THE WORKING GROUP ON LEVEES AND FLOOD DEFENCES UNDER THE EUROPEAN CLUB OF ICOLD

ISSUE 06 – September 2020

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LEVEES Working Group Newsletter

Note from the Chairman

Rémy Tourment

As all of you are aware, since the last issue of our newsletter, the Covid19 pandemic has had a major impact on our everyday lives, including our work. This is even more true when it comes to international activity, given the measures affecting travel and gatherings of large numbers of people. First, let me say that I do hope that all of you are healthy and safe, as well as your families, loved ones and colleagues. We have all had to adapt how we live and work, relying more on electronic communication and less on physical interaction.

Unfortunately, the annual meeting of ICOLD in New Delhi had to be postponed twice already, the latest dates being November 28th - December 3rd 2020. I refer you to the letter of the President of ICOLD, Mr Michael Rogers, which is included at the end of this issue. Let's all wish for success for the meeting, and thanks to our Indian colleagues who have worked hard for its preparation.

FLOODrisk 2020

The FLOODrisk2020 conference, which would have been a very important event and moment for the international, and particularly European, community of levees and more broadly, flood risk management, has also been postponed. The new dates are 21st June - 25th June 2021 and will still be in Budapest. Although difficult for the organization's committee, this postponement gives everyone a new opportunity to submit papers (see https://floodrisk2020.net/ and https://floodrisk2020.net/covid-19-announcement/faqs/, submission for abstracts closes on 14th September). Do not hesitate to take advantage of this new slot for submission.

Anyway, business, like the show, must go on and even in these difficult times it is important to maintain contact and keep our international community alive. This has been the case within the ICOLD Technical Committee, where we have been actively working on our deliverables and have planned a series of teleconferences on 28th, 29th and 30th September. I take this opportunity to thank all members of the TC and of our WG who have actively contributed, by email and with many teleconferences since the beginning of this year. Our plan is to have a draft of our two reports ready for the dates of these teleconferences, for review by all TC members. WG members interested in participating in this review should contact their national TC member. Both reports should be ready to be presented to ICOLD in Marseille during the 2021 congress.

As usual, in this issue of our newsletter you will find interesting technical and scientific information, as well as news about projects. But don't forget that we are always expecting information that YOU can send to share in the newsletter, but also on our web site!

The International Levee Performance Database (ILPD) and the SAFElevee Project

By Alex Curran, TU Delft

The Dutch SafeLevee project, led by TU Delft, is coming to a close with an online conference on September 25th. Noteworthy research conducted under this project has focussed on the use of satellite technology for long- and short-term monitoring of levee safety, and the analysis of historical levee failures and breach characteristics (link to thesis Understanding Levee Failures from Historical and Satellite Observations (Ece Özer) and systematic hindcasting of historical levee failures due to instability (link to the journal article; Forensic Analysis of Levee Failures: The Breitenhagen Case (Job Kool)).

As part of the project, an efficiently structured, global, open access database, called the International Levee Performance Database (ILPD) (see articles in Issues 01 and 03 of this newsletter) has been developed, which now contains information on over 1500 cases of experimental and historical failures of levee and dam failures. Data can be freely downloaded from https://leveefailures.tudelft.nl/ and filtered using a variety of fields related to levee properties, geographic location, and failure modes.

Information from the database can be used by researchers, consultants, governments and levee managers to improve models of failure mechanisms and gain insight in levee performance in extreme situations in practice – also for purposes of flood fighting and crisis management.

The development and standardisation of the database is explained in a recent journal article, which also includes a macro-scale analysis of levee failures. This exemplary application of the database provides information on (amongst others) the geography, development, mechanisms (see example graph in Figure 1) and event density of failures.

The research of SafeLevee and the ILPD will be discussed an online final conference on the 25th of September, at 13.30pm CEST. If you would like to register for the event, please send an email to leveefailures@tudelft.nl.

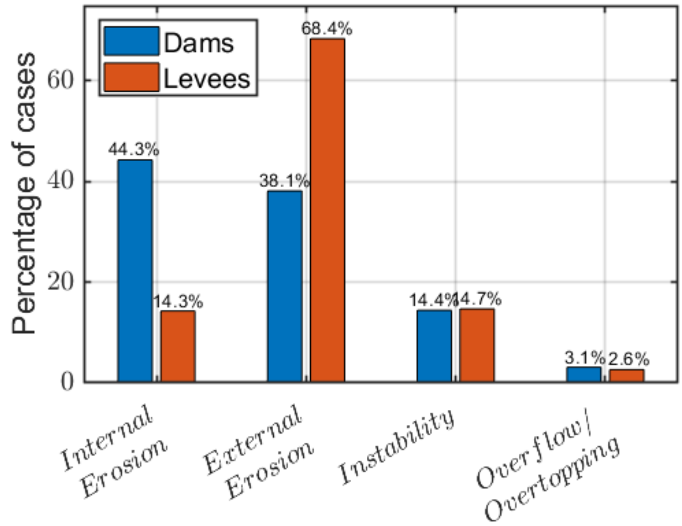

Figure 1 - Percentage of cases in ILPD per failure mechanism

Levee Refurbishment on Borkum Island, Germany

Report by Jennifer Robinson, Tractebel Hydroprojekt, Hamburg

In October 2019, the town of Borkum acquired a flood protection system in the area of the former naval base managed by the Federal Agency for Real Estate affairs. The entire flood protection system consists of a 1100 m long flood protection wall and a 1400 m long coastal levee with five dike openings. A prerequisite for the acquisition was a plan revision and renovation of the flood protection system. Tractebel Hydroprojekt GmbH was tasked with planning the renovation at the end of 2016.

Figure 1 - Installation of the Verkalit® system

The construction work for the dike refurbishment began in May 2019. The scope includes the renovation of approximately 40,000 m² of revetment on the dike, the repair of the five sluices in the dike and the removal and extension of the flood protection walls at the dike ends. The special challenge here lay in working within the period between April 15th and October 15th, 2019. when no storm surges were expected.

The Verkalit® system was chosen for fastening the new revetment. The revetment bricks have a full-surface compound effect due to a circumferential "ball-bearing mounted" tongue and groove system. The revetment can absorb settlement or elevation in the dike's core through this system and voids are detected faster than with rigid construction methods. Due to the heavy weight of 30-50 kg per brick and the large area to be completed in such a short period of time, machine installation was mandatory. Figures 1, 2 and 3 show installation of the Verkalit® system.

Figure 2 - Installation of the Verkalit® system

Figure 3 - Installation of the Verkalit® system

At the beginning of the construction period, the contractor suggested grinding the asphalt surface, which had to be demolished and disposed of, and using it as a base material for the top layer. The biggest advantage of this procedure is the time saved, since, among other things, the exposed levee does not have to be additionally secured against erosion. Furthermore, the demolished materials do not have to be transported to the mainland for disposal. The purchase of material to fill in the missing parts of the dike support body is also omitted.

The work on the sluices and the flood protection walls was largely trouble-free. The main construction work was completed by the end of November 2019. With all side works the Levee Refurbishment was finished in April 2020. The start of the third construction phase, the replacement of the five dike slits, was in April 2020 and will be done in October 2020.

Failure Paths for Levees: An Inventory by ISSMGE TC 201

Article by E. Rosenbrand, M. Van, R. Tourment, P. Smith & C. Zwanenburg

The objective of the design, assessment and maintenance of levees and embankments is to avoid a situation where breach and consequential flooding occurs. Flooding can occur when water passes over, through or beneath a flood retention structure. Typically, the most dangerous flooding is caused by a catastrophic breach as this can lead to an uncontrolled release of water through the flood defence, under conditions of a high hydraulic load. In such cases, the breach may have been caused by a sequence of events, possibly happening over an extended period of time, that may have caused deterioration, damage and eventually failure of the structure. Such a sequence of events is called a failure path or also a failure scenario.

ISSMGE TC 201[1] is working on a report on the use of failure paths and failure trees (also called event trees, fault trees and bowtie trees) for levees around the world. This report will include a compilation of examples of failure paths, which have been determined following damage or breach, as well as a compilation of examples of failure paths or trees that are the result of, or used for, design, assessment or risk analysis.

Failure paths can be the result of a forensic assessment to determine, as far as possible, how the damage or failure occurred. The reverse is done to design levees; the designer should anticipate all of the possible failure mechanisms (or combinations of mechanisms) and verify that failure will not occur in any of these situations. Alternatively, as part of the assessment of an existing levee, it may be necessary to carry out a probabilistic assessment of the risk of failure. In this case, it might be necessary to develop a failure tree which combines all potential failure mechanisms into one analysis. In this way, the assessment of the probability of occurrence of each event in the failure path can be used to assess the probability of failure of the levee as a whole.

[1] https://www.issmge.org/committees/technical-committees/applications/dykes-and-levees-

For embankment levees assessment and design, it is usual to consider the range of potential failure mechanisms which will control performance during design scenarios (such as external erosion, internal erosion and sliding collapse). The failure paths including such mechanisms are commonly based on theory and experience. An example is the failure path for the internal erosion mechanism of backward erosion piping, which is shown below in Figure 1. Note that this failure path proceeds from rising water levels until inundation in one continual sequence. In many cases, however, this process may take some or many cycles of high-water level for the internal erosion to progress to a point where instability occurs. In such a case, the ongoing process of internal erosion will present itself as deterioration.

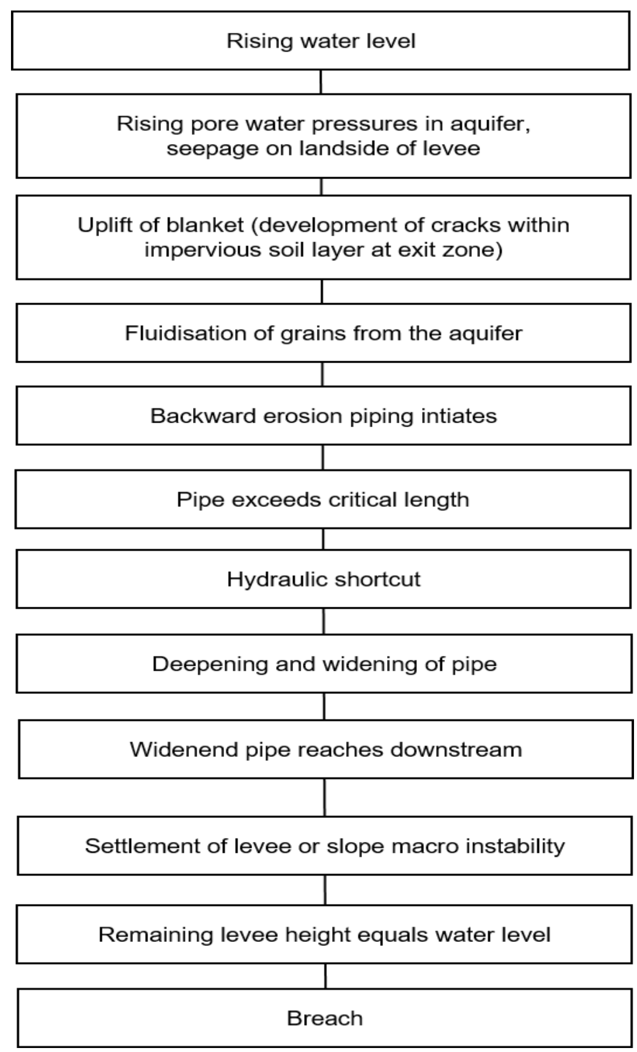

Figure 1: Example of a theoretical failure path for the internal erosion mechanism of backward erosion piping.

Failure paths derived on the basis of theory can differ in the level of detail of the individual stages that are included. These differences often reflect differences in the level of knowledge that is available relating to an individual site. The report, therefore, will include an inventory of potential failure paths as an aid to identifying potential chains of mechanisms and helping to identify gaps in current knowledge.

In reality, a number of failure paths may occur simultaneously and the combined effect might be that breach occurs before any individual failure mechanism had fully developed. For example, overtopping flow during a flood might occur at the same time as seepage through a levee. The combination of the two may accelerate the rate of overtopping erosion and hasten the breaching process. In this case, it can be helpful to combine these individual failure paths into a more complex failure tree. This procedure helps to create a realistic picture of how levees can behave. If this process is carried out well so that the correct combinations of mechanisms are identified, it can also facilitate the process of performing a quantitative risk assessment for the levee as a whole by combining risk assessments for the individual mechanisms. Therefore, trees which also show interactions between mechanisms, form an important part of the report.

A concept outline of the report is in preparation by a working group. After the summer, this outline document will be shared with the full TC201 group, along with a brief questionnaire to gather the experiences of individual TC201 members and to request input on different components of the report. Interested members of the EUCOLD LFD WG and ICOLD LE TC are encouraged to participate to this effort. Please contact Rémy Tourment if you want to contribute. Based on the input from the TC, the inventories will be completed and the report will be presented at the 20th ISSMGE conference in Sydney 2021.

DIGUE2020 Project

Article by Alexis Pelud, INRAE, G2DR

Adaptation to climate change is a major challenge, the coastline of Région SUD Provence-Alpes Côte d'Azur, with more than 2,700 km of river and sea dikes and nearly 250 managers, will be particularly affected by the rise in sea level. Faced with this observation, the DIGUE2020 project (www.digue2020.fr) aims at the creation of a scientific research platform to provide better control of the risk of marine submersion.

The research platform will make it possible to study, in a marine environment, the implementation of an innovative dike design concept using lime-treated soil.

The objectives of the project are multiple:

- To reduce the risks of failure by breach caused by internal erosion and to allow a precise quantification of external actions on the structure (anthropic, hydraulic, natural…),
- Reduce dike construction and maintenance costs,
- Reduce transport nuisances by limiting the use of materials from distant deposits, and by using local soils,
- Visually integrate dikes and weirs into the environment without breaking ecological continuity,
- Enable the restoration of old dikes without deconstruction: using local resources and reducing waste production,
- Integrate a reflection on the management of coastal flooding and the role of dikes,
- Share this knowledge with managers and residents via a communication platform.

A Call for Contributions

- *Information about levees and flood defences projects and works*
- *News, media or press releases on current flood or storm events involving levees and flood defences.*
- *Current, ongoing or recently completed research projects.*
- *Documents related to levees or flood defences: handbooks, guidance, reports and regulations.*
- *Information on any event or conference relating to levees or flood defences*
- *Links to informative / educational websites and related organisations*
- *Pictures to be used in the web site banner, randomly chosen every time a page loads (resolution has to be 1024x300)*

- *Contact the WG web site team: lfd-eurcold@irstea.fr*

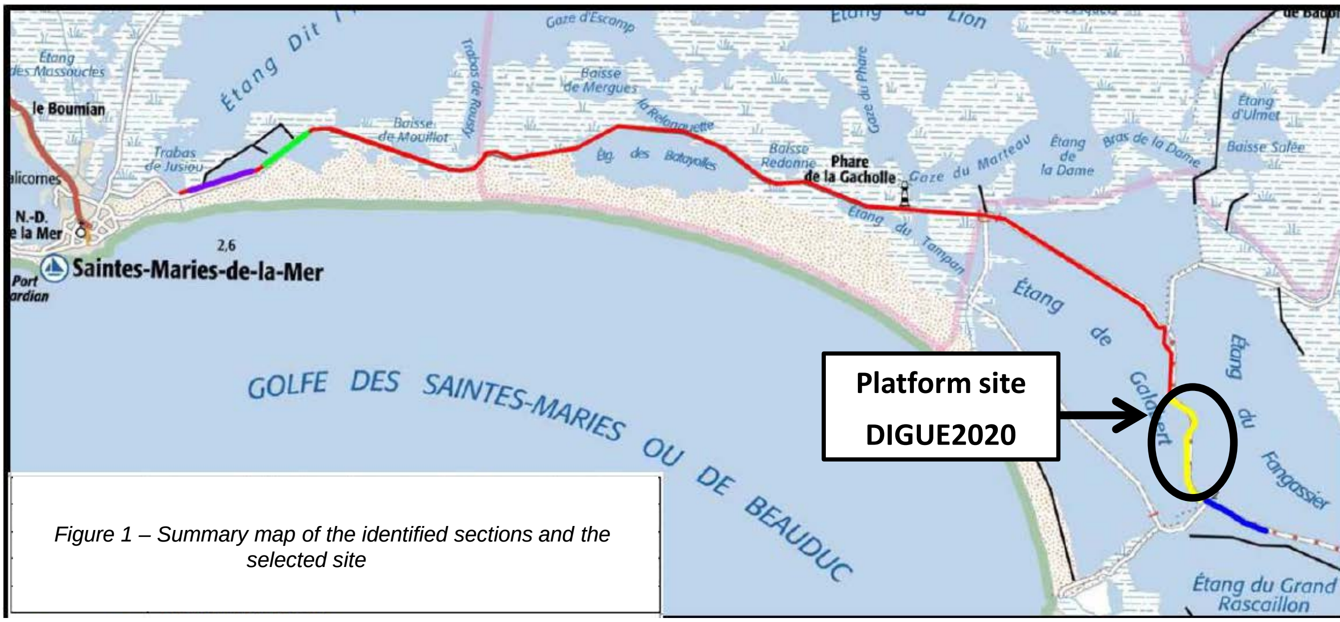

Figure 1 – Summary map of the identified sections and the selected site

Several sections were identified in the pre-project phase; the choice retained is to implement the platform on an existing dike separating two ponds, the "Galabert" and the "Fangassier" in the Camargue regional nature reserve (Figure 1). Work on the Digue2020 platform, initially planned for 2019, is nearing completion after three years of design and construction.

The project faced several difficulties, particularly during this construction phase. Heavy rainfall brought the construction site to a halt for the first time and in particular damaged the access roads and disrupted the quality of the materials by affecting their characteristics especially the water content. Then, the Covid-19 health crisis also led to a postponement of the completion dates with a new shutdown of the construction site. The recovery, 2 months later, was able to take place with numerous constraints and the implementation of safety and protection measures. These delays were accentuated by the environmental constraints linked to the site of the regional nature park; in particular the disturbances that the worksite can cause during the breeding cycle of pink flamingos.

The platform is built in two zones, a research zone to the west and a circulating dike zone to the east managed by SYMADREM (Figures 2 and 3). After several reworkings of the initial construction plans, the dike on the west side was broken down into several research plots with different compaction and lime rate characteristics. Numerous sensors and equipment have been installed in the different plots to enable long-term monitoring. The instrumentation consists of several point probes (temperature, humidity, electrical resistivity, suction, pore pressure, Ph, salinity), an internal flow measuring system, a seismic and geoelectric measuring system, and a resistivity measuring system.

Soon the Digue2020 research platform will enter a new phase of experimentation through its exploitation. It will constitute a field laboratory for research in the medium and long term, i.e. 20 years for scientific and technical activities.

The knowledge developed and shared via the research platform will lead to the development of reinforcement projects or the design of new dikes with a sustainable design, which could be proposed as part of the Rapid Submersion Plans, several of which are planned in the Région SUD Provence-Alpes Côte d’Azur in the coming years.

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Figure 2 - Photo of the current progress of work (July 2020) of the DIGUE2020 platform

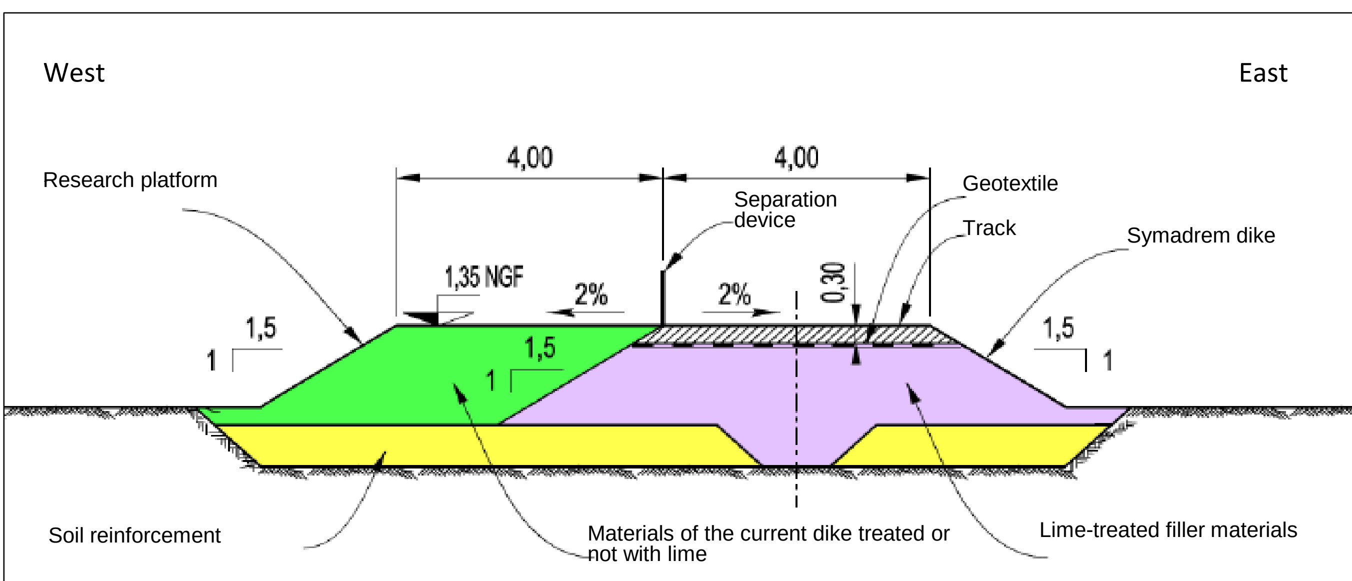

Figure 3 - Typical section: non-vegetated platform slope

POLDER2C's Update

Report by Dr Matthew Badger, Patrik Peeters and Andre Koelewijn

The Interreg4a-funded POLDER2C's project's first testing season will commence in October 2020. Over the next few months, full-scale destructive tests on a decommissioned flood defence embankment on the Dutch-Belgian border will help better understand the resilience of embankments to extreme loading conditions.

Project Partners like Mobility and Public Works (MOW, BE), Environment Agency (EA, UK) and Rijkswaterstaat (RWS, NL) maintain tens of thousands of kilometers of fluvial, tidal, and coastal flood defence embankments, and so the opportunity to participate in the POLDER2C's project was too good to miss.

One set of tests that will be particularly useful in daily levee management are those to better understand the role of grass length in protecting embankments from damage. With increasing focus on developing management strategies that maximise biodiversity benefits and reduce carbon emissions, these tests will help to identify opportunities and trade-offs.

The EA will contribute to the development of the POLDER2C's asset inspection app, which will initially allow photographs and descriptions of damage caused during the experiments to be recorded. Our ambition is to use this app to improve the way people in England can let the EA know about damaged assets in real-time from the field. This will help us to respond more quickly to undertake repairs which protect people and properties from flooding.

Looking into next year, RWS will focus on developing and testing options to enable practitioners to respond more effectively during and after high-water events. The work to trial new responses to breached embankments will be valuable for all levee managers in coming years.

Over this winter, however, everybody is really looking forward to seeing the **wave overtopping** as well as **steady overflow** experiments, where MOW is taking the lead. The yellow wave overtopping simulator that will be used in the POLDER2C's project is pictured below (Figure 1). It is owned by RWS. It allows the wave volumes and frequency of the water to be adjusted to replicate local severe storm conditions. It has a width of 4 metres and can generate flow rates up to 150 litres per second per metre. These tests will be conducted in November this year, then from March to April 2021.

Figure 1: Wave overtopping tests at Nijmegen (top) and Millingen (bottom)

Wave overtopping tests primarily simulate conditions experienced by coastal or estuarine embankments, characterised by dry periods between waves. Overtopping (aka 'overflow') of inland embankments is better represented by **steady overflow** experiments (Figure 2).

In steady overflow experiments, a continuous discharge of water is generated across the crest of the embankment. The tests are typically executed for many hours with periodic short breaks to assess damage. Standard equipment is not available for this type of test, and MOW is working on developing a suitable configuration for the proposed parameters.

Figure 2: Steady overflow simulation by Flanders Hydraulics Research (MOW)

Additionally, there will be experiments to simulate **wave impacts** conditions (Figure 3).

Figure 3 : A wave impact generator in action

The project will investigate the role that such factors as vegetation maintenance strategies, animals burrows, transition points, and droughts have on embankment resilience using these various methods of simulating extreme loading conditions.

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Global Slope Stability of Levees with Construction Machinery Loading

Article by Sam Leonard, Environment Agency

The Environment Agency (EA) are working to produce a guide to help construction operatives assess the risk of slope failure of levees while they experience loading from construction plant and machinery (Figure 1).

The EA has many kilometres of flood embankments and these are constantly being used as working platforms, or access routes to other sites. The additional load of construction machinery on the crest of an embankment structure increases the risk of a global slope failure.

Additional plant loading increases the disturbing moments which act about a slip circle, which then increases the possibility of shear failure along this slip plane (Figure 2).

If any of our friends in the European ICOLD have undertaken work to assess the stability of their levees with the additional load of construction plant please could they send any information to Sam Leonard at Sam.leonard@environment-agency.gov.uk.

Figure 1 – Fallen machinery due to slope failure

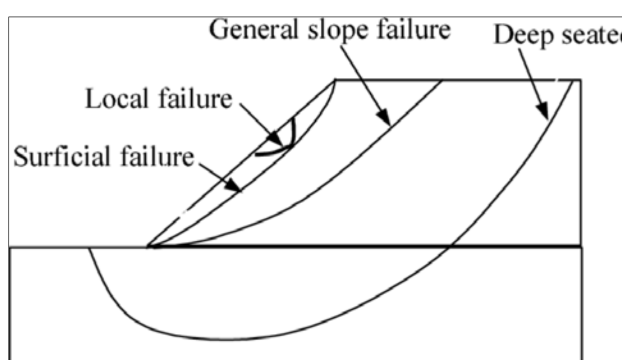

Figure 2 – Potential failures due to machinery slope loading

Handbook on Flood Emergency Response for Levees – An Invitation

Flood risk can be managed using a mix of strategies, such as protection (flood defences), spatial planning and flood emergency response. In many countries, both dams and levees help to protect against floods. In practice however, absolute protection against flooding is rarely feasible. Therefore, additional reliance on emergency response is often essential.

International relationships on flood emergency response have developed recently. This proved to provide benefits to all organizations involved. In line with this development, Dutch parties are keen to promote a bottom-up initiative to write an International Handbook on Emergency Response Measures to Flood Risk and hope that other parties will join this initiative. We aim for a Handbook that is well-rooted into practice, both by drawing on lessons from flood fighting during flood events as well as lessons from flood exercises, for which a special Living Lab is now being set up.

We want to invite the existing communities on levees and dams (and the EURCOLD Levee Working Group and the ICOLD Levee Committee as linking pin between those communities) to share inputs and ideas about scope, structure and contents of the Handbook, all the more so since dams and levees often act together to reduce flood risk. We intend to present and discuss our first ideas on the scope, structure and contents of the Handbook by June 2021 at the postponed Floodrisk2020-symposium, and also at the ICOLD2021 Congress. The position of the Handbook is still open for discussion (as are its scope and contents), but one option might be to strive for the Handbook becoming an appendix to the International Levee Handbook.

For further information, please contact Ir. Bart Vonk, Rijkswaterstaat WVL, bart.vonk@rws.nl

Further reading:

Draft document, outlining some initial ideas regarding the International Handbook for Emergency Response to Flood Risk.
https://www.researchgate.net/publication/343714352_International_Handbook_for_Emergency_Response_to_Flood_Risk_A_call_for_collaboration_INFORMAL_DRAFT

Living Lab Hedwige Prosper Polder:
https://www.interreg2seas.eu/en/Polder2C%27s
see also the Polder 2C's Update on pages 8-9 of this Newsletter.

Dutch Wiki on Emergency Response (with a few elements in English on which you can click)
https://v-web002.deltares.nl/sterktenoodmaatregelen/index.php/Hoofdpagina

Upcoming Events

2020

- 28th November – 3rd December: New Delhi, India.
  ICOLD 2020 Annual Meeting / Symposium on Sustainable Development of Dams and River Basins.
  https://www.icold2020.org/

2020-2021

- 13th October 2020 – 14th April 2021: on-line.
  The Flood and Coast 2020 event has, this year, changed from a face to face event into a series of four digital sessions tackling some of the major challenges of our time.
  https://www.floodandcoast.com/

2021

- 4th – 11th June: Marseille, France.
  ICOLD-CIGB 27th Congress and 89th Annual Meeting.
  https://cigb-icold2021.fr/en/

- 21st – 25th June: Budapest, Hungary.
  Floodrisk2020: 4th European Conference on Flood Risk Management- Science and practice for an uncertain future.
  https://floodrisk2020.net/

- 29th June – 1st July: Telford, England.
  The Flood and Coast conference.
  https://www.floodandcoast.com/

Weblinks

German Committee on Large Dams:
https://www.talsperrenkomitee.de/de/das-dtk.html

Japan Flooding due to Typhoon Hagibis

Article links provided by Hiro Mori, Associate Professor, Yamaguchi University

Figure 1: Chikuma River breach (from https://www.hrr.mlit.go.jp/river/chikumagawateibouchousa/chikuma-02.pdf*)*

In October 2019 Japan was hit by typhoon Hagibis, their biggest in six decades. Heavy rain caused levels to rise in many rivers and led to more than 120 breaches.

The Chikuma River breached in a number of locations. One of the breaches is shown in Figure 1; the collapse was 70 m long and happened in the early hours of the morning, following a few hours of overflowing. The inundation area was in Nagano city and covered a 9.5 km square area, with depths up to 4.3 m. Temporary repairs were in place by 17th October. The original levee was completed in 1984 and work to increase its width was completed in 2007.

A technical committee has been set up for investigating the breaches, some of their discussion papers, in Japanese, can be found at https://www.hrr.mlit.go.jp/river/chikumagawateibouchousa/chikuma-02.pdf and https://www.hrr.mlit.go.jp/river/chikumagawateibouchousa/chikuma-03.pdf.

Finland Flooding

Article information provided by Eija Isomäki

Finland's spring flood, caused by snow melt, is considered a normal event each year. In 2020 they prepared for the most extreme flooding forecast in 50 years in Northern Finland (Lapland), with many river breaches expected. Record amounts of snow had fallen during the winter and were melting rapidly as temperatures quickly increased; rain was also forecast. Private and state preparations were made to temporarily better protect properties through extra barriers and pumping, a healthcare centre was evacuated and a hydroelectric power station lowered levels in its reservoir to allow for water storage.

Fortunately, the flooding was not as significant as first forecast; cold weather reduced the snow melt and there was no rain.

Special feature!

An Evaluation of Time Dependent Slope Sliding Failure of Levees within the Lower Rhine Region

Ronald Haselsteiner, Bjoernsen Consulting Engineers, Koblenz, Germany

INTRODUCTION

In German design practice usually the steady state seepage conditions are applied for stability analysis and the check of serviceability. According to the technical code for flood protection structures in Germany, DIN 19712, also the consideration of unsteady seepage conditions is allowed.

Among several sorts of failure modes the global slope sliding failure is one the most crucial which may result in a sudden total failure of the structure. This slope sliding failure is critically affected by the pore water pressure distribution along the sliding surface.

Within the Lower Rhine region levees are usually designed with both a surface clay sealing and a base sealing (see figure 1). The result is that for permanent design situations (BS-P) the levee body is relatively dry also in consideration of steady state seepage conditions. But, the full pore water pressure originating from the upstream water level conditions develops underneath the base sealing reaching to downstream almost undamped.

Depending on the specific zoning, the duration of a flood incident, the applied soil materials within the levees in respect to permeability, and the absolute impoundment height levees may face steady state seepage conditions to nearly no seepage. Hence, the factual safety level of levees are crucially depending on the actual seepage conditions which may be far away from the steady state conditions. Is this the case levees may show an overdesign and a considerable safety margin.

For levees within the Lower Rhine region the technical specifications regarding zoning and dam construction materials are so strict, that steady state seepage conditions are unlikely to occur in the dam body itself. But, high pore water pressures develop in the permeable underground layers so that heave and global slope failure are of concern and the levees does not show too much safety margin although the levee body is not subject to strong seepage.

During the planning stage of the presented case study the described topic were controversially discussed. The levee section was designed without a downstream berm although high pore water pressures occur underneath the base layer. Thus, an unsteady seepage analysis was performed in order to investigate whether the global slope failure would occur before the heave leads to a pore water pressure release in the underground. Basics for unsteady seepage modelling of levees are described, e. g., in Scheuermann (2005) or Haselsteiner (2007).

DESIGN SITUATIONS, CODES AND GUIDELINES

A levee according to DIN 19712 is an embankment along a river which is protecting against floods and which is only temporarily impounded by a flood. Assuming the occurrence of steady state conditions postulates long-lasting flood events. As far as sealing elements or low permeable soils are applied the seepage development may theoretically take years before reaching steady state conditions. For the concerned case study levee a surface sealing with a maximum permeability of $k \leq 10^{-8}$ m/s is applied. The dam body/filling shall show a permeability which is approximately maximum 100 times more permeable, so that $k \leq 10^{-6}$ m/s are stipulated. The drain again shall be maximum 100 times more permeable that the filling which results in $k \leq 10^{-4}$ m/s (STUA, 2005).

In Figure 1 the cross section of the standard levee is shown. The levee section is characterized by flat slopes, a crest road and a berm with the defense road. The levee section shows a sealing as well as a drain and therefore is a 3-zone-levee as propagated also by the code DIN 19712/2013 and by the technical guideline DWA-M 507 Part 1. The levee body is underlain by a base sealing which may be of natural origin . As shown in figure 1 a freeboard of 1.0 m is applied, the crest and berm are 5.0 m wide and the slopes show inclinations of V:H = 1:3.5.

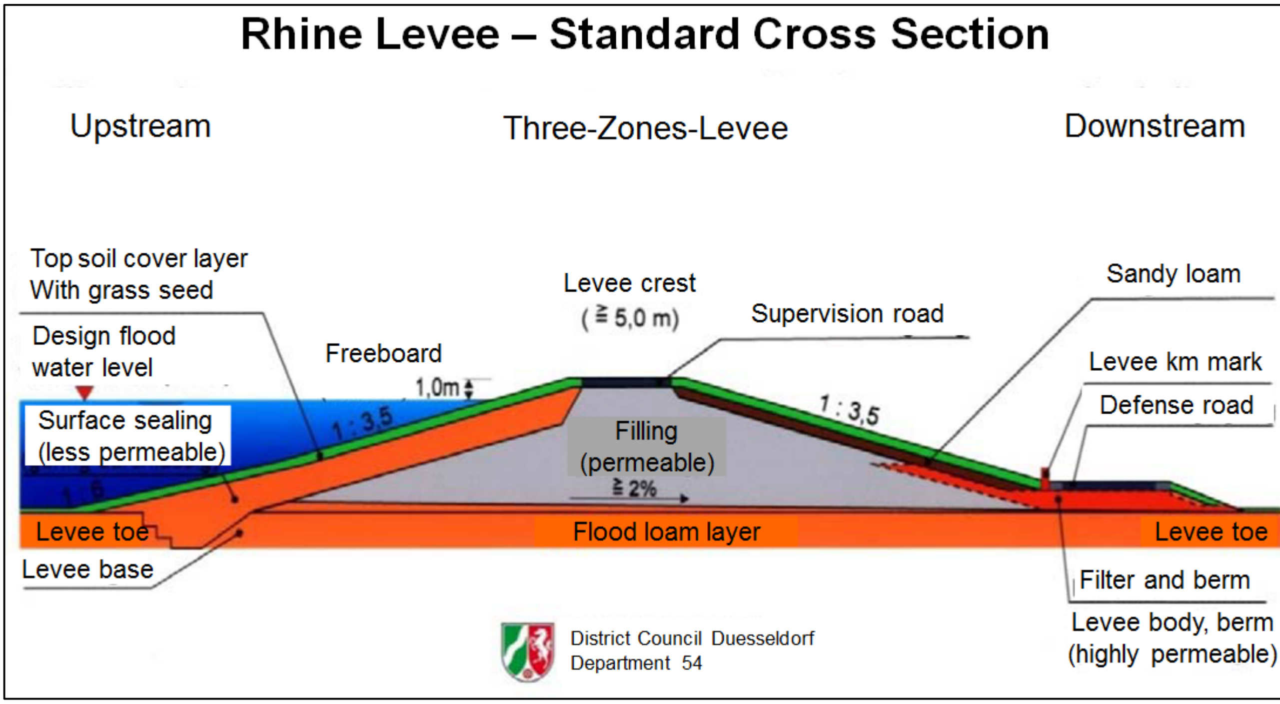

Figure 1: Levee standard cross section propagated within the district of Duesseldorf (Source: District Council Duesseldorf, Department 54) (taken and translated from Börger, 2016)

The national design code for flood protection structures such as levees, DIN 19712, is already considering European harmonization efforts on the engineering sector and, therefore, incorporated permanent (P), temporary (T) and accidental (A) design situations and the partial safety factor design philosophy. The ordinary flood level belongs to the permanent design situation whereas crest water level belongs to the accidental design situations.

Usually, steady state seepage conditions are considered for the subsequent analysis of the geostatic or geo-hydraulic stability of a levee. An analytical evaluation of seepage through embankment dams with small heights, as performed in Haselsteiner (2007), shows that the factual seepage conditions are depending on the impoundment period and the permeability of the concerned embankment and foundation materials and soils. As soon as sealings and/or low permeable materials or soils are showing a permeabilities which are less than, let's say, $k_s = 10^{-6}$ to 10^{-7} m/s steady state seepage conditions are very unlikely to occur during a flood event in middle Europe. The duration of a flood and the impoundment duration, respectively, are usually too short for causing a steady state seepage situation in low permeable embankments since durations of floods show days to maximum few weeks in combination with high flood water levels.

SOIL PARAMETERS, FLOOD HYDROGRAPHS AND MODELING

For the modeling of unsteady seepage conditions additional information and data are required in comparison to steady state seepage modeling. The seepage flow through unsaturated soils is important as well as the setting of the initial saturation conditions for all soils in consideration of the environmental effects such as precipitation and drying. These drying and wetting effects within the unsaturated zone can be usually modeled by simple Van-Genuchten soil equation as explained in Haselsteiner (2007, 2007a, 2008) for various soils and selected sealing types (see table 1).

Table 1: Geo-hydraulic soil parameters for selected, typical levee soils (taken from Haselsteiner, 2007)

			Drain gravel	Filling gravel	Subsoil gravels	Sand	Surface sealing	Flood loam
			Gravel, narrow graded	Gravels, sandy, silty		Sand, gravelly, silty	Silt, sandy, clayey	
DIN 4020			G, st	G, s, u		S, g, u	U, s, t	
DIN 18196			GE	GI oder GW		SE oder SU	UM	
Porosity	n	[-]	0.20 (0.15 - 0.32)	0.25 (0.15 - 0.32)	0.30 (0.25 - 0.35)	0.35 (0.30 - 0.38)	0.35 (0.28 - 0.37)	0.45 (0.39 - 0.56)
Natural moisture content / field capacity	$\theta_{r,FK}$	[-]	0.01 (< 0.03)	0.05 (0.03 - 0.06)	0.08 (0.05 - 0.15)	0.175 (0.15 - 0.28)	0.25 (0.25 - 0.40)	0.30 (0.25 - 0.40)
Residual mooisture content / Permanent wilting point	θ_r	[-]	0.00	0.00	0.00	0.05 (0.03 - 0.16)	0.05 (0.03 - 0.06)	0.05 (0.03 - 0.06)
Air pore content (0,1 - 0,5 $\theta_{r,FK}$)	θ_a	[-]	0.005	0.025	0.040	0.035	0.025	0.040
Saturated moisture content	θ_s	[-]	0.195	0.225	0.26	0.315	0.325	0.30
Saturated conductivity	k_s	[m/s]	$2 \cdot 10^{-2}$ ($1 \cdot 10^{-0}$ - $1 \cdot 10^{-3}$)	$5 \cdot 10^{-4}$ ($1 \cdot 10^{-2}$ - $5 \cdot 10^{-4}$)	10^{-3} ($1 \cdot 10^{-2}$ - $5 \cdot 10^{-4}$)	$2 \cdot 10^{-5}$ ($1 \cdot 10^{-3}$ - $5 \cdot 10^{-7}$)	10^{-7} (10^{-7} - 10^{-8})	10^{-6} (10^{-5} - 10^{-6})
Anisotropy factor	k_h/k_v	[-]	1 (2 - 30)	2 (2 - 30)	5 (2 - 30)	2 (2 - 30)	2 (2 - 30)	10 (2 - 30)
Capillary height	h_k	[m]	0.03 (0.03 - 0.05)	0.05 (< 0.20)	0.10 (< 0.20)	0.30 (0.20 - 0.40)	4.00 (1.00 - 5.00)	2.00 (1.00 - 5.00)
van Genuchten Parameter – Wetting	α_w	[1/cm]	0.200 (0.005 - 0.035)	0.050 (0.005 - 0.035)	0.070 (0.005 - 0.035)	0.060 (0.005 - 0.035)	0.050 (0.005 - 0.035)	0.060 (0.005 - 0.035)
van Genuchten Parameter – Wetting	n_w	[-]	4.0 (1.5 - 10)	5.0 (1.5 - 10)	5.0 (1.5 - 10)	2.5 (1.5 - 10)	2.0 (1.5 - 10)	2.0 (1.5 - 10)
van Genuchten Parameter – Drying	α_d	[1/cm]	0.150	0.040	0.060	0.030	0.010	0.020
van Genuchten Parameter – Drying	n_d	[-]	4.0	2.5	2.5	2.5	2.0	2.0
Mualem Parameter	L	[-]	0.75 (0.26 - 1.03)	0.80 (0.26 - 1.03)	0.80 (0.26 - 1.03)	0.60 (0.26 - 1.03)	0.50 (0.26 - 1.03)	0.50 (0.26 - 1.03)

The corresponding graphs for the saturation – suction and saturation – relative permeability relations are included in Haselsteiner (2007) or other publications of the authors such as Haselsteiner (2007a, 2008, 2011). The author holds the opinion that for the ordinary task of the determination of seepage conditions within embankment structures with the purpose of evaluating the stability the exact determination of the unsaturated soil characteristic as well as the definition of initial saturation conditions are not critical. The most important step is the determination and selection of an adequate permeability value concerning soils and materials in order to establish a realistic model.

Flood hydrographs can be derived from measured floods, which are adjusted in consideration of design requirements regarding absolute water levels and durations, or from flow modeling. For the presented case study the Rhine flood discharge hydrograph was derived from a real recorded flood in 1995. The data was transferred to a water level hydrograph by applying the discharge – water level characteristic from a nearby flow gauge (Ruhrort close to Duisburg city) (Figure 2).

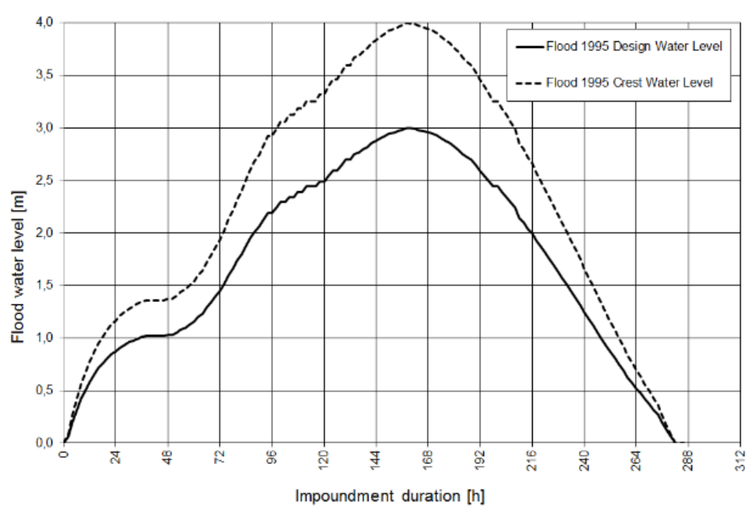

Figure 2: Considered flood hydrograph(s) for the case study 2 (left) derived from a real flood event

For the unsteady seepage modeling the initial conditions need to be defined. This is usually quite a scientific work since only limited data concerning the actual saturation condition of the levee are usually available. Usually, the author defines the unsaturated soil characteristics in consideration of the values presented in Table 1 and applies a “wet” moisture content value or steady seepage conditions for the initial conditions. After this setting a dry period of 100 to 180 days is modelled only considering the mean groundwater level so that the soils have the possibility to drain and dry until they reach their natural water content which may be close to the natural field capacity. For special cases and problems also rain events can be considered before and/or while a flooding event in order to model a pre-saturation.

The size of a levee model needs to be adapted in consideration of the local conditions. Usually the extension of the model to 10 times of the height of the levee towards up- and downstream direction (x-axis) and minimum two times of the height to the levees (y-axis) to consider foreland, hinterland and underground conditions is sufficient.

The meshing should be done in consideration of the required accuracy of the resulting values and the computing time. For unsteady seepage modeling the computing time is increasing by multiple in comparison to steady state conditions. A global mesh size of 0.5 to 1.0 m should not be exceeded for small embankment structures with a height of less than 5 to 10 m. For preliminary investigations coarser meshes should be applied in order to reduce computing time. Due to the coupled analysis a mesh size of 2.0 m on average was selected for the case study.

For the modeling the SEEP/W module of the GEOSTUDIO software package was used. The program enables the engineer modeling steady and unsteady seepage and integrating specific soil functions. With the 2018 version the coupling of seepage and slope stability analysis is possible at every time step so that also the critical slope stability situation can be determined reliably.

STABILITY AND PORE WATER PRESSURE ASPECTS

For the presented case the global slope sliding stability was investigated hand in hand with the heave stability at the downstream levee toe. The considered levee section is shown in figure 3.

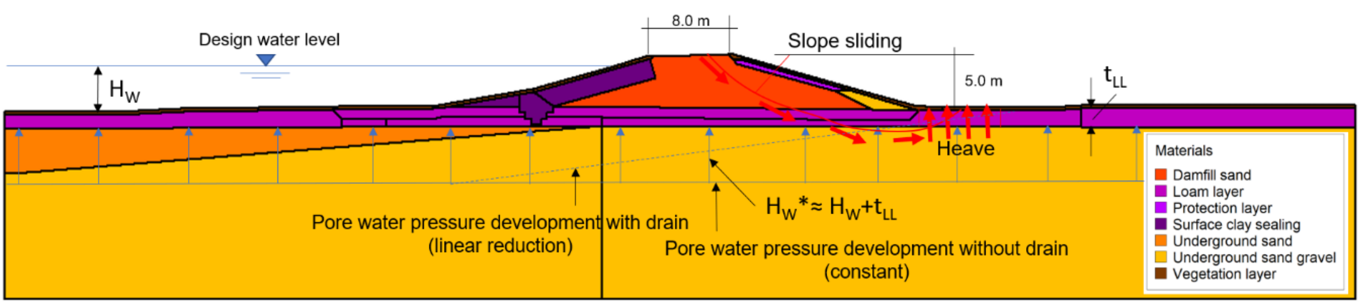

Figure 3: Principal levee section with failure mechanisms and pore water pressures

The levee is 5.0 m high and lacks a downstream berm. The crest width is 8.0 m. The slopes are inclined by V:H = 1:3.5.

As soon as the downstream loam layer shows a rupture or is drained by other means such as a drainage trench the pore water pressure will reduce as it is considered in form of a linear decrease in figure 3. If no draining effect occurs the pore water pressure will emerge in accordance to the flood level almost without reduction. In reality, there is a little reduction of 30 cm / 100 m seepage path which is negligible in the case study and its focus on the tow failure modes (see Kärcher et al., 2001).

For a better understanding the steady state seepage conditions are shown for both situations with and without drain at the downstream toe (figure 4). The pore water pressure reduces critically as soon as there is a permeable heave failure or drain structure. When heave does not occur the pore water pressure beneath the loam layer is more or less constant as aforementioned.

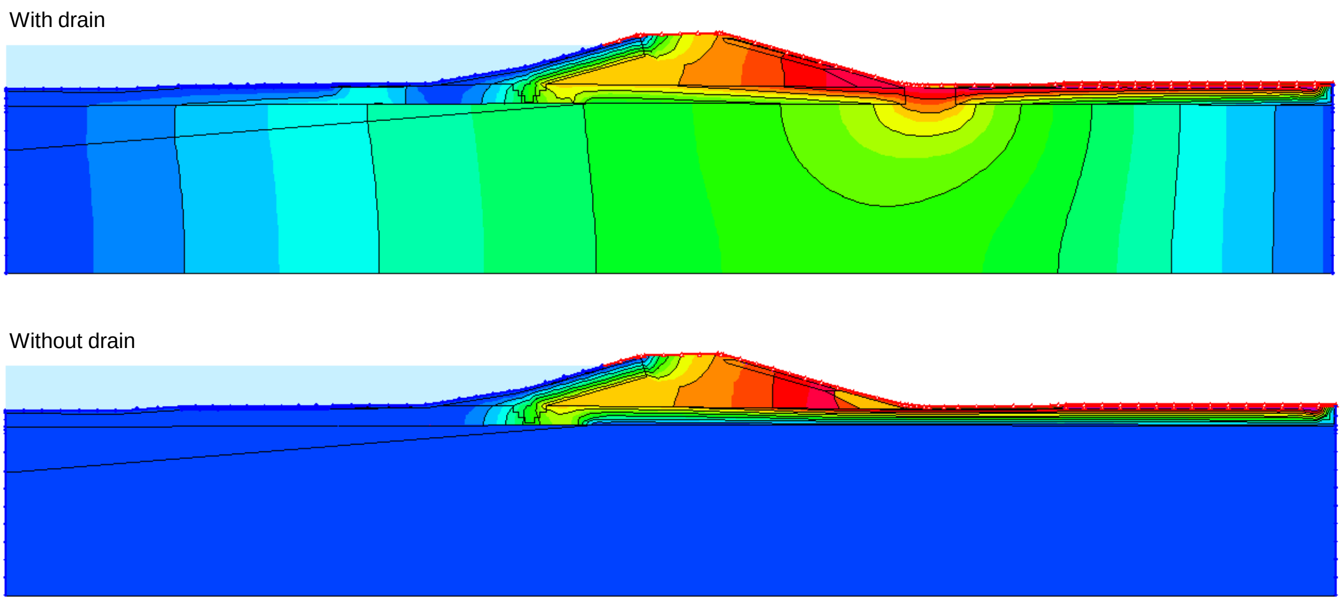

Figure 4: Pore water pressure distribution with and without downstream drain effect

CASE STUDY – LEVEE CROSS SECTION WITHOUT BERM

The case study levee shows a cross section without a downstream berm (figures 1, 3, and 4). The seep model is illustrated in figure 5. The Rhine River is located on the left. Generally, the underground consists of high permeable sand-gravels, the levee fill shows fine sands with a low permeability. The levee is founded on the levee base with a thickness of 1.0 to 1.5 m which consists of flood loam.

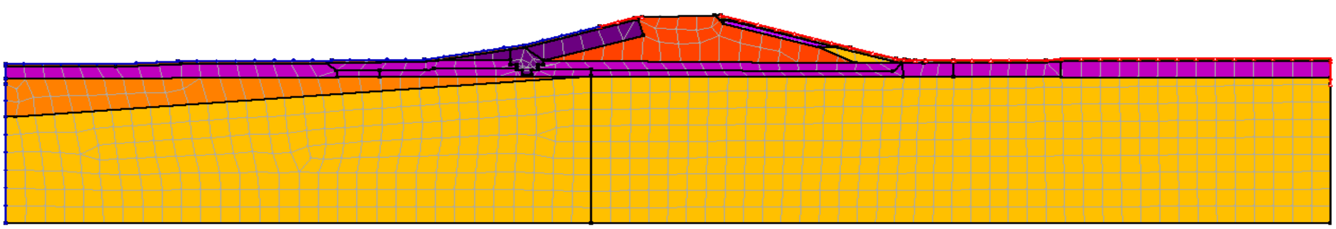

Figure 5: Model area with levee geometry, mesh and regions

The processed results of the slope and heave stability analyses are shown in figure 6. The flood hydrograph is integrated in the graph and is reaching a maximum water level of 4.0 m at 77.5 h. The flood impoundment starts at 70 hours.

At a water level of 2.5 m the degree of utilization of the heave is reached after approx. four days after impoundment started. The initial degree of utili ation for sliding of the downstream slope is m 0.2 in dry conditions with low groundwater level. Two days after heave gets critical so six days after impoundment started the slope sliding failure is reaching critical conditions at a water level of 3.5 m. The maximum load is reached one and a half days after the theoretical slope failure hand in hand with the maximum water level. The reason for this simultaneous effect is that the dam body itself is still dry and the destabilizing pore water pressures beneath the loam layer which are corresponding with the upstream flood water level.

The graphs were prepared for permanent design situation considering the flood water level (BS-P). The partial safety factors were defined according to BS-P. The levee reveals highly unstable conditions at water levels larger than 3.5 m, reflecting three days a situation which does not comply to the design specifications.

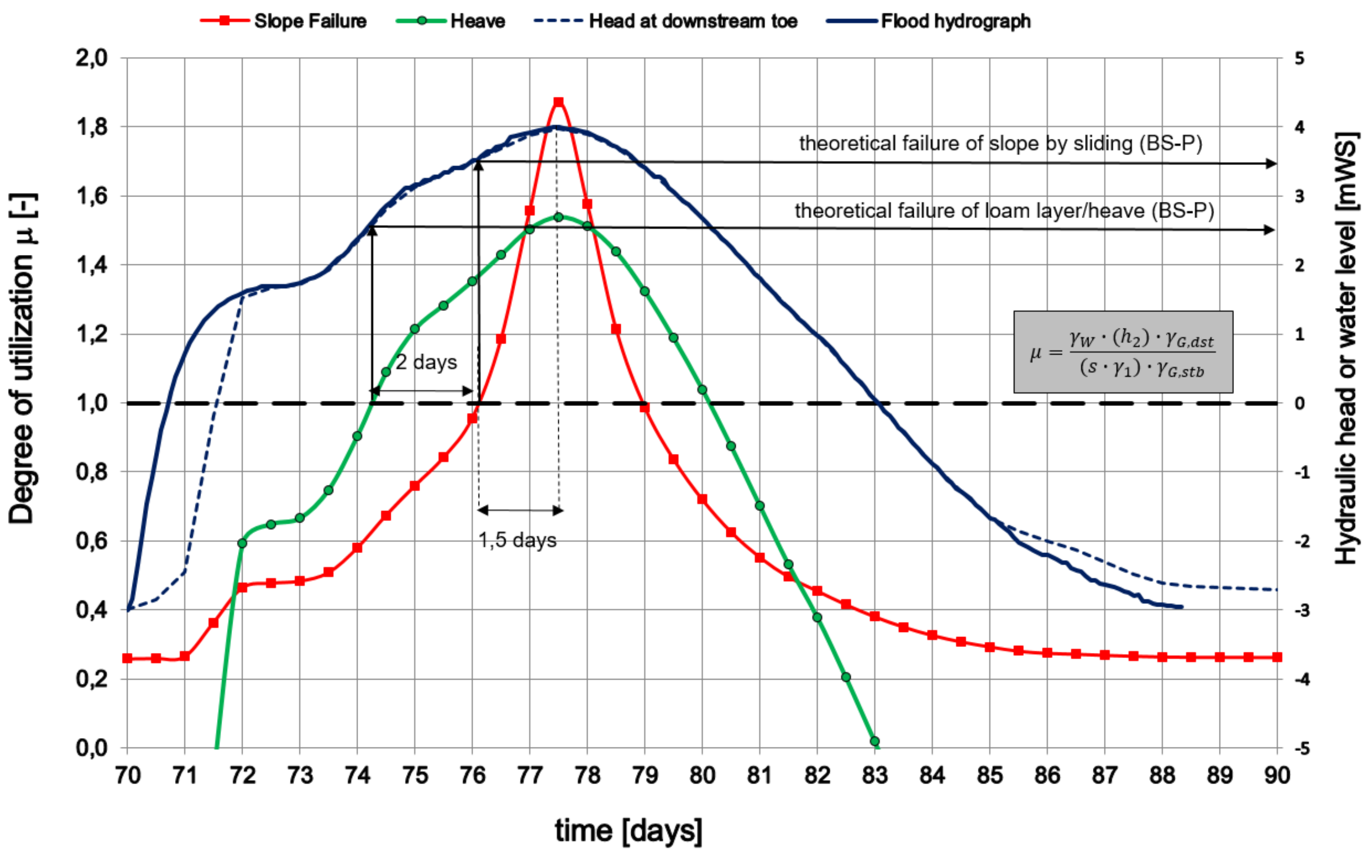

Figure 6: Results of modelling – comparison of degrees of utilization for slope failure and heave vs. time

Several more analyses and parameter studies were performed with the same model in order to gain a better understanding of levee's response to changing loads and shear strength parameters. Generally, the results show that critical heave conditions are arising before the critical slope sliding conditions. But, things may change if the loam layer shows strong cohesion and its position/elevation is lower compared to the upstream terrain. As soon as the loam layer withstands its loads and no local failure in form of a heave occurs global slope sliding is a matter of concern.

The levee body shows unsaturated conditions which could be also considered as unsaturated strength values within the analysis. For the first approach this additional withholding resistance was neglected. As one of the countermeasures the placement of a berm was considered as shown in figure 7. But this countermeasure could not show the required effect. The consideration of the unsaturated cohesion in the loam layer and the levee body could contribute to model a more realistic behavior.

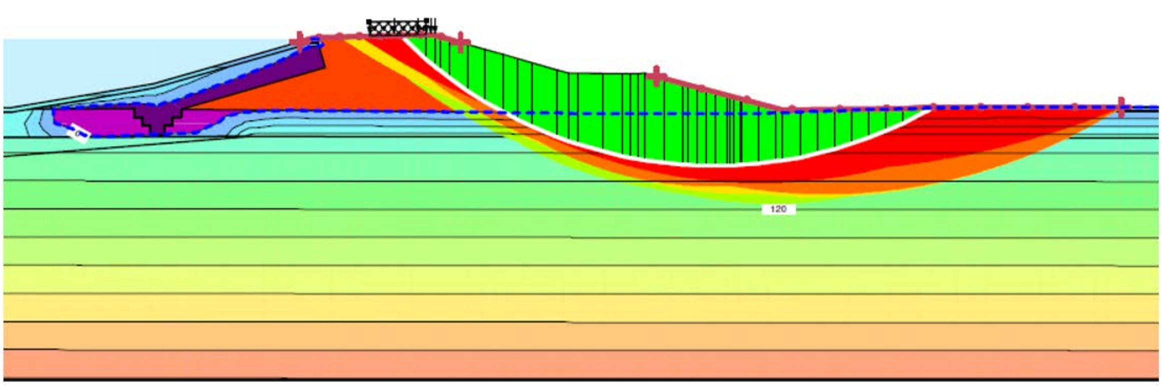

Figure 7: Slope sliding circles for levee with berm – critical maximum degree of saturation at 77.5 h with m ≥ 1.5

CONCLUSION

The coupled unsteady seepage and stability analyses revealed that heave is theoretically occurring earlier than the slope sliding. Therefore, a pore water pressure release may help to reduce the actual pore water pressures. The high critical pore water pressures underneath the loam layer/base sealing which are responsible for the global slope sliding failure may not develop. Thus, the local failure of the loam layer by heave prevent a global slope failure.

Of course, the theoretical analysis contains some inaccuracies and rough assumptions concerning the real drainage effect of a heave process as well as the actual shear strength of the affected soils and materials. In addition the heave failure may also initiate backward erosion (Fell et al., 2005) which again may have some negative influence on the failure mode. And, also the sliding deformation may also effect the pore water pressure conditions in the subsoil.

As a countermeasure a berm with a height of approx. 2 to 3 m and a width of 5 m can be added to stabilize the downstream slope. Nevertheless, due to the unhindered water pressure development underneath the loam layer heave still may occur downstream and cannot be avoided by structural load but only by draining works. Additionally, the placement of a berm may not completely be sufficient to theoretically stability the slope due to the high pore water pressures and the low effective shear forces along the sliding surface underneath the loam layer.

For the time being, two engineering views/opinions are facing each other. One side claims that a controlled pore water pressure release by the placement of a drain is the only way to get rid of the heave failure; the other side assumes that the loam layer itself is adding safety to the overall levee structure and in case of heave failure gets critical it will drain the subsoil anyway. In this context the local failure by heave is acceptable.

The author holds the opinion that the available approaches do not reflect actual conditions and that the complete failure process at the downstream toe should be investigated thoroughly by large scale tests. Pore water pressures, saturation, and deformation of the concerned levee parts should be monitored in order to obtain a better understanding of the actual processes. The stress-deformation-pore water pressure behavior of both discussed failure types should be considered not independently but it is expected that both are interacting. Since no adequate approach or solution is available for the described practical problems research is required in order to define the actual safety of concerned levees.

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COMMISSION INTERNATIONALE DES GRANDS BARRAGES INTERNATIONAL COMMISSION ON LARGE DAMS

IMPORTANT DATES TO REMEMBER

2020, Aug 31
Deadline for submitting abstracts & full papers for New Delhi 2020 Symposium

2020, Oct 5
Deadline for submitting Congress Questions Reports for Marseille 2021 Congress

2020, Oct 15
Deadline for submitting Innovations Awards Propositions for Marseille 2021 Congress

2020, Nov 28 - Dec 3
NEW DELHI ANNUAL MEETING & SYMPOSIUM

2021, Jun 4 - 11
MARSEILLE ANNUAL MEETING & CONGRESS

ICOLD WEBSITE
www.icold-cigb.org

NEW DELHI 2020 WEBSITE
www.icold2020.org

MARSEILLE 2021 WEBSITE
www.cigb-icold2021.fr

Dear Colleagues, Dear Friends, Dear ICOLD Family

Warm greetings. As you all know, the world has been in a turmoil this year due to the Covid-19 Pandemic, which took global proportions. For the first time during peace, all the events, even the Olympic Games, have been postponed, including our ICOLD 2020 Annual Meeting in New Delhi, which has been postponed twice.

With the Secretary General, Michel de VIVO, and the Vice-Presidents, we support and thank the efforts done by the Indian Organizing Committee for making sure that the Annual Meeting & Symposium will take place without risks in **New Delhi in 2020, Nov 28 - Dec 3.**

I remind you of the important **Symposium** prepared by our Indian friends on **"Sustainable Development of Dams and River Basins"** with a new **deadline** for submitting abstracts & full papers on **2020, Aug 31.**

While we continue to hope for the best that our conference will take place as planned, the ICOLD Board is also planning for the worst. If the health situation prevents us from organizing our Annual Meeting this year, we would hold the important 88th General Assembly by videoconference and postpone our Annual Meeting in New Delhi to another year. The details of the virtual General Assembly Meeting and disposition of conference papers will be provided later, if needed. I expect a final decision at our next virtual ICOLD Board Meeting in early September.

In the meantime, we encourage all National Committees to start planning for our next **Congress in Marseille in 2021, June 4-11**.

COMMISSION INTERNATIONALE DES GRANDS BARRAGES
INTERNATIONAL COMMISSION ON LARGE DAMS

The French Organizing Committee is working hard to make this a wonderful and safe event.

I remind you that the **deadline** for sending **reports for the Questions** of the 2021 Congress is **2020, October 5** and deadline for nomination papers for the **ICOLD Innovation Award** is **2020**, **October 15**.


World declaration on Dam Safety

"Better Dams for a Better World"

I would like to ask that all National Committees kindly circulate and strongly promote our **ICOLD World Declaration on Dam Safety**, which is more relevant than ever after the recent dam failures. Through this declaration, ICOLD is playing a crucial role in awareness in this matter of dam safety. You will find copies of the Declaration attached to this message.

I also encourage the Technical Committees, Regional Clubs and Young Engineers Forum to continue their work at a distance, by videoconferences. This is the important work of ICOLD that I ask each National Committee to support as much as possible.

Finally, I offer my words of encouragement. I am confident that ICOLD will come out of this period stronger than ever! Please, continue to stay safe and remain healthy, and I will see you soon.

Michael ROGERS

President

INTERNATIONAL COMMISSION ON LARGE DAMS
COMMISSION INTERNATIONALE DES GRANDS BARRAGES

president@icold-cigb.org