Anomalous behavior investigation of the sealing core at the Slezska Harta dam

Untersuchung des Dichtungskern an der Slezska Harta Talsperre

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Abstract

Unusual development of pore pressure was observed in the clay core of the dam. Regarding observation, the level of pressure was very close to the water level in reservoir and its change caused the same change of pressure measured by in-core sensors. Geophysical methods were used as action for the investigation and the drill holes were carried out. The site with high porosity and humidity was detected inside the core. Jet grouting technology was used for the repair.

Zusammenfassung

Im Dichtungskern des Dammbauwerks wurde eine ungewöhnliche Entwicklung des Porenwasserdrucks festgestellt. Die Messungen zeigten, dass sich dieser Porenwasserdruck nur sehr wenig vom Druck des Oberwasserstands unterschied. Ein Wechsel des Speicherwasserstandes verursachte nahezu die gleiche Änderung der Porenwasserdrücke im Tonkern. Geophysikalische Methoden und Bohrkerne fanden zur Analyse dieses Verhaltens Verwendung. Ein Bereich mit hoher Durchlässigkeit und Bodenfeuchte wurde innerhalb des Kernes ermittelt. Bei die Sanierung kam das Düsenstrahlverfahren zum Einsatz.

1 Dam and reservoir

The Slezská Harta dam is located in the north part of Moravia. The purpose of the reservoir is improvement of the water quality for water-supply purposes, improvement of discharge on the river Moravice, Opava and Odra, facilitation of water intake for industrial purposes and usage of water energy. The construction began in 1987 and finished in 1997. The filling of the reservoir, which began at the beginning of 1996, was quickened by the floods in 1996 and 1997 and it finished in 1998.

The dam Slezská Harta is stony with inclined average clay sealing, two-stage filter and transitional zone. Upstream face is at the slope within sections of 1 : 2 – 2,05, downstream face at the uniform slope of 1 : 1,8.

Within the ground plan, the dam is camber contrary to water in the shape of circular and transition curve arch. At the crest, there is a main road. The dam was filled with local materials. Stabilizing stony zones of the dam were filled with basalt taken from the nearby stone pit. Loose material was put into the dam in the layers of 1,2 m and they were compacted the vibrating roller or plate. Greywacke was used for a part of upstream face within the range of fluctuation of water level. Transitional zones and parts of filter were filled in the layers of 60 cm from the valley boulder gravel mined in the area of nowadays backwater area. The major part of the filter was filled with imported sand. Central core of the dam is relatively massive and it is filled with local sealing clay. It is, at the whole length, based on concrete block of grout gallery and on spread wing. In the abutment, the core widens and it is joined on grout gallery, in the right abutment it is joined on undergroung wall. The dam is situated in the difficult geological conditions. In the area of the right bank under the mantle of basalt, there is situated massive strata of fluvial and deluvial sediments with variable permeability. The strata of Kulm is represented here by shale and it is broken in this area breakdown zone of the cross cutting, which crosses the dam axis in the width of 20 m. Inside the breakdown zone, there are zones of extremely disrupted material with the character of mould. Distinct mechanical softening of ground massif up to the depth of 30-40 m was found in the left slope. (**Figure 1**)

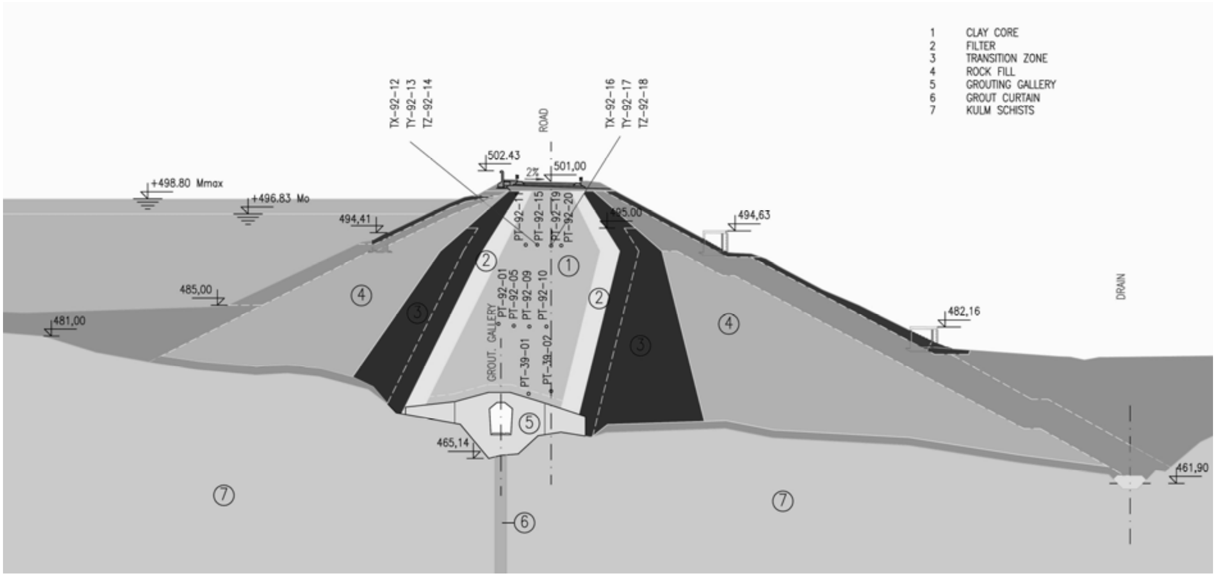

Figure 1: Instrumentation in right abutment

2 Dam monitoring system

Regular measurement of deformation and seepage regime is made at the dam within the dam safety maintenance. Regarding this purpose, most of the measurements is equipped with automatic measurement system with the transmission dispatching centre.

Vertical deformations are observed by geodetic measurement on the crest of the dam and in the grouting gallery. Horizontal deformations are measured on the crest and downstream face by geodetic measurement too. There are also extensometers for measuring deformations inside the dam fill. Monitoring system for measuring seepage regime consists of seepage measurements in the drainage system, measurement of water level in piezometers in grouting gallery and the dam surrounding. Pore and total pressures are measured inside the clay core. Gauges are situated in three profiles in several levels. One profile is in the middle of the dam and next two in abutments. Measurement of them is fully automatic.

2.1 Anomalous results of measurements

In the right abutment, there are gauges placed in two levels (**Figure 1**). Since June 2001, the change in level of pore and total pressures in the upper group of gages was observed. From that time, values of pressure immediately react to change of water level in reservoir. Level of pressures indicated connection with water level in reservoir. The group of sensors consists of ten sensors which are divided into four groups. There are four sensors of pore pressure, each in one group and six sensors of total pressure. All of them had a similar reaction.

2.2 Analyzes

Investigation started after anomaly was recognized. At first, all measurements were checked, and the whole system was tested. There were few inaccuracy discovered, but the result of measurement was confirmed. Relationship with other measurements especially with deformations was searched in next step. There was found an increased settlement in 1998 in the right abutment. Investigation was carried out by a group of experts who created four hypotheses reasons of that anomaly. As a main reason, wrong implementation of the sensors inside the clay core was signified. Sensors were installed in more than one-meter deep and 0.8 meter wide cut with vertical wall. The material inside the cut could not probably be enough compacted. It might have resulted into the creation of zone with high porosity and maybe cavern. But in that area, other influences were found, such as small total pressure in the vertical direction, arching effect of transition zones between rockfill and filters with high inelasticity, which could influence the creation of that anomaly. Probably, there was a combination of more of those factors. The connection among those factors is being verified with the mathematic model now.

3 Investigations

For the understanding of mentioned anomaly, survey were carried out which were divided in two parts – geophysical and drill.

3.1 Geophysical survey

There were used two methods: multi-electrode cable for resistance measurement and ground penetrating radar (GPR). For the first one, holes were drilled with 2 m spacing across the roadway construction to the clay core and electrodes were placed there. Measurements were carried out in two areas; under the cut with sensors and the other one in the middle of the dam. It was measured twice with different level of water in reservoir. Result was the foundation of the location with increased resistance near the group of sensors (**Figure 2**) [2]. The cut is more than 8 m under the crest. The GPR measurement did not indicate any anomaly and it was evaluated as unsuitable.

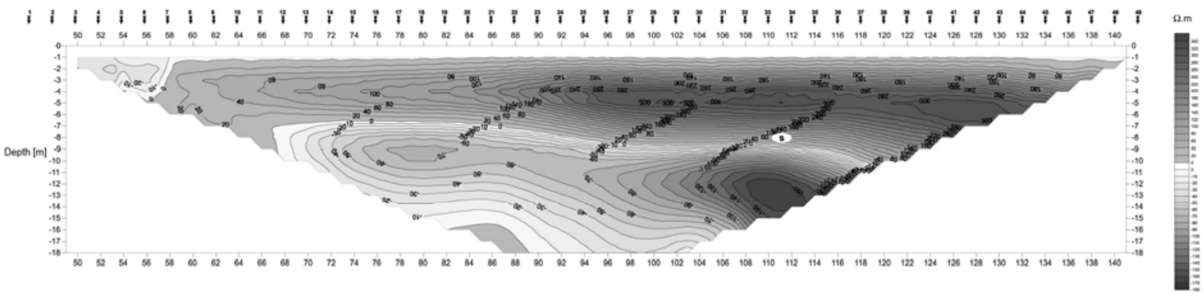

Figure 2: Result of geophysics measurement

3.1 Drill survey

The core hole was carried out straight to the cut. Video inspection and a number of geophysical measurements were made in the borehole, which confirmed results of visual assessment. From used methods here, e.g. Natural Gamma Ray Logging, Caliper Logging, Magnetic susceptibility etc. could be mentioned. There was found the material with high humidity and porosity in depth from 7 to 9.4 m under the crest (**Figure 3**). Next core hole was carried out in the downstream side of the cut and the same series of investigation was proceeded. But no anomaly was found there. Both boreholes were fixed by casing pipe.

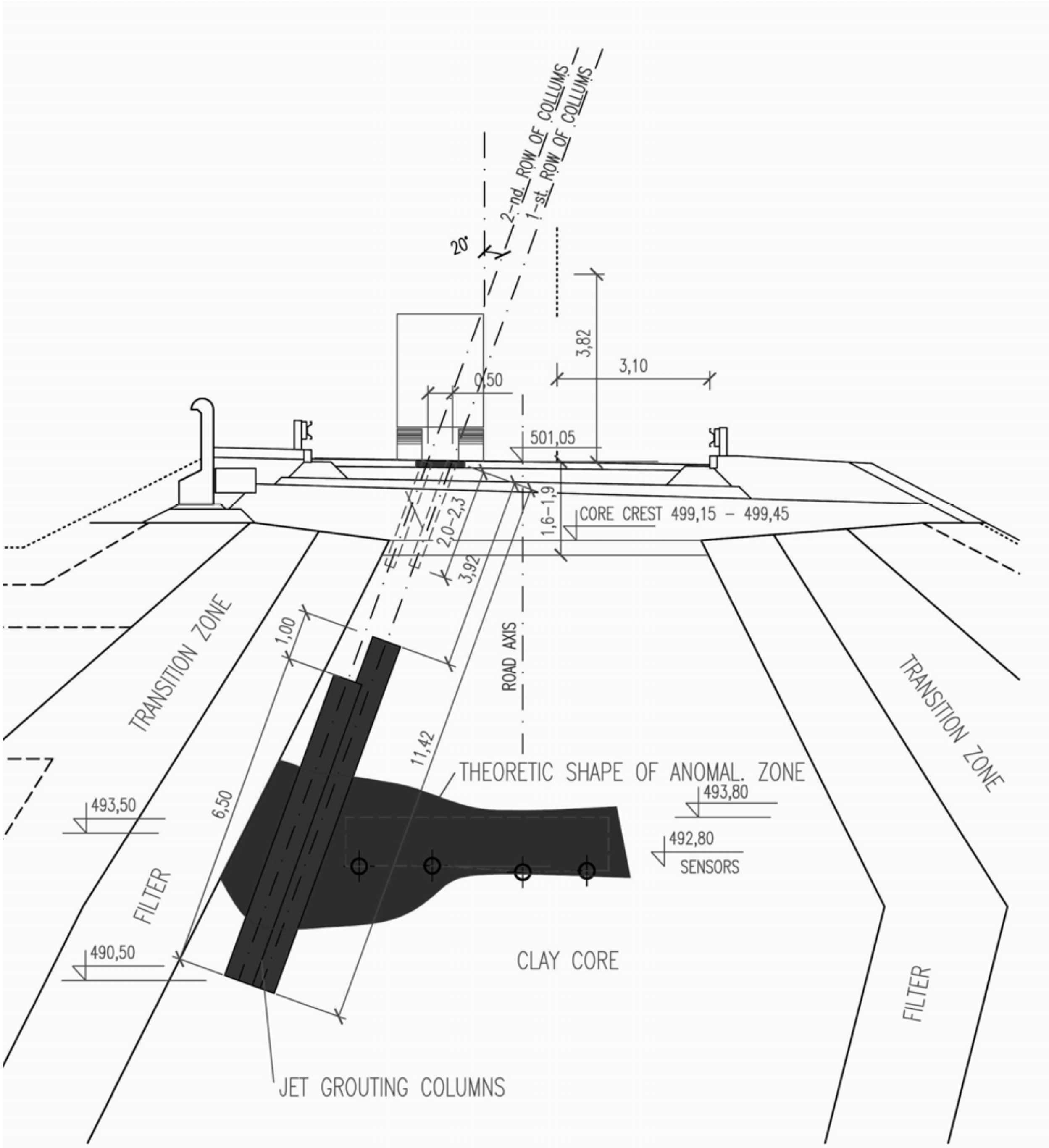

Figure 3: Repair scheme

For the limitation of defective site, dynamic penetration test was realized in nine places. Results confirmed that there is strictly bounded 1.5 m wide area with humid and porous clay and that this area is not going crosswise the clay core.

4 Repair work

For repair of that site, technology which could create impermeable element in upstream part of clay core was searched. The material of that element has to have similar deformation properties like the origin undamaged clay core. Technology of jet grouting was used. There were created 41 columns consequently in two rows. The expected values of impermeability, solidity and deformational module were achieved. It was confirmed by two boreholes witch were carried out 90 days after grouting work. All installed sensors are still work. They could be used for control of seepage throw the new sealing.

Literature

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