ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 11, Issue, 07, pp.5739-5745, July, 2019

DOI: https://doi.org/10.24941/ijcr.35640.07.2019

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

REVIEW ON THE CAUSES OF EMBANKMENT DAM OVERTOPPING, BEHAVIORS OF DAM DURING OVERTOPPING AND MITIGATION MEASURE

Getachew Bereta and *Peng Hui

Department of Hydraulic Engineering, College of Hydraulic and Environmental Engineering, China Three Gorges University, Yichang 443002, Hubei, China

ARTICLE INFO

Article History:
Received 11th April, 2019
Received in revised form 15th May, 2019
Accepted 19th June, 2019
Published online 31st July, 2019

Key Words:
Embankment dam,
Embankment Dam Failure,
Overtopping, Breaching,
Breach Characteristics,
Cause of overtopping.

***Corresponding author:** Peng Hui

ABSTRACT

In recent years, recurrent floods have been observed in many countries around the world that may have led to overtopping dams, resulting in dam breaches and catastrophic floods on the downstream of these structures. This leads to various damages such as loss of social wealth, large-scaled economical expenses, and the loss of lives. Therefore, reviewing and understanding the cause of embankment dams overtopping, behaviors of dams while overtopped and suggestion of possible solution is of tremendous significance for dam failure damage assessment, disaster control, risk analysis and mitigation, etc. In this review paper, a number of factors that influence embankment dam overtopping were identified and discussed, and the areas that require further studies were also recognized. Meanwhile, by considering types of construction materials, the characteristics and the appearances of embankment dam breaching during overtopping and mitigation measure discussed, the importance of breach models were described and summarized. Finally, recommendations and proposed future studies were made on traditional design approaches, breach characteristics for composite dams, breach modeling, the position for breach initiation and statistical analysis for dams at the end of service life.

***Citation: Getachew Bereta and Peng Hui,* 2019.** "Review on the causes of embankment dam overtopping, behaviors of dam during overtopping and mitigation measure", *International Journal of Current Research*, 11, (07), 5739-5745.

INTRODUCTION

Embankment dams are widely applied hydraulic structures throughout the world, and preferred under certain conditions, particularly when suitable materials exist near the dam site, the foundations are porous, the ratio of dam length to height is large enough, and for the purposes: power generation, irrigation, water supply etc. These structures have been brought remarkable social and economic benefits to the human beings. However, due to the nature of construction materials they may fail and present catastrophic flooding to the protected areas within the vicinity. In 1889, the overtopping of South Fork dam, Pennsylvania, USA, caused over 2200 deaths and enormous property damages. In 1975, the unusually heavy rainstorms (rainfall 830 mm maximum 6 hours) in central China resulted into disastrous failures of the Banqiao reservoir dam and the Shimantan reservoir dam causing about 26000 deaths (1-3). The most common types of dam problems is uncontrolled overtopping that would normally result in complete or partial failure (4). In addition, Zhong *et al.* (5), reported that there were 98002 reservoir dams in China by the close of 2011 based on the bulletin for first national census on water. According to the statistical data of dam safety management center of the Ministry of Water Resources for Peoples of Republic China, from 1954 to 2014, there have been 3530 dam breach accidents recorded in China, with over 50% of dam failures ascribed to overtopping. Therefore, in order to carry out detail research discussing, identifying and summarizing of the main cause of overtopping, the characteristics of the structures during overflow and controlling mechanisms is very essential to look for a solution for the existing and newly designed dams. Embankment dam failure which occurs as a result of overtopping rarely begins with a disastrous breach. Characteristics of earthen embankment while or during overtopping where studied by(6-8)experimentally (i.e., laboratory and field) test to determine the breaching characteristics of embankment dams, and also different equation with their justifications were developed based on the construction materials, for instance (2, 5, 9, 10). Several problems have been identified as overtopping causes for overtopping; hence, to improve the performance of embankment dam, different defensive mechanisms have been developed. In the past decades, several solutions addressed to solve problems observed during overflows were presented by (4, 11-13) to increase the durability of overtopped embankment dams. However, there is no consensus concerning the determination of the breaching process during overtopping. Over the past three decades there has been numerous studies regarding the embankment dams (14), nevertheless, there are still needs for detailed studies concerning the problems observed around the embankment dam. The objective of this paper is to summarize and analyze on the causes of overtopping and its solution, characteristics of embankment dam during overtopping and also the measure to be taken to protect the influences of overflow on the surface of embankment dams. Moreover, this research work presents a theoretical analysis that was carried out based on the facts provided by previous studies on the challenges and the solution to these structures. Finally, the areas on which the research gaps exist or observed were identified and reported.

Embankment dam failure

The most common and oldest dams in the world are embankment dams; they currently account a large number of newly and widely constructed dams. Over 70% large dams registered by ICOLD with a height of over 15m, having a reservoir capacity greater than or equal to$10^6 m^3$ are embankment dams. Example, China is the leader in embankment dam construction, and reasons for the preferences of these structures are usually economical when compared with other dam types (6, 15).

In the history of water retention structures is accompanied by a history of their failures, because water stored behind a dam always find a weak path or a way with weak resistance through which it escapes. Failure occurs as result of collapse or the movement of a component or part of a dam or its foundation. Failure result with the release of large quantities of water which is hazardous for property and life of people dwelling at the downstream side of a dam (15, 16). Mostly the destruction of embankment dams occurs at critical points where effective compaction is hard to perform; example, at the structural boundary, at steep abutments etc. These locations are prone to the destructive path of seepage, thus, there have been several failures on the sideways of the outlet surface. Even though, embankment dams are accurately constructed, and able to resist considerable movements, they have relatively poor resistance to overflow. Conservatively designing of their freeboard and related dam appurtenant works have the greatest influence on the dam safety. In contrast, most of the concrete dam can withstand overflow for at least several hours. The major failure of embankment dams are attributed to overtopping which is consequential of washout, internal erosion, and piping formation due to the removal of fine from the body of the dam and foundation leading to instability (17). Moreover, failure leading to catastrophic outcomes occurs mostly at first filling of reservoir stage, although overtopping during construction has occurred in some case, example, Panhet dam in India, Sempor dam in Indonesia, and S.Tomas dam in the Philippines(18).

Overtopping

The result of increased water level is overtopping (11), it happened when the outlet works are incapable to discharge water properly as required and water level raise higher than the allowable safe height of the dam and spillway (19). As explained in the introduction, the most common type of failure for embankment dams is overtopping. It may occur due to following reasons: high extra inflow into a reservoirs due to high perception or the failure of upstream reservoir; landslide into a reservoir; extreme wave by wind and surges; improper design and prompt maintenance of structure; debris blockage of outlets and discharge channels; and settlements of embankment height or crest (11, 20).

In extreme scenarios, both high and low temperatures parallel with other climate change situations could change the basin water distribution-equilibrate spatially and temporally. The possibilities of an influential change in the hydrological cycle, and the amount of sedimentation also affected. In the evaluations of climate change, three main serious changes factors to be under considerations are the magnitude of precipitation and stream flow, the severity and magnitude of flood and rainstorm events, and the change in land use and vegetation cover. In recent years, as remark indicates that the influence of climate change on the global will be overwhelming (21-23).

According to the Intergovernmental Panel on Climate Change (IPCC), in climate change conditions, warmer temperature complemented by greater. The rises in temperatures which in itself does not always mean that better sunny weather but more possibly the potential increase of the intensity of flash floods, mudslides, heat waves and droughts, leading to disastrous social, economic and environmental damages. As shown on figure 1, the declining ice level in Arctic, the Greenland ice sheets due to increased melting rate and the rise in global mean sea level are the most evident consequences of global warming (24). Hence, the overtopping failures possible to happen, because of a significant scaling up in global warming results in storage variability and extremes in precipitation patterns.

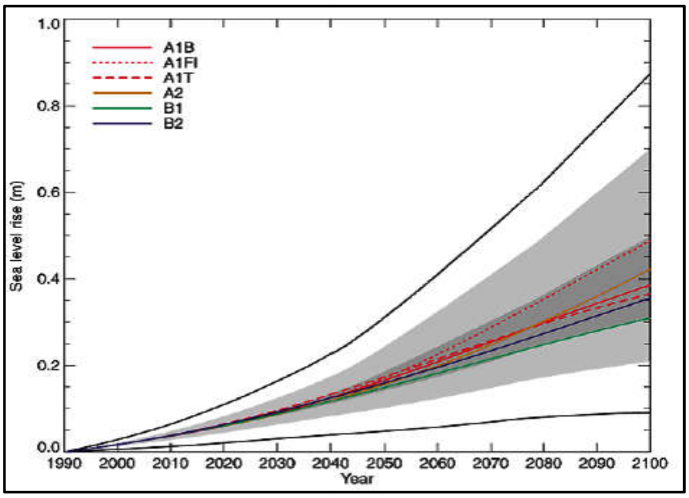


Figure 1. For different scenarios Global average sea level rise for the period 1990 to2100, adopted (IPCC, 2001) (24)

However, dams and its appurtenant works are designed on the bases of predictable flood return periods calculated from an analysis of a longyears back historically recorded hydrological data. This clearly indicates that a dam and its components are seriously threatened if a certain shift in precipitation occurrences and intensity is encountered (15, 20). Therefore, the design of dam spillways and other flood controlling outlet structures based on anticipated flood return periods; evaluated from analysis of historically documented hydrological data, which does not consider the futures of hydrological data (i.e. Probabilistic hydrological data) due to the climate change, that could certainly be hazardous to a dam.

Many embankment dams as approach the ends of their planned service life or end to their design period are normally filled with sediments; this accumulation of sediments in the reservoir minimize flood storage. In addition, development activity in the watershed and around the dam may escalate runoff, and increase the cause of failure. The ages of these embankments along with characteristics changes within the watershed can lead to embankment trough flood events that cause overtopping(7, 15, 16, 22). In dam design, most of the time operational and physical parameters are indeterminate variables. The supposed magnitudes are assumed in design which may probably varies in time as well in space and cause uncertainty in dam performance. Conventionally, design parameters are usually assumed to be considered as safety factors. Currently, this safety factor methodology approach should have to be re-examined, because of this approach clearly does not consider the uncertainties for numerical analysis of safety (17, 25). This indicates that the design method is one of the challenges for embankment dam overtopping.

Behaviors and mechanisms of breaching during overtopping

The output of erosion process and erosion degree of embankment overtopping failure can identify the performance of embankment dam while overtopping, and provides basic information for design of protective measure (15). For instance, when water starts flowing over a crest of embankment dam two kinds of flow developed i.e. an infiltrating flow through the dam's body and a free surface flow along the dam face. This is depending on the duration of overflow, the magnitude of overtopping event and dam type. As a consequence of which, increased reservoir level may lead to two things that would likely threaten the safety of embankment dam viz. internal erosion due to piping and erosion of downstream dam face (11). Hence, embankment dams are attacked internally and externally (see figure 3) when subjected to overtopping.

and then an extension of breaching width. Finally, breach invert touches the channel bed, as shown in figure 2 for the observed breach process (26).

Generally, for homogenous embankment dams, the two recognized breach mechanisms are overtopping erosion: surface erosion is progressive and sediment transport in dispersed particles and overtopping headcut: erosin is migration of a vertical or nearly vertical drop on the bed (more of see figure 3 and 5) (15, 28). In the previous decades, several experiments have been conducted on the breaching of embankments. These experiments comprise both small-scale tests in the laboratory and large-scale tests in the field. The small-scale tests in the laboratory include many wave basin and flume experiments. Nevertheless, the breach formation and development in embankment dam is such an intricate process with numerous influencing factors involved in, such as material type (non-cohesive or cohesive, and erosion of cohesive soil is already a very difficult phenomenon), structure of embankment and profile, and causes of failures (piping, overtopping, slope sliding, etc.)(3). Likewise, from earth embankment dam breaching processes, various scholars as shown in the table 1 have developed many models. Breach modeling is essential for understand breach mechanisms, behaviors and the prediction of breach parameters.

The models developed in the past grouped as parametric, simplified and detailed multidimensional physically-based breach models. The Parametric breaching models normally estimate the breach side slope, breach width, peak outflow and time to failure using statistically derived regression equations that are based on data from historical dam failure databases, without considering the detailed breaching process.

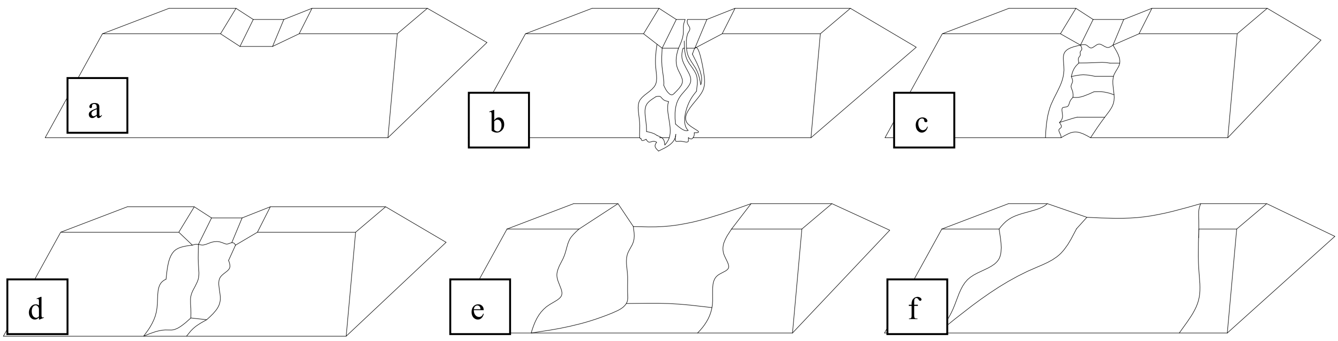


Figure 2. Cohesive embankment dam model tests, observed breaching process, modified and adopted from Zhu *et al.* (14).

The general term breach mostly used to describe the procedure regressive erosion and ultimate failure all types of embankment dams leading to overtopping (26). When the shear stress imposed by the flow greater than the shear stress of embankment material erosion begins. With the increase in velocity, there is a corresponding increases in shear stress and velocity depends on the headwater and tail water conditions. In addition, the erodibility of the construction materials, slope, and duration of overtopping affect the total volume materials which are ultimately removed (27).

From both prototype observations and experimental studies in laboratory flow conditions indicates, it has been shown that the embankment dam structure breaching process starts with initiation stage, followed by a quick development of a breach

The simplified physically based breaching models considers the breach cross-section commonly simplified as a triangle or rectangular, the water flow at the breach is computed using the broad-crested weir equation, while the erosion is estimated using a different simplified model.

Physical-based multidimensional models consider the morphodynamic processes due to embankment breaching and simulate the flow in more detail. The embankment breach flow are most commonly in mixed flow regimes with discontinuities, thus, the numerical schemes often used are shock-capturing estimated total variation diminishing and Riemann solvers schemes in 1D and 2D depth-averaged models, while volume-of-fluid and smooth particle hydrodynamic methods in vertical 2D and 3D models (15, 29).

However, the understanding of the mechanism of embankment dam breaching is currently unsatisfactory still is requires advanced work to each the best state-of-the-art of breach model. For example, almost all of the numerical and mathematical models currently exist are limited to the breach in homogenous embankment dams due to overtopping. The models do not consider development of the first opening in the dam, the effect of dam slope protective layers and the composite embankment dam structure. Moreover, there must be embankment dam breach models validation and calibration, which requires good quality data from prototypes or actual dams. breached cross-section shape opening can be approximated as a trapezoid, triangle, rectangle or whichever shape is probable that is governed by embankment dam geometry, construction material behavior, water situations and manner of failure(2, 6, 34, 35).

Hunt *et al.* (7), used Hanson *et al.* (2003a) laboratory experiment to described a four-stage erosion process for cohesive dam. Firstly, the initial flow sheet and rill erosion on the downstream face; secondly, the headcut migrates from the downstream to the upstream embankment crest; thirdly, the lowering of the embankment crest; and fourthly, the final stage at which the breach widens and from the reservoir the flow is released and the breach formation is following. However, Zhong *et al.* (5)described a five-stage erosion process for cohesive dam.

Table 1. Some of breaching models developed and investigated to calculate the breachingprocess (5, 8, 15, 29).

Parametric breaching models (developed by)	Simplified physically based breaching models (developed by)	Physically based multidimensional models (developed by)
Kirkpatrick (1977)	NWS BREACH (Fread 1988)	Broich (1998)
Bureau of Reclamation (1988)	HR BREACH (Mohamed 2002;Morris 2011)	Wang and Bowles (2006)
Bureau of Reclamation (1982)	WinDAM (Hanson *et al.* 2005;Temple *et al.* 2005)	Faeh (2007)
MacDonald and Langridge-Monopolis (1984)	BRESZHU (Zhu 2006)	Wu *et al.* (2012)
Singh and Snorrason (1984)	DLBreach (Wu 2013)	Marsooli and Wu (2015)
Froehlich (1995a,b)	Qi-mingetal.(2017)	Wang *et al.* (2008)
Evans (1986)		Roelvink *et al.* (2009)
Von Thun and Gillette (1990)		Cao *et al.* (2011)
Xu and Zhang(2009)		

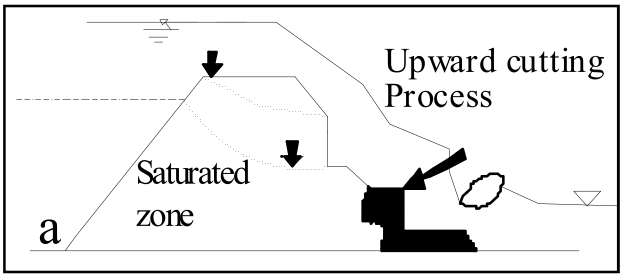
The accessible data on the many historical embankment dam failures in the world is incomplete and limited and is mostly obtained from the eye-witness reports(14).

Breach characteristics of homogenous and composite fill embankment dams

As indicated above one of the challenges for embankment dam performance is breaching, and it is the most common problem ascribed to embankment dam failure. Mostly an embankment starts to breach due to overtopping over the crest formation of erosion channel and the driving of downstream by shear forces when a portion of an embankment essentially breaks away forming a wide opening for water to inundate the area secured by the embankment dam. Breaching occur suddenly or slowly due to failure that happens by surface erosion and/or headcut erosion in the embankment dam (see figure 3 and 5). Due to behavior of construction materials during overtopping the nature of failure (breaching process) for breached composite embankment dam is not similar to the homogenous ones(28, 30). Thus to identify the characteristics of breach physical model, laboratory experiments and case studies were undertaken by many scholars(5, 7, 8, 15, 31).

Cohesive homogenous

Headcut erosion characteristics are commonly observed during overflow either as a vertical or nearly vertical drop on the bed headcut formation (see Figure 3b and Figure 2c). In the case of headcut erosion, both sheet and rill erosion are initially overtopping flow result with one or more dominant rill developing into a sequence of flowing over falls and then on the downstream surface slope a large headcut occurs as shown in figure 2(7). The migration of headcut from the toe of the downstream towards the top crest of the dam is usually gradual, moreover, the headcut consists of a sequences of mass intermittent failure events (32, 33). As shown in figure 3, erosion usually begins at the toe of the downstream end and propagates towards upstream, through the erosion embankment crest height and length becomes reduced. In instances of surface erosion, depending on the soil type, the downstream slope may flatten, steepen, and erode parallel. Finally, the



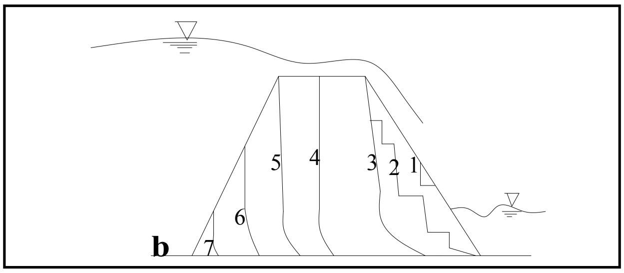


Figure 3. a. Sketch of head-cut erosion of homogenous cohesive embankment dam (1). b. Headcut migration, number right to the left indicates time slits (5)

Based on the above discussion, it is considered that the initial headcut position is located at the downstream toe of the dam. However, the large-scale model tests by NHRI (Nanjing Hydraulic Research Institute) (31) show that the beginning scour location is not at the downstream toe of the dam, but rather governed by the dam height and water head. On the downstream slope, the flow accelerates from the crest to a certain location where it reaches the normal flow velocity, if the slope is long enough to permit this occurrence, the initial scour position is located here; otherwise, the initial scour position will be located at the downstream toe. Considering the dam height for NHRI model tests the initial scour location was at the downstream slope (5).

During literature review, for cohesive embankment dam most of the studies indicate the initial breach position is at the downstream toe, but as recent field experiments showsthe position of initial breach depends on the water head and dam height.

Composite

The overtopping of composite embankments are different from homogenous embankments dams (6, 15, 28, 34).When water overtops a composite embankment dam with central core clay, a core with concrete or steel. The headcut migration or surface erosion starts on downstream end slope until it reaches the flood wall or core as shown in figure 4a.This erosion may affect the stability of the wall and core (see figure 4b), thus resulting in failures. Based on types of internal material used, possible failure mechanism of core and the flood wall are overturning, bending and sliding(15). As the breach flow increases the materials which failed may be rapidly relocated or eroded out to downstream. Then the created channel breach may be farther depressed through the down cut, lateral erosion, and mass failure there by widening the width of channel more. Overtopping flow may wash out cover surface first, and then more erosive headcut of embankment dam may follow(15), (see figure 4).

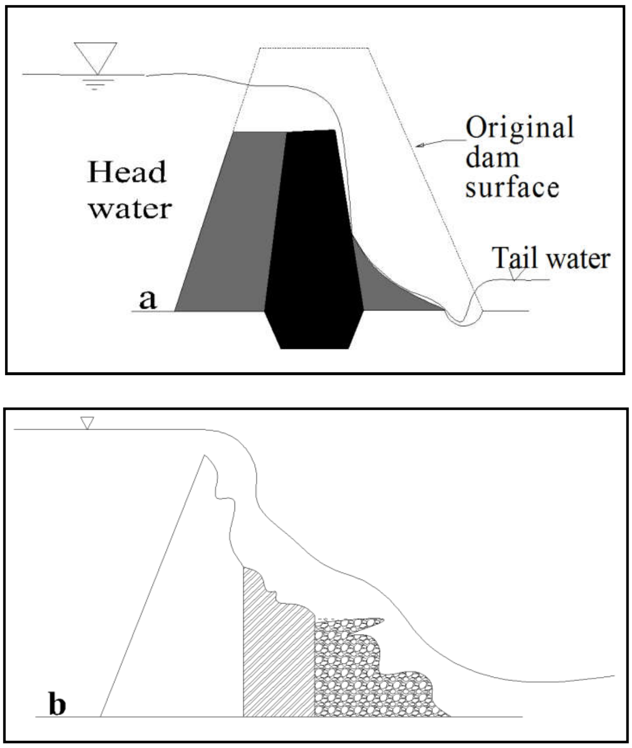


Figure 4.a, Sketch of embankment breaching for composite with clay core (15). b, Clay core with rock fill (28)

Non-cohesive homogenous dam

Laboratory and field investigations have indicated that homogenous and non-cohesive embankments undergo progressive erosion (see Figure 5). The dam surface erosion mechanism is typically happened during overtopping is that erosion progress from embankment crest to the toe (33, 36). In other hands, the experiment carried out on 13 large scale non-cohesive compacted earthen dams showed that the initial breaching was initiated by cutting a notch across the dam crest, and then forms a specific channel that developed channel stepped into a profile(37). This shows that the compacted and consolidated non-cohesive embankments dam breach initiation is through cutting. Yang *et al.* (38) carried out theoretical and experimental studies for the determination of breach process of non-cohesive homogeneous dams due to overtopping. The results of their work established a five-stage theoretical model for the entire breaching process steps: first was seepage; the second was an initial breach; third was erosion toward the head; the fourth was breach expansion; and finally re-equilibration consecutively. It indicates that once activated the entire breach process goes continuously without interruption.
The literature review showed that regardless of breach stage, failure progression depends on the types of construction materials, degree of compaction, breach flow, flow type etc. The entire breaching process for headcut development of cohesive dam and erosion process for non-cohesive embankment dam have different shape from the beginning to the final stage. However, the perception of scholars concerning the number of breach stage development is not the same. Thus far, for composite embankment dams, there is no description and experimental observation on stages of breaching.

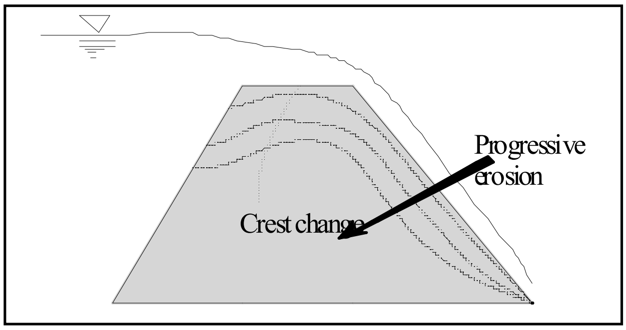


Figure 5. Progressive erosion for non-cohesive uniform embankment dam (36)

Mechanisms to solve the problems

The impacts of overtopping have varied from no destruction to a serious erosion resulting in a breach of the embankment dam because of it is governed by the duration of overtopped water, the surface feature that causes flow turbulence, the nature of construction materials etc. The consequence of overtopping is not only breaching or structural failure or hydraulic failure, but also an uncontrolled release of stored water to downstream and subsequent flooding which is a danger to the life and property. Therefore, the safety of dam is a matter of great concern to the public and has become a global accountability to insure the safety of these structures (17, 39). Therefore, understanding the behaviors of embankment dams during overtopping provides significant information for the design of protective measures as well as maintenance.

The variability of design parameters makes the hydro-system complex for proper and accurate design. The traditional approach that is used for dam design focuses on deterministic analysis of the catastrophic events example, probable maximum flood (PMF). This focuses on a higher range of flood potential and assumes no failure reliability, although the dam design problem has not been totally addressed, due to uncertainty in variables, and the applied procedures remains a difficult issue in dam engineering. The appropriate design of dams and their appurtenant works should guarantee the safety of the dam and avoid undesirable problems like overtopping. For Instance, by using univariate frequency analysis of historically recorded peak discharge for evaluating design discharge, the method would likely underestimate the effects of overtopping because it estimates a peak discharge for a specific return period, so; dam still suffers as of overtopping. Therefore, focusing on a new approach for design embankment dams that depends on the variables parameters of hydro-system components is cardinal by civilizing statistical models, mathematical model, computer program and using long periods of recorded data, to change the design approach from the deterministic design to probabilistic methods. Further, including risk and uncertainty analysis in hydro system engineering considered as a means of upgrading the quality of decision making processes to reduce the effects of uncertainty on decision making procedure and provide the best solution to the among existing alternatives (17, 25, 39, 40).

Additionally, overtopping due to impulse wave at embankment dam structures can be prevented by providing sufficient freeboard. Moreover, a rapid drawdown rate can even generate a more dangerous condition and acts as a triggering mechanism for fully or partially submerged slides. If the mass wasting does not occur, then there is adequate freeboard, the created drawdown of the water level is the only remaining unexpected mitigation measure. Though, the process of water level drop can be protracted based on appurtenant structure and the reservoir geometry (41).

For existing dam, to prevent or reduce the erosion during flood overflows different mechanism have been identified. Recently the design discharge of many dams were re-evaluated, and the analyzed flows were mostly larger than those used for original design discharge. In many situations, the re-analyzed design floods outcome with dam overtopping due to insufficient storage and spillway capacity of the existing reservoir were probable. Embankment dams exhibited a number of overtopping of the protection system. The most encouraging protection systems for preventing overflow erosion are those that incorporate a modification to a surface. Embankment dams surface protection against erosion are such as vegetation, geotextiles, cements concrete blocks, ripraps, gabion, minimum energy loss weir, stepped spillways and the protection precast concrete block system have been developed(13, 28, 42). Furthermore, for existing dams, it is significant periodically review and predict breach parameters to minimize the risk that may arise from the breach. Accordingly, peak warning, and evacuation time are governed by the variation in breach parameters(43).

In addition, to determine the characteristics of the overtopping flow hydraulic analyses is important, this includes: flow depth, velocity, and type flow (turbulent or laminar, subcritical or supercritical), discontinuities and slope changes, and the energy dissipation requirements at the downstream toe(44). These are the fundamental parameters for the design embankment dam surface protection against erosion. However, surface erosion protection against overtopping is not recommended on new embankment dams because of settlement that might follow, unless it is indicated in the case of design and no other practical options exist (45).

Conclusion

Characteristics of the structure during overflow and solutions are enormous important for the dam safety, dam failure early warning system and planning for emergency evacuation, and subsequently also for the disaster mitigation measure. It was evident from the literature that many dams have been constructed around the world in the past century and the dawn of this century, but many of them have failed due to overtopping as one of the main challenges. Considerable progress has been made in the past over three decades of studies of the events that lead to dam failure in spite of the complexity of the process involved. The challenges observed around the embankment dams are not simple. Because of these structure is exposed to several external and internal factors, some of which are discussed above, and the conclusion elucidated the following:

- As studies show that all researchers have a common sympathetic on the cause of embankment dam overtopping. Climate change is one of the major contributing factors for overtopping because it leads to the unpredictability of future conditions, this has compelled the researchers and designers to re-examine the old method of hydrologic and hydraulic design for all types of dams not only embankment dam.
- The recognized breach behaviors of homogenous dams are erosion and headcut. However, the breach process of non-homogenous or composite dams are still not clearly established, especially during the transition between two different construction materials, particularly at their interface (contacts of two different materials), thus, requires detail or further study. Moreover, for the last decades, several models have been developed by different researchers from the observed breach to compute the breach process, numerous experiments have also been conducted, and the knowledge acquired. Nonetheless, there is no collective understanding to compute the breachingprocess or parameters, and embankment breaching mechanisms are still not satisfactory and need studies that are more supplementary, which is significant for the prediction of breach parameters and can help to formulatemitigation measure, for the safety of human life and properties.
- The initial breaching position is still controversial issue; though more researchers have a common agreement that it is located on the downstream toe of embankment dam, while some authors argued that it depends on dam height, water head, downstream slope etc. thus to identify its clear location more studies are required.
- Despite the presence of several embankment dams around the world nearing the end of their service life, there is no statistical data on them. The existence of statistical data whether continuous or periodical can be used for re-evaluating design discharge of existing embankment dams and the check previously used design method and to develop new approaches to the design method.
- Based on the evidence from different scholars, the mechanisms for embankment protection from the breaching put forwarded were anchored on same concept or idea. Nevertheless, the disadvantages of the mechanism used were not identified and well contrasted e.g. riprap, geotextile, vegetation etc.

Acknowledgments: The research was supported by the National Natural Science Foundation of China (Grant number 51379108), China scholarship council (CSC No.2016DFH250) and Arba Minch University, Ethiopia.

Conflicts of Interest: The authors declare no conflict of interest.

REFERENCES

1.Manso Pedro A., Schleiss Anton J. Stability of linings by concrete elements for surface protection of overflow earthfill dams. Laboratoire de Constructions Hydrauliques Ecole Polytechnique Fédérale de Lausanne,Communication 12, 2002.
2. Xu Y, Zhang L M. 2009. Breaching Parameters for Earth and Rockfill Dams. *J Geotech Geoenviron Eng.,* 135:1957-70.
3. YongHui Z, J VP, K VJ, Guang Qian W. 2011. Experimental investigation on breaching of embankments. *Sci China Tech Sci.,* 54(1):148-55.
4. Manso Pedro A., Schleiss Anton J. 2002. Improvement of embankment dam safety against overflow by downstream face concrete macro-roughness linings.Laboratory of Hydraulic Constructions (LCH), EPFL, Lausanne, Switzerland, 1-10.
5. Qi-ming ZHONG, Sheng-shui CHEN, Zhao DENG, 2017. Numerical model for homogeneous cohesive dam breaching due to overtopping failure. *J Mt Sci.,* 14(3):571-80.
6. Hanson G., Cook K. R., Hunt S. L. 2005. Physical modeling of overtopping erosion and breach formation of cohesive embankments. *American Society of Agricultural Engineers,* 48(5):1783−94.
7. Hunt S. L., Hanson G., Cook K. R., Kadavy K. C. 2005. Breach widening observations from earthen embankment tests. *American Society of Agricultural Engineers,* 48(3):1115−20.
8. Wu Weiming, 2013. Simplified Physically Based Model of Earthen Embankment Breaching. *Jof Hydraulic Engineering,* 139(8):837-51.
9. Singh VP, Scarlatos PD, Collins JG, Jourdan MR. 1998. Breach erosion of earthfill dams (BEED) model. *Natural Hazards,.* (1):161-80.
10. Wang Z, Bowles DS. 2006. Three-dimensional non-cohesive earthen dam breach model. Part 1: Theory and methodology. *Advances in Water Resources,* 29(10):1528-45.
11. Gilbert Paul A., Miller S. Paul. 1991. A study of embankment performance during overtopping. Washington: US Army Corps of Engineers, Contract No.: Technical report GL-91 -23.
12. Ullmann Craig M., Abt Steven R. 2000. Stability of rounded riprap in overtopping. *Water Resources,* Building Partnerships,ASCE 2004:1-9.
13. Hubert C. 2015. Embankment overtopping protection systems. *Acta Geotechnica,* 10:305-18.
14. Zhu Y-h, Visser PJ, Vrijling JK. 2004. Review on embankment dam breach modeling. In: Wieland M, Ren Q, Tan J S Y (eds), New De, 1-8.
15. Committee AET. 2011. Earthen Embankment Breaching. J of Hydraulic EngASCE, 137(12):1549-64.
16. Duricic door Jasna, 2014. Dam Safety Concepts. Sieca Repro, Delft: Delft University of Technology, The Netherlands.
17. Abate N. 2009. Probabilistic safety analysis of dams methods and applications: Technische Universität Dresden, Germany.
18. Deangeli C., Giani G.P, Chiaia B., Fantilli A.P. 2009. Dam failures,Chapter 1. WIT Transactions on State of the Art in Science and Engineering, 6.
19. Visser P. J. 1998. Breach growth in sand-dikes. Delft University of Techinology, The Netherlands, 1-189.
20. Milly P.C.D., TWetheraid R., Dunne K.A., Delworth T.L. 2002. Increasing Risk of Great Floods in a Changing Climate. Macmillan Magazines Ltd., 415:514-7.
21. Hyun-Han Kwon, Young-Il Moon, 2006. Improvement of overtopping risk evaluations using probabilistic concepts for existing dams. *Stochastic Environmental Research and Risk Assessment,* 20(4):223-37.
22. Synthesis. Ecosystems and human well-being. Island Press, Washington, DC.: The Millennium Ecosystem Assessment series, 2005.
23.Archer David. Global Warming Understanding the forecast. Blackwell publishing,Australia: Blackwell, 2007.
24. Change Climate. Climatechange, 2001. The Scientific Basis is the most comprehensive and up-to-date scientific assessment of past, present and future climate change. Cambridge University, United Kingdom, 2001.
25. Goodarzi E., Shui L. T., Ziaei M. 2013. Introduction to risk and uncertainty in hydrosystem engineering Springer.
26. Coleman Stephen E., Andrews Darryl P., Webby M. Grant, 2002. Overtopping breaching of noncohesive homogeneous embankments. *J Hydraul Eng.,*128(9):829-38.
27. Li Simons., Inc Associates. Minimizing embankment damage during overtopping flow. 1988.
28. Powledge George R., Ralston David C., Miller Paul, Hai Chen Yung, Clopper Paul E., Temple D. M. 1989. Mechanics of overflow erosion on embankments. II: hydraulic and design considerationsa. *J Hydraul Eng.,* 115(8):1056-75.
29. Wu W. 2016. Introduction to DLBreach-A Simplified Physically-Based Dam/Levee Breach Model (Version 2016.4); Version 2016.4. Clarkson University,Clarkson Avenue Potsdam, NY 13699, USA.
30. Chee S. P. 1984. Washout of spillway dams:Channels and channel control structures. 1st Int Conf onHydraulic Design in Water Resources Eng; Southampton, UK.
31. Zhang JianYun, Li Yun, Xuan GuoXiang, Wang XiaoGang, Li J. 2009. Overtopping breaching of cohesive homogeneous earth dam with different cohesive strength. Science in China Series E: Technological Sciences, 52(10):3024-9.
32. Zhao Gensheng, 2016. Breach growth in cohesive embankments due to overtopping. Delft Academic Press / VSSD uitgeverij, the Netherlands: Delft University of Technology.
33. Ellithy G. S., Savant G., Wibowo J. L. 2017. Effect of soil Mix on overtopping erosion. World Environmental and Water Resources Congress, p. 35-49.
34. MacDonald TC, Langridge-Monopolis J. 1984. Breaching characteristics of dam failures. *Journal of hydraulic engineering,* 110(5):567–86.
35. Froehlich. David C. 2008. Embankment dam breach Parameters and their Uncertainties. *J of hydraulic engineering,* 134(12):1708-21.
36. Volz Christian, 2013. Numerical simulation of embankment breaching due to overtopping. Z¨urich: ETH Zurich,University of Stuttgart,Germany.
37. Walder Joseph S., Iverson Richard M., Godt Jonathan W., Logan Matthew, Solovitz Stephen A. Controls on the breach geometry and flood hydrograph during overtopping of noncohesive earthen dams. *Water Resources Research.* 2015;51(8):6701-24.
38. Yang Yang, Cao Shu-you, Yang Ke-jun, Li Wen-ping, 2015. Experimental study of breach process of landslide dams by overtopping and its initiation mechanisms. *J of Hydrodynamics, Ser B.,* 27(6):872-83.
39. Goodarzi E., Mirzaei M., Shui L. T., Ziaei M. 2011. Evaluation dam overtopping risk based on univariate and bivariate flood frequency analysis. *Hydrology and Earth System Sciences Discussions,*8(6):9757-96.
40. Goodarzi E., Shui Teang Lee, 2012. Ziaei Mina Dam overtopping risk using probabilistic concepts-Case study: The Meijaran Dam, Iran. Ain Shams Engineering Journal,Ain Shams University Production and hosting by Elsevier, 4:185–97.
41. Kobel Johannes, Evers Frederic M., Hager Willi H. 2017. Impulse Wave Overtopping at Rigid Dam Structures. *J of Hydraulic Engineering,* 143(6):04017002-8.
42. Abt S. R., Thornton C. I. 2014. Riprap design for overtopping - man do I need a martini!World Environmental and Water Resources Congress , Water without Borders © ASCE, 1191-8.
43. Singh KP. 1984. Sensitivity of outflow peaks and flood stages to the selection of dam breach parameters and simulation models. *J of Hydrology,* 68:295-310.
44. FEMA. Technical manual: Overtopping protection for dams. The U.S. Department of the interior protects America's natural, resources and heritage. Denver Federal Center: Bureau of Reclamation, 2014 Contract No.: Denver CO 80225-0007.
45. Miguel Á.T., Rafael Morán, Eugenio Oñate, 2014. Dam protectionsagainst overtoppingandaccidental leakage. Madrid, Spain: CRC Press/Balkema, 2014.

****