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A Comparative Study of the Effect of Coated and Natural Jute Fibers on the Strength Properties of Kuttanadu Soil

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Abstract. It is a well-known fact that now a days finding a construction site with good soil condition is difficult. Kuttanadu region is the largest agricultural area in Kerala, India. The soil in this region is dark brown in color having high compressibility with high organic content. Construction of any type of structures on this soil is still a challenge to civil engineers. Jute is one of the most valuable natural fibers produced extensively in India. The natural fibers are cheap and non-hazardous to mother earth compared to artificial fibers, however in long run these natural fibers will undergo biodegradation. To reduce the biodegradable nature, it is coated with an alkali, sodium hydroxide. This paper presents the influence of coated and natural jute fibers on the strength properties of Kuttanadu soil. The percentage of fiber by dry weight of soil was taken as 2%, 4%, 6%, and 8%. The effect of length of fiber on the strength properties is studied by using 20mm and 40mm length jute fibers. The effect of diameter is studied with jute fibers having 3mm and 5mm diameters. The fibers were soaked in the alkali solution for 24 hours and then dried at room temperature for 7 days. Coating is done at different percentages of NaOH solution varying from 1% to 30%. Based on the analysis of results, it is concluded that the Kuttanadu soil has been stabilized effectively with the addition of jute fibers and the durability of the jute fibers are enhanced by the coating of NaOH solution.

Keywords: natural fibers, NaOH solution, durability

1 Introduction

Construction of engineering structures on clayey soil is a challenging task; Depending upon the properties of the soil, the safety and stability of structure will vary. Hence an attempt is be made to know about the extent to which the soil properties should be improved or other alternatives for the stabilization of soil. Reinforce the soil by blending with locally available materials enhance their physical and geotechnical properties. Soil at Kuttanadu region, is categorized as one of the problematic soils in India. During rainy season, a major portion of this area lies below the sea level and will be submerged under water for more than a month every year. The soil in this region is dark brown in color with high organic content. Due to increase in developmental activities of the area, there is a major construction activity is carried out in kuttanadu region. Many foundation failures and embankment failures have been reported in this soil due to its poor shear strength and compressibility characteristics. An attempt is made to stabilize this soft clay using jute fibers, which is one of the most valuable natural fibers.

Neeraja et al (2010) conducted a study using a special type of jute fibers that is plastic jute along with lime. To reduce the brittleness of soil stabilized by lime only, a recent

study of a newly proposed mixture of plastic jute fiber and lime for ground improvement is reported in this paper. Prosenjit Saha et al (2012) studied on durability of transesterified jute geotextiles. A process for transesterifying jute fibers or textiles using reagents largely derived from natural sources has been developed for enhancing the long-term tensile strength and water repellence of fiber or textile samples. Pandey et al (2013) studied the effect of fly ash, jute, lime, and water proofing compounds by improving the properties of black cotton soil. It is concluded that mixing of 1% jute fiber, 20% fly ash and 5% lime together in a soil gives better result as compared to addition of each material separately for improvement of soil which reduces the construction cost of road in black cotton soil area near and CBR value also improves about 18-20 folds. Ramesh et al (2011) evaluated strength performance of lime and sodium hydroxide- treated coir fiber reinforced soil. A series of compaction and Unconfined Compressive Strength (UCS) tests were conducted to study the effects of Randomly Distributed Coir Fiber (RDCF) inclusions and lime on the geotechnical properties of Black Cotton soil (BC soil) as one combination and effect of sodium hydroxide on lime treated – coir fiber reinforced BC soil as another combination. These UCS tests were conducted up to 60 days of curing. Indian brown color coir fiber was mixed with lime treated BC soil in different proportions. The strength increases up to 30 days linearly with curing period, with further curing the increase in the strength is marginal. The Optimum fiber of 0.5 % (by weight) was found to be optimum for improving the strength of BC Soil. The lime and Sodium Hydroxide are used in the investigation are collected form the Sd fine Chemicals Limited.

2 Materials and Methodology

2.1 Soil

For this study**,** the soil was collected from Kuttanadu region in Allepey district, Kerala. The representative soil sample were taken from a depth of 1m below the riverbed and preserved in natural water content. Laboratory tests were conducted as per IS standards for finding out the various index and engineering properties. Results are discussed in the table shown below.

Table 1: Properties of Kuttanadu soil

PROPERTY	VALUE
Specific gravity	2.56
Insitu Water Content	160%
Color	Grey
Plastic limit	60.23%
Liquid limit	110%
Max. Dry Density	1.18g/cc
Optimum Moisture Content	38.75%
% Clay	81
% Silt	15
% Sand	4

2.2 Jute Fibers

The jute fibers were dried in air to remove the excess moisture from it. The materials are collected from the local market of Trivandrum District, Kerala State. The fibers are cut into different samples according to their length and diameter as per requirement.

2.3 Preparation of Soil

Soil was preserved at field condition for the entire duration of the project. Fibers were randomly mixed with soil to form a homogeneous mixture. The percentage of fiber added is calculated by considering the wet weight of soil. Figure 1 shows the representative soil sample taken from Kuttanadu riverbed. The Jute fibers were soaked in NaOH solution at desired concentration. This arrangement is kept undisturbed for 24Hrs and then dried at room temperature for 7 days. Figure 1(b) shows jute fibers collected from market of 5mm diameter.

(a) (b)

Fig. 1. (a) Kuttanadu soil preserved in natural condition **(b)** Jute fibers

2.5 Unconfined compression test

The test was performed under the reference of IS :2720 (Part 10)- 1973. The soil samples were prepared in a split mould having diameter 38mm and length 76mm. The cylindrical shaped test specimens thus obtained were neatly wrapped in an aluminum foil and cure it for 3,7,14 and 28 days by storing inside a plastic bag.

2.6 Scanning Electron Microscope

A SEM is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample. The coated jute fibers with different percentages of NaOH are tested under SEM to study the surface characteristics and their bonding with soil.

3 Results and Discussions

3.1 Effect of natural jute fibers in plain soil

Unconfined Compression tests were conducted on the soil sample treated with jute fibers in different percentages. The dimensions of jute fiber used for the study is 5mm diameter and 20mm length, 5mm diameter and 40mm length, 3mm diameter and 20mm length, 3mm diameter and 40mm length. The jute fibers are added to the soil at different percentages such as 2%, 4%, 6% and 8% by weight of the soil. Figure 2 shows the variation of unconfined compressive strength of soil when jute fibers are added. From the results it can be concluded that the optimum amount of jute fiber in Kuttanadu soil is 6% and the peak compressive strength is obtained when fiber of length 40mm and

diameter 5 mm is added. When length increases from 20mm to 40mm, 15% increase in compressive strength is noticed. strength when the jute fiber diameter changes from 5mm to 3mm. When diameter increases from 5mm to 3mm, 2% increase in compressive strength is noticed.

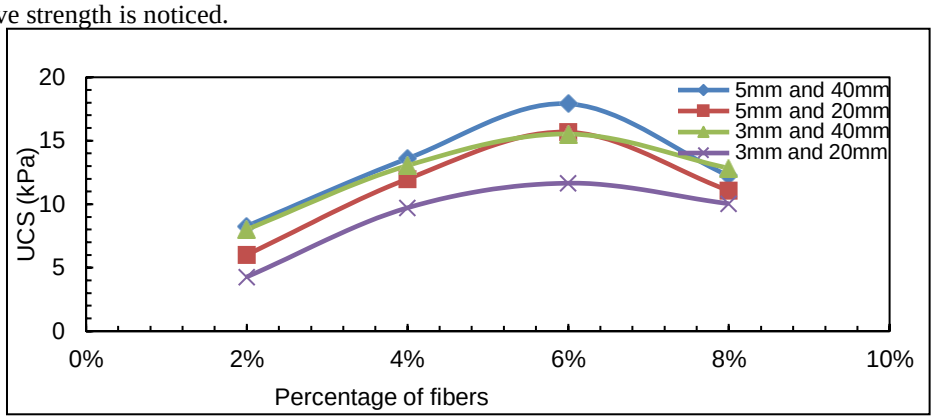

Fig 2: Variation of Unconfined compressive strength of Kuttanadu soil coated with natural jute fibers

3.2 Effect of NaOH coating on strength of Kuttanadu soil reinforced jute fibers

Degradation of natural fibers is one of the main issue occurs in stabilization process. To reduce the degradable nature of jute fibers and to increase the durability the fibers are coated with alkaline solution. There are so many methods available for coating the jute fiber such as bitumen, kerosene, NaOH, $Ca(OH)_2$, etc. In this study, an attempt is made to treat the fibers with NaOH, which are used for preparing the solution. The jute fibers which were cut into desired length are kept it in solution for 24 hours, then dried it in air for 7 days and then used for testing. Coating is done at different percentages of solution 1%, 2%, 3%, 4%, 5%, 10%, 20% and 30% NaOH solution. Unconfined Compression tests were conducted by adding different percentages of fibers having different dimensions such as 5mm diameter and 40mm length, 5mm diameter and 20mm length, 3mm diameter and 40mm length, 3mm diameter and 20mm length. 1% NaOH solution were prepared by adding 1-gram NaOH flakes in 1 liter of water. The jute fibers are kept in the prepared solution for 24 hours and air dried it for 7 days at room temperature. Figure 3 shows the variation of UCC strength when 2%, 4%, 6% and 8% 1% NaOH coated fibers are added. It can be observed that optimum amount of fiber is 6% and maximum strength is obtained when fibers of 5mm diameter and 40mm length. When comparing it with natural fibers, 19 % increase in shear strength is observed. Figure 4 shows the variation of UCS when 2% NaOH coated jute fibers are added. Figure 5 displays the variation of unconfined compression strength of jute reinforced Kuttanadu soil for various NaOH solution. It is observed that fiber with maximum diameter and greater value of length are exhibiting more strength. Strength is proportionally varying with diameter and fiber length. Every specimen exhibited its peak value when clayey soil is mixed with 6% fibers (treated with 3% NaOH).

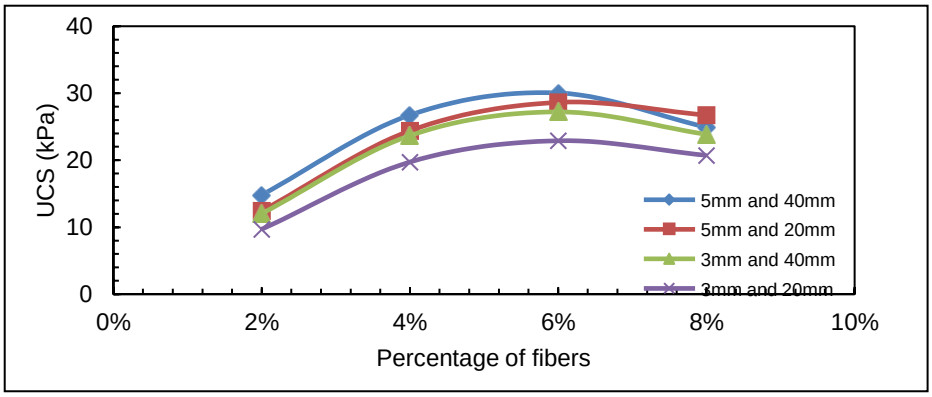

Fig 3: Variation of Unconfined compressive strength of Kuttanadu soil reinforced with jute fibers coated 1% NaOH

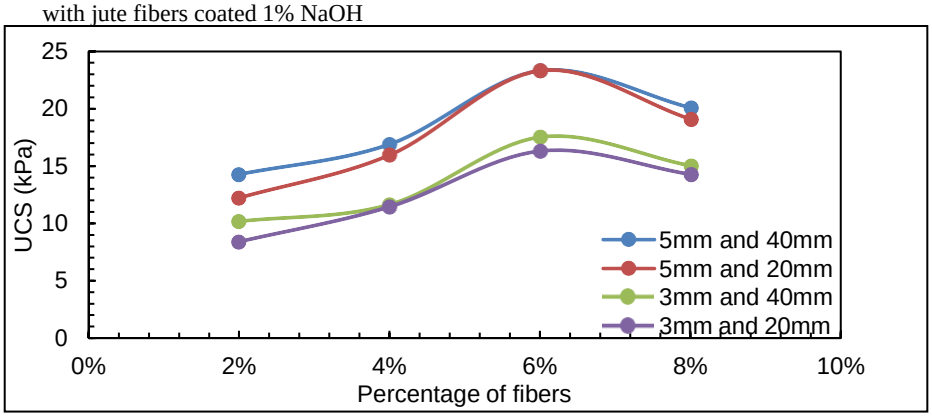

Fig 4: Variation of Unconfined compressive strength of Kuttanadu soil reinforced with jute fibers coated 2% NaOH

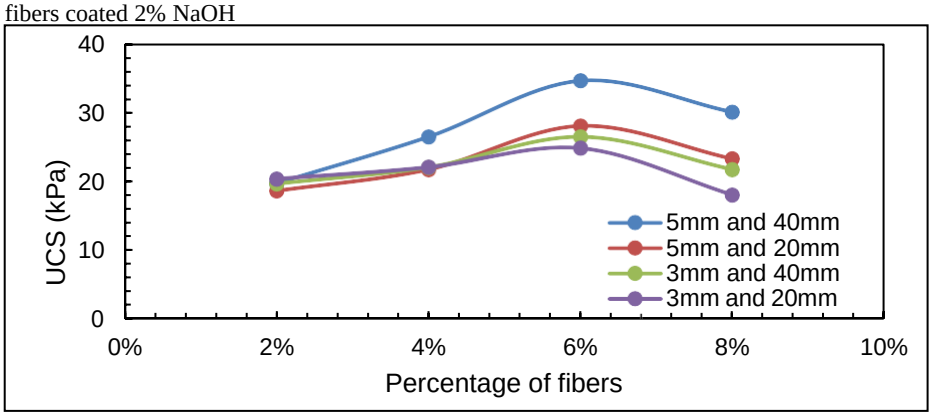

Fig 5: Variation of Unconfined compressive strength of Kuttanadu soil reinforced with jute fibers coated 3% NaOH

5.3 Effect of chemical coating on UCS

Figure 6 represents the UCS variation of representative sample which are reinforced with fibers having diameter 5mm and length 40mm which were coated with different percentages of NaOH solutions. It shows that strength is proportionally increasing with increase in NaOH content. When the concentration of NaOH increases the impurities in the fiber removed to maximum extent, hence weight of fiber is reduced, and the amount of fiber used here is increased. As length increases, the surface area of fiber increases and the bonding between fiber and soil increases, hence the compressive strength also increases.

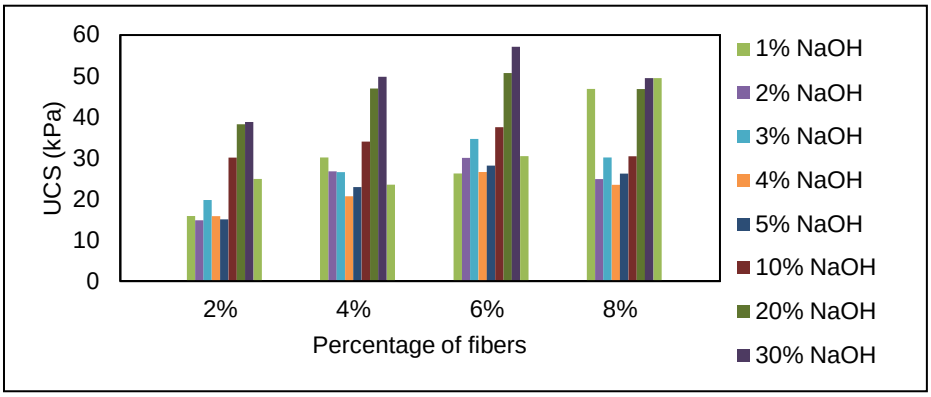

Fig 6: Variation of Unconfined compressive strength when different percentage of NaOH coated jute fibers are added

5.4 Scanning Electron Microscope tests on Jute Fibers

Scanning electron microscope tests were conducted uncoated and coated jute fibers. This test helps to identify the changes occurring on the fiber after the treatment. Figure 7 shows the test result of uncoated jute fibers which has clear and smooth surfaces. Figure 7a shows the image of 1% NaOH coated jute fiber in Scanning Electron Microscope. The surface becomes rough and the impurities starts detaching from the surface. In coated jute fiber the bonding between soil and fiber increases as well as the strength increases. Figure 7b shows the result of 2% NaOH coated jute fiber in Scanning Electron Microscope. The surface becomes rough and the impurities detached from the surface. The coated jute fiber the bonding between soil and fiber increases as well as the strength increases. Figure 7c shows the image of 3% NaOH coated jute fiber in Scanning Electron Microscope. When compared with 1% NaOH coated the surface roughness is increased.

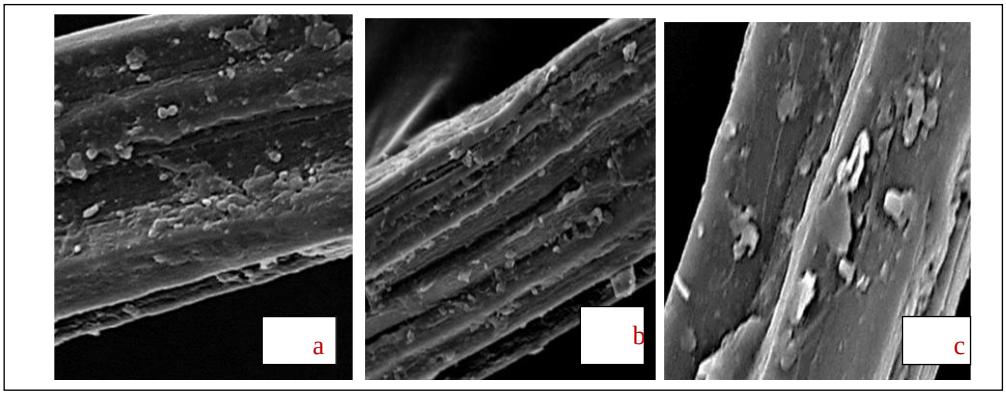

Fig 7 (a – c): Scanning Electron Microscope Images of soil (a) untreated condition (a) treated with 1% NaOH (c) treated with 2 % NaOH

6. Conclusions

Different laboratory tests were carried out on Kuttanadu soil samples treated with jute fibers. The soil samples are kept at its natural condition throughout the study. Based on the test results and detailed analysis, the following conclusions are drawn:

- When uncoated jute fibers are added, the unconfined compressive strength increases and settlement decreases. The optimum amount of fibers added is obtained as 6%. Peak compressive strength is obtained when the fibers of length 40mm and diameter 5 mm are added.

- Kuttanadu soil reinforced with 1% NaOH coated jute fibers are subjected to unconfined compressive strength tests. As percentage of fibers added increases, the compressive strength of the soil increasing proportionally. The optimum amount of fiber is 6% and peak strength is obtained when fibers of 5mm diameter and 40mm length is added. When comparing it with natural fibers 19 % increase in shear strength is noticed.
- 2% NaOH coated jute fibers reinforced soil samples are subjected to unconfined compressive strength tests. As percentage of fibers added increases, the compressive strength increases. The optimum amount of fiber is 6% and peak strength is obtained when fibers of 5mm diameter and 40mm length. When comparing it with stabilizing natural fibers 30% increase in shear strength is noticed. Similar trends are observed with soil reinforced with 3,4,5 and 10% NaOH coated jute fibers.
- The effect of NaOH coating on natural fibers is studied with the help of Scanning Electron Microscope. With the percentage of NaOH is increased, the surface roughness of fiber and bonding between the soil and fiber is increased.

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