected by moisture and dampness and not easily combustible due to these properties of coir it is used as a stabilizing material in soil.

Coir fibers are mainly of two types,

- Brown coir and,
- White coir.



Fig. 3.1: Brown coir fibre

We have procured brown coir fiber from the institute for our study.

The following sets of experiments were conducted on the coir fibre to study the properties of the material:

- Specific gravity
- Tensile strength
- Water absorption test
- Porosity
- Diameter
- Length
- Density.

3.3 Experimental Analysis of Soil

The procured soil has very fine particles and consists of less organic matter. These soils have very less space between particles. Because of the particles are smaller in size, water can be trapped in the tiny gaps between them.



Fig. 3.2: Soil

The following set of experiments was conducted on the soil to test its engineering soil properties:

- Particle size distribution
- Specific gravity
- Atterbergs limit
- Compaction test



3.3.1 Particle size distribution

Particle size distribution, also known as gradation refers to the proportions by dry mass of a soil distributed over specified particle size ranges. Gradation is used to classify soils for engineering and agricultural purposes, since particle size influences how fast or slow water or other fluid moves through a soil.

Procedure:

- i. Take a 100g of oven dried soil
- ii. Weigh the cleaned sieves and pan separately and note down the values.
- iii. Stack the sieves (4.75mm,2mm IS sieves, 600,425,300,150 and 75 microns IS sieve) in decreasing order of sieve opening. Keep a pan at the bottom.
- iv. Pour the soil into the stack of sieves from top and place the cover. Put the assembly in the sieve shaker and fix the clamps. Sieve for 10 minutes.
- v. Stop the sieve shaker and weigh each sieve with the soil retained on it separately. Obtain the weight of soil sample retained on each sieve.
- vi. Plot sieve size in log scale along x axis and percentage finer along y axis to obtain grain size distribution curve.

The results from sieve analysis of the soil when plotted on a semi-log graph with particle diameter or the sieve size as the abscissa with logarithmic axis and the percentage passing as the ordinate gives a clear idea about the particle size distribution. From the help of this curve, D10 and D60 are determined. This D10 is the diameter of the soil below which 10% of the soil particles lie. The ratio of, D10 and D60 gives the uniformity coefficient (Cu) which in turn is a measure of the particle size range.

3.3.2 Specific gravity

The specific gravity of soils refers to the mass of solids in the soil compared to the mass of water at the same volume. Specific gravity of a substance denotes the number of times that substance is heavier than water. In case of soils, specific gravity is the number of times the soil solids are heavier than equal volume of water. . Different types of soil have different specific gravities, general range for specific gravity of soils:

Table 1: Range of specific gravity of different soil types

| SOIL TYPE | RANGE |
|---------------------|-----------|
| Sand | 2.63-2.67 |
| Silt | 2.65-2.7 |
| Clay and Silty clay | 2.67-2.9 |
| Organic Soil | <2.0 |

Procedure:

- i. The density bottle was dried and its weight, with its cap was taken(W1).
- ii. The density bottle was filled with soil passing through 4.75mm sieve and weight was taken with soil (W2).
- iii. Sufficient water was added to cover the soil and shaken well to avoid air bubbles and weight was noted (W3).
- iv. Then the density bottle was filled with water and then its weight was noted (W4).

3.3.3 Atterbergs limit:

Atterberg Limits is a basic measure of the critical water content of fine-grained soils. These tests include shrinkage limit, plastic limit, and liquid limit, which are outlined in ASTM D4318. Depending on the water content of a soil, it may appear in four states: solid, semi solid, plastic and liquid.

Plastic Limit (PL): The plastic limit (PL) is the moisture content at which a soil transitions from being in a semisolid state to a plastic state. This limit lies between the plastic and semi-solid state of the soil.

Liquid Limit (LL): The liquid limit (LL) is defined as the moisture content at which a soil transitions from a plastic state to a liquid state. It is the water content of the soil between the liquid state and plastic state of the soil.

Shrinkage Limit (SL): The shrinkage limit (SL) is the water content where further loss of moisture will not result in any more volume reduction. It can be more accurately defined as the lowest water content at which the soil can still be completely saturated. The shrinkage limit is much less commonly used than the liquid and plastic limits.

Procedure:

Liquid limit:

- i. About 120g of dried soil finer than 425 microns was placed in a evaporating dish.
- ii. It was mixed with a 15cc to 20cc of water to form an uniform paste.
- iii. A portion of the paste was placed in a cup of liquid limit apparatus.
- iv. The surface was smoothened and leveled with a spatula to a maximum depth of 1 cm.
- v. A groove was cut through the sample along the symmetrical axis of the cup, preferably in one stroke using casagrande grooving tool.
- vi. The handle was turned at a rate of 2 revolutions per second until the two parts of the soil sample comes into the contact at the bottom of the groove along a distance of 12mm.
- vii. The number of blows required to close the groove was noted.
- viii. The above steps were repeated at different water contents so as to get blows in the range of 10-40.
- ix. Some amount of soil near the closed groove was taken for water content determination.
- x. Flow curve was made between the water content as ordinate and the number of blows on log scale as abscissa.
- xi. Liquid limit was obtained from the curve, corresponding to 25 blows.

Plastic limit:

- i. About 30g of thoroughly mixed dried soil was placed in an evaporating dish.
- ii. It was mixed with sufficient quantity of water until the mass became the plastic and can be easily moulded with fingers.
- iii. About 10g of plastic soil mass was taken in one hand and a ball was formed.
- iv. The ball was rolled with fingers on a glass plate to form a soil thread of uniform diameter. If the diameter of the thread becomes smaller than 3mm, without the crack formation, it showed that water content was more than the plastic limit.
- v. The soil was kneaded further and was again rolled out in the form of a thread.
- vi. The above procedures was repeated until a 3mm threads showed a sign of crumbling.
- vii. Some of the crumbled material was taken for water content determination.
- viii. Plastic limit is the water content at which the soil can be rolled into a thread of approximately 3mm in diameter without crumbling.

3.3.4 Compaction test

This experiment gives a clear relationship between the dry density of the soil and the moisture content of the soil. Compaction process helps in increasing the bulk density by driving out the air from the voids. The theory 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 experimental setup consists of cylindrical metal mould (internal diameter- 10.15 cm and internal height-11.7 cm), detachable base plate, collar (5 cm effective height), rammer (2.5 kg) as given in IS 2720-PART 7.

Procedure:

- i. Take about 3Kg of soil passing through 4.75mm sieve.
 - ii. Thoroughly mix the soil sample with adding a certain percentage of water to it.
 - iii. The mould is cleaned and greased thoroughly.
 - iv. Mass of the empty mould with collar and base plate is taken.
 - v. The soil is filled into the mould with collar into 3 layers and each layer is compacted 25 times with the free fall hammer 310mm height.
 - vi. Collar is removed and the soil is trimmed off.
 - vii. Mass of the mould with compacted soil is taken.
 - viii. Bulk density can be calculated as $\frac{\text{wet weight of soil}}{\text{volume of mould}}$
 - ix. Dry density of the soil is calculated as $\frac{\text{bulk density}}{1 + \text{water content}}$
 - X. The value of dry density is obtained by plotting against corresponding moisture content.
- The above steps are followed by mixing 1.2% of coir fiber along with the soil.



IV. RESULTS

Physical and chemical properties of the coir fibre

Table 3.2: Properties of the coir fibre

| | |
|--------------------------------|------------|
| Breaking load(kg) | 0.45 |
| Tenacity(g/tex) | 10.00 |
| Extension at break (%) | 29.13 |
| Density (g/cc) | 1.40 |
| Porosity (%) | 40.00 |
| Specific gravity | 1.15 |
| Fibre diameter, mm | 0.1 to 0.8 |
| Length of individual fibre, mm | Up to 250 |
| Water absorption | 40% |

SOIL

Index and engineering properties

a) Specific gravity

Specific gravity = $\frac{W2-W1}{(W4-W3)-(W3-W2)}$; Specific gravity = 2.29

b) Particle size distribution

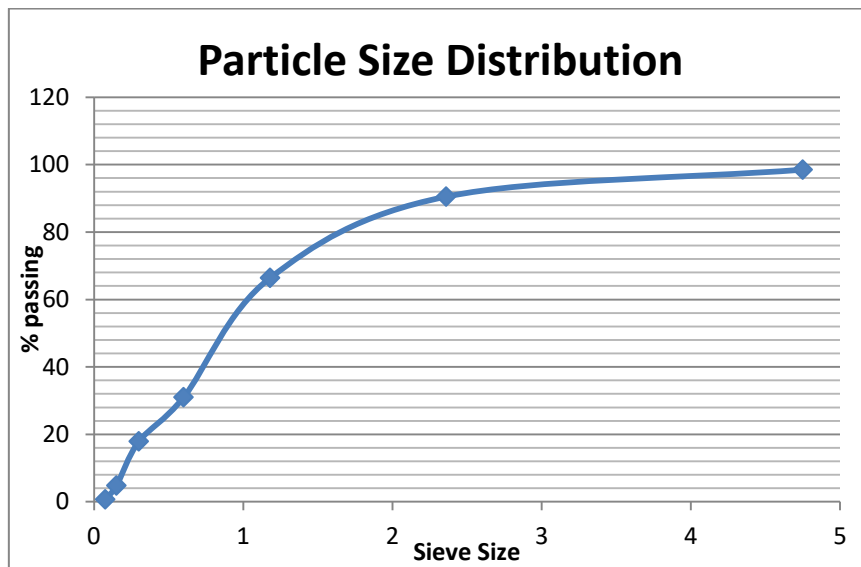


Fig. 4.1 – Particle Size Distribution curve of the soil

From graph,

D₁₀ = 0.01

C_c = 0.0004

C_u = 13

D₃₀ = 0.08

D₆₀ = 0.13

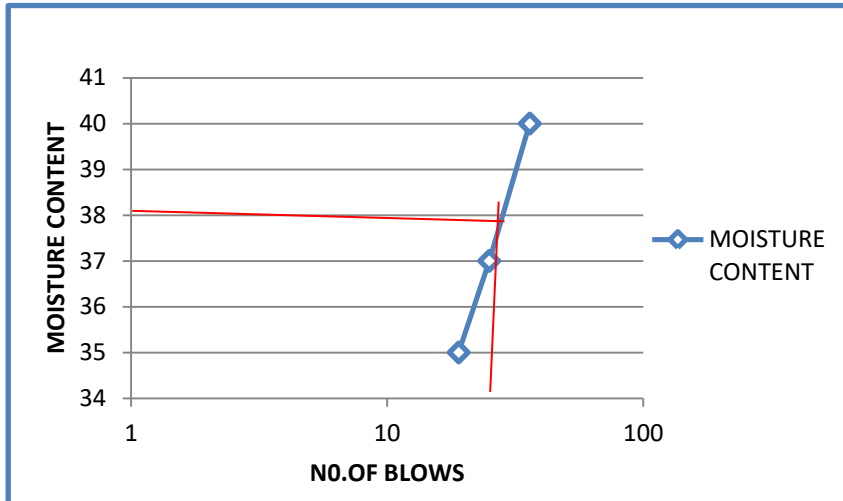


b) Atterbergs Limit

Liquid limit:

$$\text{Liquid limit } I_p = LL - PL$$

Where, LL- Liquid limit and PL- Plastic limit



Liquid limit = 38

b) Compaction test

$$\text{Bulk Density} = \frac{M}{V}$$

Where, M-mass of the soil and V- volume of the soil

Bulk density = 1.725g/cc

$$\text{Dry Density} = \frac{\rho}{1-w}$$

Where, ρ - density and w- water content

Dry density = 0.136g/cc

Optimum moisture content = 11.4%

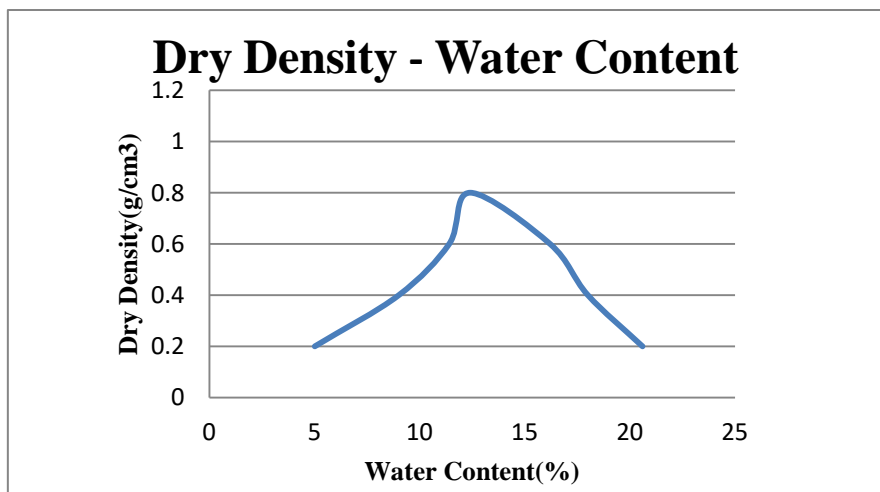


Fig. 4.3- Compaction curve of soil alone

Soil with soaked coir fibre

Coir fibre was soaked in water for 48 hrs and was mixed with the soil. The mixture was compacted using standard proctor test.

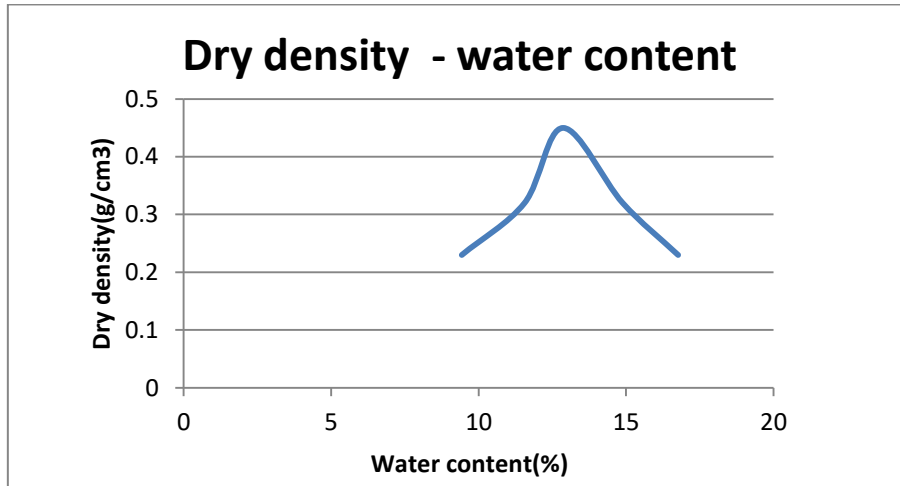


Fig. 4.4- Compaction curve of soil with soaked coir fibre

Dry Density = 0.35g/cc

Optimum moisture content = 15.4%

Soil with unsoaked coir fibre

Coir fibre in unsoaked condition ie in dry condition was mixed with soil in irregular pattern. The mix was hand mixed and compacted using standard proctor test.

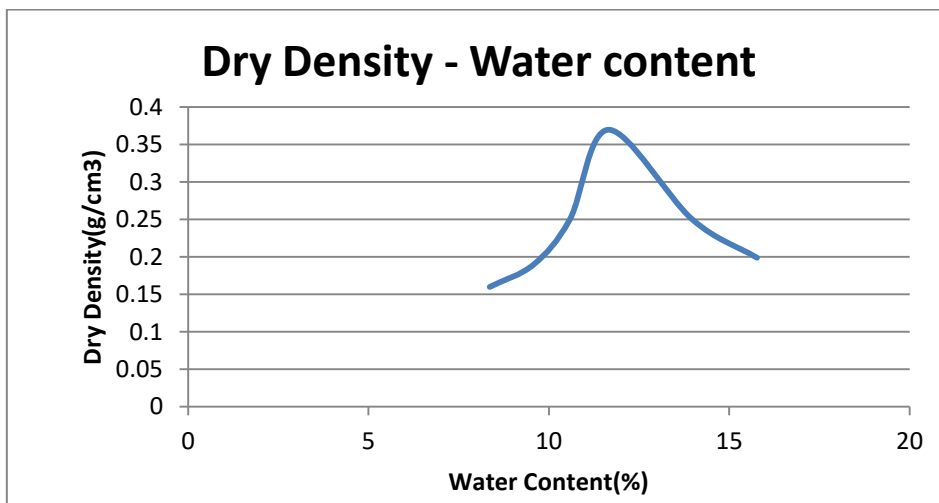


Fig. 4.5 - Compaction curve of soil with unsoaked coir fibre

Dry Density = 0.62g/cc

Optimum moisture content = 12.7%



Hence , the final results are as follows

| Sample | Optimum moisture content(%) | Dry density(g/cc) |
|--------------------------|-----------------------------|-------------------|
| Soil Alone | 11.4 | 0.136 |
| Soil with soaked fibre | 15.4 | 0.35 |
| Soil with unsoaked fibre | 12.7 | 0.62 |

From our study we have found that the OMC and MDD values of soil alone after conducting compaction test is 11.4% and 0.13g/cc respectively, 12.7% and 0.62g/cc respectively in the case of unsoaked fibre and 15.4% and 0.35g/cc respectively in the case of soaked fibre. From the above results there is an increase of 2.7% of OMC value than unsoaked coir fibre addition to the soil. There is also a difference of 4% in OMC value between the ordinary compaction and compaction of soil with soaked fibre. From our study we have also noted that as OMC increases the MDD decreases and the least MDD was obtained in the case of soaked coir fibre. The addition of soaked coir fibre into the soil gives better results compared to other cases. In all three cases the amount of fiber added into the soil is 1.2%. Its also proven that the addition of coir fibre from 1.2% to 1.5% gives much better results.

V. CONCLUSION

The present study explains the performance of coir fibre as a filler component without chemical stabilizers.

- From the laboratorial investigation it can be concluded that with the addition of 1.2percentage of coconut coil fiber with clay soil the optimum moisture content increased and there was a statistical decrease in maximum dry density.
- The addition of soaked coir fibre proved the subgrade strength could be improved further as the water helps in binding the coir fibre with this subgrade.
- The results from experiments showed that the strength of soil increases with the increasing percentage of fibre.
- The requirements of pavement thickness are greatly reduced due to composite effects to the waste materials on the subgrade expansive soil compared to individual effect of materials.
- There is an increase of 2.7% in the OMC value by addition of soaked and unsoaked coir fiber addition..
- There is an increase of 4% in the OMC value by addition of soaked coir fiber addition and ordinary compaction of soil.
- For future experimental studies, the California bearing ratio test can be conducted in two
- different conditions that is in soaked coir fibre and with unsoaked coir fiber.

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