Dam Break Analysis - A Case Study

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Abstract: This paper is mainly focused on the effects of post dam break. It can be estimated from the flood developed from the dam break. It will also throw light on high flood areas in the downstream side of the dam which will help assess the type of emergency facilities.

Keywords: Dam-Break Analysis, Dam Breach, Dam CFD, Pawana Dam

I. Introduction

1.1. Dam Break Analysis:-

Dam break analysis is characterization and identifying of potential dam failures are post effects of resulting floods from dam breach. It is this characterization of the threat to public safety that a dam poses decides the classification of the dam and also the standard of care, safety and maintenance to which the dam is held. The requirement to prepare an emergency action plan, requiring preparation of inundation maps which accurately predict dam breach flood depths and arrival times at critical locations. The population associated along with the critical section are located in close proximity downstream of a dam, details of the breaching process and the calculated peak discharge may have little effect on the results. The breach parameters like breach width, depth, and rate of development are more crucial to analyse especially when the locations of population centres are near to the dam. The associated cost and assumptions increases if the breach parameters cannot be predicted with reasonable accuracy. A recent query of the dam safety engineers within the Colorado Dam Safety Branch determined that there is currently no consensus nor up-to-date guidance regarding the state-of-the-practice procedures for performing dam breach analysis.This study can also estimate high flood level and, to fix the flood control lines on downstream side of the dam, estimation of wave pressure after dam break. The study also focus on to understand the hydraulic characteristics and breach shape, understand the flow of huge debris from upstream as well as downstream which will be carried away with flow after dam break, study the erosionof dam after dam break, it give important information for embankment on the downstream sides of the river. It also helps to avoid erosion of soil along the embankment of downstream.

1.2. Need for Dam-Break Analysis:-

Two major consequences of a bam failure are:-

1. Life loss: This loss occurs if the villages and the residing families are washed away by the flood resulting from dam-break.

2. Economic: Economic loss is calculated in terms of revenue which will be required to rebuild the washed away villages in terms of infrastructure, and other allied facilities.

1.3. Objective:-

"Pawana dam" which is gravity dam constructed on Pawana River near Lonavala in 1972 is selected for case study of dam break analysis. Pawana Dam is located about 7 km from Lonavala and about 19 km in the interior of Kamshet. Pawana Dam is has been used for generating electricity and supplying water for irrigation.

The dam break analysis willmake possible to estimate the flood and flood affected areas at downstream due to breach. This enablesthecost estimation in case of rehabilitation.This study seesthe possibilities of precautionary measures which can be taken to completely avoid the dam break which avoid or minimize damage.

This study will help the town-planner decide on the no development zone, flood control lines within certain limit after the embankment along the river.

II. Methodology

For understanding dam-breach analysis tools, it is important to understand the critical breach parameters. There are four such critical parameters:

1) Breach parameter estimation (breach size/shape and time of failure),
2) Breach peak discharge and breach hydrograph estimation,
3) Breach flood routing, and
4) Estimation of the hydraulic conditions at critical locations.

Empirical Methods:-

Empirical methods are used to predict time to failure and breach geometry, as well as to predict peak breach discharges. The empirical approach relies on statistical analysis of data obtained from documented failures. The four most widely used and accepted empirically derived enveloping curves and/or equations for predicting breach parameters are: MacDonald & Langridge – Monopolis (1984), U.S. Bureau of Reclamation (USBR-1988), Von Thun and Gillette (1990), and Froehlich (1995a, 1995b, 2008).[i]

In this study Empirical equations have been used to estimate the dam breach flood.

A study on estimation of flood using Empirical methods was performed.

As mentioned in Guidelines for dam breach analysis the MacDonald & Langridge-Monopolis (1984), Washington State (2007) and Froehlich (2008) methods are the recommended empirical tools for predicting dam breach parameters within the State of Colorado.

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The appropriate equations are mentioned in equation no. 1 & 2 in this paper. All the calculations are in English units. Accordingly, unit conversions have been performed and the discharge has been calculated.

MacDonald & Langridge-Monopolis (1984) & Washington (2007) proposed empirical equations are Volume Eroded and Breach Development Time. It is calculated from reservoir volume (Vw) and maximum water depth (Hw).Parameters like volume of embankment eroded during breach formation, based on the product of the reservoir volume (Vw) and maximum water depth (Hw) are very well computed by the MacDonald & Langridge-Monopolis method.[ii]

Wetmore and Fread (1984) provide an alternative to the MacDonald & Langridge-Monopolis (1984) and Froehlich (2008) equations for breach peak discharge. [iii]

Washington State (2007) took the MacDonald & Langridge-Monopolis method and adjusted it based upon whether the dam is made of cohesion less or cohesive material.

However, The Froehlich (2008) method is dependent only on:

a) The volume of the reservoir,
b) Height of the breach and
c) The assumed breach side-slope.

This method also distinguishes between piping and overtopping failure. A failure mode factor (Ko) is used.

Froehlich equation stands valid because with his consideration dams with greater height tend to produce shorter failure times for a given reservoir volume.[iv], [v]

To calculate breach development time

Where:
K_o = Failure Mode Factor
H_b = Height of breach in feet
V_w = Reservoir volume stored in acre-feet

To calculate Discharge:

Where:
Q_p = Dam break peak discharge in cfs
B_{avg} = Average breach width in feet
H_w = Maximum depth of water stored behind the breach in feet
T_f = Breach development time in hours
γ = Instantaneous flow reduction factor = 23.4 As/Bavg (equivalent to 'C' in Wetmore and Fread (1984)
A_s= Surface area of the reservoir in acres corresponding to H_w

III. Results and Tables

Manual Calculation for Discharge through dam breach using Froehlich equation

(All the dimensions in Fig. no. 1 are in meters, however wherever necessary the values are converted to British units)

Dam Dimensions are as follows:

Length	= 1329 m	
Total height	= 42.7 m	
Freeboard	= (42.7-38)	= 4.7 m
Total Volume	= 30,500 km^3	

Slope is assumed to be:
Depth of water at 1 km = 34m (approx.)

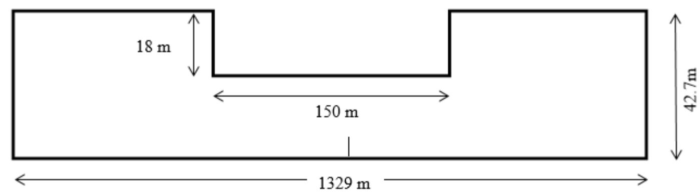

Figure 1: Sketch of Breach

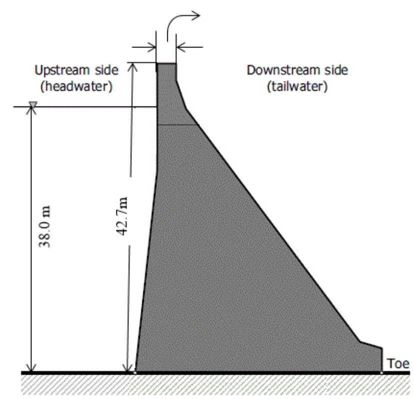

Figure 2: Section of Breach

Slope = 0.894473

Substituting values of Slope and Volume of water in equation (1) gives Breach development time in hours

Again, substituting these values in Froehlich equation; gives the discharge through dam breach from equation no. (2)

Assuming Breach width of 150 meters, discharge was calculated as by using the Froehlich empirical equation. As per this equation the breach development time in hours was calculated as .

Same breach dimension was modelled in ANSYS Fluent (CFD) software. Volume of Flow (VOF) model was used to simulate the dam break.[vi], [vii], [viii]The discharge was calculated as 81520cfs, i.e.2308.38 m^3/s. Thus, the results for both are in close agreement with about 3% error which is acceptable for this type of simulation.

Results for 2-D dam break analysis using ANSYS Fluent – VOF Model has been presented in figure 3[ix] [x].

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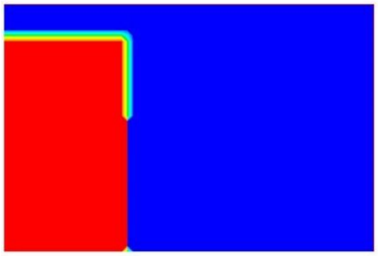
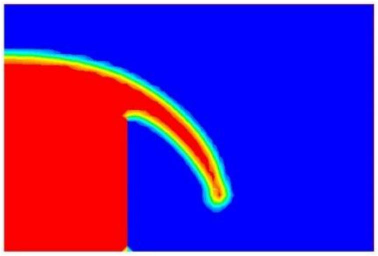
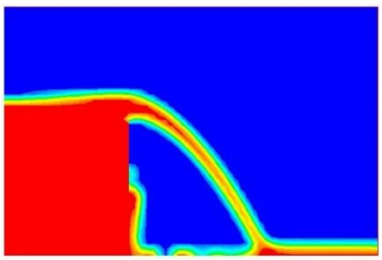


Time = 0 sec



Time = 5 sec



Time = 10 sec

Figure 3: CFD Simulation Results for time 0,5 & 10 sec.

It was observed that, villages such as Phagne, Kale, Bramnoli, Kothume, Pavanangar, Yelse, Shivali, Bhodavali, Kadhade, are in very close proximity to the pavna dam and are highly prone to the flood from the bam break.

Villages like Bour, Thugaon, Malvandi, Shivane, Oxarde, Pimpalkhule, Adhe are a bit far from the dam but still come under the flood affected area by the dam breach.[xi]

About 9 villages (i.e: Phagne, Kale, Bramnoli, Kothume, Pavanangar, Yelse, Shivali, Bhodavali, Kadhade) can be completely under flood and might need rehabilitation.

Table 1: Table showing Rehabilitation cost

Sr. No.	**Name of the Village**	**Human Population (Approx)**	**No. of Famalies (Approx.)**	**Rehabilitation cost (in lacs)**
1	Phagne	594	100	1,500
2	Kale	2,480	454	6,810
3	Bramnoli	648	189	2,835
4	Kothume	1,102	354	5,310
5	Yelse	1,041	182	2,730
6	Shivali	1,289	206	3,090
7	Bhodavali	342	55	825
8	Kadhade	1,250	217	3,255
	TOTAL	**8,746**	**1,757**	**26,355**

Thus, the total cost for rehabilitation of the villages is estimated to be Rs. 26,355 lacs. This has been calculated considering 15 lac per family which includes land, construction, and infracture cost.[xii]

Precautionary measures which can be taken are:

1) Monitoring: visual inspection which can be on site.
2) Dam logbook: a logbook in which activities (such as maintenance and inspections) are recorded.
3) Dam safety review: at regular intervals, dam must undergo a safety review by an engineer.[xiii]

IV. Conclusion

It is very difficult to estimate the cost of maintenance and safety precautions for the given dam.The estimated cost of rehabilitation of villages is Rs. 26,355 lacswhich is much morethan the dam maintenance cost. Thusit can be said thatprecaution is better than cure.

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