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EFFECT OF ORGANIC SOIL AND ARECANUT FIBER ON THE PIPING BEHAVIOUR OF SAND

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ABSTRACT: Piping is a form of seepage erosion and refers to the development of subsurface channels in which soil particles are transported through porous media. If the piping process continues the structure may collapse. A laboratory modeling program has been conducted to assess the mechanism of piping erosion in sandy soil. The objective of the study was to undertake a comparative study on the seepage velocity and piping resistance of sand ,3 sand mixed with different percentage of natural fiber (Arecanut fiber) and organic soil. The experiments were carried out for various hydraulic head. The discharge velocity, seepage velocity of flow of water through the soil is calculated in each case and compared with plain sand. It was observed that the fibers reduce the seepage velocity of plain sand considerably and increases piping resistance of sand. Mixing of organic soils with erodible sand reduces the potential for piping erosion. But higher percentage of organic soil in sand resulted in lower piping resistance.

INTRODUCTION

Internal erosion is the phenomenon that small grains are washed out through the voids between the coarse grains by seepage flow leaving the soil skeleton.It results in changes in void ratio and increases hydraulic conductivity. Piping is a subsurface form of internal erosion. Piping erosion is described as the formation of an open channel, or “pipe”, within or beneath the soil mass of a water-retaining embankment (Fig. 1). If the channel is able to connect the wet (upstream) side to the dry (downstream) side, stored water can rush through the opening due to the difference in hydraulic head between the two sides of the structure. Continued erosion caused by the increasing flow of water enlarges the channel size. This can ultimately undermine the integrity of the embankment and eventually lead to failure and collapse of the entire structure. Thus the process of piping erosion has four phases-initiation and continuation of erosion, progression to form a pip and formation of breach/failure. The Required conditions for piping erosion are source of water,flow path, erodible material in flow path and unprotected exit.

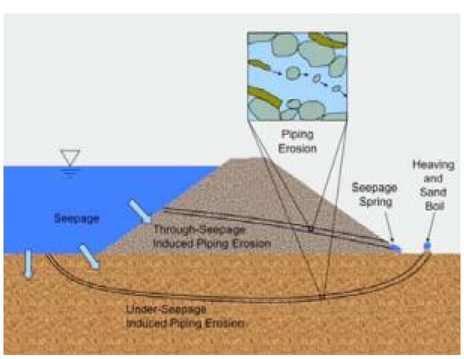

Fig.1. Schematic of piping erosion within and beneath an embankment

Piping of base soils is a common problem downstream of earth embankments under the influence of upward seepage. Seepage induced failures in the form of piping are generally observed in irrigation and drainage projects for sustainable watershed management such as river levees, contour bunds, temporary canal diversion works, temporary check dams, and soil structures. When the seepage velocity exceeds the critical velocity, piping occurs and the soil in the constructed areas flows out and the structures are weakened. Therefore, effective countermeasures against the piping are needed. Traditional remediation methods include filters, cutoff walls, impermeable blankets and berms, and combinations of toe trenches, drains, and pressure relief wells.

Recent studies ([1],[2],[3],[4]) have recognized the ability of organic materials to reduce the severity of piping erosion in sand. This paper presents a preliminary investigation into a bio-remediation method in which the piping potential of an erodible granular soil is reduced through the addition of organic soil. Various researchers have studied the efficacy of the use of fiber reinforcement in improving the piping resistance of soil using laboratory experiments ([5],[6],[7]).Since fibers are distributed throughout a soil mass, they impart strength isotropy and reduce the possibility of formation of weak zones and contribute to improved piping resistance([6]).previous studies concluded that piping resistance of soil increases when mixing short fibers to effectively restrict soil particles movement and the resistance of piping is improved. A laboratory study was undertaken to evaluate the feasibility of using natural fiber(Arcanut fiber) in soil to reduce seepage velocity and improving piping resistance. Arcanut fiber , obtained

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from arecanut ,is a naturally material available abundantly in south India.

The specific objectives of the present study are to examine the possibility of using (1) organic soil and (2) arcanut fibers for controlling seepage velocity and improving piping resistance of sand using laboratory experiments.

THEORETICAL CONSIDERATIONS

Discharge velocity of water flowing through the soil specimen is calculated for different hydraulic gradients using Darcy's law

$$v = ki \quad (1)$$

where v=discharge velocity,k=coefficient of permeability of soil,which is calculated by using

$$k = \frac{QL}{hAt} \quad (2)$$

where i=hydraulic gradient,which can be calculated for various hydraulic heads (h) and length of specimen, L(11.0cm);A=cross-sectional area of specimen cm^2 ;Q=discharge cm^3 in time t (s); and seepage velocity is calculated by using

$$V_s = v/n \quad (3)$$

where n=porosity of soil, which is calculated from the void ratio of fiber mixed sand.For the calculation of void ratio , fibers are considered to be similar to soil solid particles

$$\text{void ratio of fiber mixed soil} = \frac{V_v}{V_s + V_f} \quad (4)$$

where V_v = volume of voids; V_s =volume of soil solids,and V_f=volume of fibers

$$V_f = \frac{w_f}{G}$$

where w_f=weight of fibers (g);and G=specific gravity of fibers which is taken as 1.26.

Seepage and piping resistance

Seepage force acts in the direction of flow, i.e., in the upward direction, for the present case. Piping resistance of soil acts in the direction opposite to seepage force. Hence for equilibrium, piping resistance should have a magnitude equal to that of seepage force

and the line of action of these two should be the same. The soil is under equilibrium just before failure due to piping starts. Once this equilibrium is disturbed, failure of soil mass occurs due to piping. Hence piping resistance of soil is equal to the seepage force at which soil particles start lifting due to the upward flow of water. The seepage force at this hydraulic gradient can be calculated by using

$$P = \Upsilon_w hA \quad (6)$$

where P=seepage force at critical gradient ;Υ_w =unit weight of water; h=critical hydraulic head ; and A=cross-sectional area of soil specimen.

MATERIALS USED

Sand

The sand used in the study was collected from a construction site at Thrissur. The properties of sand are shown in Table 1. The maximum and minimum dry unit weights were found to be 16.7 kN/m^3 and 15.5 kN/ m^3. The Uniformity Coefficient (Cu) and Coefficient of Curvature (Cc) were obtained as 4.20 and 1.54. From the values obtained, it can be concluded that the sand is well graded and it comes under the group SW as per Indian Standard Classification System (ISCS).The gradation curve is shown in Fig. 2.

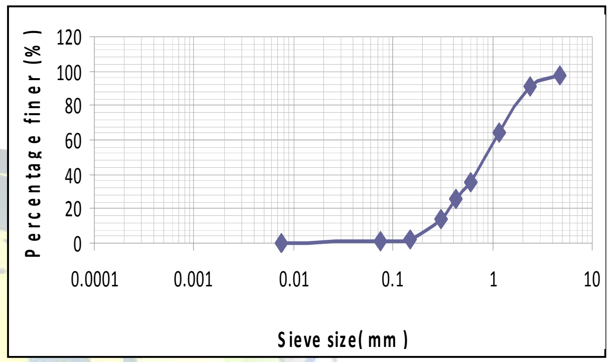

Fig 2: Gradation curve for sand

Table 1. Properties of sand

Description	Value
Specific gravity	2.64
Gravel (%)	2
Sand (%)	97
Silt and clay(%)	1
Coefficient of uniformity Cu	4.20
Coefficient of curvature C_C	0.86
Type of sand	SW
Angle of internal friction($^\circ$)	40
Coefficient of permeability(cm/sec)	6.87E-04

Organic soil

The organic soil was collected from kadukutty region, Thrissur. Organic content of the soil was determined by dry combustion using the muffle furnace. From the grain size distribution of organic soil(Fig. 3) it was observed that it contains 39.85% sand,49.54 % silt and 10.61% clay particles. The properties of organic soil are shown in Table 2.

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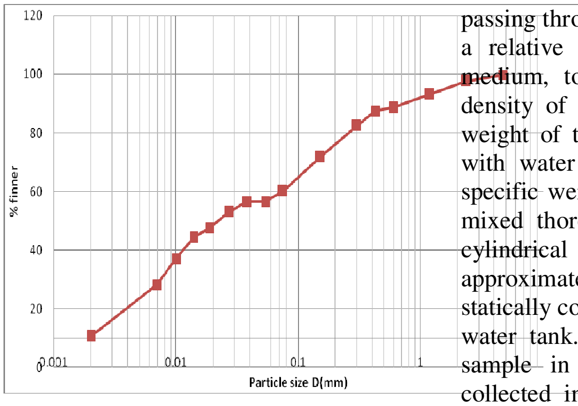

Fig. 3 Gradation curve for organic soil

Table 2. Properties of organic soil

Description	Value
Specific gravity	2.30
Liquid limit	54.30
Mximum dry density (g/cc)	1.15
Optimum moisture content (%)	31.5
Sand (%)	39.85
Silt (%)	49.54
Clay (%)	10.61

Table 3. Chemical composition of arecanut fiber

Description	Value
Cellulose(%)	-
Hemicelluloses (%)	35-64.8
Lignin (%)	13-24.8
Ash (%)	4.4
Pectin (%)	-
Wax (%)	-

Arcanut fiber

The fiber used in this study is arcanut fiber . The fiber used are of average length and diameter of 55mm and 0.35 mm respectively.The chemical composition of arecanut fiber is shown in Table 3.

EXPERIMENTAL PROGRAM

A laboratory investigation was conducted for studying the effect of organic soil and arecanut fiber in reducing seepage velocity and improving piping resistance of sand. Piping behaviour of sand was studied and compared with that of specimen prepared by mixing organic soil to sand and arcanut fiber to sand. The experimental setup used in this study is shown in Fig. 4. It consisted of a tank 40 cm in diameter and 100 cm in height with an attached graduated scale to measure the level of water. The mold for the soil specimen has a diameter of 10 cm and height of 11.7 cm. Sand passing through 2mm sieve and retained on 75 µm; organic soil passing through 1.18 mm sieve are used. For all the cases a relative density of 60% was chosen for the soil medium, to carry out the tests, based on which the density of soil medium was determined. The required weight of the soil for the specified density was mixed with water over a plane glass plate. Organic soil of specific weight was spread uniformly over the sand and mixed thoroughly. The soil mixture was filled in the cylindrical mould(up to a height of 11.0 cm) in approximately three equal layers and each layer was statically compacted. The mold was then connected to the water tank. Water was permitted to flow through the sample in an upward direction and discharge was collected in a measuring jar. Discharge under various heads was monitored. The experiment was continued by increasing the head of flow until piping failure of soil occurred. The experiments were conducted for plain sand, sand mixed with different organic contents (0.25, 0.50, 0.75, 1.0% of dry weight of sand) and fiber contents(5, 10, 15and 20 % of dry weight of sand).

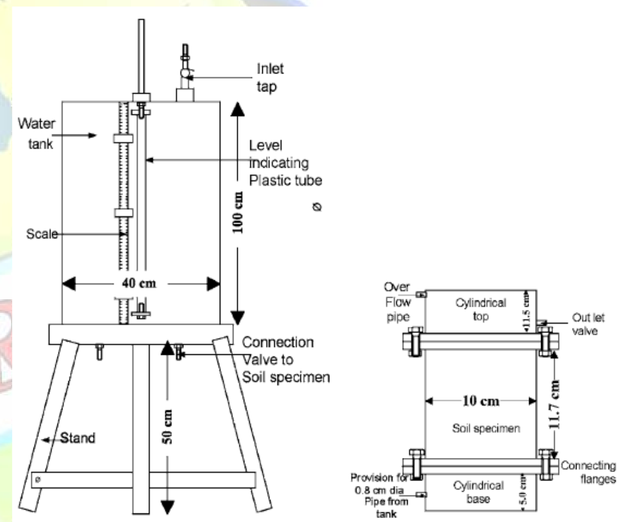

Fig. 4 Schematic representation of test setup.

It was observed that seepage velocity increased with the increase in hydraulic gradient. When the hydraulic head reached a certain level, small bubbles and local boiling were observed and finally the specimen failed by piping. Hydraulic gradient corresponding to this head was termed critical hydraulic gradient. It was observed critical hydraulic gradient increased with the increase in fiber content. Whereas, the hydraulic gradient was found to increase and then decrease, when mixing different percentage of organic soil to sand .The point corresponding to critical hydraulic was not clearly noticeable in case of sand. Thus it was obtained by considering logarithms on both the axes.

ANALYSIS AND DISCUSSION OF TEST RESULTS

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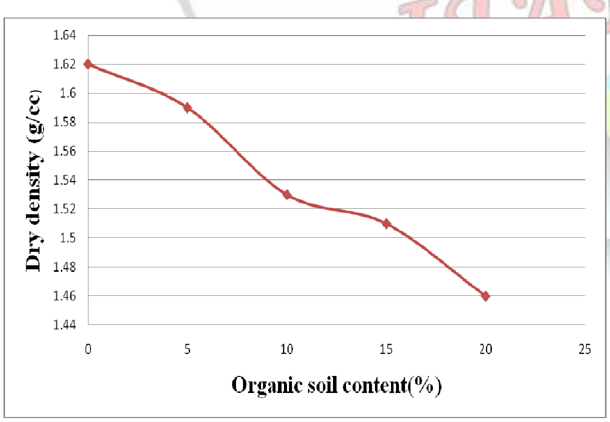
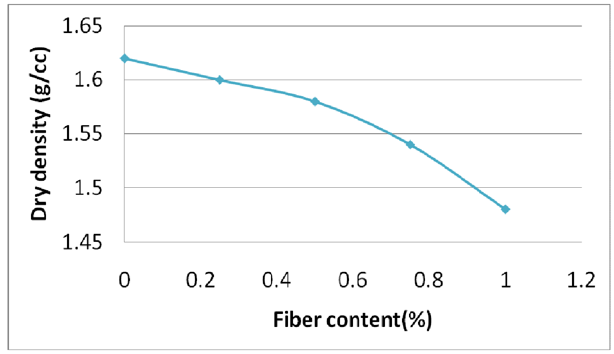
The effect of adding organic soil to sand and arecanut fiber to sand on piping resistance was investigated and compared to the piping resistance of plain sand. The study was conducted using four different percentage of organic soil- 5,10,15,20 % of dry weight of sand .Shaking table test was conducted for each case to obtain the dry unit weight of soil specimen. The variation of dry density of specimen with different organic content is shown in Fig. 5.(a).The variation of seepage velocity with hydraulic gradient for various organic contents is shown in Fig.6.(a).It is clear that organic content affect the seepage velocity in addition to hydraulic gradient. Seepage increased as the gradient is increased. when organic soil was added in 5% and 10 % to sand the seepage velocity decreased and contributed to the increase in piping resistance. The increase in critical hydraulic gradient (i.e., the gradient at which piping failure occurs) was observed up to 10% organic soil. With the increase in organic content (i.e., 15% and 20%)the hydraulic head and the piping resitance was found to decrease.

To investigate the effect of fiber content on seepage velocity and piping resistance experiments were carried out with fibers content of 0.25, 0.50, 0.75,and 1.0 % of dry weight of sand. The variation of dry density of specimen with different fiber content is shown in Fig. 5.(b).The variation of seepage velocity with hydraulic gradient for various fiber content is shown in Fig.6.(b). Seepage steadily increased as the gradient is increased. In all the cases, the seepage velocity decreased with the increase in fiber content and contributed to the increase in piping resistance. With the increase in fiber content, the increase in gradient was observed .

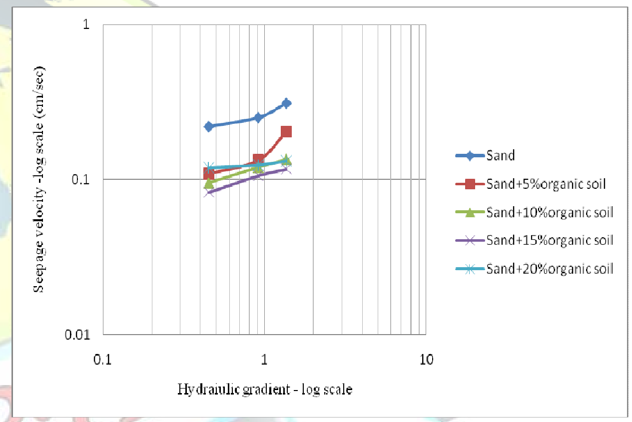


(a)



(b)

Fig.5.(a) Dry density versus organic soil content ;(b) Dry density versus arcanut fiber content



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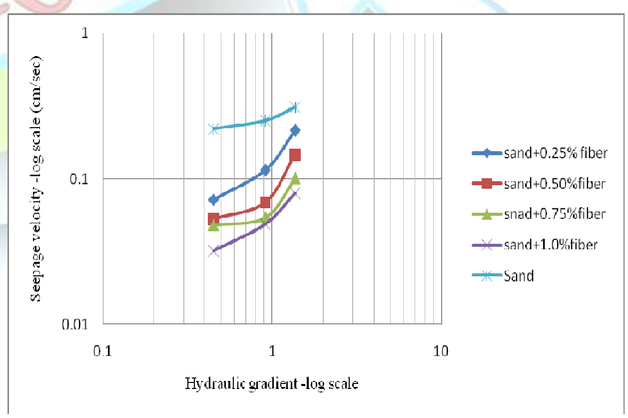


(b)

Fig.6.(a) Seepage velocity versus hydraulic gradient for various organic soil content;(b) seepage velocity versus hydrulic gradient for various arcanut fiber content

Critical Hydraulic Gradient and Piping Resistance

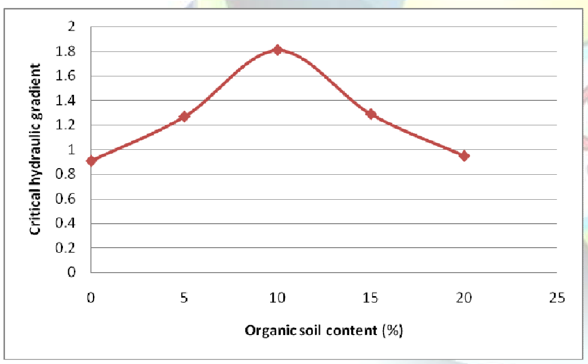
Values of critical hydraulic gradient for various organic content and various fiber content are presented in Table

4 , Fig. 7(a) and Fig. 7.(b) respectively. From the results, it is clear that critical gradient increases as fiber content increases. Due to mixing of soil with fibers, the critical hydraulic gradient increased resulting in an increased value of seepage force and piping resistance. The critical hydraulic gradient increases and then decreases as the organic soil content increases. Piping resistance is calculated using Eq.(6).Piping resistance of sand with various organic content is presented in Table 4 and Fig. 8.(a);and with various fiber content is presented in Table 4 and Fig.8(b) . Results show that piping resistance of sand increases as fiber content increases. The piping resistance of sand increases and then decreases as organic content increases. The piping resistance is maximum obtained at 10% organic soil content.

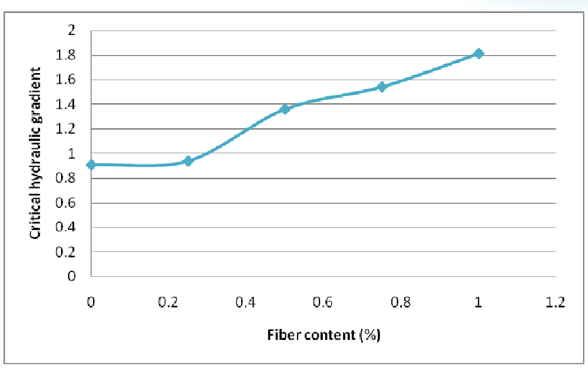
Table 4. Piping Resistance for Various cases

SI No.	Specimen	Critical hydraulic gradient	Critical hydraulic head(cm)	Piping resistance (N)
1	Sand	0.91	10	7.85
2	Sand+ organic soil			10.99
	Sand +5% organic soil	1.27	14	15.71
	Sand +10% organic soil	1.81	20	11.15
	Sand +15% organic soil	1.29	14.2	8.25
	Sand +20% organic soil	0.95	10.5	
3	Sand + fiber			
	Sand +0.25% arecanut fiber	0.94	10.4	8.17
	Sand +0.50% arecanut fiber	1.36	15	11.78
	Sand +0.75% arecanut fiber	1.54	17	13.35
	Sand +0.10% arecanut fiber	1.81	20	15.71

Fig.7.(a) Critical hydraulic gradient versus organic soil content;(b)Critical hydraulic gradient versus fiber content



(a)



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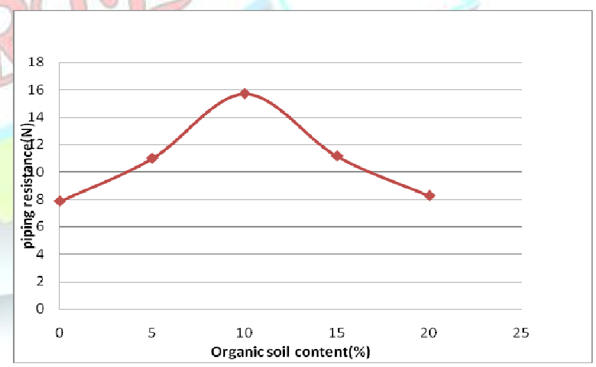

(a)

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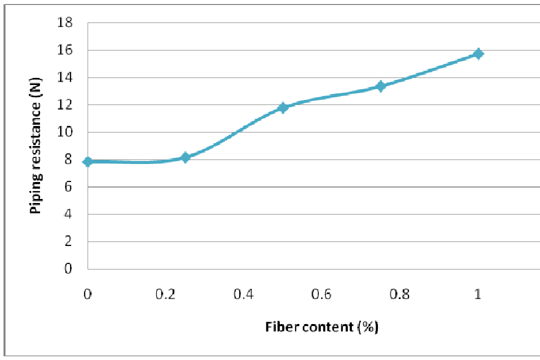

(b)

Fig.8.(a)Piping resistance versus organic soil content; (b) Piping resistance versus fiber content

CONCLUSIONS

Based on the experimental observations the following conclusions are made. Organic matter content appears to play a role on soils resistance to piping progression. The presence of small percentage of organic soil in sand resulted in increase of piping resistance.The highest resistance to piping erosion was observed for 10 % organic soil content..Inclusion of arecamut fiber in sand reduced the lifting of individual particles when water flowed in the upward direction through the soil mass. Piping failure is found to occur at high gradients for fiber mixed sand, whereas plain sand failed at comparatively low hydraulic gradients. The upward seepage rate is decreased due to decrease in void ratio and blocking of pore spaces of sand by fibers replacing the sand particles.

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