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

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Levees Working Group Newsletter

A CALL FOR CONTRIBUTIONS

- News, media or press releases on current flood or storm events involving levees and flood defences.
- Current, ongoing or recently completed research projects, with weblinks.
- Documents related to levees or flood defences: handbooks, guidance, reports and regulations.
- Information on events 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 1024x300)

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

INSIDE THIS ISSUE:

Note from the chairman

Rémy Tourment

We are getting close to the annual meeting of ICOLD, that will be held this year in New Delhi, India, from April 4th to 10th (see https://www.icold2020.org).

Our closely linked international group, the ICOLD Technical Committee on Levees, will have, like in previous years, two days of activities, with a workshop on the Monday 6th and a meeting on the Tuesday 7th. This year during the workshop we plan to have a half day devoted to technical and scientific presentations and half day of interactive discussion on the content of the dams-levees comparison report. The meeting will be the occasion to discuss all TC activities, present and future, and also for member countries to present short update on levee issues. It will be the last TC meeting before the Marseille 2021 ICOLD Congress, where the TC will have to present its two reports, a white paper and its new terms of reference. So it is a particularly important milestone.

During this New Delhi ICOLD meeting, we also plan to hold a short meeting specific to our LFD working group. And the board of the European Club of ICOLD will have its own meeting where we will report on our WG activities. It's not too late to register, join us there!

In this issue of our newsletter you will find technical and scientific information that we hope you will find interesting, as well as a feedback on our WG meeting in Crete .

And don't forget that we are always expecting information that YOU can send to share!

In September, the FLOODrisk2020 conference will be another opportunity for our levee community to meet and exchange information and knowledge. See https://floodrisk2020.net (registration now open). We hope to give you in a next issue of our newsletter more details on the many levees and flood defences activities already planned in Budapest.

Levees under pressure in 1995. And less so in the future?

By Jelmer Krom, Water Authority Rivierenland, The Netherlands

Bring in the Dutch! We have a reputation to uphold as dike or levee builders, with significant parts of our country being below sea level, at the mouth of major European rivers. The Netherlands is vulnerable to flooding. At the same time, the Netherlands is the most secure delta in the world. Without our dikes and dunes, sixty percent of our country would regularly be flooded. Yet we, too, needed a wake-up call twice in the last century.

After the devastating flood of 1953 resulting in 1836 deaths and 100,000 people affected in the Netherlands, we built the Delta Works to keep out the sea. The national government took the initiative, because this protection was of national importance.

The fact that the river dikes and levees in our Rhine and Meuse delta also needed to be strengthened, became clear in 1995. A unexpected coincidence happened: extensive rainfall and snowmelt in the Ardennes and in Southern Germany created a river discharge peak moving downstream along the Rhine and Meuse rivers, towards the Netherlands. Unfortunately, the rain continued and moved along with the high river discharges, with every tributary adding to the discharge peak.

The Waal river during the 1995 floods, near the village of Varik. Source: Rijkswaterstaat

Along the Meuse river, the December 1993 flood events were repeated during the floods of early 1995: The Meuse overtopped its banks along a number of unleveed areas in the South of the Netherlands, leading to significant damage and the evacuation of people. At the Dutch-German border, discharges of the Rhine river exceeded 12000 m^3/s and reached the second-highest level ever; only the peak discharge in 1926 was slightly (5%) higher. The Rhine near the Dutch-German border doubled its regular level, reaching a peak of 16.68 metres above sea level. The main concern along the Rhine branches was the water pressing against dikes that had long been in need of reinforcement. They were only just high enough and completely saturated. Cracks and erosion led to emergency reinforcement with sandbags or geotextiles. Meanwhile, the threatened village of Ochten became the centre of media attention. As a precaution, an unprecedented mandatory evacuation of some 200,000 people took place. In total, a quarter of a million Dutch people fled the water. This was extensively remembered in January 2020, where it was recognised that it was important to consider the future as well.

Required safety

The response after "1995" came quickly. To protect people, investments, infrastructure and added value behind the dikes and levees, the builders joined forces. This time for the rivers. A large number of major projects were carried out in the floodplains and on the dikes along the main rivers, the most urgent 150 kilometres within a time span of a single year. In the Netherlands every resident should soon have no more than a 1/100,000 chance of becoming a victim of a flood. In areas with high concentration of people or economic assets, that safety standard for levees is even stricter.

In addition, in 2017 the safety standard that we set on dikes shifted from "required height" (water level) to "flood probability" (strength). Because not only height counts, but also stability and strength of the levee. New insights into climate change are also considered: sea level rise, and an increase in extreme precipitation and extreme river discharges. Our aim is that by 2050, all our primary flood defences will meet the new safety standard.

Continued on page 3

Levees under pressure (from page 2)

Until 2028 we will reinforce 1100 kilometres of dikes in order to meet that new safety standard. These 1100 kilometres are the dikes which are furthest from meeting the requirements, so they are most in need of reinforcement. The central government does this together with the Water Authorities (also known as Water Boards), which are regional administrations with their own mandate, democratic governance and taxation.

Governance and government

In addition to the physical changes in flood plains and dikes, the biggest changes can be seen in the approach of these authorities. For centuries the management and maintenance of levees and waterways in the Netherlands have been a matter that does not rest with individual citizens, but with (regional) government. After the floods of 1995, the water authorities saw a flow of initiatives, including legislation (The 1996 Flood Defence Act), professionalization, technical development, investment and administrative renewal. Crisis management and communication also developed rapidly.

"with climate change and weather extremes increasing, we are never done with dikes and levees in the Netherlands"

The management of dikes, levees and waterways remains the main task of the Water Authorities. Water treatment for sanitation was added. A situation like the one in 1995 is now unlikely. But with climate change and weather extremes increasing, we are never done with dikes and levees in the Netherlands. That awareness is of critical importance.

A view from Crete

EUCOLD WG LFD

By Adrian Rushworth

The Working Group on Levees and Flood Defences under the European Club of ICOLD (EUCOLD WG LFD) held a 2-day programme at the 11thICOLD European Club Symposium in Crete. The two days were a mixture of meetings, presentations and workshops.

Joint co-ordinators for the European Levee Working Group in Crete— Patrik Peeters, Adrian Rushworth, Remy Tourment

Day 1 September 30th

After a warm welcome to everybody, attendees introduced themselves. Feedback was given from the ICOLD conference at Ottawa. Other topics discussed included planned activities, the Terms of Reference and the newsletter. The morning finished with presentations on

- Application of soil mixing for dike stabilization (Patrik Peeters, FHR, BE)
- Levee reinforcement measures and innovations (Marcel Bottema, RWS, NL)
- SEAL tool, use of LiDAR for levees (Adrian Rushworth, Environment Agency, UK)
- 10 years of experience with erosion tests (Patrick Pinettes, geophyConsult)
- Transitions (Jonathan Simm, HRW, UK)

In the afternoon there was a special session on the use of fibre optics for monitoring levee and dam behaviour. This session appears as a special feature in this newsletter.

Day 2 October 1st

The second day was a whole day workshop considering similarities and differences between dams and levees. The results are being used to further develop the dam/levee comparison report which is being written by the ICOLD Technical Committee on Levees.

Building a resilient flood protection system, including to overtopping. Creating openings in an existing railway Summer 2019

By Rémy Tourment

On the left bank of the south of the Rhône river (in France), between the cities of Tarascon and Arles, a railway embankment has performed for many years as a flood protection structure although it was not a role falling under its owner's (the French National Railway company) responsibility.

In December 2003, because of breaches in ancillary embankments, the north of the city of Arles was flooded for many weeks.

Breaches on ancillary embankments in 2003

In the aftermath of this centennial flood, the State and local authorities have put in place a vast flood prevention plan at the scale of the catchment, called Plan Rhône, which notably provides for the complete renovation of the levees of the Rhône Delta over 20 years. Within this ambitious program, it was decided to create a levee resistant to overtopping up to the 100 year flood, parallel to the railway embankment, and to create 10 openings (concrete structures) in the railway in order for it to be "hydraulically transparent". This segment of levee with the reinforcement of the rest of the system against all other deterioration and failure mechanisms allows the whole levee system to withstand floods up to the 1000 year with a 50 cm margin (the crest level of the levees not-resistant to overtopping). Floods above the protection level (100 year) will flood the protected area in a controlled way and with many times less water volume and speed than any previous scenario with the same probability (see Fig. 3). A second line levee will prevent the flood going over the new levee to reach the densely inhabited suburbs of Arles.

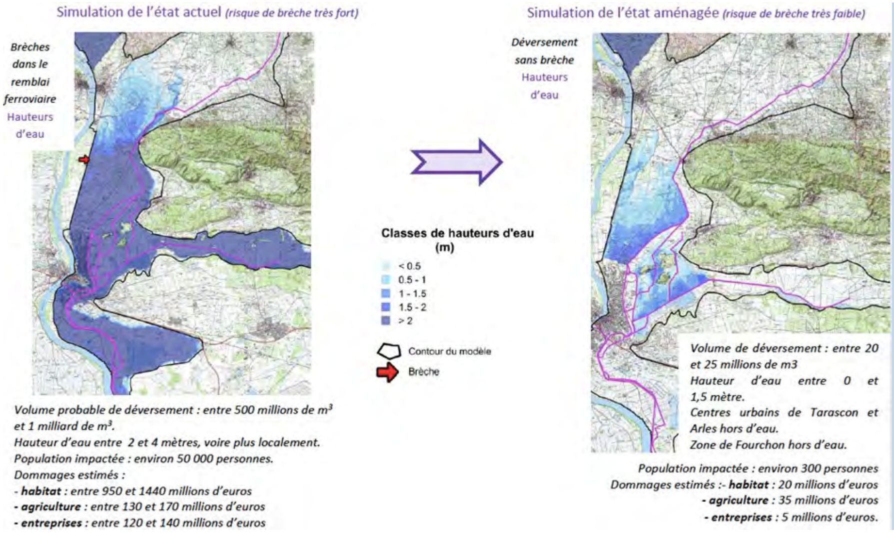
During the summer of 2019, over two periods of barely more than 48 hours, five out of the ten opening structures were put in place in the railway embankment. The planning of these operations started years in advance, as it involved the disruption of the rail traffic on a major train line used to transport both passengers and goods. The five other ones are being constructed now at a short distance along on the side of the railway embankment and will be put in place during the summer of 2020.

During each of these sequences of non-stop operation, a series of carefully co-ordinated steps had to be successively completed.

One of the opening structures and the equipment used to move it

During the Marseille 2021 ICOLD congress, one of the field trips will be organised in this area and the whole complex system will be presented: overtopping resistant levee, opening structures, second line of defence and flood water management.

More information : https://lfd-eurcold.inrae.fr/index.php/2020/02/23/building-a-resilient-flood-protection-system-including-to-overtopping-summer-2019-creating-openings-in-an-existing-railway/



Compared modelled consequences of the historic flood (1856 – 250 years event) before and after the project (Source: SYMADREM)

Living Lab Hedwige-Prosperpolder

By Patrik Peeters

How can you prepare for climate change related challenges, such as the sea level rising? This is a serious threat to low-lying countries, especially, since the actual strength of the flood defences is not well known nor how well emergency response can be organised in practice. The international Polder2C's project will address these issues and is using the depoldering of Hedwige- and Prosperpolder as a unique 6 km² Living Lab to validate flood defences, their revetment and emergency response practices.

The Foundation of Applied Water Research (STOWA, NL) and the Department of Mobility and Public Works (DMOW, Flanders) are the lead partners and drivers of this project.

Flood defences

The actual levee strength and the validity of today's levee assessment methods are evaluated in practice in the Living Lab. In addition, the Living Lab will offer the opportunity to test innovative and alternative techniques to strengthen or maintain dike covers under realistic but controlled circumstances, aiming for an extension of the lifespan of levees.

Emergency response

Besides assessing the actual strength, levee patrol and emergency response exercises will take place. The effectiveness and reliability of several existing and new emergency response measures will be executed in practice, such as the so-called Bresdefender, under development by the Dutch military.

Knowledge Infrastructure

Knowledge transfer is another important element of this project. It is essential that all findings and new knowledge is accessible for this as well as next generation of water managers. All outcomes will be documented, embedded in relevant (trans)national educational programs and dissemination initiatives. In this way, we are aiming at stakeholders being better prepared for future water related challenges.

The Living Lab Hedwige-Prosperpolder is receiving 3,9 million of euros from the European Interreg 2 Seas Program. The total sum is 6,5 million euros. Interreg 2 Seas aims to increase the adaptability to climate change of the coastal area of the Canal and North Sea. More information can be found at www.interreg2seas.eu.

This project has received funding from the Interreg 2 Seas programme 2014-2020 co-funded by the European Regional Development Fund, contract NO [2S07-023].

Coming events

2020

April 4-10Annual Meeting of ICOLD in New Delhi India

August 31–September 3 FLOODrisk2020 in Budapest. 4th European Conference on Flood Risk Management – Science and practice for an uncertain future

7.- 8 October DWA Levee-Day in Leipzig Germany. Note that the language of the event is German

2021

ICOLD Congress in Marseille France

27th Congress – 89th Annual Meeting

Fusion of information from geophysical and geotechnical investigations for levee assessment **By Théo Dezert**

The identification of levees constitutient materials, as well as the detection of possible interfaces and anomalies, are crucial for site characterization. During investigation campaigns, complementary geophysical and geotechnical methods are usually used. These two sets of methods yield data with very different spatial scales and different levels of incompleteness, uncertainty and inaccuracy. On the one hand, geophysical methods are generally non-intrusive and provide physical information on large volumes of soils but with significant potential uncertainties. These uncertainties are due in particular to the integrative and indirect aspects (relative to the parameters related to failure modes limit state equations) of the methods as well as to the resolution of the inverse problems. On the other hand, geotechnical investigation methods are intrusive and provide more local information but also more accurate and very often directly related to parameters related to failure modes limit state equations.

An important issue to improve the characterization of subsoils and existing levees is to be able to combine acquired geophysical and geotechnical data, while taking into account their respective uncertainties, inaccuracies and spatial distributions. The complementarity of these two sets of methods is often underused since the uncertainty and inaccuracy associated with each method are rarely considered. Furthermore, results are usually only graphically superimposed and considered with an expert opinion instead of being mathematically merged.

These works propose a specific methodology in order to manage conflicting and incomplete information as well as different levels of uncertainties and inaccuracies from different investigation methods, expanding geotechnical information between borehole positions. It presents a new way of mathematically combining data from these two types of information sources, taking into account the specificities of each kind of method. This new methodology considers the framework fixed by the theory of belief masses and improves the characterization of lithological sets within levees and their foundation. It provides information on the level of conflict between information sources while proposing a confidence index associated with the results.

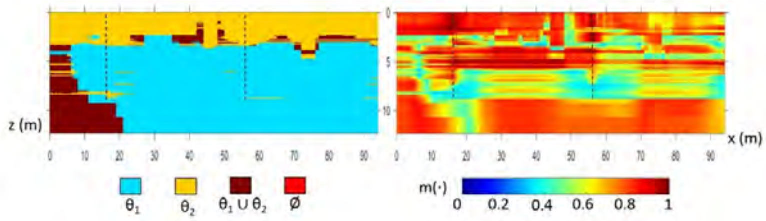


Figure 1: Section of a levee with representation of lithological materials having the highest belief mass values after fusion process between electrical resistivity, granulometry and CPT data (left) and their associated belief mass values (right).

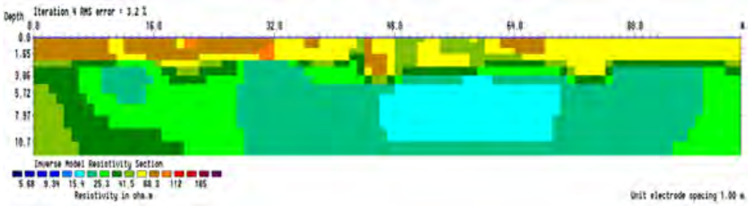


Figure 2: Levee modeled resistivity longitudinal section obtained by inverting Wenner-Schlumberger apparent resistivity data

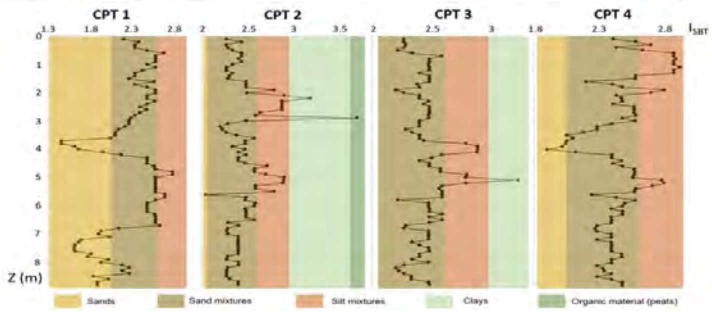


Figure 3 : ISBT vertical profiles for each CPT test and associated soil classes

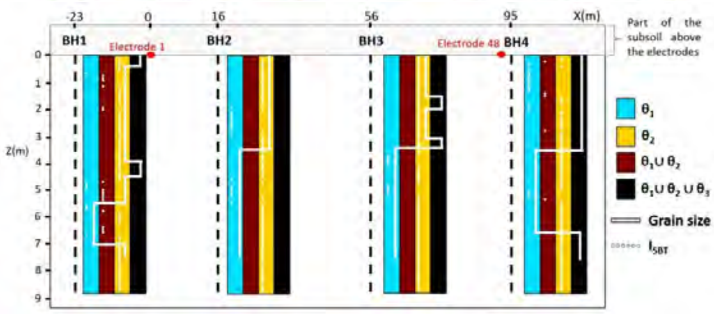


Figure 4 : Representation of the levee section displaying borehole positions in dashed lines and associated ISBT (white dotted line) and particle size distribution (white solid line) corresponding classes

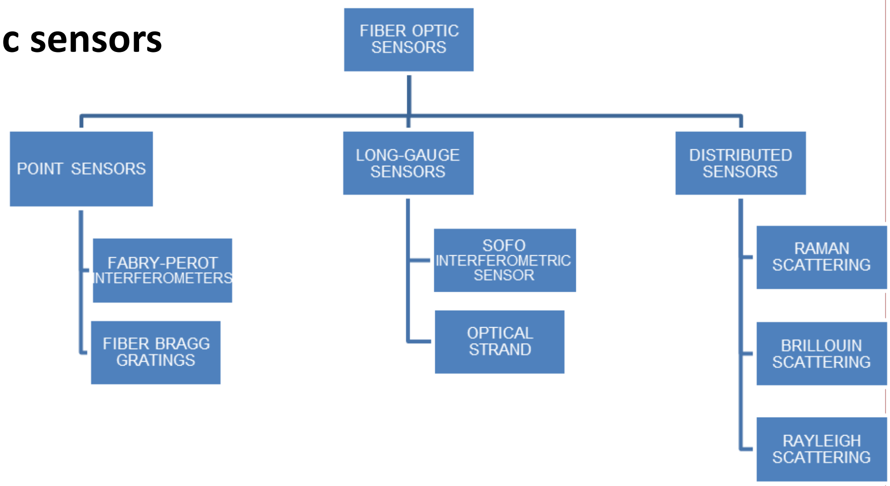
Special feature - **Using fibre optics**

At the 11thICOLD European Club Symposium in Crete the Working Group on Levees and Flood Defences under the European Club of ICOLD organised a 2-day program which included presentations on the use of fibre optics in levee and dam monitoring. In this special feature the presenters have summarised some of the key points.

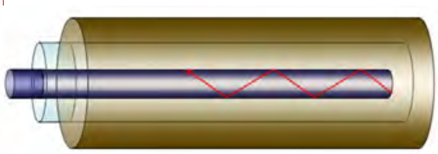
Introduction to fiber optic sensors

By Ivan Cottone, Smartec *SA*

A fiber optic sensor is a sensor that use the optical fiber as sensitive element and as a means of transmitting the signals. So the fiber optic sensors are intrinsically linked to the optical fiber, which is either simply a link between the sensor and the signal conditioner. In a distributed sensor, the connecting cable is the sensor. The optical fiber is a thin glass fiber (core), surrounded by the cladding and then usually protected mechanically with a polymer coating, (see figure). Afterwards it is inserted in a cable designed to be suitable for targeted applications.



Classification of fiber-optic sensing technologies according to the measurement principle



Light in the core. Cladding and coating.

Glass is an inert material, very resistant to almost all chemicals, even at elevated temperatures, and is therefore an ideal material for hardly all SHM projects. It is also interesting, since it is resistant to weathering effects, it is not subject to corrosion and it is immune to electromagnetic fields. Fiber sensors may be used because of their small size or because their measurement is not sensitive to drift over time.

Furthermore, the ability to measure over distances of several tens of kilometers without electrical power is also another important advantage of this family of sensors, especially when the task is to monitor large and remote structures, such as pipelines, multiple bridges or levees.

Fiber optic sensors offer a great variety of parameters that can be measured, so that multiple parameters can be mixed on the same network.

Compared with traditional electrical sensors, fiber optic sensors offer unique sensing topologies: multiplexing and fully distributed sensing. They therefore offer new monitoring opportunities.

The point sensors measure parameters like strain, temperature, tilt, load or acceleration in a confined zone around the sensor where it is in contact with the structure.

The long base sensor has the characteristic of measuring deformations over a few meters, up to 20m.

Finally, the distributed sensors can provide values of strain, temperature and vibrations over many kilometers and with a spatial resolution of some decimeters

Old and new technologies for the monitoring of a levee

By Ivan Cottone, Smartec SA

In 2012 we deployed a permanent monitoring system near Krško, in Slovenia, on Sava river. The monitoring system was composed of eleven vibrating wire piezometers and two fiber optic hybrid cables. The scope of the work was to measure the pore water pressure and to detect and localize water infiltration through the soil. It has been considered a successful combination of traditional (vibrating wire) and innovative (fiber optic and wireless communication) technologies.

The stainless filter of the piezometers have been saturated with clean water and put in contact with the host material to get continuity with the filters and the pore water (see figure). The sensors have been installed every 100m on both sides of the river and linked to the Smartec datalogger via radio waves.

Piezometer with soil on the tip and hybrid cable

The 1000m of hybrid distributed temperature sensing cable was also installed on the two levees. Hybrid means that it is made of copper and fiber optic wires (see figure). We use that type of cable when the temperature contrast between the soil and the leaking fluid is so small that it is difficult to measure and can be hidden in the noise of the acquisition unit.

Sava river near Krško on the left and hybrid DTS cable during installation

By means of an electric relay module controlled by the software the temperature cable was heated for a specific time to arrive at a certain temperature and as well a certain time to go back in its initial condition. Studying the cooling transient and the value of the maximum temperature reached during the heating phase we are able, through the DiView software, to determine if some events are occurring. DiView system controls the heating as well as the analysis; the detection algorithm is applied to all the points of the sensing cable.

Heating modules on the left and reading units and modem on the right

Better understanding local (mis) behaviour of levees in Flanders through the use of fibre optics

By Leen De Vos & Patrik Peeters, Xperta

Due to the large length of dikes, lacking personnel and the fact that the onset of damage cannot always be identified easily by visual inspection, in Flanders 'new' levee monitoring techniques are deployed in areas which need special attention, such as 'levee watch' as a managerial control measures.

Hereafter, two examples of dike monitoring using fiber optics are presented, one consisting of continuous strain measurements, based on Brillouin scattering, along a 3 km long levee, another being temperature measurements, based on Raman technique, for leak detection along a vertical profile.

The levees/banks of the river Schelde at Schellebelle, downstream of Gent, are prone to macro-instability. As we don't know where failure will occur, a large scale test for use of fibre optics over the full length of the levee was opted for as an early warning system.

Cut and cover installation of FO

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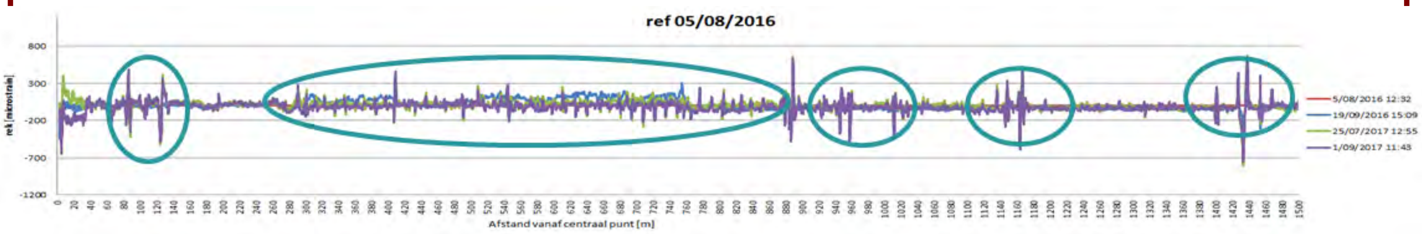


Signal relative to reference measurement along the levee with areas of interest

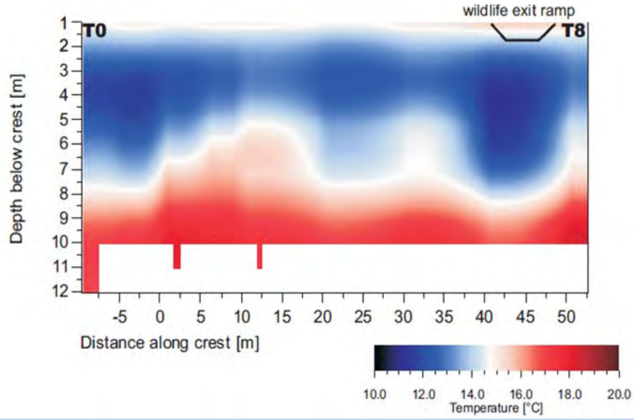
The raw signal can be converted into microstrain and consecutive measurements are presented relative to the reference measurement. Several areas stand out and require explanation. A, mong there are possible settlement of top soil layers, location of the sheet pile with L-wall and possible influence of unintended pre-tension of the cable during placement.

Summarising our experience and impressions after 2 years of levee watch: broken fiber on 2 locations (without 100% successful recovery), no accurate measurement of displacement but indication of areas sensitive to differential movement and hence, possible to elaborate control measures.

In the eastern part of Belgium, canals which are dug out in very sandy soil result in leakage issues: instability of ditch slopes and presence of small sand boils. Leakage is sometimes induced by overdredging. Canal bank restoration often consists of sheet-piling.

Slope instability and sand boils in a ditch along the canal

Vertical steel tubes were installed to conduct soil water temperature measurements in summer against depth were performed by GTC Kappelmeijer with a fiber probe.



Interpolation of temperature measurements in depth along the canal

In summer, canal water being about 20 °C, the soil water temperature in absence of leakage would likely decrease with depth. However, from 6 m below the surface, the soil water temperature seemed to increase again, indicating leakage from the canal.

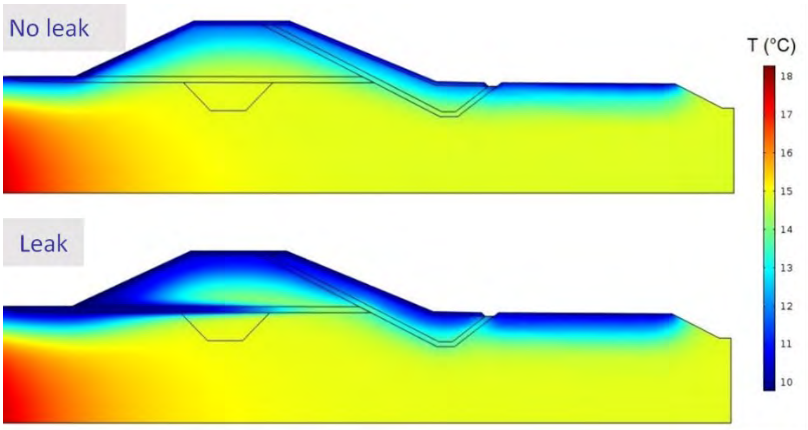
Summarising our experience and impressions after 1 summer of levee watch: leakage in deep sand layer and not in the upper sand layer (as was first expected), recently placed sheet piles hammered in the deep sand layer do not prevent seepage possibly even temporarily enhancing leakage and the possibility to perform extra follow up measurements. The decision was made that placing sheet piles into the very hard soil is not required, thus saving on installation costs. Local measures for the ditch are suggested.

Common experience of EDF and geophy*Consult* regarding fibre optics monitoring **By Patrick Pinettes, geophy*Consult***

geophy*Consult* is one of the pioneers and world leader of Fibre Optics monitoring systems of infrastructures (see http://geophyconsult.com/faq/faq.html for a general presentation of such systems).

It was launched in 2010 originally to provide the European market with innovations aimed to significantly improve the way the risk of failure of embankment hydraulic infrastructures due to erosion is managed. The first of these innovations was erosion tests, which are aimed at quantifying the resistance to erosion of embankment infrastructures. The second one was fibre optics monitoring of hydraulic infrastructures, which is particularly adapted to the risk due to erosion.

Today, after 10 years of operation with major dam owners all around the world, it has designed and is operating, more than 100 km of embankment dykes or levees equipped with FO monitoring systems mostly for EDF. This enables the company to provide all the mentioned services that are requested to deliver well managed FO monitoring projects. This starts with thermo-hydraulic simulations of the hydraulic structures to instrument, so as to determine whether the system is worthwhile and, if so, where the fibres have to be installed. The company also offers to supervise the installation works (as installations of FO monitoring systems are still new and require strong care so as not to delay the works, or so as not to be impacted by hazards which often occur during civil works). It finally provides the customers with all the tools that are requested to protect the monitoring system from internet attacks, ease the data transfer, enable relevant data analyses and visualizations in user-friendly interfaces including structure pictures and drawings, as well as generating automated alarms. These tools can be either installed in the customers computers or accessible via a secure web interface. The company also offers 24 hour, 365 days a year enhanced remote monitoring and real-time analysis by experts during crisis episodes, for structures that are of utmost importance and that owners do not have time to analyze in real time during such episodes.



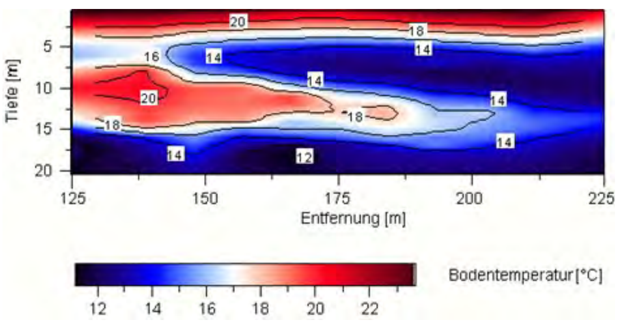
Simulation of a targeted leak scenario approved by the dam owner – and which lead to the decision by the owner to invest in a FO monitoring system

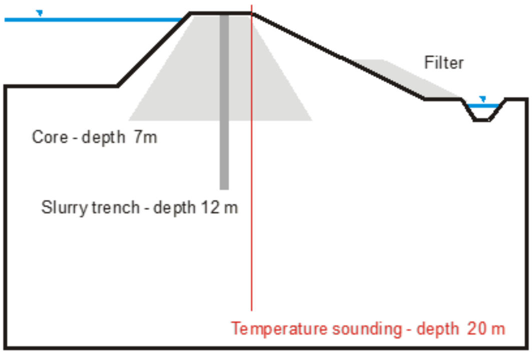
Active Fibre Optics cables being installed in the central drain of a canal, to locate leaks in the sealing and movements in the foundation

From Development to Automatic Online Fibre Optic Alarm Systems - FO Dam Monitoring from 1996 to Date

By Axel Fabritius, GTC-Solexperts

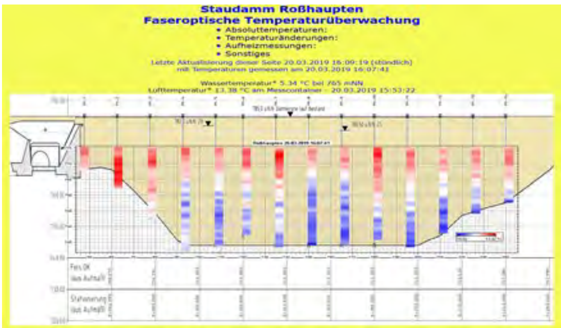
Solexperts GmbH (formerly GTC Kappelmeyer®) started with commercial Thermal Leakage detection, based on in-situ temperature sensing, in 1990. A few years later, in 1997, the world-wide first application of fibre optic temperature measurements as leakage detection system inside embankment dams was installed at the „Mittlerer Isarkanal“ a power supply channel.





Temperature acts as a natural tracer and e.g. in summer the warm temperature mark the extent of the seepage zone through the faulty sealing system.

Axel Fabritius of Solexperts says *“Solexperts offers turn-key and first-hand solutions to monitor all parameters relevant for dam safety and provides the analysis and the interpretation of the data. With these data and our expertise the owners dam engineer has all means to quickly assess the current dam health status and decide on further actions.”*



Fully automatic seepage monitoring system.

Discussion and take home messages collated by Patrik Peeters

- Don’t just install this technology, especially when dealing with low-risk assets, and see what comes out. A (thermo-hydraulic) modelling study prior to installation is recommended. On the other hand, installing FO in conjunction with retrofitting and construction activities, FO technology can provide improvements.
- Strain and temperature can be sensored directly. All other parameters are indirectly determined.
- Following a proper installation procedure will likely result in a long lasting sensor network. Among other recommendations: always surround FO cables with sand and have the interrogator in operation during installation.
- Governance (financing, organization) should be better talked through with all stakeholders. Guidance on installation and interpretation is lacking and can be obtained by bringing (certified) specialists and users together. However, there is no such thing as a standard case. Therefore, it will be restricted to describing some classical examples.
- The usefulness of FO within dry levees still needs to be proven on real sites, in operation (a setup along the Rhône River is almost ready to become operational).
- Coupling an insurance model with a surveillance scheme seems to be promising.
- In order to ensure a reliable location of the anomalies detected by the fibres, a precise table must be set up during the installation phase of correlation between the marks printed on the cable and their actual location on site, as measured by certified surveyors with a precision of typically 10 cm
- In order to reduce uncertainty over time regarding location of anomalies, anchor points along the cable can be installed (although it may lead to cable rupture unless specific precautions are taken).

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Fusion of information from geophysical and geotechnical investigations for levee assessment References:

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Conference papers:

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