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Monitoring of shallow landslides by distributed optical fibers: insights from a physical model

Schenato Luca (1), Camporese Matteo (2), Palmieri Luca (3), Pasuto Alessandro (1), and Paolo Salandin (2)

(1) Research Institute for Geo-Hydrological Protection, National Research Council, Padova, Italy, (2) Department of Civil, Environmental and Architectural Engineering, University of Padova, Italy, (3) Department of Information Engineering, University of Padova, Italy

Shallow landslides represent an extreme risk for individuals and structures due to their fast propagation and the very short time between appearance of warning signs and collapse. A lot of attention has been paid in the last decades to the analysis of activation mechanisms and to the implementation of appropriate early warning systems. Intense rainfall, stream erosion, flash floods, etc, are only few of the possible triggering factors that have been identified. All those factors may induce an increase in the forces acting and/or in the pore water pressure that eventually trigger the collapse. Due to the decrease of the shear resistance of soils, significant stresses develop at the sliding surface, determining local anomalous strain even before the collapse. This highlights the importance of monitoring the early appearance of hazardous strain fields.
In light of the intrinsic lack of control and reproducibility in real cases, strain sensors have been applied in small-scale physical models and testbeds. Nonetheless, it has been observed that a reliable correlation between the landslide evolution and the strain field can be determined only by using minimally invasive sensors, while comprehensive information can be achieved at the cost of very fine spatial sampling, which represents the primary issue with small-to-medium scale physical models. It is evident how the two requirements, i.e. minimal invasiveness and high spatial resolution, are a limiting factor for standard sensor technology.
In this regard, strain is one of the first variable addressed by optical fiber sensors, yet only recently for geotechnical applications and in very few case for landslide monitoring. In particular, the technology of distributed fiber optic sensors, with centimeter scale resolution, has the potential to address the aforementioned needs of small scale physical testing.
In this work, for the first time, the strain field at the failure surface of a shallow landslide, reproduced in an artificial experimental hillslope, has been monitored by a distributed optical fiber sensing system based on optical fiber domain reflectometry with centimeter spatial resolution. The optical sensing system has been integrated with hydrological sensors for pore water pressure and moisture content, to the aim of supporting the data analysis. From the whole monitoring system a thorough knowledge of the collapsing mechanism has been achieved and it has been possible to identify precursory signs of the soil collapse well before its actual occurrence. The deployment of the sensing system and analysis of the collected data are discussed, together with possible potential for field installation.