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Technical note

Failure of a geomembrane lined embankment dam – Case study

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ABSTRACT

The right wing embankment of the headrace channel of a hydropower plant, failed adjacent to the concrete intake structure. The failure also caused damages of the penstocks and flooding of the powerhouse.

The root-cause analysis showed that water from the reservoir entered, through an open joint in the adjacent concrete structure, the geomembrane lined homogeneous embankment dam fill. This seepage water had eroded dam material from below the geomembrane and transported it to the drainage zones located at the interface of the embankment and concrete structures.

Due to continuing seepage and erosion of dam material the geomembrane ruptured and this resulted in the full reservoir head being applied to the embankment fill material. This increased the seepage through the dam fill and caused concentrated leak erosion of the fine-grained material at the contact with the concrete structure, and this lead to the failure of the embankment.

1. Introduction

The failure of the geomembrane lined homogeneous embankment dam at the water intake of the hydropower plant was a major event and called a detailed root-cause analysis. Some of these investigation activities are presented in this paper.

To fully understand this failure case, the intake structure is described in Section 2. The observations made by the site personnel before and during the failure are summarized in Section 3.

For the root-cause analysis, given in Section 4, the failure process was analysed in steps, for each of which defects and mechanisms were identified and discussed, before the most likely mechanism and consequently the most likely sequence of events is presented in Section 5. The failure steps were studied in the order of the seepage and erosion sequence, as follows.

- Source of seepage water.
- Path of seepage water.
- Storage of eroded dam material.
- Rupture of the geomembrane.
- Concentrated leak erosion and failure.

2. The hydropower project

The run-of-river hydropower scheme discussed in this paper is the lowest of three plants on a cascade. For this lowest plant, 155 m^3/s are diverted from a reservoir with around 5 Mio m^3 through a geomembrane lined headrace channel to the intake basin and then through steel penstocks to the powerhouse (Fig. 1a and b).

2.1. The headrace channel

The 2900 m long headrace channel follows the hilly landscape and is formed of cut and fill sections. The latter are constructed from materials excavated nearby and placed to form homogeneous fill embankments.

The inner channel slopes have an inclination of 1V:2H and the outer channel slopes of 1V:1.5H (Fig. 1c). Channel invert level is 37.5 m asl., and its width is 10 m. The channel invert and the inner channel slopes are lined with a geomembrane up to the berm level of 46.25 m asl. The berms are 3 and 5 m wide for the right and left channel sides, respectively. The slopes from the berm to the 3 m wide crest have an inclination of 1V:1.5H. The normal operation level is 45.75 m asl., which is 0.5 m below the berm and 2.75 m below the crest. The maximum flood level of 48.10 m asl., is 0.4 m below crest level.

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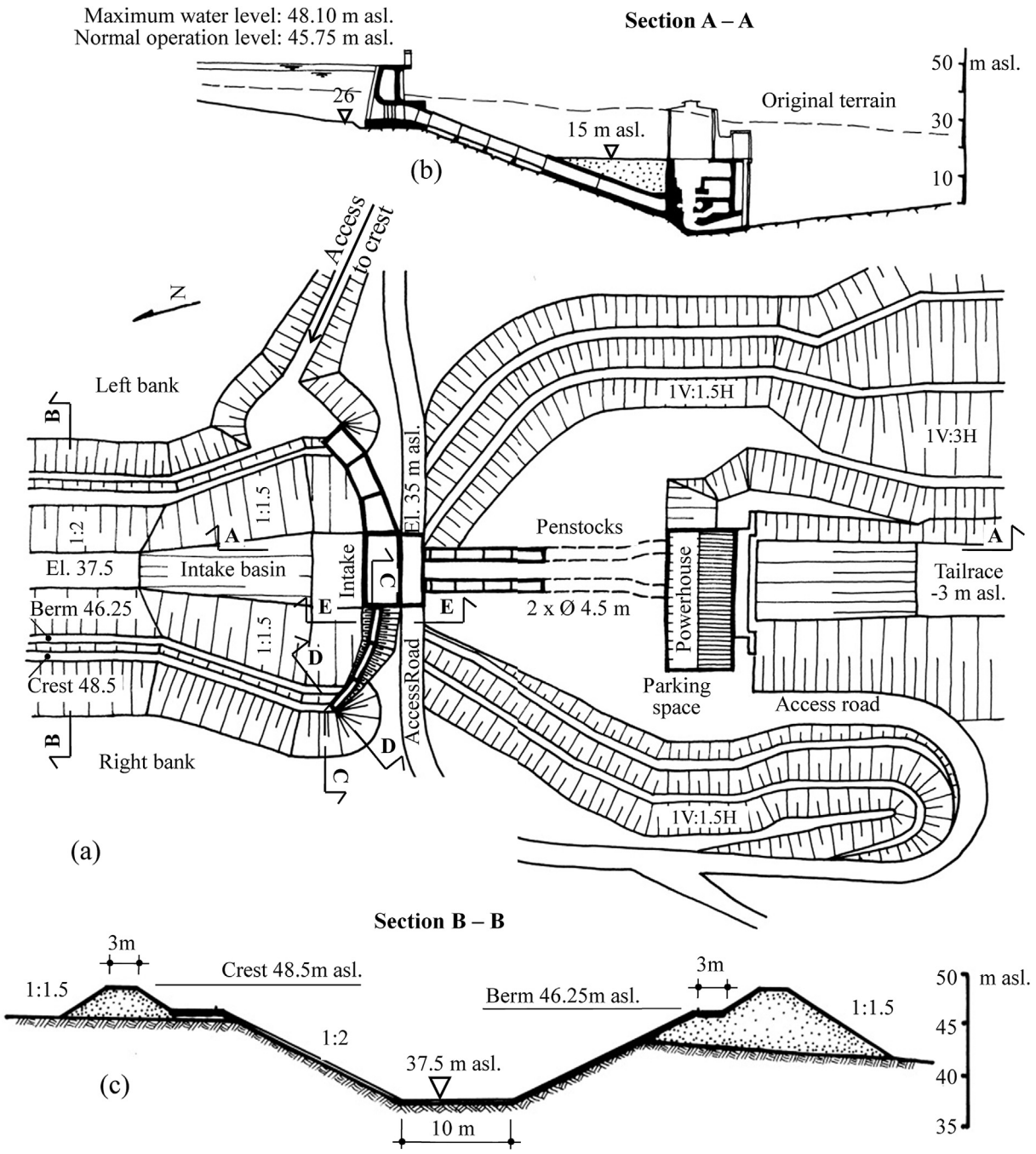

Fig. 1. (a) Layout and (b) longitudinal section of the intake and powerhouse structures. (c) Typical cross-section of the channel.

The geomembrane, used for the inner channel lining, is of high density polyethylene (HDPE) with a thickness of 1.5 mm. This geomembrane has a yield and break strengths of 22 and 40 kN/m respectively, and yield and break strains of 12 and 700% respectively, according to the producer's specification. The geomembrane was placed on two layers of geotextile.

A geotextile with a breaking strength of 26 kN/m, a breaking strain of 65% and a permeability of around 46 l/s/m^2 was selected for the purpose of avoiding damages on the geomembrane. Below the geotextile, a bedding layer of fine-grained material with reduced maximum grain size of around 10 mm was placed.

2.2. The intake basin

The intake basin is located at the end of the headrace channel. It is formed of homogeneous embankments, such as the headrace channel, which widen to form the intake basin. The south side of the intake basin is closed by a concrete gravity dam (Fig. 1a), i.e. the basin is enclosed by a combined concrete-earth structure. The C-shaped concrete gravity dam is formed of seven blocks, the central intake block with three blocks on each side (Fig. 1a). To both ends the geomembrane lined embankment dams are connected.