CASE STUDY OF A SMALL DAM FAILURE – SOME EXPERIENCE AND SOME THOUGHTS

Dimitar S. Kisliakov
Assoc. Prof., Dr., Dept. of Hydraulic Engineering,
Univ. of Architecture, Civil Engineering and Geodesy (UACEG),
1 Chr. Smirnenski Blvd., BG-1046 Sofia, BULGARIA, E-mail: kiss_fhe@uacg.bg

1. Introduction

There are quite stringent regulations regarding the operation and the technical monitoring and maintenance of the large dams (according to the ICOLD formulations). In this connection, the Bulgarian legislative environment, professional experience and actual conditions are no exception. The control mechanisms in this field are relatively properly formulated and well functioning with regard to both Owner / Operator and Regulator. The situation with the so-called small dams is however different. There are more than 2000 such dams spread over the territory of the land, most of them built for irrigation from the 50-s to the 70-s of the last century. The process of political change caused some severe problems with the ownership of many such dams and with the conditions for obtaining a permit for operation as well as with the regulatory mechanisms in respect of the technical maintenance of the facilities and the responsibility for their safety conditions. For many years, problems of this kind have remained outside of the attention focus of the competent authorities. Small dams as small facilities have been always associated only with small problems, if any at all. However, the particular situation may become quite severe when a built-up area is located downstream of a dam, even of a small one.

On 08 May 2008 in the morning, there was a sudden request to the Department of Hydraulic Engineering at the University of Architecture, Civil Engineering and Geodesy (UACEG) in Sofia for an immediate visit of a small dam near the town Pernik in connection with an emergency situation. The author was the only one freely available staff member on that day, so he went there instantly.

Very soon, the whole expected commission came together to discuss the emergency situation with the small dam and its lake. There were about 20 experts representing the Civil Defense State Agency at the Ministry of Emergency Situations, the Basin Directorate in Blagoevgrad at the Ministry of Environment and Waters, the Municipality of Pernik, the fire service, the power and water supply services as well as representatives of the population of Leskovets, the directly underlying village.

The following presentation is a short description of the case with some discussion of its causes, solution measures undertaken and drawn conclusions. Unfortunately, although unique in its appearance, the further discussed failure case is more or less typical for the situation with many Bulgarian small dams.

2. The case

The small dam Leskovets (better known in the region as “Kavatsite” after the tavern on the right bank) just above the village of the same name has been built in the 50-ies of the last century on the river Sitovska by an agricultural cooperative society for irrigation, Figure 1. After the political change in 1989, several court procedures have run between the successors of the cooperative and the municipality about the ownership of the dam. They all have been won by the municipality. However, at the time of the here discussed
accident, the cooperative society successors were objecting these decisions in Strasbourg. Moreover, at the end of the 90-ies, a famous local businessman (at the very same time being in jail for drugs), has bought the tavern, built an illegal fence around the dam and the lake and started fishery. He also started construction of two houses on the lake shore but this activity was stopped as illegal.

The earth-fill embankment dam had a height of about 8 m. The design total reservoir volume was about 75000 m$^3$, but according to the local representatives it was considerably more due to heightening and back-filling of the spillway (for access to the tavern), Figure 2 – estimated about 90000 m$^3$. In fact, no technical maintenance activities were carried out for at least 20 years. In the last 10 years of operation, the tavern owner had strongly limited the access to the dam and its appurtenant facilities, thus preventing any surveillance and maintenance.

During the inspection of the dam and its facilities, the following findings could be formulated:

- the water volume in the reservoir was obviously much more than designed. However, dredging of a bypass canal beside the heightened (and subsequently back-filled) spillway was already running as emergency measure for partial release of the most upper part of the reservoir;
- there was a fence built on the dam crest, thus preventing the free access of both dam slopes from each other, Figure 5;
- concrete pylons were driven into the dam body on the crest for an air power supply line to the former tavern on the other river bank, Figure 7;
- the upstream slope of the dam has not been maintained for a long time (a 15-20 years old tree had grown there, Figure 5);
- totally unattended downstream dam slope, Figure 3;
- spillway in fact out of operation and useless, as already mentioned, Figure 2;
- totally unattended and clogged bottom outlet;
- no available documentation about the dam and its appurtenant facilities.

Figure 1: Leskovets dam – look to the lake from the right end of the dam
3. The situation

Some time ago, cracks in the dam body had been observed. In the last one and a half months before the failure, these cracks had developed more and more intensively together with a massive settlement of a large wedge in the central part of the dam body with average length of about 10 m, Figure 5. During this last time (about 45 days), the dam has been monitored regularly and more carefully for following the development of the damage state.

In the last few hours before the morning of 08 May, the cracks were established to be fresh and much more deep, Figure 6. This finding was actually the occasion for the requested emergency meeting of the expert commission on site. The following features of the situation were found:

- the disrupted part of the dam body was moving – the crack opening was already about 10 cm, Figure 6, and when a wood stick or a piece of straw to both sides of the crack was detached at about limit state equilibrium, after 15 min it was fallen. The vertical settlement in the central part of the dam was about 0.7 m;
- the downstream reach below the dam was inundated, Figure 4 (i.e. intensive and increasing seepage flow had developed);
- the bottom outlet of the dam was clogged for years and out of operation;
- the reservoir was full, moreover, above its design capacity.

In summary: a dam in a developing process of catastrophic failure was determined.

4. The solution

The discussion about the necessary measures was intensive and concentrated – on one hand due to the rapidly progressing failure of the dam, and on the other hand due to the quite narrow boundary conditions of the problem since no possibility for reservoir release was available at that time.

Meanwhile, the diver team of the Civil Defense Agency already was working on the bottom outlet trying to unclog it. As already mentioned above, a temporary canal bypassing the spillway was also being dredged in the right bank, however, only for a partial release of the most upper part of the reservoir.
The mayor representative of the village asked only one simple question: *Should I evacuate the people?* The major concern of the municipal authority was the organization and the medial response of an evacuation. It also was important what type of time, effort, organization and resources the activity of evacuation would require. We made the proposal, that if the bottom outlet was not to be unclogged within the next half an hour, the village should be evacuated. Moreover, even if the drainage of the reservoir successfully started, the state of the dam should remain permanently carefully monitored and the people set in preparedness for immediate evacuation. Following features of the dam behaviour were to be constantly followed:

- movement of the disrupted part of the dam;
- opening of cracks on the upstream slope of the dam with possible direct water flow into the cracks;
- water sources with outflow on the downstream slope of the dam.

Thus, evacuation of the village population and setting alarm conditions in the whole downstream reach of the river remained the only possible alternative in the situation.

![Figure 3: Downstream slope of the embankment dam](image)

Very soon (within the next 2 hours), the divers succeeded to unclog the bottom outlet, and controlled drainage of the reservoir started with a discharge of about 0,5 – 0,7 m³/s. Nevertheless, some people from the most endangered houses yet had to be evacuated shortly after midnight due to concerns about the stability conditions of the dam. On the next day, the water level in the reservoir was already more than 2 m below the initial level (corresponding to a maximum depth of about 6,5 m at the dam), and the controlled water release from the reservoir could be continued in less dangerous conditions for complete emptying of the dam lake. The clear decision for further dam removal was made since no structural repair of the dam body was in fact possible after the occurred failure.

5. Concluding considerations

The shortly presented failure case exceptionally got immediately a place also in the news reports, thus focusing the public attention (although only for a while) to the bunch of problems with the operation of small dams having remained forgotten for many years.
Unfortunately, the here described operation conditions, although not to the same extent, are still typical for many small Bulgarian dams. Moreover, downstream of many of them there are built-up areas.

Figure 4: High water level in the downstream reach

Figure 5: Moving wedge in the central part of the dam body

The technical requirements of the regulations and codes in the field of dams differ only in regard of technical parameters and number of potentially endangered people. This in turn results in a quite different approach to the technical maintenance of the facilities in respect of the corresponding class of importance. However, people at risk downstream of a (small) dam are always people at risk, no matter how many they are.
In this connection, the experience gained with the solution of the emergency situation of the dam failure Leskovets may help to overcome the still lasting and wide spread problems with such small dams. The requirements for the use permit for a water object need to be closely related to the surveillance and technical maintenance of the facilities appurtenant to the water object. The responsibility for all necessary technical activities should be clearly formulated in the frame of regulations covering all aspects and relations of ownership, operation and regulatory activities.

A conceptual revision of the related regulations is maybe necessary. Of course it would be followed by the necessity of widely spread activities for improving the state of numerous small dams, but the need for and the importance of such work were unfortunately cruelly proven in some tragic flood events still in the following 2009.

**Related codes, regulations, contributions**

1. **Норми** за проектиране на хидротехнически съоръжения. Основни положения – БСА, кн. 11, 1985 (Codes for design of hydraulic facilities. Basic conditions – in Bulgarian)
2. **Норми** за проектиране на насилия язовирни стени – БСА, кн. 1,6, 1986 (Codes for design of embankment dams – in Bulgarian)
3. **Правилник** за експлоатация на ХТС към ВЕЦ, ТЕЦ и АЕЦ (вътрешноведомствен). Предприятие “Язовири и каскади” – НЕК АД, 2003 (Regulation for operation of hydraulic facilities of water power plants (PP), thermal PP and nuclear PP – in Bulgarian, for internal use)
4. **Наредба** № 13 от 29.01.2004 г. за условията и реда за осъществяване на техническата експлоатация на язовирните стени и съоръженията към тях, МОСВ, МРРБ, М3Г, МЕЕР, 2004 (Ordinance № 13 of 29.01.2004 for the conditions and order for performing the technical operation of the dams and their appurtenant facilities – in Bulgarian)
6. **Закон** за водите, посл. 03.05.2011 (Water law – in Bulgarian)
7. **Закон** за устройство на територията, посл. 29.12.2005 (Law on Territory Planning – in Bulgarian)