HYDRAULIC MODEL OF HARCOV HISTORICAL DAM

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Summary

The article deals with increase of safety of dams in connection with increasing safety standards, and it focuses on intelligent and careful methods of saving their cultural and historical value. The example is the historical dam Harcov: here, the hydraulic solution allowed to increase the safety of the dam in agreement with technical norm TNV 75 2935 „Considering safety of dams in case of flood“, and regulation No. 590/2002 Sb., about technical standards for dams, and at the same time, the original historical nature of the dam could be preserved.

To evaluate the suggested change on the spillway, hydraulic physical modelling was used. In case of Harcov Dam, a new shape of the overflow surface with a low-pressure regime of water flow was designed for floods higher than Q_{20} (20-years-flood). The maximum capacity of the newly designed spillway is 76,3 $m^3.s^{-1}$; that in sum with a bottom outlets is adequate to flow rate $Q_{10\,000}$. The project documentation for reconstructing the dam will be properly solved on the base of results of the physical model research.

Keywords: historical dam, hydraulic research, physical hydraulic model

1 Description of the dam

Harcov Dam is situated near the centre of Liberec. Originally it was built on the edge of the city, but in course of last one hundred years it became an integral part of city environment as the city had naturally developed. The reservoir with wooded slopes nearby is a pleasant part of Liberec, serving for rest and recreation through the year. The uniqueness of the dam is confirmed by the fact that it can be found on the list of cultural heritage of National Heritage Institute since 1958. The impulse for construction was a series of damaging floods in the second half of 19^{th} century.

The dam consists of a masonry gravity dam with height 19 m above excavation line and length 157 m in crest. Flood and safety facilities consist of two bottom outlets and crest spillway. The bottom outlet is a 16-meter-long pipe with an 800 mm diameter conducted in a tunnel. The crown spillway has five sluices (each 5 meters wide); above them there are bridges; chute and stilling basin follow immediately after cascade (**Fig. 1** and **2**). The main purpose of the dam is to retain flood discharges and their lowering to a harmless discharge 6,7 $m^3.s^{-1}$. Furthermore, the purpose is to create an accumulative space to assure consumption 0,150 $m^3.s^{-1}$ for industrial purpose and last but not least, recreation, fish farming and sports fishing.

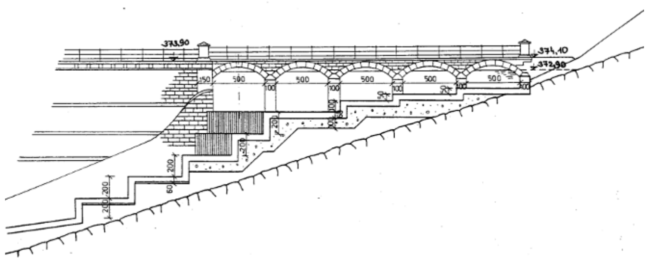

Fig. 1 *Harcov Dam – spillway and chute from the downstream site*

Fig. 2 *Safety spillway and chute*

In the last several years, the attention of the dam administrator, the Labe Basin Authority state enterprise, has been focused on the issue of the dam safety during extreme flood discharges. Because of that a number of studies have been made.

2 Flood flows in consideration

Firstly, hydrological data were considered. It is obvious that the original data used for projecting more than 100 years ago will differ from data nowadays used for evaluations of the safety of dams. The value of protection required increased from Q_{100} (100-year flood) to the value of a higher order, i. e. $Q_{1\,000}$. In case of important dams, even the situation of $Q_{10\,000}$ is examined. That is why the highest flood flow value available was considered for designing safety spillways of the dams, after evaluating hydrological data from a short period of time. After many years of operation the hydrological data were precised; it contributes to evaluation of the safety of a particular dam as for the really existing flows.

The experience with extraordinary floods between years 1996 and 2012 proved that the real discharge could be markedly higher in case of extreme flood. Due to that there has recently been an obvious pressure to evaluate the border safety of dams (including the less important ones) related to extreme floods (in agreement with the methodical instructions of Ministry of Environment of the Czech Republic – TNV 75 2935 „Evaluation of safety of dams in case of floods“). That is why the up-to-date knowledge of hydraulic function of spillways in case of exceeding the suggested limits is becoming a very important presupposition for safe operation of a dam as a whole.

In recent years the evaluation of extreme floods in dams has changed in favour of a dam safety. The discharge of an extreme flood repeated in 1,000 or 10,000 years (depending of the category of the dam) is used for the evaluation of safety facilities' capacity. To find out the value of extreme flow $Q_{1\,000}$ and $Q_{10\,000}$, extrapolating methods and models of the precipitation-runoff processes are used. These values are further analysed and serve as a minor condition of designing a safety spillway in relation to maximal safe water level in reservoir. The value of an extreme discharge is a limit for evaluation of the safety of dams and usually it is $Q_{10\,000}$ (in case of dams of lower category it is $Q_{1\,000}$ flow, rarely lower).

3 Issue of capacity of a spillway

Recent capacity of safety spillway was calculated to the value 16,31 m^3s^{-1} and the capacity of both bottom outlets to ca. 12 m^3s^{-1}. Just to remind: the highest flow observable at Harcovský potok during projecting dam was 20 m^3s^{-1} (July 30, 1897). Nowadays the Q_{100} value is 30,1 m^3s^{-1}. The safety spillway of Harcov Dam was evaluated on the base of a hydraulic calculation for a spillway:

$$Q = \sigma_z m b_0 \sqrt{2g} h_0^{3/2}, \tag{1}$$

where: Q – flow discharge [$m^3.s^{-1}$], σ_z – downstream water coefficient, m – overfall coefficient, b_0 – effective spillway crest length [m], g – gravity acceleration [$m.s^{-2}$], h_0 – overflow head (including velocity head) [m].

Increase of a dam capacity can theoretically be realized by various technical acquisitions: increase of a capacity of present safety spillway; construction of a new bottom outlet; adding another safety etc. However, when choosing a solution it is absolutely necessary to have all the responsibility for not damaging both the overall historical nature of the dam and its surroundings and environment.

4 Hydraulic model research

Hydraulic phenomena, water flow and hydraulic characteristics may be observed on an existing dam, but out of objective reasons the research is very complicated; therefore, a small-scale model in a lab is observed as a more accessible option. Starting, border and limiting conditions are provided by a dimensional, force and weight analysis proceeding on the conditions of observing phenomena on a model using Froud's law of mechanical similarity.

The aim of the model research was to certify and precise the calculations of safety spillway and chute. The results of this research are followed with another phase which is going to answer questions about choosing the most suitable variant of a safety spillway and chute for transferring a control flood with flow $Q_{10\,000}$ = 194 $m^3.s^{-1}$. The model of Harcov Dam was designed and modelled at a scale M – 1:20.

5 Results of experiments

In sum there were 17 different variants of measuring of disposition and construction settings of a safety spillway and bottom outlets as well as various solutions of transferring flood discharges. For all these variants, surface levels in the reservoir, chute, stilling basin, riverbed under the dam were observed, pressure ratios in chute and speed fields at the end of the stilling basin were measured (by means of hydrometric micropropellers). A new design of a shape of the overfall surface, ribs in the spillway and layout of the zone in front of the spillway were undertaken.

Discharge curves of both the existing and the newly designed safety spillway (spillway edge lowered by 0,4 m) and the influence of widening the forefield were observed (**Fig. 3**). When the calculated discharge curve of the spillway and the one measured on the hydraulic model were compared to each other, differences in capacity up to 17,5 %. The difference in capacity is caused by inexact calculations of all coefficients.

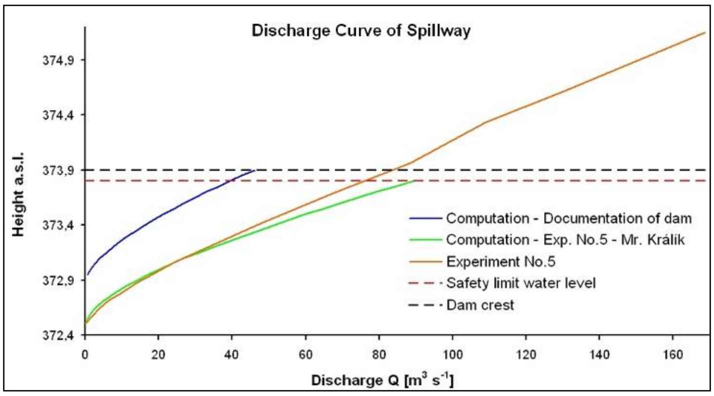

Fig. 3 *Comparison of current and proposed state of spillway*

6 Conclusion

Hydraulic physical modelling plays its role in settling complicated constructions of safety spillways. For evaluating the original conditions of safety spillway and related objects and for designing a reconstruction of safety facilities at Harcov Dam, a physical model accurately describing the flow in the object was used. Results of these calculations and measuring serve for proposing, evaluating and optimization of partial objects of dam safety facilities. All results will be respected and used for choosing the final solution of a new more capacitive solution for constructing safety spillway. Based on results from a physical model research, a project documentation of a particular dam can be properly solved with respect to the historical value of the object and its preservation. The capacity of newly designed spillway is at surface of safety water level limit 373,80 m a. s. l. 76,3 $m^3.s^{-1}$, which in sum with bottom outlet is adequate to the flow $Q_{10\,000}$.

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