DOTTORATO DI RICERCA IN INGEGNERIA CIVILE PER L'AMBIENTE ED IL TERRITORIO
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ABSTRACT
TESI DI DOTTORATO

GENESIS AND MECHANISMS OF RAINFALL-INDUCED HYPERCONCENTRATED FLOWS IN GRANULAR SOILS

(GENESI E MECCANISMI DI FLUSSI IPERCONCENTRATI INDOTTI DA PIOGGIA IN TERRENI GRANULARI)

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Heavy rainfall on steep hillslopes may cause either shallow landslides or soil superficial erosion and different flow-type phenomena may originate in adjacent/overlapping source areas. Consequently, great amount of water and debris can be conveyed at the outlet of steep mountain basins where huge consequences are often registered.

Recent studies outline that first-time shallow slides may turn into debris flows or debris avalanches; conversely, slope instabilities initiated by erosion phenomena generally propagate as hyperconcentrated flows. In particular, the scientific literature points out that the latter ones are mass transport phenomena, that involve granular unsaturated soils covering steep slopes and are constituted by water and debris with solid concentration (in volume) variable from 20 to 47 %. Generally, these phenomena are characterised by a high spatial and temporal variability, especially in water discharge and sediment concentration. Therefore, suddenly and repeatedly, high peak discharge with high sediment concentration can reach the outlet of the basin and cause victims and damages.

The genesis of the hyperconcentrated flows is related to three main processes: i) rainfall infiltration, ii) runoff generation and iii) solid particle mobilisation due to erosion processes.

The main goal of the PhD research activity is twofold: i) to achieve a better understanding of the genesis mechanisms of hyperconcentrated flows, ii) to perform quantitative evaluations of the amount of water and debris propagating inside a mountain basin and, finally, reaching the outlet of the basin.

A multi-scale approach is used: i) at slope scale, the mechanisms of runoff generation are analysed through a Finite Element Method (FEM) model; ii) over large area and at basin scale, the triggering of hyperconcentrated flows and propagation of water and solid are analysed through an empirical model and a physically-based Finite Difference Method (FDM) model, with special emphasis on a study area repeatedly affected by these phenomena, iii) at particle scale, the rainsplash erosion is preliminary modeled through the numerical Discrete Element Method.

At slope scale, the mechanisms of rainfall infiltration and runoff generation are analysed taking into account the soil unsaturated conditions and rainfall intensity. The analyses show that time to runoff, failure time and the amount of rainfall infiltrating the ground surface and runoff flowing as wash out, strongly depend on soil water characteristic curves, soil initial conditions, rainfall intensity and slope angles.

At large area, a study area (about 130 km^2), repeatedly affected by flow-type phenomena, is selected and parametric analyses are performed concerning either first-time shallow landslides or soil erosion. The results point out that different possible scenarios may occur, depending on soil initial suction, that, in turn, changes during the year and also strongly affects the spatial and temporal occurrence of the runoff generation. These results are compared with a relevant past event occurred in the study area, obtaining a satisfactory agreement with in situ evidences.

At basin scale, two medium-size mountain basins (about 10 km^2) are selected in the previous study area, and parametric analyses are performed in order to evaluate tha spatial distribution of soil erosion, the water and solid discharges and the sediment concentration at the outlet of the basins. The achieved results show the possibility to simulate realistic rainfall events, to forecast the soil erosion along steep slopes and channels and to compute the water and solid discharge over the time that may be conveyed at the outlet of the basin.

At particle scale, the mechanism of rainsplash erosion due to impact of the drops on the ground surface is deepened through a numerical Discrete Element Method (DEM) model. This new type of analysis allowed to verify the applicability of the geomechanical approach to this erosion mechanism, also reaching some interesting preliminary results.

Globally, the PhD thesis provides an update overview of the genesis processes of an hyperconcentrated flow with novel specific contributions at different scales of analysis, from large area (> 100 km^2) to single soil particle (diameter < 1cm).