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A Review on Effects and Control of Seepage through Earth-fill Dam

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

All earthfill dams have seepage from water percolating slowly through the dam and its foundation. Many seepage problems and failure of earth-fill dams have occurred because of inadequate seepage control measures. This study was reviewed the conditions, causes, and effects of seepage and control measures in the earth dam. Types of earth dams such as homogeneous embankment, zoned embankment and diaphragm embankment well were highlighted. Seepage conditions, such as rapid water level decreases or the water falling below the level expected with normal use (sudden drawdown condition), wet spots and aquatic vegetation (like cattails) below the dam; causes, such as poor compaction of environment soil, poor foundation and abutment preparation, Rodent holes, Rooted tree roots and wood and so no and effects due to piping, internal erosion, solutioning, internal pressure and saturation and uplift, heave and blowout were highlighted. This study also examines the control measures included cut-offs; upstream clay blanket; filter blanket; seepage drains; berms and loading berm; upstream and downstream slope protections; And relief well. Besides, in order to keep continuous watch on the health of dam and monitor that is, take curative

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steps before failure occurs., instruments such as pore pressure, settlement gauges, horizontal movement devices, and seismic activity measurements should be embedded into the dam were mentioned.

Keywords: Earth dam; seepage; dam failure; piping; effects and control of seepage.

1. INTRODUCTION

Water is essential for life; However, too much in the wrong places under the wrong conditions could have detrimental effects. It is one of the most power forces of nature. It hides in rock crevices and soil pores, under the down pull of the force of gravity, it exerts unbelievable forces that tear down mountain sides and destroy engineering structures [1]. Soil and Water Engineers, structural Engineers, highway Engineers, dam designers and builders and many others have known the great importance of controlling water in pores and cracks in earth and rock formation. A dam is a hydraulic structure of fairly impervious material built across a river to create a reservoir on its upstream side for impounding water for various purposes [2]. These purposes may be irrigation, hydropower, water-supply, flood control, navigation, fishing and recreation. Dams may be built to meet the one of the above purposes or they may be constructed fulfilling more than one. As such, dam can be classified as: Single-purpose and Multipurpose dam. A dam can also be defined as a barrier that blocks the flow of water and produces a reservoir. A dam and a reservoir are complements of each other [3].Dam's failures and incidences have been taking place all over the world over a long period of time in history. Reports on failure of dams are common things nowadays. Effects of dam's failure on man and environment are well known. These require both preventive and mitigation measures. Dam failures may occur due to a variety of causes. The most common causes of dam failure are leakage and piping (35%), overtopping (25%), spillway erosion (14%), excessive deformation (11%), sliding (10%), gate failure (2%), faulty construction (2%), and earthquake instability (2%) [4]. [5] reported that about 40%, 25% and 35% of failures of earth dams are due to hydraulic, structural and seepage failures respectively. Investigations carried out by [3] also showed that about 35%, 30% and 20% of failures of earth dams are due to hydraulic, seepage and structural failures respectively, while there remaining 7% of the failures are due to other miscellaneous causes such as accidents and natural disasters (external causes).Seepage failure was due to lack of monitoring and instrumentation to detect earlier symptoms before failure occurred [6].

One of the main causes of earth dam failures all over the world was the so called piping event, which occurs due to the constant migration of soil particles towards free exits, or into coarse openings; this event might occur through the earth embankment or its foundation soil [7]. Another cause of constant earth structure failures was due to uncontrolled saturation and seepage forces. In this context, phenomena known as drawdown, which occur in earth structures subjected to sudden changes of water level (decrements) that modify flow conditions inside a soil mass, are assessed. Among these factors are: a) the erodibility of the soil; b) the water velocity inside the soil mass; c) geometry of the earth structure [8]. Other important factors are the homogeneity or anisotropy of the earth structure and its foundation soil, the soil graduation and degree of compaction of the materials used during the construction process; the hydraulic conductivity of such materials, the upstream water energy head, as well as the hydraulic gradient.

Researchers like [1,8-14] reported that erosion in earth structures due to water flow occurs when the soil resistant forces are less than the seepage forces that tend to produce it, in such a way that the soil particles are removed and carried with the water flow. The soil resistant forces depend on the cohesion, the interlocking effect, the weight of the soil particles and the kind of protection they have downstream, if any. Since the seepage through an earth structure is not uniform, the erosion phenomenon increases where there exists a concentration of seepage and water velocity; in places where this concentration emerges at the downstream side, the erosive forces on the soil particles might become very significant. This erosion process might occur at any crack that exists in the earth structure, due to differential settlements, seismic movements, tension stresses, or holes caused by dry roots or gnawing animals (rabbits, rats, and so on). The existence of cracks was also due to shrinkage drying or swelling due to saturation. Favourable internal erosion conditions also exist in contacts between soils and rigid walls, concrete structures, interface with bedrock foundation, and others. Areas where ark effect is present are also very susceptible to internal. The erosion starts at any point where the seepage water discharges and works toward the reservoir, gradually enlarging the seepage channel [7]. Depending of the stage of this process, the occurred damage might be classified as a simple "incident", an accident, or a complete failure. . The main focus of this study is a summary of a review into earth dam and seepage, presenting basic seepage conditions, causes, effects in the dam and methods to control seepage in the dam

2. MATERIALS AND METHODS

Literature review on earth dam and seepage, personal observations on earth dam and group discussion are the materials used for this study.

2.1 Earthfill Dams

Earthfill dams are simple structures which stand on their self-weight to prevent the sliding and overturning [3]. These dams are the most common type of dams known in the world. At the earlier time the earth fill dams are constructed to divert massive water body and protect the community. Later it was structurally improved and used to construct the reservoirs. Small earth fill dams contain a variety of advantages in both technically and economically. They are [9,15]:

(i) Construction materials are readily available
(ii) Simple design criteria
(iii) Less foundation preparation required when compared with other dams.
(iv) Quiet flexible than other rigid dam structures and suitable for seismic sensitive regions.

On the other hand, there are some disadvantages when compared with other dam types [15].

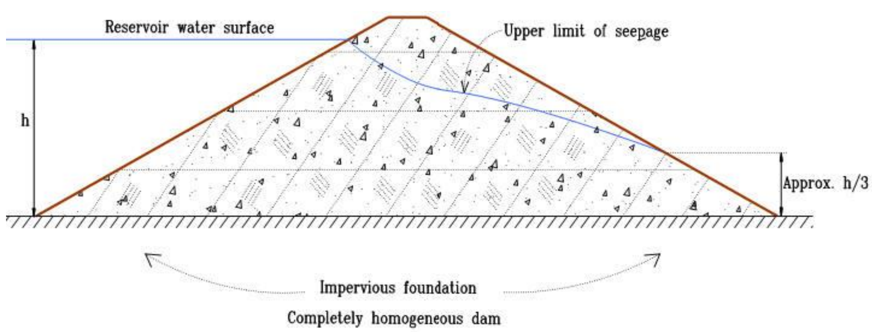
(i) Higher possibility to damage or slide than other dam types
(ii) Lack of compaction of material leads to increased seepage
(iii) Continuous monitoring and assessment needed to prevent slope erosion, abnormal seepage and growing plants.

An earth dam is made of earth (or soil) built up by compacting successive layers of earth, using the most impervious materials to form a core and placing more permeable substances on the upstream and downstream sides. The earthen dam can be of the following three types:

Homogeneous Embankment, Zoned Embankment and Diaphragm Embankment

2.1.1 Homogeneous embankment type

This is the simplest type of an earthen embankment consists of a single material and homogeneous throughout (Fig.1). A purely homogeneous section is used, when only one type of material is economically or locally available. Such a section is used for low to moderately high dams and levees. Large dams are seldom designed as homogeneous embankments. [1,2] reported that a purely homogeneous section usually prone to the problems of seepage, and huge sections are



Seepage flow through earth dam with no filter at the dam toe

Fig. 1: Homogeneous embankment type
Sources: Flores-Berrones et al. [11]

required to make it safe against piping and stability. Internal drainage systems are always provided in almost all types of embankments. Low dams are always constructed as homogeneous dams. Because by making zones, cost will increase due to complication in construction.

2.1.2 Zoned embankment type

Zone embankment is usually provided with a central impervious core, covered by a comparatively pervious transition zone, which was finally surrounded by a much more pervious outer zone (Fig. 2a and b).In zoned dams, generally, the well-drained materials such as coarse sands and gravels are placed in the outer shells whereas the clay soil was placed in the central zone. This will increase the water tightness of the dam. The shells provide main strength to the dam embankment. This type of embankment was widely constructed and the materials of the zones are selected depending upon their availabilities.

2.1.3 Diaphragm embankment type

Diaphragm type embankment has a thin impervious core,which was surrounded by earth or roch fill (Fig. 3). The impervious core, called diaphragm, was made of impervious soils, concrete, steel, timber or any other material. It acts as a water barrier to prevent seepage through the dam. The diaphragm type of embankment was differentiated from zoned embankment, depending upon the thickness of the core. If the thickness of the diaphragm at any elevation is less than the height of the embankment, the dam embankment is considered to be 'Diaphragm Type'. But if the thickness equals or exceeds this limit, it is considered to be zoned embankment type.

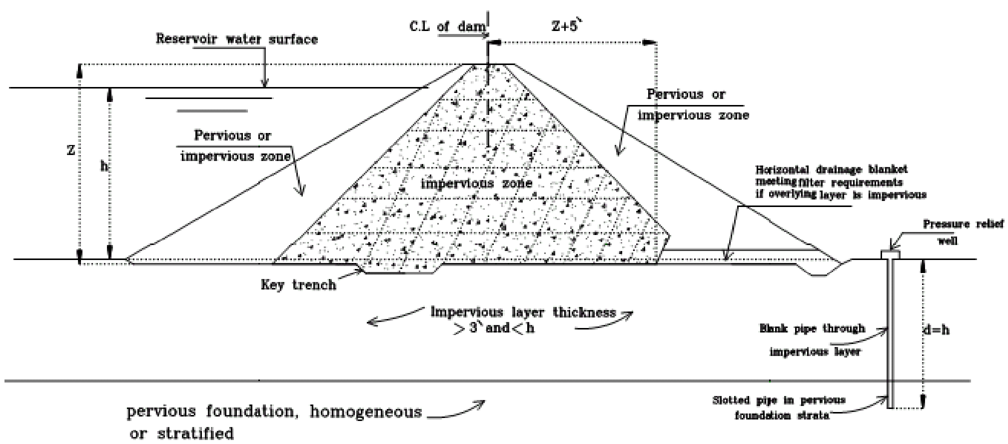


Fig.2a: Zoned Embankment type
Sources: Flores-Berrones et al. [11]

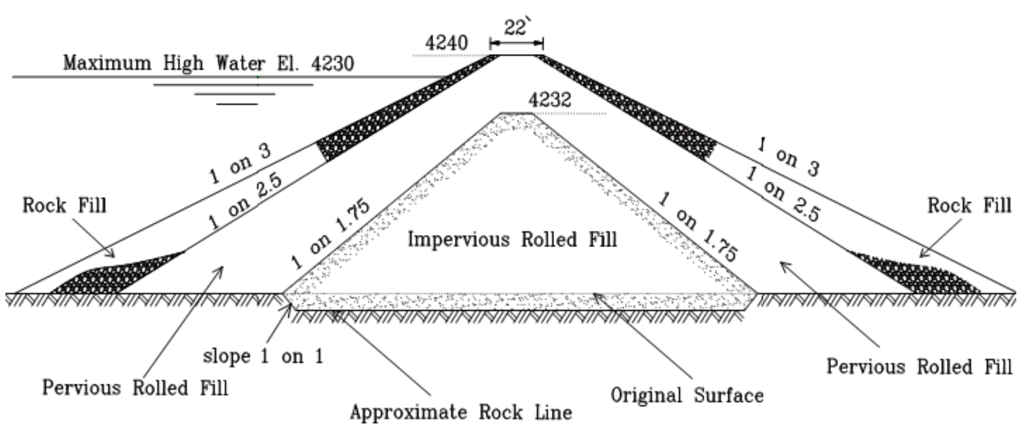


Fig.2b: Zoned Embankment type
Sources: Flores-Berrones et al. [11]

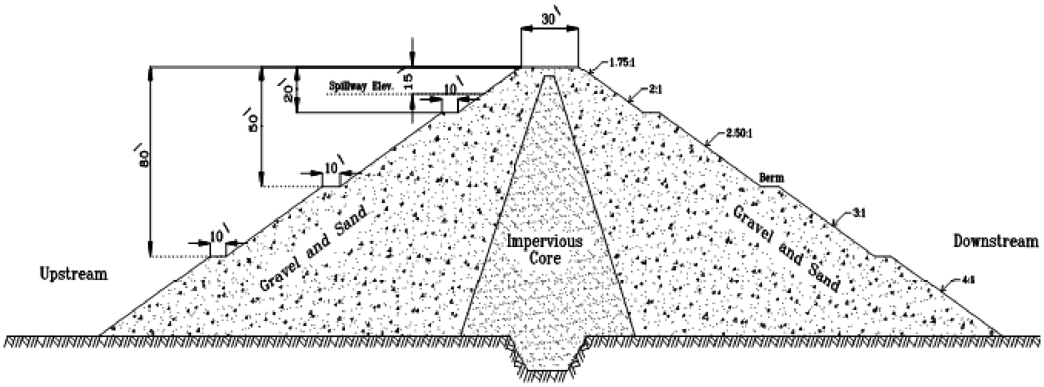


Fig. 3: Diaphragm embankmemt type
Sources: Flores-Berrones et al. [11]

2.2 Seepage

Seepage, in soil engineering, is the movement of water in soils, often a critical problem in building foundations. Seepage depends on several factors, including permeability of the soil and the pressure gradient, essentially the combination of forces acting on water through gravity and other factors. Permeability can vary over a wide range, depending on soil structure and composition, making possible the safe design of such structures as earthen dams and reservoirs with negligible leakage loss, and other structures such as roadbeds and filtration beds in which rapid drainage is desirable. Seepage always occurs in the dams, if the magnitude is within design limits, it may not harm the stability of the dam. However, if seepage is concentrated or uncontrolled beyond limits, it will lead to water loss, reducing shear strength and could lead to failure of the dam. Piping is one of the types of seepage failure. Piping occurs when reservoir water moving through the pores of the soil (i.e., seepage) exerts a tractive force on the soil particles through which it is flowing, sufficient to remove them at an unprotected exit point of the seepage [12]. The initial physical expression of piping is often a cone shaped mound of soil called a boil or a stream of muddy water exiting in the slope. The removal of soil may progress upstream forming a characteristic open tube or “pipe” through the dam, from which the phenomenon derives its name. Water stored behind a dam always seeks to escape or flow along the path of least resistance. This route may be through the dam, beneath it, or around it. Seepage conditions, causes, effects and control were highlighted by [16,6,9-12].

2.2.1 Conditions of seepage

All earth dams have seepage from water percolating slowly through the dam and its foundation. Most dams have some seepage through or around the environment as a result of water moving through the soil structure. If the seepage forces are large enough soil could be eroded from the environment or foundation. Seepage can also develop behind or breathe concrete spillways or headwalls. The signs of this type of problems could be cracking or leaving. The rate at which water moves depends on the type of soil in the environment, how well it is compacted, and the number and size of cracks and voids within the environment. Saturation of environment soils, abutments and foundation due to seepage generally result in reduced soil strength leading to sloughing, sliding and instability. In the worst case, seepage can result in total environment failure if situation is not monitored. Many seepage problems and failure of earth dams have occurred because of inadequate seepage control measures or poor clean up and preparation of the foundations and abutments. Seepage could lead to dam failure. Soil piping occurs when materials are washed out at the base of the downstream face causing a hole to form underneath the dam. The whole was enlarged as more material was washed out by water flow, which increases due to the shorter flow path that gradually developed. Eventually a tunnel or pipe was created within the soil under the dam from the downstream to the upstream face which causes a collapse of the dam environment. Excessive seepage not picked up by an embankment or foundation drain will be noticed as wetness, spring or boils on the lower back slope and toe of the dam. A change in vegetation is another indicator of seepage. Areas with water-loving plant such as cattails, reeds and mosses or with normal vegetation than is greener and lush than adjacent vegetation should be checked for seepage. Seepage may be difficult to spot due to vegetation. Probing the soil in suspect areas could help to locate and identify whether seepage is present and the limits of the problems. Differences in vegetation and flowing water on the downstream side of embankments are the two most noticeable signs of seepage. Others recognisable sign of seepage areas follows:

(1) The most recognisable sign of seepage israpid water level decreases or the water falling below the level (sudden drawdown condition) expected with normal use. Wet spots and aquatic vegetation (like cattails) below the dam.
(2) A portion or large portion of water gets accumulated in the adjoining area of dam site.
(3) The adjoining land shown different colours and growth rate of vegetation of the same type.
(4) Variation in electrical conductivity and temperature of water at different locations of same depth of water. The seepage flow causes a seasonal temperature variation inside the dam. This seasonal temperature variation can be measured in the dam and used to evaluate the seepage flow through the dam.
(5) Development of water logging and salinity in nearby areas (land)
(6) Clean water is seen flowing in seepage toe drain shows no internal cracking while turbid water indicates internal cracking [17,6].

2.2.2 Causes of seepage

Poor compaction of environment soil; poor foundation and abutment preparation; rodent holes; rooted tree roots and wood; open scams; cracks; joints in rocks in dam; coarse gravel or sand in the foundation or abutment; dogging of coarse drains; filter or drains with pores so large soil can pass through; frost action; shrinkage cracking in the environment soil; settlement of environment soil; uprooted trees; earthquakes; insufficient structural drainage; trapped groundwater; excessive uplift pressure [18,9,12, 2,4].

2.2.3 Effects of seepage

Seepage causing problems that can lead to dam failure are classified as follows:

(i) Piping. (ii) Internal erosion. (iii) Solutioning of soluble rock. (iv).excessive internal pressures and/or saturation (v) and Excessive uplift, heave, or blowout

2.2.3.1Piping

There are two types of piping

(i) **Piping through dam body:** This is occurred when seepage starts through the body of the dam due to poor soils, formed small channels which transport material downstream [19]. The channels (hollows) continued glow bigger and bigger as more materials are transported downstream which could lead to wash out of dam body, and subsequent subsidence of the dam (Fig. 4). These flow channels may develop due to faulty construction, insufficient compaction, cracks developed in embankment due to foundation settlement, shrinkage cracks and animal burrows.
(ii) **Piping through foundation:** Sometimes, when highly permeable cavities or fissures or strata of gravel or coarse sand are present in the foundation of the dam, water may start seeping at a huge rate through them (Fig.5). This concentrated flow at a high gradient, may erode the soil. This leads to increased flow of water and soil, ultimately resulting in a rush of water and soil, thereby creating hollows below the foundation. The dam may sink down into hollow so formed, causing its failure [19].

Other forms of piping include movement of materials across internal material zone boundaries where proper filter protection was not provided. This movement often happens between fine grained core materials and rock-fill or coarse gravel. The movement of embankment soil into untreated foundation rock openings was another possible type of piping failure. Five conditions must exist for piping to occur:

1. There must be a flow path/source of water.
2. The hydraulic gradient must exceed a certain threshold value that is dependent on the type of soil through which the flow path travels.
3. There must be an unprotected exit (open, unfiltered) from which material can escape.
4. Soils that are susceptible to piping must occur within the flow path near the dischargepoint of the seepage.

5. The material being piped or the soil directly above it must be able to form and support a"roof" to keep the pipe open [18,9,7,12].

When:

- Seepage occurs through soil layers that are susceptible to piping and seepage reductionmethods are not used to reduce the hydraulic gradient that causes piping, or
- Filters and pressure relief measures are not used at seepage discharge points to preventthe particle movement of susceptible soils, or
- Seepage reduction measures are not properly maintained [9,12].

Soils most susceptible to piping are loose, poorly graded fine sands. Also highly susceptible are silts and sands with low-plasticity fines (Plasticity Index less than 6), as well as loose, well graded sand and gravel mixtures that are very broadly graded and have low-plasticity fines [19].

2.2.3.2 Internal erosion

A failure resulting from internal erosion may appear similar to a piping failure.

Internal erosion and backward piping erosion are used to describe failure mechanisms of embarkment dams associated with the uncontrolled flow of water rather than the single term piping. These terms describe the distinctly different mechanisms by which water can damage embarkment dams.

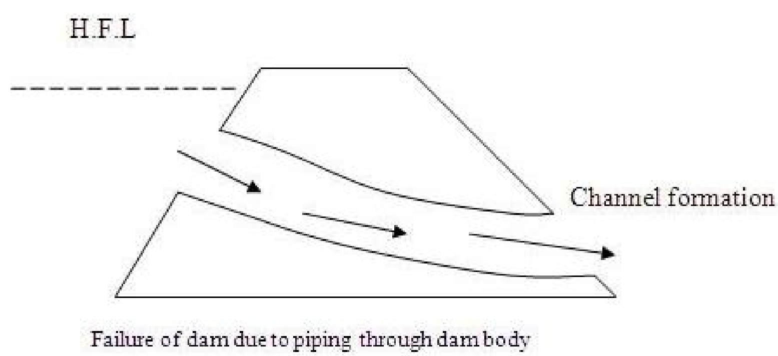


Fig. 4: Piping through the dam body
Source: Federal energy regulatory commission, [9]

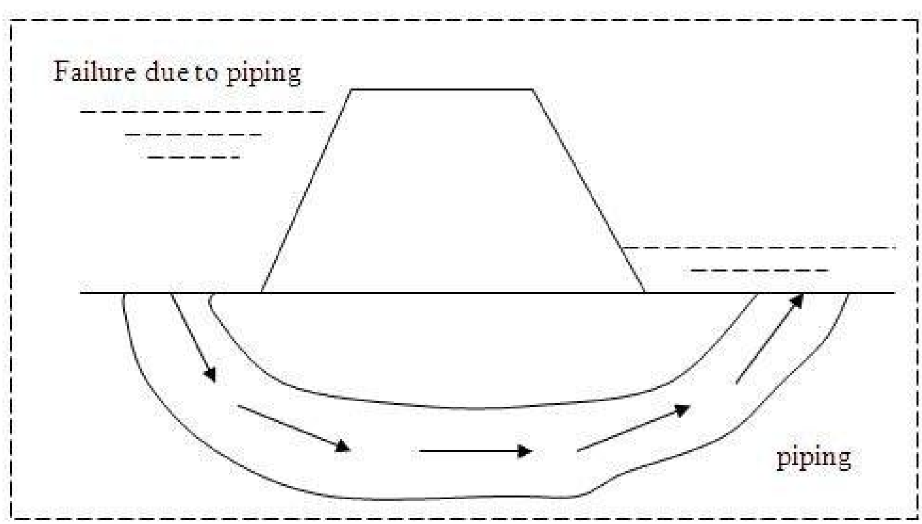


Fig. 5: Piping through dam foundation
Source: Federal Energy Regulatory Commission, [9]

However, the mechanisms of backward piping and internal erosion failures are very different. In both cases the seepage forces of high gradient flow move particles. In the case of backward piping is caused solely by intergranular flow causing excessive seepage forces at an exit face. These seepage forces cause a boil condition or particle detachment at an exit face, if it is not protected by a properly designed filter. Internal erosion, on the other hand, describes the common way that water can damage embarkment dams and it occurs when water flows:

- Along cracks or other defects in the soil or bedrock in the cross-section.
- Along boundaries between soil and bedrock.
- Between soil and concrete or metal appurtenances [9,7,12].

Internal erosion failures are most common in areas where hydraulic fracturing can occur [9,12]. Prime areas for hydraulic fracturing are as follows:

(a) **Slicken slides:** If the clayey soil is over compacted by smooth rollers, when moisture is more, the upper layer will not be bounded properly with the lower layer.
(b) **Careless construction:** Casing or pervious material may be wrongly dumped or may spill over the trucks during transport across the hearting, forming a pervious layer connecting upstream and downstream casing; and over compaction due to the passage of loaded trucks and scrapers along service roads may cause a blind drain.
(c) **Cracks:** Cracks may be developed due to differential settlement of foundation in some part of the dam or due to shrinkage in clayey soils on drying. Water can form a drain through these cracks.
(d) **Horizontal piping:** This results in the gradual formation of a drain from downstream and upstream through which water in the dam erodes its way under the high head, carrying soil particles in increasing quantities [6,9].

2.2.3.3 Solutioning

Seepage causing problems can arise in foundations or abutments where water-soluble rock can be dissolved by ground water or reservoir seepage. At earth's surface rain fall can dissolved the soluble rocks in the zone above the water table by percolating water and below the water table by groundwater in motion. Materials susceptible to solutioning include minerals such as gypsum, anhydrite and halite (rock salts) and limestone rock. Solutioning enhanced internal erosion as well as piping. Dam to be constructed on material that can be affected by solutioning such as limestone should always be treated with extreme caution. In addition, gypsum, halite, and a few similar minerals are so soluble that severe solutioning and distress can occur during the life of a project. The failure of Quail Creek Dike is one of the failures caused by solutioning. It is has been identified that arid areas may contain considerable amounts of soluble alts that can be dissolved by seepage. This dissolving of salts may lead to loss of density, volume, and strength [9,11].

2.2.3.4 Internal pressures and saturations

When water is stored in the dam as reservoir, seepage takes place through the body and the foundation soil of the dam. This seepage causing problem has the following adverse effects:

> (i) loss of water, (ii) pore pressure, reducing the shear strength, (iii) piping-horizontal, if through the body of the dam and vertical, if through the previous soil in foundation between ground level and the previous strata below.(iv) sloughing of downstream side of dam and (v) Shear slides in foundation soil [6,9].

The pore pressure is required in stability analysis as overturning force. The weight, in turn depends upon saturation (full or partial) of the soil.

Progressive sloughing is a type of damage that results from both saturation and the seepage forces' effect on stability. Progressive sloughing starts when a small quantity of material erodes at the downstream toe and produces a small slump. This leaves an over-steepened face, known as a scarp, which slumps again forming a higher unstable scarp. The process of failure due to sloughing begins when the downstream toe of the dam becomes saturated and begins getting eroded causing small slump or slide of dam. The process of saturation and slumping continues, until the dam becomes too thin to withstand the water pressure and leading to failure of dam [9].

2.2.3.5 Uplift, heave, or blowout

It is one of the symptoms of internal pressures and saturations. It is occurred when the foundation seepage pressure in pervious layers exerts an excessive force on an overlying confining layer. Failure starts when the pore pressure on the bottom of the confining layer exceeds the overburden pressure created by the weight of overlying soils. The resulting uplift eventually breaches or breaks through the confining layer in what is known as a blowout, commonly forming a sand boil [9].

2.2.4 Controlling seepage

[7,8] highlighted that regularly scheduled monitoring and inspection is essential to detect seepage and prevent dam failure. Inspection should be made periodically throughout the year. Frequency should be based on hazard classification of the dam. Higher classified dams should be checked more common compared to those that are lower hazard classified. At a minimum all dams should be visually inspected at least every six months, before a predicted major storm event, during or after severe rainstorms or snowmelts, and inspected weekly after construction is complete and reservoir has been filled. If seepage is detected on a dam embankment or foundation, it should be closely monitored on a regular basis until it is corrected. If seepage flows increases or embankment soil are showing signs of instability, corrective action should be taken quickly. A qualified geotechnical engineer or dam safety professional should be contacted for inspection and advice for all high dam seepage problems. The reservoir level should be lowered if serious piping or embankment sledding or sloughing is occurring. Sloughing and sliding due to seepage at the two of the embankment may be corrected by removing the unstable soil and constructing a two drain with filter out of permeable soil. Seepage, piping and boils in existing dams may be corrected or slowed by intercepting the water before it exits on the downstream side of the dam. Some typical methods of intercepting include impermeable upstream blankets, cut-off trenches, in the embankment, grout curtains, relief wells, and toe drains. Impermeable upstream blankets or liners are the most effective method, but require complete drawdown or the reservoir. These blankets may consist of low-permeability soil or a synthetic geo-membrane. The blankets may be deployed on the floor of the reservoir to prevent foundation seepage. All cracks and erosion rills on the embankment should be filled, re-graded and re-seeded. Borrowing rodents should be eliminated from dams and any damage created should be repaired by back filling a soil or filtered drain.

2.3 Instrumentation

In order to keep continuous watch on the health of dam, instruments should be embedded into the dam. The main purpose of this is to observe the health of the dam and monitor that is take curative steps before failure occurs. The important characteristics to be observed are pore pressure, settlement, stresses development and response to earthquake. The instruments are as follows:

(i) Pore pressure measurements: Piezometers of various types like simple stand pipe, Cassagrade’s porous tube, closed hydraulic type such as Pneumatic type, electrical type. Usually closed hydraulic type is preferred.
(ii) Settlement gauges or vertical movement devices are used for measurement of consolidation of dam and settlement of foundation. The instruments used are cross arms, fluid level devices, surface monuments.
(iii) Horizontal movement devices for measurement of internal strain or relative movement. The types are USBR vertical cross arm provided with horizontal motion recorder, extensometer, inclinometers, and surface reference point.
(iv) Seismic activity measurements (earthquake affected areas) to be made for dam are strong motion accelograph, structural response recorder, Seismoscope, pressure cells.

Instruments like Piezometers should be located at several elevations in foundation and in dam.

3. CONCLUSIONS AND RECOMMENDATIONS

The main conclusions derived from this chapter are the following:

All hydraulic structures constructed with earthen materials such as earth dams are generally prone to seepage. The effects of seepage on dams are functions of the soil permeability which one of the engineering properties. Internal erosion caused by water flow or seepage through earth dams, levees, and other earth structures that contain water.

A change in vegetation, presence of water-loving plant such as cattails, reeds and mosses or with normal vegetation than is greener and lush than adjacent vegetation, rapid water level decreases or the water falling below the level expected with normal and wet spots and aquatic vegetation (like cattails) below the dam were the conditions of seepage in the dam.

Seepage causes are due to piping, internal erosion, solutioning of soluble rock, and excessive internal pressures and/or saturation. However, if seepage is concentrated or uncontrolled beyond limits, it will lead to water loss, reducing shear strength and failure of the dam.

4. RECOMMENDATIONS

- Field exploration and geological mapping for dam projects should identify the important soil and rock formations that could cause failure by internal piping or heave. The geotechnical properties of these materials should be thoroughly investigated. If the materials are proven to be unsuitable then remedial action should be taken to improve their geotechnical properties.
- All new dams and reservoirs should be carefully observed and monitored once in service to detect the development of unsafe conditions. If seepage quantities increase or if there is an unexplained change in seepage conditions then protective measures should be put into action.
- Such actions should include lowering the reservoir and placedconduits through Embankment Dams
- Installations of cut off trenches, upstream clay blankets, filter blankets, grout curtains, relief wells, and toe drains
- Instruments such as pore pressure, settlement gauges, horizontal movement devices, and seismic activity should be installed in the dam.
- Instruments like Piezometers should be located at several elevations in foundation and in dam. It is necessity to keep continuous watch on the health of dam and monitor that is take curative steps before failure occurs.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Craig RF. Basic characteristics of soil, Crag soil mechanics, London. Taylor and Francis Group. 2004;30–49.
2. Greager V, Hinds N. Engineering of dams. John Wiley and sons, New York; 2002.
3. Arora KR. Irrigation water power and water resources engineering. Naisarak India: Standard Publishers; 2001.
4. Lukman S, Otun JA, Adie DB, Ismail A, Oke IA. A brief assessment of a dam and its failure and prevention. Journal of Failure Analysis and Prevention. 2011;11: 97-109.
5. Garg KS. Irrigation engineering and hydraulic structures. 23rd rev. ed. New Delhi, India. Khanna Publishers Delhi; 2013.
6. Dahigaonkar JK. Irrigation Engineering. Kamal Jagasia Publisher, Shahdera, Delhi; 2007.
7. Fell R, Wan C, Foster M. Time for development of internal erosion and piping in embankment dams. Journal of Geotechnical and Geoenvironmental Engineering. 2003;129,307.
8. Suresh R. Soil and water conservation Engineering. Standard Publisher, Delhi; 2007.
9. Federal Energy Regulatory Commission (FERM). Training aids for dams safety evaluation of seepage. 2006;18–27.
10. Flores-Berrones R. Water flow through soils, avances en hidráulica. Mexican Hydraulic Association and Mexican Institute of Water Technology, Mexico (in Spanish); 2000.
11. Flores-Berrones R, Alva-Garcia F, Li Liu X. Effect of water flow on slope stability. Hydraulic Engineering in Mexico, (in Spanish). 2003;18(2):35-52.
12. Flores-Berrones R, Ramirez Reynaga M, Macari E. J. Internal erosion and rehabilitation of an earth dam. Journal of Geotechnical and Geoenvironmental Engineering. ASCE. 2011;137(2)150-160.
13. Gupta BL, Gupta A. Water resources management. Standard Publishers, Naisarak, Delhi; 2008.
14. Suresh R. Land and water management principles. Standard publisher, Delhi; 2008.
15. Stephens T. Manual on small earth dams. A quide to siting, design and construction (FAO, irrigation and drainage paper N 64.Original edition. Food and Agriculture Organization of United Nations; 2010.

16. Briaud JL. Case histories in soil and rock erosion: Woodrow Wilson Bridge, Brazos river meander, Normandy cliffs and new orleans levees. Journal of Geotechnical and Geoenvironmental Engineering. ASCE. 2008;134(10):1424-1447.
17. Auvinet G, Lopez-Acosta NP. Rapid drawdown condition in submerged slopes, Int: 15 Presentations of friends and colleagues in tribute to Eng. Jesús Alberro Aramburu, Edited by Institute of Engineering UNAM and the Mexican Society of Geotechnical Engineering (SMIG). Mexico (in Spanish). 2010;167-189.
ISBN: 978-607-02-0866-9
18. Cedergren H. Seepage, drainage and flow nets, Third edition, John Wiley & Sons Inc; New York; 2009.
19. Alberro J. Effect of transient flows on the behaviour of earth structures, 8th Nabor Carrillo Lecture, Mexican society of geotechnical engineering SMIG, Tuxtla Gutierrez, Chiapas Mexico (in Spanish); 2006.

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