Technical workshop TW 4
Internal Erosion in Dams and their Foundations

Friday, 7 July, 13:30 – 16:30

Designated organizer: *Jaromír Říha (Brno University of Technology, Czech Republic)*
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Internal erosion is one of the most common causes of failures of water retaining hydraulic structures like dams, levees, etc. The aim of the workshop is to share knowledge and latest findings in the field and also to develop a link between ICOLD community and professionals integrated within the European Working Group (IEWG) on Internal Erosion in Dams and their Foundations.

Programme:

13:30 – 13:40 Invitation (J. Riha)

13:40 – 13:50 Bonelli, S. (IRSTEA - present chairman of the IEWG). Recent activities of the IEWG.

13:50 – 14:10 Fry, J. J. (EDF – former chairman of the IEWG, present chairman of European Club) Commentary on the current State of the art and the role of laboratory testing.

14:10 – 14:30 Koelewijn, A.R. (Deltares – organizer of IEWG meeting in Delft). 25th IEWG meeting & some notes on backward erosion and how to prevent it.

14:30 – 14:50 Riha, J. (TU Brno) 100 years from the Bílá Desná dam failure.

14:50 – 15:10 Bridle, R. (Editor – ICOLD Bulletin 164 on Internal Erosion) The four initiating mechanisms, speed to failure, case histories, new knowledge, research needs, terminology.

15:10 – 15:30 Beguin, R. et al. (GeophyConsult) Influence of the curing time of a newly placed silty soil on the resistance against concentrated leak erosion.

15:30 – 15:50 Landsdorfer, F. et al. (Verbund Hydro Power AG) The Durlassboden Dam, theoretical and practical assessments of the internal erosion and suffusion risk, occurrences in the past, ongoing activities.

15:50 – 16:10 Radzicki K. et al. Detection of short and long-term internal erosion using hybrid application of thermo-hydraulic finite element modelling and statistical analysis of piezometric data.

16:10 – 16:30 Nombre, A. – Lessons learned from internal erosion induced failures of small dams in Burkina Faso

16:30 – 17:00 Discussion (possibly after individual contributions).

Short abstracts

13:50 – 14:10

Fry, J. J.

Commentary on the current State of the art and the role of laboratory testing

In the presentation the role of laboratory testing after introducing the role of the ICOLD bulletin 164 will be underlined. Lab tests bring a clear understanding of main phenomena and can characterize erosion rate on site. However they cannot characterize all the situations on site. For instance limit conditions and time play an important role and new developments are required to capture their impact. Finally, methods of leakage detection and surveillance of leakage progression are complementary to lab tests.

14:10 – 14:30

Koelewijn, A.R.

25th IEWG meeting & some notes on backward erosion and how to prevent it

The 25th meeting of the Internal Erosion Working Group will be held in Delft (4-7 September). About forty contributions will be presented on all types of internal erosion; a short preview will be given on the programme.

Several of these contributions deal with the process of backward erosion through the foundation of a dam or a dike. Components of various models are discussed as part of the search of a robust, reliable model to predict this failure mechanism. Attention is paid also to the research of several methods to interrupt backward erosion, thus avoiding failure in an efficient way, reducing the costs and impact of rehabilitation works.

14:30 – 14:50

Riha, J.

100 years from the Bílá Desná Dam failure

In 2016 we remembered the collapse of Bílá Desná Dam located in the north of the Czech Republic. The failure resulted in 57 fatalities and considerable economic losses. Numerous studies were focused on the discovering the reasons of the failure. All agreed that the principal cause was internal erosion of the dam and its sub-base due to the combination of several imperfections. In the presentation the event is described and major causes of the failure are discussed. Lessons learned were gradually incorporated into dam design standards in the Czech Republic.

14:50 – 15:10

Bridle, R.

The four initiating mechanisms, speed to failure, case histories, new knowledge, research needs, terminology.

Internal erosion is comprehensively dealt with in ICOLD Bulletin 164 available from the ICOLD website (Volume 1 preprint dated 19 February 2015, Volume 2 preprint dated 6 May 2016). Internal erosion causes about half of all dam failures, and one-third of those failures are in existing dams and embankments. The Bulletin makes an important advance in the engineering of water-retaining embankments by defining for the first time the mechanics of internal erosion. Internal erosion occurs when the hydraulic forces imposed by water seeping through pore spaces or flowing through openings in embankments exceed the ability of the soils in the fill and foundation to resist them. Hydraulic loads are highest when water level is high, usually during floods.

There are four mechanisms of internal erosion: concentrated leak erosion when water flowing through cracks and openings erodes soil particles from the walls; contact erosion which occurs at the interface between coarse and fine layers when the velocity in the coarse soil imposes sufficiently high hydraulic forces to erode particles from the fine layer; by suffusion when seepage drives fine particles through the matrix of coarse soils in gap-graded soils; and backward erosion which occurs in fine sand in foundations below embankments able to 'hold a roof' when backward erosion pipes initiate at the downstream toe and progress upstream and break through into the waterway or reservoir.

Internal erosion may develop to failure in four phases: initiation, continuation, progression and breach. Continuation may be prevented by filters, including filtering that may be provided in zoned dams by fill zones downstream of the eroding zone. If continuation is not prevented progress to failure can be expected to be rapid. There will be no time to take any evasive action other than to issue warnings to people downstream. Unzoned dams (often called 'homogeneous' dams) are particularly vulnerable to internal erosion because there are no downstream zones that may arrest erosion if it has initiated.

It is not possible to detect by monitoring the onset of internal erosion that will lead to failure. For this reason, it is recommended that investigations to provide parameters for analysis to estimate the hydraulic load (usually expressed as water level) that will lead to failure are completed at all dams, other than those where failure would be of no consequence.

If a risk approach is required the annual probability of occurrence of the water level causing failure can be estimated from the flood hydrology.

15:10 – 15:30

Beguin, R. et al.

Influence of the curing time of a newly placed silty soil on the resistance against concentrated leak erosion

The Hole Erosion Test (HET) is a laboratory test that characterizes the internal erosion resistance, particularly against concentrated leak erosion of an intact or remoulded soil sample. The test makes it possible to obtain the erosion index and the critical shear stress of the sample. These parameters characterize respectively the initiation threshold of erosion and its kinetics. It has already been shown that these characteristics do not depend solely on the composition of the soil (granulometry, mineralogy) but also on its state and structure (density, water content, suction, saturation,...) [1], [2].

The influence of the curing time on erodibility has not, to our knowledge, been analyzed. On the initiative of SYMADREM, a real site study was therefore carried out to determine whether the erosion resistance of a soil measured in laboratory on samples remoulded under the conditions of implementation on the site is relevant for characterizing its resistance in the medium term (1 year), or if it evolves under the effect of the different processes acting on this horizon (consolidation, cementation ...).

As part of the engineering phase of a major operation of the Rhône Plan: the creation of a dike between Tarascon and Arles, involving the implementation of 1 million m^3 of silts, SYMADREM benefited from a repair of a sea dike following a storm to test at real scale the resistance to medium-term erosion of materials intended for the creation of the dike. The silty soil embankment (type A1 in the GTR classification) implemented by compaction for repair, was specifically monitored: at different times after the soil was placed (3, 7, 28, 94 and 360 days). Intact samples were taken at 2 m depth by core sampling over an area approximately 5 m long and 1.5 m wide. A section of each of these cores, located between 1.0 and 1.4 m deep, was cut and subjected to a HET. The remaining of the soil was used for identification tests. The identifications showed a very good homogeneity of the various samples, all classified A1 in the GTR classification, with similar particle sizes (percent passing 80 µm between 79 and 84%, percent passing 2 µm between 17 and 25%), a similar plasticity (plasticity index between 7 and 12, VBS between 1.37 and 1.52) and a similar Optimum Proctor Normal (water content between 18 and 21%, dry density between 1.63 and 1.67). The density and water content of the samples remained comparable, with a water content of +3.0 to +5.3% relative to the Optimum and a density corresponding to between 88 and 97% of the density of the Optimum Proctor. No significant changes in the characteristics of the backfill over time have therefore been demonstrated by the identification tests.

The results of the whole erosion test show a slight increase in resistance to erosion compared to the uncertainties of the test from D+3 to D+94. However, it becomes significant at D+360 with a shear stress multiplied by 7 (50 and 55 Pa at respectively D+3 and D+7, compared to 350 Pa at D+360) and an erosion index increased by about one unit (2.84 and 2.50 at D+3 and D+7, up to 3.42 at D+360). The soil has thus passed from a "very rapid" erosion rate to D+28 according to the Fell classification to a "moderately rapid" erosion rate (Figure 1). This result merits to be confirmed over a longer period. However, it opens up interesting perspectives on the understanding of the parameters controlling erosion resistance.

15:30 – 15:50

Landstorfer, F. et al.

Durlassboden Dam, occurrences in the past, theoretical and practical assessments of the internal erosion and suffusion risk, ongoing activities.

Durlassboden dam is an embankment dam with an earth core and was built in the 1960s. The dam has a maximum height of about 80 m and is founded on a non-homogenous geology that consists of erodible alluvial deposits with a maximum depth of 130 m. Due to economical and technical reasons the grout curtain was not carried out to the full depth of the alluvium, but only down to a silt layer at a depth of about 50 m below foundation. Therefore, water can pass through the “window” below the silt layer.

This planned underseepage results in artesian pressure in the dam foreland. Pore water pressure is reduced with relief wells and surveyed with a large number of piezometers. However evidence of internal erosion, like boiling sands, could be observed over the decades. An occurrence in 2015 led to an extensive internal erosion assessment that included laboratory tests, review of all readings and site investigation.

The results of the assessment will be presented.

15:50 – 16:10

Radzicki K., Opalinski P., Przecherski P., Bonelli S

Detection of short and long-term internal erosion using hybrid application of thermo-hydraulic finite element modelling and statistical analysis of piezometric data

Precise identification and determination of range and dynamic of internal erosion, and malfunctioning of seepage barriers and development of seepage have major impact on reliable technical state assessment of earth dam.

The Kozłowa Góra embankment dam has manifested symptoms of all above-mentioned problems. The most serious of them included the settlement of a part of downstream slope more than 0.5 m and instability of its slope during the 2010 flood. Because of this, an innovative quasi 3D thermal monitoring system was installed on the dam in order to verify the hypothesis of the existence of erosion within the body or foundation of a dam. Numerical modelling by means of a thermal-hydraulic model, validated on real data, led to precise estimation of Darcy coefficient in dam foundation, rule out of backward erosion or piping, and to identify seepage flow path underneath wooden sheet pile. In addition to that, an analysis of long-term data of piezometric levels was carried out with the statistical HST model. This analysis supports the assumptions that a slow suffusion process is present in the foundation of the dam.

The information about Kozłowa Góra dam and its monitoring system and about the results of above-mentioned analysis of data will be presented.

16:10 – 16:30

Nombre, A.

Internal erosion on small embankment dams and their foundations - the case of Gasandoure and Bampela Dams in Burkina Faso

Internal erosion in Embankment dams and their foundations is the second cause of earth dam incident and accident and this happen at the first filling for many of the dams failed. The paper will present case stories where we have erosion at the contact with concrete structure at the same time an erosion in the foundations of the spillway section of the dam and erosion in the embankment fill. The link between material selection, compaction and design will be presented.

Last update: 22-05-2017