International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

Flow Through a Breach Levee – A review

Chirag Parmar [1], Sudhanshu Dixit [2], V. M. Patel [3]

[1]*Research Scholar, Department of Civil Engineering, L. D. College of Engineering, Ahmedabad, Gujarat, India*
[2]*Assistant Professor, Department of Civil Engineering, L. D. College of Engineering, Ahmedabad, Gujarat, India*
[3]*Associate Professor, Department of Civil Engineering, L. D. College of Engineering, Ahmedabad, Gujarat, India*

Abstract - *The dam or dike are structures were held from long times ago to withstand against the overtopping and preserved water in front of the upstream of the dam or dike. It is the first hydraulic structures in history and which use as a tool for development of irrigation engineering. Due to their objectives of preserving water, they exposed to different types of failures like overtopping failure, piping failure, side-slope failure and others. During the overtopping failure, an initial breach channel is initiated inside the levees body and extended downstream to upstream slopes of the dike because of several geotechnical parameters. As a result of breach failure whole reservoir water is transferred from the upstream to downstream parts of dike and thus effect lives and properties. The researchers focusing on understanding the mechanism of the breach channel development and tried to conduct a mathematical equation as well as an experimental test to observe levees failure and new method to prevent or close breach, so that lives and property can be saved from disaster. This paper is review about parameters which influence levees breach and different methodology studied to prevent or close levees breach till now.*

***Key Words**: Levees breach, levees closer, overtopping failure, earthen embankment. Channel flow.*

1. INTRODUCTION

A number of structures such as dams, levees, dikes, and barriers are built along rivers, lakes and sea coast around the world. The levees had been constructed long times ago since the damage of public property and people lives increases during large flooding, when no flood resistance structures like dike, dam etc. are available. All of these structures are very important in flood defence but these structures can sustain only design safety levels and may fails when stress on structures increase beyond design safety level and it may fail due to other many reasons. Several factors such as lack of maintenance and changing geological condition are led to levee failure, many cases are available all over the world for flood damage like Yangtze flood in China 1998, the Elbe flood in Germany 2002, the New Orleans flood in 2005, the Mississippi Flood in 2008, the Pakistan flood 2010 and the Queensland flood in Australia in 2011, M. A. Hassan (2017).

The 'failure' mean inability to achieve a defined objective. Failure of levee includes deterioration-process such as an overtopping over the levee in large flood and erosion of levee by hydraulic forces, and as a result breach occurs at the end. The main parameter which cause levee failure is geotechnical stability Lee (2019)

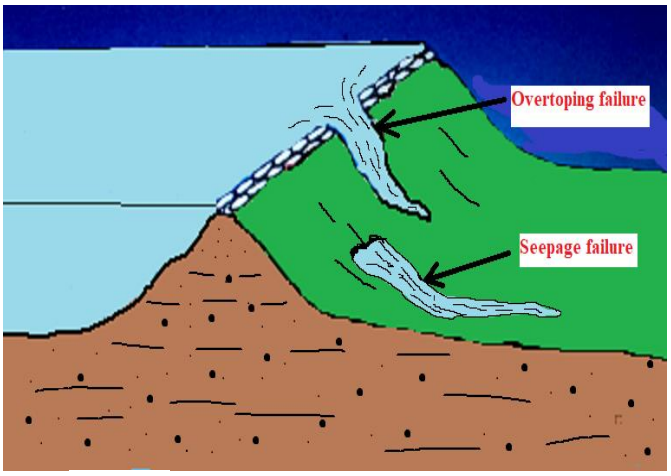

Fig – 1 Schematic diagram of levee failure

Many researcher have studied breaching pattern of levees on different parameters, Roland Faeh (2007) studied discharge through the breach by different processes and different material parameters and compared with experimental as well as field data. Ezzat Elalfy (2008) conducted Laboratory experiments on various inlet discharges and downstream water depth and recorded breach shape using a sliding rods technique. Riahi-Nezhad (2013) performed experiment using 17th street canal breach as a case study and studied experimentally the hydraulics of steady flow during levees breach. Fujita et al. (1987) presented the process of enlargement of breaches in levees on alluvial plains and also hydraulic characteristics and the

mechanisms for the enlargement of a breach were discussed and methods for the prevention of breach enlargement were also consider. Schmocker and Hager (2009) carried out a series of experiments to study the test repeatability, side-wall, and scale effects of plane embankment breach of loose, uniform, non-cohesive sediment. Ali Asghari Tabrizi (2016) perform laboratory experiments on embankment overtopping as well as erosion measurements by using the Submerged Jet test. Some of recent studies have been reported by Seung Oh Lee (2019), G. J. Hanson et al (2005), Sachin Dhiman et al (2017), Mahmoud Al-Riffai (2014)

Few studies have been conducted to protect levee but now numerous new technologies were developed according to the installation method and material still there is no any accurate and economical method is not available to control breach. Donald Resio (2011) performed various experiments to develop and demonstrate rapid levees closer for U.S. Department of Homeland Security. Joon-Gu Kang et al (2016) developed a magic retaining wall block to protect river from running water. Dongwoo Ko (2018) performed experiment using a biopolymer to improve the durability and environmental friendliness of the levee along with the soil.

S. J. Boc et al (2010) the Portable Lightweight Universal Gasket (PLUG) would be used for the repairs of the narrow deep breach which are typical of river levee failures and surge-driven breaches in large earthen levees. J. Dagher (2016) and E. C Burg et al (2019) perform experiment by using barges to close the breach. M. Hanif Chaudhry et al (2010) developed digital particle tracking Velocimetry technique for application to particle tracking for breach closure. Different breach closure procedures (Toe dumping, transverse damping and a combination of both) are studied. Ahmed M. A. Sattar (2019) and Donald Resio (2009) performed various experiment using sand bags of various size for breach closer. Other researchers who study in same field are David A. Jaffe et al. (2001), Paul J. Bouchard and Sandra S. Bouchard (2011), S. J. Boc et al. (2010), Kenneth R. Olson and Lois Wright Morton (2013), Mitchell F Crusto (2006).

2.1 Levee breach – A review

Levees may fails due to many of the reasons but failure of levees may cause catastrophic damage to life and property, which we experience in past, examples of such disaster are Yangtze flood in China 1998, the Elbe flood in Germany 2002, the New Orleans flood in 2005, the Mississippi Flood in 2008, the Pakistan flood 2010 and the Queensland flood in Australia in 2011. Therefore it become very important to control this type of damages and for that identification of problem which causes breaching is important to research community to develop new technology to prevent levees from failure.

Fig – 2 Levee breach during experiment

2.1 Parametric study of levees breach

In this section some of the past studies by different research regarding parametric study of levee failure and preventive and closing measures of breach are discuss in present work.

Table 1- Levee breach analysis

Sr. no.	Author	Study area	Description
1	-Cyrus K. Riahi-Nezhad (2013)	Experimental Investigation of Steady Flows at a Breached	In this paper water surface elevation and the three-dimensional velocity field are measured using point gauge and acoustic doppler velocimeter (ADV). From result author concluded that flow is one dimensional at

		Levee	the channel inlet and outlet and it is three dimensional at the breach. There is a zone of depression on the water surface levels.
2	-Roland Faeh (2007)	Numerical Modeling of Breach Erosion of River Embankments	In this paper author investigated sensitivity of the discharge through the breach related to different processes and material parameters. The results show that the most sensitive parameter for an erodible levees breach is the side-slope angle of breach which determines the lateral erosion of levees.
3	-Dongwoo Ko -Joongu Kang -Yonguk Ryu (2018)	Experimental Study on Relation between Breach Process and Velocity Distribution on Levee due to Overflow	This paper shows surface velocity distribution on earthen and reinforced levee determined with new environmental friendly substance and were measured using a LSPIV technique. The characteristics of flow velocity distribution follows levees breaching processes and during overflow evaluate the initial points of failure and the weak points.
4	Mahmoud Al-Riffai (2014)	Experimental study of breach mechanics in overtopped non-cohesive earthen embankments	In first and second phases author focused on two test series that is drainage and compaction for three-dimensional breach due to overtopping. Water surface levels and video footage captured from upstream, downstream and above the embankment models. In third phase experiment was comprised of two-dimensional overtopping tests to investigate the erosion of a steep slope in overtopped non-cohesive embankment models.
5	-Sachin Dhiman -Kanhu Charan Patra (2017)	Estimates of Discharge Coefficient in Levee Breach Under Two Different Approach Flow Types	Author performed 8 types of experiment at the time of failure to study dam failure to investigate effect of compaction effort and moisture content of head-cut migration, breach parameters, and flood hydrograph and assessing the overtopping behavior of embankments when they are air dried for a long time so that they develop cracks in there surface.
6	-Dongwoo Ko -Joongu Kang (2018)	Modelling dike breaching due to overtopping	Author investigated systematic variation of both the dike dimension and the sediment diameter which result basic findings relative to test repeatability, Side wall effect and Scale effects. The results indicate that definite minimum dimensions for both the dike height and width, sediment diameter and overtopping.
7	-Seung Oh Lee	Estimates of Discharge Coefficient in Levee	In this paper two different openings rectangular and trapezoidal shape are constructed and the effect of two

	-Kwang Seok Yoon -Jun Seon Lee - Seung Ho Hong (2019)	Breach Under Two Different Approach Flow Types	different approach flow types the river and reservoir type approach are explored to suggest a discharge coefficient. The results show that the ratio of head above the bottom of an opening and the opening width is a key variable for calculating the discharge coefficient of a reservoir type, but the approach Froude number should also be considered for a river type approach.
8	-Ali Asghari Tabrizi (2006)	Modeling Embankment Breach Due To Overtopping	The main goal of author was to develop non-dimensional relationships for the crest height and embankment bottom length of levee with respect to time and compaction energy on basis of measured data, so that ultimately introduce relationship which predict progressive breach shape evolution. At the time evolution of the breach, downstream outflow hydrograph, and degradation rate of the embankment crest for different compactions are determined.

2.2 Breach closer study

In past very few studies regarding prevention or mitigation of levees breach have been done by researchers. We know that it is not an easy task to close or prevent levees from breaching but still researchers develop many technics to prevent levees from breaching. In below table new and innovative ideas for levees closer and preventive measured are given which developed by different researchers and presented in their work. New technics developed are not economical and very difficult to install. Therefore still there is requirement of accurate, easy installation, and more economical method to prevent lives and property from damage caused by levees breach.

Table 2 - Breach closer study

Sr. No.	Author	Study area	Description
1	-Donald Resio -Stanley Boc -Stephen Maynord -Donald Ward -David Abraham	Development and Demonstration of Rapid Repair of Levee Breaching Technology	In this paper author describe four metrics to close breach and to select method to close breach. First critical metric is time in which a system can be effectively deployed. A second key metric is to be effectively deployable into a breach while the water is flowing through it and third is the amount of force that the rapid levee repair system imparts to the levees on either side of the breach. A final metric that will be utilized here involves a measure of the repair system's complexity.

	-Duane Dudeck -Brian Welsh, (2009)		
2	-J. Dagher -R. Jüpner -N. Bhaskar (2016)	Possibilities of closing levee breaks in flood events from the German experience	In this paper parameters which effect levees failure, installation of the closing structure, logistics resources, and stability of the closing structure, are chosen on the basis of types of measures taken to close breach. The author analysis that the use of barges to close the breach is a suitable choice and he analyze that first two barges led to a reduction of the inflow by 60% to 70% and with the use of third barge the inflow decreased even more.
3	-M. Hanif Chaudhry -Mohamed Elkholy -C. Riahi-Nezhad (2010)	Investigations on Levee Breach Closure Procedures	The author proposed the development of digital Particle Tracking Velocimetry Technique for application to particle tracking for breach closure and develop flow velocity versus particle size relationships, different breach closure procedures and velocity profiles for different flow rates. The results shows that water elevation in channel of 9 ft., the 6,000 Ib sandbags used would easily washed away and that sandbags weighing 30,000 Ib and 50,000 Ib would be required to close the breach.
4	-Paul J. Bouchard -Sandra S. Bouchard (2011)	Rapid deployment, multi-dimensional wedge barrier levees & dike repair system	Author invention relates to the unique three dimensional design and integration of with selected materials including both natural and made-made, bio and/or photo degradable, non-toxic materials. These materials are engineered and integrated into an interconnected modular matrix barrier of varying dimensions based on site. Which can be deployed quickly and not require use of heavy equipment for installation.
5	-J. L. Florsheim -M. D. Dettinge (2007)	Climate and floods still govern California levee breaks	Author focused on the influence of anthropogenic alterations of levees on fluvial processes affected by climate variability. The results indicate that the frequency of breaks has not changed from first to second half of the 20th Century, despite heroic engineering of rivers in both uplands and lowlands.

6	-Elizabeth C. Burg (2010)	Rapid Repair of levees breaches: PLUG dimension parameterization	Investigated the relationships between the dimensional characteristics of the Portable Lightweight Ubiquitous Gasket (PLUG). This technology is used for temporary rapid repairs of deep and narrow levee breaches and can close breach successfully. The performance of the PLUG is dependent on the dimensional parameters of length, diameter, and percent fill, as well as on site conditions at the time of breach.
7	-Ahmed M. A. Sattar -Hossein Bonakdari -Bahram Gharabaghi -Artur Radecki-Pawlik (2019)	Hydraulic Modelling and Evaluation Equations for the Incipient Motion of Sandbags for Levee Breach closer operation	Author performed laboratory experiment on an open channel levee breach model capturing velocity in 3-D, at selected locations in the breach. Sandbags of various shapes and sizes are tested for incipient motion by the breach flow. And author analyze that a prism sandbag has a better hydrodynamic characteristic and more stability than spherical bags with the same weight.
8	-S. J. Boc, -D. T. Resio -E. C. Burg (2010)	New techniques for the rapid repair of levee breaches	In this paper author tested three concepts for levee repair at the large scale in Stillwater. And he concluded that Rapidly Emplaced Protection for Earthen Levees (REPEL) would provide protection to a levee/dam section from overtopping in extreme flood event and Portable Lightweight Universal Gasket (PLUG) would be used for the repairs of the narrow-deep breach.
9	-David A. Jaffe -Brett F. Sanders (2001)	Engineered levees breaches for flood mitigation	Author examined influence of flood plain storage, levee breach size, flood discharge, and levee breach time on the effectiveness of a breach by treating the breach design as a scaling problem, and obtain a relationship to guide the design of levee breaches.
10	-Joon-Gu Kang -Jong-Tae Kim -Kyoung-Young Choi (2016)	Experimental Study on Stability of levee Protection Method	In this study author installed a magic retaining wall block, which was developed to protect river levee from running water. This study divided the experiment into a total of six steps. According to the experiment results, there was no surface deformation of the magic retaining wall block or any soil loss at the bottom either in case of maximum flow velocity.

3. CONCLUSIONS

The structures like dam or dike were held long times ago to protect downstream area from flooding. Because of their objectives in reserving water, they are exposed to different failures such as overtopping failure, piping failure, side-slope failure etc. During the failure, an initial breach channel is initiated inside body and slowly extended downstream and upstream slopes of the dike due to several geotechnical parameters, As a result of which whole reservoir water is transferred from the upstream to downstream parts of dike leads to catastrophic damage to life and properties. Above literature shows some work done regarding levees breach failure and same for levees breach closer. From literature concluded that till now there is no any effective method or technique is available which is economical and effective to control or reduce levees failure. So there is requirement of some alternating method which can control breaching of levees effectively to protect lives and property.

REFERENCES

[1] Faeh, Roland. "Numerical modeling of breach erosion of river embankments." *Journal of Hydraulic Engineering* 133.9 (2007): 1000-1009..

[2] Elalfy, Ezzat, Ali Asghari Tabrizi, and M. Hanif Chaudhry. "Numerical and experimental modeling of levee breach including slumping failure of breach sides." *Journal of Hydraulic Engineering* 144.2 (2018): 04017066.

[3] Riahi-Nezhad, Cyrus K. "Experimental investigation of steady flows at a breached levee." (2013).

[4] Feliciano Cestero, Jose A., Jasim Imran, and M. Hanif Chaudhry. "Experimental investigation of the effects of soil properties on levee breach by overtopping." *Journal of Hydraulic Engineering* 141.4 (2015): 04014085.

[5] Kakinuma, Takaharu, and Yasuyuki Shimizu. "Large-scale experiment and numerical modeling of a riverine levee breach." *Journal of Hydraulic Engineering* 140.9 (2014): 04014039.

[6] Tsujimoto, Tetsuro, and Md Islam. "Numerical simulation on breach evolution process of a river levee by overtopping." *Journal of Emerging Trends in Engineering and Applied Sciences* 6.1 (2015): 12-18.

[7] MURAMOTO, Y., and Y. FUJITA. "Prediction of water and sediment outflow hydrograph caused by dam and river-levees failures." *US-Asia conference on engineering for mitigating natural hazards damage*. 1987.

[8] Schmocker, Lukas, and Willi H. Hager. "Modelling dike breaching due to overtopping." *Journal of Hydraulic Research* 47.5 (2009): 585-597.

[9] Tabrizi, Ali Asghari. "Modeling Embankment Breach Due To Overtopping." (2016).

[10] Lee, Seung Oh, et al. "Estimates of Discharge Coefficient in Levee Breach Under Two Different Approach Flow Types." *Sustainability* 11.8 (2019): 2374.

[11] Hanson, G. J., K. R. Cook, and S. L. Hunt. "Physical modeling of overtopping erosion and breach formation of cohesive embankments." *Transactions of the ASAE* 48.5 (2005): 1783-1794.

[12] Risher, Paul, and Stanford Gibson. "Applying mechanistic dam breach models to historic levee breaches." *E3S Web of Conferences*. Vol. 7. EDP Sciences, 2016

[13] D. Kornack and P. Rakic, "Cell Proliferation without Neurogenesis in Adult Primate Neocortex," Science, vol. 294, Dec. 2001, pp. 2127-2130, doi: 10.1126/science. 1065467.

[14] Dhiman, Sachin, and Kanhu Charan Patra. "Experimental study of embankment breach based on its construction parameters."

[15] LaRocque, Lindsey Ann, et al. "Experiments on urban flooding caused by a levee breach." *Journal of Hydraulic Engineering* 139.9 (2013): 960-973.

[16] Al-Riffai, Mahmoud. Experimental study of breach mechanics in overtopped noncohesive earthen embankments. Diss. Université d'Ottawa/University of Ottawa, 2014.

[17] Wu, Weiming. "Introduction to DLBreach–A Simplified Physically-Based Dam/Levee Breach Model." *Clarkson University, NY* (2016).

[18] Saghaee, Gholamreza, Ahmad A. Mousa, and Mohamed A. Meguid. "Experimental evaluation of the performance of earth levees deteriorated by wildlife activities." *Acta Geotechnica* 11.1 (2016): 83-93.

[19] Chaudhry, M. H. "Open Channel Flow, 523 pp." (1993).

[20] Kang, Joon-Gu, Jong-Tae Kim, and Kyoung-Young Choi. "Experimental Study on Stability of Levee Protection Method." *Engineering* 8.12 (2016): 852.

[21] Crusto, Mitchell F. "The Katrina Fund: Repairing Breaches in Gulf Coast Insurance Levees." *Harv. J. on Legis.* 43 (2006): 329.

[22] Ko, Dongwoo, and Joongu Kang. "Experimental studies on the stability assessment of a levee using reinforced soil based on a biopolymer." *Water* 10.8 (2018): 1059M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

[23] Resio, Donald, et al. *US Army Engineer Research and Development Center: Rapid repair of levee breaches*. No. SERRI REPORT 81000-01. OAK RIDGE NATIONAL LAB TN, 2011.

[24] Boc, S. J., D. T. Resio, and E. C. Burg. "New techniques for the rapid repair of levee breaches." *WIT Transactions on Ecology and the Environment* 133 (2010): 85-93.

[25] Dagher, J., R. Jüpner, and N. Bhaskar. "Possibilities of closing levee breaks in flood events from the German experience." *Proceedings of the 5th International Conference on Flood Risk Management and Response (FRIAR 2016)*. 2016

[26] Sattar, Ahmed M., Ahmed A. Kassem, and M. Hanif Chaudhry. "Case study: 17th street canal breach closure procedures." *Journal of Hydraulic Engineering* 134.11 (2008): 1547-1558.

[27] Burg, Elizabeth Cathleen. *Rapid repair of levee breaches: plug dimension parameterization*. Diss. Mississippi State University, 2019.

[28] Chaudhry, M. Hanif, Mohamed Elkholy, and Cyrus Riahi-Nezhad. "Investigations on levee breach closure procedures." *Dep. of Civil and Environmental Engineering: Technical Report, University of South Carolina* (2010).

[29] Olson, Kenneth R., and Lois Wright Morton. "Impacts of 2011 Len Small levee breach on private and public Illinois lands." *Journal of soil and water conservation* 68.4 (2013): 89A-95A.

[30] Sattar, Ahmed, et al. "Hydraulic modeling and evaluation equations for the incipient motion of sandbags for levee breach closure operations." *Water* 11.2 (2019): 279.

[31] Jia, Yafei, et al. "Numerical modeling of flow through a breached levee and during levee closure." *World Environmental and Water Resources Congress 2010: Challenges of Change*. 2010.

[32] Resio, Donald, et al. "Development and Demonstration of Rapid Repair of Levee Breaching Technology." *Report to Development of Homeland Security* (2009): 124.

[33] Bouchard, Paul J., and Sandra S. Bouchard. "Rapid Deployment, Multi-Dimensional Wedge Barrier Levee & Dike Repair System." U.S. Patent Application No. 13/165,435.

[34] Jaffe, David A., and Brett F. Sanders. "Engineered levee breaches for flood mitigation." *Journal of hydraulic engineering* 127.6 (2001): 471-479.