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Comparative study of Hill-slope-debris flow using field estimation and continuum and discrete numerical approaches to determine impact pressures

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In Switzerland, shallow landslides and hillslope debris flows are responsible every year for high infrastructure damage, blocking of important highways, evacuations and deaths. Moreover, these processes could increase the damage caused by floods by clogging channels and rivers at bridges and passages. Unlike rockfalls and avalanches, the understanding of these processes is still lacking; specially in predicting the triggering, frequency and magnitude of shallow landslides in a realistic manner. Assessments of such natural hazards is therefore mostly based on experience of experts. In order to improve the hazard assessment, new tools and methods are needed to calculate the disposition, the evolution as well as the run-out of a shallow surface sliding on a slope for different situations (normal situation, severe precipitation, with and without forest cover, etc).

We present a comparative study of shallow landslide events that took place in different Swiss cantons. The events included considerable damage to the nearby houses. The pressure applied by the flow on the houses was back-calculated using the strength of damaged structural elements. This pressure was then compared to three numerical models: MFlow, YADE-dry and YADE-cohesive. MFlow model, which is a continuum based model, is a further development of the tool RFlow which was developed in the University of Lausanne for modelling Rockfalls, avalanches and floods. MFlow has been developed and applied to the different events of hill slope debris flows predicting the run-out distance and the pressure applied by the flowing mass. YADE on the other hand, is a discrete-element-method (DEM) based tool which is used to describe interactions on the micro-scale. At each time step, particles in contacts are detected and their overlapping distances are estimated. Afterwards, the chosen contact law is used to calculate the interaction force which is then used in Newton's second law to get the acceleration. Next, by integration, the new positions of particles are calculated. Surface elevation models were imported from GIS to YADE using special STL algorithms. YADE-dry uses a linear elastic contact law presenting the flow as a dry one. YADE-cohesive is a more advanced one (based on the work of Luding 2008) which accounts for the presence of cohesion by using an elasto-plastic-adhesive model.

The comparison of applied pressure on the houses between the different methods revealed that MFlow and YADE-dry predict similar values with a slight advantage of the latter. YADE-cohesive provided a more-detailed description of the flow and allowed to consider the cohesion caused by the water-clay mixture of the flow. After calibrating YADE-cohesive, a further investigation was carried out for the flowing velocity, flow height and the run-out distance. In addition, relation between water content percentage and cohesion values were investigated. Conclusions of all these micro-scale investigations will be used to develop MFlow into a tool in which engineers can use for the prediction of Hill slope debris flow run out distance in addition to their damage to infrastructural elements.