DEBRIS FLOW SIMULATION AT ILLGRABEN, SWITZERLAND, USING 2D NUMERICAL MODEL RAMMS

DEBRIS-FLOW MODELING APPLICATION IN PRACTICE

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INTRODUCTION

Debris flows are an important natural hazard in mountainous areas. Endangering people, settlements and transport corridors, they have to be considered in hazard analyses and consequently in protection measures. Debris flows are gravity-induced mass movements composed of sediment and water and have large flow velocities and transport capacities. Damages occur from the large impact forces at the front, erosion and deposition of sediment in the channel and on the fan.
The Illgraben in Switzerland is one of the most active torrents in the Alps, with several debris flow events per year. The village Susten located on the Illgraben fan is endangered by large debris flow events. Therefore, hazard zones were mapped and various protection measures were planned.
Numerical models, where both the process and the interaction with possible protection measures are analyzed, can give useful information for practical projects. For this project we used the 2D numerical model RAMMS developed by the Swiss Federal Institute for Forest Snow and Landscape Research WSL. The model results were used in combination with traditional methods and estimates.
Here we show how RAMMS was applied in a practical project and discuss advantages and difficulties we experienced during debris flow modeling and in the interpretation of the results.

FIELD SETTING

The Illgraben catchment (10.4 km^2) located in southwestern Switzerland extends from the summit of the Illhorn (2716 m asl) to the outlet of the Illgraben into the Rhone River (610 m asl). The climate is temperate-humid and annual precipitation is relatively low. The subcatchment (4.6 km^2) with debris flow activity is composed of quartzite, dolomite, limestone and schist, and slopes are very steep. The Illgraben fan has a radius of about 2 km, and the slope of the channel on the fan is 8% to 10%. The village Susten (community of Leuk) is located on the right side of the fan; the left side is covered by the Pfyn forest (protected area). After a large rock avalanche in 1961, the Illgraben channel was protected by a large sediment retention basin in the middle section of the Illgraben trunk channel and additional 28 check dams farther downstream. A large variety of flow types has been observed spanning the range from granular debris flows to muddy debris flows and floods. To take advantage of the frequent debris flow events, an observation station is run by WSL since 2000 and debris flow properties and precipitation data are recorded automatically (e.g., Badoux et al., 2009).

DEBRIS FLOW MODELLING WITH RAMMS

RAMMS is a 2D numerical simulation tool developed by the Swiss Federal Institute for Forest, Snow and Landscape Research WSL. The debris flow process is modeled dynamically, using the shallow water equations for granular flow. The model is designed to predict the flow in 3D alpine terrain and simulation output maps for flow height, flow velocity and impact pressure of a flow can be generated. Due to similarities of debris flows and avalanches, we used the avalanche module in this project (a debris flow module is in development at the WSL, however the equations solved by the model are

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identical with the avalanche model). A Voellmy-fluid friction model is employed to describe the frictional behavior of flowing debris and consists of a dry-Coulomb type friction (μ) and velocity squared drag (turbulent friction, ξ). For reliable simulation results, these friction parameters have to be calibrated carefully using historical debris flow data.

APPLICATION OF RAMMS FOR HAZARD MAPPING AND PROTECTION MEASURES

RAMMS was run in this project with a digital elevation model (DTM) with 2.5 m grid size (DTM AV by swisstopo). The entire debris flow volume was released as a single block and no erosion was specified. For the calibration of the friction parameters, debris flows with volumes of 50'000 and 100'000 m^3 material (debris and water) were modeled. The friction parameters were adjusted to yield plausible flow velocities, flow heights and runout distances on the fan considering data from historical events recorded by WSL. Best simulation results were achieved with the friction parameters set at μ=0.07 and ξ=200 [m/s^2].

Scenarios for debris flow events at Illgraben are 100'000 m^3, 250'000 m^3 and 500'000 m^3 debris material for frequent, rare and very rare events, respectively. Additionally, the DTM was modified in the channel area to account for large changes in the level of the channel bed over a short time (Berger et al., 2010). After visualization of the modeling results in a GIS, flow paths on the fan were analyzed and outbreak locations along the torrent were identified. These findings were compared with traditional estimates of debris flow parameters (e.g., Rickenmann, 1999), cross-profiles of the channel regarding discharge capacities, and verified in the field. Generally, modeling results fitted well. However, excessive spill over was observed in curves and runout distances outside the torrent on the fan tended to be too large. For the protection measures, the DEM was modified (e.g., lateral dams, increased discharge capacity, or deflection of the flow), and the effects of the protection measures on flow behavior and outbreak locations were analyzed.

OUTLOOK

At Illgraben, preconditions were ideal for application of RAMMS in a practical project. A large number of debris flow events are documented and information on flow parameters is available due to the monitoring by WSL (McArdell et al., 2007). This reduces much of the uncertainty in applying models for such situations. The modeling results were very useful for the project with respect to the flow behavior, flow paths and outbreak locations. However, the calibration process was time consuming despite the good data basis, and a simulation run took more than 24 hours.

Calibration of the friction parameters is essential for a realistic model output. At many other torrents where dynamical runout models could be applied, good records on historical events are sparse. Therefore, a major difficulty would be the calibration of the model in this setting. Furthermore, the critical interpretation and verification of the modeling results in the field is essential and simulations should only be used in combination with traditional, field-based methods, also because no guidelines have yet been developed for the application of dynamical computer models for hazard mapping in Switzerland.

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Keywords: debris flow modeling, RAMMS, hazard mapping, protection measures