# ESTIMATION OF DEBRIS-FLOW IMPACT FORCES USING A SMALL SCALE MODELLING APPROACH

**Christian Scheidl**[1], Michael Chiari[1], Matthias Müllegger[1] and Dirk Proske[1]

## INTRODUCTION

Debris flows provide a severe threat to human living in mountainous regions all over the world. Structural mitigation measurements, like debris-flow barriers, or the maintenance of infrastructures such as bridges, require the estimation of possible impact forces. Currently it is not possible to develop debris-flow impact estimations models (entirely based on theoretical considerations) with sufficient accuracy and computable in periods common for design offices (Hübl et al., 2009). Debris-flow impact forces are therefore often estimated based on real-scale or large scale observations and laboratory experiments. Real-scale observations are based on real debris-flow events, whereas large scale observations need an artificially triggered debris flow like mass movement. Ideally, no scaling effect exists, but the measurements of indicators, such as the flow velocity or the bulk density is often complicated. For this reasons several experiments have been carried out in laboratories (Ishikawa et al., 2008; Tiberghien et al. 2007). Hübl et al. (2009) showed that the impact forces of the real-scale observations have mainly be estimated in a Froude range between 0 and 2, but only the test by Tiberghian et al. (2007) are within this range. Miniaturized tests were mainly carried out in higher Froude ranges, concluding that these models are developed based on an input data range which does not comply with field data. The objective of this study is to analyse debris-flow impact forces in a laboratory experiment, based on a 1:20 scale flume model and a kinematic similarity of the debris-flow behaviour described by a Froude-number < 2. The study is part of the research project P21653 "*Historical arch bridges under horizontal debris flow impacts*" funded by the Austrian Science Fund.

## METHODS AND FIRST RESULTS

**Fig. 1** Debris-flow flume model.

The first step was the development of a concept of a miniaturized physical model for a debris-flow flume. The principal approach for the flume was to find a minimum scale in order to avoid too many biased effects between the laboratory and real-world situations. Here the scale of length was limited due to the dimensions of the laboratory at the Institute of Mountain Risk Engineering in Vienna. Furthermore, boundaries of the flume concept were based on the model's flow-cross section, the maximum chosen grain diameter and the maximum release volume. The release mechanism was made to simulate a dam-break triggering situation. Fig. 1 shows the flume model with a slope of 30 % and mounted with two lasers and three ultrasonic devices to measure the flow heights within known distances from the release device.

The used bulk mixture is based on a certain amount of water combined with a typical debris-flow grain size distribution. For our study the dry mass of the solid

[1]Dr. Christian Scheidl. Institute of Mountain Risk Engineering (IAN), University of Natural Resources and Life Sciences, Vienna (email: christian.scheidl@boku.ac.at)

particles is fixed ($m_s$ = 370kg) and only the water content remains variable. Two bulk mixture setups are defined, accounting for a more granular and viscous flow regime. The different setups are either based on a grain-size distribution i) with fine material or ii) without fine material. Here, the minimum diameter of the particles for the granular setup amounts to $d_{gmin}$ ~ 0.1mm. The maximum diameter amounts to $d_{max}$ = 50mm. The fine material applied to the viscous setup consists of 26 % clay, 60 % silt and 14 % sand.

The maximum slope of the flume remains 30 % due to space limitations within the laboratory. The maximum selected sediment diameter (50mm, b-axis) is based on the size of the physical model respectively a constant flow width of 0.5m. The basal shear friction condition was set constant within the flume, independently of the used material mixture. The observed Froude number is then estimated by means of the measured average flow height and average surface velocity.

First results of the coarse material mixture with a total volume of 0.3m$^3$ showed a flow height of about 0.1m with a Froude number of 1. Based on a 1:20 scale, the observed flow height and flow velocity in the flume model correspond therefore to a natural debris-flow with a velocity of 4m/s and a flow height of 2.0m. However, installing a measuring device to quantify impact forces will directly influence the measurements of the flow heights due to limited space and backwater effects. Such a "force-plate" will lead to biased observed Froude numbers. We therefore accomplished several experiments without installed force-plate, and related observed Froude-numbers with used water contents of different material mixtures. Based on the water contents for the granular and viscous setups two regression models could be developed to predict the related Froude numbers. The linear regression model for the granular setup covers Froude numbers between 0.3 and 2.5, with water content by weight, ranging from 16 % to 28 % (Fig. 2) The linear regression model for the viscous setup, predicts Froude numbers between 1.0 and 3.0, including water content by weight, ranging from 16 % until 23 %.

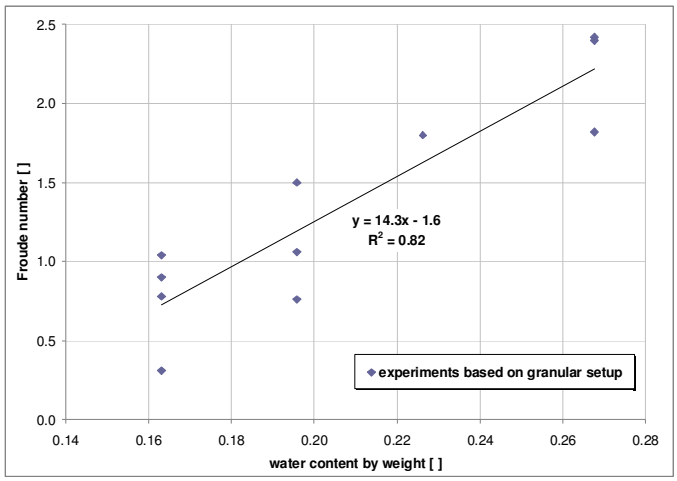


**Fig. 2** Observed Froude numbers related to used water contents by weight for granular experiments.

In the next step the installation of the force measuring device (force plate) will now be realised, in order to quantify impact forces of different setup mixtures. The force plate consists of 24 aluminium elements mounted with resistance strain gauges to measure normal stresses in flow direction. First results of measuring forces will be expected for summer 2011. Nonetheless, it is additionally planned to numerically simulate the laboratory experiment with selected discrete element methods.

## REFERENCES

Hübl J., Suda J., Proske D., Kaitna R., Scheidl C. (2009). Debris flow impact estimation. In: Popovska C., Jovanovski M. (eds.) 11th Int. Symposium on Water Management and Hydraulic Engineering, University Ss. Cyril and Methodius, Faculty of Civil Engineering, Skopje, Macedonia: 137–148.

Ishikawa N., Inoue R., Hayashi K., Hasegawa Y., Mizuyama T. (2008). Experimental approach on measurement of impulsive fluid force using debris flow model. Conference Proceedings Interpraevent 2008, Dornbirn, Austria: 192-193.

Tiberghien D., Laigle D., Naaim M., Thibert E., Ousset F. (2007). Experimental investigation of interaction between mudflow and obstacle. In: Chen C.-I., Major J.J. (eds) Debris-Flow Hazards Mitigation. Mechanics, Prediction, and Assessment. Rotterdam, Millpress. Chengdu. China: 281-292.

**Keywords**: debris-flow, impact forces, laboratory flume