Runout analysis of rapid, flow-like landslides

A review of common methods and back-analysis of two examples

Introduction: A growing population and a need for natural resources is resulting in new developments on or below unstable slopes. This trend and more extreme weather conditions are responsible for an increasing number of landslides, resulting in huge socioeconomic losses. Debris flows, debris avalanches, rock avalanches, and flow slides are amongst the most dangerous landslides. They are extremely rapid and cause significant destruction along their path, often far from their origin.

Objective: Runout analysis, used for the prediction of landslide motion and its effects, is a very important assessment component for the management of landslide risks. The overall objective of this thesis is to present a broad view of the post-failure motion of landslides. Different runout approaches are discussed and applied to the USGS debris flow experiments and the case study: the Goldau rock avalanche. The ultimate goal, however, is the creation of a substantial database of calibrated input parameters for the numerical models. This database may in future be a useful tool for predicting landslides.

Result: Runout prediction methods can be empirical or analytical. The empirical methods use correlations of real events to estimate the runout distance, but they are generally not capable of estimating the intensity parameters, and show a large scatter. In sensitive areas it is recommended to use the more rigorous analytical approaches which are capable of accounting for local geometry and materials. Analytical approaches include the sliding block model and depth-averaged continuum dynamic models. Both models were tested and used in this work. For the continuum dynamic models, DAN and DAN3D were used; in the former, the landslide motion is simulated along a user prescribed path and in the latter, across three-dimensional terrain. These models are capable of accounting for strain-dependent, non-hydrostatic internal stresses, material entrainment; and varying rheologies along the path. They are efficient and have been tested against and back-calculated full-scale tests, showing good results. The back-calculations for the USGS debris-flow experiments and the Goldau rock avalanche performed in this work confirm the capability of DAN and DAN3D to model a large variety of flow-like landslides. Since these models are based on the "equivalent fluid" approach, a hypothetical landslide mass based on a rheological relationship, typical patterns regarding the rheology and motion mechanisms of different landslides have to be identified through back-calculation of real events. Some typical patterns of debris flow and rock avalanches have been identified in this work: self-channelization in debris flows; the lubricating effect of eroded liquefiable path material; and a mud surge ploughed on the margins in rock avalanches, all resulting in a larger impact area. The back-calculated rheology-parameter in this work, together with other reported values, can be used for a forward prediction of the runout of landslides in similar environments.