SAFETY PROBLEMS OF SMALL EMBANKMENT DAMS IN THE CZECH REPUBLIC

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ABSTRACT

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In the Czech Republic there are about 20 000 small reservoirs, the majority of them being historical ponds older than 100 years; dams older than 300 years are not unusual. The technical state of some of these small dams has in many cases been found to be unsatisfactory in terms of both hydraulic and structural safety. Historical dams usually suffer from insufficient spillway capacity due to the poor state of knowledge as regards hydrology at the time of their origin and also due to the higher level of hydraulic safety currently required than the check flood taken into account when the small dam was designed. In the case of new dams, including dry reservoirs, most of the problems surprisingly arise from improper design and also inadequate technological discipline, followed by poor technical supervision by the investor administering the structure. These facts result in hydraulic, structural and seepage safety problems. In some cases these problems lead to operational difficulties when the purpose of the reservoir cannot be fulfilled.

The safety assessment of dams during floods in the Czech Republic is carried out according to the TNV 75 2935 standard [1]. In this paper, experience from such assessment of about 600 small dams is summarized. For technical issues like the survey, calculation and design of small dams, two Czech national standards [2], [3] are also available. In this context the following specific issues are discussed in this paper:

- Documentation for the assessment of the safety of small dams.
- An inventory of main defects and deficiencies at small dams.
- Methods of surveillance and examples of observed deficiencies.
- Hydrologic, hydraulic and stability calculations.
- Hydraulic safety.

The quality of recordkeeping and the extent of existing documentation on small dams are quite varied. At least some archive documentation like design documents and operating instructions is available in most cases. However, documentation on the dam's structure that records its real state is available only in exceptional cases. Commonly available documents include handling regulations and reports on technical and safety inspections and surveys of the dam. One of the basic inputs is a check flood hydrographs provided by the hydrological services.

Particularly for old, small dams, detailed verification of the documentation has to be carried out. It is especially important to carefully verify the conformity between the real geometry, dimensions and elevations of the structure and its design parameters. For this purpose, geodetic surveying of the dam and appurtenant works should be performed. For most of the surveyed small dams, significant differences were found between their design parameters and their real state, and this includes dam crest elevations. Thus, geodetic surveying of the dam is crucial for further assessment.

If no archive documents are available, or in the case of doubts about the materials used in the dam, a geological and geotechnical survey has to be performed. Usually, non-invasive

geophysical survey methods are utilised. They are typically supplemented by invasive methods (trial pits, boreholes). Part of the survey involves the examination of appurtenant works, namely bottom outlets and spillways. It is desirable to carry out a camera survey of the bottom outlets focused on cracks in the pipes and on seepage into the outlet pipe.

A site investigation by the auditor is an absolutely necessary part of the assessment. During the site visit, the dam body and its slopes should be examined and the basic dimensions verified. The overall inspection aims to find any defects like uncontrolled seepage or the deformation of slopes, and also to determine the functionality of appurtenant works, etc.

An extensive inventory of the state of small dams has been carried out over the last decade. The inventory was conducted using various methods including visual observation, geophysical methods, geotechnical prospecting, the use of video cameras, etc.

The results include the following typical deficiencies and percentages related to all assessed small dams (about 600):

- Poor condition of bottom outlets 40 %.
- Unmaintained vegetation on the dam body 35 %.
- Seepage problems, wetted downstream slope and toe 40 %.
- Variable level of the dam crest and slopes, with depressions 30 %.
- Poor condition of the emergency spillway 26 %.
- Insufficient spillway capacity 45 %.

In the following text, examples of the typical deficiencies related to individual parts of the dam body and its appurtenant works are described and discussed.

There are several typical arrangements of <u>bottom outlets</u>:

a) Bottom outlet equipped with a valve tower made of concrete, stone or wood:
   - the tower is located upstream of the bottom outlet, which is usually designed as a free water flow pipe,
   - the tower is located in the dam body, dividing the bottom outlet pipe into two sections – an upstream one with a pressure flow regime and a downstream one with free water flow,

b) Submerged structure used mostly at dry reservoirs,

c) Combined structure – usually a bottom outlet and an emergency spillway,

d) Gated sluice.

Improper and unmaintained vegetation can affect the watertightness of the dam body by penetrating the sealing element (core, upstream membrane) with its root system. It also complicates observation of the dam and the geodetic surveying of dam displacements. When located at the downstream toe, vegetation can damage and obstruct the bottom outlet and also drainage pipes by penetrating the pipe with its roots.

Uncontrolled seepage may result in considerable increases in pore pressures and significantly decrease the stability of an embankment dam body. It also contributes to the initiation and sometimes progression of the internal erosion of soils in the dam.

The following typical seepage locations may be identified within small dams:

- seepage through the dam body,
- seepage along the bottom outlets,
- seepage along the side wall of the emergency spillway,
- seepage through the sub-base.

The above mentioned seepage modes are frequently combined. Experience shows that at least one of these seepage modes occurs at practically all inspected small dams.

The dam body shape changes over time due to consolidation and rheological processes. Usually the dam crest is subject to settlement, which is usually greatest at the place with the maximum dam height. Sometimes, due to poor compaction or even internal erosion, considerable subsidence occurs at the line of bottom outlets. This local deformation also occurs at places with heavy traffic in the form of tractors, lorries, etc. The subsidence of the dam crest, which can reach even tens of centimetres in extent, contributes to dam overtopping. Therefore, for safety assessment the lowest crest elevation should be taken into account. When the dam crest is not paved, it is necessary to include the wind wave run-up height in the hydraulic safety assessment. Many small embankment dams suffer from inadequately steep slopes. When uncontrolled seepage occurs, cracking and even slope slides may occur.

The emergency spillway is typically designed as either lateral or frontal. It comprises a weir, spillway channel, chute and stilling basin connected to the channel downstream. It is advantageous to perform calculations for each part of the spillway separately and to take its interactions into account (e.g. backward flooding of the weir). The spillway capacity is given primarily by the length of the weir crest and by the overflow head. Local conditions should be taken into account, such as the limiting of weir length by landscaping or by sediments and vegetation.

Weir capacity is often limited by a shallow spillway chute below the weir, especially in the case of a very long weir crest. In such conditions back flooding can be expected.

A crucial cross section for the back flooding of the weir is usually at the intersection of the chute and the dam crest. At this location the flow is often reduced by a narrow bridge profile, culverts, or by an improperly designed footbridge. These structures cause back flooding of the spillway channel and reduce the capacity of the whole emergency spillway.

Another typical arrangement reducing emergency spillway capacity is a screen placed directly on the weir crest. A clogged screen located at the weir crest significantly decreases weir capacity by increasing the elevation of the weir crest.

Hydraulic safety assessment consists of the following steps:

- Determination of the check flood max. water level (CML),
- Determination of the maximum "safe" water level (MSL),
- Assessment of the relation between CML and MSL.

The CML is determined by the calculation of check flood routing through the reservoir. Check floods in the Czech Republic are designated according to following table.

Table 1 Required check flood return period

Loss	**Description of consequences**	**Annual probability**	**Return period**
		$P \approx 1/N$	**N**
Extremely high	Considerable loss of human lives	0.0001	10 000
	Fatalities improbable	0.0005	2 000
High	Expected single fatalities	0.001	1 000
	Fatalities improbable	0.005	200
Low	Losses downstream of water structure, no fatalities	0.01	100
	Losses only for the owner, other losses minor	0.02–0.05	50–20

Summary: Based on safety assessments performed for numerous small dams in the Czech Republic it can be concluded that quite a large percentage of these dams do not comply with current safety requirements. The reasons for this lie in their design and its parameters, inadequate construction techniques and the poor maintenance of the dams. The consequence of this unsatisfactory situation is that every significant flood (e.g. in 1997, 2002) results in the breaching of several small dams. The periodic assessment of the safety of small dams and the subsequent implementation of remedial measures are necessary for the improvement of the present situation with regard to the safety of small dams.

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[1] TNV 75 2935 Dam safety assessment of hydraulic structures during floods. Czech technical standard.

[2] ČSN 75 2410 Small water reservoirs. Czech national standard.

[3] ČSN 75 2310 Dry reservoirs. Czech national standard.