Flood Wave Transmission on D/S of Sina-Kolegaon Project, India; due to PMF, Gate Opening and Dam Breach

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***Abstract*—The Sina Kolegaon Project in Maharashtra, India is an earthen dam with central Masonry spillway. It has total length of 1612.2m, maximum height of earthen portion is 15.64m and in masonry portion is 26.10m. The project is constructed on the river Sina, a tributary of river Bhima in Krishna basin. The river Sina originates in Ahmednagar district and joins river Bhima in Solapur district. It flows through a considerably flat terrain and has a very mild slope. The catchment area of the river up to dam site is 5569sq.km. The annual rainfall in the catchments varies from 500mm to 700mm. After completion of project there is change in downstream floods (pattern, frequency, severity). There is fear on banks of river on d/s project is "the project created flood situations in dry area" which is not true. It is necessary to determine peak discharges for various conditions, time to reach peaks at various locations and its inundation. In present paper it showed how the flood waves are transmitted on downstream of project for PMF, gate opening hydrograph and various dam breaks. The flood hydrographs at various locations are determined and time to reach the peaks is worked out. Also inundations due to these peaks are worked out. This is very useful data in emergency action plan and preparedness in floods.**

***Index Terms*—hydrology, flash flood, flood wave transmission, dam breach, inundation, HEC-RAS**

I. Introduction

In the present study flood analysis on downstream of the Project is studied using HEC-RAS. The floods due to gate opening, PMF and dam breach in masonry portion are studied and its effects are presented. The analysis is done up to confluence of Sina river with Bhima river, which is 166.57km from dam site. The inundation analysis and flood depths at various locations due to floods are also evaluated. The flood hydrographs at various floods are derived and presented. Based on these hydrographs the peaks and time to reach these peaks is determined. The results are presented in graphical format for comparison.

II. HEC-RAS Model

The analysis is done on projects geometry, topography, hydraulic and hydrological data. The data is modeled in HEC-RAS. It can be broadly classified in (i) Geometry and Topography (ii) Hydraulics and Hydrological.

A. *Geometric Modeling*

The geometry of HEC-RAS model (Fig. 1) consists of river system, reaches, and cross sections at nodal points, reservoir details, dam properties, and spillway and gate properties, gate opening properties. The details of each term are well explained in User's Manual [1].

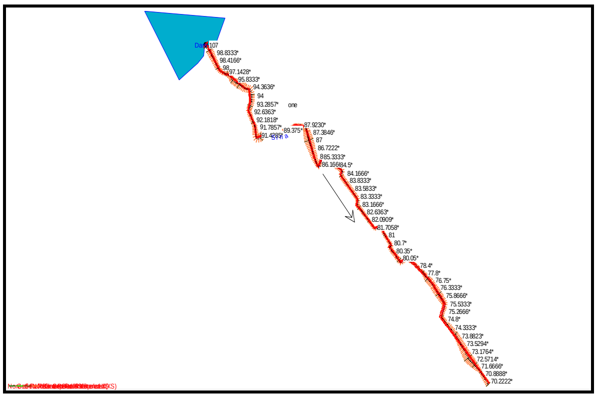

Figure 1. Geometry of sina - kolegaon project in HEC-RAS

The geometry of the Sina Kolegaon project is modeled as following:

The reservoir is modeled as storage area. The capacity curve is given for its volumetric consideration.

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- The connection to reservoir to the river is made with river reach “one” directly at cross section number 107. (Fig. 2)
- The dam proper is input as “Inline Structure” river station no 105.1.
- The Inline structure has two minimum cross sections on u/s are RS 106 and RS 107.
- The Inline structure 105.1 is embankment type with in gorge portion having weir with ogee shape and gated spillway.
- The gated spillway is modeled in a single group with 21 numbers of gates having size 12×5 with crest level of 497.8m. (Fig. 3)
- Gate opening schedule is planned as elevation controlled gate opening for simplicity.
- Total d/s length of 170km of Sina River is divided into various cross sections.

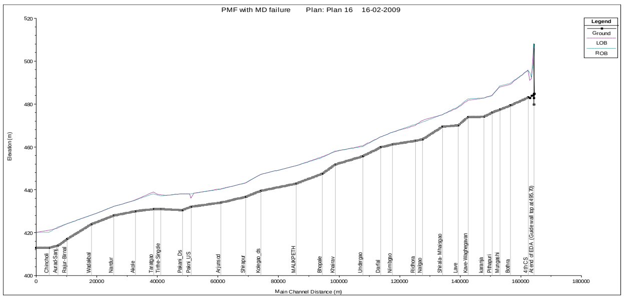

Figure 2. Longitudinal section

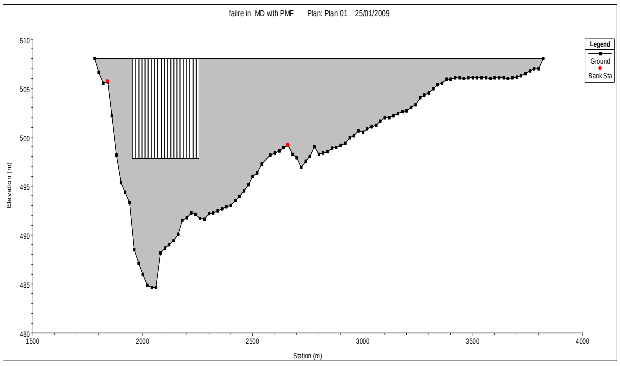

Figure 3. Cross section at dam site with spillway gates

B. Hydrological & Hydraulic Data Input

The hydraulic data consists of Manning’s constant “n”, initial boundary condition, flood hydrographs, PMF, SPF, Dam breach parameters, gate opening properties etc. The problem is analysed mainly using unsteady flow condition, hence the hydraulic parameters related to the problem and unsteady flow conditions are only discussed here. The Manning’s constant assumed is 0.03 for river portion and 0.035 for bank portions. The initial boundary conditions are initial water levels in reservoir, and at various cross section locations. Initial flow equal to 10 Cumecs is also given at u/s boundary for initiations of the model. The boundary conditions for various approaches are different and are discussed in details in next paragraphs in various alternatives. These mainly consist of:

- PMF hydrograph.
- Gate opening hydrograph.
- Dam breach hydrograph.

III. Flood Wave due to PMF Hydrograph Applied at Dam Site

The PMF means probable maximum flood. This is the worst flood that can occur at dam site. It is derived based on unit hydrograph from catchment properties and maximum storm that can occur in the region. For this dam PMF as given by CDO is presented in Fig. 4 below.

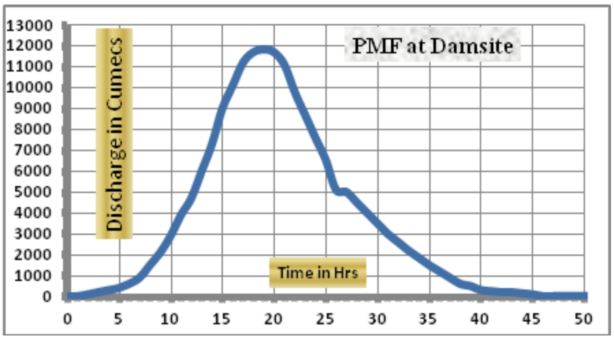

Figure 4. PMF at dam site

In this case the PMF is applied at damsite as if there is no dam. This is natural maximum flood without any human interference. The analysis is done with above geometrical conditions with inflow hydrograph as PMF; the analysis is type is off course unsteady flow. The flood hydrographs at various downstream locations are derived from this inflow hydrographs are derived. These hydrographs are plotted on same time scale, the datum of time being starting time of PMF at damsite. Though there are hundreds of cross section locations within 166.57km, few hydrographs at selected locations (roughly at every 25km) are represented in Fig. 5 below. The individual hydrograph is named by cross section village name and distance on downstream from dam site.

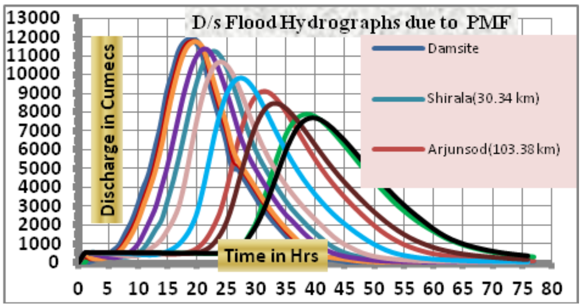

Figure 5. Downstream flood hydrographs occurred due to PMF at dam site

It can be seen from Fig. 5 that peak of hydrographs get reduced as we go on downstream. It is maximum 11848 Cumecs near dam site as and minimum 7680 Cumecs at confluence (166.57km). The hydrograph gets flattened. The time to reach peak is increased as we traverse on downstream. To understand the flood wave pattern in better manner, the peak flood values are plotted against the distance from damsite. On the same graph the time to reach peak flood at various location is plotted and presented in Fig. 6 below.

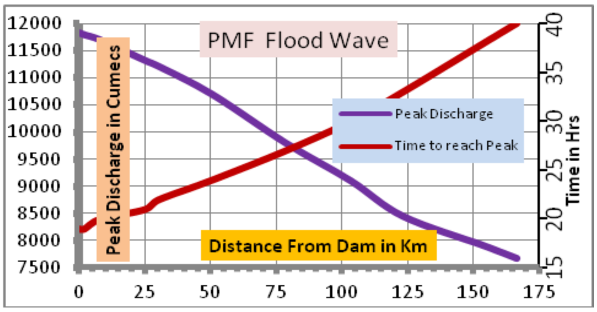

Figure 6. Peak flood pattern and time to reach peak occurred due to PMF at dam site

It can be seen from Fig. 6 that, the reduction in peak discharge is more or less linear. The maximum value of peak discharge near damsite is 11848 Cumecs and minimum is 7680 cumecs at confluence. The time to reach the peak discharge is also linear. The time to reach peak flood at confluence is 40 hrs. It means the peak flood wave will transfer the distance of 166.57km in 25 hrs.

IV. Gate Openning Flood Hydrograph

As explained earlier there are 21 numbers of radial gates admeasuring 21×5m in size on spillway. If all gates are in open condition with reservoir at FRL, the discharge through them is sizable. It creates flood on downstream of dam. All gates open condition may occur several times in a year, only the difference may the gates are partially opened and duration of opening may differ. For analysis purpose in this case the gates are assumed to be opened in 1.5 hrs and closed in 3 hrs. The inflow hydrograph is straight line with peak of 8750 Cumecs. The unsteady flow analysis is done with this hydrograph in HEC-RAS. On similar manner as explained in PMF case the flood hydrographs at various locations on downstream are derived and plotted in Fig. 7 below. The first hydrograph at damsite itself is input hydrograph.

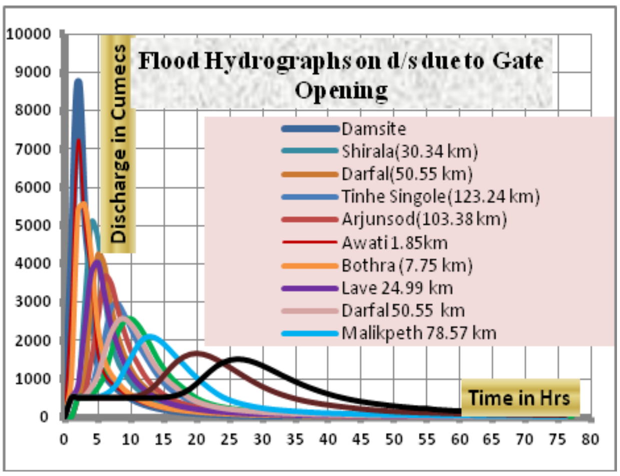

Figure 7. Flood hydrographs on downstream due to gate opening

It can be seen that, in this case the reduction in peak flood is from 8750 Cumecs to 1527 Cumecs when it travels 166.57km distance. The percentage and rate of reduction rate is high. The hydrograph is flattened too much. It is extreme flat at Korsegaon at confluence. To analyse these flood wave pattern and time to reach flood wave, the peak discharges at various downstream location are plotted against the distance from dam site in Fig. 8 below. The times to reach the peak flood at various locations are also plotted against the same axis.

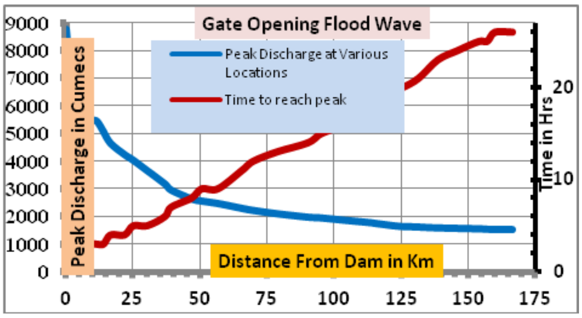

Figure 8. Peak flood pattern and time to reach peak occurred due to Gate opening flood

It can be seen from Fig. 8 that the reduction pattern in peak flood is rapid and nonlinear up to 75km from damsite. Then it is more or less linear and slow. The graph pattern shows that peak flood get reduced to 60% in first 7.5km, 48% in 25km and 20% (8750 to 2000 Cumecs) in 75km. Interesting thing is the time to reach these peak values is more or less linear as in earlier case, though the reduction in peak is rapid. The time to reach this peak at confluence is 26 hrs, which same as in case of PMF wave (in that it was 25 hrs).

V. Dam Breach Flood Hydrograph

Following dam breach instances are studied for the analysis purpose, with different studies.

- Sunny day Earthen Dam Failure [2].
- Sunny day Masonry Spillway failure [3].
- Design PMF applied with Reservoir full condition and Earthen dam failure [4].
- Design PMF applied with Reservoir full condition and Masonry Spillway failure [5].

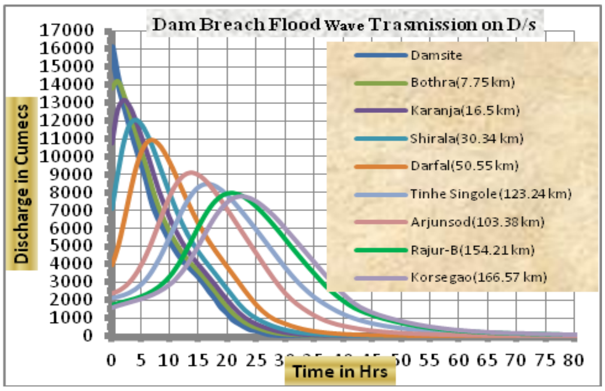

Figure 9. Flood hydrographs on downstream due to dam breach flood wave

Out of four dam breach cases above, the last case of failure in masonry portion with PMF and reservoir full condition is worst and hence it is explained here. The HEC-RAS has its own option of dam breach with input of breach parameters. In this case breach parameters are one monolith in masonry portion of width of 40m in George portion assumed to be failed. The inundation, hydrographs on stream is derived from HEC-RAS. The results of flood waves and downstream hydrographs are more important in present study are essentially evaluated and discussed here. The flood hydrographs at various downstream locations are plotted as in earlier cases and presented in Fig. 9.

The analysis results are shown on downstream of dam from breach instance. The instantaneous flood at damsite is 16119 Cumecs at the breach instance. As in earlier cases the flood hydrographs are flattened as it travels on downstream. The peak is reduced from 16119 to 7810 Cumecs in travel up to confluence at Korsegaon (166.57km). As in earlier two cases the flood wave pattern and times to reach the peaks at various downstream locations are plotted in Fig. 10 below.

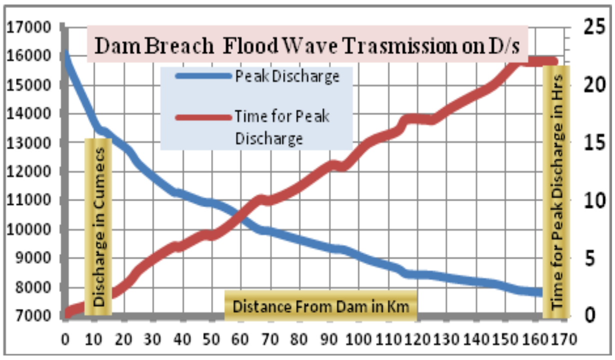

Figure 10. Peak flood pattern and time to reach peak occurred due to dam breach flood

It can be seen that peak flood value is reduced from 16119 Cumecs to 7810 Cumecs in distance of 166.57km. This reduction is nonlinear. In initial reaches it is rapid and the rate of reduction is reduced. The time to reach peak at downstream is more or less linear. Time to reach flood wave at Korsegaon (166.57km) is 22 hrs, which is 3 hrs lesser than earlier two cases. This may be because of higher flood values and obviously more velocities.

VI. Results

- It is essential to analyse flash flood waves in time frame.
- The time to reach peak flood waves on downstream of damsite is more or less linear in all three cases in flood waves due to PMF, Gate opening and dam breach.
- The time to reach the peak at confluence is 22 to 26 hrs.
- Gate opening flood wave diminishes rapidly on d/s than other cases.
- Gate opening flood wave does not create much flood and downstream.
- Dams are not flood creator, but they are flood absorber.
- Flood waves analysis and time analysis (time to reach flood peaks) are essential tools to plan emergency action plan and evacuation plan.

VII. Conclusion

While preparing the emergency action plan [6] and evacuation plan main parameters are:

- Peak floods at various locations
- Time to reach floods from dam sites.
- Duration of floods.
- Evacuation sites and safe locations.
- Durations of safe locations to be safe.

All above five parameters can be determined with time frame analysis of flash floods. The time frame analysis must be obligated while preparing emergency action plans.

Referencses

[1] *HEC-RAS: River Analysis System User's Manual*, *Version 4.0 beta*, U. S. Army Corps of Engineers, Hydraulic Engineering Center 2006b, CPD-68, Hydrologic Engineering Center, November 2006.

[2] T. L. Wahl, "Prediction of embankment dam breach parameters - a literature review and needs assessment," Dam Safety Report No. DSO-98-004, US Dept. of the Interior, Bureau of Reclamation, Denver, 1998.

[3] D. L. Fread, "Some limitations of dam-breach flood routing models," in *Proc. ASCE Fall Convention*, St. Louis, MO, October 26-30, 1981.

[4] D. C. Froelich, "Embankment dam breach parameters," in *Proc. National Conference in Hydraulic Engineering*, ASCE, New York, August, 1987, pp. 570-575.

[5] MacDonald, C. Thomas, and Langridge-Monopolis Jennifer, "Breaching characteristics of dam failures," *ASCE Journal of Hydraulic Engineering*, vol. 110, no. 5, May 1984.

[6] USACE, *Flood Emergency Plans, Guidelines for Corps Dams*, Hydrologic Engineering Center, June 1980.

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