Behaviours of Randomly Distributed Natural Fiber Reinforced Clay

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Abstract- Randomly distributed natural fiber reinforced soil has been advantageously applied in many civil engineering field to improve the engineering characteristics of soft compressible soil. In the subgrade construction of road, soils found at many sites are of low strength and highly compressible even after proper compaction. To improve their characteristics, fibers can be randomly mixed with weak soil. Since, synthetic fibers are costly and non-degradable, natural fibers can be utilized for cost effective and eco-friendly construction. In this paper, applicability of natural fibers to improve weak subgrade material is investigated.

Keywords – Randomly distributed fibers, Reinforced soil, Natural fiber, Eco-friendly.

I. Introduction

In India, huge amount of construction of road is being made through different schemes like PMGSY, etc. But available soils near construction sites are sometimes found to be weak in strength and of high compressibility. Therefore, there is a need of suitable methods to improve the weak sub-grade. In this regards, reinforced earth is a composite construction material in which the strength of the engineering fill is enhanced by the addition of strong extensible tensile reinforcement. The concept of reinforced earth was first developed by Vidal [1969], by introduction of reinforcing elements in a soil mass increases shear resistance of the medium. The uses of reinforced earth techniques for improving the engineering properties of soils are getting importance day by day and are very effectively used in many areas of civil engineering.

In the recent years, randomly distributed fiber reinforced soil are being valuably used as a ground improvement technique in the case of subgrades and embankments construction. Compare to other conventional methods of reinforced soil, randomly distributed fiber reinforced soil shows some advantages. The main advantages are the simplicity in mixing, maintenance of strength isotropy and absence of potential planes of weakness which may develop parallel to the oriented reinforcement. The fibers added in constructions are expected to provide better compact interlocking system between the fiber and the soil system. Shetty and Rao [1987] conducted a series of laboratory CBR tests and reported that when 10% coir fibers (by volume) mixed with silty sand (SM), resulted increase in CBR value under soaked and unsoaked conditions by 26% and 22% respectively. Santoni and Webstar [2001] had also shown the improvement on the load carrying capacity by fiber stabilization of sand for airfields and road constructions. However in India, the cost of synthetic fibers is very high compare to natural fibers which affects the cost effectiveness. Therefore for low traffic unpaved roads, use of locally available natural fibers as reinforcing material are very encouraging. Natural fibers like Coir, Jute, Palm fiber, etc. are mostly available in third world countries at a low cost and their supply is ensured from agriculture. Chattopadhyay.et.al [2008] reported that geotextiles made from natural fibers like jute or coir is being employed as economic and eco-friendly solution.

In the present investigation, an attempt has been undertaken to study the compaction and strength characteristics of locally available soils by randomly mixing natural Jute and Coir fibers.

II. PROPOSED INVESTIGATION

A. Scope of Work –

An experimental programme has been undertaken by the author to study the compaction and strength characteristics of locally available clayey soils reinforcing by randomly distributed natural Jute and Coir fibers. Results of the experimental study of clayey soil-natural fiber mix composite with varing fiber percentages and various fiber length of Jute and Coir fiber, are presented here.

B. Materials Used –

Clay: Locally available clayey soil from Nazirabad around Kolkata of West Bengal was used in this experimental study. The clay was CI as per IS soil classification. The physical properties of clay are given in Table 1.

Natural fibers: Natural fibers like Jute and Coir fibers have been used as reinforcing material, taken from local market. The fibers after cutting into small pieces of length, 10mm, 15mm and 20mm, have been randomly mixed with clay with varying percentages of 1%, 1.5% and 2% to form homogeneous mixture. The summary of the physical properties of fibers is given in Table 2.

Table 1: Physical Properties of Clay

Soil classification	CI
Coefficient of uniformity, C_u	5.56
Coefficient of curvature, C_c	0.88
MDD (gm/c.c)	1.52
OMC (%)	21.5
California Bearing Ratio (%)	3.2
UCS at OMC (kg/cm^{2})	8.5

Table 2: Physical Properties of Fibers

Tests	Jute	Coir
Density (gm/c.c)	1.47	1.40
Diameter (mm)	0.03 (av.)	0.25 (av.)

C. Test Programme –

A series of Standard Proctor test and California Bearing Ratio test have been conducted on clay-fiber mix composites to study the effects of inclusion of natural fibers of various lengths and proportion. Standard Proctor tests have been done as per I.S. 2720, Part 7 (1980), to determine the Optimum moisture content (OMC) and Maximum dry density (MDD) values for each case. California Bearing Ratio tests have been conducted at OMC as per I.S. 2720, Part 16 (1987) to determine strength characteristics of the soil-fiber mix composites. All these tests have been performed for various parameters of clay-fiber mix composites, as given in Table 3. The mixing of fibers and clay has been done manually with proper care for preparing uniform mixture at each stage of mixing.

Table 3: Various parameters of fiber used in clay-fiber mix

Type of fiber	Length of natural fiber (cm)	Fiber content (%)
Jute, Coir	1, 1.5, 2	1, 1.5, 2

III. EXPERIMENT AND RESULT

Standard Proctor tests and California Bearing Ratio tests have been conducted on clay-fiber mix composites to study the effects of inclusion of natural fibers of various lengths and proportion. The results of Standard Proctor tests and California Bearing Ratio tests have been presented subsequently.

A) STANDARD PROCTOR TEST:

The standard Proctor tests have been conducted for clay mixed with randomly distributed Jute and Coir fibers of length 1cm, 1.5cm and 2cm with varying percentages of 1%, 1.5% and 2%, to determine the Optimum Moisture

Content (OMC) and the corresponding Maximum dry density (MDD) for each soil-fiber mix. The effects of fiber content and fiber length on the value of MDD and OMC of clay-fiber mix composites are discussed as below.

(i) Effect of fiber content on MDD

The variations of Maximum dry density (MDD) with fiber content for Jute and Coir fiber are shown in Fig.1 and Fig.2 respectively.

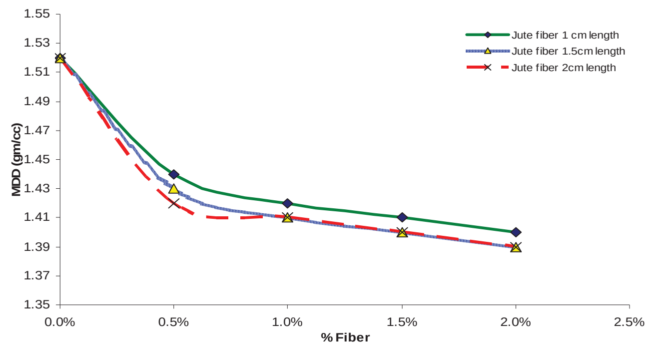

Fig.1: Variation of MDD with fiber percentage for soil mixed with randomly distributed Jute fiber.

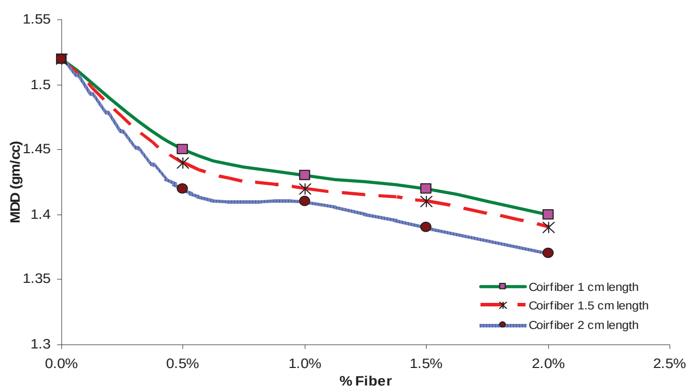

Fig.2: Variation of MDD with fiber percentage for soil mixed with randomly distributed Coir fiber.

From the figs.1 and 2, it is observed that Maximum dry density (MDD) of fiber mixed clayey soil is decreasing with the increase in percentages of both Jute and Coir fibers. The decrease in MDD is about 8.6% for 2cm length, 2% Jute fibers by dry weight of soil whereas for 2cm length, 2% Coir fibers, the decrease in MDD is about 9.9%. The decrease in density is most likely as a result of natural fibers having less specific weight in comparison with solid clay particles.

(ii) Effect of fiber content on OMC

The variations of Optimum Moisture Content (OMC) with fiber content for Jute and Coir fiber are shown in Fig.3 and Fig.4 respectively.

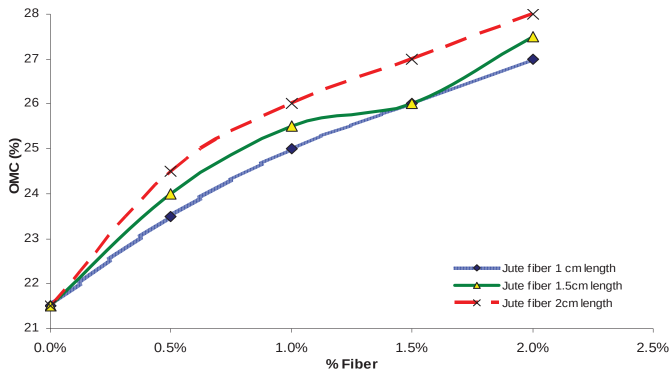

Fig.3: Variation of OMC with fiber percentage for soil mixed with randomly distributed Jute fiber.

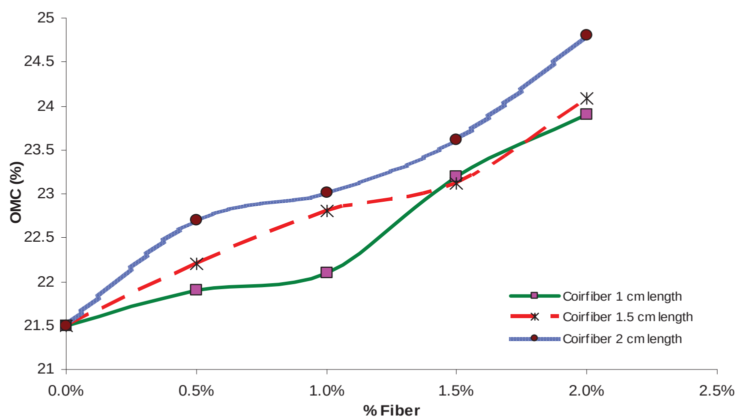

Fig.4: Variation of OMC with fiber percentage for soil mixed with randomly distributed Coir fiber.

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From the figs.3 and 4, it is observed that OMC of fiber mixed clayey soil is increasing with the increase in percentages of both Jute and Coir fibers. The increase in OMC is about 30.2% for 2cm length, 2% Jute fibers by dry weight of soil whereas for 2cm length, 2% Coir fibers, the increase in OMC is about 16.3%. The increase in OMC is most likely as a result of greater water absorption capacity of natural fibers compare to clay particles.

(iii) Effect of fiber length of on MDD

The variations of Maximum dry density (MDD) with fiber length for Jute and Coir fiber are shown in Fig.5 and Fig.6 respectively.

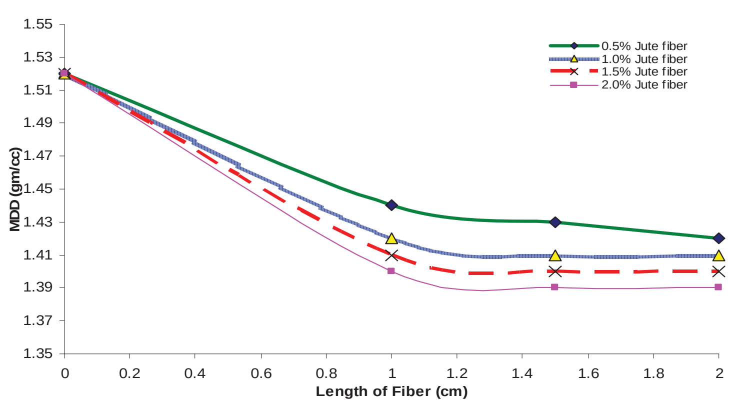

Fig.5: Variation of MDD with fiber length for soil mixed with randomly distributed Jute fiber.

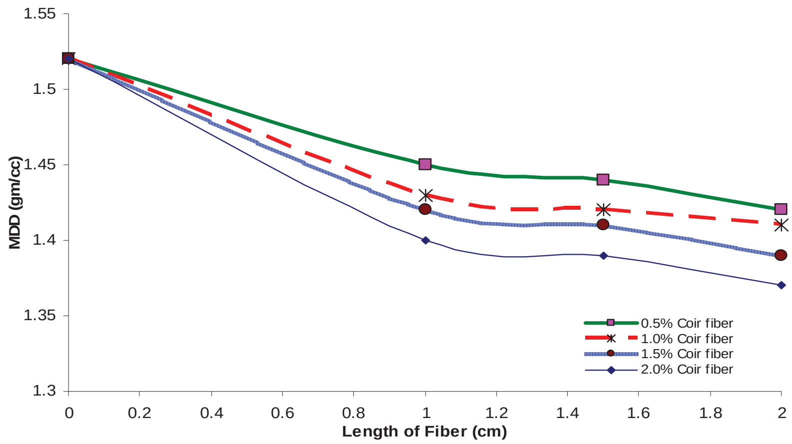

Fig.6: Variation of MDD with fiber length for soil mixed with randomly distributed Coir fiber.

From the figs.5 and 6, it is observed that Maximum dry density (MDD) of fiber mixed clayey soil is decreasing with the increase in length of both Jute and Coir fibers. It is also observed that MDD decreases asymptotically to a constant value for further increase in fiber length up to 2cm length of fiber. However, the decrease in the MDD value is more significant when length of fiber in between 0 to 1cm. Thereafter, the rate of decrease of MDD value is much lower for further increase in fiber length for both Jute and Coir fiber mixed clayey soil.

(iv) Effect of fiber length of on OMC

The variations of Optimum Moisture Content (OMC) with fiber length for Jute and Coir fiber are shown in Fig.7 and Fig.8 respectively.

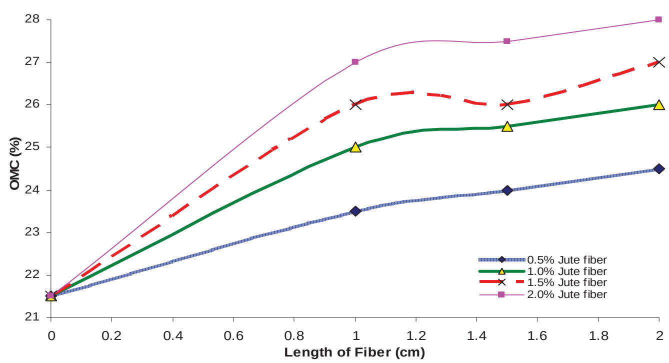

Fig.7: Variation of OMC with fiber length for soil mixed with randomly distributed Jute fiber.

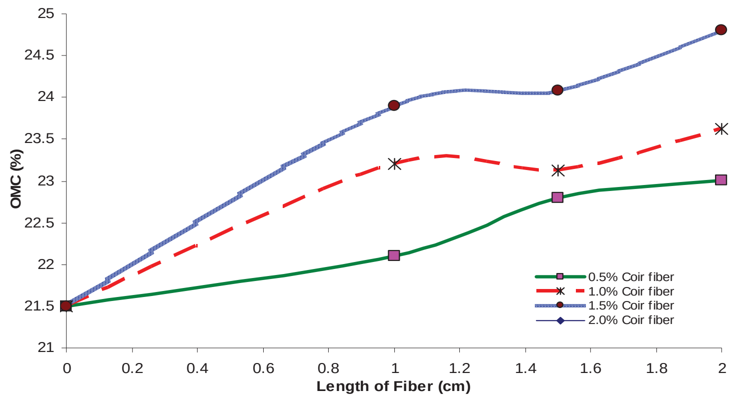

Fig.8: Variation of OMC with fiber length for soil mixed with randomly distributed coir fiber.

From the figs.7 and 8, it is observed that OMC of fiber mixed clayey soil is increasing with the increase in length of both Jute and Coir fibers. However, the increase in the OMC value is more significant when length of fiber in between 0 to 1cm. Thereafter, the rate of increase of OMC value is much lower for further increase in fiber length for both Jute and Coir fiber mixed clayey soil. But the relative rate of increase is more in case of Jute fiber compare to Coir fiber.

B) CALIFORNIA BEARING RATIO TEST:

Unsoaked CBR tests have been conducted at optimum moisture content, for the clayey soil mixed with randomly distributed Jute and Coir fibers of various length of length 1cm, 1.5cm and 2cm and with varying percentages of 1%, 1.5% and 2% of the dry weight of soil, as per I.S. 2720 Part 16. The effects of fiber content and fiber length on the value of unsoaked CBR of clay-fiber mix composites are discussed as below.

(i) Effect of fiber content on unsoaked CBR

The variations of Unsoaked CBR with fiber content for Jute and Coir fiber are shown in Fig.9 and Fig.10 respectively.

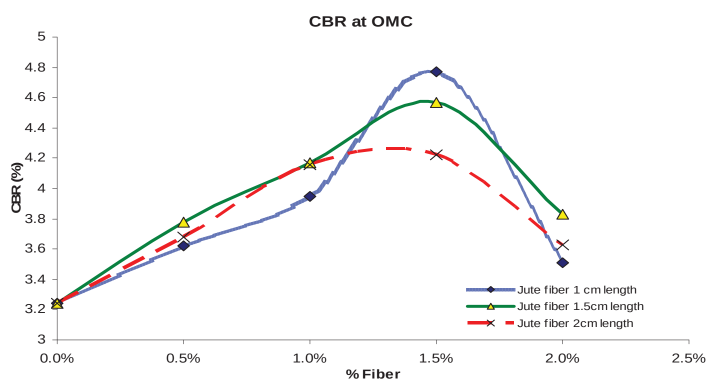

Fig.9: Variation of unsoaked CBR with fiber percentage for soil mixed with Jute fiber.

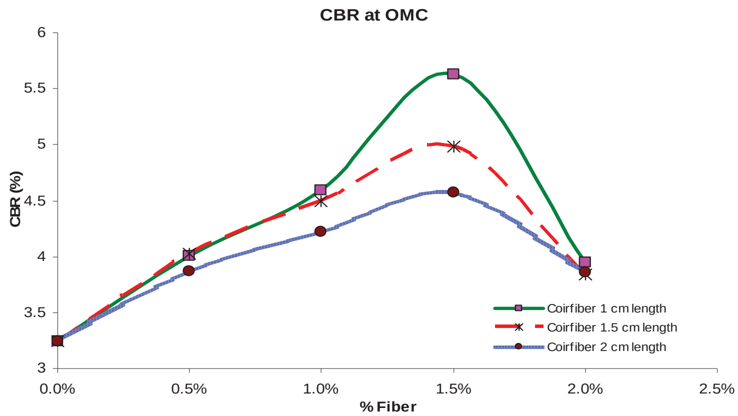

Fig.10: Variation of unsoaked CBR with fiber percentage for soil mixed with Coir fiber.

From the figs.9 and 10, it is observed that unsoaked CBR value increases with the increase in Jute and Coir fiber content up to 1.5% of fiber inclusion of the dry weight of soil and after that, it decreases. For both Jute and Coir fiber, the maximum increase in unsoaked CBR is for 1.5% fiber content with fiber length of 1cm. The decrease of unsoaked CBR value with the increase in fiber content may be due to the fact that, at that fiber content, fiber quantities are higher enough to effect more fiber-fiber interactions than fiber-soil interactions.

(ii) Effect of fiber length of on unsoaked CBR

The variations of unsoaked CBR with fiber length for Jute and Coir fiber are shown in Fig.11 and Fig.12 respectively.

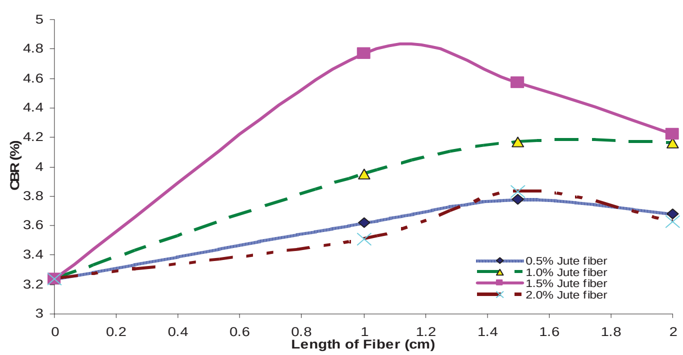

Fig.11: Variation of unsoaked CBR with fiber length for soil mixed with randomly distributed Jute fiber.

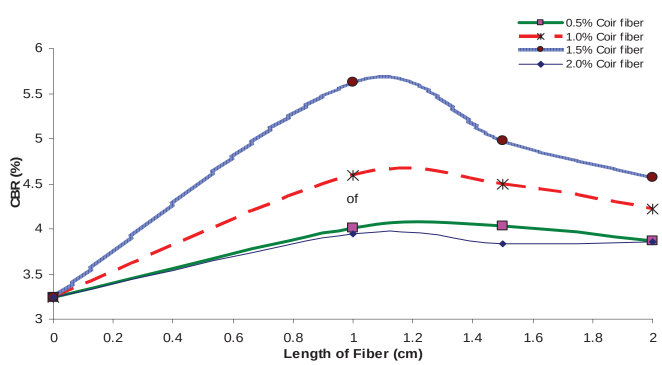

Fig.12: Variation of unsoaked CBR with fiber length for soil mixed with randomly distributed Coir fiber.

From the figs.11 and 12, it is observed that unsoaked CBR value increases with the increase in Jute and Coir fiber length up to a peak value and after that, it decreases. It is also observed that unsoaked CBR value increases upto a maximum value when fiber length is of 1cm. However, the rate of relative decrease in unsoaked CBR value for Jute fiber is much less compared to Coir fiber.

IV.CONCLUSIONS

From the experimental study reported above, following conclusions may be drawn.

1. With the increase of fiber content as well as fiber length, MDD of Randomly distributed fiber reinforced clay decreases. Similar observations are also found for Coir fibers.
2. The OMC of Randomly distributed fiber reinforced clay increases with the increase of fiber percentage as well as fiber length. However, the increase in OMC value is more in case of Jute fibers compared to Coir fibers.
3. The unsoaked CBR value increases with the increase in Jute and Coir fiber content up to 1.5% of fiber inclusion of the dry weight of soil and after that, it decreases. For both Jute and Coir fiber, the maximum increase in unsoaked CBR is for 1.5% fiber content with fiber length of 1cm.
4. Similarly, unsoaked CBR value increases with the increase in Jute and Coir fiber length up to a peak value and after that, it decreases. It is also observed that unsoaked CBR value increases upto a maximum value when fiber length is of 1cm. However, the rate of relative decrease in unsoaked CBR value for Jute fiber is much less compared to Coir fiber.

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