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Modification on Coir Fiber in Durability and Shear Parameters in Flyash Soil Mixture

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***Abstract:** Coir (Cocos nucifera) is a natural fiber known for its high lignin content which can be effectively made use of provided they are given suitable treatment. Notable disadvantage of natural fiber is its polarity, as they are exposed to diverse pH, salinity, moisture and microbial attack it makes them incompatible with hydrophobic matrix. This paper focuses on modification of coir fiber in improving the durability of fiber and thereby improving the strength characteristics of weak thonnakal soil by suitable sustainable material and fiber. The main idea behind the usage of industrial products is not only conserve the natural resources but a way of implementing two suitable materials to create a 'synergy' within the ecosystem. With this view, Flyash was used as a sustainable material. The present work involves modification of coir fiber using chemical treatment called quick precipitation method where nanoparticles of $Ca(OH)_2$ are impregnated into the pores and surface of the fiber. To study the effectiveness upon modification both treated and untreated coir fiber were subjected to alkaline and neutral pH conditions for alternate wetting and drying cycles and its durability was assessed by measuring individual fiber tensile load test. Both treated and untreated coir fiber were added in different percentage from 0.5 to 1.5% to the soil-flyash mix to study the strength improvement by conducting unconfined compressive test. The modified coir fiber was found to withstand adverse durability conditions much better than the untreated coir fiber. Nanomodification of fibers enhanced the interfacial adhesion by better interaction with the soil flyash matrix and the tensile strength also improved. The strength parameter of the soil was also improved upon the addition of modified coir fiber*

***Keywords:** Coir, Quick precipitation, Durability, Tensile strength.*

I. INTRODUCTION

Soil is a construction material which has been used from time immortal. Thonakkal soil being poor in mechanical properties has been putting challenges to civil engineers in building up its properties primarily based upon the need. Hence this soil was adopted for the study. From the start of the industrial and economic revolution the most important issue in ahead of the industries is that the disposal of the industrial waste and it is a major issue within the current situation. The solution to the above problem is to use these industrial wastes to a most level for varied functions like road construction, highways and embankments. Therefore flyash was used in the study and its optimum dosage to soil was found out. A lot of work has been studied and done on the strength deformation behavior and characteristics of fiber strengthened soil and it's been obtained that addition of fiber in soil improves the overall engineering properties of soil. Analyzing the addition of treated fiber in soil is less attempted. Natural fibers are lot more advantageous over synthetic due to their handleness, availability, low cost, and they are biodegradable hence will not cause disposal problem[1]. The effectiveness of fiber depends on the strength of fiber and its interaction at normal stress with the soil. Among the natural fibers, coir fiber is used in study in the study which has highest lignin content of all. The tensile strength, durability of coir fibers can be modified by changing the cellulose packing and physical changes in it. The presence of hydroxyl groups (OH) in cellulose and their hydrogen bond formation is what makes coir fiber amenable to chemical modification. Quick precipitation method was chosen were the structure of coir fiber was altered using $CaCl_2$ and NaOH solution. The tensile strength and durability of individual fiber was analyzed and its effect on soil-flyash was studied using unconfined compressive strength.

II. LITERATURE REVIEW

Usage of natural fiber in geotechnical application has attracted researches from past many years. Coir is a natural biodegradable fiber which has high amount of lignin content around 40-45% and cellulose content of 32-43% and hemi-cellulose content of 0.15-0.25% [2]. The individual tensile strength of coir fiber is high compared to other natural fiber. This individual strength of fiber will be mobilized and works together with the soil. Hence coir as reinforcement helps in improving the strength at a early stage and it provides good stability to soil because of high initial strength [3]. Addition of randomly distributed fibers to soil in improving geotechnical properties of soil has found to be beneficial.1% coir fiber had higher slope indicating more ductile behavior in soil-lime mixture. Hence indirect tensile test and unconfined compressive test was higher at 1% addition of fiber. More fiber content dominated the fiber-fiber interaction and there by forming lumps and full contact with soil particles is not possible[4].1 to 1.5% coir fiber content helped in reducing swelling and compressibility of soil to large extent [5]. Natural fibers are amenable to chemical modifications due to presence of hydroxyl groups and ability to form hydrogen bond with the new particles. Many researchers have tried lot of surface coating and chemical treatment on fibers to improve its tensile strength and durability.

The effect of gum resin coating on sisal fiber in shear and compressive strength on soil-fiber mix was investigated. Initially the UCC value was low but upon drying it improved. Thus gum resin could improve the shear property and potential durability of fiber soil mix [6]. A comparative study between CCl_4 and NaOH treated fiber on consolidated undrained test was performed.

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The results indicate that the peak deviator stress can be significantly improved upon the addition of treated fiber and this improvement, cohesion, friction angle was highest for the one treated with CCl_4 [7].

Behavior of NaOH treatment on coir fiber in cement stabilized clay-pond ash mixture was investigated. The incorporation of treated coir fiber in soil sample reduced the rate of loss of post-peak strength, stiffness and the behavior of the composite changed from brittle to ductile [8].

Nanotechnology is a recent approach of fiber modification by impregnating with nanoparticles onto the surface and pores, thereby improving their mechanical properties as well as introducing a new function onto the fiber surface [1]. The effect of nanomodified coir fibre through quick precipitation method and its effect on soil properties are less attempted. The effect of reinforcement by nanomodification method in water hyacinth (WH) fibres by ferric hydroxide was studied. The water absorption capacity treated fiber reduced as the surface changed to hydrophobic nature and also because it was less exposued to water surface. The tensile strength of fiber was increased by 1.25 times compared to unmodified WH fiber. The improvement in tensile strength of modified fibres reflected in the increase of unconfined compressive strength of soil–fibre mix [9]. The effect of nanomodified coir fibre through quick precipitation method in limed marine clay improved the tensile strength by 63% and 33% for $Al(OH)_3$ and $Fe(OH)_3$ modified fibers. The shear strength and durability increased by the modification of fiber. Besides that increase, internal friction angle and the cohesion intercept were also observed to increase [10].

III. OBJECTIVE AND SCOPE

A. Objectives

- To understand the extent of soil stabilization using Flyash and Recron-3s fiber
- To evaluate the strength and volumetric parameters of stabilized soil

B. Scope

- Improving the soil properties of Kaolinite clay by using waste material as additives, thereby reducing its adverse effect on environment.
- In order to reduce the environmental issues caused by the Fly ash produced from various industries, it is used as an additive for soft clay

IV. MATERIALS AND METHODOLOGY

The soil used in the study is collected from Thonnakkal region at Trivandrum district from a depth of more than 5 m. The geotechnical properties of soil are tabulated in Table 1 .Fly ash used in this study was collected from Tuticorin thermal power plant, India. Class F flyash was found to be with low calcareous content and high siliceous content according to IS 3812 – 1. Chemical composition of flyash is shown in Table 2. Coir fiber was collected from Neyyattinkara Coir Cluster, Trivandrum

Table- I: Properties and Composition of soil

Property	Value
Colour	Pinkish white
Natural moisture content (%)	20
Specific gravity	2.5
Liquid limit (%)	46
Plastic limit (%)	25
Plasticity index (%)	21
Sand (%)	48
Silt (%)	14
Clay (%)	38
Maximum dry density (g/cc)	1.8
Optimum moisture content (%)	16.67
Unconfined compressive strength (kN/m^2)	28.49
California bearing ratio	2.68

Chemical composition	**Component (wt %)**
$SiO_2 + Al_2O_3 + Fe_2O_3$	92.11
SiO_2	61.53
MgO	0.63
SO_3	0.82
Na_2O	0.39
Total Chlorides	0.008
LOI	0.95
Mean particle size	24µm
Fineness-specific surface (Blaine)	365 ^{2}/kg

4.1 Nanomodification of Coir Fiber

The process is carried out through Quick precipitation method in which $Ca(OH)_2$ nanoparticles were loaded onto the surface of fibers and into the fiber pores. The procedure was carried out at ambient conditions of temperature and pressure. The procedure is as follows, Initially 50 g of coir fibers were submerged in 500 ml aqueous solution of 0.5M $CaCl_2$ for 24 h in order to uniformly fill the pores and the surface of the fibers with $CaCl_2$ solution. Then the submerged coir fibers were separated and then incubated in another beaker containing 500 ml of 0.5M sodium hydroxide solution. After that it was kept in ambient conditions for another 24 h. Here $Ca(OH)_2$ quickly precipitates as nanoparticles on the fiber surfaces and on its pores. Finally, the coir fibers were separated from sodium hydroxide solution and were washed with distilled water to remove the unwanted residue of the reaction, such as NaCl and NaOH. At last the fibers were dried at ambient room temperature. The chemical reaction undergoing during the process is represented through a chemical equation given below and the entire process of modification is depicted in the Fig 5.1

$$CaCl_2 + 2NaOH \rightarrow Ca(OH)_2 + 2NaCl$$

4.2 Testing Programme

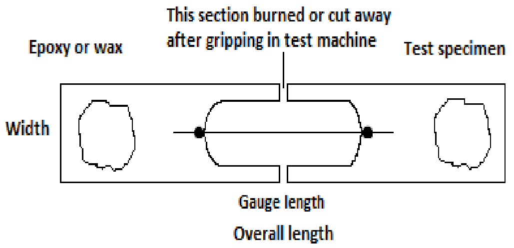
SEM analysis

The surfaces of chemically modified and unmodified coir fibers were examined with scanning electron microscope. The samples were sputtered by ejecting gold atoms to have proper conduction. The properly sputtered samples were then placed inside the SEM chamber for obtaining micrographs.

The micrograph is obtained at 1000x magnification and the images are then digitally analyzed.

Water absorption. The steady state water absorption was carried out by drying the fiber and immersing in distilled water at room temperature in accordance with Saha et al (2012)[11]. The portion of fiber was taken out of the distilled water at fixed time interval. It was carefully wiped with cloth to remove the excess water and the weighed to get the water absorption. This process is continued for longer immersion period until a steady value of water absorption is obtained.

Tensile test. Coir fibers were randomly selected and tension test was conducted as per ASTM D3379-75: 1989 in Universal Testing Machine at constant rate of extension of 5mm/min. Samples of uniform shape and average thickness 0.15 mm were tested at gage length of 20 ± 5mm.The tab was prepared according to ASTM D-3379-75 [12] as shown in fig. 25 strands of fiber was subjected to tensile test and average breaking load was taken, expressed in Newtons(N).



Alternate wetting and drying study. Durability studies were carried out on treated and untreated coir fiber. The fibers were subjected to neutral and alkaline pH condition for alternate wetting and drying cycles as per the condition outlined by Sumi et al. (2018)[13]. The fiber samples were weighed accurately and immersed separately in aqueous solutions of alkaline (pH 10.0) and neutral (pH 7.0) pH at room temperature (27 ± 1 °C) for seven days. The fiber to solution ratio of 1:10 (by weight) was maintained to ensure the complete immersion of it in the solution during the test period in the tray. Afterwards fibers were removed and placed on steel container to remove excess water for 30mts and exposed to sunlight for seven days. Seven days of wetting and seven days of drying were considered as 1 cycle and the tensile test of each set of samples was determined at the end of each cycle

Unconfined compressive strength. UCC was done to find out the optimum flyash content and then different percentage of treated and untreated fiber (0.5, 1, 1.5%) were added to soil-optimum flyash mix to study the effect of modification of coir fiber in the mix. The samples were compacted at maximum dry density and optimum moisture content obtained from light compaction test. The samples were wrapped with thin plastic sheet and kept for curing for 7, 28 days prior to testing.

V. RESULTS AND DISCUSSION

5.1 SEM Analysis

Figures 2a and 2b illustrate the morphology of the fiber surface of unmodified and modified coir fiber, respectively. It can be seen that clusters of the proposed materials changed the morphology into a relatively rougher surface

Fig. 2. Surface structure of coir fiber (a) unmodified (b) $Ca(OH)_2$ modified

5.2 Water Absorption

Treatment on fiber helped to reduce the hydrophilicity of the fiber. Fig 3 shows variaition in water absorption with time. In chemical treatment water soluble constituents and lignin were substantially removed to some extent and dissociable groups were partially blocked by the treatment leading to a reduction in swelling tendencies. There was 160% water absorption in untreated fiber which was reduced to 74% upon treatment.

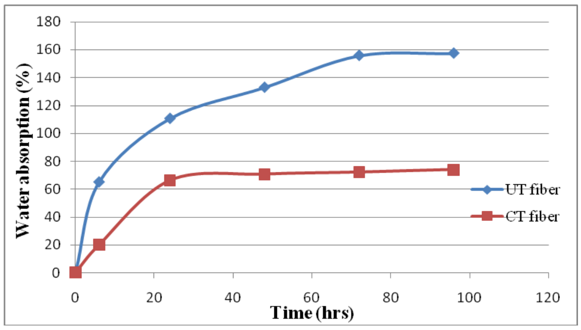


Fig. 3. Percentage variation in water absorption with time

5.3 Tensile Test and Elongation

As per IS 235-1989 code tensile test of individual fiber is expressed in terms of its breaking strength, ie the maximum force supported by a specimen in a tensile test carried to rupture. It is usually expressed in Newtons (N). The average tensile load of untreated was 6.58N and when it was chemically treated it increased to 8.05N ie 22.4% increase. Fig.4 shows the load extension graph of treated and untreated fiber. The extension of fiber was also found to increase. This is due to the formation of nanoparticles within the fiber and this may increase the surface area of fiber acting as a single unit during tensile test.

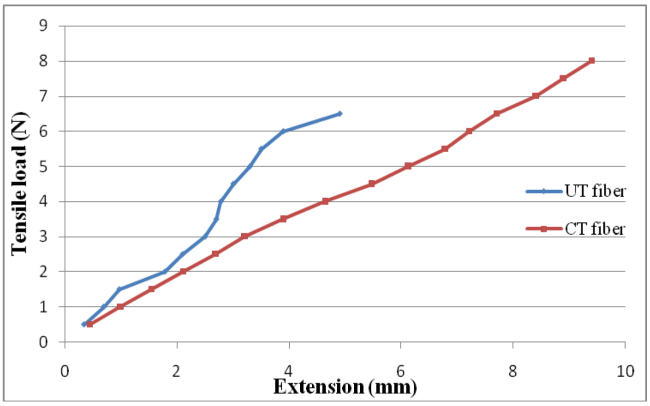


Fig. 4. Load extension curve of fibers before and after treatment

5.4 Effect of Treatment on Durability Of Fiber

The fiber was subjected to accelerated degradation study and the tensile load was noted at the end of each cycle. Percentage reduction in tensile load is expressed in graph in Fig 5 and Fig 6 at neutral and alkaline medium respectively. At the end of fifth cycle there was 27.38% decrease for untreated fiber at neutral medium and 30.39% decrease at alkaline medium whereas upon treatment the rate of decrease was less, which was 8.11% under neutral medium and 12.52% under alkaline medium. The untreated fiber subjected to alternate wetting and drying had faster loss in tensile load compared to treated. It is because more water penetrates during wetting cycle and more released during drying cycle causes hydration-dehydration. This behavior can extend for a longer period of time. Under chemical treatment the surface morphology changed and it reduced the dissolution of lignin especially in alkaline medium. The enhanced tensile strength may be due to the crystallization of the $Ca(OH)_2$ particle into the cellulosic pores and available capillaries present within the fiber. Alkaline medium resulted in faster lose of strength which can be due to the capacity of alkali to remove the waxy and oily coating of fiber and exposing them to moisture intake. Treatment on fiber showed sufficient durability and they were able to resist the adverse pH condition compared to untreated fiber. Thus it is evident that $Ca(OH)_2$ impregnation into the fiber was found to be effective in its potentiality for long term use.

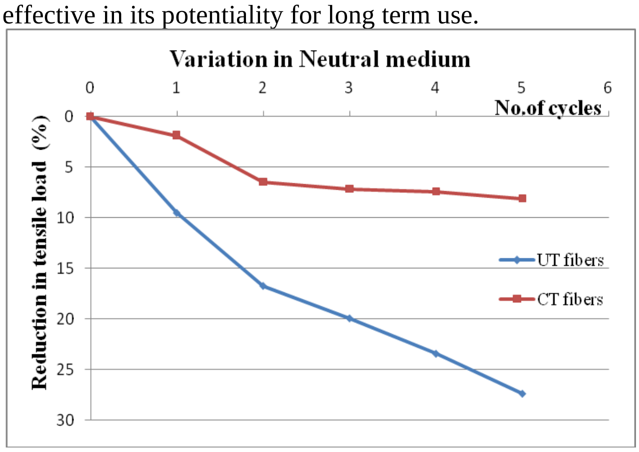


Fig. 5. Percentage variation in tensile load with time for fibers in neutral medium

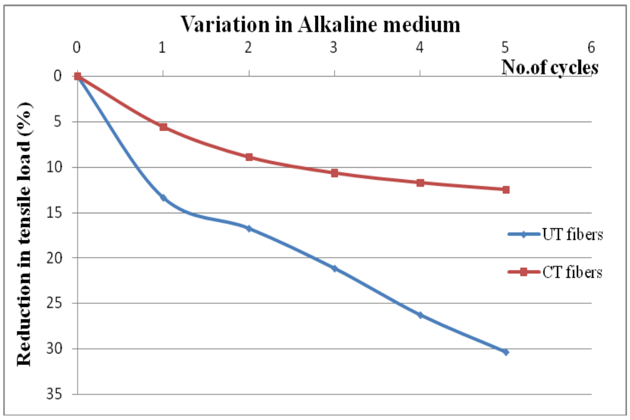


Fig. 6. Percentage variation in tensile load with time for fibers in alkaline medium

5.5 Effect of Treated Fiber on Soil-Optimum Flyash Mix

Addition of flyash showed a great improvement in unconfined compressive strength with a brittle failure. Figure 7 shows the behavior of stress strain curve with addition of flyash. It showed a distinct failure stress at strain about 4.5-6.5% after which the collapsed. Maximum value was obtained at 10% of flyash. Hence that was taken as optimum. Next different percentage of fiber was added to soil-optimum flyash mix. The variation in UCC value upon addition of untreated (UT) and chemically treated fiber (CT) for 0, 7, 28 days is shown in figure 8.

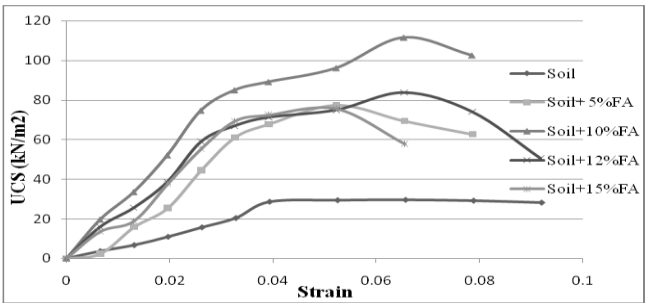


Fig. 7. Stress strain curve for varying percentage of flyash

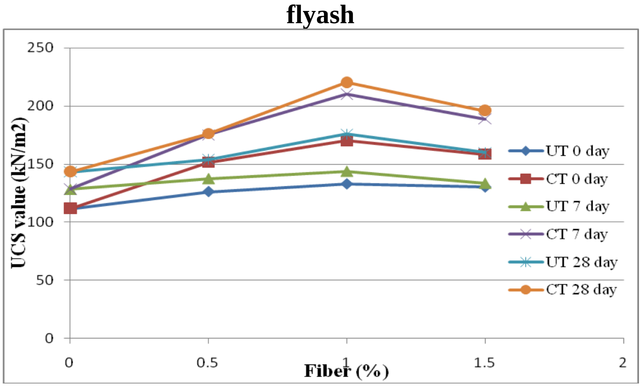


Fig. 8. Variation in UCS value upon addition of treated and untreated fiber

Fiber reinforced soil samples exhibited a ductile behavior. The ductile behavior was more at 1% fiber content. After that the UCS value reduced, that might be due to large content of fiber adhere themselves and its contact and bond with soil becomes less.

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Addition of Chemically treated fiber showed a much improvement in unconfined compressive strength of soil. Maximum value was observed at 28days curing at 1% fiber content. This increases is because of improved tensile strength of fiber upon treatment improved the overall strength of soil at 0 day. Upon curing the UCS value was found to increase, is because of crystallization of nanoparticles within the surface and cellulosic pores of fiber and the surface of fiber changed the morphology to a rougher surface which led to more interfacial adhesion with soil and frictional resistance to force application improvement and consequently the strength of soil-flyash-fiber mixture increased.

VI. CONCLUSION

Ca(OH)2 nanoparticle impregnation was tested for improving the durability or extending the life of coir fiber under adverse condition. Suitably pretreated coir fiber by the above process showed much retention of its tensile strength after different cycles under neutral and alkaline medium.

27% reduction in tensile load value of untreated fiber was reduced to 8% reduction upon this treatment.

Percentage reduction in water absorption up to about 74% from 160% could be attained with this treatment.

Modification of fiber did not reduce the mechanical property of fiber. There was 22.4% increase in tensile load upon treatment.

The morphology of fiber changed to a rougher surface, thereby it provided better adhesion and interlocking ability with the soil.

The optimum flyash was found to be 10%, hence the combination of 10% flyash and 1% treated fiber showed the maximum unconfined compressive value. Its effect of curing was also studied shows improvement in UCS value

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