STUDY ON EMBANKMENT BREACHING PROCESS AND ANALYSIS OF BREACHING PARAMETERS

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Abstract - *The breaching of earthen dam and embankment occur mainly due to overtopping, erosion and seepage. The dam breach parameters can be predicted using empirical and physical based methods. Three common breach prediction and analyis methods, namely Von Thun and Gillette, Mac Donald and langridge-Monololis, Froehlich are generally used to calculate breach parameters. In this paper an attempt has been made to study various research works done to study the breach parameters.*

Key Words: Embankment breach, Characteristics of failure, Overtopping and Piping hole.

1. INTRODUCTION:

Earthen embankment for example dikes and dams provide large amount of benefit to people all over. Large numbers of embankment structures are man-made structures. Permanent or temporality earthen embankments were built up of cohesive soil or impervious soil, mostly to provide flood protection, from flood water level of some magnitude. However, as flood disaster is an unpredictable natural phenomenon, sometimes the flood level might be higher than the embankment height and which may result in overtopping flow. Thus, embankment could pose danger to human lives and properties due to some extent for their failures due to overtopping, piping and other factors. Generally, the result of overtopping flow is the erosion on the embankment surface and the scour of the toe. No matter how well the embankment was compacted at the construction phase, but due to weathering effects and negligence of proper maintenance and increase in soil moisture during flood event, decreases its strength and it is something which is unavoidable. These are basically among the prominent cause of the embankment failure.

To predict failure time, breach geometry and peak breach discharge empirical methods are used. The three mostly used empirical equations for predicting breach parameters are:

- **Von Thun and Gillette(1990)**

$$B_{avg} = 2.5\, h_w + C_b\,;$$

$$t_f = 0.015\, h_w \qquad [1]$$

Where,

B_{avg} = breach width (meter)

t_f = failure time

C_b = reservoir coefficient

h_w =depth of water above the bottom of the breach (meter)

- **Mac Donald and langridge-Monololis (1984)**

$$V_{er} = 0.0261\,(V_w h_w)^{0.769}\,;$$

$$t_f = 0.0179\, V_{er}{}^{0.364} \qquad [2]$$

Where,

V_{er}= volume of the material eroded from the embankment (cubic meter),

V_w = volume of water that passes through the breach (cubic meter),

h_w = depth of water above the bottom of the breach (meter)

- **Froehlich(1995)**

$$B_{avg} = 0.1803\ K_o\ {V_w}^{0.32} {h_b}^{0.19}$$

$$t_f = 0.00254\ (V_w)^{0.53}\ {h_b}^{-0.9} \qquad [3]$$

Where,

K_o = failure coefficient

B_{avg} = breach width (meter)

t_f =failure time (hour)

1.1 Failure Mode of Earthen Embankment:

a. Hydraulic failure
   i. Overtopping
   ii. Erosion of upstream.
   iii. Erosion of downstream due to heavy rains.
   iv. Erosion of downstream due to tail water.
b. Seepage failure
   i. Piping through embankment.
   ii. Sloughing of the downstream toe due to seepage.
c. Structural failure
   i. Sliding of upstream face due to sudden draw down.
   ii. Sliding of downstream slope due to continuous saturation.
   iii. Inadequate cross-section
d. Cutting of embankment
   i. Cut by miscreant
   ii. Public cut
e. Others
   i. Due to afflux of bridge
   ii. Structural failure due to sudden thrust of flood water
   iii. High pressure of flood water from country side.

2. HISTORY OF BREACH ANALYSIS:

In the mid 1960's, Cristrofano (1965) developed a model for analyzing dam breach peak discharge. The U.S. Bureau of Reclamation (USBR) and sediment transport specialist investigated breach erosion process. In the early of 1980's, many computer programs were put forward to analyse dam breach process. Mac Donald and Langridge-Monopolis (1984) told that for accuracy of breach study, breach geometry and failure time information were used. Mac Donald and Langridge-Monopolis (1984) studied 42 existing failure dam data and performed the first systematic analysis to establish empirical relationship between breach width, breach time failure and peak discharge. Like Mac Donald and Langridge-Monopolis equations, many other researchers like USBR (1988), Von-Thus and Gillette (1990), Dewey and Gillette (1993) and Froehlich (1995a, 1995b) also put forward their own equations. Their equations are referred as "Empirical Methods"

Now-a-days many computer programs are put forward for analysing embankment breach process. Some of the most widely used programming are National Weather service (NWS), Dam-Break flood forecasting model (DAMBRK), the U.S. Army Corps of Engineers, Hydrologic Engineering Centre flood Hydrologic Package, HEC-1 (Hydrologic Engineering Centre, 1981) and the NWS Simplified Dam-Break Flood Forecasting Model, SMPDBK (wetmore and fread, 1983).

Breaching analysis methods are grouped into six categories:

I. Comparative Analysis:
In this method a given dam geometry, height, slope angles, dam area and volumes are compared with similar size of failure dam and appropriate breach parameters or peak outflow may also be determined by comparison.

II. Empirical Method:
This method is used to predict time of failure, breach geometry and peak discharge. The four most widely used empirical equations for predicting breach parameters are:
Mac Donald and Langridge-Monopolis (1984), USBR (1988), Von-Thun and Gillette (1990) and Froehlich (1995a, 1995b).

III. Physically-Based Models:
This model is used to predict breach development and breach outflows using an erosion model based on the principle of hydraulics, soil mechanics and sediment transport.

IV. Hydraulic Models:
Hydraulic models are physically based models and have only one parameter (the roughness coefficient) to calibrate. For evaluating hydraulic model flow data, channel geometry, roughness co-efficient and initial boundary condition are required. This model is further

subdivided into steady flow analysis and unsteady flow analysis. With HEC-RAS computer programming, hydraulic model for dam safety and both steady and unsteady flow can be analysed.

V. Parametric Models:

For estimating peak discharge and breach hydrographs, parametric computer models i.e. HEC-1, HEC-HMS and HEC-RAS are used and for estimating critical condition at downstream locations, HEC-RAS can be used.

VI. Hydrologic Models:

Hydrologic routing models are put on an analytical or an empirical relationship between storage within the reach and discharge; it is ease of use, simplicity and computational efficiency (USACE 1994).

3. BACKGROUND

The research on embankment breach was started many years back and has been a topic of interest till date. Different journals have been put forward by various researchers on coupling flow and sediment transport, flow processes on embankment breaching, prediction of embankment breach parameters etc.

4. LITERATURE REVIEW:

4.1 Literature related to numerical modelling:

U.S Army Corps of Engineers (1994) discussed the various methods for evaluating flood run-off characteristics of watersheds. [14]

Wetmore J.N and Fread D.L (1984) expressed a simplified predicting flood procedure produced in downstream due to dame failure, commonly known as the Simplified Dam Break (SMPDBK) Flood Forecasting model. [16]

Jai Yafei, Sherry Hunt, developed two dimensional embankment breach model which is capable of simulating one or multiple embankment breaches at the same time in more complicated general surface flow condition. This model is developed by surface flow implemented into CCHE2D model and the breach mechanism, WinDAM model. For simulation of free surface flows, sediment transport, bank erosion, vegetation effect and water quantity finite element method is used based on CCHE2D depth-integrated model (Jai and Wang 1999, Jai et al. 2002, 2006, Ding et al. 2003, and Zhu et al. 2008). [19]

He Zhinguo, Hu Peng et al. (2015) developed a depth averaged 2D couple flow and sediment model to enquire earthen embankment breach due to overtopping flow with or without wave. The model tested across two experimental data which shows the flow characteristics, sediment transport and bed changes. For overtopping flow with and without wave, the flow and morphologic changes are analysed. They adopted non-equilibrium and angle of repose for total land sediment transport and non-cohesive embankment slope. [9]

Visser Paul J., Ren Yankai et al. (2013) developed the counterfeit through physical and numerical model of complex hydraulic characteristic of breach flow. Hydraulic factors of breach flow, including distribution of velocity, water level, Froude numbers etc. is analysed and verified through physical model and breach flow is simulated by 2D and 3D model. [20]

Ahmad.M.N, Razad.A.Z.A etal (2010) studied dam break process for the Saddle Dam to establish breach characteristic and outflow hydrograph. [12]

Muda Z. C., Rohani H. et al. (2013) analyse Kahang Dam failure by prediction breach hydrographs and generate flood inundation map from MIKE21 at down-stream. [10]

Gogoi.L and Borpujari.C (2014) investigate the bank line erosion to study the extent extorting erosion in Majuli Island. Finally some protective measures for reducing the impact have been suggested. [8]

Dhara.S and Paul.A.K (2016) study some embankment of the south western part of Sundarban to identify the impact of costal environment, to analyse embankment type, structure and breaching purpose and hence suggest the embankment management options. [2]

Fread D.L., (1998a) describe the algorithm and a user's manual for running simulation in DAMBRK model. [6]

Fread D.L., (1998b) describe the algorithm and a user's manual for running simulation in BREACH model. [7]

4.2 Literature related to experimental work:

Sanit Wonga (2015) work on experiment and simulation of earthen embankment breach. For performing the experiments (overtopping, beneath structure and piping hole), the fixed embankment slope with scale 1:8.5 were setup and four constant discharges were supplied (4.14, 7.78, 11.59 and 16.48 l/s). By using physical and numerical simulation the embankment breach and failure characteristics were

studied and iRIC Nays2D numerical model is used to study both water flow and breach morphological characteristics. The result which is developed can be used for protect hydraulic structure from embankment breach failure and flood. [17]

Emelen.S.V, Zech.Y. et al (2015) done an experimental work on embankment breach processes in different small-scale by overtopping, conducted on different sand embankment and hence the results are analysed by compare with existing theories, evolution in levees of the longitudinal breach profiles made of either cohesive or non-cohesive soil. [3]

4.3 Literature related to analytical modelling:

Von Thun, Gillette, et al (1990) analysed 57 dam failures by Froehlich (1987), Mac Donald and Langridge-Monopolis (1984) empirical equations and calculated breach width at mid-height, side slope angles and failure time for assumed trapezoidal breach dam. [15]

U.S. Army Corps of Engineers (1993) represence technical procedures and basic principles for analysis open channel flows in river system. [13]

Gary W. Brunner, P.E. et al. gathered and prepared data to create a river hydraulic model in HEC-RAS accordant with HEC-GeoRAS to estimate breach parameters using regression equations, simulation of dam failure analysis and mapping the resulting flood using GIS. [1]

Mac Donald, T.C and Langridge-Monopolis.J (1984) analysed various dam failure case histories (42) in order to developed graphical relationship for predicting breach characteristics on dam erosion. [11]

Yi (Frank) Xiong (2011) analysed Froster Joseph Sayers dam Break by USACE Hydrologic Engineering Center's River Analysis System (HEC-RAS), model based on available geometry data. Foster Joseph Sayer Dam fails due to leakage elongates the time of high wave surface level. The result of dam break is comprehensive and complicated; the actual failure mechanics are not well understood. [18]

Froehlich,D.C., (1995a) analysed 22 dam failures using regression method and developed new empirical equations for estimating peak outflow for breach dams. [4]

Froehlich D.C., (1995b) analysed 63 embankment failure cases and developed empirical equations using multiple regression analysis for estimate average breach width, side slope ratio and breach formation time. [5]

5. CONCLUSION:

After studying extensive literature on Embankment Breaching, it has been observed that many researchers have research on embankment breaching, based on prediction of embankment breach parameters, coupling flow and sediment transport, flow processes on embankment breach etc. An extensive study has been carried out also for predicting embankment breach parameters.

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