ABSTRACT. Flow-like mass movements involving volcanic soils are widespread all over the world and often result on catastrophic consequences. Modelling of triggering mechanisms represents a fundamental step towards an adequate hazard assessment. Moving in the field of environmental geomechanics, integrated approaches and multidisciplinary studies appear as fundamental aspects for a better understanding, modelling and classification of such complex phenomena.

1. Introduction

Flow-like mass movements involving volcanic soils are among the most dangerous natural hazards because of their weak warning signals, long travel distances, high velocities and often huge involved volumes (Legros, 2002). They are widespread all over the world and can be triggered by several causes as rainfall, earthquake, weathering, human activities or their combination, frequently producing catastrophic consequences. Notwithstanding their similar consequences, these phenomena can present different first-failure and post-failure mechanisms, according to regional, seasonal and local features, triggering factors and mechanisms, soil properties and boundary conditions.

When facing such a complex problem, analyses are generally based on both classifications and models aiming to capture, under different assumptions, the essential features of the first-failure, post-failure and propagation stages. However, available classifications do not always allow a unique conceptual framework for the instability phenomena and a sector-based modelling can disregard some relevant factors characterizing the first and post-failure stages. This topic is in the following discussed with reference to the first-failure stage induced by rainfall.

2. Modelling of rainfall induced triggering mechanisms

Referring to flow-like mass movements induced by rainfall, a variety of triggering mechanisms are discussed in literature. They are mainly related to the soil shear strength reduction caused by the pore water pressures increase as a result of several phenomena: surface run-off, raising of the water table, groundwater supplies provided by artesian conditions or hidden springs, particular groundwater flow patterns related to the stratigraphic setting, increase of saturation degree in unsaturated soils (Leroueil, 2004). The appropriate modelling of triggering mechanisms, that can arise from one or more of the above conditions, represents a powerful tool for landslides hazard assessment. To this aim, the different available approaches can be classified into the following main groups: the black-box models, the geological models, the physically based models, the geomechanical models and physical models.

The use of each model, often allows satisfactory back-analyses of several phenomena at regional, local and site scale. However, with reference to hazard assessment and forecasting, the output of each model can be strongly conditioned and/or limited by several approximations. More reliable results could be achieved by joining the potentialities of some available models, in order to provide an adequate recognition, at different scales, of the relevant key factors, so allowing a significant improvement of both the understanding and classification of the studied phenomena. An example of the usefulness of a multidisciplinary approach is hereafter discussed.

3. A case study from Southern Italy

The case study refers to a sample area involved, on May 1998, by a catastrophic event that threatened five little towns of Southern Italy causing 160 victims (Cascini, 2004). To study this event several investigations were carried out. The in-situ activities included topographical surveys, stratigraphic investigations and soils suction monitoring using portable and in-place tensiometers (Cascini & Sorbino, 2002). Moreover, an extensive laboratory test program was performed on undisturbed and remoulded specimens by means of Suction Controlled Oedometer, Volumetric Pressure Plate Extractor, Richard
Pressure Plate and Suction Controlled Triaxial Apparatus, allowing the collection of a noticeable data set of physical and mechanical properties of the involved ashy and pumice soils (Bilotta et al., 2005).

By adopting a geological approach, rainfall-triggered mechanisms were found to be as strictly related to the bedrock morphological and hydro-geological features, as well as to the past and actual processes involving pyroclastic covers. From the analysis of all the available elements, six typical triggering mechanisms were recognised and mapped all over the sample area. They are characterised by different intensity in terms of mobilised volume and travel distance and they are not casually distributed on the massif.

In order to validate these triggering mechanisms, simulations on the mechanical processes, able to reproduce in-situ evidences, were performed at massif, site and Representative Elementary Volume (REV) scales. The preliminary analyses took account of: simple constitutive models with a non-associated flow rule; a saturated-unsaturated groundwater modelling by means of a commercial finite element code (Geo-Slope, 2005); limit equilibrium method, analysing the slope stability conditions, based on the previously computed pore water pressures. The obtained results were then used to assess the instability scenarios and to point out the most relevant triggering factors at massif scale (Geo-Slope, 2005). Successively, uncoupled finite element analyses were addressed to deepen the understanding of the in-situ instability conditions, by adopting an elasto-plastic model with a Mohr-Coulomb criterion extended to unsaturated conditions (Fredlund et al., 1978). Finally, fully coupled analyses were performed by means of the GeHoMadrid finite element program (Pastor, 2002), assuming plane strain and 3D conditions and using respectively eight-node and twenty-node elements for the calculations.

The obtained results strongly encourage towards an integrated multidisciplinary approach, as highlighted in Figure 1 that refers to a typical triggering mechanism, producing elongated source areas, induced by both rainfall and water supplies from the bedrock. As a matter of fact, the results of both geological and geomechanical analyses are capable to match the in-situ evidence, while similar results are not obtained by any of the sector-based approaches used to face the problem, as it can be observed referring to the wide scientific literature on the topic (Cascini et al., in press).

![Figure 1](image)

Figure 1. A typical triggering mechanism: a) in-situ evidence, b) geological model, c) limit equilibrium analysis, d) displacement contours for 2D uncoupled FEM analysis, e) plastic strains for 3D coupled FEM analysis.

4. References


