Early detection of dikes and dams anomalies with a Fiber-Optics based monitoring solution

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Joint UrbanFlood & SSG4Env Workshop
Monitoring and Flood Safety
11th and 12th November 2010 - Amsterdam
TenCate develops technical textile based solutions for these markets

Safety and protection

Space and aerospace

Environment and infrastructure

Sports and landscaping
TenCate develops technical textile based solutions
introduces innovations aimed at managing the erosion risk:

1. Assessment of the vulnerability to erosion,
2. Detection of early signs of internal erosion.

Erosion tests

Fibre optics surveillance
The need to monitor earthworks ....

- Sensitive structures
- Meteorological events
- Optimization of structures
- Follow-up during construction
- etc.
... and hydraulic works as well

Danube – Austria - 2002

New Orleans – USA - 2005

Rhône – France - 2003

Wilnis – Netherlands - 2003
• It turns out that conventional monitoring (telemetered piezometers, electric gages, etc.) are generally complex hence not very reliable over long periods of times (important maintenance costs).

Besides, *in some cases*, conventional surveillance systems were unable to detect:

✓ internal erosion early enough so that the structure could be secured,
✓ leakage that were beyond the specifications of the watertightness.

=> *New monitoring technologies are requested!*
• Temperature:
  ✓ is known as a good indicator of leakage within embankment structures
    (thermal profiles in boreholes):

  ✓ can easily be measured with fibre optics:

**Surveillance based on fibre optics = combination of...**

✓ the measurement of a parameter which is intrinsically adapted
  to the detection of leakage within an embankment structure,

✓ a low-cost but reliable technology, with a great potential!
• Fibre optic = sensitive in time (10 min) and space (1 m) distributed sensitive thermometer (0.1°C), low-cost, can be installed anywhere, passive (no long-term drift or sensitivity to the electromagnetic or radioactive noise), very stable with time (> 30 years), easy to combine with other products (geotextiles, etc.).

• Anchored Brillouin fibre optics = able to detect 20 με shrinkage of lengthening that last > 10 min:

  ➔ microstrain measurement (settlement, etc.).
• Detection of early signs of leakage = localized thermal regime change: from *conduction*—slow evolution— to *advection*— rapid evolution:
  ☞ regime change can be detected as soon as it initiates with eDF algorithms, which are real-time compatible.

• Fibre position = depends on the structure:

  ☞ detection of leakages generating $\delta T > 0.1^\circ\text{C}$ over $> 1$ m during $> 10$ min.

• eDF return on experience = detection threshold:
  ☞ $> 0.2 \text{l}\times\text{min}^{-1}\times\text{m}^{-1}$ (when positioned on a drained upstream facing),
  ☞ $1 \text{l}\times\text{min}^{-1}\times\text{m}^{-1}$ (downstream facing).

⇒ Enables to secure the structure before failure.
• Temperature measurements:

• Strain measurements (referred to the initial state):
• Search for daily temperature anomalies:

✓ Leakage precursor detection (with localization in space and time),
✓ monitoring of the evolution of the anomaly (in space and time).
In summary…

• Surveillance system able to prevent or, at least, drastically reduce the risks linked with internal erosion.

• Other advantages:
  ✓ combined to heating ⇒ enable to estimate the leakage flow rate (① : $r_{acces}$ reduced from 1 m to 15 cm),
  ✓ can be connected to internet via a basic PC ⇒ automated alerts and alarms!
  ✓ can be used for repeated measurement ⇒ running costs can be adapted to any financial situation.

• Limits:
  ✓ opto-electronics instrumentation cannot go beyond 30 km,
  ✓ warranting the eDF leakage detection thresholds require detailed design and advanced data analysis (⇒ skills).
TenCate GeoDetect®: the concept

A double protection:

- **A structural barrier**
  A filtration geotextile to stabilise the soil and to prevent erosion

- **A monitoring barrier**
  Leakage and strain detection with fiber optics sensors - Warning
The technical solution GeoDetect®

Early warning system of causes of dike failure
TenCate GeoDetect® function 1: stability control

Settlement

movement detection: Warning!

Slippage

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TenCate GeoDetect® function 2: leaks & erosion control

Water channel (hole, crack, tree root)

Leak detection: Warning!

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The TenCate GeoDetect® solution for hydraulic works

1. The sensor: a fiber optic textile composite
Production of the TenCate GeoDetect®
geotextile enabled sensor
2. Distributed measurement: Raman & Brillouin OTDR

TenCate GeoDetect® S-BR
Innovation 2002: GeoDetect System for infrastructure

Geosynthetic: reinforcement + detection

No settlement at the surface

For soil-subsidence, the Tencate GeoDetect system:
- stabilises the structure and avoids sudden collapse
- generates a warning signal when the strain reaches a threshold value
First projects

Saint-Saturnin
Reinforced bridge wall
Installed in July 2004

GeoDetect® S - FBG
Strain monitoring

Arbois
Rail embankment over cavities
Installed in October 2004

GeoDetect® FBG
Strain early warning

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The TenCate GeoDetect® solution for hydraulic works

1. The TenCate GeoDetect® textile fiber optics sensor

2. Instrumentation / Installation

3. Measures / Data analysis

Purposes:
- Early detection
- Localization
- Monitoring
- Warning

Parameters:
- Soil strain / Deformation
- Temperature / Leaks

Optical technologies:
- Fiber Bragg Grating
- Stimulated Brillouin Scattering
- Distributed Raman Scattering
Performance assessment on scale 1:1 experimental dikes

1. Detection of dike instability

Dutch IjkDijk project
Macro stability experiment
IjkDijk project – Macro stability experiment

IjkDijk = Calibration Dike
IjkDijk project – Macro stability experiment

1. Trench at the toe
2. Increase internal water pressure
3. Load at the top

100 m
6 m
IjkDijk project – Macro stability experiment

Rotational slope failure
IjkDijk project – Macro stability experiment

System performance?
IjkDijk project – Macro stability experiment
Installation of the TenCate GeoDetect® sensor
23/9 - 4 p.m.

TOP

24/9 - 8 a.m.

MIDDLE

TOE / BOTTOM

START OF THE EXPERIMENTATION

Wed 24/9 08:00 a.m. : D - 3.5
Thu 25/9 08:00 a.m. : D - 2.5

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Urban Flood workshop – Amsterdam - 11.11.2010
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Fri 25/9 04:00 p.m. : D - 1
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Performance:

- Early signs detected 2 days before dike collapse
- Minimum strain detection: 0.02%
Performance assessment on scale 1:1 experimental dikes

1. Detection of dike instability

2. Detection of piping leaks
   - Safedike project – Experimental basin (2006)
   - Dutch IjkDijk project - Piping experiment (2009)
The PERINE experimental basin
(Cemagref - Aix en Provence)
Leak detection- Experimental dike
Installation of the TenCate GeoDetect ® panel with FOS
Tests in experimental dike – Aix-en-Provence (F)
Covering with a soil layer – June 2006
Tests with experimental dike – Leak detection

FOS lines

Leaks

Basin filling
Leak and piping detection

IJkDijk project
Piping experiment - 2009

Early detection of erosion pipes

GeoDetect® S-BR
Temperature & strain measurement
IjkDijk project – Piping experiment
IjkDijk project – Piping experiment
Fibre optics

Downstream and upstream the experimental dike

- Fibres Multimodes
- Fibre Monomode
Example of installed projects

1 km long flood protection dike on the Loire river
Example of installed projects

1 km long flood protection dike on the Loire river
Example of installed projects

100 m long Rhine to Marne canal dike
Example of installed projects

100 m long Rhine to Marne canal dike
Example of installed projects

Rehabilitation of the Amsterdam-Volgermeer dike and basins
Example of installed projects

The industrial site on the Rhine river

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Conclusions

- Early Warning Systems based on Fibre Optics are affordable operational state-of-art technologies for automated surveillance of embankment dams, dikes and levees.
- They can predict failures with high space and time accuracy.
- The textile fiber optics composite sensor TenCate GeoDetect® is a very innovative solution to monitor geotechnical applications and specially dikes since 2004.
- It is a reliable, accurate, easy to install, and durable solution.
- Multi-parameter measurements, strain and temperature.
- It uses the powerful data analysis models developed by eDF to enhance early warning function.