Geophysical Research Abstracts
Vol. 13, EGU2011-8247-2, 2011
EGU General Assembly 2011

Physical and mathematical modelling of infiltration into layered pyroclastic covered slopes

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During intense and persistent rainfall events, shallow landslides are frequently triggered in mountainous areas of Campania (Italy). The physical characteristics of the involved soils are such that landslides often evolve in form of debris flows, causing huge damages to buildings and infrastructures and, in some cases, casualties.

The slopes are covered with pyroclastic deposits, in form of alternating layers of volcanic ashes and pumices, laying above a pervious fractured calcareous bedrock, in some cases covered by a layer of impervious weathered ashes. Slope inclination is often larger than internal friction angle of such ashes (around 38°), thus equilibrium is assured by the contribution of apparent cohesion due to soil suction in unsaturated conditions. That is why, when soil approaches saturation and consequently suction decreases, slope failures often occur.

Understanding the role played by the different layers and by the bottom boundary condition at the soil-bedrock interface is essential to develop reliable models of layered slope response to rainfall infiltration, allowing to define triggering conditions of landslides. To this aim, infiltration tests in small scale model slopes have been carried out in an instrumented flume.

In the flume, a model slope is reconstituted by a moist-tamping technique and subjected to an artificial uniform rainfall. The state of stress and strain of the soil is monitored with various sensors during the entire test. In particular, soil suction is measured at different locations and depths with mini-tensiometers, and soil moisture is measured with TDR, here applied with an innovative technique allowing to estimate soil water content distribution along the entire thickness of the deposit. Infiltration and evaporation experiments in artificial slopes, with alternating layers of volcanic ashes and pumices, have been carried out with various inclinations and bottom boundary conditions.

Coupling measured values of soil suction and water content have allowed to define water retention curves for volcanic ashes and pumices. The curves obtained for the ashes look quite different form retention curves obtained with standard laboratory techniques over either undisturbed or reconstituted soil specimens. The performed infiltration experiments have been simulated with a mathematical model based on the integration of Richards equation with the finite volumes technique. The use of the retention curves obtained from the slope infiltration experiments, rather than the curves estimated from small specimens, resulted in a substantial improvement of the agreement between simulation results and experimental data, confirming the reliability of the obtained curves and the importance of physical modelling for building up reliable mathematical models of infiltration in complex geometry.