Geophysical Research Abstracts
Vol. 15, EGU2013-7968-1, 2013
EGU General Assembly 2013

Modelling the impact of shallow landslides and debris flows on rigid bodies and flexible barriers: Linking rheology to grain size distribution and water content

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While most research on shallow landslides and debris flows is focussed on determining the local risk of impact on structures, our aim is to quantify the impact itself for a proper design of protection barriers. The demands on 3D impact simulations for complex geometries were extended to allow simulation phenomena like shear thinning rheology, free surface flow and fluid-structure interaction with dynamic mesh movements due to flexible protection barriers.

Within this context, the rheology of the debris flow material became a key issue. With the aim of gaining an engineering numerical tool that models impacts without necessary recalibration of the rheology parameters as the case arises, a linkage of rheology parameters to grain size distribution and water content was compiled, validated against laboratory experiments and applied to full-scale testing of shallow landslide impacts on flexible protection barriers.

The resulting model consists of a Herschel Bulkley representation of the material, valid for debris flows and viscous hillslope debris flows. The yield stress of the material is estimated based on a mixed approach derived from findings for water-clay and water-sand mixtures, and the consistency factor is formulated in dependency to the yield stress. The exponent of the Herschel Bulkley law which is responsible for the shear thinning effect is estimated due to the share of gravel.

The resulting model is validated against rigid impact flume experiments and 2 and 4 m diameter rotating drum experiments and is finally applied to experimental impacts of up to 50 m3 of debris material into flexible steel net protection barriers and to debris breakers in the field.