AN EXTRAORDINARY EVENT AT THE MARIBORSKI OTOK DAM

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ABSTRACT

The Mariborski otok concrete gravity dam, part of the corresponding HPP on the Drava River, in Slovenia, was completed in 1960, and renovated in 1997-2000. Its structural height is 33 m, and the dam crest's length is 184 m. The dam structure contains three turbine piers, placed between four spillways, as well as bank structures. The spillways, closed by two steel gates, have a total capacity of 5600 m^3/s. In December 2017, the malfunction of the steering system of the upper spillway gate management of the fourth spillway caused unexpected overflowing, which severely damaged the upper gate and the concrete beam of the crane rail on the dam's crest. Measurements and visual inspections carried out immediately after this event showed that fortunately the safety of the dam, as well as the operation of the HPP was not threatened. However, technically demanding rehabilitation works on the dam, estimated at about 2 million euros, were anticipated. Firstly, auxiliary spillway gates were inserted, which enabled, for the first time since the dam was built, the required lowering of the reservoir level by 6.5 m. In September 2019, the second phase started, which includes restoration of the damaged concrete structure and of the spillway gate.

1. INTRODUCTION

1.1 Large dams in Slovenia

There are over forty large dam structures in Slovenia, both concrete and embankment dams, which are intended for water retention for different purposes; mainly electricity production, but also flood protection, irrigation and recreation. There are also some historical dams and the dams which are used for other commercial purposes (Fig. 1).

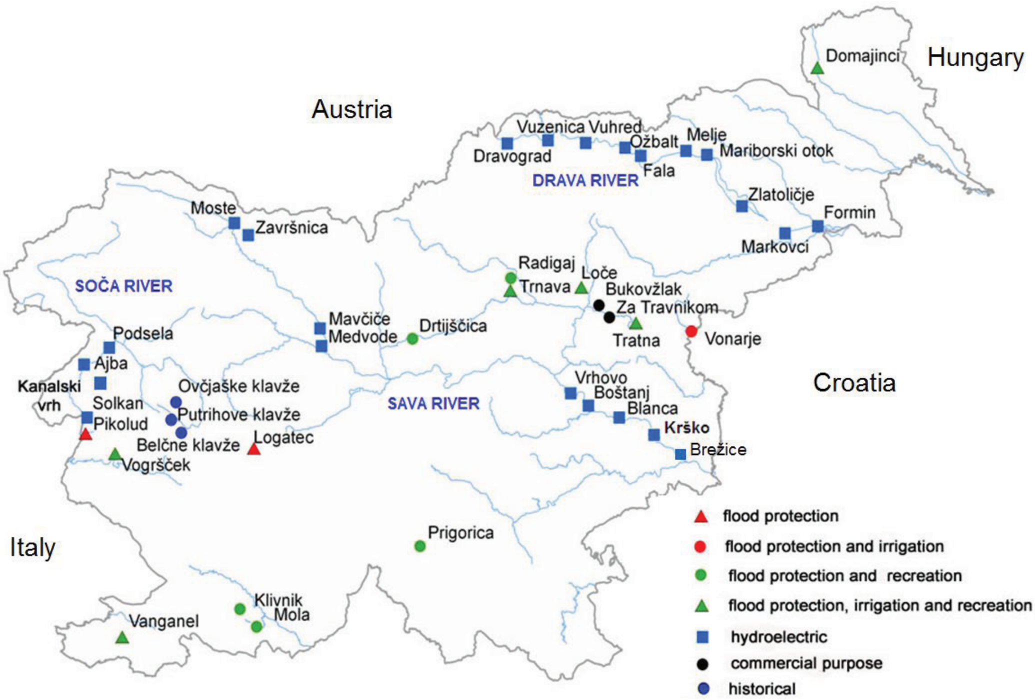

Figure 1 : The locations of large dams in Slovenia.

1.2 Dams on the Drava River and location of the Mariborski otok Dam

The Drava River flows through southern central Europe, and is approximately 725 km long. It is a tributary of the Danube River. The Slovenian section is 133 km long, and over this distance it has a descent of 148 m. Because of the high rate of flow and also the relatively steep gradient, eight HPPs are located on this section. Six HPPs (Dravograd, Vuzenica, Vuhred, Ožbalt, Fala and Mariborski otok) are located directly in the river stream, whereas the other two HPPs (Zlatoličje and Formin) are situated in derivation channels of the river (Fig. 2). Between the years 1918 and 1978 ten concrete gravity dams were built. Their structural heights vary between 17 and 54 m.

Figure 2 : Location of the HPPs on the Slovenian section of the Drava River.

2. DESCRIPTION OF THE DAM

The Mariborski otok concrete gravity dam (Figs 3-4), part of the corresponding HPP on the Drava River, in Slovenia, was completed in 1960, and renovated in 1997-2000. Its structural height is 33 m, and the dam crest has a length is 184 m. The dam structure contains three turbine piers, placed between four spillways, as well as bank structures. The spillways, closed by two steel gates, have a total capacity of 5600 m^3/s. The reservoir, which contains 18.7 hm^3 of water, has a length of 15.5 km and the surface area of 2.4 km^2, whereas the catchment area of the reservoir is 13,410 km^2. The Mariborski otok Dam is founded on sedimentary bedrock.

Figure 3 : Bird's-eye view of the Mariborski otok Dam.

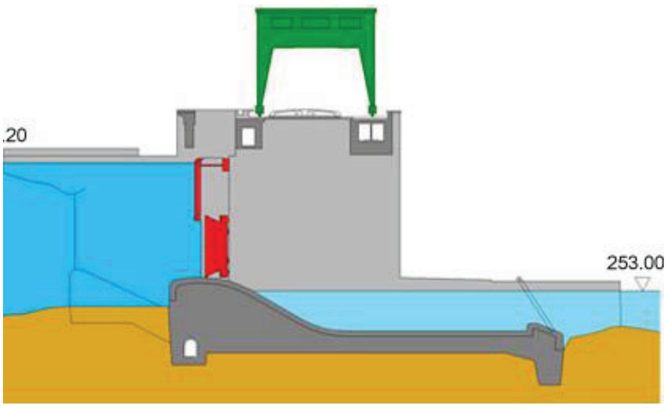

Figure 4 : Cross-section through a spillway.

3. MONITORING SYSTEM OF THE DAM

Long-term manual technical monitoring of the behaviour of the dam began in 1969 and included all necessary types of measurements and visual inspections. In 1990, the monitoring system was supplemented by two additional side piezometers on the right bank of the dam. In 2002, the modernization of the technical monitoring system of the dam was carried out and because of the need for more accurate determination of the state of the dam, automatic measurements of several parameters, mainly hydrostatic and partly hydrodynamic, began.

Monitoring system of the Mariborski otok Dam behaviour includes: deformation measurements (vertical, horizontal and relative displacements, and inclinations; see Fig. 5), visual inspections (structural, geotechnical), groundwater measurements (piezometric levels, uplift pressures, temperatures, electrical conductivities and outflows; see Fig. 5) and measurements of external loads on the dam. The latter are carried out in the reservoir, in the stilling basin and in the dam itself (including the inspection gallery and the crest of the dam).

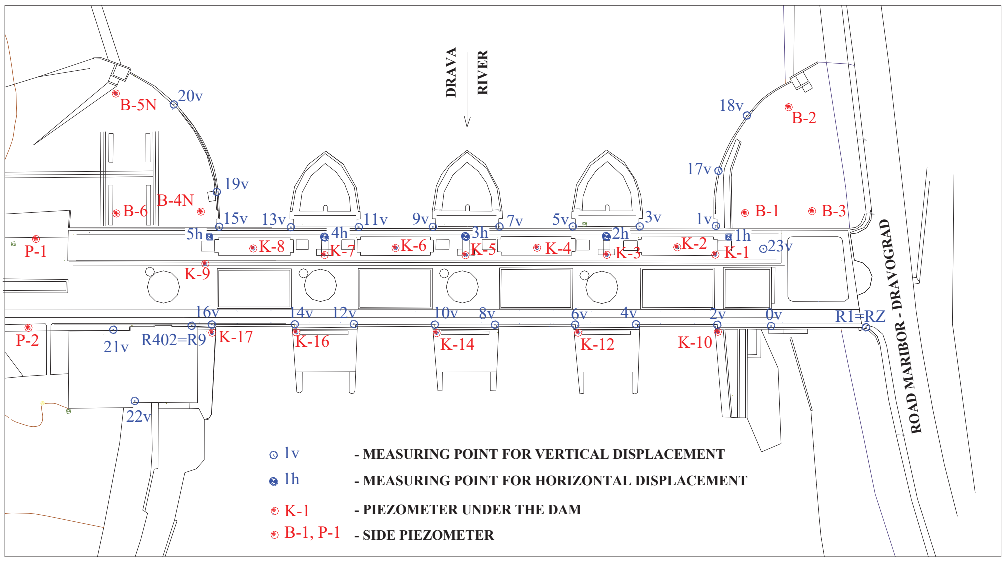

Figure 5 : Monitoring system for deformation and groundwater measurements.

4. AN EXTRAORDINARY EVENT

In December 2017, the malfunction of the steering system of the upper spillway gate management of the fourth spillway caused unexpected overflowing of 230 m^3/s of water between steel gates, which severely damaged the upper spillway gate (Fig. 6). In addition, the concrete beam of the crane rail on the crest of the dam was also damaged (Figs 7-8).

Immediately after this event, the necessary deformation and groundwater measurements were carried out. Measurements of horizontal displacements and inclinations of the dam were performed twice in a short span of time, whereas the measurements of piezometric levels, uplift pressures and outflows were carried out three times in the short time intervals. In addition, the detailed visual inspection of the dam was also performed, which involved overview of the state of the damaged part of the concrete. The results of measurements and visual inspections carried out instantly after this event showed that fortunately the safety of the dam, as well as the operation of the HPP was not threatened.

Figure 6 : Inclined and damaged the upper spillway gate in the fourth spillway.

Figure 7 : Damaged concrete beam of the crane rail on the dam's crest (right side of the fourth spillway).

Figure 8 : Damaged concrete beam of the crane rail on the dam's crest (left side of the fourth spillway).

5. REHABILITATION WORKS

However, technically demanding rehabilitation works on the dam, estimated at about 2 million euros, were anticipated. Firstly, auxiliary spillway gates were inserted (Fig. 9), which enabled, for the first time since the dam was built, the required lowering of the reservoir level by 6.5 m. In September 2019, the second phase started (Fig. 10), which includes restoration of the damaged concrete structure and of the spillway gate as well as the restoration of the remaining undamaged equipment of the fourth spillway, with the main purpose of extending its service life by another 30-40 years. Rehabilitation works are expected to be completed by the end of 2020.

The scope of the renovation includes the repair of damage of the concrete structure and the repair of the equipment of the spillway gate of the fourth spillway on the following sets of equipment: upper spillway gate, lower spillway gate, drive mechanisms and concrete parts.

Figure 9 : The first phase of rehabilitation works - auxiliary spillway gates inserted.

Figure 10 : The start of the second phase of rehabilitation works – disassembly of the upper spillway gate.

Damage rehabilitation and restoration of the spillway gate of the fourth spillway involve the following activities:

- disassembly and cutting of the upper spillway gate,
- displacement and support of the lower spillway gate,
- disassembly of the lower spillway gate equipment,
- implementation of non-destructive testing on equipment,
- production and supply of new upper spillway gate and other equipment,
- renovation, reconstruction and modification of existing equipment,
- corrosion protection of equipment,
- construction works,
- delivery and replacement of electrical equipment,
- assembly of equipment,
- testing of equipment and finally
- trial operation.

6. CONCLUSIONS

Large dam structures represent a significant safety risk, since major damage to them or even their failure can have disastrous consequences, such as the loss of human lives, major economic losses and severe ecological effects. A very important role in ensuring the safety of large dam structures has the regular technical observation of these structures, which is carried out with numerous measurements and visual inspections, covering the monitoring of deformations in the area of the dams and their influenced areas, as well as the monitoring of groundwater filtration in the areas of the dam structures.

In the case of unfavourable behaviour of the dam or major damage, immediate intervention is required, which includes appropriate investigations of the dam structure and also the necessary actions to ensure both the safety of the dam and the operation of the hydropower plant.

REFERENCES

Bevc, L. 2017. Visual inspection of the state of the damaged part of the concrete of the Mariborski otok Dam after an extraordinary event. *Report of extraordinary inspection*. Slovenian National Building and Civil Engineering Institute, Slovenia.

DEM. 2020. *Mariborski otok Dam - general data*. http://www.dem.si/. Maribor, Slovenia.

SLOCOLD. 2020. *Large dams in Slovenia - general data*. http://www.slocold.si/. Ljubljana, Slovenia.

Žvanut. P. 2003. Updating of the project of technical monitoring of the Mariborski otok Dam. *Report*. Slovenian National Building and Civil Engineering Institute, Slovenia.

Žvanut, P. et al. 2019. Technical monitoring of the Mariborski otok Dam. *Annual reports 1997-2019*, Slovenian National Building and Civil Engineering Institute, Slovenia.

Žvanut, P. & Prnaver, A. 2012. Long-term behavior of the Ožbalt concrete gravity dam. *Proc. 24th Int. Congress on Large Dams, Kyoto, 6-8 June 2012*. Paris: ICOLD.