A combined model approach for debris-flow impact forces

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For the design of mitigation measures knowledge of debris-flow impact forces, usually estimated based on hydrostatic, hydrodynamic, or combined approaches, is essential. As these approaches are based on Newtonian fluids, they must be adjusted by empirical correction factors to account for the solid-fluid nature of debris flows. The values for the correction factors shown in the literature vary over a wide range and several studies showed a clear dependence with the Froude regime of debris flows.

To better understand the correction factors and to be able to calculate them using parameters that describe the flow behaviour a total of 32 experiments were conducted in the course of the project "Debris flow impact forces on bridge super structures (DEFSUP)", funded by the Austrian Science Fund (FWF). Two different material compositions, different water contents as well as a total impact and a bypassing of the measuring block were tested.

The experimental setup designed within the project consists of a 4 m long semi-circular channel with a diameter of 300 mm and an inclination of 20°. The material is released from a rectangular reservoir in a dam-break scenario and accelerated with zero roughness on a length of 1.2 m and transferred to the semi-circle profile. The subsequently introduced roughness with a grain diameter of 1-2 mm generates a stationary phenomenological debris flow until it hits the measuring setup. With a starting volume of 50 kg, flow heights between 8 and 12 cm and velocities from 0.8 to 2.2 m/s were achieved according to the material composition and different water content. With these different mixtures a Froude-range from 0.6 to 3.6 was covered. In addition, normal stresses and pore water pressures were measured at the exact same point.

A detailed analysis of the measured impact forces together with the above mentioned measured parameters showed that the hydrodynamic correction factor is a constant mainly corresponding to the liquification ratio of the debris-flow mixture. Hence, the hydrodynamic correction factor can be regarded as a drag coefficient and seems to depend mainly on the internal friction of the flowing medium. At low Froude numbers measured impact forces exceed even a full momentum transfer if the mean bulk density is used for the calculation. This indicates that the impact forces can no longer be described by the hydrodynamic approach alone. For this reason, an additional pressure term based on a hydrostatic approach is considered in the combined concept. This

additional pressure term depends on the dynamics of flow (Froude number) and can be modelled via a dynamic earth pressure coefficient.

The findings from these experiments contribute to a better prediction of debris-flows impact forces in terms of their material composition and flow behaviour.