



Improvement Of Piping Resistance Of Sand Using Coir Fibre

Submitted by

DEVI D S

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NIMA B R

MCE21CE049

SWEETY G

MCE21CE063

MAHESWARI R

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MARIAN ENGINEERING COLLEGE

THIRUVANANTHAPURAM - 695 582.

DEPARTMENT OF CIVIL ENGINEERING

Guided By

PROF. GREESHMA T

PROFESSOR

DEPT. OF CIVIL ENGINEERING

MARIAN ENGINEERING COLLEGE

Head of the Department

PROF. Dr. RANI. V

PROFESSOR

DEPT. OF CIVIL ENGINEERING

MARIAN ENGINEERING COLLEGE

ABSTRACT

Piping of soil refers to the movement of soil particles caused by seepage flow, which poses a significant challenge in geotechnical engineering. This phenomenon can compromise the strength, stability, and integrity of earth structures such as dams, embankments, and their foundations. Conventional methods to enhance soil stability often rely on synthetic materials, which are expensive and environmentally harmful. This study explores an alternative approach to reduce seepage velocity and improve soil's resistance to piping by incorporating coir. A one-dimensional piping test was conducted to

compare the seepage velocity and piping resistance of pure sand, sand mixed with different proportions of coir under various hydraulic head conditions. The preliminary findings reveal that adding coir significantly enhances the soil's resistance to piping. Distributing coir throughout the soil mass increases isotropic strength and minimizes weak zone formation. Due to its high lignin content 46%, it is stronger than other natural materials such as coir or cotton. Coir geotextiles have been used in various slope stabilization projects and soil erosion control.

1. INTRODUCTION

Dams play a critical role in water resource management, providing essential services such as water storage, flood control, and hydropower generation. However, the construction and operation of dams can make them susceptible to internal erosion, particularly due to the large volumes of water retained behind the dam. Internal erosion, often referred to as piping failure, occurs when water infiltrates the dam structure, gradually eroding soil particles and forming voids, conduits, or pipes. This process can significantly undermine the structural integrity of the dam, potentially leading to failure, downstream flooding, and the loss of life and property.

The Neyyar Dam in Thiruvananthapuram, Kerala, a gravity dam built across the Neyyar River, serves critical functions such as irrigation, drinking water supply, and hydroelectric power generation. During its rehabilitation under the Dam Rehabilitation and Improvement Project (DRIP), funded by the World Bank, seepage issues were identified. DRIP, carried out in two phases (2012-2021 and Phase II from 2021 onwards), focused on enhancing the dam's safety and addressing seepage problems to ensure long-term stability. Likewise, the Chimony Dam in Thrissur, Kerala, experienced significant seepage, with rates reaching 30 litres per second through its inspection gallery and downstream face, particularly above the 60.00m level. These issues highlight the ongoing risks of seepage in masonry dams and emphasize the need for continual monitoring and intervention. In response to these challenges, there is increasing interest in innovative and sustainable solutions to improve soil resistance to piping and seepage in dams. Coir, derived from coconut husks, is gaining recognition as a promising material for reinforcing soil in dam structures. Coir is a natural, biodegradable fibre known for its high strength, excellent compatibility with various soil types, and resistance to degradation. Coir fibres can improve soil cohesion by binding particles together, preventing erosion and reducing the likelihood of internal erosion, including piping. It creates a synergistic effect, strengthening the soil's resistance to hydraulic forces and significantly reducing the risk of subsurface tunnel formation that leads to piping.

Through research into the optimal use of coir fibres, the construction industry can enhance dam stability, reduce erosion risks, and promote sustainable engineering practices. This method is not only effective in improving dam performance but also contributes to the long-term ecological health of the surrounding environment.



Fig.1.1 Neyyar Dam

Source: (www.google.com)

1.1. INTERNAL EROSION IN DAM

Internal erosion, also known as piping, is a primary cause of dam failure. Piping occurs when water flowing through the dam carries soil particles out of the structure, gradually creating voids or holes within the embankment. Managing piping failure is crucial in maintaining the integrity of watershed systems. As water moves upward through the soil, it decreases the soil's effective stress. When seepage forces increase in the upward direction, the effective stress drops to zero, resulting in a quicksand condition. In this state, the piping resistance becomes negligible, allowing the soil to be eroded more easily. The critical head, the height of water above the soil that leads to piping failure, marks the threshold beyond which the structure is at risk of collapse. Above this head, the dam can fail without visible signs of ongoing erosion, as the hydraulic gradient reaches the critical point, causing sudden bubble formation and initiating the failure process.

Piping failure is often triggered during flood events, when the head of water increases rapidly, leading to an increase in water pressure. This surge in pressure can exceed the critical hydraulic gradient, accelerating the process of internal erosion. Notably, the lack of external indicators during the early stages of piping failure makes it challenging to detect and mitigate, emphasizing the need for continuous monitoring and effective risk management strategies.

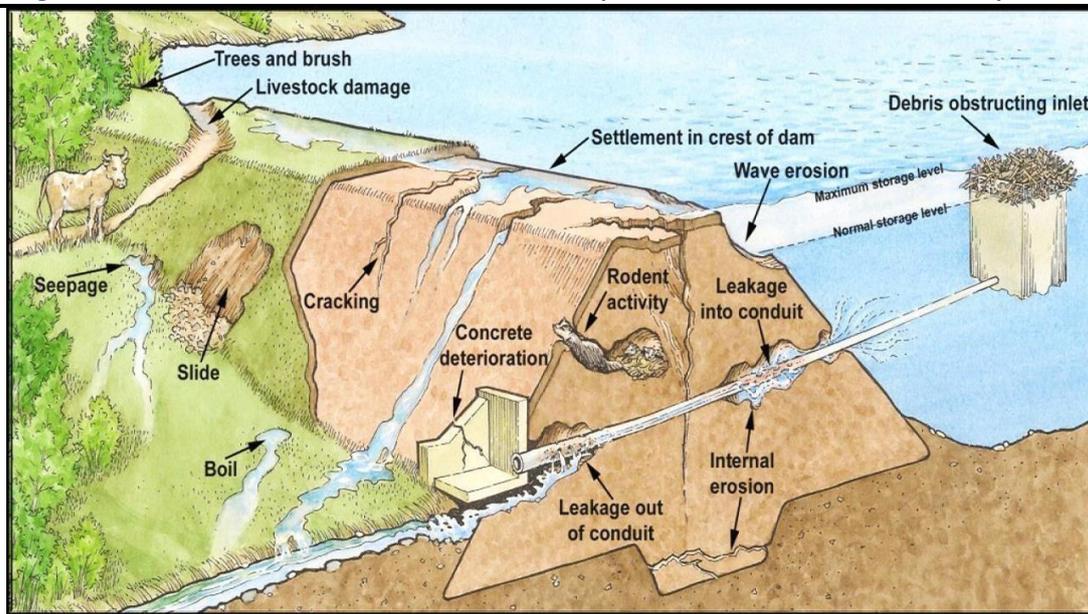


Fig.1.2 Causes of seepage and piping erosion in dams

Source: (<https://geoenvironmental-disasters.springeropen.com>)

1.2. ENHANCING PIPING RESISTANCE USING FIBER REINFORCEMENT TECHNIQUE

To prevent piping failure, various methods, such as impermeable blankets and cut-off walls, are commonly employed to reduce the water head. However, finding alternative solutions that do not involve decreasing the head of water would be advantageous. One such approach is to enhance the soil's piping resistance by using external materials. Intermixing fibres with soil has proven to be an effective method. Fibres can be classified into two types: natural and artificial. While artificial (synthetic) fibres can enhance soil stability, their use poses environmental challenges, including soil pollution and difficulties in removing randomly mixed fibres. As a result, natural fibres are preferred due to their sustainability and eco-friendliness. A wide variety of natural fibres, such as coir, jute, and sisal are readily available across the globe. These fibres, known for their high tensile strength and biodegradability, significantly enhance soil piping resistance when mixed with soil. By forming a reinforced composite, the fibres create a network within the soil matrix, increasing cohesion and structural integrity. This network bridges soil particles, improving resistance to hydraulic forces and reducing the likelihood of subsurface erosion, such as piping. In addition to stabilizing the soil, natural fibre reinforcement improves its shear strength and permeability, enabling it to better withstand erosive forces. Unlike synthetic materials, natural fibres decompose over time, contributing to soil fertility and reducing the overall environmental impact. This sustainable and eco-friendly solution not only mitigates soil erosion but also reduces the carbon footprint of geotechnical applications. By leveraging the mechanical properties of natural fibres, this method provides a cost-effective and environmentally responsible way to enhance soil stability and mitigate piping failure across various engineering projects.

1.2.1. Natural fibre materials

Natural fibres are increasingly utilized across a wide range of engineering applications and industries, including automotive, food, and agriculture. Their popularity stems from their abundance, sustainability, cost-effectiveness, low density, and advantageous mechanical properties such as strength and stiffness. Based on their source, natural fibres can be categorized into three types: plant fibres (e.g., bamboo, jute, coir, hemp), animal-based fibres rich in protein (e.g., silk, hair, wool), and mineral-based fibres. In geotechnical applications, plant fibres are particularly favoured due to their widespread availability and suitability for large-scale implementation. Economically, plant fibres used for soil reinforcement are further classified into three groups: crop species, non-crop species, and invasive species. These fibres are derived from various parts of the plant, including stems, leaves, seeds, fruits, wood, and cereal straw. The durability and performance of natural fibres depend on several factors, including the plant part from which the fibre is extracted, the age of the plant, and the treatment processes applied to the fibres. Proper selection and treatment of fibres are crucial to achieving optimal results in geotechnical and other engineering applications.

1.2.2. Biochemical properties

Natural fibres, with their unique microstructure, can be described as naturally occurring composites primarily composed of hollow cellulose fibrils bound together by a matrix of lignin and hemicellulose. These fibres may also include pectins and waxes, which contribute to their mechanical and biochemical properties. Pectins enhance flexibility, while waxes, located on the outer surface of the fibres, provide protection against environmental factors and contain alcoholic compounds. The cellulose fibrils, measuring approximately 10–30 nm in diameter and consisting of chained-cellulose molecules, align along the fibre's length. This alignment enhances the fibre's mechanical strength and rigidity, making them particularly effective for applications requiring high tensile and shear resistance. Lignin serves as a protective barrier, safeguarding the fibre's internal structure from microbial degradation, thereby extending its lifespan. The cellulose and hemicellulose content directly influence the fibre's moisture-absorption capabilities, which is crucial for their performance in moisture-rich environments such as dams. The reinforcing efficiency of natural fibres is closely linked to the nature and crystallinity of cellulose, which play a significant role in their mechanical behaviour. The unique microstructure of natural fibres makes them ideal reinforcements for geotechnical applications, including enhancing soil resistance to piping in dams. The matrix of hollow fibrils and the protective role of lignin combine to create a durable and sustainable solution for soil stabilization. Understanding this intricate structure enables the effective optimization of natural fibres in soil reinforcement strategies, contributing to the resilience and longevity of dam infrastructure.

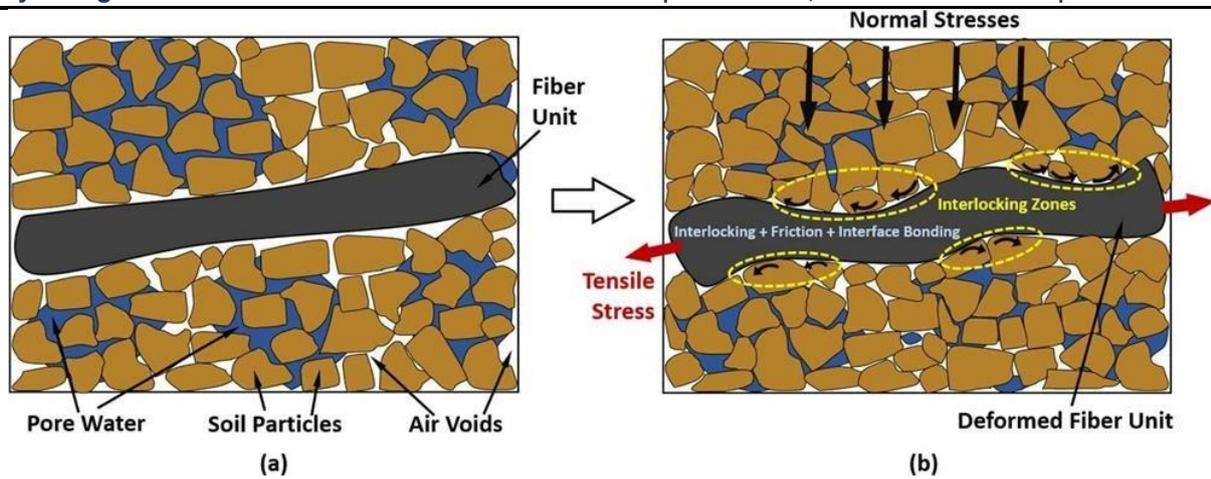


Fig.1.2.1. Schematic representation of a randomly distributed fiber unit at (a) initial stage (b) deformation stage due to loading, where the effect of interlocking, friction, and interface bonding induces mobilization of the tensile stress on the fiber units. (Source: Nassar et al.2019)

This study explores the use of coir as natural materials for enhancing the resistance of soil to piping. Coir, being biodegradable and abundant, along with organic matter, offer potential benefits for sustainable soil stabilization. Their application could reduce reliance on synthetic materials and promote environmental conservation.

1.2.3. Coir fibre

Coir geotextiles, derived from coconut husks, have proven to be an eco-friendly and sustainable solution for various geotechnical applications, including slope stabilization, soil erosion control, and hydraulic structures. Their role in enhancing piping resistance is particularly significant, as piping—caused by the seepage of water through soil—poses a serious threat to the stability of embankments, dykes, and other soil-based constructions. Coir geotextiles improve soil structure by providing reinforcement in multiple directions, thereby minimizing the development of weak zones where piping can initiate. Their interwoven structure acts as an effective filter, preventing soil particle migration while allowing water to flow freely. This dual function helps maintain soil stability and mitigate piping erosion.

Additionally, coir geotextiles increase the shear strength of the soil, reducing the potential for soil displacement caused by seepage forces. They also lower the hydraulic gradient within the soil by dissipating seepage forces over a wider area, directly decreasing the likelihood of particle mobilization and piping. Their durability under saturated conditions, coupled with natural resistance to microbial and fungal activity, ensures long-term performance in controlling piping erosion. Moreover, by regulating pore-water pressure in saturated soils, coir geotextiles contribute to the stability of embankments and slopes. As a biodegradable and cost-effective alternative to synthetic geotextiles, coir aligns with green engineering principles while delivering robust performance during its effective life span.

Field studies have shown their success in mitigating risks associated with saturated clay dykes in low-lying areas and in reducing piping-induced soil erosion in riverbank protection projects. By combining filtration, reinforcement, and drainage capabilities, coir geotextiles offer a holistic approach to enhancing soil stability and hydraulic behaviour.



Fig.1.2.2. Coir fibre Source: (www.google.com)

1.3. SCOPE OF STUDY

In Kerala, dam piping failure has become a critical issue, intensified by extreme weather events and aging infrastructure. A notable example occurred during the catastrophic floods of August 2018, which exposed severe seepage problems in dams like Thenmala and Chimony in Thrissur. To address such challenges, the use of random fibres to enhance piping resistance in dams has gained attention as an innovative solution. Among these fibres, coir is particularly effective, as it enhances soil stability and cohesion, reducing erosion and the risk of piping. The inclusion of coir fibres reinforces soil by binding particles together, thereby increasing resistance to hydraulic forces and minimizing the chances of piping failure. Additionally, bio-abatement techniques using organic soil offer another promising strategy for improving soil cohesion and structure.

1.4. OBJECTIVES

By conducting a one-dimensional piping erosion test,

- a. Evaluate the effectiveness of coir fibre in enhancing piping resistance and thereby reducing seepage velocity in soil by varying fibre length and fibre content
- b. Identify the optimal coir fiber content and fiber length required to maximize the reinforcement effect and improve piping resistance
- c. Compare the variation in seepage velocity of soil treated with coir fibre matter to untreated soil

2. LITERATURE REVIEW

Prithviraj et al. (2023) investigate the interface behaviour of granular soil reinforced with surface modified coir geotextiles. The researchers conducted large-scale direct shear tests on sands reinforced with untreated and treated coir geotextiles at different normal stresses (50 kPa, 100 kPa, and 150 kPa). Sands of three different particle sizes (coarse, medium, and fine) were used for the study. The shear strength parameters of reinforced soil samples were measured in terms of interface friction angle, apparent cohesion, and interface coefficient. The experimental investigations revealed that cashew nut shell liquid-treated coir geotextiles improved the interface shear strength parameters for all sand fractions. The tensile strength of CNSL-treated coir geotextile was also improved by 13%.

Teng et al. (2022) studied suffusion restraint in gap-graded soil reinforced with fibres and discussed internal erosion and its four failure modes, including suffusion, contact erosion, and concentrated leak erosion. It also explores the reinforcement modes and effects of different types of fibres in preventing suffusion. The study analyses pore water pressure, seepage velocity, and fine-particle loss to determine the best fibre type, content, and reinforcement-layer thickness for effective soil reinforcement. The results show that polypropylene fibre (PPF) has the highest restraining effect on suffusion, followed by Coir fibre (CF) and Basalt tape fibre (BTF). Increasing fibre content and reinforcement-layer thickness enhance the reinforcement modes and make it more difficult for fine particles to migrate. By analysing the suffusion failure process and the results of suffusion and by comparing the suffusion-restraining effects of the different types of fibre-reinforced soil (FRS) the best fibre type, fibre content, and reinforcement-layer thickness were obtained, which have reference values for eliminating risk and protecting embankment dams by using FRS. The microscopy analysis shows that the reinforcement mode of PPF is netting reinforcement, CF reduces the channel spaces because of their water absorption and expansion, while BTF blocks the migration channels because of the large contact area of its tape structure.

Tamassoki et al. (2022) studied compressive and Shear Strengths of Coir Fibre Reinforced Activated Carbon Stabilized Lateritic Soil using an experimental study. Based on the study the conclusions obtained were that adding coir fibre in Activated Carbon soil improves mechanical parameters, such as peak shear strength, friction angle, cohesiveness, flexibility, and residual strength. The compressive strength of soil samples is enhanced significantly with rising AC content and the addition of coir fibre. Coir fibre provides interlocking effects when dispersed equally in soil. The failure strain increased from 2.85% for untreated soil to 2.90%, 3.22%, and 3.65% for 1%, 2%, and 3% AC, respectively, showing the increased flexibility. Moreover, the brittleness of the ACF specimens further decreased, resulting in plastic deformation and a significant increase in failure strain for about 3.22%, 4.13%, and 3.87% for 1%, 2%, and 3% ACF, respectively. In this study, when AC is added to lateritic soil as a stabilizer, it improves compressive strength, shear strength, cohesion, and deformability and decreases pore size and pore volume in the soil. Adding coir fibre in the AC-stabilized specimens

significantly improves the peak shear strength and post-peak residual strength and increases the elastic modulus value, deformability, internal friction angle, and cohesion.

Chen et al. (2020) focus on numerical modelling of earthen dam breaches due to piping failure. A simplified model has been proposed for calculating the breach process of earthen dams due to piping failure. The model focuses on formulating the breach development of piping passage and the transition from piping to overtopping. Verification was conducted using one model test and two artificially filled dam failure cases, and the model provides more accurate peak breach flow discharge and final breach widths than the widely-used NWS BREACH model. However, soil erodibility and initial piping position can significantly affect the breach process, making it crucial to reduce uncertainty in determining soil erodibility. The model is based on assumptions such as the development of piping passage and the instant disappearance of collapsed soil. Further study is needed to enhance and validate the numerical model. Sensitivity analysis shows that the soil erodibility and initial piping position significantly affect the prediction of the breach flow discharge. Furthermore, a comparison with a well-known numerical model shows that the proposed model performs better than the NWS BREACH model.

Nassar et al. (2019) this study focuses on reducing seepage velocity and enhancing piping resistance using coir fibres. An experimental investigation was conducted to compare the piping behaviour of unreinforced soil with soil reinforced with coir fibres. Different proportions (0.5%, 0.75%, and 1%) and lengths (1.5cm to 6cm) of coir fibres were tested under varying hydraulic heads. The results showed that an optimal fibre content of 1% and a length of 4cm provided the most effective reinforcement. The study revealed that the inclusion of coir fibres reduced seepage velocity and improved piping resistance. Longer fibres and higher fibre dosages were found to be more effective in reducing seepage velocity and improving piping resistance. However, it was also noted that not all combinations of fibre dosages were efficient in achieving these objectives. The research suggests that the use of coir fibres can be a viable method for reinforcing soil and enhancing its resistance to piping. The findings also emphasize the importance of carefully selecting the dosage and length of fibres to achieve the desired results.

Estabragh et al. (2017) The study conducted experimental tests on unreinforced and randomly reinforced silty sand samples using polyethylene and polyester fibres. The tests were carried out for different fibre contents (0.5, 0.75, 1.0, and 1.25%) and fibre lengths (5, 25, and 35 mm) under different hydraulic heads. The results indicated that the inclusion of fibres reduced the seepage velocity, increased the piping resistance, and delayed the occurrence of piping by increasing the critical hydraulic gradient. The amount of increase in piping resistance and hydraulic gradient was found to be dependent on the percentage and length of the fibres. For fibres with lengths of 5 and 25 mm, the increase of piping resistance continues with increasing the fibre content until 0.75% and then remains constant. The study concluded that reinforcing soil with randomly distributed fibres can effectively improve the mechanical

behaviour of soil against piping, and shorter and thinner fibres could be more effective in improving piping resistance.

Anggrainia et al. (2015) investigated the impact of coir fibre content on soft marine clay through unconfined compression, tensile, and flexural tests. The results indicate that coir fibre content significantly impacted the strength of soil specimens, with compressive strength increasing up to 1% fibre content and showing a similar trend in tensile and flexural strength. Strength and ductility improved notably up to 1.5% fibre content, indicating the potential of fibre-mixed soft marine clay for construction. Beyond 1.5% fibre content, the relative volume occupied by fibres increased, affecting soil-fibre interactions and reducing interlocking and friction in the sample. Unconfined compressive strength of fibre-reinforced soil exhibited ductile behaviour at large axial strain, with maximum strength enhancement at 1% fibre content for 7, 14, and 28-day curing periods.

Sheela et al. (2015) studied the effect of coir fibres on various parameters such as unconfined compressive strength, compaction characteristics, and one-dimensional piping tests. It is found that the unconfined compressive strength increases with higher fibre content and length, while the permeability of reinforced pond ash decreases compared to unreinforced samples. The critical hydraulic gradient and piping resistance also increase with higher fibre content and length, reaching a maximum of 0.5% fibre content and 50mm fibre length. Furthermore, the study explores the impact of geotextile placement on critical hydraulic gradient, with non-woven geotextile showing higher critical gradient compared to woven geotextile. The numerical analysis using MIDAS software demonstrates that the seepage velocity is minimized for a fibre content of 0.5% and fibre length of 50mm in the embankment model. In conclusion, the research provides valuable insights into the potential of coir fibre-reinforced pond ash in improving piping resistance in geotechnical constructions. The findings suggest that the optimum fibre content is 0.5% and the optimum fibre length is 50mm, with reinforced pond ash exhibiting reduced seepage velocity and improved piping resistance. The study also emphasizes the importance of geotextile placement in mitigating piping effects. Overall, the research presents a comprehensive assessment of the effectiveness of coir fibres in enhancing the geotechnical properties of pond ash, thereby offering sustainable solutions for environmental and construction challenges.

2.1. CRITICAL REVIEW

- a) There are high erosion rates due to soil piping in water-retaining structures pose significant challenges to their stability and integrity.
- b) Coir fibre, known for its high tensile strength and biodegradability, has been demonstrated to improve the engineering properties of soil, thereby increasing its resistance to piping.
- c) The combination of fibre reinforcement presents a robust strategy for reducing soil piping in water-retaining structures.

- d) Studies have highlighted that both methods work synergistically to enhance soil stability by improving physical properties, increasing cohesion, and facilitating better water management.

2.2. GAP IDENTIFIED

- a) Lack of detailed studies on effective measures to prevent soil piping in different climatic regions and with different soil types
- b) Lack of physical models or experimental studies on soil pipe development, collapse, and erosion rate on sandy soils
- c) Lack of detailed studies on dam break analysis due to piping failure in Kerala
- d) Limited studies on piping failure resistance of soil using in filled materials such as natural fibres.

3. MATERIALS AND METHODOLOGY

3.1. MATERIALS USED

- a) Sand
- b) Coir fibre

These materials are used to evaluate the piping resistance in these soils. The soils were collected from different locations and a study was conducted about the basic properties.

3.1.1 Sand

The soil used in this study is collected locally from the Neyyar dam region, Thiruvananthapuram district, which was collected at a depth of 1.5m from the ground.



Fig. 3.1: - Collected Soil Sample

Sand particles that passed through 2.36 mm sieve were used for the experimental investigation. The properties of the soil were studied using standard procedures in the laboratory as per IS 2720 (Part 2)-1973, IS 2720 (Part 3)-1980, IS 2720(Part 4)-1985 and IS 2720 (Part 13)-198.

PROPERTIES	VALUES
Specific gravity	2.6
Initial moisture content%	4.25
Percentage of coarse sand (%)	34.4
Percentage of medium sand (%)	49.6
Percentage of fine sand (%)	3.6
Percentage of gravel (%)	12.4
D10 (mm)	0.6
D30 (mm)	0.78
D60 (mm)	2.3
Cu	3.83
Cc	0.44
IS classification	SP
Angle of Internal Friction (°)	36.12
Cohesion (kg/cm ²)	0.1
Density (g/cc)	1.89

Table 3.1. Material Properties of Sand

Fig 3.2 shows the particle size distribution curve of sandy soil. From the graph, different values for D10, D30, and D60 were obtained. From those obtained values C_u and C_c values were calculated.

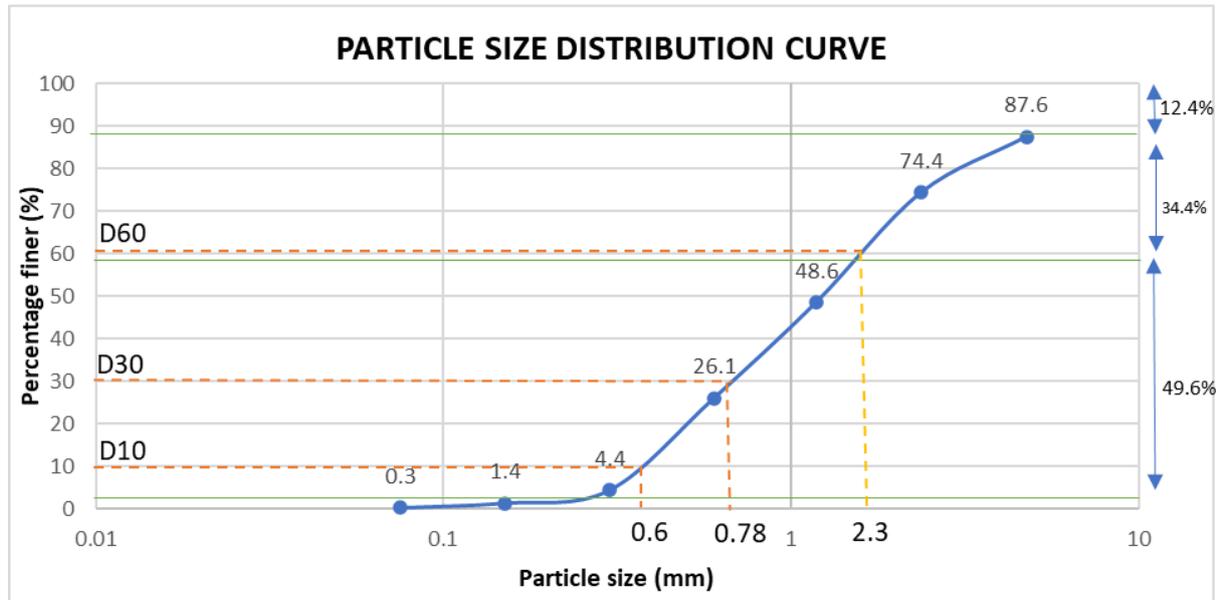


Fig 3.2:- Particle size distribution curve for sand

The percentage of coarse, medium, and fine sand was also obtained from the particle size distribution curve.

3.1.2. Coir fibre

The coir was collected from Anathalavattam Coir Society. The properties were tested in National Coir Research and Management Institute.



Fig 3.3: - Coir processing unit



Fig 3.4: - Final coir product

Table 3.2. Material properties of coir fiber

Tenacity (N/Tex)	0.22
Young's Modulus (N/Tex)	3.20
Elongation at break (%)	27.47
Cellulose (%)	27.56
Lignin (%)	43.71

3.2.METHODOLOGY

Experimental setup

A laboratory investigation was conducted to study the effect of coir fibre in reducing seepage velocity and improving the piping resistance of sand. The piping behaviour of sand was studied and compared with that of a specimen prepared by mixing organic soil with sand and coir fibre to sand. The experimental setup used in this study is shown in the figure. 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 mould for the soil specimen has a diameter of 10 cm and a height of 11.7 cm. Sand passing through 2.36mm sieve and retained on 75 μm and 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 the soil medium was determined. The required weight of the soil for the specified density was mixed with water over a plane glass plate. The soil mixture was filled in the cylindrical mold (up to a height of 11.0 cm) in approximately three equal layers and each layer was statically compacted.

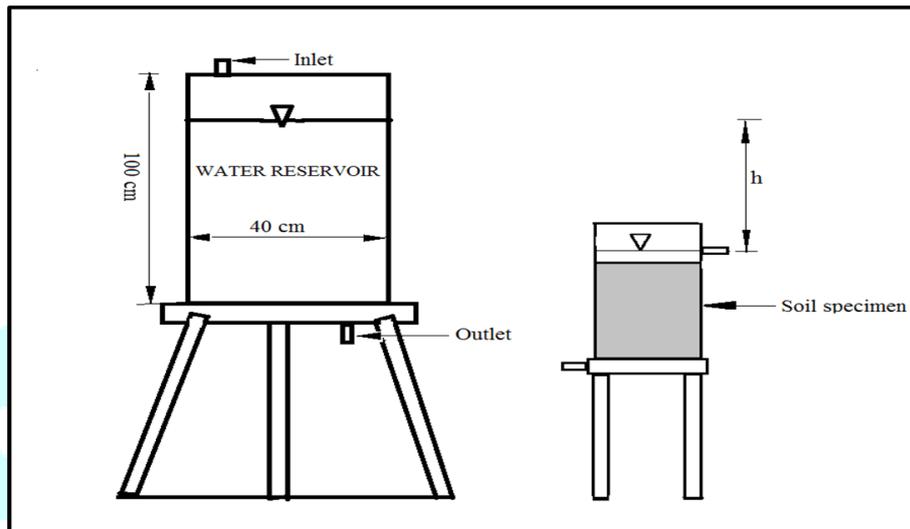


Fig.3.5: - Schematic representation of test setup

Source: (Vasudevan et al. 2008)



Fig.3.6: - Experimental setup



Fig. 3.7: - Mould with sand specimen

The mould was then connected to the water tank and 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 the piping failure of the soil occurred. The experiments were conducted using plain sand, sand mixed with fibre contents (0.5%, 0.75%, and 1% of the dry weight of sand) at lengths of 10mm, 25mm.

4. RESULTS AND DISCUSSION

One dimensional piping test was conducted to find the seepage velocity and piping resistance characteristics of sand reinforced with coir fibre under varying conditions. The readings were obtained using the graduated scale attached to the water tank, and discharge under various heads was monitored.

4.1. UNREINFORCED SOIL

From the experimental analysis, the seepage velocity characteristics of unreinforced sand were obtained. Fig.4.1. represents the seepage velocity characteristics of unreinforced soil sample using experimental methods.

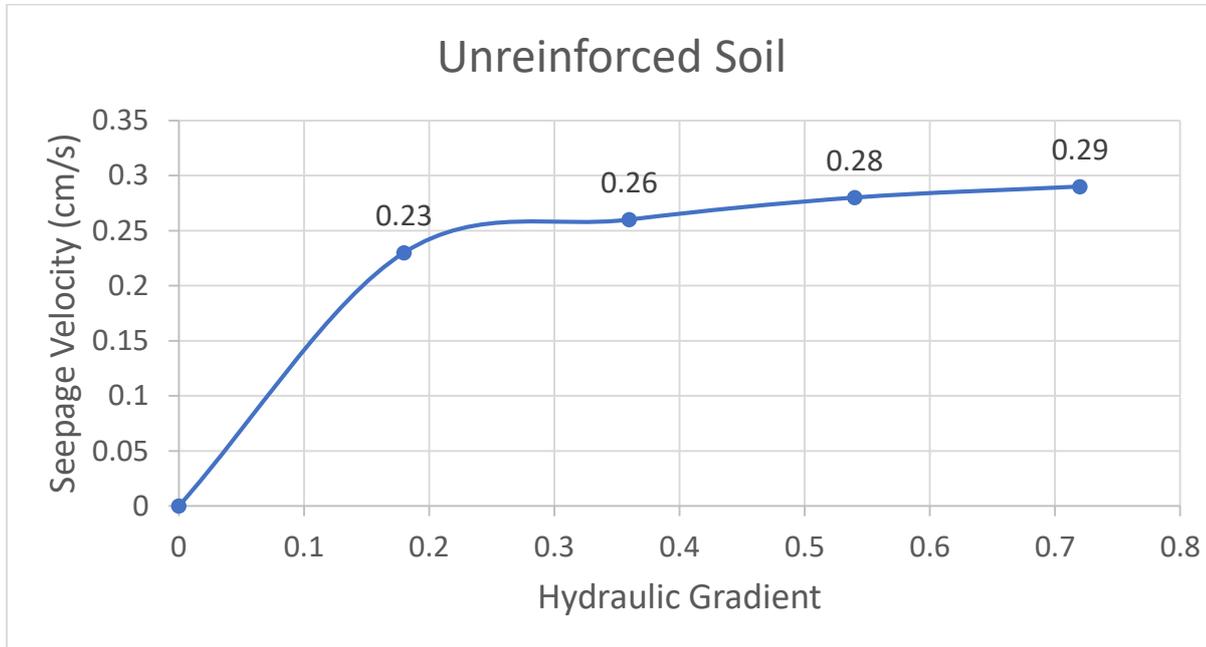


Fig.4.1: - represents the variation in seepage velocity in unreinforced sand

4.2. SAND REINFORCED WITH COIR FIBER

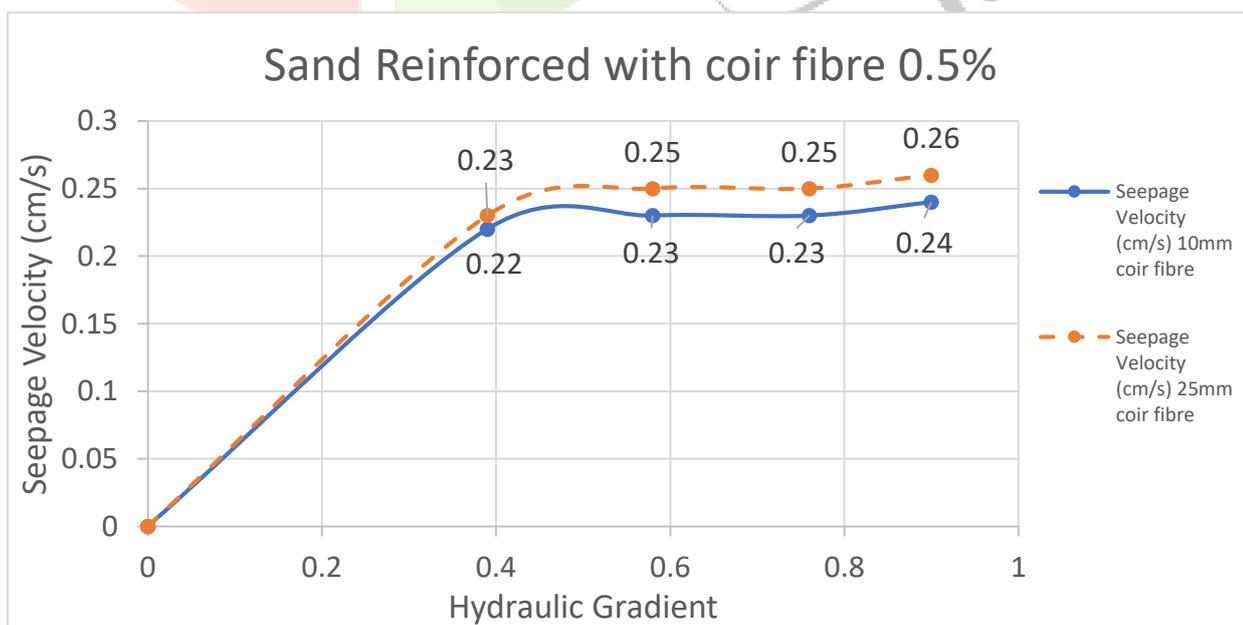


Fig.4.2: - represents the variation in seepage velocity with hydraulic gradient for 0.5% of coir fibre.

The graph illustrates the relationship between seepage velocity and hydraulic gradient for sand reinforced with various lengths of jute fibres (10mm, 25mm).

From the graph obtained it can be seen that, among all tested fibre lengths, indicating that 10mm is the most effective length for reducing seepage

- All curves exhibit a rapid increase in seepage velocity with increasing hydraulic gradient initially. This is typical behaviour as the driving force (hydraulic gradient) increases the flow rate through the sand.
- As the hydraulic gradient continues to increase, the seepage velocity tends to level off, indicating that the sand's permeability is reaching a steady state.
- From the graph we can see that 10 mm coir fiber length may result in better erosion reduction compared to 25 mm fiber length, depending on factors like fiber-soil interaction, dispersion, and reinforcement efficiency.
- Better Dispersion in Soil – Shorter fibers (10 mm) can mix more uniformly within the soil, leading to a more effective reinforcement network. Longer fibers (25 mm) may clump together, creating weak zones.
- More Contact Points – With shorter fibers, there are more individual fibers per unit volume of soil, increasing the number of reinforcement points and improving stability.
- Improved Bonding – Shorter fibers can anchor better within soil particles, preventing displacement and reducing seepage-induced erosion more effectively

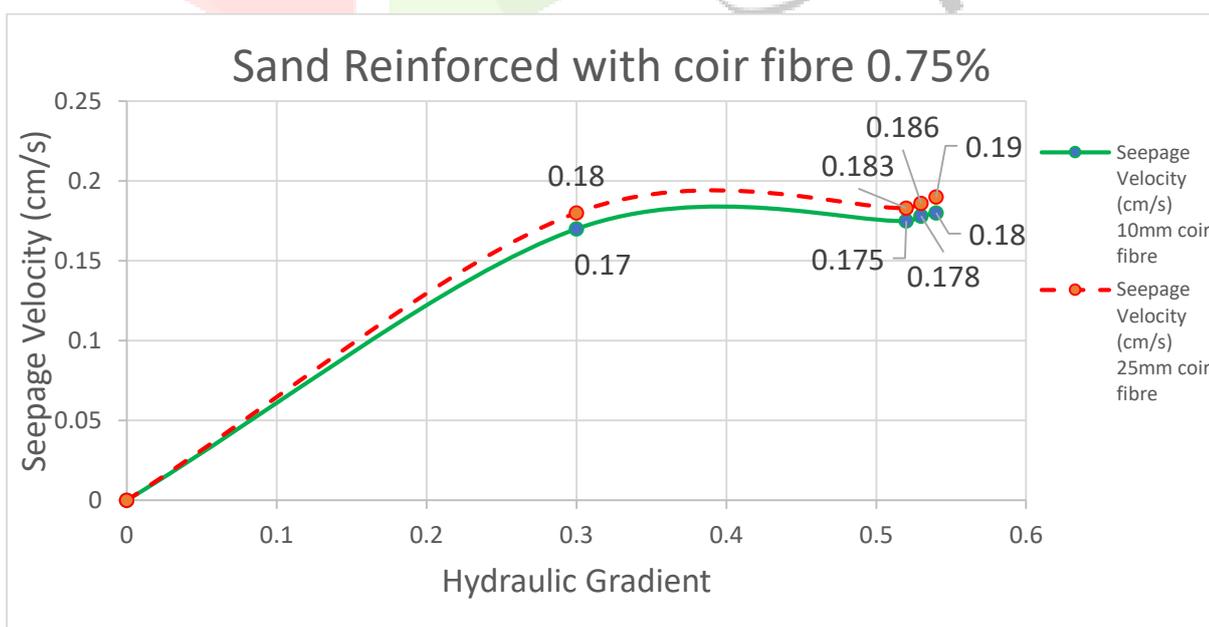


Fig 4.3: - Represents the variation of seepage velocity with hydraulic gradient for 0.75% of coir fibre.

The graph illustrates the relationship between seepage velocity and hydraulic gradient for sand reinforced with various lengths of coir fibres (10mm, 25mm)

- The incorporation of coir fibres reduces seepage velocity across all lengths compared to unreinforced sand.
- The most substantial reduction is observed with 10 mm fibres, indicating optimal fibre-soil interaction

From the graph plotted it can be seen that 10mm length fiber shows the highest reduction in seepage velocity among all other fibres. The graph highlights the effectiveness of coir fibre reinforcement in increasing the piping resistance of sand

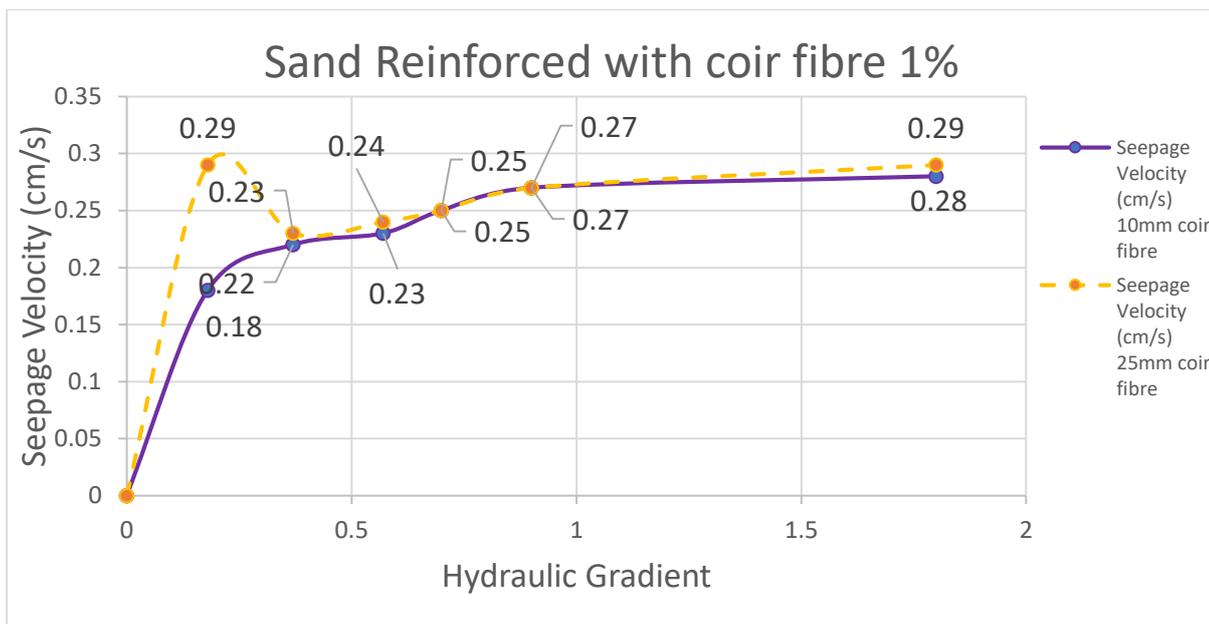


Fig. 4.4: - Represents the variation of seepage velocity with hydraulic gradient for 1% of coir fibre

From the graph plotted it can be seen that 10mm length fibre shows the lowest reduction in seepage velocity. The graph highlights the effectiveness of coir fiber reinforcement in increasing the piping resistance of sand. The optimal fibre length for maximizing resistance is 10 mm, providing the highest improvement. 25 mm fibers offer significant benefits, but the 10 mm length is the most effective for enhancing soil stability.

4.3. Discussion

Seepage velocity, hydraulic gradient, and piping resistance are critical factors in understanding the behaviour of fibre-reinforced sand under hydraulic conditions. The introduction of coir fibres into sand aims to improve its mechanical properties, including its permeability characteristics.

Effect of fibre content

- 0.5% Coir Fibre: At lower fibre content, the seepage velocity generally decreases slightly compared to unreinforced sand. However, the reduction is not substantial enough to significantly alter the permeability.
- 0.75% Coir Fibre: This percentage appears to be optimal, as it significantly reduces the seepage velocity, indicating improved soil structure and reduced permeability.
- 1% Coir Fibre: Higher fibre content may lead to fibre clumping and ineffective distribution, potentially leading to an inconsistent effect on seepage velocity.

Effect of fibre length

- 25mm Length: May not create sufficient interlocking within the soil matrix, leading to a less effective reduction in seepage velocity.
- 10mm Length: This length of fibre provides the best performance, likely due to optimal interaction with the soil matrix, enhancing soil stability and reducing permeability.

Thus, the detailed analysis of seepage velocity versus hydraulic gradient graphs for varying concentrations of coir fibre indicates the following:

- Optimal Fibre Content: 0.75% coir fibre content consistently provides the best reduction in seepage velocity, indicating improved soil structure and reduced permeability.
- Optimal Fibre Length: 10mm fibre length proves to be the most effective across different percentages, offering the best reinforcement by enhancing interlocking within the soil matrix.

4.4 COMPARATIVE ANALYSIS OF VARIOUS SEEPAGE VELOCITY GRAPHS OBTAINED

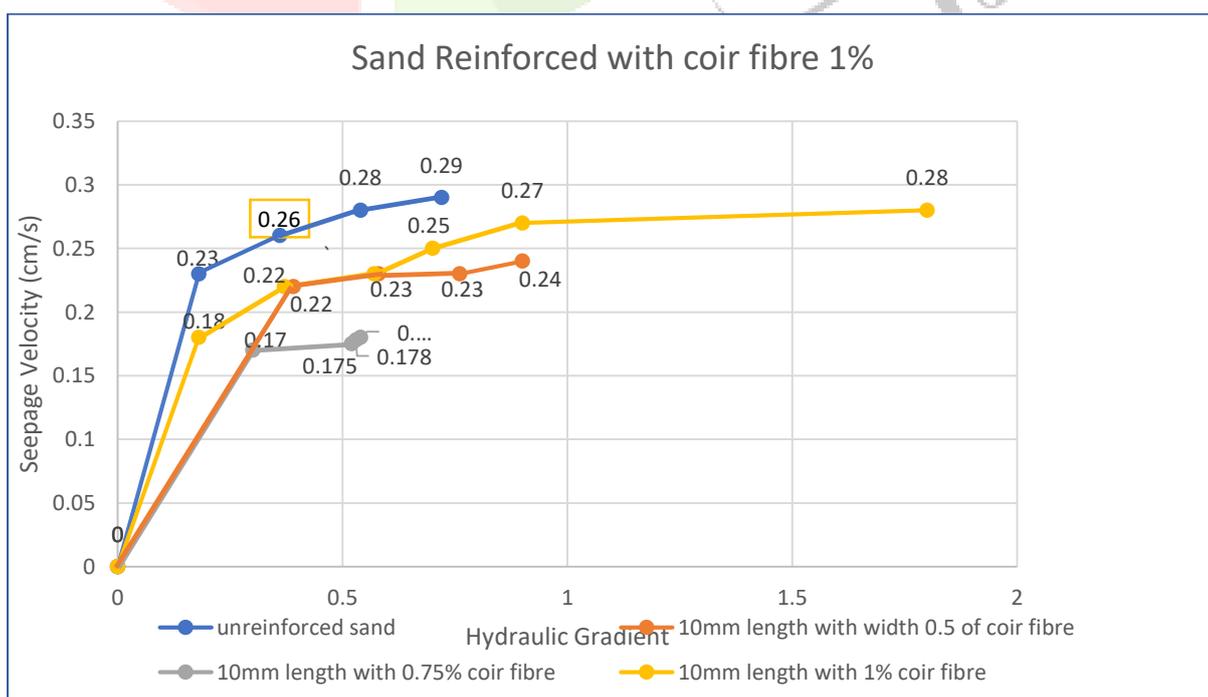


Fig 4.5: - Comparison graphs for various seepage velocities obtained

The above graph illustrates the relationship between seepage velocity (cm/s) and fibre content (%) for three conditions: unreinforced sand and sand with 10mm coir fibre reinforcement at 0.5,075 and 1% fibre contents. The comparative analysis indicates that :

- Seepage velocity is consistently lower for 10mm fibre length with 0.75% fibre content than that of unreinforced sand and sand with 0.5 and 1% fibre content.
- This shows a significant improvement in reducing seepage velocity, indicating enhanced soil structure and reduced permeability due to fibre reinforcement. ie, seepage velocity decreases significantly when coir fibre soil is mixed with unreinforced sand.
- This is because adding organic content and fibres can create a more heterogeneous soil structure, which in turn helps to manage and control seepage paths within the soil.

4.5. EROSION PATTERNS DEVELOPED DURING ONEDIMENSIONAL PIPING TEST



Fig 4.5.1: -Piping developed in unreinforced soil sample



Fig 4.5.2: -Piping developed in coir fibre reinforced soil sample

5. CONCLUSIONS

5.1 CONCLUSIONS DERIVED FROM ANALYSIS

The study comprehensively evaluated the performance of coir fibres in enhancing the piping resistance of soil. Through a series of laboratory experiments, key insights were gained into the effectiveness of these sustainable reinforcement techniques in mitigating piping erosion in geotechnical applications.

The following conclusions are made from the study:

- a) Coir fiber content in soil significantly improves resistance to piping erosion.
- b) Coir fiber reinforcement reduces seepage velocity and increases piping resistance by 50-75%.
- c) Enhanced Stability: Coir fiber improves the cohesion and interlocking of sand particles, increasing resistance to piping.
- d) Reduced Erosion: The addition of fibers helps in mitigating internal erosion and seepage-induced failures.
- e) Key Factors: Fiber content, length, and distribution significantly affect the soil's resistance to piping.
- f) Eco-Friendly Solution: Coir fiber is a biodegradable and sustainable material for soil reinforcement.

5.2 SCOPE FOR FUTURE WORK

- a) Studies can be conducted to investigate the combined effect of coir and other natural or synthetic stabilizers on the piping resistance of soil.
- b) Advanced imaging and modelling techniques can be used to visualize and simulate soil piping processes.
- c) The environmental impact of using coir fibre on a large scale can be evaluated.

6. REFERENCES

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