MCIT Modeling, control & information technologies

Using computer modeling during the design and reconstruction of hydropower facilities

https://doi.org/10.31713/MCIT.2024.015

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***Abstract* – The role of computer modeling during the design or reconstruction of the hydroelectric complexes is shown. The results of using the software HEC-RAS for the reconstruction of the Krimov Dam are given.**

***Keywords* – modeling; hydropower engineering, hydroelectric complex; dam; flood, HEC-RAS.**

I. Introduction

The development of the energy sector of the national economy is aimed at increasing the share of electricity produced by renewable energy sources. Hydropower engineering is the largest and oldest source of renewable energy.

Since hydropower engineering has developed for many decades, there are hydroelectric complexes that are fifty years old or more. Hence, for many of them, the issue of reconstruction is acute.

In hydraulic engineering, physical modeling for building and reconstructing hydraulic structures is often used. However, due to the high cost of making a physical model and the time required for the modeling process, computer modeling is now widely used during the design and reconstruction of hydropower facilities.

II. General information on hydroelectric complex

Usually, water is accumulated to meet the complex needs of the national economy. Practice shows that reservoirs created for operating hydropower plants with different capacities can be used for other purposes [1]. In particular, fish farms are being established, recreation centers are being built in the adjacent territories, and water from the reservoir can be used for both technical and drinking water supply, as the water quality does not change, but rather the opposite – the water passing through the turbine is enriched with dissolved oxygen during aeration, which helps to activate chemical and biological self-purification of water and has a positive impact on the natural regime of the river [2].

Moreover, hydropower plants with reservoirs regulate water flows and protect territories and settlements from floods. Many rivers in Europe have pronounced floods and flash floods, which flood the surrounding areas and cause destruction to the local population. In the case of the hydropower plants with reservoirs, the reservoirs manage to partially delay and reduce flood flow, which helps to avoid or significantly reduce material damage. Recently, scientists have been considering small hydropower plants as one of the effective measures to adapt to climate change, which resulted in a decrease in flood flow and an increase in the number of flash floods and their flow volumes. A river basin approach to water management is applied to reduce the negative impact. It limits the negative economic and social consequences, mitigates the effects of climate change, and increases energy capacity [3].

Taking into account mentioned above, the typical hydroelectric complex can consist of [4]:

- Dam for creation of water reservoir.
- Powerhouse for electricity generation.
- Shipping gateway for the passage of ships.
- Water spillway for flood passage.
- Water intake for water supply or irrigation.
- Fish passing facility.
- Headrace and tailrace canals.

During the design or reconstruction of any constructive elements of the hydroelectric complex the usage of computer modeling is very important. It helps to consider different variants of structures and choose the best one.

III. Modeling of tailrace canal of Krimow dam

To study computer modeling more deeply, the tailrace canal of Krimov Dam, Czech Republic, was modeled in HEC-RAS software.

A. Information on Krimow Dam

Krimov Dam is located near Chomytov in the Ústí nad Labem Region of the Czech Republic and was created to supply the town of Chomutov with drinking water [5, 6]. The Dam was built in 1958 and is 39.5 m high. As a typical dam, it has structures for flood control. They include two ungated spillways, two bottom outlets, a stilling basin, and a tailrace canal.

B. Stilling Basin and Tailrace Canal

For energy dissipation and flood water diversion from the dam, there are stilling basin and tailrace canal (Fig. 1).

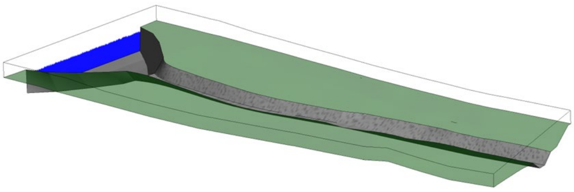

Figure 1. Scheme of stilling basin and tailrace canal

The stilling basin can be characterized by further features. It is shallow and short. Therefore, the curved shape of the stilling basin accelerates water outflow and reduces energy dissipation. It was constructed in the 50s with a much lower design discharge than nowadays.

The tailrace canal can be characterized by further features. It has the trapezoidal shape of a cross-section with different sizes. The inclination of the canal is rather high – about 5%. Moreover, it has a plane change of direction of 17°.

After significant flood events in 1997, 2002, and 2013 in the Czech Republic, new hydrological data were received, and the rules for flood control were restricted. Therefore, it was necessary to check whether new values of control flood Q = 74 m^3/s could be safely passed through the stilling basin and tailrace canal.

C. Model Creation

For computer modeling, the open software HEC-RAS was used [7]. The boundary conditions for modeling are presented in table 1.

To make 2D modeling in HEC-RAS, the geometry of the stilling basin and tailrace canal was created (Fig. 2).

TABLE I. BOUNDARY CONDITIONS FOR MODELING

Parameters	Values
inflow	flow hydrograph
outflow	Rating curve
wall	Manning's coefficient
- stilling basin	n = 0.015
- canal	n = 0.025
- inundation	n = 0.030

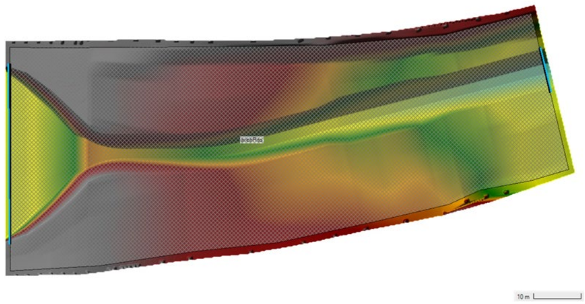

Figure 2. Geometry for 2D modeling

D. Results and Discussion

After making the 2D computation, the values of velocities and water surface elevation (WSE) were received (Fig. 3 and Fig. 4).

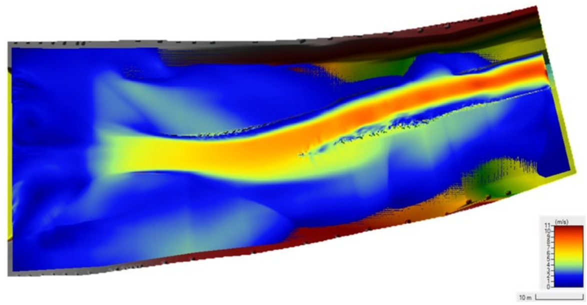

Figure 3. Velocity values of 2D modeling

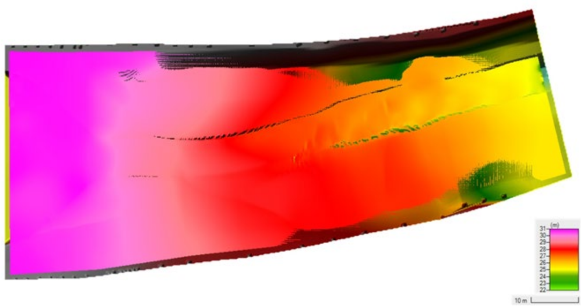

Figure 4. WSE values of 2D modeling

The longitudinal profile of the stilling basin and tailrace canal is shown in Fig. 5.

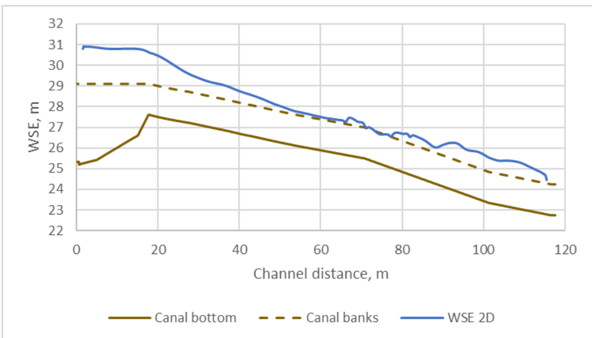

Figure 5. Longitudinal profile of the stilling basin and tailrace canal

Figure 3 shows the velocity values in and outside the canal when the flood of 74 m^3/s will pass. Moreover, it is visible that due to the plane change of direction, part of the water will run in a straight line and not turn in the canal. The maximum value of velocity will reach 11 m/s.

Figure 4 shows the flooded area during passing the flood of 74 m^3/s. However, Figure 5 shows the depth of flooding. According to Figure 5, the highest depth will be near the stilling basin, confirming the fact that the existing design accelerates water outflow and reduces energy dissipation. The water surface level will exceed the level of stilling basin banks by 2 m. Therefore, almost all areas downstream of the dam will be flooded.

Conclusions

Hydraulic and computer modeling in hydropower engineering is widely used. Since hydraulic modeling requires a lot of time and money, computer modeling, in many cases, is rather promising.

Computer modeling allows to study and analyze of different variants of situations and use the results during the design, building, or reconstruction stages.

The analysis of modeling results of the real facility shows that the existing form of stilling basin and tailrace canal is not enough for safe flood passage of 74 m^3/s. To prevent flooding of adjacent areas, it is necessary to change the parameters of the stilling basin and tailrace canal.

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