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Physical and mathematical modeling of transient infiltration through shallow layered pyroclastic deposits

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Layered pyroclastic deposits covering steep slopes, characteristic of large mountainous areas of Campania (southern Italy), are often affected by shallow landslides triggered by heavy rainfall events. In fact, the equilibrium of such deposits is usually guaranteed by the contribution to soil shear strength offered by soil suction, which decreases during wetting. As the return period of the triggering events has been in many cases not extreme, other factors concur to establish triggering conditions. In this respect, heterogeneities, strongly affecting transient infiltration, may in some cases play a crucial role.

In this study, the effect of the presence of soil layers, characterized by markedly different hydraulic properties, on the rainwater infiltration process is investigated. In fact, the pyroclastic covers of Campania, being the result of the deposition of materials originated by several eruptions of the nearby volcanic complexes, usually consist of alternating layers of ashes (silty sands) and pumices (gravel with sand).

The presence of coarse-textured pumices between finer ashes strongly affects the infiltration process. In fact, the pumices, which are characterized by saturated hydraulic conductivity larger than ashes, are capable of retaining less water than ashes in unsaturated conditions, so that their unsaturated hydraulic conductivity is usually very small. Hence, depending on the water potential distribution throughout the cover at the onset of rainfall, pumices may act as a barrier to the propagation of the wet front (the so-called capillary barrier effect), or, approaching saturation, let the water pass through them very quickly.

Such a complex behavior has been studied by means of a series of infiltration experiments carried out in an instrumented flume in the Geotechnical Laboratory of the University of Campania (http://www.dicdea.unina2.it/it/dipartimento/laboratori/laboratorio-di-geotecnica). Starting from different initial moisture conditions, small scale physical models of layered slopes, with various geometry and inclination, have been subjected to rainfalls of various intensities. During the infiltration processes and the following water redistribution phases, soil moisture and matric potential have been measured at various locations by means of TDR probes and tensiometers, respectively. The interpretation of the experimental results has been aided by a 2D mathematical model based on the integration of Richards' equation with the finite differences method.

The obtained results indicate that a layer of dry pumices may induce lateral redistribution of water through the overlying ashes. In steep sloping deposits, this may favor the establishment of downslope directed subsurface runoff, which drains part of the infiltrating water towards the toe of the slope. In real slopes, depending on local morphology, such a downslope flow may have a beneficial effect on slope stability, as some water is drained out of the slope, or may even contribute to the establishment of triggering conditions, as it can result in flow concentration leading to local failure.