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Safety of a historical Dam in Romania

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Abstract. The safety of dams in Romania follows the current engineering trend and is governed by The Dam Safety Law, issued in 2001. A special concern refers to historical dams, where two cumulative contributing factors are endangering the safety - ageing and modifications in the catchment area that bring alterations in flood formation and flood characteristic values. To illustrate the specific problems, the paper presents a case hystory. The dam is one of the oldest storage reservoirs in Romania (Tăul Mare Dam), still operational, built prior to the 18th century in the Metaliferi Mountains in central Transylvania for the gold mines, where a relative minor incident has created a lot of concerns regarding the structure's safety. Thorough investigations have revealed an intense degradation due to ageing and lack of proper maintenance. The proposed rehabilitation works consist in refurbishing the bottom outlet gallery and repairing and strengthening of the downstream face of the dam.

Keywords: old storage reservoirs, hystorical values, rehabilitation.

1. Introduction

The safety of dams in Romania follows the current engineering trend and is governed by The Dam Safety Law, issued in 2001. A special concern is related to historical dams, where two cumulative contributing factors are endangering the safety - ageing and changes in the catchment area that bring alterations in flood formation and flood characteristic values (i.e., peak discharge and flood volume). Historic preservation laws were developed to protect cultural, archaeological and architectural sites, structures, and landscapes that are significant to our heritage. Dams and bridges can be historically significant and may receive protection if their engineering is unique and/or they served an important role in local, regional or national history. If safety of such infrastructure is threatened, rehabilitation works

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are promoted but are restricted to preserve the type, material and appearance of the old structures.

The present paper deals with an old dams mainly built for water supply of water powered machines and tools for grinding golden ore in the ancient gold mines.

The oldest dams in Romania are associated to gold mining and were built by Romans in Rosia Montana mine area in central Transylvania. The water stored in these ponds ("tau, tauri (pl)" regionalism) created behind some small dams was used for grinding the gold ores. Historical documents witness the upgrading of such reservoirs in the 18th century. The largest one in Rosia Montana mining region was Taul Mare. One of the oldest documented upgrading of the dam was done in 1779 [1]. The reservoir capacity was increased to 0.3 hm^3. In 1913 a new upgrading was performed aiming to improve the dam safety: a new intake tower, strengthening of the bottom outlet gallery, reinforcement of the masonry at the downstream face and repair works at downstream face buttresses. The last significant refurbishment was done in 1929 when additional downstream face strengthening was performed under the supervision of the Romanian Technical Superior Council [2]. The recent incident occurred at the dam in October 2022 and the proposed rehabilitation works are presented in the paper.

The first hydropower developments in Romania started at the end of the 19th century (1888 - 1900), a few years later than the first similar developments in the world. The hydropower station Grozavesti, on Dambovita River, was the first one (1888 - 1890) and it was built in the frame of Dambovita river training in Bucharest. The first large dams included in hydropower developments were Valiug dam, a masonry gravity arch dam, 27 m high, Rasca Mica, a gravity masonry and concrete dam, 20 m high and Sadu II, a masonry gravity arch dam, 13 m high. All these dams were built in 1907 - 1909, using design concepts of the prestigious dam engineer Otto Incze from Aachen, Germany. All these dams were rehabilitated in recent years but the one that was significantly transformed by upgrading solutions was Sadu II. The Sadu II dam rehabilitation is presented in the paper.

2. Taul Mare Dam general information

Taul Mare Dam has a height of 18 m and a crest length of 260 m. The dam provides a storage of 0.27 hm^3. The initial purpose of the storage reservoir was water supplying for grinding ore at the gold mines. Currently, the pond ("tau") is used for recreation and fishing.

The dam was built from local natural materials: earth, loam, gravels etc. The dam as it was in 1779 is presented in figure 1 [1].

After the upgrading works performed in 1913 the dam was significantly improved. The present dam structure is similar with the one in 1913. The actual cross section is presented in figure 2, adaptation from the original drawings from the Report of The Romanian Technical Superior Council [2].

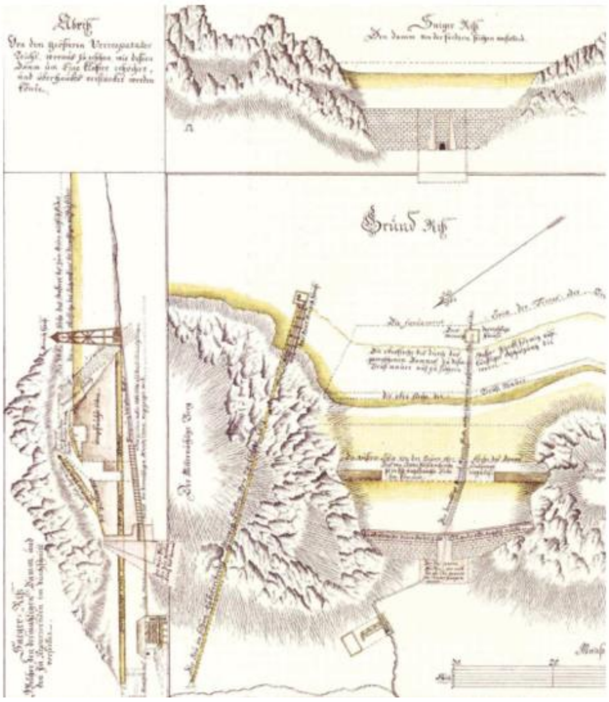

Fig. 1. Taul Mare Dam (Romanian National Archives, Transylvania Region 1779).

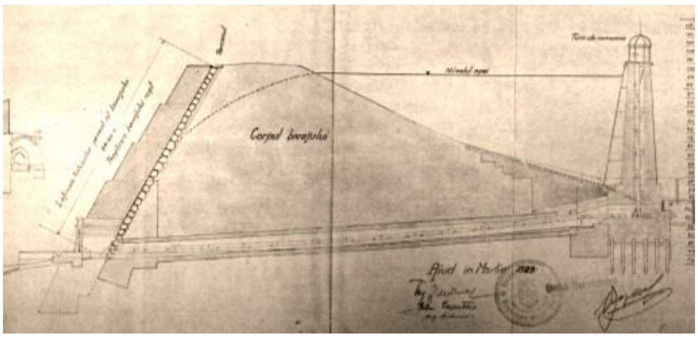

Fig. 2. Taul Mare Dam cross section at 1929 (Ministry of Public Works 1929).

Most of the dam body is an earthfill one, with the upstream face with a slope of 1:2 to 1:3, while the downstream face, with a slope of 2:1, consists of a supporting and protective wall made of masonry. Three buttresses of masonry were added to strengthen the wall.

Figure 3 shows the general view of the dam, after a photo from circa 1936.

Fig. 3. Taul Mare Dam general downstream view (1936 photo).

The spillway is a free overflow one, located near the left abutment. The bottom outlet is a steel conduit D500 mm protected by a 2x2 m gallery, crossing the bottom section of the main dam. An intake tower controls the discharge through the bottom outlet.
Figure 4 shows the present day's situation of Taul Mare Dam and the appurtenant structures - spillway, bottom outlet intake tower and exit portal.

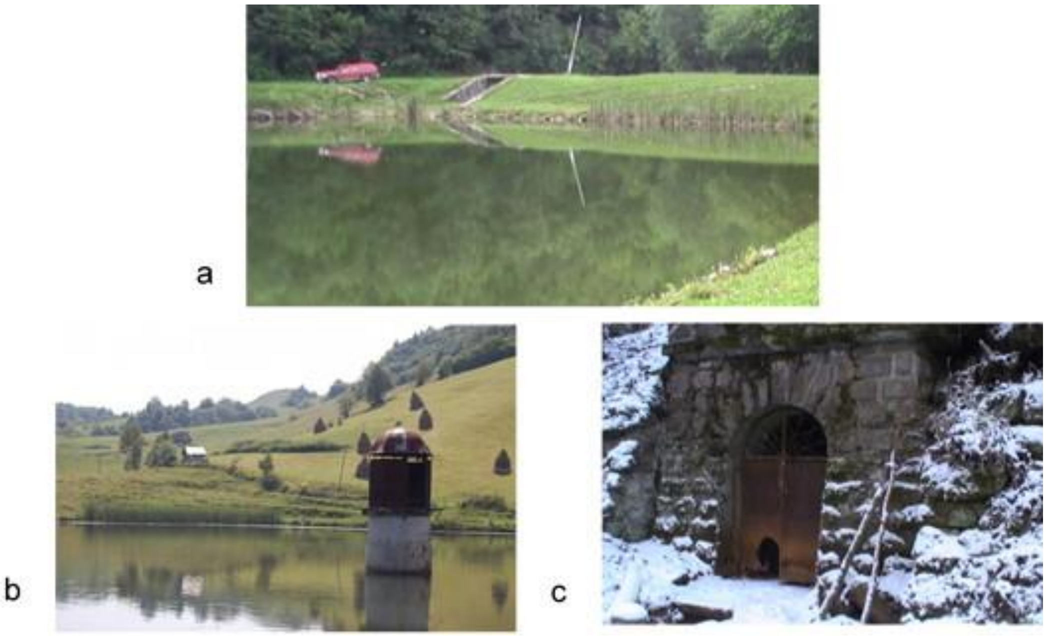

Fig. 4. Taul Mare Dam appurtenant structures;
a – spillway; b – bottom outlet tower intake; c – bottom outlet gallery exit portal.

3. Taul Mare Dam incident

The incident was noticed on the 1st of October 2022 and apparently was prompted by a sinkhole revealed on the dam crest, some 1-2 m from the downstream face. The hole had a diameter of 50-60 cm at the crest surface and up to 1.50 m in depth (Fig. 5).

Fig. 5. Sinkhole at dam's crest during Taul Mare Dam incident (Oct. 2022).

Considering the sinkhole as a sign of an incipient dam failure, the local authorities started emptying of the reservoir and demanded for the evacuation of the downstream village people living in the potential flooding area.

A thorough technical inspection was made in the following days. The most relevant findings were revealed in the gallery of the bottom outlet pipeline (Sofronie 2022). A local deposit of gravel with a length of some 6 m, created by the collapse of gallery lining was discovered (Fig. 6).

Fig. 6. Local failure of bottom outlet gallery.

Fortunately, the failure had no connection with the reservoir, since no seepage was encountered. Based on these findings the incident mechanism was clarified. The influx material in the failed zone of the gallery originated from the dam body. Apparently, an unstable "chimney" was opened in the earthfill dam body after the gallery lining collapse, propagated up towards the vicinity of the dam crest (Fig. 7).

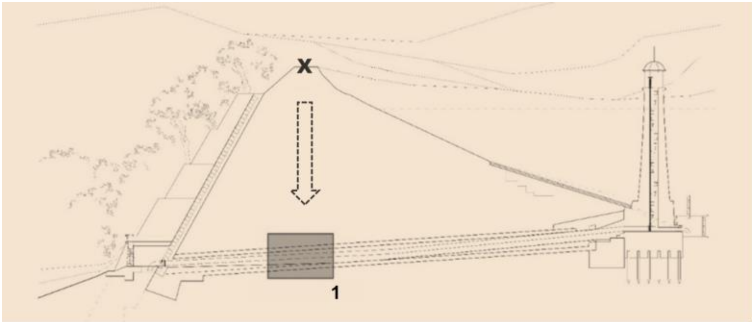

Fig. 7. Mechanism of local failure of bottom outlet gallery; **X** – sinkhole; 1 – bottom outlet gallery lining collapse.

Geophysical investigations using electrical resistivity imaging (ERI) were performed to verify the dam body integrity. The results presented in figure 8 have shown that there were no other cavities within the earthfill mass (Mihai et al. 2022).

A renewed bathymetry of the reservoir was also performed, showing some 30%-40% of the pond was severely silted.

The technical inspection rendered evident some other issues affecting the dam safety: degradation of the buttresses that used to support the masonry wall of the downstream face, abundant vegetation on the downstream face preventing a proper visual inspection of the dam structure and the blocking of the bottom outlet valve with the local clogging of the conduit.

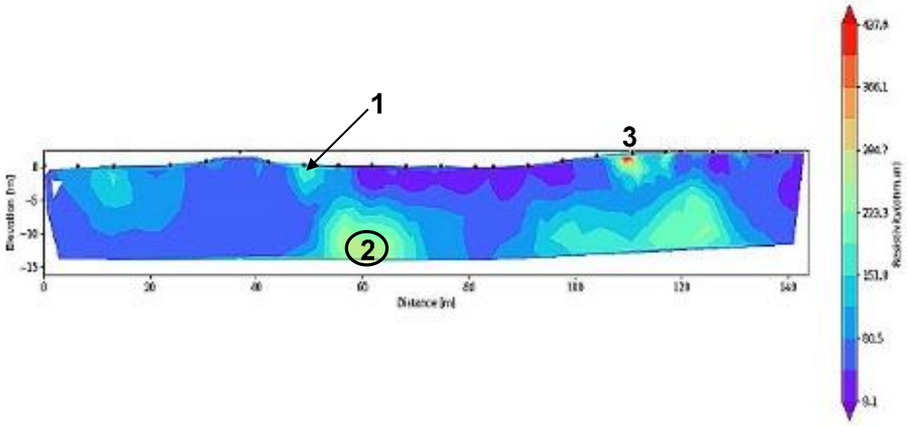

Fig. 8. Electrical resistivity imaging (ERI) investigations interpretation;
1 – approx. location of crest sinkhole; 2 – bottom outlet gallery; 3 – rock abutment

Consequently, among the proposed dam restoration works one can mention the most important: relining the bottom outlet gallery using the same type of stone

lining; filling up the chimney hole; replacing the outlet conduit with a new one, rebuilding the buttresses at the downstream face, cleaning the dam faces etc.
Subsequent investigations will allow for a possible relocation of the bottom outlet intake elevation, due to the thick layer of sediments in the reservoir. Obviously, the dam needs post analyses to assess the safety status, both structural and related to the capacity of flood routing according to present day's conditions. Since the dam is included in the list of UNESCO world inheritance sites, the technical solutions will have to preserve the type, materials and appearance of the ancient structures and the design project will be approved by The Romanian National Commission of Historical Monuments (Ministry of Culture, National Institute of Patrimony 2022).

Concluding remarks

Engineering heritage includes structures, sites and objects that have contributed to the history, culture and creativity of the engineering community and of the community as a whole. In the case of hydraulic structures, the unique nature of each dam means that every structure will get old at different rates and in different ways. Some dams may remain safe for centuries. According to a panel on dam ageing at 1991 ICOLD Congress, "in the future, attention and activity [will] be more and more shifted from the design and construction of new dams to the restoration of the structural and operational safety of existing dams". A special issue is the rehabilitation of historic dams.
The preserve-as-found approach is not always practical and interventions and alteration works may be unavoidable to extend the life of an existing dam or of another asset. Any intervention needs to be very carefully considered, since one may simply conclude that repair works are required or, even worse, that the dam or asset completed its useful life and consequently should be demolished and replaced. Prior to designing any intervention, it is essential first to understand the dam concept and the reason of any decay. This examination and appraisal will help to build a better understanding of the existing structure, the causes of the defects that have occurred and whether any intervention works are necessary.
If interventions are required, they should be carefully considered, sympathetic to the character of the dam. Often the use of *like-for-like* materials and construction techniques used at that time can be appropriate interventions. For an engineer, it is often important to appreciate and understand the philosophy of conservation and develop the necessary judgement on how this can be best achieved on a specific dam.
On the other hand, rehabilitation of historic dams needs thorough assessment of safety conditions of the ancient structure and the need for restoration works to assure dam's compliance to the actual safety standards and norms.
To conclude, any rehabilitation works must be carried out very carefully, and while minimal intervention should be the starting point, some change may seem inevitable.

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