Flood Risk Analysis Caused by Dam Break

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ABSTRACT

The break of a hydraulic structure is an exceptional event but sometimes considerable magnitude. This event of significance is known to cause extensive damage. To assess the impact and risk of spatio-temporal dam break, it is necessary to know the extent of flood areas in the valley downstream of the structure and time of arrival of wave power to determine whether the safety of lives, living in the vicinity of the dam is taken into account. Following the rupture of a dam, it forms a zone of discontinuity in severe turbulence before the area where the flow is not permanent. It is a hydraulic phenomenon outside of the equations of Saint-Venant. It occurs when switching from a hydraulic system to a torrential river water regime and results in a rapid change in water level accompanied by a loss of energy. The height of the wave front is approximately 1 / 3 the height of the dam, but it decreases rapidly with distance from the latter. The characteristics of the wave allows for solutions with discontinuities satisfying relationships so-called Hugoniot–Ranking. The work is complemented by the use of the Castor software, which simulates the propagation of the wave of flooding at the dam and represent it with maximum impact with regard to water levels, speed and propagation time.

INTRODUCTION

For a long time, needs, in particular of potable water and irrigation, have led to carry out works of considerable size to ensure the use and satisfaction of water needs. These structures are called structures of accumulations which are made of the retaining structure (dam), and a retaining zone (or storage basin).

The conception of a dam must consider hydrological, topographical and geological environment in which it is built. While dams are built on design standards and building the most rigorous, however we are still in the face of multiple causes of break that are natural (heavy rain, wind, earthquake ...), technical hypothesis related to design (foundation, materials used, ...), human errors associated with operating (Bekkouche1987).

The break dam, although rare in our days is however possible and considering the magnitude of such an accident, the problem needs to be taken seriously. This break is manifested by the liberation of water retained that propagate and downstream of the dam. View of the character accidental and unexpected as this, it is necessary to know the evolution of the flood wave in time downstream of the dam, and the variation in water depth along the axis of wave propagation (Bischof 2002).

In the context of this work, our main objective is to determine the hydraulic characteristics of the flood wave, to evaluate the risk, to establish a flood map. The study also discusses the hypothesis of a break dam, and the procedures for calculating the flood wave downstream, resulting in a total break and instantaneous dam.

DESCRIPTION OF MATHEMATICAL MODEL

The break of a dam is a hydraulic phenomenon very particular, in view of the characteristics of water flow in time and space. In practice, the principle of dam break can be explicitly presented by the different stages that characterized it, which are as follows:
Step 1

In an initial time $t_0$, the dam is stable and no flow is recorded.

Step 2

At a time $t$, the dam begins to break. Three zones begin to form (Fig. 1), each of which is characterized by its type of flow, the equations that govern them and limits flow.

![Figure 1: Schema the different phases of dam break.](image)

AREA I

It is characterized by an unsteady flow located between the upstream limit $x_0$ and the dam site. In this area the Saint-Venant equations are used (Eq. 1). The system consists of the equation of continuity and movement is called system Barré de Saint-Venant (Graf 2008). This system expressed in a dimensional space dimension up to the wired transient flows with free surface. It can also be obtained by integration of the Navier Stokes.

\[
\frac{a Q}{a t} + \frac{a s}{a t} = 0
\]

\[
\frac{V a V}{g a l} + \frac{1}{g a t} + \frac{a h}{a l} = -f + I
\]

Where:
- $g =$ gravity ($m/s^2$);
- $l =$ wave length;
- $Q =$ flow discharge after the break dam;
- $S =$ wetted area ($m^2$);
- $t =$ time ($s$);
- $T =$ wave period;
- $V =$ flow velocity ($m/s$);
- $Z =$ geometric height ($m$);
- $\Delta l =$ space step;
- $\Delta t =$ time step.

AREA II

It is presented by a flow discontinuous (Fig. 2) which the limits are very narrow making it difficult to keep track of the wave in time is of the order of seconds. In this case, we apply the equations of Rankine Hugoniot (Ancey 2008). The limits of this zone are between the two fronts of sections $x_{i-1}$ and $x_i$t at time $t_{i-1}$ and $t_i$ (Eq. 2)

\[
X^4 - X^3 h_{01} + (1+2 F^2) h_{01} + X ((4q_0 / g) * Y + h_{01}) - ((2q_0 / g) * Y) = 0
\]

\[
X^4 - X^3 h_{02} + (1+2 F^2) h_{02} + X ((4q_0 / g) * Y) = 0
\]

Where:
- $F =$ Froude number;
- $q_0 =$ unit flow ($m^3/s$);
- $h =$ water depth ($m$);
- $h_{01} =$ water depth in the upstream reach at $t = 0$;
- $h_{02} =$ water depth in the downstream at $t = 0$;
- $h_c =$ water depth critical;
PRESENTATION OF THE PROGRAM

The step of the description of the different areas of dam break leads to the conclusion that the Saint-Venant equations are not applicable in the area of discontinuity and a combination of the Saint-Venant equations and Rankine-Hugoniot is necessary to solve this problem (mixed regime). Based on this information, a computer program (SORB) is established in Visual Basic (Bouhellala 2009). The general flowchart of the program SORB (Fig. 3) allows to calculate the hydraulic parameters characterizing the phenomenon of wave propagation of dam break and this based on solving the Saint-Venant equations with the boundary conditions were determined from the Rankine-Hugoniot equations. This program also calculates the rate of break over time and gives the corresponding curve of the wave propagation downstream of the dam site.

Figure 3: The main flowchart of the program SORB.

Numerical application

This application is the study of the flood wave in the case of dam break Gargar (Relizane province, Algeria).

The dam of Gargar is located in the province of RELIZANE, 5 km southwest of the town of Oued Rhiou and about 3 km upstream from the bridge on the RN 4 Oued Rhiou, a left tributary of Oued Chellif. The groove cut into the ridge of limestone hills along the southern edge of the plain of Chellif form the dam site. The useful volume of the reservoir is 450m$^3$. The general situation of the dam is shown in Figure 4.

Used for this study SORB code and software developed by the Cemagref (Paquier 1995), called CASTOR. The main objectives of the application are:

- Identify the possible scenarios of dam break (Bouhellala 2009),
- Determination of the wave propagation characteristics in the downstream to the breakpoint study.

Program SORB

A comparison of discharge obtained with discharge given in the literature for more or less similar cases revealed a remarkable similarity, for against the curves (Fig. 5) did not show a great similarity and this is especially the assumptions used for our computing and especially the boundary conditions chosen.
Figure 5: Flow variation over time in each section.

Figure 6: Flood map downstream of the dam.

The results obtained (Fig. 6), just after the dam break, there is a sudden rise in water level on the downstream side. The flooded area is estimated to be about 2800 hectares.

- After a few minutes of dam break, considerable damage was done to the town of Oued Rhiou,

- After 3 minutes, destruction was caused to the inhabitants of Hai-Echbira (1300m) with their property destroyed pressurized,

- After 6 minutes, the plant "hydro-channel", located at 1800m,

- After 7 minutes, Oued Rhiou Bridge on National Road No. 4, a few houses next to the bridge (2050m) and hundreds of hectares of agricultural land known for their grain, fruit and vegetables mainly citrus fruits: oranges, lemons, etc.

- After 21 minutes, a quarter of the town of Oued-Rhiou was under water, and much of the plain of Chlef was also under approximately 9 feet of water.

- After 25 minutes, the water would join the railway line and the bowl of the dam of Sidi Abed, which would add about 10 m to its normal high

- Finally the number of dead and missing important squeezed.

**Computer code CASTOR**

To confirm, a universal software was used CASTOR.

This code (Paquier 1995) simulates the propagation of the flood wave and dam failure and to represent it with maximum impact with regard to water levels, velocity and propagation time.

The maximum rating (Fig. 7) of the flood wave at the beginning of the valley (immediate area) is high and then decreases progressively to reach the bottom level of the valley in the most remote sections of the immediate area.

Figure 7: Longitudinal profile of the maximum rating of the flood wave.

The height of the flood wave throughout the valley is shown in Figure 8. At the beginning of the valley, the height is high because of the high discharge recorded in this section. The height of the wave also differs from one section to another, due to widening or narrowing of the section considered, moreover, there is decreased discharge of the wave with time. The maximum height recorded at the section (1) is about 49.7m, and the minimum height is 6.25 m at the section (23).
The time of arrival of the flood wave along the valley modeled is shown in Figure 9. It increases with the distance of the valley from the benchmark (dam). The total propagation time along the modeled valley is estimated at 109 minutes (1 hour and 49 min).

The maximum discharges in each section are shown in Figure 10. Note that the maximum discharge of the flood wave decreases with distance from the dam, against widening and narrowing of the valley have no effect on it. The max discharge at the moment of break is found about 92,489 m$^3$/s, and the minimum discharge recorded is about 20,630 m$^3$/s.

The maximum velocity of the wave through the valley is shown in Figure 11. The difference between the velocities of the wave at each point of the valley is due to the distance of a point from the dam and the width of the section considered. The velocity of the flood wave will also change depending on the local slope of the modeled section. The maximum velocity recorded is about 14.69 m/s at section 1, while the minimum velocity is 1.24 m/s at section 6.

The line of energy throughout the valley is shown in Figure 12. At first, the power line is high because of the high discharge recorded in this section. It also differs from one section to another because of the widening or narrowing of the section considered.

CONCLUSIONS

An approach to the problem of wave propagation of dam break was established according to well-defined steps. The stage of the description of the phenomenon identified three areas of rupture of a dam (unsteady flow, flow discontinuous unsteady flow). The instantaneous rupture leads to the conclusion that the Saint-Venant equations are not applicable in the area of discontinuity and a
combination of the Saint-Venant equations and Rankine-Hugoniot is necessary to solve this problem (mixed regime).

To avoid the occurrence of such disaster, it is important to implement the following stages during the study of a project creation (i.e. design, stability analysis, taking into account the seismic, geological actual condition), the stage of the work (technical specifications to be met, auscultation device in place and operational on) during operation. (Regular monitoring of the dam and related structures 'spillway, bottom outlet', through devices auscultation).

Finally, a safety plan and rapid and effective response must be mobilized and determined to reduce the damage brought about by a particularly human catastrophe of this type.

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