ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

IJARCCE

International Journal of Advanced Research in Computer and Communication Engineering

PCON-2019

National Conference and Seminar on Innovations in Engineering & Technology

Govt Polytechnic College, Palakkad

Vol. 8, Special Issue 1, January 2019

An Innovative Technique to Improve Soil Characteristics using Human Hair as Stabilizing Agent

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Abstract: The suitability of Human Hair Fibre (HHF) as a stabilizing agent to enhance the strength of weak soils was investigated. The main aim was to develop a technique to reduce environmental problem caused by improper disposal of waste human hair from beauty parlours and hair salons. The study also investigates the potential of non - biodegradable, locally available and cheap HHF to replace conventional commercially available costly fibres used in embankments and weak soil stabilization.

Keywords: Human Hair Fibre (HHF), Non - Biodegradable, Soil Sample, Embankments & Weak Soil Stabilization

I. INTRODUCTION

Stabilization is the process of blending and mixing materials with soil to improve certain properties of the soil. Soil stabilization is used to reduce the permeability and compressibility of the soil and to increase its shear strength and bearing capacity. The main objective of soil stabilization is to increase the strength of soil and to reduce the construction cost by making best use of frequently available material. Recently soil reinforcement with short discrete randomly oriented fibres gives more attention in soil stabilization. A variety of materials including steel, concrete, glass fibre, wood, rubber, aluminium and thermoplastics can be used as reinforcing materials. Natural fibres can be obtained from natural resources such as plants, animals or minerals.

With the increase of global energy crisis and ecology risk, the unique advantages of natural fibres such as its abundance quantity, non-toxic, non-irritation of the skin, eyes, or respiratory system, noncorrosive property, biological fibre reinforced polymer composites have attracted much interest owing to their potential of serving as alternative reinforcement to the synthetic ones. The lower weight and higher volume of the natural fibres as compared to the synthetic fibres improve the fuel efficiency and reduced emission in auto applications. Hair is a protein filament that grows from follicles found in the skin and it is also an important biomaterial primarily composed of protein, notably keratin. Keratins are proteins, long chains (polymers) of amino acids. During current times Human Hair Fibre (HHF) is considered as a waste material and it create many environmental problems however it has many known uses like randomly reinforced fibre in the present state of art and technology. Human hair fibre is a natural non-biodegradable waste material, which creates health and environmental problem due to its improper disposal. It is also available widely and is very economical. Using it as a fibre for stabilization of the soil can reduce these problems. Thus the necessity of this project can be stated as to improve the engineering properties of the soil.

II. OBJECTIVE

The objective of the work is to study the suitability of HHF as a stabilizing agent to enhance the strength of weak soils. Hence it aims to investigate a measure to reduce environmental problems caused by improper disposal of waste human hair from beauty parlours and hair salons. The study also investigates the potential of non-biodegradable, locally available and cheap HHF to replace conventional commercially available costly fibres used in embankments and weak soil stabilization.

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III. LITERATURE REVIEW

Extensive studies were carried out on the stabilization of soft clays and expansive clays using various additives such as lime, cement, synthetic and fibres. Ranjan et al. (1994) conducted a series of triaxial tests to study the behaviour of plastic fibre reinforced sand. Randomly distributed fiber reinforced soils have recently attracted increasing attention in geotechnical engineering (Hejazi et al, 2012).

Naeini and Sajadi (2008) reported that waste polymer materials has been chosen as reinforcement material and it was randomly included into the clayey soils with different plasticity indexes at five different percentages of fibre content (0, 1, 2, 3, 4 %) by weight of raw soil to enhance its engineering properties. Most of the study reported till date with natural fibre is either coconut/jute fibre, which are biodegradable in nature. From the literature, it is quite evident that very few studies (Renju. R. Pillai and Ayothiraman Ramananthan 2012) have been reported in the stabilization of soils with hair reinforcement. Therefore, in the present study an attempt has been made to use HHF as reinforcement for the improvement of clayey soil.

IV. MATERIALS

Collection of Materials

Soil samples were collected from various places in Palakkad district. Soil sample 1 was collected from Chittur. Sample 2 was collected from Kozhinjampara and sample 3 was collected from college premises (Akathethara). The samples were collected manually from 1 metre depth and it was in disturbed state. The samples were then oven dried and crushed using hammer.

Figure 1: Soil sample 1

Figure 2: Soil sample 2

Figure 3: Soil sample 3

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Human hair

Human hair was collected from nearby hair saloon, cleaned and dried. Fibres of approximately same length were segregated manually. Majority of the sample were of required length of 25mm while the others were cut to get the same length. To remove the dirt particles from the fibres they were treated with sodium hydroxide (NaOH) solution. For 1 litre distilled water 10g of sodium hydroxide pellets were used.

V. METHODOLOGY

Various laboratory tests were conducted on virgin soil sample as per IS standard (IS: 2720) to determine the engineering properties. The amount of human hair fibres for stabilization is taken in the proportion of 0.05%, 0.1%, 0.2%, and 0.3% by dry weight of soil. Using the proportion, mix samples were prepared and a set of laboratory tests were performed to determine the engineering properties of fibre reinforced soil sample.

VI. LABORATORY INVESTIGATIONS

6.1 Properties of Soil Sample and human hair

Table 1: Properties of soil sample

Sample	Sample 1	Sample 2	Sample 3
Specific gravity	2.278	2.46	2.6
Liquid limit	66%	33%	28%
Plastic limit	9.42%	22.29%	22.58%
Plasticity index	56.58%	11.71%	5.42%
Optimum moisture content(OMC)	40%	14%	14.8%
Maximum dry density (MDD)	17%	1.79g/cc	1.77g/cc

Table 2 Properties of hair

Cross section	Circular
Diameter	17-100 micron
Length	25mm
Linear density	1.25 – 1.40 g/cc
Elongation	1.5 times its dry weight
Tensile strength	About 400Mpa
Flexural strength	25-30Mpa

6.2 Compaction Characteristics

The empty weight of the mould used is 3.702 Kg and its volume is of 1000cm^3. The dry density of sample 1, 2 and 3 without hair and with various percentage of hair were calculated. Experiments were designed as per Maher and Ho (1994). The observed variations in dry density are shown in Figure 4, 5 and 6.

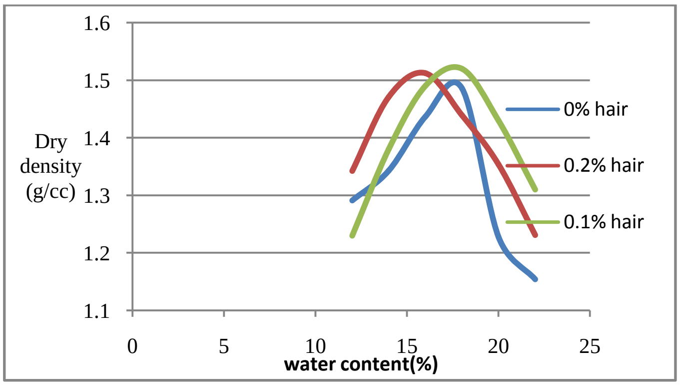

Figure 4: Compaction characteristic of soil sample 1

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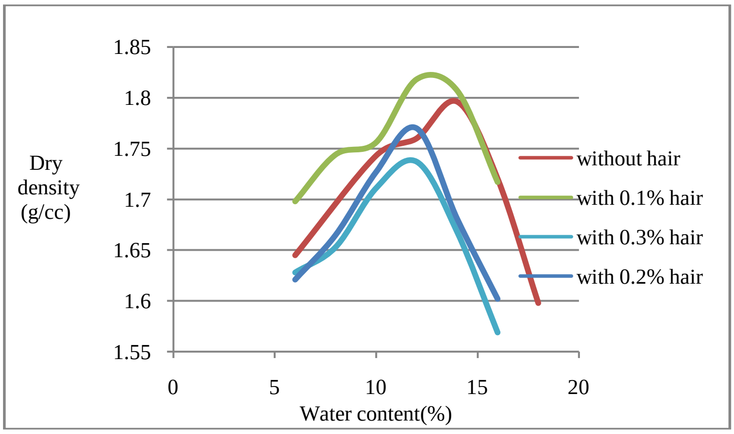

Figure 5. Compaction characteristics of soil sample 2

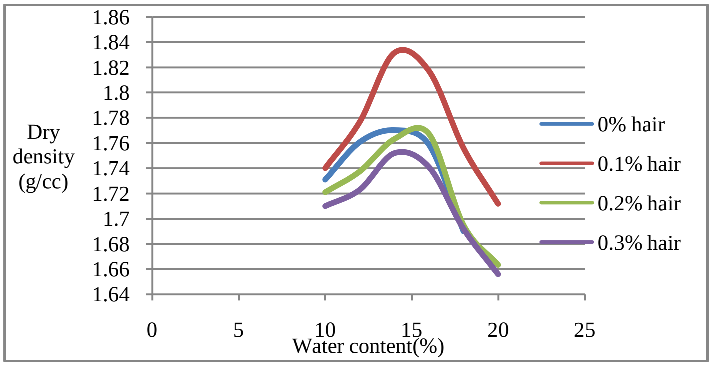

Figure 6. Compaction characteristics of soil sample 3

The standard Proctor test was conducted with an initial target moisture content of 10% with an increment of 2%. Two trials of tests were conducted in soil to get more reliable results. The effect of addition of hair fibres in the soil sample 1 was found out by adding 0.2% fibre content. It was observed that the soil sample with hair increases the OMC and almost same dry density as virgin soil. So it is clear that in case of organic clay the addition of hair is not in good effect. In soil sample 2 and 3 the dry density increases and OMC decreases with increase in % of hair, further addition decreases the dry density and increases OMC. Similar results were obtained by Renju. R. Pillai and Ayothiraman Ramananthan in 2012. A comparison of dry density obtained in the three soils is shown in Figure 7.

6.3 Unconfined Compressive Strength Test

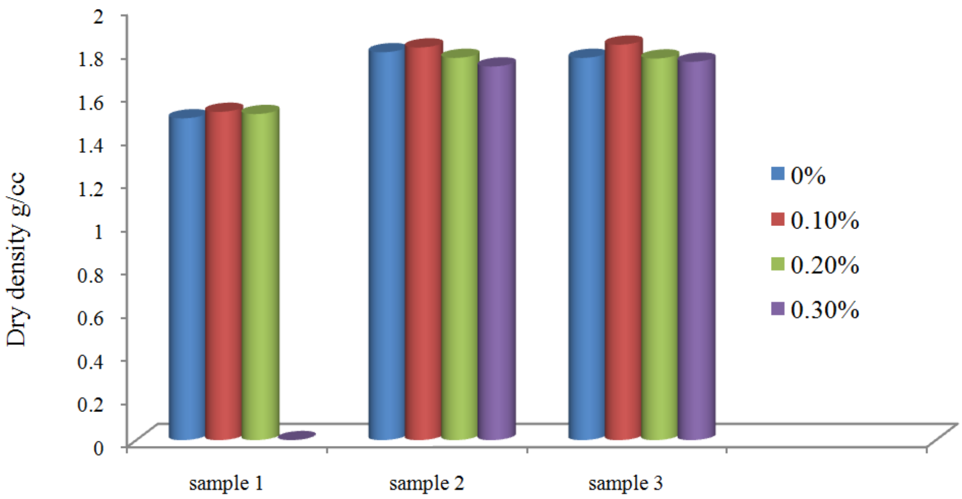

Figure 7: Dry density variation in different soil samples

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Five series of UCC test were undertaken on soil sample specimens to determine the influence of UCC strength. In the first series the test were carried out on soil specimen compacted at their respective maximum dry unit weight and optimum moisture content. The next four series UCC test were conducted by adding different percentages of hair such as 0.05%, 0.1%, 0.2% and 0.3% ,compacted with same dry unit weight by maintaining corresponding optimum moisture content obtained from compaction. To achieve uniform distribution of fibres within the soil specimens, several methods such as mixing pre-wetted hair fibres with dry clay power, mixing dry fibres with wet clay and mixing dry clay and fibres followed by adding water were examined. It was observed that most suitable mixing method is achieved when water is added to dry mixture of fibre and clay. The stress-strain curves of soil sample without fibre and hair reinforced soil samples are approximately linear at the initial stage, the axial stress increases with the increase of axial strain, and the rate is a little large.

After the sample reaches comparatively large stress initially, the strength generally begins to decline with increasing of the strain. However, the decline process of fiber reinforced soil is gentler than the soil without fibre, and the strength stabilizes after a slight decline. The results indicate that, compared with soil without fiber, the fiber reinforced soil not only has a higher breaking strength, but also has a higher residual strength and more stable performance in the latter part of deformation. The soil specimen of sample 1 gave first crack under normal load at 250kN and ultimate load obtained was 400kN. As in the case of soil reinforced with 0.1% of hair, first crack was formed at 300kN and ultimate load obtained was 500kN. Also there was an increase in the unconfined compressive strength by 31.5 %. Soil reinforced with 0.2% hair gave first crack at 450kN and ultimate load obtained was 650kN and it showed maximum increase in compressive strength (62.5%). Soil reinforced with 0.3% hair showed first crack at 300kN and ultimate load obtained was 550kN. A decrease in strength was observed that is 23.40%. The sample gave maximum unconfined compressive strength on addition of 0.2% hair as reinforcement than 0.1%, 0.3% and virgin soil. The soil specimen of sample 2 gives first crack under normal load at 350KN and ultimate load obtained at 550KN. As in the case of soil reinforced with 0.05%hair, first crack was formed at 500KN and ultimate load obtained was 650KN. Soil reinforced with 0.1% hair gave first crack at 450KN and ultimate load obtained was 700KN and it showed increasing unconfined compressive strength of 9%. Further addition of hair decreases the strength of soil.

The virgin soil specimen of sample 3 and sample with 0.05% addition of hair gave first crack under normal load at 250KN and ultimate load obtained at 300KN. As in the case of soil reinforced with 0.1% and 0.2% hair, first crack was formed at 300KN and the ultimate load for 0.1% addition of hair is at 350 KN and for 0.2% addition is at 300KN. Further addition of hair decreases the strength of soil. UCC strength variation with different percentages of hair in soil samples 1, 2 and 3 are shown in below figure 8. The increase in UCC values due to addition of HHF to weak soil may be attributed due to improved interfacial adhesion between the soil particles and the fibre, which allows a more efficient transfer of stress along the fibre matrix interface. However, the decrease in UCC values beyond optimum fibre content may be due to the increase in fibre - fibre interaction. The fibre may not be perfectly aligned with soil matrix leading to poor dispersion of fibre in the soil matrix thus resulted in a lower efficiency of load transfer with increase in fibre. However, the overall performance of any fibre depends to a large extent upon the fibre-matrix interface which in turn is governed by the surface topography of the fibre and by the chemical composition of fibre surface and resin properties.

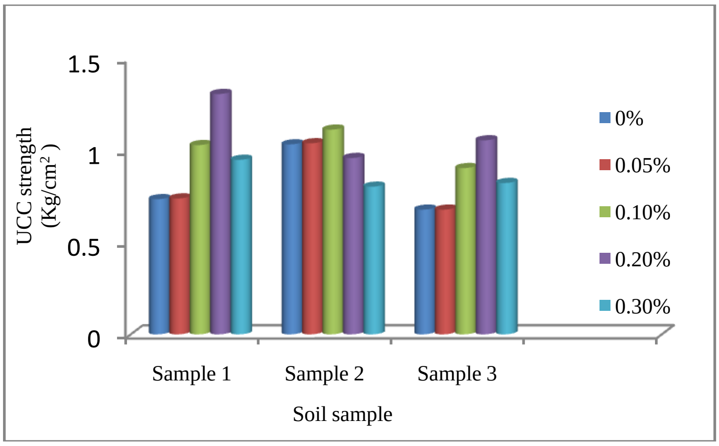

Figure 8: Variation in UCC strength with different percentages of hair in soil samples.

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VII. CONCLUSION

Various environmental problems caused due to the improper disposal of human hair fiber can be effectively minimized by addition of hair fibre to soil. It leads to the improvement of strength parameters of soil. Based on the obtained results the following conclusions can be drawn

- From the compaction test, it was observed that inclusion of human hair fiber marginally affect the dry density-moisture content relationships of clay. Maximum Dry Density initially increased due to the addition of hair fiber and then decreased. Optimum Moisture Content decreased due to the moisture absorption of hair fibers. The presence of organic matter in soil also causes reduction in MDD and increase in OMC.
- The soil sample 1 and sample 3 reinforced with 0.2% hair showed a maximum increase in unconfined compressive strength of 62.5% and 55.60% respectively. In soil sample 2 with the addition of 0.1% fibers by weight, the unconfined compressive strength increased up to 9% than that of unreinforced soil. This clearly indicates that human hair fiber could be used in the improvement of cohesive soil.

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