OPTIMIZING SOIL STABILITY: EFFECTS OF ORGANIC MATTER ANDJUTE FIBERS ON PIPING RESISTANCE OF SOIL

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Abstract - *The stability of earthen structures like dams, embankments, and levees depends on the soil's resistance to piping, a process where water flow creates subsurface erosion paths leading to potential failure. This study investigates the performance evaluation of jute fibers and organic matter in enhancing the piping resistance of the soil. Experimental analyses were conducted to determine the optimal composition of soil stabilizers, focusing on varying lengths and concentrations of jute fibers in conjunction with organic matter. The soil samples were prepared with organic matter content varying from 0% to 20% and jute fiber of length 50mm at concentrations ranging from 0.5% to 1.0% to the dry weight of the soil. The key parameters measured included the seepage rate, piping resistance, and critical hydraulic gradient. The results indicated a significant improvement in the piping resistance with the inclusion of jute fibers and organic matter. The optimum combination was found to be 10% organic matter and 50mm length jute fiber at a concentration of 0.75%. This specific mix demonstrated the highest increase in the critical hydraulic gradient and the longest time to piping initiation, suggesting enhanced soil cohesion and structural integrity.*

Keywords: Piping failure, Jute fiber, Organic soil, 1D piping test

1. INTRODUCTION

Soil erosion and instability pose significant challenges in geotechnical engineering, impacting infrastructure development and agricultural productivity. Among various forms of soil erosion, piping—subsurface erosion caused by the removal of soil particles by percolating water represents a critical problem, often leading to the formation of underground channels and the eventual collapse of the soil structure. This phenomenon can compromise the stability of embankments, dams, and levees, making it imperative to explore effective soil reinforcement strategies. A significant incident related to piping failure occurred during the floods in Kerala in August 2018, whichled to major seepage issues in the Thenmala Dam and the Chimony Dam in Thrissur. Traditional methods for enhancing soil stability have primarily relied on synthetic materials and mechanical interventions. However, growing environmental concerns and the push for sustainable engineering solutions have spurred interest in natural and biodegradable alternatives. In this context, jute fibers, a natural and abundant resource, and organic matter have emerged as promising candidates for soil reinforcement. Jute fibers, known for their tensile strength and biodegradability, can enhance soil cohesion and resistance to erosion, while organic matter can improve soil structure and water retention properties.

Recent studies ([1] [2], [3]) have shown that organic materials can reduce the severity of piping erosion in soil. The authors found that soil organic carbon and light fraction organic carbon, representing the labile portion of organic matter content, played key roles in increasing soil aggregate stability and reducing aggregate disintegration during splash erosion events. Also, various researchers have studied the efficiency of using fiber reinforcement in improving the piping resistance of soil using laboratory experiments. Estabragh et al. [4] in 2017 indicated that the inclusion of fibers reduced the seepage velocity, increased the piping resistance, and increased the critical hydraulic gradient hence, considerably delaying the amount of piping. Coghlan et al. [3] 2014 utilized both natural and synthetic fibers, as well as additives such as cement, lime, and ash. The research found that natural fibers yielded better results compared to synthetic ones. In particular, jute fibers demonstrated the best adhesion with the soil mix.

The study will involve a series of laboratory experiments to assess the impact of varying concentrations of jute fibers and organic matter on the soil's physical and hydraulic properties. Key performance metrics will include piping resistance, seepage velocity variation, and the critical hydraulic gradient at which piping initiates.

2. EXPERIMENTAL INVESTIGATION

To better understand how organic matter and fiber reinforcement can lower seepage velocity and increase soil piping resistance, a laboratory experiment was carried out. Investigations were conducted on the piping behavior of specimens of unreinforced soil and specimens reinforced with jute fibers and organic soil, compacted in a specially designed one-dimensional piping setup.

2.1 TEST MATERIALS

2.1.1 Soil

Soil was collected from the Thenmala dam region in the Kollam district. The 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

Table - 1: Properties of soil

Property	Value
Specific Gravity	2.41
Effective particle size (D10)	0.6
Uniformity Coefficient (Cu)	3.8
Coefficient of curvature (Cc)	0.44
Angle of internal friction	36.12
Cohesion (kPa)	0.1
Density (g/cc)	1.89

2.1.2 Organic soil

Table 2: Properties of Organic soil

Property	Value
Specific Gravity	1.80
Cohesion (kPa)	18
Effective particle size (D10)	0.48
Uniformity Coefficient (Cu)	3.9
Coefficient of curvature (Cc)	0.61
Density (g/cc)	1.78
pH	6.7
Organic content (%)	85
Organic carbon (%)	23

2.1.3 Jute fiber

Jute fiber of an average length and diameter of 50mm and0.5mm were used.

Table 3 - Properties of jute fiber

Cellulose (%)	64
Lignin (%)	12
Density (g/cc)	1.1
Tensile strength (Mpa)	395
Young's Modulus (Gpa)	15

2.2 SAMPLE PREPARATION AND EXPERIMENTAL SETUP

The piping test was initially conducted on soil without fibers at the optimum moisture content (OMC) and maximum dry density. The experimental setup consisted of a 40 cm diameter and 100 cm height tank with a graduated scale for measuring the water level. The soil specimen mold had a diameter of 10 cm and a height of 11.7 cm. Sand passing through a 2.36 mm sieve and retained on a 75 µm sieve, along with organic soil passing through a 1.18 mm sieve, was used. The required weight of soil for the specified density was mixed with water on a glass plate. Organic soil of a specific weight was evenly spread over the sand and thoroughly mixed. The soil mixture was then filled in the cylindrical mold in about three equal layers, with each layer being statically compacted. The mold was connected to the water tank, and water was allowed to flow upwards through the sample while the discharge was collected in a measuring jar. The experiment involved monitoring the discharge under various heads, and it continued by increasing the flow head until soil piping failure occurred. The experiments were conducted for plain sand, sand mixed with different organic contents (5%, 10%, 15%, 20% of the dry weight of sand), and fiber length 50mm with 0.5%, 0.75%, and 1% of the dry weight of sand. The experiment setup is shown in Figure below.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 05 | May 2024 www.irjet.net p-ISSN: 2395-0072

Fig - 1 Experimental setup

3. ANALYSIS AND DISCUSSION OF TEST RESULTS

Fig 2 and 3 show the variation of a hydraulic gradient with seepage velocity for unreinforced soil samples in comparison with that for samples reinforced with organic contents of 5,10,15, and 20%, and 50mm jute fiber length at varying contents (0.5,0.75, and 1%).

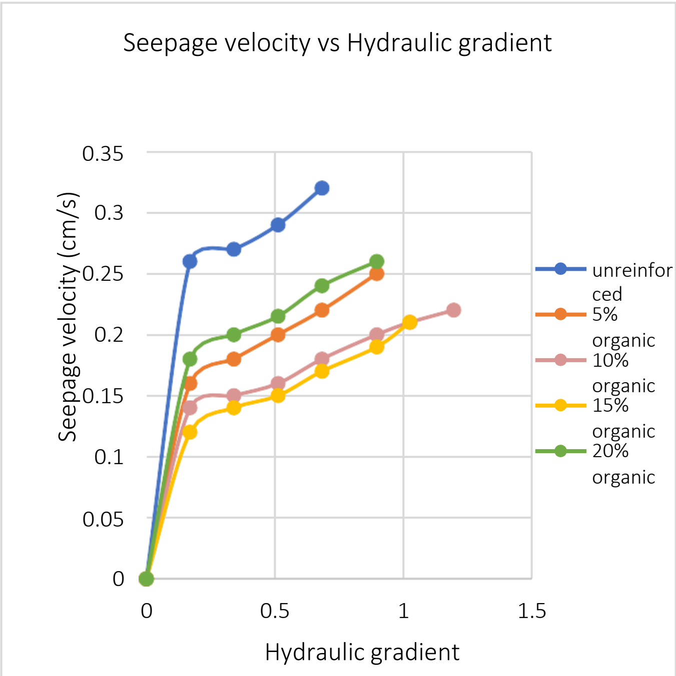

Fig -2 Seepage velocity Vs hydraulic gradient for various organic contents

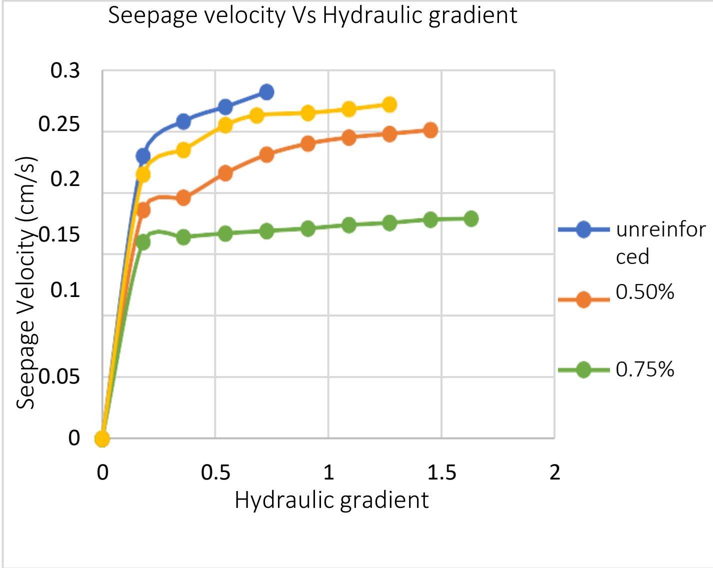

Fig -3 Seepage velocity Vs hydraulic gradient for 50mm length jute fiber

Fig 4 and 5 show the variation of piping resistance with fiber contents for unreinforced soil samples in comparison with that for samples reinforced with organic contents of 5,10,15, and 20%, and 50mm jute fiber length at varying contents (0.5,0.75, and 1%).

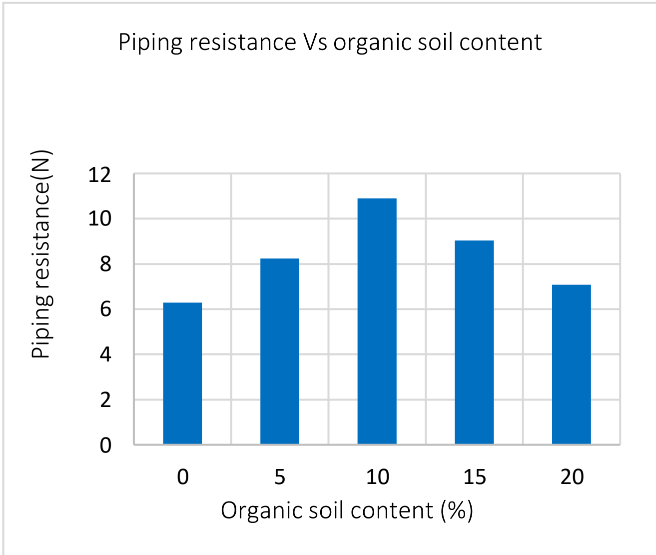

Fig- 4 Piping resistance Vs organic soil content

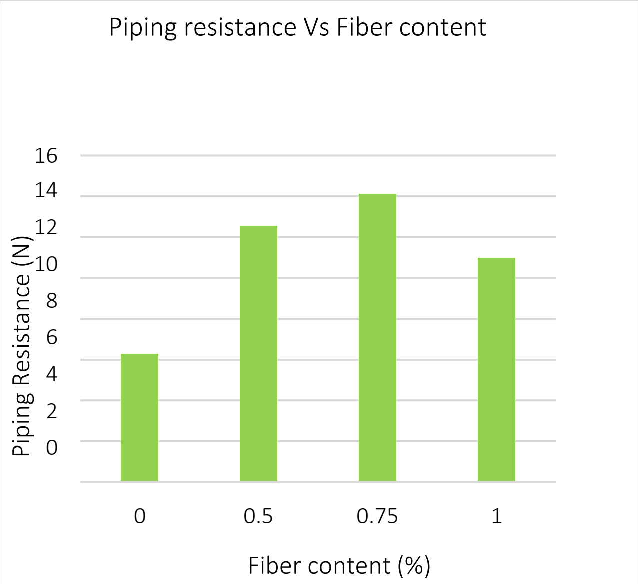

Fig- 5 Piping resistance Vs. fiber content for length jute fiber50mm

Fig 6 and 7 represent the variation of the critical hydraulic gradient with different organic and jute fiber content.

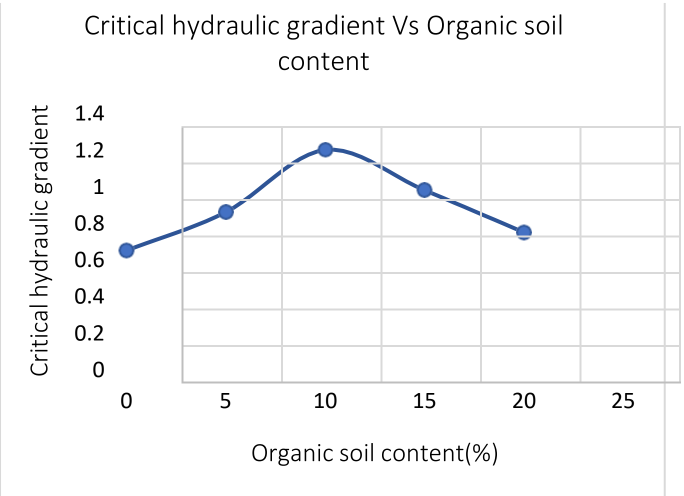

Fig -6 Critical hydraulic gradient vs. organic soil content

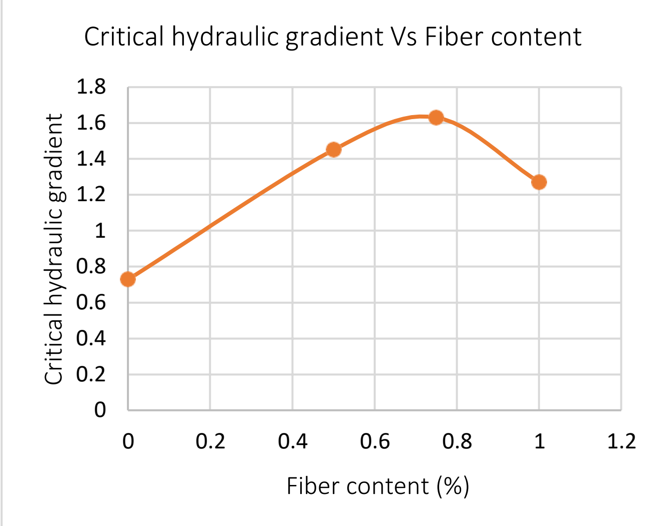

Fig – 7 **Critical hydraulic gradient Vs fiber content**

The experimental data, as illustrated in Fig. 2, shows that seepage velocity varies with both the hydraulic gradient and organic content. Specifically, as the hydraulic gradient increases, seepage velocity also increases. However, the inclusion of organic soil at 5% and 10% concentrations reduces seepage velocity, thereby enhancing piping resistance. The addition of organic soil improves the critical hydraulic gradient. This improvement is observed up to an organic soil content of 10%. Beyond this threshold, at 15% and 20% organic content, the hydraulic head and piping resistance decrease.

To investigate the effect of jute fiber content on seepage velocity and piping resistance, experiments were carried out with 50mm length jute fiber with varying fiber content of 0.50, 0.75, and 1.0 % of dry weight of sand. Thevariation of seepage velocity with hydraulic gradient for various fiber content is shown in Fig.3. Seepage steadily increases as the gradient is increased. For 50mm the seepage velocity decreased with the increase in fiber content particularly in 0.75% fiber content. And contributed to the increase in piping resistance.

4. CONCLUSIONS

During the laboratory tests, soil sample specimens were reinforced with organic soil and jute fibers of different dosages and lengths to study the effect of fiber reinforcement on piping resistance and seepage velocity.The main conclusions are as follows:

1. The addition of organic content to soil samples has led to a decrease in seepage velocity and an increase in piping resistance at 10% organic content. Organic soil, which is

recognized for its greater cohesion and water retention properties that has played a key role in enhancing the soil's resistance to piping. The organic matter has contributed to improved soil structure and reduced permeability. which collectively reduced the risk of piping.

2. The inclusion of fibers in soil reduced the lifting of soil particles and the extent of piping when water flowed in the upward direction through the soil. The specimens displayed a clear initiation of piping failure. The observed improvement in resistance can be attributed to the addition of jute fibers, which substantially bolstered the soil's resilience against piping. These fibers served as reinforcements within the soil matrix, decreasing its vulnerability to internal erosion by enhancing the cohesion and interlocking of soil particles.

REFERENCES

1] Adams, B. T., Xiao, M., & Wright, A. (2013). “Erosion mechanisms of organic soil and bio abatement of piping erosion of sand”, Journal of Geotechnical and Geoenvironmental Engineering, Vol 139(8), pp 1360-1368.

2] Al Rawi, O., Assaf, E. M. N., & Rawashdeh, T. (2017). “Effect of organic content on the engineering properties of Jordanian clayey soils”, IJCIET, 8, pp 1018-1026.

3] Coghlan, S. (2014). “Bonding in fiber-reinforced earthen construction materials.”, Meng Dissertation, Durham University, UK.

4] Estabragh, A. R., Soltannajad, K., & Javadi, A. A. (2014). “Improving piping resistance using randomly distributed fibers”, Geotextiles and Geomembranes, Vol 42(1), pp 15-24.

5] Smith, D. J., Snead, M., & Thompson, T. M. (2022).“Soil amended with organic matter increases fluvial erosion resistance of cohesive streambank soil”, Journal of Geophysical Research: Bio geosciences, Vol 127(6)

6] Yang, K. H., Adilehou, W. M., Jian, S. T., & Wei, S. B. (2017). “Hydraulic response of fiber-reinforced sand subject to seepage”, Geosynthetics International, Vol 24(5), pp 491-507.