Plunge pool rehabilitation with prismatic concrete elements - case study and physical model of Ilarion dam in Greece

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Ilarion Dam

The Ilarion Hydroelectric Power Plant is constructed on the Aliakmon River, in the north of Greece (Fig. 1). It lies approximately 100 km southwest of the town Thessaloniki. This is a 130 m high earthfill dam with a clay core. The construction of the dam and all the appurtenant structures has been completed and the reservoir was impounded in 2012, with the closure of the diversion tunnel on July 13th of the same year. There are two gated spillways (No. 1 and No. 2) that arrive in this plunge pool as well as the bottom outlet. The two spillways release together a total maximum discharge of 5500 m^3/s.

Two major floods affected the dam: one in 2013 and the other in 2015. Although these two floods were different in terms of intensity but above all in terms of duration, they caused heavy damage to the plunge pool and its banks (Fig. 2).

Fig. 1. General view of the Ilarion Dam (image from YouTube https://www.youtube.com/watch?v=KKm203f0r_k)

Materials and Methods

In order to determine a reliable protection measure, a 1:55 scale model and a numerical model with **FLOW-3D®** were created. **FLOW-3D®** is a very complete and powerful program solving free surface flows problems in three dimensions. This software performs finite-difference approximations of the fundamental differential equations of fluid dynamics, the Navier-Stokes equations. The hydrodynamic behaviour of the flow in the plunge pool and in the spillways as well as the trajectory of the jets could be determined.

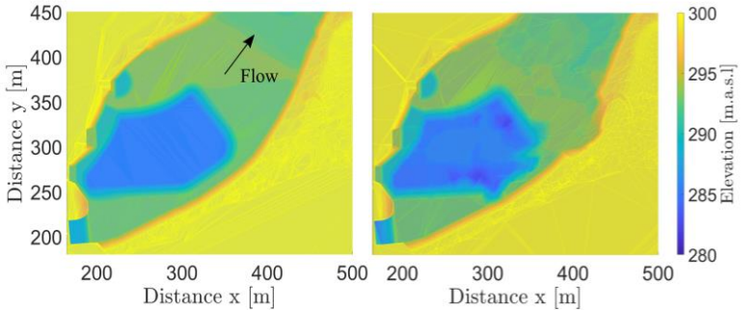

Fig. 2. Topography before the 2013 flood (left) and after the 2015 flood (right)

Results and Discussions

A vortex phenomenon is at work when only one of the two spillways is operating. This can be seen in Fig. 3 in which water velocity vectors are shown. The creation of this vortex can be explained by the fact that the jet impacts the plunge pool in a very asymmetric way. This gradually causes the water to rotate in this area and thus forms a vortex.

In order to measure the full extent of this phenomenon, another numerical simulation was conducted with both spillways operational with both flows of 250 m^3/s each. The velocity vectors are shown in Fig. 3. The vortex is strongly attenuated, located at a different place, and rotates in a different direction. The velocities are also lower as shown by the colouring of the water. However, the creation of a vortex is inevitable because the plunge pool is not symmetrical.

This vortex singularity and the resulting circulation of water is a key phenomenon in the case of the Ilarion Dam, resulting in a much higher flow rate than would be expected. While the simulated flow rate is only 500 m^3/s, the effective discharge that goes through the lower part of the plunge pool is about 1650 m^3/s. That is more than three times what was expected. The considerable damage that occurred during the 2015 flood can therefore be largely explained by this asymmetric phenomenon.

If the two spillways operate symmetrically, the vortex is greatly reduced but not completely eliminated. Thus, the upper baffle recorded a discharge of 856 m^3/s and the lower one a discharge of -346 m^3/s. The addition of the two is therefore 510 m^3/s, slightly higher than what is expected. Two points should be noted here, firstly the inversion of the direction of rotation of the vortex since the flow which was negative before is now positive and vice versa. Secondly, the effective discharge is reduced by 48%, compared to the previous flow rate of 1650 m^3/s, which is very beneficial from a scouring point of view.

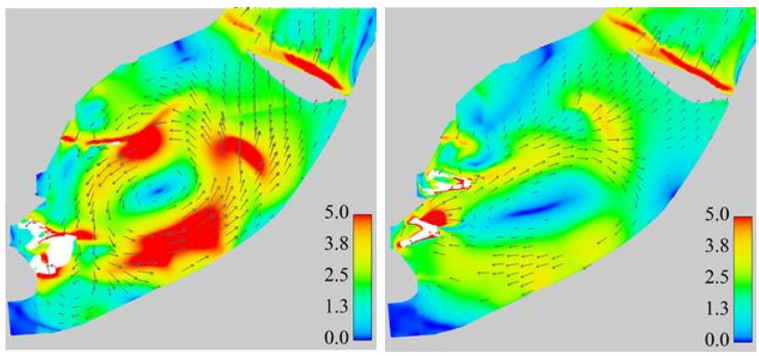

Fig. 3. Top view of the velocity vectors at 293.5 m.a.s.l. for a total discharge of 500 m^3/s with only one spillway operational (left) and with two spillways operational (right); the water is coloured according to its velocity in m/s

Conclusions

The two spillways of the Ilarion Dam in Greece were studied by numerical modelling with **FLOW-3D®**. The study focused on the hydrodynamic behaviour of the flow in the plunge pool. It was found that the recirculation current in the plunge pool is a problematic phenomenon. This creates an effective discharge more than 3 times larger than the one expected. A simple and cost-effective solution is to operate the spillways symmetrically. However, this may not always be possible for any given flood discharge. Indeed, the opening range of the gates may be limited for reasons of operability or vibration of the gates.