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Instability conditions of the landslides triggered by the 2006 rainfall event in Ischia Island, Italy

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Ischia is an active volcanic island located in the Tyrrhenian Sea, approximately 30 km WSW from the city of Naples in Southern Italy. On 30 April 2006, following several hours of rainfall, four small soil slips-debris flows were triggered on the slopes of Mt. Vezzi (ca. 400 m a.s.l.), in the SE portion of the island. The flows caused the deaths of 4 people, forced the evacuation of another 250 inhabitants and destroyed several buildings.

The steep slopes of Mt. Vezzi are conditioned by the volcanic activity of the last 10.000 years: a 1 – 2 m thick soil derived from the weathering of pyroclastic material overlies thick fallout deposits produced by the last eruptions. The debris flows initiated as soil slips at the soil – fallout interface, in hollows with slope gradients ranging between 35˚ - 40˚, and quickly transformed into flows that reached the floodplain at the base of the hill, finally coming to a stop in a low gradient road. The flows started at elevations ranging between 310 and 350 m and stopped at approximately 80 m, corresponding to travel angles of 20-24˚. The volumes of the single events ranged from 2000 – 5000 m^3.

Two field campaigns carried out immediately following the events were focused on collecting geotechnical data in the source area (angle of internal friction, unit weight, water content, grain size, etc.). Material shear strength was determined both in the laboratory on reconstituted samples and in-situ by means of Borehole Shear Tests (BST) coupled with a tensiometer for the measurement of matric suction. Soil strength

was assessed both in partially and totally saturated conditions.

Soil hydraulic conductivity was quantified by means of in-situ constant head permeameter tests. These highlighted a marked contrast in permeability between the soil and the underlying pumice layer. Saturated hydraulic conductivity values ranged from 1.2 x 10^{-5} m/s in the former to 6.2 x 10^{-8} m/s in the latter.

Soil slip triggering conditions were analyzed on the basis of precipitation data related to the 24 hour period prior to the event using two different approaches: a coupled seepage-stability analysis and a geotechnical modelling by means of the ring shear apparatus DPRI-No.7.

The former approach consists in the modelling of changes in positive and negative pore pressures during the event by a finite element analysis in transient conditions, using the software SEEP/W (Geo-Slope Int.). Positive and negative pore pressure distributions obtained from the seepage analysis were used as input data for the stability analysis. This was performed with SLOPE/W, applying the limit equilibrium method (Morgenstern-Price) for each of the time steps used in the seepage analysis. The Mohr-Coulomb criterion in terms of effective stress was used in the case of positive pore pressures, while the Fredlund et al. (1978) criterion was applied in the case of negative pore pressures. The results show that the distribution of pore pressure conditions are largely influenced by the high permeability contrast between the soil pyroclastic cover and the underlying pumice layer, by the soil type and by the limited thickness of the cover. The instability condition are reached 10 hours after the beginning of the rainfall event with a value of pore water pressure along the shear surface of about 7 kPa.

The ring shear apparatus DPRI-No.7 is a geotechnical instrumentation developed at the Disaster Prevention Research Institute at Kyoto University. The shear apparatus has an inner diameter of 27 cm and an outer diameter of 35 cm, the maximum sample height is 11.5 cm. The apparatus has two kinds of shearing controlling modes: shear speed-controlled mode and shear stress-controlled mode. By means of a gap-controlling system with a precision of 0.001 mm, the shear box can be kept in fully undrained condition.

Seven tests have been conducted on Ischia samples: 5 stress-controlled tests at naturally drained conditions and 2 speed-controlled tests at undrained conditions. Given certain values of normal load and back pressure, shear displacement, shear resistance and pore water pressure were measured. The simulation of the triggering conditions on Ischia samples highlights that the drop of shear resistance occurs when the pore water pressure on the failure surface reaches a value of about 6.5/7 kPa, in good agreement with SEEP/SLOPE modelling.