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Alleviation of Piping of Soil using Human Hair Fibres

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ABSTRACT

Piping is a subsurface type of disintegration which includes the expulsion of subsurface soils in pipe-like channels to a break exit. It principally happens in generally loose soils with high porousness. Henceforth, successful countermeasures are required and soil reinforcements as support strategy is valuable in this application. Past examinations have reasoned that piping resistance of soil increments, when blending short fibres to successfully confine soil particle movement. In this venture an exertion is made to utilize bountifully accessible, characteristic waste Human Hair Fibers (HHF) as soil fortifications and the impact of the same when discretely and randomly distributed on the piping conduct of soil are inspected. The experimental tests for piping using human hair fibres were carried out for different fiber contents (0.5, 1.0, and 1.5%) and fiber lengths (2,3,4,and 5 cm). The critical hydraulic gradient and piping resistance for each soil sample were calculated and compared to find the most effective combination of fibre length and content.

KEYWORDS: *Soil Piping; Human hair fibre; Piping resistance*

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I. INTRODUCTION:

Kerala confronted the rage of nature as floods and landslides in 2018 which nearly took a reiteration of its structure in the year 2019 too. This occasion left afterward, a path of devastation all through the state with many regions lowered and submerged in water, decimating life and land.

Piping is a subsurface type of disintegration which includes the evacuation of subsurface soils in pipe-like erosional channels to a break exit. Piping disintegration happens in structures made of free soil with moderately high penetrability. The subsequent "pipes" are generally a couple of millimeters to a couple of centimeters in size, however can develop to a meter or more in distance across. They may lie near the ground surface or broaden a few meters subterranean. Once started they become combined with time. The courses grows because of subsurface disintegration prompting rooftop breakdown and subsidence includes on surface. Since it occurs underground, much of the time the wonder goes unnoticed. The cavities or channels created underneath the ground develop as for time and influence huge degrees of land as subsidence. It likewise makes the land inadmissible for development. To limit this, strengthened soil can be utilized as a halfway solution. Fibres have been utilized as an admixture to control the leakage and increment piping resistance of soil. In this project, soil is mixed with randomly distributed discrete human hair fibers which bestow solidarity to soil and well as assists with forestalling the upward drainage of water to a more noteworthy degree.

II. OBJECTIVE OF THE STUDY

- To comprehend the system of randomly distributed human hair fibre as reinforcement incorporations in soil.
- 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.
- To establish the impact of fiber content and fiber length on the channeling conduct of soil.
- To provide an alternative way for the safe management of human hair waste.

III. MATERIAL PROPERTIES SOIL SAMPLE

For the present investigation soil sample was taken from Peringassery in Udumbanoor, Thodupuzha taluk of the Idukki district from 1m depth. The soil was very loose in nature. The initial moisture content of the soil as obtained from the field was about 15.8%. Texture analysis was done preliminarily and inferred that the soil contained 79.26% silt and 20.289% of clay thus showing characteristics of a clayey silt soil. Various other tests were also done to investigate the geotechnical properties of the raw soil which described in the subsequent sections. Specific Gravity as per IS: 2720 (part 4) – 1985, Particle Size Distribution By Sieving (Grain Size Analysis) as per IS: 2720 (part 4) – 1985, Liquid Limit And Plastic Limit By Using Casagrande Apparatus as per IS: 2720(part 5)- 1985, Maximum dry density and Optimum moisture content by standard proctor compaction method as per is 2720-7(1980) and Unconfined compressive strength as per 2720-10 (1991).

Fig.1. Soil Sample

DESCRIPTION		PROPERTIES
Specific gravity		1.968
Liquid Limit (%)		38.5
Plastic Limit (%)		36.19
Plasticity Index (%)		2.309
Moisture content of soil sample (%)		15.8
Grain size distribution (%)	Sand	0.459
	Silt	79.26
	Clay	20.289
Effective particle size(mm)	d_{10}	0.53
	d_{30}	0.95
	d_{60}	1.1
Coefficient of uniformity		2.075
Coefficient of curvature		1.548
Optimum Moisture Content (%)		23
Max Dry density (g/cc)		1.874
Unconfined Compression strength(kN/m²)		16.66

TABLE 1.Virgin Soil Properties

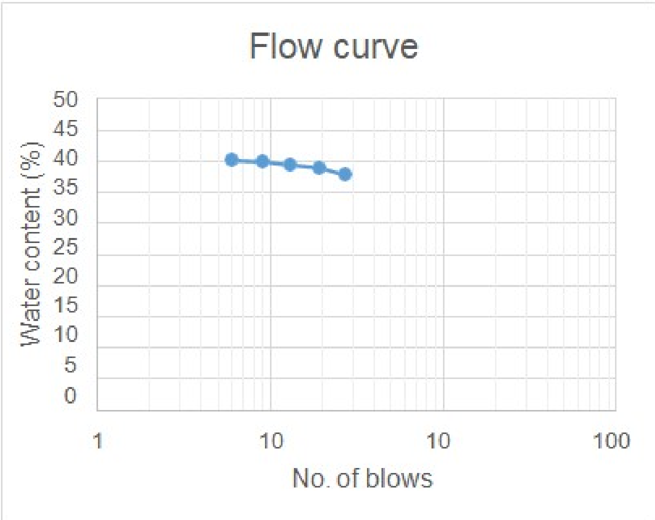


Fig.2. Flow Curve

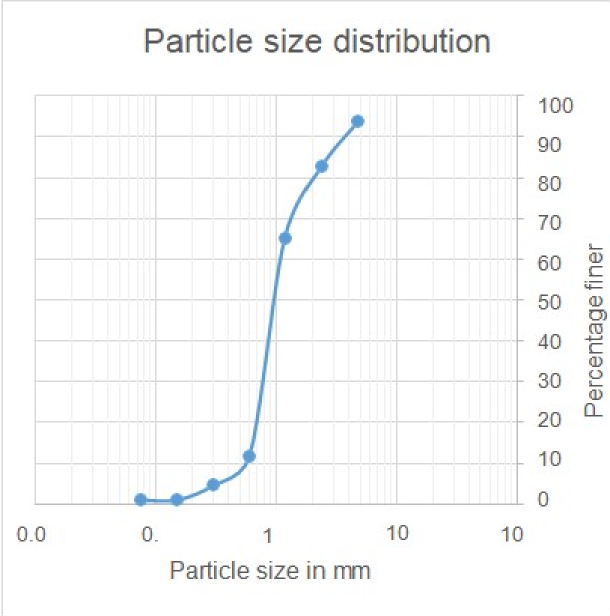


Fig.3. Particle Size Distribution

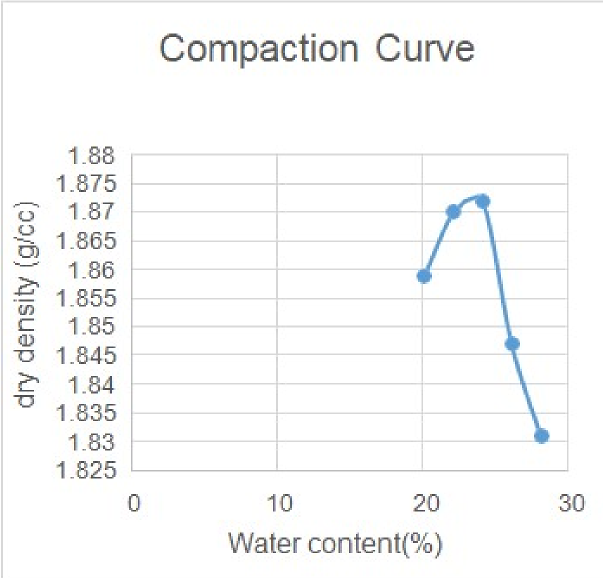


Fig.4. Compaction Curve

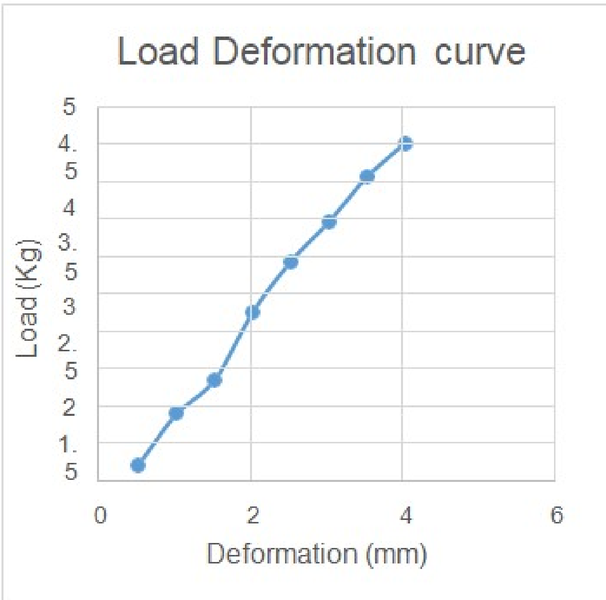
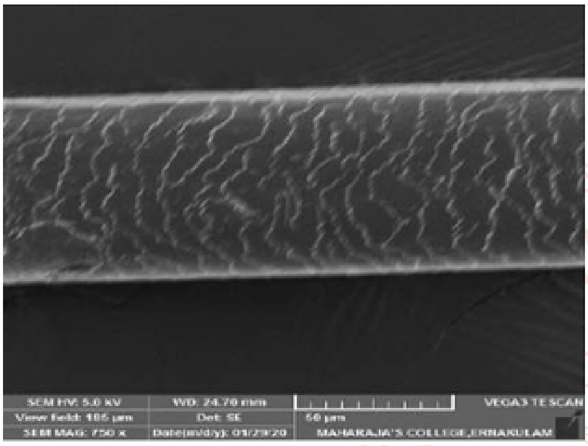


Fig.5. Load Deformation Curve

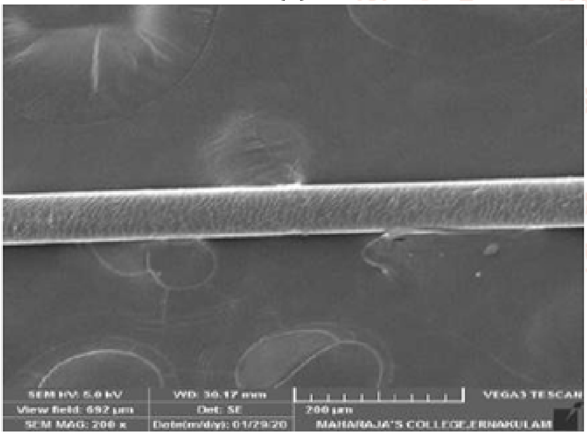
HUMAN HAIR FIBRE

The HHF was gathered from local sources, salons and parlours. Initially in order to remove the moisture content, fibres collected were dried under sun. It was sorted then, and cut into the required dimension lengths of 20, 30, 40 and 50mm.

Morphology of the human hair fibres used in this study were investigated using Scanning Electron Microscopy (SEM) analysis. The SEM images of the sample so obtained is given in Figure 6. Decomposition properties were also studied using the TGA analysis at a programmed temperature range of $30.00° C - 550.00° C$ at a heating rate of $20°C$ / min from room temperature. The temperature at onset of degradation was about $245°C$, the temperature at which rate of decomposition became 50% was $315°C$ and the temperature at which the rate of decomposition was maximum was found to be $360° C$.



(a)



(b)

Fig.6. SEM images of HHF fibre samples

IV. TEST APPARATUS

A one-dimensional piping test assembly was developed and utilized in the current investigation. Its primary part comprises of a cylindrical faced hollow beaker with an inner width of 100 mm. Sodden compacted soil samples, 65 mm thick, were set up inside it with a freeboard for all the tests. To guarantee even water distribution inside the assembly, a water sump was given at the base piece of the device, associated with the primary water store reservoir. During piping tests, the water head was raised in steps at the reservoir from a particular level. A permeable stone and filter paper was set at the base of the beaker for each test to convey the water equitably, and to forestall descending movement of soil. During the test, at the beginning of gradual increment of water head, upward seepage occurred through the samples, and the release coming out from the highest point of the sample was estimated using a discharge collecting chamber. The head increment was proceeded until the piping failure occurred.

Fig. 7. View of Piping Test Apparatus

V. SAMPLE PREPARATION

All the soil samples were compacted at their respective maximum dry density (MDD) and optimum moisture content (OMC), corresponding to the standard proctor compaction tests. The different values adopted in the present study for

the percentage of fibre reinforcement are 0.5%, 1.0%, and 1.5%.In the preparation of unreinforced samples, the adopted content of fibers was first mixed into the soil dry by using hand, making sure that all the fibers were mixed thoroughly, so that a fairly homogenous mixture is obtained. Then the required amount of water up to the OMC was added.

Fig.8. Fibre-mixed Dry Soil

Fig.9. Fibre-mixed Soil Sample brought to OMC

VI. EXPERIMENTAL PROGRAM

A total of 13 piping tests were directed on both unreinforced and reinforced soil samples using HHF. Soil samples were compacted in three approximately equivalent layers in the mould. For setting up the fiber-strengthened soil, dry soil was altogether blended in with the necessary measure of fibres in the dry state so that no fiber aggregation could happen. After careful blending, the ideal measure of water was included as referenced in the sample preparation. At first the piping test was done for soil without fibres under OMC and MDD, then the test was carried out for soil reinforced with HHF of length 20, 30, 40,50mm and fiber content of 0.5%, 1% and 1.5%.Details of all the piping tests are summarized in Table 2. A manual fiber blending strategy was embraced in the current examination, however a mechanical method would be ideal for huge scope blending in the field. The hydraulic gradient was increased in steps of 0.25, by increasing the water level in the reservoir until the critical hydraulic head was reached, at which the specimen was observed to experience piping.

TABLE 2. Piping Test Results

Sample	F (%)	L (cm)	t_c (min)	Δh_c (cm)	*icr*	K (m/s)	Piping Resista-nce (N)
UR	0	-	13.2	5.4	0.830	8.4×10^{-5}	4.155
FR_1	0.5	2	36	5.9	0.907	5.2×10^{-6}	4.540
FR_2		3	49	6.4	0.784	3.9×10^{-6}	4.926
FR_3		4	54	9.1	1.400	2.0×10^{-6}	7.009
FR_4		5	48.5	8.9	1.369	2.1×10^{-6}	6.853
FR_5	1	2	47	6.3	0.969	3.7×10^{-6}	4.851
FR_6		3	59	7.2	1.107	2.2×10^{-6}	5.542
FR_7		4	60.1	10	1.538	1.1×10^{-6}	7.700
FR_8		5	63.2	7.1	1.092	1.7×10^{-6}	5.467
FR_9	1.5	2	65	9.8	1.507	2.9×10^{-6}	7.544
FR_{10}		3	71	10.9	1.676	1.3×10^{-6}	8.390
FR_{11}		4	83	11.7	1.800	9.9×10^{-7}	9.011
FR_{12}		5	69	10.2	1.646	1.1×10^{-6}	8.240

f=fibre content (%), l=length of fibre, i_{cr}=critical hydraulic gradient, t_c= piping initiation onset time k=coefficient of permeability

Piping failure was characterized by local boiling, formation of bubbles at critical locations and continuous and increased discharge.

The coefficient of permeability for each soil sample was calculated using the equation

$$k = \frac{QL}{hAt}$$

Here h=hydraulic head, L= length of specimen, A=cross-sectional area of specimen; Q=discharge in time't'

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

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

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

$$P = \gamma_w \; x \; i_{cr} \, X \, V$$

Where P=seepage force; γw =unit weight of water and V=volume of soil sample specimen.

Fig.10.Piping Experiment

VII. ANALYSIS AND DISCUSSION OF TEST RESULT

Piping tests were performed on soil sample specimens both on unreinforced and HHF reinforced with varying dosages and fibre lengths in the laboratory. Effect of fiber reinforcement on piping resistance was studied. The summary of results obtained from the 13 piping tests with or without fibre specimens is given in Table 2.

EFFECT OF FIBRE CONTENT

The variation of piping resistance was plotted against fiber content as shown in Figure 11. This indicates that, irrespective of fiber length, 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. A distinct increase in critical hydraulic gradient and piping resistance was observed for soil reinforced with HHF fiber content of 1.5%.

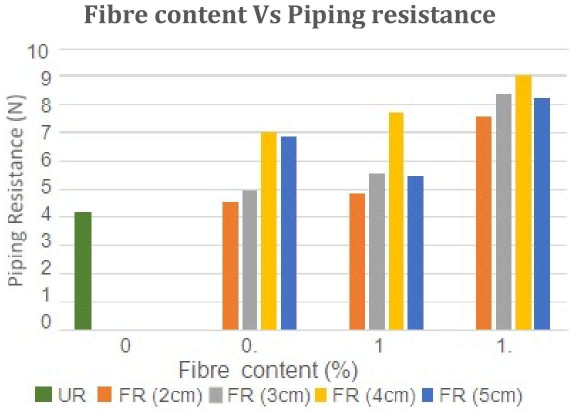


Fig.11.Variation of piping resistance with fibre content

EFFECT OF FIBRE LENGTH

Four fibre lengths were used in the present study (i.e. 2, 3, 4, and 5 cm).Previous studies by Sivakumar Babu and Vasudevan (2008) and Das et al. (2009), on the use of discrete and randomly distributed fibres for improving the piping resistance of soil/fly ash, indicated that long fibers were ineffective as reinforcement inclusions, as a result of the fibers buckling or twisting. Fiber length was therefore restricted to 5 cm in this study. A bar graph was plotted with fibre length Vs Piping resistance. The plot is shown in Figure 12 and it indicate that piping resistance increased with increase in fiber length. This trend was seen only till the inclusion of 4cm fibres. The maximum piping resistance was observed for soil specimen reinforced with 4cm fibres.

With further increase in length of the HHF, the piping resistance value decreased. This may be due to the reason that there was tangling of fibres when longer lengths were used.

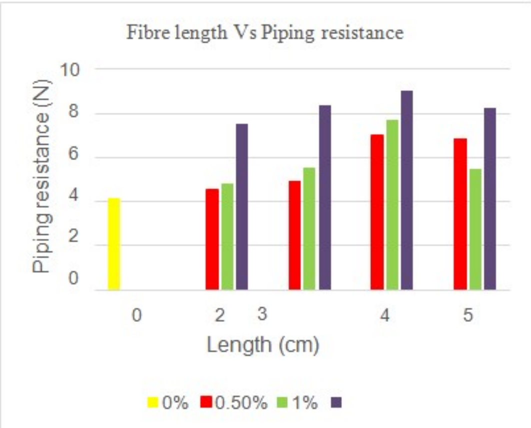


Fig.12.Variation of piping resistance with fibre length

VIII. CONCLUSION

In this project, the efficacy of discrete, randomly distributed Human Hair fibers in improving the piping resistance of soil sample was examined. A series of 13 piping tests were performed in the laboratory on HHF reinforced soil specimens with fibre contents of 0.5%, 1% and 1.5%, and fibre lengths 2,3,4,and 5 cm. In view of examination and understanding of the test outcomes, the chief conclusions are as follows:

1. Reinforcing soil specimens with HHF improved piping resistance. This was found to be most effective for Human Hair fibers with fiber content f=1.5% and length l=4cm. Improved piping resistance can be ascribed due to effective soil sample–fiber contact area, which brings about hindering of pore spaces of soil by fibers replacing soil particles.
2. Inclusion of fibers in soil decreased the lifting of soil particles and degree of piping when water flowed in the upward direction through the soil. Piping failure is found to occur in a fiber reinforced soil with an optimum dosage at high gradients and after long duration. For soil specimens with and without fibers, a clear distinct initiation of piping failure could be obtained.

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