Time-lapse ERT measurements to monitor rainfall triggered landslides at the laboratory scale

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ABSTRACT

To study landslide activities and monitor the conditions of the slope body, different parameters should be measured and evaluated over time. Rainfall is considered as one of the main landslide triggering factors for a majority of landslides in Europe. Considering the importance of groundwater in the mechanisms that govern the stability of slopes, monitoring of the hydrological conditions of hazardous slopes is very critical.

In a research initiated at the 'Applied Geology and Geophysics Lab' of Politecnico di Milano, Lecco campus, a landslide simulator was designed and used to reproduce small scale slopes. Integration of different geoengineering techniques (geology, photogrammetry, topography surveying, and geophysics) was possible to monitor a variety of parameters.

Time changes in the water saturation of the soil body were monitored using inverted resistivity sections. Failures were also detectable in resistivity sections, being compatible in time and space with the results of photogrammetry and topography surveying.

MATERIALS AND METHODS

To simulate rainfall triggered shallow landslides, a landslide simulator (Fig. 1) was designed with base dimensions of $2m \times 0.8m$. Scaling down a real event, a 15*cm*-thick sand layer was used for the landslide body, satisfying also the condition $h/L<1/10$ usually required to adopt the hypothesis of infinite slope used in slope stability analysis.

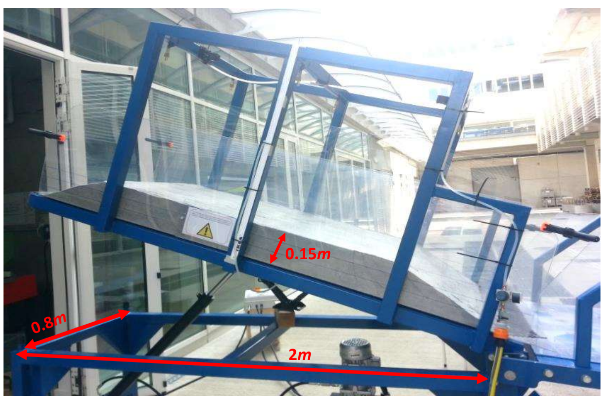

Fig. 1. Shallow landslide simulator.

We prepared two laboratory scale 24-channel cables (Fig. 2a) with 48 stainless steel mini electrodes for performing time-lapse ERT measurements on the landslide body. Four experiments were carried out in May and June 2017. Resistivity measurements were tried to be optimized after the first experiment (e.g., reducing the time of measurements, changing the azimuth of the profile). The electrodes were buried at the depth of 1*cm* in the middle of the slope body along the slope dip direction. The Wenner array with the spacing of 3*cm* was used for measurements. After failure of the downslope part of the soil body and losing the contact of the first electrodes, resistivity measurements continued with the remaining upslope 24 electrodes (Fig. 2b). Measurements continued until the upslope body also experienced failure.

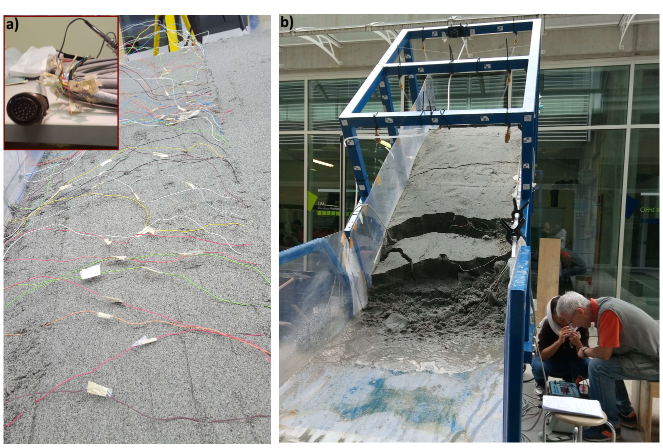

Fig. 2. a) Laboratory scale 24-channel cables were prepared to be compatible with IRIS Syscal Pro. b) After failure of the downslope part, resistivity measurements continued with the remaining upslope 24 electrodes.

RESULTS AND DISCUSSION

After activation of sprinklers and due to the infiltration of rainwater, significant changes occurred in resistivity values compared to the initial background measurements. Knowing the resistivity of water, we used TDR data to establish the petrophysical relationship between resistivity and water saturation for the material used in landslide simulator. All resistivity sections were then translated into water saturation models based on the obtained relation (Fig. 3).

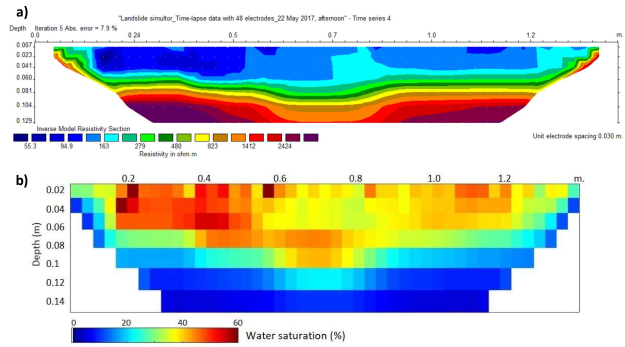

Fig. 3. a) Example of an inverted resistivity section. b) Translation of the resistivity section into water saturation section.

Fractures were observed to develop mainly at the borders of non homogeneous zones or where the soil was highly saturated. High resistivity zones began to be recorded before collapse and their times and locations were compatible with the development of fractures (Fig. 4).

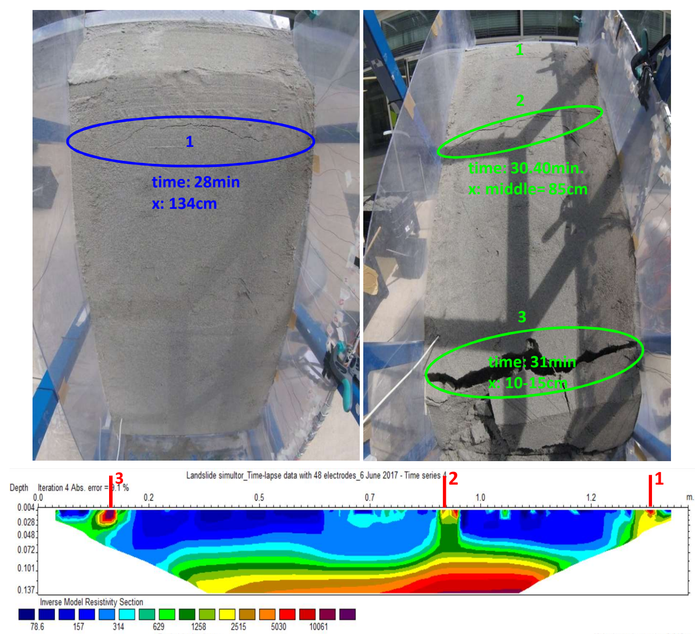

Fig. 4. Times and locations of fractures are compatible with high resistivity zones.

CONCLUSIONS

- Time-lapse ERT measurements can monitor water movement and accumulation in the slope body. This is helpful in assessing the hydrological state of the slope and its geotechnical state.
- Fractures developed at the borders of non homogeneous zones or when the soil was highly saturated. ERT images could predict fractures as high resistivity discontinuities being developed with time.
- Landslide body showed to become unstable where water saturation exceeded 40-50%. However, to define landslide triggering thresholds based on water saturation, more experiments should be performed to correlate different parameters.

ACKNOWLEDGMENTS

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