

Human Hair Fibre Reinforcement-An Inventive Measure to Improve Soil Piping

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Abstract— Soil Piping, a subsurface form of erosion mainly occurring in relatively loose soil needs effective counter measures and soil reinforcement technique is very useful in this application. Previous studies concluded that piping resistance of soil increases when various natural or artificial fibers are mixed. Hence, In this project an effort is made to use profusely available, natural waste Human Hair Fibres (HHF) as soil reinforcements and the effect of the same when discretely and randomly distributed on the piping behavior of soil are examined. HHF of an arbitrary length 50mm and two varying dosages of fibre content (0.5%, 1%) were used for the present investigation. Characterisation techniques such as SEM and TGA was done to study the morphology and decomposition properties of the fibre sample. The critical hydraulic gradient and piping resistance for unreinforced and HHF reinforced soil sample were calculated. It was found that addition of HHF effectively reduced soil piping.

Index Terms— Human Hair Fibres, Piping resistance, SEM, Soil Piping, TGA.

1 INTRODUCTION

God's Own Country, Kerala faced the wrath of nature in the form of floods and landslides in 2018 which almost took a repetition of its form in the year 2019 too. This led to a trail of destruction all through the state with several areas submerged under water, destroying life and property. Due to these phenomenon many cracks are found to be opened up in the soil. The researchers made a conclusion that one of the reason for this may be piping phenomena. Hence the study of piping becomes very relevant in the present situation of Kerala.

Piping is a subsurface form of erosion. This happens when water that percolates into the soil gets trapped in small pores or cavities within. Subsequently, the adjacent and bigger cavities may get interconnected forming pipe-like conduits which run in long lengths. To minimize the failure due to piping, the use of reinforced soil can be used as an effective remedial measure to overcome it.

Further, the accumulation of waste HHF and its disposal is posing a multifaceted problem in today's world. Human hair fiber is a natural, slow degrading waste material available in abundance. If it is not disposed or treated in a scientific way, it can cause many health and environmental issues. It can be easily used as a reinforcing material not only to improve poor/unsuitable construction sites but also to avoid its disposal problems. Reinforcing methods or systems utilize the waste HHF material as a resource, thus addressing to such problems. In addition to reducing waste, it contributes to the economy thus proving as a potential material resource having the advantage of being completely biodegradable, renewable, and available in every locality.

Fibres have been used as an admixture to restrain the seepage velocity and increase piping resistance of soil. There are many methods to prevent from piping failure and to increase the piping resistance of the soil such as using cut off walls, trenches, sheet piling, blankets of impervious material and pressure relief wells. Random reinforcement of soil is one of the mechanical methods that has been used to improve the properties of soil. In this project, soil is mixed with randomly distributed discrete fibres which impart strength to soil and well as helps to prevent the upward seepage of water to a greater extent.

The main objectives of the study are:

1. To find the possibilities of using hair as fibre reinforcement in soil.
2. To provide an alternative way for the safe management of hair waste.
3. To understand the mechanism of discretely and randomly distributed human hair fibre as reinforcement inclusions in soil.
4. To compare the behavior of unreinforced soil specimen with HHF reinforced specimens in improving the piping resistance of soil by a custom-developed one dimensional piping setup.

2 MATERIAL PROPERTIES

2.1 Soil Sample

For the present investigation loose clayey silt soil sample was taken from piping infested area in Idukki district, Kerala.

2.2 Human Hair Fibre

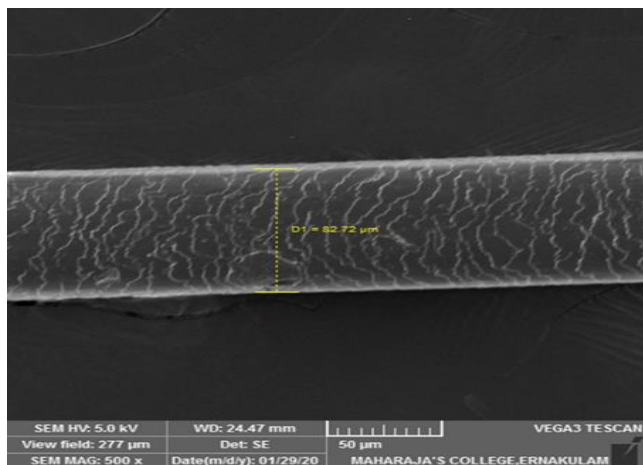
The HHF was gathered from local sources, salons and parlours. Fibres collected were dried under sun, just to remove moisture. It was sorted then, and cut into the required dimension lengths.

Characterization techniques:

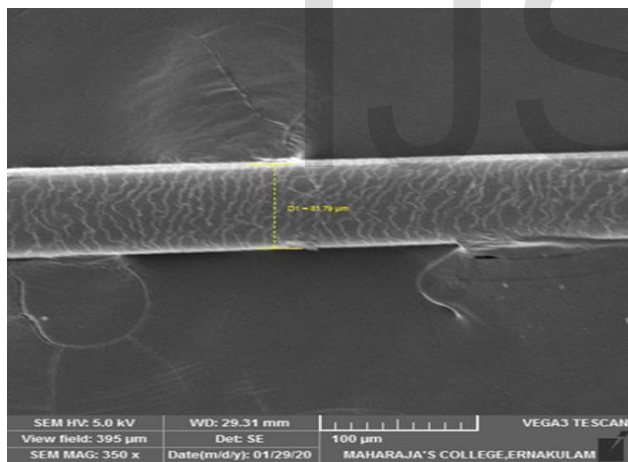
1. Scanning Electron Microscopy
2. Thermogravimetric Analysis

2.2.1 Scanning Electron Microscopy (SEM)

Morphology of the human hair fibres used in this study were investigated using SEM. In this technique, the electron beam interacts with a thin film surface layer of the specimen resulting in back scattering of electrons of high energy, generation of secondary electrons of low energy and X rays. In SEM, the emission of secondary electrons is used for the surface analysis. From the images as obtained, the surface of the hair samples were found to be smooth without any cracks or tears. The average diameter of the samples were about 82.255 μm .



(a)



(b)

Fig. 1. SEM images of the HHF samples

2.2.2 Thermogravimetric Analysis (TGA)

Thermal decomposition of the sample was carried out at a programmed temperature range of $30.00^{\circ}\text{C} - 550.00^{\circ}\text{C}$ at a heating rate of $20^{\circ}\text{C}/\text{min}$ from room with 0.6 gm of the sample, in nitrogen environment. The temperature of onset of degradation (T_i), the temperature at which rate of decomposition is 50%, the temperature at which the rate of decomposition is maximum (T_{max}), and the residue at 550.00°C are given in table 1.

Table 1
Degradation characteristics of HHF obtained on TGA analysis

Onset degradation temperature (T_i)	245°C
Maximum degradation temperature (T_{max}),	360°C
Decomposition peak temperature	315°C
Residue at 550.00°C	1.7mg

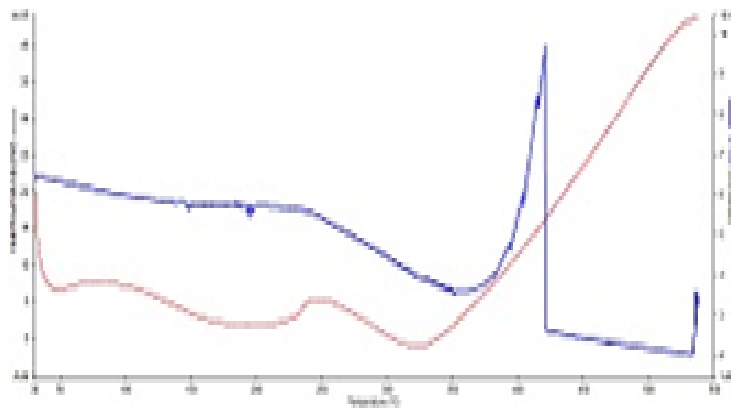


Fig. 2. Thermogravimetric traces of human hair fibre sample

3 TESTING PROGRAM

A one-dimensional piping test apparatus was developed and used as there is no standard test equipment unlike other soil testing. The main principle of the setup developed was to provide an upward seepage through a soil with and without fibers. Its part consists of a cylindrical transparent beaker, with an internal diameter of 100 mm. Moist compacted soil samples, 65 mm thick, were prepared with a free board of 40 mm for all the tests. To ensure even water distribution within the sample, a water sump was provided at the bottom part of the apparatus, connected to the main water reservoir as well as to the soil specimen mold.

The piping test was carried out by increasing the waterhead in the reservoir from a particular level after providing a saturation of 2 hours. A schematic cross-section of the apparatus is shown below.

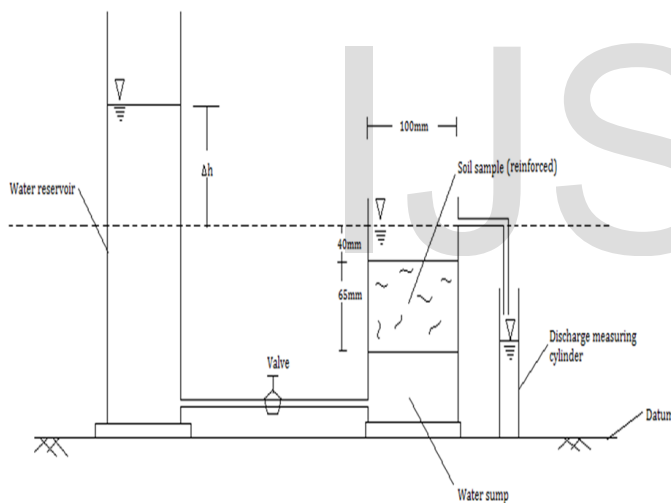


Fig. 3. Schematic cross section of the apparatus developed

The soil sample for both reinforced and unreinforced were compacted to their respective optimum moisture content (OMC) of 23%, corresponding to the standard proctor compaction tests results and the piping test was carried out. Initially the piping test was carried out for soil without fibers, then the test was carried for a sample of soil reinforced with HHF.

Piping failure was characterized by local boiling and formation of bubbles at critical locations. The coefficient of permeability for each soil sample was calculated using the constant head permeability equation

$$k = QL/hAt$$

Here h=hydraulic heads, L= length of specimen, A=cross-sectional area of specimen; Q=discharge in time t s.

The critical hydraulic gradient was calculated for various hydraulic heads and length of specimen

$$i_{cr} = \Delta h_c / L$$

The seepage force at critical hydraulic gradient can be calculated by using,

$$P = \gamma_w \times i_{cr} \times V$$

Where P=seepage force at critical gradient; γ_w =unit weight of water and V=Volume of soil sample specimen

4 ANALYSIS AND DISCUSSION OF TEST RESULTS

Piping tests were performed on soil sample specimens both on unreinforced and HHF reinforced with two varying dosages of fibre content in the laboratory. Effect of fiber reinforcement on piping resistance was studied. The summary of results obtained from the piping tests with and without fibre specimens is as follows:

Table 2
Piping Test Results

Sample	UR	FR1	FR2
f (%)	0	0.5	1
t_{cr} (min)	13.2	48.5	60.1
Δh_c (cm)	5.4	8.9	10
i_{cr}	0.830	1.369	1.538
k(m/s)	8.42×10^{-5}	2.1×10^{-6}	1.1×10^{-6}
Piping Resistance(N)	4.155	6.853	7.700

f =fibre content (%), i_{cr} =critical hydraulic gradient,
 t_{cr} =time at onset of piping initiation, k =coefficient of permeability calculated from the piping results



Fig. 4. View of cracking observed in soil specimen

The variation of piping resistance was plotted against fiber content as shown in Figure 5. This indicates that the piping resistance increased with an increase in fiber content. This can be attributed to blockage of the soil pore spaces by the short tiny fibers. These fibers not only restricted the flow of water, but also held the soil particles and resisted their movement under an increasing hydraulic gradient. A distinct increase in critical hydraulic gradient and piping resistance was observed for soil reinforced with HHF fiber content of 1% than unreinforced and 0.5% reinforced.

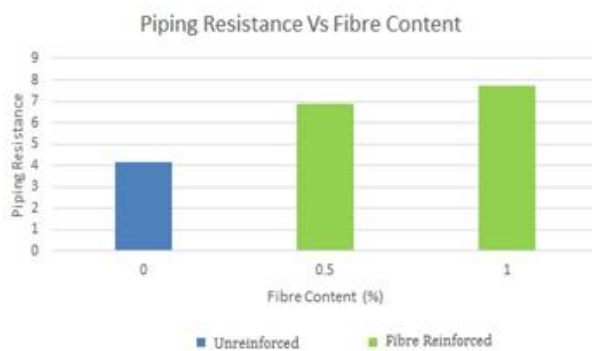


Fig. 5. Piping Resistance Vs Fibre Content graph

5 CONCLUSION

In this project, the pertinency of Human Hair fibres as rein-

forcement against soil piping was examined. Based on analysis and interpretation of the test results, the chief conclusions are as follows:

1. Reinforcing soil specimens with HHF effectively improved piping resistance. For soil specimens with and without fibers, a clear distinct initiation of piping failure was observed. Among the reinforced specimens, the piping resistance was found to be more effective for a fibre dosage of 1%.
2. This method also provides an alternative way for the safe management of waste human hair, which otherwise would have caused a threat to the environment due to its improper disposal.
3. The thermal decomposition properties of the HHF also prove that it can withstand diverse conditions.

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