Comparing a newly developed DEM-based runout model for hillslope debris flows with full-scale experiments and historical events

Adel Albaba, Niels Hollard, Christoph Schaller, Massimiliano Schwarz, and Luuk Dorren
Department of Forest Science, Bern University of Applied Science, Zollikofen, Switzerland (adel.albaba@bfh.ch)

The increasing urbanization of mountainous areas increased the risk imposed on residential buildings and infrastructure. In Switzerland, shallow landslides and hillslope debris flows are responsible every year for high infrastructure damage, blocking of important highways, evacuations and deaths. Up till now, the assessment of these processes has been mainly based on the experience of experts, especially in the assessment of their run-out extent and expected damage. In this research we present a new computationally efficient Discrete Element Model (DEM) which has been developed for the aim of simulating the run-out of hillslope debris flows.

YADE-DEM open source code has been extended and an elasto-plastic adhesive contact law have been implemented, which partially account for the presence of the fluid composed of water and find material. This is achieved through the adhesive aspect of the contact law, which would indirectly take the presence of such fluid into account, as this fluid would increase the cohesion of the flowing mass. A parametric study has been carried out to define the most sensitive model parameters, which were found to be the microscopic basal friction angle ($\Phi_b$) and the ratio between stiffness parameters (loading and unloading) of the flowing particles ($k_1/k_2$). Data of full-scale experiments of hillslope debris flows were used to compare the flow kinematics with the model's prediction. A good agreement between the model and experiments was observed concerning the mean front velocity (average margin of error of 8%) and the maximum applied pressure (average margin of error of 5%), with less agreement of the flow height (average margin of error of 13%). Detailed comparisons of pressure evolution between different selected experiments and simulations revealed the model's capability of reproducing observed pressure curves, especially during the primary loading phase, leading to maximum pressure.

In order to test the model's prediction of run-out distance of hillslope debris flow, hundreds of past hillslope debris flow events in the Swiss Alps were analyzed and 30 cases were selected representing different situations (i.e. different release volumes, slopes and forest cover). Due to the discrete nature of results in YADE, a GIS algorithm was developed in order to create envelopes representing the temporal evolution of the simulated propagating processes, which were compared to the those of the historical events. Results of the comparison revealed that, with the calibration of the two sensitive parameters in YADE, a fair to very good agreement was observed.
between the envelopes of the model and those of historical events for 87% of the tested cases. Difficulties in reproducing the envelopes of the rest of the cases are linked to the uncertainties in the mapping of the envelopes of past events, the role of the forest which is not taken into account in the model, and the lack of direct representation of fluid in the model.

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