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Numerical modelling of entrainment/deposition of rock and debris-avalanches

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Rapid moving landslides includes different types of phenomena. Rock and debris avalanches, as well as debris flows, are characterized by different behaviours with respect to other landslide types. In particular they can travel long distances along variable topographies made of different materials. The evolution of debris and rock avalanches can be strongly influenced also by the conditions in the initial part of the failure. Water content within the landslide mass and the geometry of the initial failure surface can cause an accelerated rock mass opening and fragmentation and a successive increment in mobility. On the contrary, the geometry of the failure surface can also preclude the dismembering of the rock mass and the general behaviour tends to be similar more to that of a rock-slide with only minor flow characteristics. As a consequence, the rock mass tends to behave more or less coherently and very large rock mass blocks can be found in the deposits. Because of these constrains the study of debris- and rock-avalanches requires a complete analysis by taking into account the initial water content, three dimensional effects connected to failure surface geometry and path topography. Furthermore, during their motion the rock avalanches can entrain large volumes of sediments both in a dry state and in a saturated state. Entrained dry material has generally the consequence to reduce the total landslide runout, whereas entrainment of almost saturated material can have a more complex consequence. Sudden undrained loading and entrainment of a saturated substrate can cause enhanced mobility and major consequences on the hazard zonation. Results from a finite element code, allowing to simulate the motion of the moving landslide mass on materials with different properties (e.g. hard substrate or erodible soils) and along very rough topographies (e.g. including sharp geometries as deep and narrow gorges), are presented.

Erosion and deposition can thus be modelled as well as interaction with obstacles of different characteristics. We present two main examples of the modelling problems and capabilities by starting from two case studies. One showing instability of a large rock slide for which detailed pre- and post-failure topographic descriptions are available. Final geometry, mass redistribution, velocities and runup are used to validate the model capabilities. The second example shows the effects of the interaction of a large rock-slide/rock-avalanche with the thick alluvial sediments placed along the flat sector of the landslide path. Again the available pre- and post-failure topographies, together with cross-sections showing entrainment, pushing and folding of the sediments, are used to verify the model capabilities. The role of the physical and mechanical properties of both the landslide material and the sediments has been studied through a sensitivity analysis showing the various evolutionary possibilities. We retain this as a major step in numerical modelling of such phenomena where only depth averaged models are currently available with entrainment models based only on empirical and semi-empirical laws without considering the real physical and mechanical properties of the erodible substrate. Eventually, this approach should allow for more realistic and physically based spreading forecastings and design of countermeasures.