Flood Risk in case of Yesa’s dam break

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A dam breach is one of the most important disasters that can happen in the structural world. The potential risk of flood implies the consideration of it as a critical structure. This work shows the evolution of a flash flood in case of Yesa’s dam break, taking special interest in the area of Sangüesa’s village. The break is simulated by IBER Software according to ICOLD (International Commission on Large Dams) advices.

Keywords: $Flood$, Dam, $Risk$, $Yesa$

1 Introduction

Dams are considered inside of the critical infrastructure group due to the potential risk of flood in case of break. History proves the potential risk of disaster that can lead in case of collapse. The disaster at Vajont (Italy), in 1963, is a good example of that. The third fulfilled of the reservoir in combination with a landslide generated a big wave which passed over the dam and caused severe damage. This disaster caused near 2000 deaths, and high quantities of material losses. The dam still stands today. Another example happened at Tous (Spain), in 1982, where two days of intensive rains resulted in a dam collapse. The contained water went down causing 30 deaths.

Yesa’s dam is located close to the Pyrenees. The reservoir is known as ”Pyrenees Sea” due to the high quantity of water in comparison with others, since it is the dam of Aragon’s river. Close to the dam, downstream, Sangüesa’s village is located. The population is about 5000 people. As has been commented, that situation can be very dangerous in case of disaster. The main aim of this work is to know the water behaviour in case of a structural failure. Some facts prove that a structural collapse is possible

Figure 1: Aerial view of the dam and the reservoir

due to adjacent hills movement. Geotechnical experts claim about the movement and the possibility of a landslide.
The main objective is to know the evolution of the water flow and provide information to the emergency forces in order to establish an evacuation plan for the population.

This simulation has been performed with Iber's Software. This software is based on Saint Venant 2D equations which are the appropriate ones in this study.

2 Methodology

2.1 Numerical Foundations

Previously we have commented that the software used is based in Saint Venant 2D equations, using finite volumes in 2D. This section explains how the equations can be gotten from Incompressible Navier-Stokes equations in 3D for isotropic fluids (Equations 1, 2), and shows the limitations of them.

$$\partial_t \mathbf{u} + (\mathbf{u} \cdot \nabla)\mathbf{u} - \nu \Delta \mathbf{u} + \nabla p = \mathbf{f} \tag{1}$$

$$\nabla \cdot \mathbf{u} = 0 \tag{2}$$

The performed simulation covers a large area. Therefore, simulating all the involved phenomena would be impossible in computational terms. For instance, effects, as turbulence or Coriolis, can be neglected. According to turbulence theory, we can split up the velocity u in two parts (Equation 3)

$$u = \overline{u} + u' \tag{3}$$

where $\overline{u}$ is the average variable (Equation 4) and u' is the turbulent fluctuation.

$$\overline{u} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} u dt \tag{4}$$

with this, the problem is simplified. Turbulence is neglected because it is a chaotic phenomenon that needs a lot of nodes/particles to perform it.

On the other hand, another important simplification can be taken into account. The study area has two predominant dimensions, x and y, in relation with z. The magnitude for x and y is Km, and for z is meters. This fact, leads to the follow simplification, the application of depth integration (Equation 5) in this dimension,

$$u = \frac{1}{h}\int_{z_0}^{z_0+h} \overline{u} dz \tag{5}$$

thanks to this, it is not necessary to take into account all the small variations in this direction. After the application of Liebniz integration rule derivation under the integral, we obtain the Saint Venant 2D (Equation 6, 7, 8);

$$\frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} = 0 \tag{6}$$

$$\frac{\partial (hu)}{\partial t} + \frac{\partial}{\partial x}(hu^2 + g\frac{h^2}{2}) + \frac{\partial (huv)}{\partial y} = gh(S_{0x} - S_{fx}) \tag{7}$$

$$\frac{\partial (hv)}{\partial t} + \frac{\partial (huv)}{\partial y} + \frac{\partial}{\partial y}(hv^2 + g\frac{h^2}{2}) = gh(S_{0y} - S_{fy}) \tag{8}$$

The unknowns in these equations are; h, related with the draft, and u and v, related with the velocity components. These are the governing equations in our simulation.

2.2 Features of Yesa's dam & Reservoir

The construction phase started in 1928, but it was in 1959 when the construction phase ended. That large period was due to a large quantity of problems occurred during the execution, in part due to hill movements. It is a gravity dam and the main features are shown in Table 1,

Table 1: Features of Yesa's dam and reservoir

Slope	0.78
Crest length	398 m
Crest width	7 m
Concrete	480.000 m^3
Reservoir area	2.098 ha
Capacity	446.9 hm^3

2.3 Simulation

The main input files needed are the Digital Terrain model (providing the topography of the study area), the map of land use (application of roughness) and the creation of a virtual reservoir.

In order to create the virtual reservoir, we represent its total volume through seven volumes, attaching the width of $1.5km$ and using level information. Equation 9 shows the used formulation.

$$A_i = \frac{V_i - [z_i \sum_{i=1}^{n} A_i - \sum_{i=1}^{n} A_i z_{i-1}]}{\sum_{i=1}^{n} (z_i - z_{i-1})} \tag{9}$$

Once the files are correct, we apply the initial conditions and the boundary conditions. We will assign a full water level in the reservoir as initial condition and a supercritical condition in the lower part of the study area for evacuating the water surface. Regarding the break, ICOLD recommendations suggest that the break has to be a $1/3$ of the total body and the break time, about $900s$.

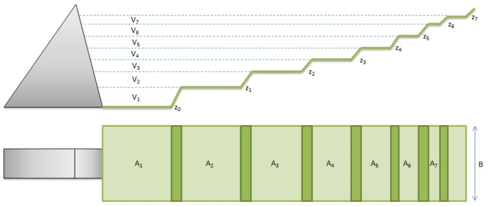

Figure 2: Shape of virtual reservoir

Regarding the mesh, a triangular structured mesh with a element size equal to $200m$ is used. The total number of element is close to $1.000.000$.

3 Results and Conclusions

The results are focused on Sangüesa's village, however, other villages that are close to Aragon's river should be studied in depth according with the obtained results.

Mainly, we are going to focus on Sangüesa's draft and in the arrival time. Figure 3, shows the maximum flood that Sangüesa's village can suffer according to the simulation. Drafts of 15 meters high arrive to the city centre. These drafts would destroy almost all the village but it is important to know the arrival time of the wave.

Figure 4 shows the evolution of the shallow water according to the time. After 45 minutes of break, water starts to arrive to the village. After an hour, the peak of water arrives. The population of the village must be evacuated before that time.

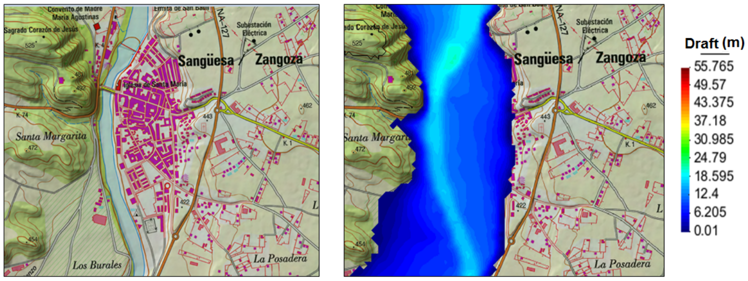

Figure 3: Maximum draft in Sangüesa's village

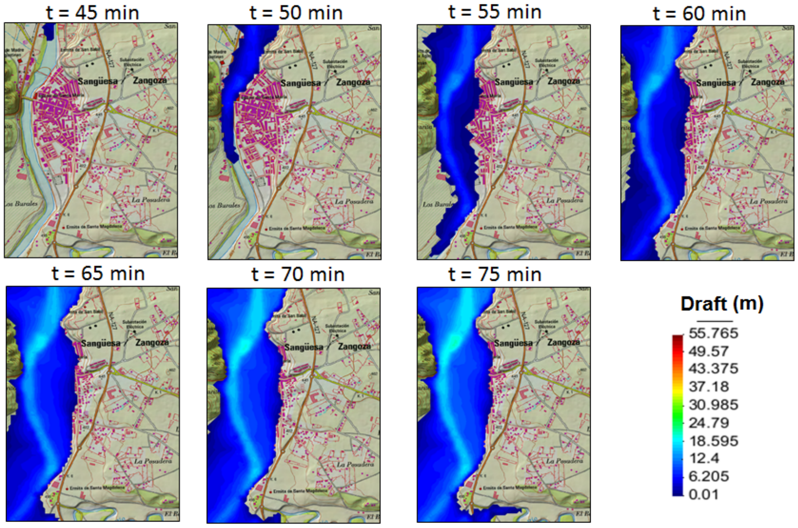
t = 45 min
t = 50 min
t = 55 min
t = 60 min
t = 65 min
t = 70 min
t = 75 min

Figure 4: Evolution of the draft in time

The obtained results are quite alarming for Sangüesa's population, although, using this information a map of safety areas can be made. It is important to remark that other villages can be affected by the river flow, for instance; Caseda, Carcastillo, among others.

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