**Marie Curie European Reintegration Grants (ERG)**

**WANDLAND : “Effects of wetting and drying cycles on landslide activity”**

Grant Agreement number: 256426

**Final summary report**

**Introduction**

The purpose of this project was to improve the capabilities to understand and predict the occurrence of landslide crisis episodes associated with alternated rainfall patterns. Landslides are among the most severe problems that affect mankind in terms of loss of human life, damages to infrastructure and irreversible changes of natural environment. The situation is even more alarming when forecasts on clime evolution are taken into account and considering the associated changes in hydrological cycles and rainfall patterns (more extreme rainfall events and concentrated rain within shorter periods of time are expected). Despite the expected impacts, many issues have yet to be addressed to develop tools and methodologies able to protect people and property from these growing natural hazards.

From a geomechanical prospective, the link between the rainfall patterns and landslide occurrences is related to both the heavy modifications of pore fluid pressure distributions associated with these phenomena and the consequent changes in available shear strength within the slope. However, this kind of phenomena cannot be the only key to fully understanding the failure processes, especially in regions where extreme events are not exceptional. In these cases, failures sometimes occur in conjunction with rainfall whose features (intensity and duration) are not the most severe ones recorded for the particular area. In this context, establishing a warning system based on rainfall intensity and duration could be inappropriate. Considering the previous drying and wetting cycles which involved the soils is of crucial importance. In this context WANDLAND focused on the geomechanical impact of wetting and drying cycles in shallow landslides activity.

**Methodology and main results**

Three main components were considered and addressed in this project, namely:

1. Improvement of the constitute analysis of natural soil geomechanical behaviour associated with wetting/drying cycles;
2. Development of advanced experimental setup to quantify the mechanical response of natural soils under variations of their degree of saturation (or suction);
3. Advanced numerical modelling of rainfall induced landslides for an improved understanding of the triggering mechanisms and the establishment of early warning systems.

The mentioned aspects were investigated with particular focus on rainfall-induced landslides in steep soil slopes of volcanic origin. As to the constitutive behaviour of natural soils undergoing changes in the degree of saturation, focus has been put on the evolution of the retention capacity of the involved materials with the deformations induced by suction changes (Fig. 1). A hydro-mechanical constitutive model for unsaturated soils has been improved in order to consider the volumetric response of soil undergoing volumetric collapse upon wetting. The model has been used to analyse and predict the geomechnaical behaviour of volcanic ashes involved in shallow landslides in steep slopes. Experimental methods and apparatuses have been improved and used to characterize the hydro-mechanical response of the volcanic ash natural soil under a variety of stress paths involving changes in confining stress and suction (Ferrari et al. 2013). The evolution of the yield stress at different suction levels was also quantified. The volumetric response with suction variations allowed the analysis of the collapse upon wetting behaviour. Water retention and permeability were also addressed. Tests results were used to calibrate the constitutive model based on the effective stress concept extended to partially saturated conditions.

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|  | *Fig.1 Experimental analysis and simulation of the retention behaviour of clayey silty sand in drying processes at different initial void ratios (Salager et al. 2013)* |

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|  | *Fig. 2. Experimental and simulated behaviour of a volcanic ash for drying and wetting cycles with intermittent mechanical loading in a suction - mean effective stress plane (a) and the resulting void ratio changes (b) (Ferrari et al. 2013).* |

The experimental and constitutive analyses were used as a basis to perform finite elements numerical simulations in the context of constructing early warning systems in regions where extensive data

on landslide occurrences and associated rainfall were inexistent. In this part of the research, it has been proved that physically-based tools offer the possibility to establish thresholds for measurable field quantities. A combined finite element infinite slope model was used to study the transient hydraulic response of volcanic ash slopes to a series of rainfall events and to estimate seasonal safety factors. Furthermore, analytical considerations of partially saturated infinite slopes were made to define capillary stress thresholds for a landslide early warning system (Eichenberger et al. 2013).

**Project impact**

As a result of WANDLAND, 4 ISI journal papers were published, 10 conference papers were presented, 2 key-note presentations under invitation were performed to present the project results (details in the project database). The results of the project can serve as a basis for establishing early warning systems in rainfall-induced landslides in steep soil slopes of volcanic origin which are a major threat to human lives and infrastructure.

**References**

**A. Ferrari**, J. Eichenberger and **L. Laloui**. Hydro-mechanical behaviour of a volcanic ash, accepted for publication in Geotechnique, 2013.

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