INSIGHTS INTO SOIL BEHAVIOR IN PIPING EROSION

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Abstract: Soil piping is a hidden yet significant form of subsurface erosion, where water flow beneath the ground removes fine soil particles, leading to the formation of underground tunnels or pipes. Theses tunnels weaken the soil structure and can result in land subsidence, sinkholes, gully formation and even structural failures such as dam or levee collapses. Unlike surface erosion, piping is difficult to detect in its early stages, making it a critical concern for geotechnical engineering and environmental management. This review paper explores the fundamental mechanisms of soil piping, with a focus on backward erosion, which is one of the most destructive types. It also examines the various factors influencing piping, including soil type, hydraulic conditions, land use, vegetation and climate. The paper highlights experimental, field and modeling techniques used to study piping behaviour along with modern tools like remote sensing and machine learning for risk assessment. Aditionally,mitigation strategies, including physical barriers, fiber reinforcement and bio-based methods are discussed. Understanding the complexity of soil piping is essential for improving prediction, early detection and designing effective control measures to protect infrastructure and reduce environmental degradation.

IndexTerms - **Soil piping, Backward erosion, subsurface erosion, internal soil erosion, hydraulic gradient**

1.   INTRODUCTION

Soil piping is a process where high water pressure beneath a dike causes erosion of sandy layers, forming underground tunnels. It starts when rising flood levels create strong seepage forces, which can break through the top soil layer and carry sand to the surface. This can lead to backward erosion, where the tunnel grows toward the river, weakening the dike and increasing the risk of failure [1]. Soil piping is a type of subsurface erosion that begins in soil macropores and is often hidden until the surface collapses, forming features like sinkholes or gullies. It involves the underground movement of water and sediments, creating pipe-like channels that can significantly alter the landscape and hydrological conditions and is a major contributor to soil loss in many environments [2]. It is a type of internal erosion where water flow carries fine soil particles through small underground channels. This weakens the soil structure , forming tunnels that can grow and lead to surface damage or dam failure if not controlled [3].

Soil piping is a subsurface erosion process where water creates underground channels, weakening the soil and triggering gully formation and expansion. Common in dryland vertisols, it often causes check dams to fail and accelerates land degradation. Since it contributes more to sediment transport than surface runoff, conventional erosion control methods are usually ineffective, necessitating solutions that also target subsurface flow [4]. It is a hidden form of erosion where subsurface water flow removes soil, forming underground tunnels that contribute to gully formation and land degradation. It commonly occurs in silt-rich soils and is influenced by factors like bulk density, land use and topography. Due to its complexity, machine learning models are used to better predict areas at risk [5]. Backward erosion piping occurs beneath hydraulic structures when seepage initiates at the soil- structure interface and erodes soil backward. This interface has higher void ratios and permeability than the surrounding soil, making it a likely path for seepage. The study found that smoother structural surfaces and looser soil packing increase piping risk, emphasizing the importance of considering interface properties in erosion assessments [6].

Backward erosion piping (BEP) is a hidden levee failure process where seepage removes fine soil particles, forming pipes that progress from the landslide to the waterside. This study presents a physics-based model that accounts for changes in soil properties like porosity and permeability over time, enabling more accurate prediction of BEP progression and associated risks [7]. The study of a landslide in Wayanad Plateau, Kerala, reveals that subsidence and piping , internal erosion by water through cavities in clay-rich soils, play major roles. Vertical electrical sounding (VES) detected low-resistivity zones linked to saturated voids, confirming subsurface piping. This underscores piping's impact on slope failure and shows geophysical methods value in detecting hidden erosion paths [8]. Soil piping is a form of subsurface where water creates underground channels, often leading to land subsidence and slope instability. Common in lateritic and tropical regions like the Southern Western Ghats, it is difficult to detect using surface methods alone. Remote sensing, geomorphological mapping and electrical resistivity to identify and analyse these hidden features for better hazard assessment and management [9].

2. FUNDAMENTALS AND MECHANISMS OF PIPING EROSION

Flooding is the most frequent and costly natural disaster globally, with piping responsible for over half of all flood protection system failures. Among its type, backward erosion piping (BEP) accounts for about one third of these cases. BEP occurs when water flowing over sandy soil gradually removes particles, creating a channel that progresses from the downstream to the upstream side of a structure. This leads to sand boils and focused water flow, often beginning at points of water escape. Despite extensive research, predicting the initiation, growth and size of BEP remains difficult, complicating the design and maintenance of flood protection systems [10]. Soil erosion caused by water, whether on the surface or underground, is a major global environmental issue. While surface erosion is well studied, subsurface erosion, especially soil piping remains under-researched despite its widespread impact. Soil piping occurs across nearly all climate zones and various landscapes, including floodplains, hillslopes, peatlands and riverbanks. It affects multiple soil types such as Xerosols, Luvisols, Histosolos, Gleysols, Cambisols and vertisols, potentially impacting up to 70% of the Earth's land. Piping often forms at soil layer boundaries or where soil meets bedrock and its development is highly variable due to diverse soil properties. This process is hard to observe directly, limiting understanding of its causes, mechanisms and control methods. Its complexity is further increased by influencing factors like land use, vegetation, climate, soil and rock types and topography, making prediction and management difficult [11].

Soil piping is a process where underground water flow creates channels or "pipes" in the soil, leading to erosion and removal of surrounding material. This process can have significant environmental and social impacts. n Italy, piping is commonly found in fine-grained bedrock, such as the Varicoloured clays of Cassio, which appear in different parts of the Apennines. These formations can contribute to gully erosion. Piping also occurs in alluvial deposits where fine and coarse layers alternate, as well as in glacial and other mixed terrains with fractures and joints that allow water infiltration. One example of damage caused by piping in Italy is the "Occhi Pollini" sinkholes, which have formed due to multiple factors and have severely affected residential areas [12]. Soil piping is the process of connecting soil cavities with subterranean water flow. Sinkholes are frequently caused by the network of channels it frequently creates that carry soil particles downslope, accelerating erosion and causing pipe roof collapse. When unstable pipe roofs collapse, the subterranean pipes can become surface gullies, reroute runoff, deplete farmland soil, and harm buildings and infrastructure, contributing to issues like eutrophication. Soil characteristics, catchment water flow, and meteorological factors like temperature and precipitation all affect how soil pipes form and spread. Certain soils, such as silt and swelling-prone clay (like montmorillonite), are especially prone to piping formation [13].

Seepage through saturated soils can wash away fine particles, creating larger voids that weaken the strength and stability of structures like embankments and earth dams, potentially leading to deformation or sinkholes. Internal erosion is a leading cause of embankment dam failures, responsible for about 50% of reported cases. It occurs through four main mechanisms: concentrated leakage, backward erosion, contact erosion and suffusion. Concentrated leakage forms pipe-like channels due to structural flaws, cracks or animal burrows. Backward erosion happens when fast-moving water removes fine particles like sand and silt from the downstream side, creating a channel that can extend upstream. Contact erosion occurs at the boundary of coarse and fine soil layers, where water carries fine particles into coarse voids. Suffusion involves fine particles being transported within the soil matrix. If it alters the soil volume, it can lead to internal instability. Both contact erosion and suffusion may eventually evolve into more severe forms, such as concentrated leaks or backward erosion [14]. The backward erosion piping (BEP) process follows specific steps and requires three key conditions to initiate failure: sufficient hydraulic head, a cohesive roof to prevent pipe collapse, and an open, unfiltered exit for water flow. Internal erosion occurs in four phases: first, erosion begins as seepage removes soil particles; second, backward erosion continues, further eroding the soil; third, a pipe forms and gradually widens; and finally, the structure weakens and starts to break apart, leading to failure [15]. For generations, rivers and the sea have posed a threat to the Netherlands. The Dutch have constructed dikes to defend their territory. One of the various ways dikes can fail is by piping, often known as backward erosion pipe. This occurs when the sand beneath the dike is eroded by groundwater movement. First, the impermeable surface layer breaks as a result of tremendous pressure building up beneath the dike. After this, the pressure differential causes water to start flowing. Sand particles are carried away by the water flow if it is strong enough, progressively weakening the dike [16]. Soil piping is a serious issue, especially in urban areas, as it can pose a threat to public safety. It refers to an erosion process that leads to land subsidence. This happens when
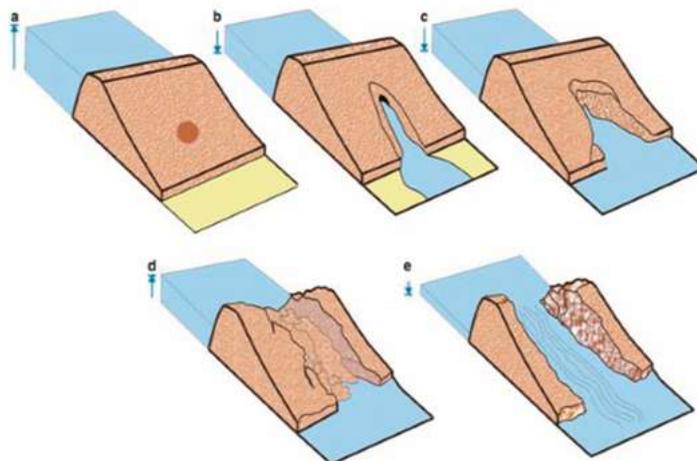

Fig 1: Process where erosion occurs due to water leaking through a
narrow path. [21]

underground soil is washed away by water, forming channels and cavities that can cause the surface layer to collapse. Soil piping can occur naturally or due to human activities. Several factors influence it, including the type and structure of the soil, waterproof urban surfaces, local water flow patterns, increasing underground development, weather conditions, and the hydrogeological properties of

the subsoil [17]. Internal soil erosion is a major concern in geotechnical engineering, triggered when seepage forces dislodge fine particles, potentially causing embankment failures, landslides and environmental damage that threatens human safety. It accounts for about 46% of embankment failures globally but is difficult to detect due to its hidden and gradual nature. Internal erosion includes four types: concentrated leakage, backward erosion, contact erosion and suffusion. Among these, Backward erosion is the most common, responsible for roughly one-third of dam embankment failures. It usually begins with small leaks or cracks that develop into pipes, eventually leading to significant structural damage or total failure[18]. Internal erosion occurs when water flow dislodges soil particles due to seepage forces exceeding the soil's resistance. It affects both natural deposits and man-made structures like embankments and hydraulic fills. Erosion tends to be more severe in areas with high seepage and water velocity. Hydraulic structures are vulnerable to several types of internal erosion, including suffusion, blowout, piping and backward erosion. Piping creates a continuous channel through which water flows, accelerating the erosion of surrounding soil and compromising structural integrity [19].

Internal erosion is a major issue for embankment dams, responsible for 46% of reported failures. It refers to any process where soil particles are removed and transported by water flow within a dam or its foundation. Internal erosion can start due to concentrated leaks, backward erosion (piping), contact erosion, or suffusion. Dispersive soils, which break apart easily in flowing water, are especially prone to erosion and piping [20]. Internal erosion is a major challenge in geotechnical engineering and is one of the leading causes of dam failures. It is generally classified into four types: backward erosion, internal instability, contact erosion, and concentrated leak erosion. While extensive research has been conducted on backward erosion and internal instability, concentrated leak erosion remains difficult to evaluate. When water flow is concentrated at a soil entrance, concentrated leak erosion occurs. Large-scale experiments were utilised in this study to examine the responses of model unsaturated slopes and existing macropores to rainfall and subsurface water flow [21]. Tunnel erosion, also known as piping erosion, is a type of underground soil erosion. It mainly happens in soils with specified features. Natural drains can carry subsurface water. Like surface water, the water can transport soil particles away if it flows quickly enough. These subterranean tunnels get deeper and wider as erosion persists. The soil above becomes weaker as a result, becoming unstable and ultimately causing gully erosion [22]. Internal erosion is a slow, progressive process where fine particles are gradually washed away, compromising the stability of foundations, abutments and embankments. It often goes undetected since underground cavities or sinkholes can from without visible surface signs. Internal erosion includes four types: suffusion, backward erosion, contact erosion and concentrated leak erosion removes larger amounts of soil, forming sinkholes and cavities that severely weaken the structure. Unlike sudden events like earthquakes, internal erosion develops gradually over time [23].

3. FACTORS INFLUENCING PIPING EROSION

Bentonite clay is commonly used as a buffer and backfill in deep geological repositories for high-level radioactive waste due to its ability to swell when wet, low permeability and capacity to slow the movement of radioactive particles. Compacted bentonite blocks are placed in disposal holes, but small gaps called technological voids often remain between the clay and surrounding rock. These voids, typically 10 to 25 mm wide are filled with bentonite granules, pellets or powder. Groundwater can enter these spaces early in washing away some of the material. If water seeps in under high pressure, it can disrupt the swelling process. Although bentonite is meant to swell and form a gel-like barrier, insufficient swelling under pressure can allow water to infiltrate, creating flow paths either within the bentonite or along the bentonite-rock boundary. This phenomenon is known as piping [24].

3.1. Soil Types and Properties

Soil piping has been found in various soil types, including loess-based, organic,clayey and sandy soils. It typically starts when fine particles smaller that the average pore size are present in the soil. As these particles are eroded by water flow, the pore spaces enlarge and begin to connect, forming channels. These channels increase the soil's hydraulic permeability and can also lead to the movement of larger soil particles [25]. The soil is predominantly loess with a sandy loam to silt loam texture. A soil profile analysis indicates that the finer fractions, including clay and silt, along with sodium content, increase with depth. This variation is attributed to local soil evolution processes, primarily influenced by aeolian activity [13]. Drained soil contains a higher concentration of fine particles than the original and water turbidity rises with the amount of soil loss. While turbidity varies by material type, it serves as a useful indicator of erosion. The higher fine particle content in eroded soil also suggests that clay particles are more prone to movement during erosion [26].

3.2. Hydraulic Conditions

Erosion continues when water pressure exceeds the critical threshold, gradually forming tunnels that connect the land to the river. The tunnel size and internal water pressure are key factors in how erosion advances [27]. Pipe initiation, or primary erosion, begins when water and sediment start to flow out at dike exit points or inner corners, forming small tunnels. High water pressure differences can cause soil lifting or quicksand-like conditions. To predict these pressure differences, referred to as the hydraulic dike gradient a resistance equation is used. It includes two key terms: the Shields term, related to sediment movement and the Darcy term, related to water flow through soil [28]. Skempton and Brogan linked the onset of suffusion to a rise in the soil's hydraulic conductivity, identifying a critical point based on water pressure and flow rate. Studies show that as fine particles detach, they can clog pores and reduce water flow. At low hydraulic gradients, water remains clear with no visible particle movement, but higher gradients trigger particle migration and pore blockage. Thus, hydraulic conductivity serves as an indirect indicator of particle movement in soil [29].
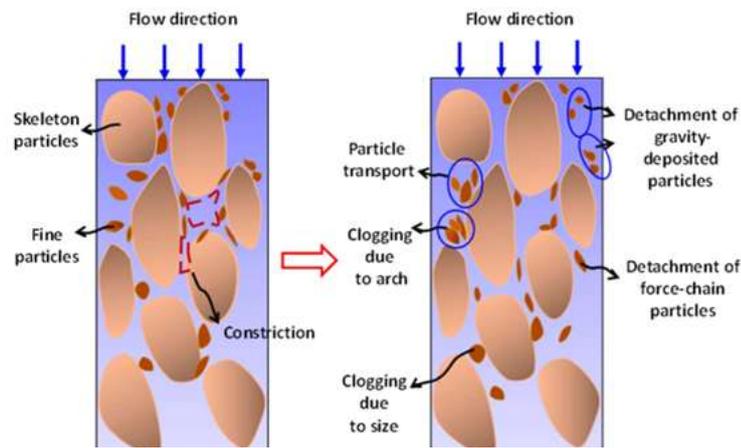
Fig 2:Simple diagram showing how internal erosion happens. [29]

Hydraulic fracture failure is common in dams made of compacted materials. It often begins with uneven settlement due to inconsistent soil compaction across layers. As internal water pressure builds, stress concentrates in weaker zones, such as around enclosed stones. When water level rise, pressure can dislodge soil particles and form channels. This pressure reduces the soil's effective stress, leading to cracks. Hydraulic fracturing occurs when water pressure equals or exceeds the soil's tensile strength [30]. Piping erosion in soil is primarily influenced by hydraulic shaer stress and the coefficient of soil erosion, which depend on factors like flow rate, fluid velocity and soil particle size. Higher shear stress initiates erosion, while stabilizers like lignosulfonate help resist it by increasing soil strength and reducing erosion rates [31].

3.3. Geotechnical and Environmental Factors

Soil piping erosion is mainly influenced by low-permeability soils with shrink-swell potential, such as peats, podzols and clays. Environmental factors like heavy rainfall, steep slopes and high water surplus in upland areas increase its occurrence. Desiccation cracking, especially on sun exposed slopes and poor drainage further promote piping. Vegetation cover and land use affect how and where piping develops [32]. Prolonged rainfall saturates soil, weakening its structure and raising erosion risk. In contrast, dry periods cause soil to shrink and crack, forming pathways for water during rewetting. Vegetation roots can stabilize soil, but their removal heightens erosion vulnerability. Fluctuations in the water table affect soil saturation and permeability, influencing erosion patterns. Additionally, climate factors like rising temperatures, sea-level rise and extreme weather events alter moisture and hydraulic conditions, further increasing erosion threats [33].

Piping erosion is mainly influenced by soil properties like specific gravity, void ratio, particle size distribution and friction. Soils with higher density, lower void ratio and a wider particle size range show greater resistance. Friction between particles and with container walls along with the soil's shape and aspect ratio also affect the critical hydraulic gradient needed to trigger piping. Environmental water flow conditions, reflected through hydraulic gradients play a key role in its initiation and progression [34].
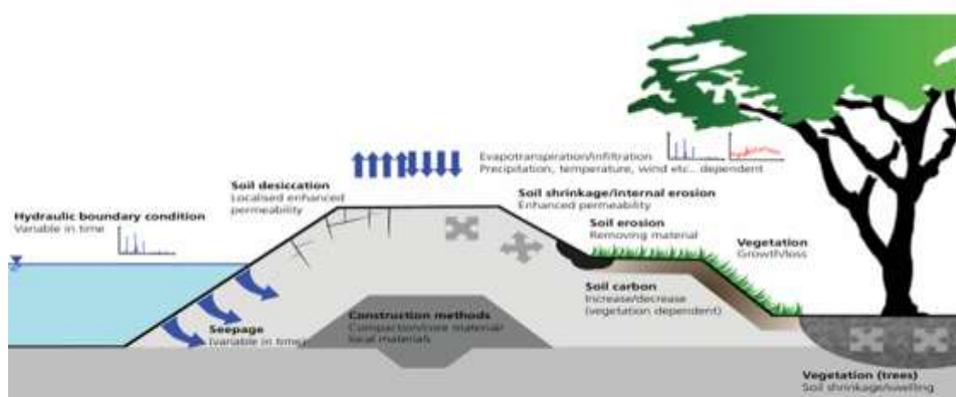

Fig 3: Geotechnical structures and how they may be affected by climate conditions. [33]

4. ANALYTICAL AND EXPERIMENTAL TECHNIQUES FOR PIPING EROSION EVALUATION

4.1. Laboratory Testing Methods

The test involved placing soil in 1.2 cm layers into a sample holder and compacting each layer by tapping with a metal rod. The sample was sealed with pressure cells, bolts and a rubber gasket, then flushed with CO_2, placed under partial vacuum and saturated with deaired water from the top. After full saturation, a backpressure of 103kPa (15 psi) was applied. The test began without a pressure difference, then pressure was gradually increased from below until sand movement occurred. At each stage, pressure was paused for stabilisation, then increased in 2.5 cm increments until the sample failed and significant soil loss occurred [35]. Laboratory pipe erosion tests were conducted on streambank soils from Dry Creek, Mississippi (silty clay loam) and Cow Creek, Oklahoma (fine sandy loam). Standard ASTM tests like liquid limit, plastic limit and compaction were performed. Soil was compacted in a Plexiglas

box (50 x 50 x50 cm) to match field densities 1.6 g/cm³ for Dry Creek and 1.5 g/cm³ Cow Creek at near-optimal moisture (13-15%) to promote erodibility. A 1cm rod placed 5cm above the base was removed after packing to create a continuous soil pipe. A constant water head was applied to mimic hillslope and streambank conditions, though maintaining it was difficult due to pipe enlargement from erosion. Water and sediment exiting the piping were measured every five seconds using a flume and scale. Sediment samples were taken regularly and sediment weight was considered in water flow calculations. In some cases, expandable foam was used to preserve the pipe shape, which was measured with callipers after drying [36].

The testing process followed a systematic approach. Soil was placed into a sample holder in 1.2 cm layers and compacted using a metal rod. Silicon sheets and a lid were added, and further compaction was done by pressing the lid to ensure uniform density. The sample was then saturated under partial vacuum by flushing with CO_2 and slowly filling with deaired water from the bottom. Pore pressure of 103kPa was applied for full saturation. Before testing, a video recorder and data logger were started. Water pressure was initially equal on both sides, then gradually increased first by 1.2 cm to initiate sand movement, then by 0.6 cm increments, allowing stabilisation at each stage. The test continued until the sample failed or stabilised under maximum pressure [37]. Three types of uniform sand from a local quarry were tested to examine the effect of porosity on erosion. Sand was poured into a vertical box with varying compaction times (0-60 seconds) to achieve different porosities. After placing a gravel layer and securing the upstream wall, the sand length was measured to calculate porosity and bulk density. The box was then rotated horizontally, a seepage pipe was formed and water connections were installed. The sample was slowly saturated. Gradual water seepage was applied by raising the tank with 15-minute intervals for stabilisation and initial isolated particle detachment during pipe formation was ignored. Piezometers and pressure sensors recorded head and gradient data and outflow was measured. Erosion began at the pipe tip once critical pressure was reached. A camera tracked pipe development and eroded sediment was collected, dried and weighed. Results were validated by comparing sediment mass with measured pipe volumes [38].

4.2. Field Investigation Methods

Piping is often associated with dispersive soils, typically influenced by exchangeable sodium and electrical conductivity. However, the loess-derived soils in this study lack exchangeable sodium. To evaluate dispersion potential in compacted fine-grained soils, tests like the crumb test, dispersive test and pinhole test are commonly used. The pinhole test, developed and standardized in ASTM D4647 (2006), is specifically used to identify highly erodible, sodium-rich soils, especially for earth dam assessments. In this test, distilled water is forced through a 1 mm hole in a soil sample under increasing hydraulic heads (50-1020 mm), with flow maintained for 5-10 minutes at each stage to stimulate leak conditions. The test is highly repeatable and results are classified into six categories based on flow rate, effluent clarity and hole enlargement [39].

In the Flemish Ardennes, field tests on 12 soil profiles and auguring at 29 pastures showed that piping erosion strongly influenced by deep biological activity mainly earthworm and mole channels and shallow stable groundwater tables. While no clear differences in soil texture or density were found at pipe depths, pastures with collapsed pipes had significantly more bio pores, which along with high groundwater levels, enhanced conditions for pipe formation [40]. On the Loess Plateau, field test using water injection into sinkholes revealed that tunnel erosion occurs in stages starting with a lag, followed by stable flow, then decline. Erosion was mainly caused by waterfall, lateral and headward actions, with the highest sediment loss at the start. The erosion rate increased with water flow, showing that loess tunnel erosion is flow-dependent and periodic in nature [41].

4.3. Numerical and Theoretical Approaches

In recent years, various multiscale experiments and models have advanced the understanding of backward erosion piping (BEP), Numerical models fall into three main types: treating the piping zone as a highly permeable porous medium, simulating particle-scale interactions using the Discrete Element Method (DEM) and separating the system into soil skeleton, fine particles and pore water phases. While the latter two offer detailed insights, they are computationally intensive and less suitable for practical use. A new model, based on the porous medium approach, integrates sediment transport with time-dependent seepage equations. Using 2D finite element analysis, COMSOL Multiphysics, it effectively simulates erosion channel development up to reservoir breakthrough, but does not model pipe enlargement or dike collapse [42]. The numerical model is based on DgFlow, a finite framework for simulating backward erosion piping (BEP) in 2D and 3D soil systems. It's 2D version, D-GeoFlow, is used in the Netherlands for levee safety assessments. Initially focused on secondary (bed) erosion, DgFlow now also includes (tip) erosion. The model operates under equilibrium conditions, identifying the critical head difference and pipe size required for BEP, but it does not simulate erosion over time. This study introduces a time-dependent component to capture the gradual nature of erosion. DgFlow integrates 3D transient seepage flow, steady 1D laminar pipe flow and a grain stability criterion to simulate pipe formation under a given head. Pore pressure is calculated using groundwater flow equations based on Darcy's law and mass conservation. Pipe flow follows Poiseuille flow principles, linking flow rate, water depth and hydraulic gradient. Since groundwater and pipe flow equations share a similar structure, pipe flow incorporated using an equivalent permeability approach [43].

5. MITIGATION AND CONTROL STRATEGIES

Piping erosion can be influenced by altering subsurface flow paths using sewer pipes embedded beneath flood defences. The study found that the impact of these structures on safety depends on their size and placement. When positioned near the erosion channel tip and close to the flood defence base, sewer pipes help redirect groundwater flow, lowering the pressure gradient that drives erosion and enhancing stability. A probabilistic analysis using finite element models and neural network emulators showed that, especially in deeper aquifers, well-placed sewer pipes generally improve resistance to piping. Overall, the research highlights that strategic pipe placement can effectively reduce erosion risk [44]. Piping erosion can be mitigated by reinforcing silty sand with randomly distributed synthetic fibres, such as polyethylene and polyester. Experiments showed that fibre addition significantly reduced seepage velocity, raised the critical hydraulic gradient and improved resistance to piping. These effects increased with higher fibre content. The fibres helped by restricting soil particle movement and enhancing soil shear strength, effectively delaying erosion onset. [45].Piping erosion can be controlled using traditional methods like filters, cutoff walls and drainage systems. Recently, bio-based strategies using organic

matter or biological substances such as polysaccharides and glomalin have shown promise in reducing erosion by improving soil stability, though they may impact soil strength and permeability [46].

6.   CASE STUDIES

A case study in Idukki district, Kerala, documented seven soil piping incidents between August 2010 and august 2011. Four sites, Kulamavu, Peringassery, Udayagiri and Thattekkanni were analysed for physical, chemical, geological and hydrological factors. Despite variations in soil properties, common triggers included steep slopes, intense short-term rainfall, structural geological features like joints and lineaments and in some cases, high soil sodium levels. Earthquake-induced subsurface dilation was also considered a possible contributor. The study concluded that piping erosion can occur under diverse soil conditions when driven by a combination of hydrological, geological and tectonic influences [47]. A case study in southeast Spain's Mula basin examined piping erosion in abandoned agricultural terraces once used for cereals and almonds. Built on dispersive marl soils with high sodium content, the terraces were eventually abandoned due to severe, irreversible erosion. Terracing unintentionally worsened piping by reducing soil bulk density and increasing hydraulic gradients, promoting subsurface flow and soil dispersion. Key factors influencing pipe formation included terrace height, low organic matter, high exchangeable measure, terracing in this context increased erosion risk [48].

A case study in the Chaco Plain, northwestern Argentina, invested piping erosion in agricultural lands with loess-derived, collapsible soils and gentle slopes (1-3%). Summer storms triggered rapid wetting, causing the porous soils structure to collapse, leading to pipe formation, sinkholes and gullies. Contributing factors included low-density loessic soils, weak clay-silt aggregates and biological activity, particularly from burrowing animals. Piping was most severe under pastures and resulted in significant soil loss, turning productive farmland into degraded land [49]. In the Flemish Ardennes, Belgium, a case study mapped 560 collapsed soil pipes mostly on pastures with slopes over 8%. Piping was linked to concave slopes and areas where loess overlays clay-rich layers like the Aalbeke Member. The study used field surveys and LiDAR data, showing that slope and drainage area strongly influence piping occurrence. [50].
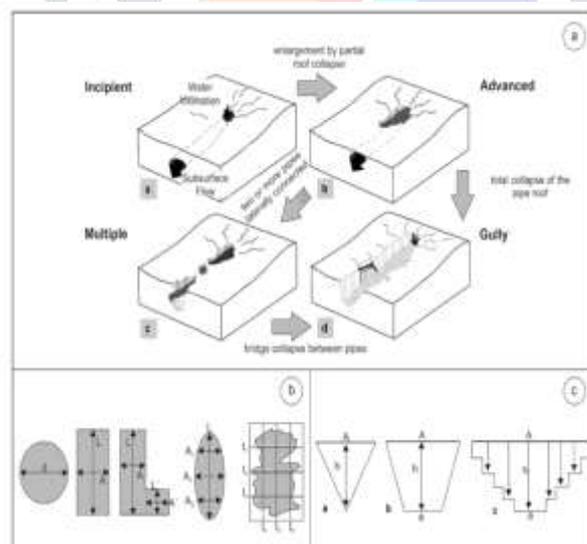

Fig 4: (a) Classification of pipe collapses based on their development stages. (b) Types of surface features seen in soil pipe collapses and how to etimate their area. (c) estimating the average depth of pipe collapses using similar geometric shapes. [49]

7.   CONCLUSION

Soil piping is a major concern in geotechnical engineering due to its hidden nature and severe impact on soil stability and infrastructure safety. It contributes significantly to land degradation and structural failure, especially in areas with loose, fine soils and high water pressure. Effective assessment of piping requires a combination of laboratory tests, field investigation and numerical models. Control measures like filters, reinforced soils show promising results. Aditionally, remote sensing and geophysical methods enhance detection capabilities. Improved awareness, early diagnosis and preventive strategies are key to reducing risks and protecting land and infrastructure from the long term effects of piping erosion.

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