

FIBRADIKE project: Preliminary Test Results

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ABSTRACT: Geohydraulic earthen structures, such as dams and river embankments, are essential for water resource management and flood risk mitigation. One of the primary failure modes for these structures is internal erosion due to seepage, which can lead to sudden collapse. Despite advances in sensor technology, traditional monitoring methods remain inadequate since they lack the spatial and temporal resolution required for effective detection.

Currently, a novel distributed pressure sensor (DPS) based on distributed fiber optic (DFO) technology has been developed at the University of Applied Sciences of Eastern Switzerland (OST). The key feature of the sensor is its unique ability to measure pore water pressure with high spatial resolution and over long distances, which is required for early detection of internal erosion phenomena. The sensor, already validated at laboratory scale, has been installed in a full-scale test basin (84 m long, 37 m wide and 4 m high) at the scientific laboratories of the Agency for the Po River (AIPo) in Boretto (Italy). This extended paper presents the results of the first preliminary test of the filling of the embankment.

Keywords: Distributed Monitoring; Distributed Pressure Sensor; Smart Dike; Distributed Fiber Optic Technology.

1 INTRODUCTION AND NEW DISTRIBUTED PRESSURE SENSOR - DPS

River dikes and dams are a major component of water resource management and flood risk protection. Their importance is heightened in the context of climate change, as flood events become more frequent and severe (Fischer et al., 2022). One of the most significant failure modes for such structures is internal erosion caused by water seepage. The main factors that trigger these phenomena are permeable layers, cracks or fissures, animal burrows, vegetation roots, and also human activities (Bonelli et al., 2012). Traditional measurement systems are limited as they have low spatial and temporal resolution, while these structures can span hundreds of kilometers and their failures can be rapid and localized. For this reason, the current most common method of detecting internal erosion relies on visual inspection.

A promising monitoring technology that meets both spatial and temporal requirements is distributed fiber optic (DFO) technique, which is currently widely used in geohydraulic applications by measuring temperature and deformation (Schenato, 2017). In this regard, a new distributed pressure sensor (DPS) based on DFO technology has been developed at the OST. This sensor can measure pore water variations with high sensitivity (on the order of centimeters water column) and a spatial resolution of decimeters over distances of several kilometers. As pointed out by Fell et al. (2003), pore water pressure within earth structures is an important parameter for monitoring anomalies due to internal erosion phenomena. The DPS consists of a helically wound fiber optic sensor attached to a cylindrical compressible central element. The pressure is obtained by measuring the constriction or expansion of the central element caused by the hydrostatic pressure of water or fluid, which induces elongation or compression of the sensing fibers. A calibration coefficient determined in a pressure chamber can be used to convert the measured deformation into pressure values. Additionally, the DPS contains a loose tube with distributed temperature sensing (DTS) fibers for temperature measurement (Höttges et al., 2023). Another important aspect is that the DPS is manufactured on an industrial scale and is now available on the market. The sensor has been validated in a 1:10 laboratory scale dike model to measure pore water pressure during dike saturation (Höttges et al., 2023) and in a wave channel to measure pressure during solitary wave propagation (Höttges et al., 2024).

2 FULL SCALE TEST EMBANKMENT

Embankment design: The test embankment is 84 m long, 37 m wide and 4 m high with a slope of 1:2 (Rabaiotti et al., 2023). The embankment is constructed of two different soil materials: silty sand according to Swiss (CH) specifications for the Rhone River and silt according to Italian (IT) specifications for the Po River. Furthermore, to ensure the applicability of the monitoring system to both new and existing structures, the experimental embankment is divided into

Experimental Setup: The new DPS is installed in a mesh grid (see *Figure 1*) at three different elevations (at 0.3 m, 1.3 m and 2.3 m above the ground level - GL) in the „ex novo“ sections in two main direction: longitudinal (in green, x-axis) and transversal (pink, y-axis). Saturable tubes are installed in various sections of the DPS, as shown in black in *Figure 2*, to protect the DPS from any earth pressure changes (e.g., erosion or sediment accumulation) and to provide only hydrostatic pressure measurements in the sections where they are installed. Conventional measuring sensors are installed to validated the DPS measurement in 4 main transversal sections (2 in the „ex novo“ and 2 in the „existing“): in total 27 piezometer, 22 tensiometer and 8 humidity sensors.



Figure 2. Installation scheme at 0.3 m – “Ex Novo”

Experimental results: in this extended paper, only the results for the Layer 01 at 0.3 m above GL are presented. *Figure 3* shows the results obtained with the temperature fibers interpolated in the two main directions at 144 h after the start of the test. *Figure 4* illustrates the pressure in cm of water column (cm wc) obtained with the DPS in the transversal direction. In the longitudinal direction, preliminary results showed significant noise due to fiber connection problems.

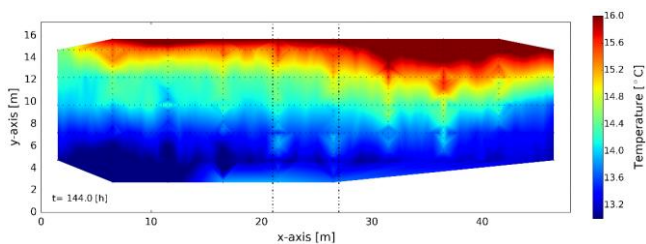


Figure 4. Pressure obtained with DPS for Layer 01 at 3.5 h.

These preliminary results demonstrate the potential of the DPS to provide distributed information on temperature and pressure within the dike, allowing for the detection of any anomalies. During testing, there were no stability issues, the measurement system responded accurately, and the filling and emptying procedures were satisfactory. Future activities include: testing at full high capacity as the water level was only raised by 1 m, installing the sensor using horizontal directional drilling (HDD) and monitoring the animal activities.

Bonelli, S., Courivaud, J., Duchesne, L., Fry, J., & Royet, P. (2012). Internal erosion on dams and dikes: Lessons from experience and modelling. 24th International Congress on Large Dams.

