Measurement Results on Full Scale Field Experiment using Optical Fibre Detection Methods

Mess-Ergebnisse beim Feldexperiment mit faseroptischen Untersuchungsmethoden

Cyril Guidoux, Yves-Henri Faure, Olivier Artières, Jean-Marie Hénault, Jean-Jacques Fry, Sylvain Blairon, Jan Van Roosbroeck, Paul Royet

Abstract

Both active and passive temperature measurement methods have demonstrated their functionality to locate leaks in dams. However the sensibility of measurements with respect to external parameters such as air temperature or solar radiative flux has not been well investigated.

A full scale experimental basin was built to test active and passive measurements. Several fillings were made since September 2006, in order to mimic sudden floods with different meteorological conditions. The equipment is described, and results are presented. A special emphasis is put on relationship between leakage flow rate and corresponding temperature measurements.

Zusammenfassung

Sowohl aktive als auch passive Temperaturmessmethoden haben ihre Tauglichkeit für das Lokalisieren von Deich bzw. Dammschäden bereits unter Beweis gestellt. Der Einfluss der Lufttemperatur und der Sonneneinstrahlung auf das Messergebnis wurden jedoch bis jetzt kaum untersucht.

Seit September 2006 wurden in einem eigens errichteten Testbecken umfangreiche Tests an aktiven und passiven Temperaturmessmethoden durchgeführt. Zu diesem Zweck wurde eine Reihe von Hochwasserereignissen mit unterschiedlichen meteorologischen Rahmenbedingungen simuliert. Die vorliegende Arbeit beschreibt die Testdurchführung und zeigt die Ergebnisse der Simulationen. Weiters wird ein Bezug hergestellt zwischen der gemessenen Strömung im Deich und den gemessenen Temperaturen.

1 Introduction

Except overtopping, the majors risks for dykes safety are regressive erosion and dyke toe slipping. During the past decade, numerous works, especially in the European Working Group (EWG) on internal erosion, have highlighted the need of localizing and quantifying these phenomenons. In such a goal, distributed optical measurements can be successfully used, both for temperature and strain measurements.

Assuming that the optical fibre sensor is located as far as possible from the downstream face and lies in the water table, the passive temperature measurement method has demonstrated its functionality to locate leaks in dams [1]. However the sensibility of measurements with respect to external parameters such as air temperature or solar flux has not been well investigated. The active method has also been quite fully developed [2]. It requires a heating cable with heating power among 3 W/m and 10 W/m, in order to detect seepages and to measure flow rates, respectively.

However, the particular case of dry dykes as not been well documented. In this case, the sensors could be above the water table. In southern countries, dry dykes have to be ensured against most and most violent flooding with a detection system that requires as less civil work as possible, for example a simple cable below a downstream shoulder that will be surely close to the downstream face. In addition to that, a power supply in those areas could not be easily available.

To go further on this particular case of dry dykes, a full scale experimental basin was built to test active and passive measurements [3]. Two major fillings were made since September 2006 in order to mimic sudden floods with different meteorological conditions. Several distributed temperature sensors (DTS) were used. The building of the basin is depicted. Equipment is described and experimental planning are presented.

2 Full scale experimental basin

The basin was built at the Cemagref facilities, near Aix-en-Provence, France. The experiment was designed with four dykes of 2.5 m high with artificial leaks inserted in at two different levels. Downstream of each dyke was planned to be covered by a geo-filter with optical fibres (OF) and heating cable (HC) installed on it (**Figure 1**), covered by a gravel shoulder. It was planned to build leakages with several geometry, in order to investigate influence of this parameter on measurements.

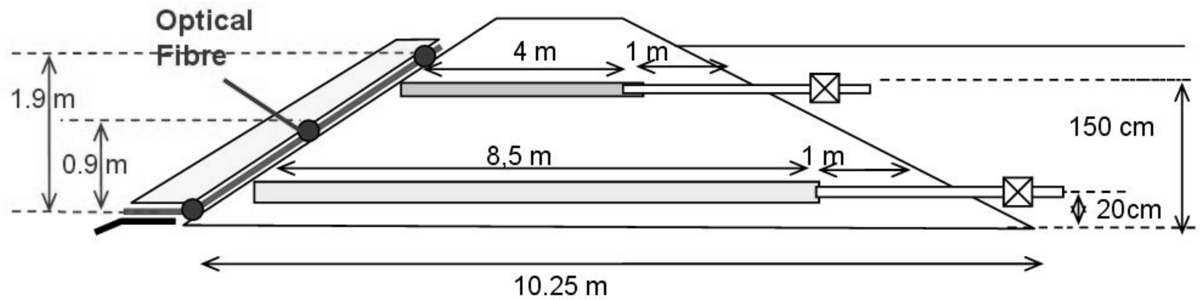

Figure 1: Cross section of one basin side.

Built-up of the basin

The basin was built in spring of 2006. It is rectangular in shape and is 36 x 23 m in size at the outer limits. The body of dykes is made of local silt clay loam with permeability around 10^{-11} m/s. Most leaks were made of 0.3-m diameter geo-textiles cylinders filled with 10^{-3} m/s permeability sand connected at the upstream side to a PVC tube ended by a gate. Other leaks were made in the same way but with plane shapes, as the 4 m wide south bottom leak (**Figure 2 and Figure 3**). Those artificial leaks are providing 10-litre.min^{-1} theoretical flow rates that can be set up with a waterproof electromagnetic flow-meter. A bottom outlet was installed for emergency emptying. The basin can be filled with a high pressure pump providing high filling flow rate. An overflow tube was inserted at the middle top of the North side, providing a 2.4-m constant water level, and a gulley was build all around the basin.

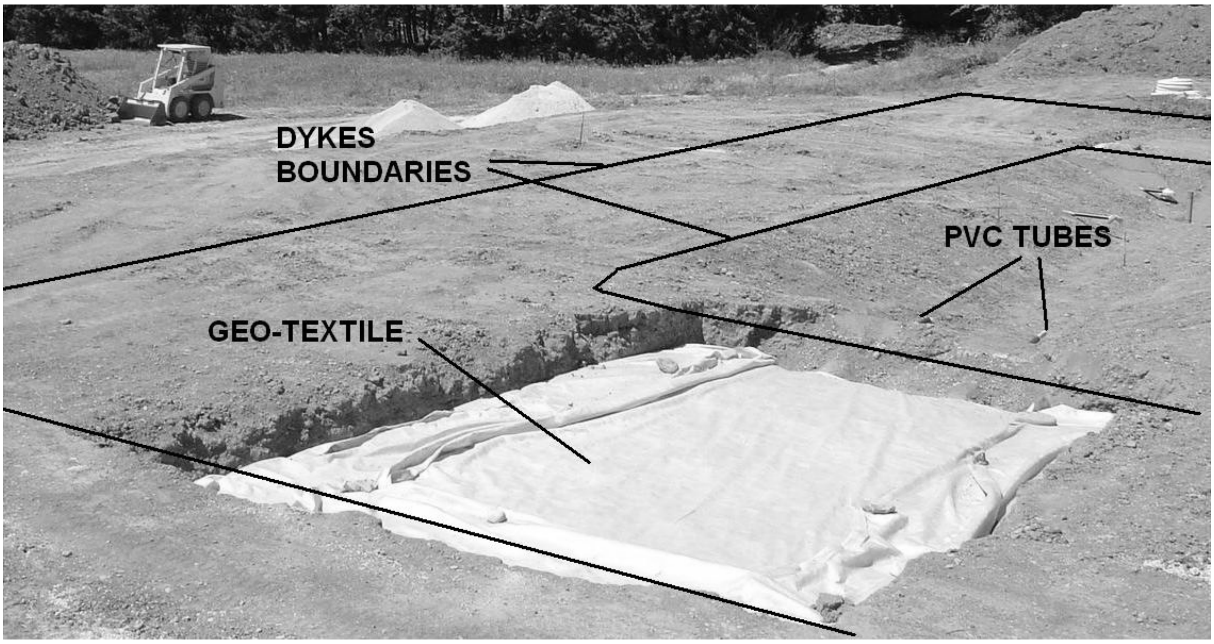

Figure 2: Scheme of the entire basin.

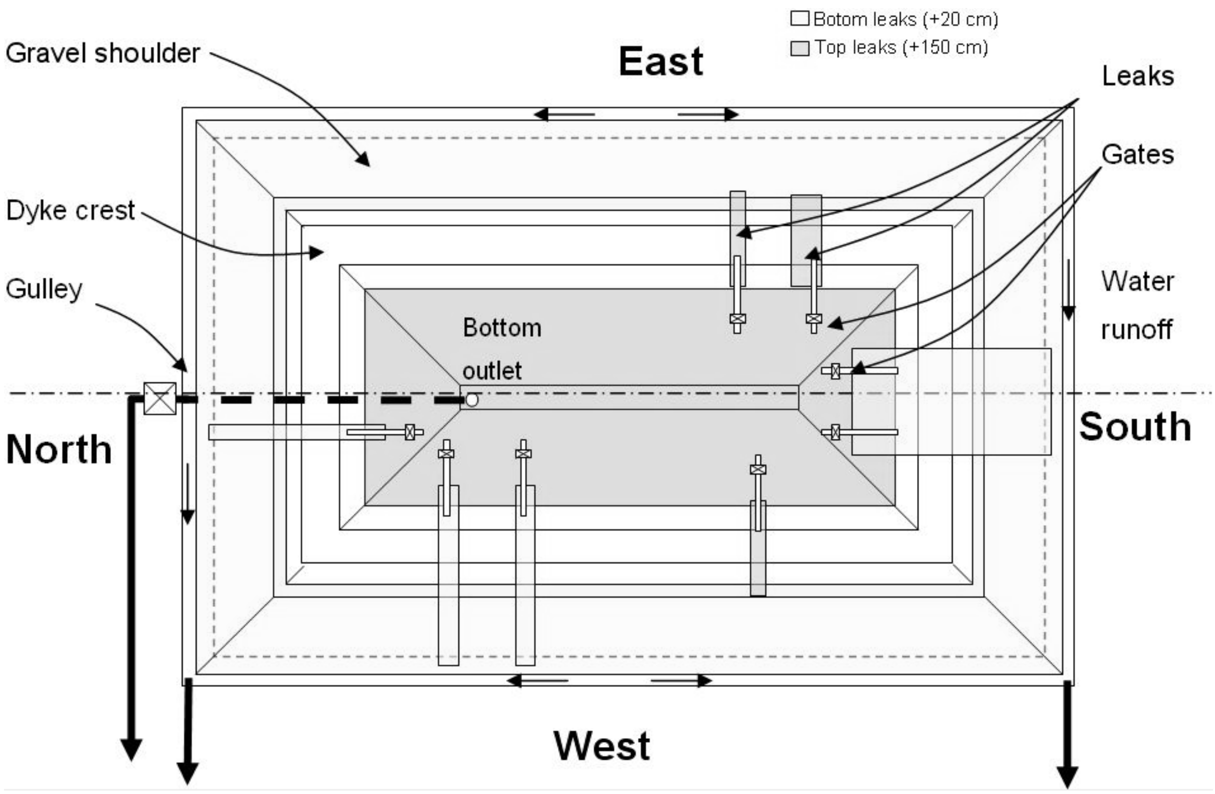

Figure 3: Built-up of the bottom south controlled leak.

After civil work, OF and HC sections were connected together in four connection boxes standing at each corner of the basin. Three OF lines were created this way: one multimode line for temperature measurements using the Raman effect, and two single mode lines for temperature and strain measurements using Brillouin effect. OF integrity were checked with Optical Time

Domain Reflectometry (OTDR). Then those OF lines were linked to a telecom cable joining the instrumentation room.

DTS and sensors setup

In order to compare on field metrological performances, three devices were used for temperature and strain measurements, provided by three suppliers: Sensornet, Sensa and Omnisens. The first two devices only measure temperature, although the last one is a Distributed Temperature and Strain Sensor (DTSS) that can measure two OF alternatively. Environmental temperature conditions were monitored by PT-100 sensors. Meteorological measurements, including wind speed and direction, solar flux and air humidity and temperature were performed with a weather station installed on the crest of the North-East corner of the basin.

Multimode fibre (Raman)

The Raman spectrometry allows to measure temperature by analysing the diffused part of the incident light inserted in multimode fibre. The multimode line installed on the basin is 960 m in length. Each side is equipped by two sections at the top and in the middle of the slope and one at the bottom: T2, T3, M2, M3, B2, respectively. Each section of a side is connected to the corresponding section of the following side in a clockwise manner starting from the North-East corner. Then each complete loop is connected with the following, in the above order.

Single mode fibre (Brillouin)

The stimulated Brillouin spectrometry (SBS) allows measuring both temperature and strain. The first line contains free single mode fibres from the geo-textile for temperature measurements; the second one those for strain measurements. The first line is composed by three level of fibres in the same way as for multimode line, with only one section by level: T2, M2, B2. Total length of interest is 611 m. The second line consists in three different fibres lying at the bottom and connected together, but only on three sides: east, south and west. Total length of interest is 471 m. This line is also temperature-sensitive, but the effect of temperature can be removed by pure temperature measurements using Raman technology.

Heating cable

The HC lies around the fibres on each level of each side. It is made of copper wires and is plugged in a 16-W power supply. According to the measured cable length and electric intensity during tests, the distributed power is about 12 W/m. Since December of 2006, this cable was extended with an extra length below early installed geo-membranes (GM) at the upstream side (see below)

3 Experimental planning

There were two major fillings of the basin, from September to November 2006 and from February to April 2007. These two periods were chosen because of their different environmental thermal conditions.

First filling.

After a few cycles of filling and emptying, the basin was durably filled from the twelve of September 2006 until the sixteen of November 2006. Some uncontrolled leaks were observed when the water level reached its nominal value, especially around top artificial leaks of the East side. Consequently, the water was maintained at a constant level of 2±0.1 m. Gates of the bottom leaks were set up to 1 litre/min the fifteen of September 2006 and were increased each month until about 10 litre/min.

Ten-minutes measurements were performed every ten minutes with the Sensornet DTS for Raman measurements and with the Omnisens DTSS for Brillouin measurements.

GM installation and second filling.

In order to avoid uncontrolled leaks mentioned before, a GM covering of the upstream face was realized during December 2006. One multimode and one single mode OF were lied on the upstream slope under the GM, and were connected at the previous end of the Raman and Brillouin temperature lines, respectively.

After a short filling done in order to check the GM integrity, the basin was filled the twenty-six of January 2007, and is still full. The water remains at a constant level of 2.4 m. Gates of all leaks were set up to 1 litre/min the thirty of January 2007, and were increased each month until 10 litre/min.

Five-minutes measurements were performed every ten minutes with the Sensa DTS for Raman measurements. No SBS measurements were realized.

The main analysis of the basin data is part of a collective work realized with the Cemagref and EDF. Results are reported in separated articles included in the final report of the EWG on internal erosion [4]. A new measurement session is planed soon in order to investigate seepage detection under the GM layer by the use of voluntary leakages in it.

4 Conclusion

A full scale experimental basin with controlled leaks was built, and fillings of several months were realized. Deeper analysis have to be performed, however the first results [4] tends to demonstrate that leaks are detectable without heat-up and without high contrast between air and water temperature.

Literature

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Authors' Names and Affiliation

Cyril Guidoux, Ph.D. Student
cyril.guidoux@ujf-grenoble.fr

Yves-Henri Faure, Ph.D.
yhfaure@ujf-grenoble.fr

Laboratoire des Transferts en Hydrologie et Environnement (LTHE)
BP53
38041 Grenoble Cedex 09, France

Olivier Artières, Ph.D.
Tencate Geosynthetics Europe
9 rue Marcel Paul
BP 40080
95873 Bezons Cedex, France
o.artieres@tencate.com

Jean-Marie Hénault
jean-marie.henault@edf.fr

Sylvain Blairon
sylvain.blairon@edf.fr

EDF
6 Quai Watier
78400 Chatou, France

Jean-Jacques Fry
EDF CIH
73 373 Le Bourget du Lac Cedex, France
jean-jacques.fry@edf.fr

Jan Van Roosbroeck, Ph.D.
FOS&S
Cipalstraat 12-14
2440 Geel, Belgium
jvanroosbroeck@fos-s.com

Paul Royet
Cemagref
BP 31
13612 Aix en provence cedex 1, France
paul.royet@aix.cemagref.fr