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LARGE SCALE FIELD TESTING OF HILLSLOPE DEBRIS FLOWS RESULTING IN THE DESIGN OF FLEXIBLE PROTECTION BARRIERS

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INTRODUCTION

In a disused quarry in Veltheim, Switzerland, we release up to 50 m^3 debris material down a 40 m long and 30° steep channel. The muddy and erosive flows obtained are similar to hillslope debris flows observed in nature. 30 m downstream from the retaining basin, we measure the front velocity, the flow height and the impact pressure on obstacles (see Fig. 1). At the lower end of the channel a flexible test barrier is installed. Load cells built in the support ropes of the barrier measure the forces during impact.The objective is to relate the flow parameters to the loads measured in the barrier during impact. The FARO software (Volkwein 2004) modelling the flexible barrier is used to compute the impact loads. The load model is chosen on the base of the impact pressure measurements. Data and computations for over 20 tests allow us to validate the flexible barrier design method.

METHODS

To design protection measures against landslides or debris flows, few approaches exist in Switzerland. Flexible barriers against debris flows are designed using a so called multi-surge model. Each surge consists of a hydrostatic and a dynamic pressure component. The dynamic load is expressed as the product of the impact velocity square with the flow density and with an impact coefficient c that depends on the material properties (Wendeler 2008). The coefficient c ranges between c=0.7 for watery flows and c=1.0 for viscous flows monitored at the Illgraben torrent in Switzerland. These values are in contradiction with the Swiss guideline setting the impact coefficient for mudflows to c=2.0 for stiff structures (Egli 2005). The question to be asked is if the difference between the impact coefficient values relies on the nature of the obstacle, flexible structure on the one hand and stiff structure on the other hand or if the impact coefficient is overestimated in the Swiss guideline. In our tests, the material density ranges between 1760 and 2110 kg/m^3 and the front velocity varies between 2 and 13 m/s. The flow heights are of the same order of magnitude as the size of the obstacles. The impact coefficients obtained range between 0.3 and 1.2 with median values of 0.65 and 0.78 for the large and small pressure plate respectively. These values are used in the procedure for the barrier design which will be described in detail in the paper. In the abstract first calculation steps for two impacts (Test 8) are described and the results are compared to the forces measured in the support ropes.

CALCULATION METHOD

The maximum impact pressure values are measured in the flow front. The front velocities are computed from the front passing time at a laser sensor and from the front impacting time at the pressure plates No 1 and No 2 located 3 m downstream of the laser sensor. Dynamic pressure for the first release ranges between $p_1 = c\cdot\rho\cdot v^2 = 0.48\cdot 1840\cdot 8.7^2 = 66$ kN/m^2 and $p_2 = c\cdot\rho\cdot v^2 = 0.43\cdot 1840\cdot 7.0^2 = 38$ kN/m^2 with the material density ρ=1840 kg/m^3. From the high speed camera recordings, we observe the maximum deformation of the flexible barrier 2 s after the front impact coinciding with the peak loads in the support ropes. The filling process lasts for about 5 s.

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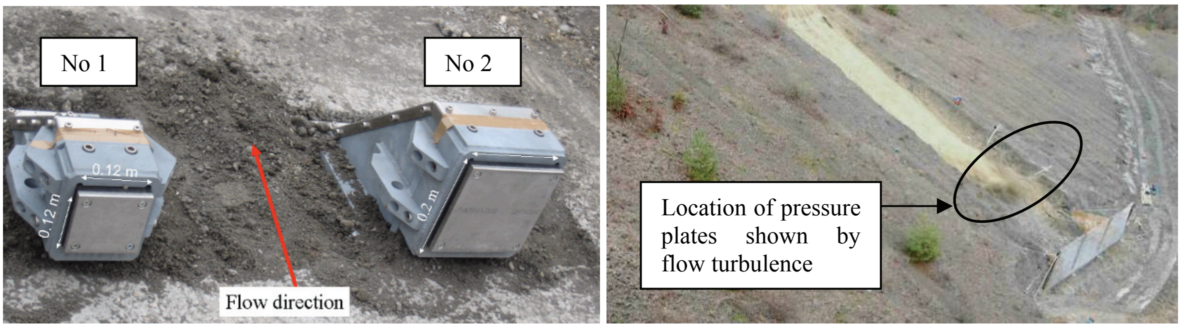

Fig. 1 Pressure plates measuring impact pressure (left side) and debris flow front impacting the pressure plates (right side).

Tab. 1 Impact pressure coefficients c and front velocities for releases 1 and 2 of Test 8.

Test release	**Cell 1 c [-]**	**Cell 2 c [-]**	**Front velocity cell 1 [m/s]**	**Front velocity cell 2 [m/s]**
8.1	0.48	0.43	8.7	7.0
8.2	0.74	0.31	8.0	6.5

We modeled the flexible barrier with the finite element software FARO developed at the ETH Zürich (Volkwein 2004). The code was modified in order to account for the present load model (Wendeler 2008). Flow height and impact width are input parameters like the maximum impact pressure acting on the flexible barrier. Between t=0 s and t=2 s the impact pressure is increased linearly from 0 to the maximum impact pressure. Between t=2 s and t=5 s the impact pressure is decreased linearly to the hydrostatic pressure value. The material is not drained so that the hydrostatic pressure acts over the total filling height of 1.8 m. The computation results for the forces in the support ropes agree with the force cells measurements within a range of 15% (see Fig. 2).

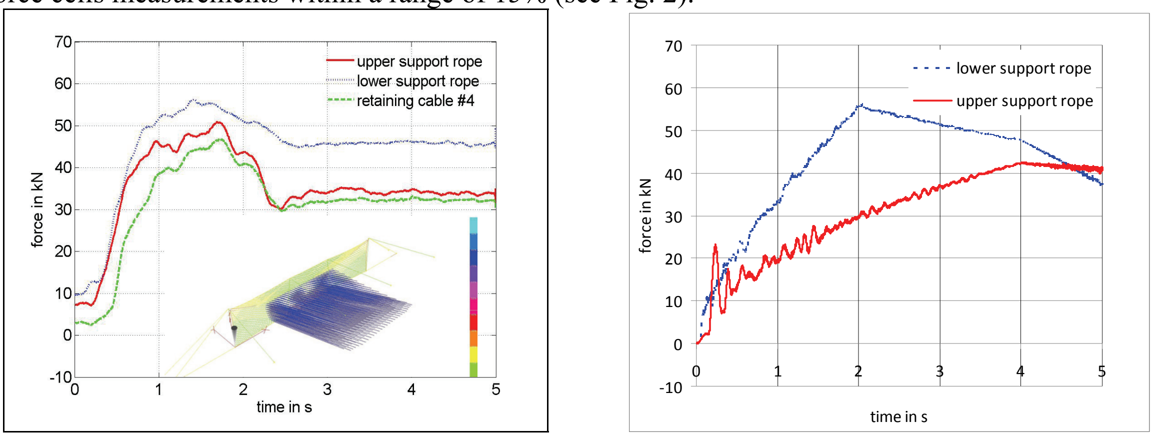

Fig. 2 Loads measured in the support ropes (left side) and forces computed with FARO software (right side).

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