EFFECT OF COIR FIBER ON THE PIPING BEHAVIOUR OF SOIL

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Abstract - *Piping is one of the major problem that occur in the hydraulic structures under the influence of the seepage forces that are acting upwards. The development of channels at the downstream of these hydraulic structures in the form of seepage erosion may lead to its failure. It has been reported and seen that one of the major problem for the failure of roads, large cracks in the surface over longer lengths, and soil subsidence, is the piping in the high range region of Idukki district in Kerala during the heavy rainfall in August 2018. This study focuses on method to reduce the seepage velocity and thereby improving the piping resistance of the soil by the usage of fibers. 1-D piping test is conducted to evaluate the piping phenomenon of the unreinforced Idukki soil and fiber reinforced soil and to the compare the results of both. Coir fiber of varying proportion (0.5, 0.75 and 1%) and lengths (1.5,2,4,5 and 6cm) are proposed to be used and tested under varying hydraulic heads. The seepage velocity through the reinforced and unreinforced samples are calculated and compared to find the most effective fiber and its percentage content and length. From this analysis the optimum fiber content and fiber length is obtained as 1% and 4cm respectively.*

***Key Words*:** Seepage velocity, Hydraulic gradient,1-D Piping test

1.INTRODUCTION

retaining structures perform important functions as barriers against the water. However, these structures may be prone to seepage erosion in the form of piping . This happens mostly during a high flood level situations. In August 2018,Kerala faced a natural disaster due to flood , landslip etc .Due to this many cracks opened up in Idukki.The researchers made a conclusion that one of the reason for this may be piping phenomena. Hence the study of piping become relevant in the Embankment dams, levees, flood walls and other water present situation of Kerala.

Piping is a subsurface form of erosion which involves the removal of subsurface soils in pipe-like erosional channels to a free or escape exit. Piping erosion occurs in structures made of loose soil with relatively high permeability.To minimize the failure due to piping concrete piles are used, due to its high cost it is not much economical for structures like smaller dams and embankments.The use of reinforced soil can be used as partial remedy to overcome the piping failure. Fibers have been used as an admixture to restrain the seepage velocity and increase piping resistance of soil.

In this study coir fibers is used with varying length and content to reinforce the soil and hence to examine the possibility of piping phenomenon of soil. The fibers are added in varying proportions and lengths to the soil for improving the piping resistance and controlling the seepage velocity . Thus the structure can withstand high hydraulic gradients without failure.

2. EXPERIMENTAL INVESTIGATION

A laboratory investigation was conducted for studying the efficiency of fiber reinforcement in reducing seepage velocity and improving piping resistance of soil .Piping behavior of unreinforced soil specimens was studied and compared with that of specimens reinforced with coir fibers. The experimental investigation was conducted on unreinforced soil and fiber-reinforced specimens compacted in a custom developed one dimensional piping set-up.

2.1 TEST MATERIALS

2.1.1. Soil

Soil was collected from high range region of idukki district. Sample is collected from a depth of 1.5m. Laboratory tests were carried out to obtain the properties of soil. Properties are described in table -1

Table -1: Properties of Soil

Property	Results
Specific gravity	2.25
Effective particle size(D10)	290µ
Uniformity coefficient	7.24
Coefficient of curvature	1.07
Density (g/cm^3)	1.72
Angle of friction	36.86°
Unconfined compressive strength(kN/m^2)	45.13
Cohesion (kN/m^2)	22.51

2.1.2 Coir Fiber

Table-2 Properties of coir fiber

Properties	Results
Diameter (mm)	0.3
Tensile strength(MPa)	69.3
Density(kg/m^3)	1140

2.2 Sample preparation and test apparatus

Initially the piping test is carried out for soil without fibers under OMC and maximum dry density ,then the test is carried for samples of soil reinforced with coir fiber of length 1.5,2,4,5 and 6 cm and fiber content of 0.5%,0.75% and 1%.

The apparatus consists of two transparent cylinders connected to each other through a flexible tube . One of the cylinders with 50mm diameter and 2 litres capacity is used for applying the desired hydraulic head and is called reservoir. A graduated cylinder is used for the reservoir and is used for measuring the level of water. The second cylinder consists of the porous stone. The perforated disc are used to contain soil particles, to distribute the flow of water uniformly across the sample and to prevent from the downward migration of soil sample. The bottom and top sections are two beakers separated from each other. The dimensions of the beaker are 65 mm height and 100 mm diameter which is used as a mould for compacted soil sample.

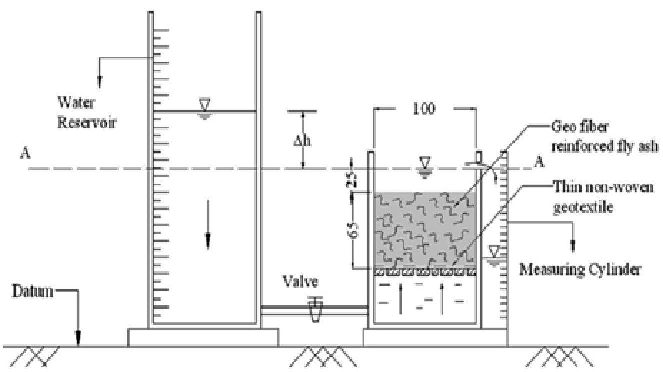

Fig-1, Skempton and Brogan Apparatus Das et al. (2009)

3 ANALYSIS AND DISCUSSION OF TEST RESULT

Figs-2,3and 4 shows the variation of hydraulic gradient with seepage velocity for unreinforced soil sample in comparison with that for samples reinforced with fiber contents of 0.5%,0.75 and 1% at varying fiber lengths (1.5,2,4,5,6cm). 1t can be noted from the graphs, seepage velocity catastrophically increased once piping was initiated .The purpose of varying lenth and fiber content was to be proved. This was verified by repeating these tests and indicates that there exists an optimum fiber content and length combination for maximum piping resistance and reducing seepage velocity.

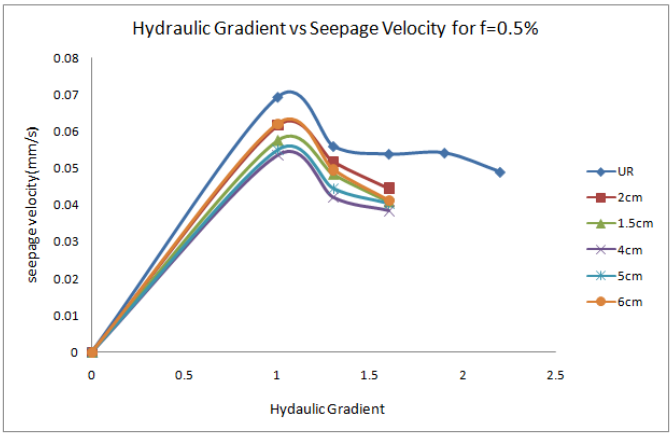

Fig-2 seepage velocity Vs hydraulic gradient(0.5%)

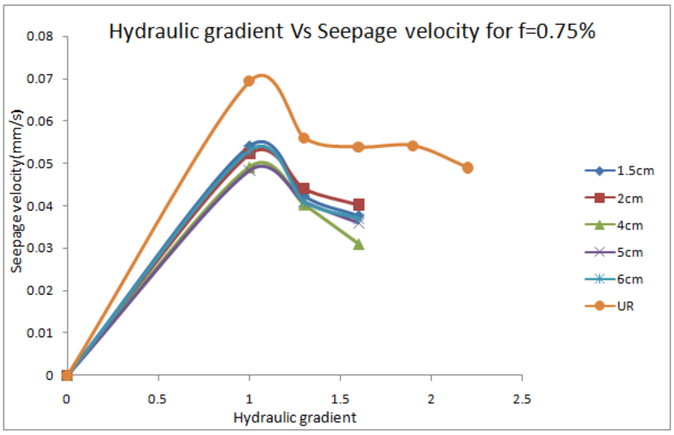

Fig-3 seepage velocity Vs hydraulic gradient(0.75%)

Table -3 Summary of Piping Test Result

Test sample	Fibercontent %	Fiber length cm	t_c(min)	Δh_c (mm)	Seepage velocity (mm/s)	Piping resistance (N)	CriticalHydraulic gradient	Permeability (m/s)
UR	0	0	12	600	0.0490	46.13	2	2×10^{-2}
RF_{11}	0.5	1.5	18	710	0.0409	54.58	2.36	2.9×10^{-3}
RF_{12}		2	20	780	0.0445	59.96	2.6	3.1×10^{-3}
RF_{13}		4	35	980	0.0384	75.34	3.26	2.6×10^{-3}
RF_{14}		5	30	950	0.0404	73.03	3.16	2.89×10^{-3}
RF_{15}		6	25	890	0.0412	68.42	2.96	3×10^{-3}
RF_{21}	0.75	1.5	21	740	0.0376	56	2.46	2.5×10^{-3}
RF_{22}		2	28	800	0.0402	61.5	2.67	2.8×10^{-3}
RF_{23}		4	42	1070	0.0031	82.27	3.56	2.3×10^{-3}
RF_{24}		5	37	1000	0.036	76.88	3.33	2.5×10^{-3}
RF_{25}		6	32	980	0.037	75.34	3.26	2.6×10^{-3}
RF_{31}	1	1.5	25	820	0.034	63	2.73	2.3×10^{-3}
RF_{32}		2	31	940	0.0268	72.27	3.13	1.9×10^{-3}
RF_{33}		4	72	1200	0.024	96.1	4	1.7×10^{-3}
RF_{34}		5	55	1130	0.0301	86.8	3.76	2×10^{-3}
RF_{35}		6	40	1080	0.0267	83.03	3.6	1.9×10^{-3}

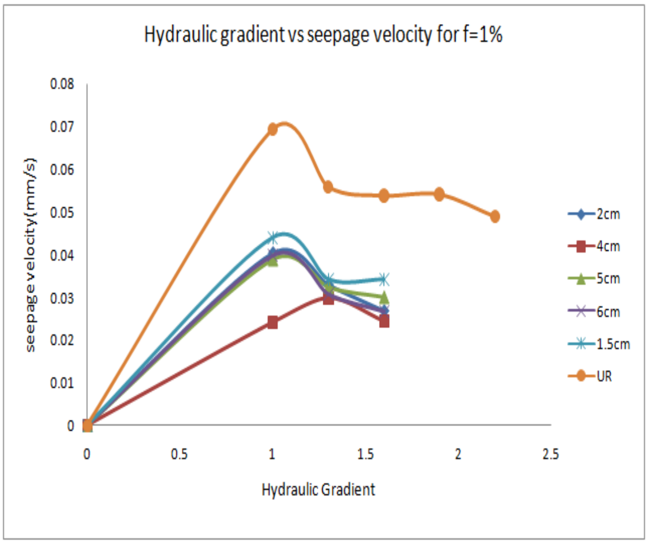

Fig-4 seepage velocity Vs hydraulic gradient(1%)

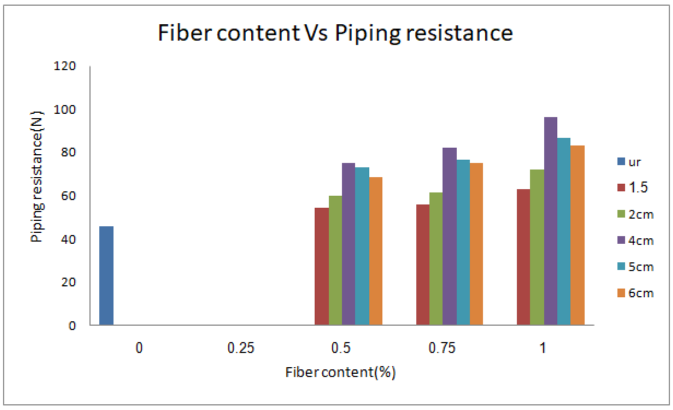

Fig-5 Fiber content Vs Piping resistance

Table-3 shows summary of results of piping tests on soil specimens with and without fibers. Columns [4]– [8] of Table-3present measured time at the onset of piping initiation, differential head at the onset of piping, computed seepage velocity, piping resistance and critical hydraulic gradient of soil specimens with and without fibers. Fig.-5 shows variation of piping resistance with fiber contents. As the fiber length was gradually increased from 1.5 to 6cm the piping resistance increased. As can be noted, a fiber-reinforced soil mix with a fiber content of 1% and fiber length 4cm exhibits a distinct increase in piping resistance. In the case of fiber-reinforced soil sample, amount of piping resistance is increased through:(i) replacement of sand sample by fiber, and(ii) resistance offered by the fiber to upward flow of water which depends upon the soil–fiber contact area.

At lower lengths of fiber, the contact between soil and fiber would have been inadequate resulting in premature initiation of piping. As can be noted, unreinforced sand sample took only 12 min for initiation of piping. In comparison, a soil sample specimen reinforced with a fiber took more time. This implies that fiber reinforced soil significantly retards initiation of piping. Column [4] of Table-3 gives the elapsed time for initiation of piping for soil specimens tested with and without fibers. For various fiber content, with an in increase in fiber length upto 4cm, an increase in the elapsed time for commencement of piping can be noted. In addition, extent of piping was also observed to decrease with an increase in fiber lengths 5and 6 ,this could be attributed to: (i) bulking of fibers and (ii) accumulation of clusters of fibers.

Permeability of soil specimen with and without fibers during piping test was determined from the slope of initial straight-line portion of seepage velocity versus hydraulic gradient curves. Table-3 summarizes the values of permeability of soil specimens with and without fibers. It is found to be that addition of fiber reduces permeability. The permeability affected by fiber content but the critical hydraulic gradient was not changed with the fiber content .

3. CONCLUSIONS

One-dimensional piping tests were performed on soil sample specimens reinforced with coir fibers of varying dosages and fiber lengths in the laboratory. Effect of fiber reinforcement on piping resistance and seepage velocity was studied. The chief conclusions are as follows:

1. Reinforcing soil specimens with coir fibers reduced seepage velocity and improved piping resistance. This was found to be effective for coir fibers with fiber content f=1% and length l=4cm. Reduction in seepage velocity and improved piping resistance can be attributed to effective soil sample–fiber contact area, which results in blocking of pore spaces of soil by fibers replacing soil particles.

2. Inclusion of fibers in soil reduced the lifting of soil particles and extent of piping when water flowed in the upward direction through the soil. Piping failure is found to occur in a geo 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.

3. Experimental results of present study also indicate that, not all combinations of fiber dosages are efficient in reducing seepage velocity and improving piping resistance. Hence, while selecting fiber dosages for adopting geo fiber reinforced soil as a structural material shall be adopted with caution. With long fibers and higher dosage of fibers, mixing becomes difficult and there are more chances of bundling and non-uniformities in the evolved fiber blended soil.

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