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A Comparative Study of Estimation of Breach Parameters for an Embankment Dam using Regression Equations

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Abstract: *Dams are built to fulfil many objectives such as irrigation, flood moderation, hydropower, water supply, sedimentation control in rivers. The breaching of dam leads to water logging, loss of life, Financial Loss. The peak outflow discharge from a breached dam and flood inundation area is solely dependent on accurate prediction of breach parameters of a dam. The dam break phenomena can be understood by the prediction of breach parameters such as breach width, breach height, breach side slope and breach formation time. Accordingly, the main objective of this paper is to calculate various breach parameters for the existing dam in India, namely the Maithon Dam using various empirical equations.*
Keywords: *Breaching Parameters, Empirical Equation, Maithon Dam*

I. Introduction

Dam failures have observed from the last two centuries. The loss of life can vary with the extent of the inundation area, the size of the inhabitants at risk and the amount of warning time available. There is a vital necessity to perceive and enhance the technology used to analyze such embankment dam breach scenario.

It is essential the fairly accurate breach parameters to develop effective emergency action plans, design of early warning systems and impersonation of threats to lives and property. The possible dam failures analyze procedure discussed through different methods in literature.

The predominant step for dam breach modeling is the calculation of outflow hydrograph through the dam breach. There are so many uncertainties involved in dam breach modeling. The mathematical explanation deficiencies are involved in the mathematical explanation of Breach formation processes, because they are based on some postulations.

Computer programs are also evolved to analyze the embankment breach process. The common breach prediction methods are, namely MacDonald and Langridge-Monopolis (1984), Von Thun and Gillette (1990), Froehlich (1995a), Froehlich (2008), and Xu and Zhang (2009) are substantially used to calculate breach parameters.

II. Failure Mode Of Earthen Dam

Failure of an embankment dam may be mainly related to i) Hydraulic Failure, ii) Seepage Failure and iii) Structural Failure.

2.1 Hydraulic failure (40% of Dam Failure)

Hydraulic failure occurs mainly due to

a) Downstream toe erosion
b) Overtopping Failure
c) Downstream side erosion by gully formation
d) Downstream toe erosion

2.2 Seepage Failure (35% of Dam Failure)

Seepage Failure is mostly related to

a) Piping through foundation
b) Piping through dam body
c) Downstream portion sloughing

2.3 Structural Failure (25% of Dam Failure)

Structural failure of an embankment dam occurs due to

a) Embankment sliding
b) Foundation sliding
c) Faulty construction and poor maintenance
d) Earthquake

III. Review Of Past Works

In the eighties, Collection have been started of detailed breaches of dam by many researchers to simulate models so that it can be able to predict the effects and mechanisms of breach and peak outflow estimations.

During the eighties, Researchers started collecting detail of breaches of dams in order to simulate models that are able to predict the effects and mechanisms of breach and estimate peak outflows. Among those, most remarkable are SCS (1981), Singh and Snorrason (1982), MacDonald and Langridge- Monopolis (1984), Costa (1985), Froehlich (1987), (1995) and Singh and Scarlatos (1988). The most recognized of those are FERC (1987), Reclamation (1988) and Von Thun and Gillette (1990).

Johnson and Illes (1976) envisaged failure shapes for earthen, gravity, arch concrete dams. They concluded that the starting breach shape is triangle which ends as a trapezoid. After the studying on 20 dam failures Singh and Snorrason (1982,1984) gave a correlation between dam height and breach width.

MacDonald and Langridge-Monopolis (1984) suggested the breach shape as trapezoidal or triangular upto base of the dam with the side slopes of 1H: 2V. They also assessed the quantity of eroded embankment materials for earthen dams based on time of failure.

43 dam failure cases for non-dimensional analysis by Froehlich (1987, 1995) to develop equations to estimate side slope, Average breach width and time of formation of breach. After thirteen years, he published a revised equations based on 63 case studies and proposed equations were not non-dimensional and had better estimated coefficients.

Bureau of Reclamation (1988) suggested a relationship between breach width and height calculated from the starting reservoir water level to the end of breach.

Singh and Scarlatos (1988) studied 52 dam failure cases and concluded that top width of breach is 6% to 74% larger than the bottom width with an average of 29% and the tolerable standard deviation is near about 18%. A Disseminating nature found in the ratio of top breach width to dam height. The breach side slopes varies between 40^0 to 80^0. Most dam failure times were less than 3 hours.

Von Thun and Gillette (1990) acquired the study data related to Froehlich, MacDonald and Langridge-Monopolis to evolve some breach parameters. They presumed that breach side slope is 1H: 1V except for dams having cohesive shells or cores, would have slopes of 1:2 or 1:3 is more allowable.

IV. Approaches Of Breaching Analysis

Bureau of Reclamation (1988) grouped the various perspectives to understand breaching analysis into four classes:

4.1 Physically based methods:

An erosion model has been made to assess breach parameters and resulting breach outflows based on the principles of sediment transport hydraulics, hydraulics, and soil mechanics.

4.2 Parametric Models:

Ultimate breach geometry and Time of failure computed based on the case study information. Breach outflows computed based on the concepts of Hydraulics.

4.3 Predictor Equations:

Peak discharge is assessed by empirical equation depend on case study and presume outflow hydrograph shape.

4.4 Comparative Analysis:

Existing dam is compared with a failed dam which is similar in size and construction, and breach parameters and peak outflows can be calculated.

V. Study Area

5.1 Geographical Description of Study Area

This study used the Maithon Dam in India as the system under study. Maithon Dam is constructed across river Barakar and the dam is located at Latitude 23°47'13.06" North and Longitude 86°49'01.44" East.

The catchment area upstream of the dam has been estimated as 6391.7 km^2, which spreads over the districts of Dhanbad, Jamtara, Giridih, Kodarma, Hazaribag and Chatra of the state of Jharkhand. It extends between latitude 23°46'34.12" north and longitude 85°09'16.26" east, to latitude 24°32'09.80" north and longitude 86°53'19.20" east.

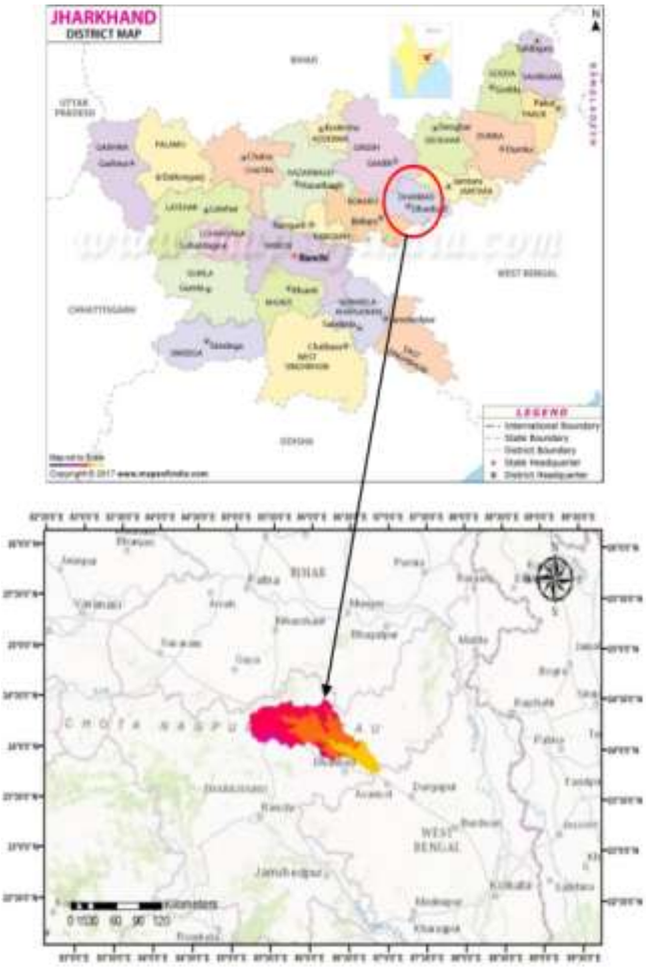

Figure 1: Study Area

5.2 Physiographic description of Maithon Dam

Maithon dam had completed in 1957 under the supervision of Mr. W.L.Voord, a civil engineer of Tennessee Valley Authority (TVA).It has the biggest reservoir in Damodar Valley Corporation. It has been designed for flood control and generates 60,000 kW of electric power. All the physiographic parameters has been described in the Table 1.

The dam is located on Barakar river, which the major tributary of Damodar River. It is seasonal river, 82% of the reservoir filled up by the rainfall in July-September and stored water is used for irrigation by Burdwan area.

Table 1: Physiographic Parameter of Maithon Dam

Description	Value
River	Barakar, major tributary of Damodar River
Height	56.08 m
Length	4064.35 m - Earthen embankment 362.41 m Concrete overflow section
Gross storage capacity	1093.54 Mm^3
Live storage capacity	441.64 Mm^3
Full reservoir level	152.40 m
Minimum draw down level	132.59 m
Dead storage level	132.59 m

Dam top level	156.06 m
Crest level	140.21 m
Spillway type	Ogee
Type of gates	Radial
Size	12.5 m (h) × 12.19 m (w)
No. of bays	12 Nos.

VI. Breach Parameters Definitions

This section contains the information about physical breach parameter (breach depth, breach side slopes and breach width) and also the parameters that specify the time required for breach initiation and development.

(i) Breach Width

It refers the top, lower or average width of the breach formed in a dam section.

(ii) Breach depth and Height

The depth is generally referred as the distance from the dam crest to the breach bottom.

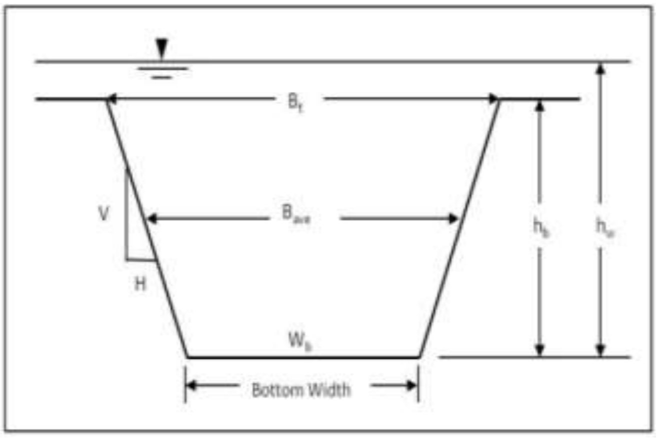

Figure 2: Breach Parameters

(iii) Breach Side Slope Factor

It describes the shape of the breach opening. Generally it is mentioned as Z H: 1V.

(iv) Breach Initiation Time

It starts when the first water flows over or through the dam body. That will help to initiate warning, evacuation or knowledge of the potential for dam failure.

It starts with first flow over or through a dam that will initiate warning, evacuation or awareness of the potential for dam failure.

(v) Breach Formation Time

The total time required for first breaching of upstream face of dam till the full formation of breach.

VII. Empirical Equations To Calculate Breach Parameters

To predict breach geometry, failure time and peak breach discharge empirical methods are used.

(i) MacDonald and Langridge-Monopolis (1984)

They developed a relationship called "Breach Formation Factor" using 42 data sets (earthfill dams, earthfill dams with a clay core, Rockfill dams). That is the product of height of water above dam and volume of water coming out of dam.

For Earthfill Dam

$$V_{eroded} = 0.261(V_w h_w)^{0.769} \quad \text{(i)}$$

$$t_f = 0.0179(V_{eroded})^{0.364} \quad \text{(ii)}$$

Base Width of Breach

$$W_b = \frac{V_{eroded} - h_b^2 (CZ_b - \frac{h_b Z_b Z_3}{3})}{h_b (c + \frac{h_b Z_3}{2a})} \qquad \text{(iii)}$$

Average Breach Side slope of breach: 0.5H: 1V Overtopping Failure.

(ii) Von Thun and Gillette (1990)

They have used the data of Froehlich (1987) and the MacDonald and Langridge-Monopolis (1984) to understand the methodology using 57 dam case studies.

$$B_{avg} = 2.5 h_w + C_b \qquad \text{(iv)}$$

The equation shows that the breach formation time is a function of water depth above the bottom of the breach.

$$t_f = 0.02 h_w + 0.25 \qquad \text{(v)}$$

Average Breach Side slope of breach: 0.5H: 1V Overtopping Failure.

(iii) Froehlich (1995a):

The breach parameters for like Earthen, Zoned Earthen, Earthen with a core wall (Clay), and rockfill dams have been calculated using 63 data sets.

$$B_{avg} = 0.1803 K_0 V_w^{0.32} h_b^{0.19} \qquad \text{(vi)}$$

$$t_f = 0.00254 V_w^{0.32} h_b^{-0.90} \qquad \text{(vii)}$$

Average Breach Side slope of breach: 1.4H: 1V Overtopping Failure.

(iv) Froehlich (2008):

He revised his result using 74 data sets that are related to earthen, Zoned earthen, earthen with a core wall (clay), and rock fill to envisage a set of equations to predict breach parameters.

$$B_{avg} = 0.27 K_0 V_w^{0.32} h_b^{0.04} \qquad \text{(viii)}$$

$$t_f = 63.2 \sqrt{V_w / g h_b^2} \qquad \text{(ix)}$$

Average Breach Side slope: 1.0H: 1V Overtopping Failure

(v) Xu and Zhang (2009):

The database of 182 dams gathered by Xu and Zhang that are earthfill and rockfill dams from the United States and China. The 50 percent of the dams are greater than 15 meters.

$$\frac{B_{avg}}{h_b} = 0.787 (\frac{h_d}{h_r}) (\frac{V_w^{1/3}}{h_w}) e^{B_3} \qquad \text{(x)}$$

$$\frac{B_t}{h_b} = 1.062 (\frac{h_d}{h_r})^{0.092} (\frac{V_w^{1/3}}{h_w})^{0.508} e^{B_2} \qquad \text{(xi)}$$

$$Z = \frac{B_t - B_{avg}}{h_b} \qquad \text{(xii)}$$

$$\frac{T_f}{T_r} = 0.304 (\frac{h_d}{h_r})^{0.707} (\frac{V_w^{1/3}}{h_w})^{1.228} e^{B_5} \qquad \text{(xiii)}$$

Average Breach Side slope: 3.41H: 1V Overtopping Failure

Where,

B_{avg} = Average Breach Width

K_0 = Constant (1.4 for Overtopping, 1.0 for Piping)

V_w = Volume of reservoir at the time of failure (cubic meters)

t_f = Breach Formation time (hours)

V_{eroded} = Volume of material eroded from the dam embankment (cubic meters)

V_{out} = Volume of water passes through the breach

W_b = Bottom width of the breach (meters)

C = Crest width of dam (meters)

h_r = 15 meters, which differentiate between large dams and small dams.

T_r = 1 hour (unit duration)

B_t = Breach top width (meters)

C_b = Coefficient, a function of reservoir size

VIII. Breach Parameter Estimation Table

The various breach parameters as estimated in the present study using various equations are summarized in Table 2.

Table 2: Summary of Results

Regression Equations	Average Breach Width (m)	Breach Formation Time (hours)	Breach side slopes (H:V)
Froehlich (1995a)	389	4.176	1.4:1
MacDonald and Langridge-Monopolis (1984)	632.904	4.584	0.5:1
Von Thun and Gillette (1990)	179.875	1.249	0.5:1
Froehlich (2008)	300.69	3.357	1:1
Xu and Zhang (2009)	393.64	3.748	3.41:1

IX. Conclusion

Dam break phenomenon is relient on the assessment of Breach Parameters. Breach parameters are really beneficial to evaluate the extent of flooding and travel time of a flood wave to certain distances that would be occur due to failure of a dam. The breach outflow hydrograph varies drastically with the variation in the breach parameters. In this study, breach parameters (Height, Average Width, Side slopes ratio, and formation time of ultimate breach) are calculated using Regression Equation for Maithon Dam. It is clearly understood that different regression equations are also based on the data sets available. Average breach width is varies from 179.875 m to 632.904 m. Breach Formation time varies from 1.249 hours to 4.584 hours. As the breach formation time increases the rate of erosion of material through the breach from a dam is reduced. MacDonald and Langridge-Monopolis (1984) overestimated the breach parameters for Maithon Dam. For the accurate prediction of breach parameters we can use different methods such as physical methods, Breach models and Comparative analysis. This study can be used to improve the accuracy of numerical simulations of dam-break waves.

References

[1]. Froehlich, David C., 1987 "Embankment-Dam Breach Parameters" Hydraulic Engineering, Proceedings of the 1987 National Conference, ASCE, Willsiams burg, VA, pages 570 - 575

[2]. Froehlich, David C. 1995 "Embankment Dam Breach Parameters Revisited" First International Conference, Water Resources Engineering, Environmental and Water Resources Institute (EWRI), 14 - 18 August 1995. ASCE, Water Resources Engineering Proceeding, pages 887 – 891.

[3]. Froehlich, David C., 1995. "Peak Outflow from Breached Embankment Dam". ASCE Journal of Water Resources Planning and Management, Volume 121, Issue 1, January 1995, pages 90 - 97.

[4]. Froehlich, David C., 2008 "Embankment Dam Breach Parameters and Their Uncertainties" ASCE, Journal of Hydraulic Engineering, Vol. 134, No. 12, December 2008, pages 1708-1721. ISSN 0733-9429.

[5]. MacDonald, Thomas C., and Langridge-Monopolis, J, 1984 “Breaching characteristics of dam failures” ASCE Journal of Hydraulic Engineering, Vol. 110, No. 5, May 1984, pages 567 - 586.
[6]. Von Thun, J. Lawrence, and Gillette, D. R., 1990 “Guidance on breach parameters” Unpublished internal document, U.S. Bureau of Reclamation, Denver, CO. March 1990, 17 pages.
[7]. Wahl, Tony L., 1998 “Prediction of Embankment Dam Breach Parameters - A Literature Review and Needs Assessment” Dam Safety Research Report, DSO-98-004. Water Resources Research Laboratory, U.S. Dept. of the Interior, Bureau of Reclamation, Dam Safety Office (DSO), July 1998.
[8]. Wahl, Tony L., 2009. "Evaluation of New Models for Simulating Embankment Dam Breach. Association of State Dam Safety Officials (ASDO) Conference, Hollywood, Florida, 27 September - 1 October 2009.
[9]. Xu, Y. and Zhang , L. M., 2009 “Breaching Parameters for Earth and Rockfill Dams” ASCE Journal of Geotechnical and Geoenvironmental Engineering, Volume 135, No. 12, pages 1957 - 1970, December 2009.