Prediction of Critical Hydraulic Gradient of Coir Fibre Mixed Soil using Artificial Neural Network

Arya S S
M-Tech Student
Department of Civil Engineering
St. Thomas Institute for Science and Technology
Trivandrum, India

Dr. Usha Thomas
Principal
St. Thomas Institute for Science and Technology
Trivandrum, India

***Abstract*— Water retaining structures are of great importance now a day because of the scarcity of water. In order to avoid the mixing of salt water from lake into the fresh river water some temporary water retaining structures are constructed across the river during summer season in some regions. The stability of these structures is thus very important. One of the main causes of failure of water retaining structure is piping failure. Here, in this study the possibility of using natural fibres for reducing the seepage velocity and piping failure of plain laterite soil is investigated. Seepage flow of water is in the upward direction and it induces reduction in effective stress and finally piping failure to soil. The ability of soil to resist piping failure is termed as piping resistance of soil. Thus here the study is conducted to know how the ability of soil to resist piping failure is improved, while natural fibre such as coir fibre is mixed randomly with soil. For quantifying the piping resistance of coir fibre mixed soil, critical hydraulic gradient is found out experimentally. Critical hydraulic gradient is the hydraulic gradient at piping failure. Different soil samples from Thiruvananthapuram city are examined. Along with experimental method an Artificial Neural Network is used for predicting the critical hydraulic gradient. Artificial Neural Network is modeled using MATLAB software.**

Keywords*— *Piping Resistance; Critical Hydraulic Gradient; Coir Fibre

I. INTRODUCTION

There is a great importance for controlling piping failure in water shed management system. When flows through the soil in the upward direction, the effective stress of soil get reduced. As the seepage flow of water increases in the upward direction effective stress of soil decreases and finally becomes zero. This condition is termed as quick sand condition. Seepage force acts in the direction of flow, opposing the piping resistance. Thus at zero effective stress piping resistance will be negligible. The head of water above the soil which causes quick sand condition or piping failure is called critical head. Above that head the structure fails. One of the main problem related with piping failure is that , there will be no proper external evidence that it is being taking place. It occurs suddenly with the formation of some bubbles. Piping failure starts when the hydraulic gradient exceeds the critical hydraulic gradient. During floods the head of water increases suddenly and there by pressure of water also increases and piping failure occurs. In order to prevent piping failure , commonly various methods like impermeable blankets and cut off walls …etc…are used to lower the head of water. If there is another way to prevent piping failure without decreasing the head of water, then it will be more adventitious. In order prevent piping failure without reducing head of water ,the soil should have great piping resistance. For that purpose some external material is to be used. Inter mixing of fibres with soil is a good approach Fibers are mainly of two types: natural and artificial. Both of these have advantages and some disadvantages. When artificial fibres or synthetic fibres are used for intermixing with soil, the soil will get polluted and the removal of these randomly mixed fibres will be difficult. Thus natural fibres are preferred. There are many types of natural fibers available all over the world. Here it is studying that whether piping resistance of soil is improved by intermixing with locally available natural fibres.

Coir fibre is the fibre derived from coconut. It is abundantly available in Kerala. [G L Sivakumar Babu, 2008] says coir fibre has high amount of lignin content (about 46%) it is stronger than other natural materials such as jute or cotton. Various studies were conducted by various researchers in coir geotextiles. [Lekha,2004] studies shows that coir geotextile id a good filter material and reinforcing media for saturated clay dykes in low lying area. Manufacturing of coir geotextile from coir fibre is done by a no of process. Hence the use of raw coir fibre randomly mixed in soil is studied here. [Sobha I, 2016] conducted seepage analysis on a number of samples of laterite soil collected from various areas of Thiruvananthapuram city and found out the critical hydraulic gradient of each sample. [G L Sivakumar Babu, 2008] conducted experimental study on sandy soil and red soil mixed with coir fibre. The study was conducted with three length of coir fibre and found that seepage was less in sample mixed with 50 mm long coir fibre.

Here in this study twenty numbers of samples were collected from various locations of Thiruvananthapuram city and mixed with 50 mm long coir fibre and seepage analysis is done to compare and study the change in critical hydraulic gradient of plain soil and coir fibre mixed soil. In this study for predicting critical hydraulic gradient of coir fibre mixed soil, an artificial neural network with feed forward back propagation algorithm is used. Critical hydraulic gradient is correlated with density, moisture content, and percentage of gravel, sand , silt and clay, and coir fibre of coir fibre mixed soil.

A. Objective of the Study

- To find whether mixing of coir fibre increases the piping resistance of soil.
- To find the relationship between index properties of soil and percentage coir fibre used to improve piping resistance.
- To compare the relative improvement in piping resistance of coir fibre mixed soil in various loctions.
- To develop an artificial neural network model to predict critical hydraulic gradient of coir fibre mixed soil.

II MATERIALS AND METHODOLOGY

B. MATERIALS

1) Laterite soil

Laterite soil samples were collected from twenty locations of Thiruvananthapuram city. 'Table 1' shows the samples of laterite soil and their locations.

Table. 1: Samples and their locations

Sample No	Place	Loction
1	Kattaikkonam	N 8.55691, E 76.9636
2	kazhakkoottam	N 8.57103, E 76.86633
3	Chanthavila	N 8.59182, E 76.88506
4	Pothencode	N 8.61946, E 76.89872
5	Andoorkkonam	N 8.60088, E 76.87497
6	Mannanthala	N 8.56155, E 76.9427
7	Nalanchira	N 8.53924, E 76.94799
8	Attingal	N 8.69503, E 76.81788
9	Kadakkavoor	N 8.68322, E 76.77103
10	Sreevaraham	N 8.47762, E 76.94198
11	Neyyattinkara	N 8.40164, E 77.08711
12	Poojappura	N 8.49161, E 76.9787
13	Pangode	N 8.50384, E 76.98302
14	Peroorkkada	N 8.54207, E 76.96535
15	Palayam	N 8.50276, E 76.9513
16	Chirayinkil	N 8.66319, E 76.79236
17	Varkkala	N 8.73194, E 76.71752
18	Cheruvallimukku	N 8.68024, E 76.80464
19	Sarkkara	N 8.65742, E 76.78851
20	Korani	N 8.65555, E 76.82696

'Table 2' shows the index properties of various samples. 'Table 3' shows the optimum moisture content and maximum dry densities of three samples.

Table. 2 : Samples and their properties

Sample No	Specific Gravity	field density (g/cm^3)	soil Classification	water Content
1	2.3	1.77	Medium sand	9
2	2.23	1.6	Medium sand	10.2
3	2.1	1.5	Coarse sand	7.4
4	2.56	1.6	Fine sand	4.3
5	2.2	1.69	Medium sand	7
6	2.5	1.8	Coarse sand	15.41
7	2.4	1.53	Medium sand	15.6
8	2.41	2	Medium sand	7.2
9	2.4	1.8	Medium sand	3.2
10	2.21	2.3	Medium sand	13.6
11	2.41	1.49	Medium sand	22.1
12	2.37	1.8	Medium sand	9.1
13	2.41	1.89	Coarse sand	20.2
14	2.02	1.54	Medium sand	9.2
15	2.78	1.8	Medium sand	2.87
16	2.46	1.83	Medium sand	5
17	2.27	1.64	Medium sand	11.6
18	2.5	1.23	Coarse sand	20
19	2.19	1.68	Coarse sand	16
20	2.21	1.54	Medium sand	4

Table . 3: Maximum dry density and Optimum moisture content of some samples

Sample No	OMC	Maximum Dry density (g/cm^3)
4	15	1.81
10	16	1.84
20	14	1.98

'Fig 1' shows the particle size distribution of sample 20 and 'Fig 2'shows the compaction curve of sample20.

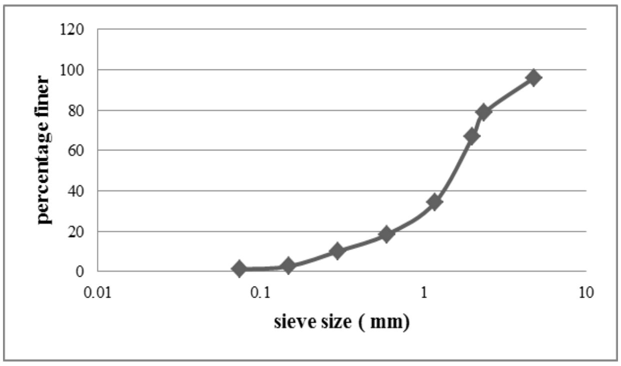

Fig. 1: Particle size distribution curve (Sample 20)

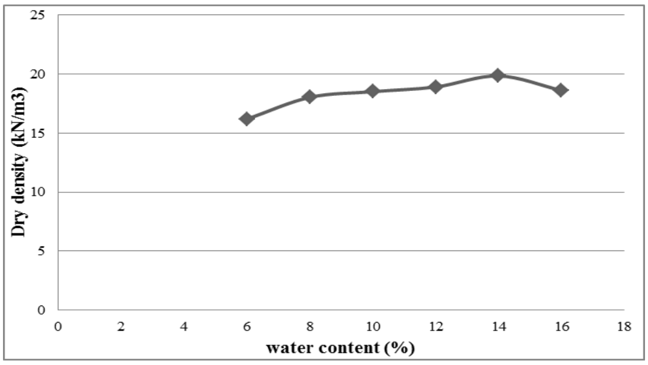

Fig. 2: Compaction curve (Sample 20)

II) Coir fibre

Coir fibre was collected from the Coir Society, Anathalavattom. The collected coir fibre was then air dried and cut into 50 mm length. 'Table 3' shows the properties of coir fibre.

Table. 3 : Properties of coir fibre

Parameter	Values
Length	50 mm
Density	1.12 g/cm^3
Color	light brown
Average diameter	0.25 mm

C. METHODOLOGY

I) Experimental Set up

The experimental set up consists of a tank of 40 cm diameter and 1 m height. It has an attached graduated scale to measure the level of water. The mould for the soil specimen has a diameter of 10 cm and a height of 11.7 cm. The experimental set up is shown in 'Figure 3'.

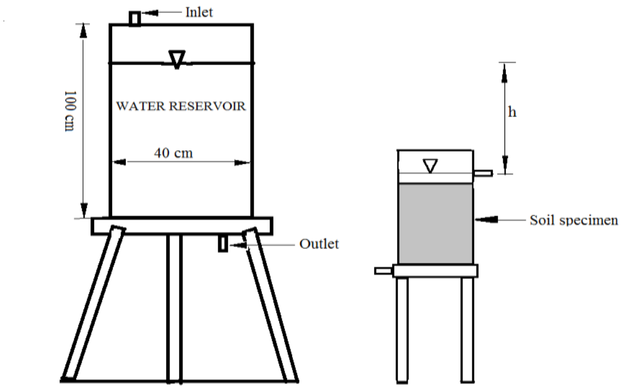

Fig.3: Experimental set up (Not drawn to scale)

The required weight of soil and coir fibre is mixed over a plane glass plate. Required water content is added for specified density and mixed well. It is then filled in the mould in approximately 3 layers and is compacted statically. Water is permitted to flow through the sample in the upward direction. Soil is allowed to be saturated and a steady flow has to be achieved. Discharge under various heads was monitored .The experiment was continued for increasing heads until piping failure occurs. When hydraulic head reached a certain level, small bubbles were observed and finally the specimen failed by piping. Critical hydraulic gradient, i_c is calculated by dividing the critical head by height of the specimen.

II) Developing an ANN model

Using MATLAB software, a neural network model is made to predict the critical hydraulic gradient of soil. A multi-layer perception network with feed forward back propagation is use to develop the model by varying the number of parameters and hidden layers. From the available data 80 percentage is used for training the neuron and remaining data are used for testing.

III. RESULTS AND DISCUSSIONS

The test result shows that, as the hydraulic gradient increases, seepage velocity also increases. The experimental result shows that addition of coir fibre increases the critical hydraulic gradient. That means the piping resistance of soil gets improved while inter mixing coir fibre randomly on it. The critical hydraulic gradients of soil samples with and without coir fibre are given in 'Table 4'.

Table.4 : Critical hydraulic gradients of soil samples with and without coir fibre

Sample No	Critical hydraulic Gradient (without Coir fibre)	Critical hydraulic Gradient(with coir fibre)
1	2.52	4.6
2	1.83	5.23
3	5.13	7.23
4	7.4	10.4
5	7.6	10.5
6	5.83	7.8
7	3.96	6.7
8	3.8	7.43
9	4.1	7.21
10	7.2	9.32
11	5.2	7.41
12	3.4	6.23
13	4.9	7.23
14	6.17	8.1
15	5.39	8.41
16	4.43	8.82
17	4.17	7.91
18	3.91	6.71
19	5.8	8.41
20	1.88	6.24

Critical hydraulic gradient of coir fibre mixed soil increases with increase in percentage of coir fibre. Above 1.5% of coir fibre 1.75% or 2% , when used , it become difficult to mix with soil and the sample become very difficult to handle. ' Table 5' shows the increase in critical hydraulic gradient with percentage of coir fibre.

Table.5: Increase in critical hydraulic gradient with percentage of coir fibre

Sample No	Percentage of coir fibre	Critical hydraulic Gradient
19	0	5.8
	0.25	6.15
	0.5	6.66
	0.75	7.18
	1	7.52
	1.5	8.41
20	0	1.88
	0.25	2.73
	0.5	3.5
	0.75	4.78
	1	5.98
	1.5	6.24

Seepage velocity increases with hydraulic gradient. But when coir fibre added to the soil seepage velocity gets reduced. That means piping resistance of soil get improved with increase in coir content. 'Fig 4' shows the seepage velocity versus hydraulic gradient of sample 19 for various fibre contents.

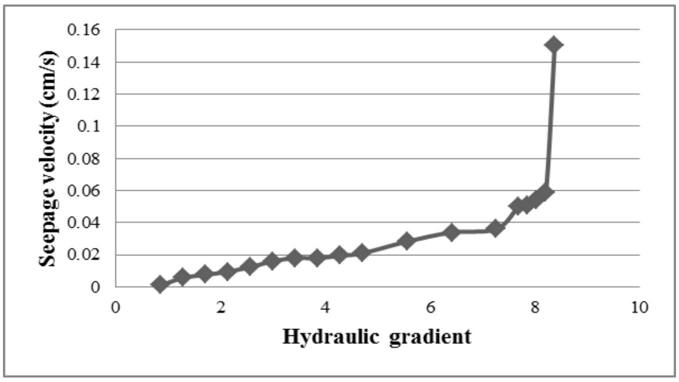

Fig.4: Seepage velocity versus hydraulic gradients of sample19 with 1.5% of coir fibre

'Fig 5' shows the seepage velocity versus hydraulic gradient of sample 19 for various fibre contents.

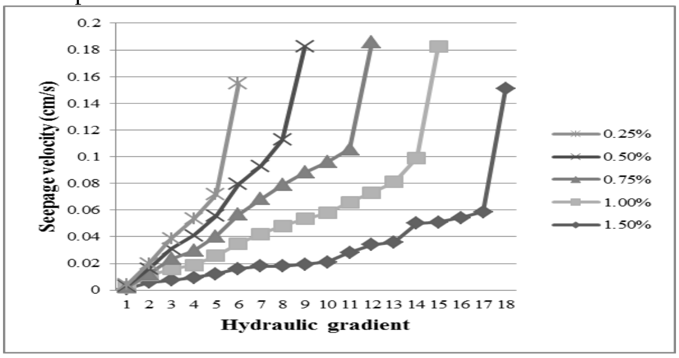

Fig.5: Seepage velocity versus hydraulic gradients of sample 19 for various coir fibre contents.

An artificial neural network was also formulated from the experimental data by using MATLAB software and found an R^2 value of 0.95

IV. CONCLUSION

From the experimental study, it is concluded that, the critical hydraulic gradient of coir fibre mixed laterite soil can be improved by intermixing it with coir fibre. Critical hydraulic gradient of sample increased with increase in coir content. Seepage velocity of soil get reduced with increase in coir content. Thus piping resistance of laterite soil can be improved by mixing coir fibre randomly on it. Since coir fibre is an easily available natural fibre, the use of the same can be done in various water shed management systems effectively.

ACKNOWLEDGMENT

I would like to express my sincere thanks to my guide, *Dr. Usha Thomas*, Principal , STIST for her invaluable guidance, motivation and constant inspiration and above all for her ever co-operating attitude that enabled me in bringing up this thesis in the present form. I am thankful to her for the encouragement she has given me in completing this thesis. She has been a great guide to me and helped me all the way in completion of this project. I express my sincere gratitude to Mrs. Sobha I , former student, STIST, for her valuable suggestions during the course of the project. I express my gratitude to Mrs. Anitha Nelson, Assistant Professor, STIST for her immense help in this project. I am also greatly thankful to all the staff members of the department in STIST and all my well-wishers and friends for their inspiration and help.

REFERENCE

[1] Gray, D.H., and Ohashi, H. (1983)." Mechanics of fibre reinforcement in sand." *J. Geotech. Engrg*., 109(3), 335-353

[2] Sherard, J. L., Dunnigan, L. P., and Talbot, J. R.(1984). "Basic properties of sand and gravel filters." *J. Geotech. Engrg*., 110:6, 684-700.

[3] Michalowsky, R. L., and Coermark, J (2003). "Triaxial compression on sand reinforced with fibres." *J. Geotech. Geoenviron.. Eng*., 129(2), 125-136.

[4] Lekha, K. R. (2004). " Field instrumentation and monitoring of soil serosion in coir geotextile stabilized slopes – A case study." *Geotext. Geomembr*., 22, 399-413.

[5] G. L. Sivakumar Babu., and A. K. Vasudevan.,(2008) " Seepage velocity and piing resisitance of Coir Fibre Mixed Soil." *J. Irrig.Drain Eng*., 134(4); 485-492