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Monitoring of shallow landslides by high-resolution distributed optical fiber strain sensing: a physical model experiment

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In the last ten years there has been an increasing interest in the application of optical fiber strain sensor systems to natural geohazards [1], including landslide monitoring [2,3]. One of the main aims of many of these research papers was to show the viability of fiber optic sensing (FOS) technology to this specific geotechnical monitoring problem. At the same time, these works also show how the FOS technology can contribute to a better understanding of the mechanism underlining landslide triggering and pave the way for FOS-based nowcast of collapse precursors. Despite this effort, many important issues are still open and soil-fiber coupling and related data interpretation are among the most prominent. The correlation between the soil movements and the induced strain on the optical fiber sensors is still not completely clear, neither it is the regime for which the soil-cable interaction is quantitatively meaningful to the sliding phenomenon.

In this work we have experimentally investigated these issues in a large-scale physical model of a slope, instrumented with a fiber optic cable and interrogated by a high resolution distributed strain sensing system. The large-scale physical model base measures 6x2 m and its height increases linearly from 0.5 to 3.5 m to form a 5 m-long slope of approximately 32°. The slope was lead to collapse by an artificial sprinkling system, previously tested and characterized [4].

The failure surface was predefined at the interface between an upper 60 cm-thick layer of permeable soil made of fine non-compacted sand loosely deployed over a less permeable, well-compacted, sandy clay. The fiber cable, installed at this interface in meanders, as shown in fig. 1, has a plastic corrugated sheath to enhance the coupling with the soil.


Figure 1. Left: The flume hosting the physical model. Right: a phase during the installation of the fiber; the cable has been then covered by a 60 cm-thick layer of permeable soil, loosely deployed.

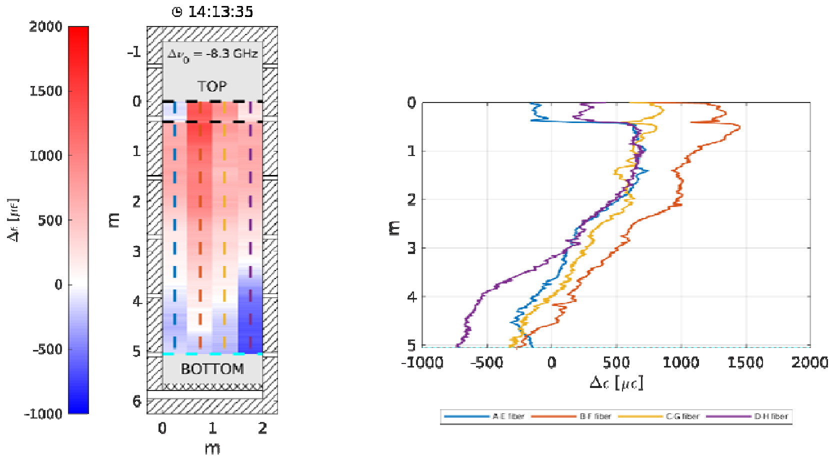

Figure 2. On the left, the 2D map of the strain field reconstructed from the strain measured by the four optical fiber section, represented on the right plot, before the appearance of external tension cracks.

The interrogator is a commercial device exploiting the Optical Frequency Domain Reflectometry to achieve a centimeter-scale longitudinal spatial resolution along the cable with <10 seconds time sampling.

The collapse, initiated upper slope with the mobilization of the entire sand thickness, with no involvement at downslope and without a surface run-off. Figure 2 shows an example of the very detailed 2D map of the strain field at the sliding interface measured by the optical fiber before the appearance of any external signs.

During the test, lasted 137 min before the collapse, it has been possible to recognize different coupling soil-cable regimes, namely *initial soil-fiber matching*, *fully-coupled soil-fiber*, *partially-coupled soil-fiber*, and *post-collapse uncoupled soil-fiber phase*, characterized by a different efficiency in the coupling mechanism [5]. Very importantly, the growth of tension cracks in the slope, associated with an instantaneous release of energy, was detected by the optical fibers that measured sharp strain variations all along the flume. That moment marked the transition between the fully-coupled to the partially-coupled soil-fiber phase and occurred approximately 10 minutes before the full collapse.

With this experiment, we have shown the potentialities of this high-resolution optical system for landslide monitoring and physical model characterization. We believe that its effectiveness and sensitivity make it also a promising candidate for possible integration in early warning systems.

Keywords: Distributed optical fiber strain sensing, Shallow landslide, Physical model.

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