IMPACT PRESSURES OF HILLSLOPE DEBRIS FLOWS

BACK-CALCULATION AND SIMULATION (RAMMS)

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INTRODUCTION

According to the analysis of the 2005 flood event, around 5000 superficial landslides and hillslope soil / debris flows have been triggered by the heavy rainfalls from August 2005. Due to their sudden initiation, the limited forecasting possibilities and the movement in form of high velocity flows, these processes may strongly endanger people, animals as well as infrastructure and material goods. The impact forces exerted by hillslope debris flows on constructions are largely unknown und poorly documented. Better knowledge of these processes and of their physical parameters is needed to establish accurate hazard assessments, or in order to effectively protect existing or new constructions, or to properly dimension technical countermeasures. The occurring intensities - a key-parameter by hazard assessment and mapping - need to be better understood, both qualitatively and quantitatively. Only a reliable hazard assessment can ensure appropriate implementation of the hazard maps with corresponding risk reduction (land-use planning, technical countermeasures, organizational measures such as preventive evacuation, etc.).
The Federal Office for the Environment, together with the Egli Enginnering Ltd and the Swiss Federal Institute for Forest, Snow and Landscape WSL has launched a research project in 2008 on these topics. Detailed analysis of the results are still in progress.

OBJECTIVES AND METHODOLOGY

The main goal of the carried investigations is to identify the intensities and effective stresses exerted on constructions by hillslope debris flows based on real events with documented damages. The following questions should be answered by the end of the project:

1. Which forces lead, by various construction types (wood, brickwork/masonry, concrete wall, combination of several types) to which consequences (no damage, partial damage, total damage)?
2. Which relationship can be found, if any, between these forces and the intensity criteria used at present in hazard assessment and mapping (thickness of the possibly unstable layer, thickness of the slide/flow deposit)? Is there a need to adapt or to complete the mentioned intensity criteria to ensure a more accurate and reliable hazard mapping?
3. Which recommendations can be issued for proper dimensioning of protective measures (taken directly at the object or construction)?

Twenty case studies (buildings partially damaged by superficial slides or hillslope debris flows) are investigated. Based on the structure of the building and the observed damages, back-calculations of the impact pressures or pressure domain, which likely occurred during the event, are made in a first step by a structural engineer. In a second step, the slide / flow events are simulated to reconstruct the resulting actions using the numerical natural hazard simulation tool RAMMS (RApid Mass MovementS) developed at the WSL.

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EXAMPLE (ALPNACHSTAD)

1. **Event /** Two houses in Alpnachstad have been damaged by several debris flows on 21 August 2005 (see Fig. 1). The studied building (marked with a circle) was protected by a wall, which suffered relatively little damage in form of cracks. The house is situated at the foot of a steep pasture where six debris flows were triggered by the heavy rainfalls; two debris flows hit the house. The thickness of the unstable layer was near to 0,5 m whereas the thickness of the deposit pressed against the protective wall reached 2 m.

Fig. 1 Debris flows from August 2005 in Alpnachstad

2. **Structure /** The considered building is a two-storey house, partly built "in" the slope. Uphill, basement and first floor have no openings and lie underneath the natural ground surface. The uphill wall is made of concrete and acts simultaneously as a protective wall. Pressures between 7-30 kN/m^2 have been necessary to generate the cracks observed in this wall after the flow impact.

   RAMMS / The RAMMS model solves the depth-averaged equation of motion for granular flows in two directions, and it uses the Voellmy rheological relation to describe the frictional behaviour of the flow. Input parameters for the simulation are the following: thickness of the unstable layer 0,5 m, volume 71 m^3, Coulomb coefficient Mu 0.4, and turbulent flow coefficient Xi 150 m/s^2. The simulation provided the following maximal values: impact pressure ~9-13 kN/m^2 (see Fig. 2), velocity ~2.5 m/s, flow height ("free", that is without any obstacle) ~0.2-0.4 m.

Fig. 2 Debris flow simulation

3. **Comment /** The impact pressures calculated with RAMMS (9-13 kN/m^2) lie in the lower part of the range specified by the structural engineer (7-30 kN/m^2).

CONCLUSIONS

The preliminary results (December 2010) show an overall good correspondence between the impact pressures reconstructed by the structural engineer and those simulated using RAMMS. One problem is the great spatial variability of the debris mixture and of the processes, ranging from "true" soil/debris slides, experiencing only minor displacement, to flow processes with very long and broad runout zones. RAMMS appears to be a suitable tool for detailed studies and dimensioning of protective measures; further development is however needed before using it in everyday practice. The usual intensity criteria for hillslope debris flows (thickness of the unstable layer, thickness of the deposit) allow deduction of the same intensity classes as those derived from the impact pressures; they seem therefore suitable for hazard assessment and mapping.

Keywords: debris flow, simulation, impact pressure