COMPARATIVE RHEOLOGIC INVESTIGATIONS OF DEBRIS FLOW MATERIAL

Roland Kaitna[1], Dieter Rickenmann[1,2], Markus Schatzmann[3]

INTRODUCTION

Debris flows represent a serious hazard in alpine regions. In order to describe the flow behaviour of debris flows often rheologic models are used. This study introduces two novel facilities to determine rheologic parameters of different models for debris flow material mixtures containing grain sizes larger than those measured in standard viscometers.

EXPERIMENTS

Experiments have been carried out in a vertically rotating drum (VRF) with a diameter of 2.46 m (Fig. 1). The rectangular cross-section has a width of 0.45 and is confined on one side by stainless steel, and on the other side by acrylic glass to allow observations from the side. The measured parameters include flow geometry, mean and surface velocity, total boundary shear stress, normal stress and shear stress along the bottom close to the centreline of the flow.

The ball measuring system (BMS), originally developed by Müller et al. (1999), is implemented in the Paar Physica MCR 300 rheometer (Fig. 1). It consists of a cylindrical container and an eccentrically rotating sphere with a diameter D = 12 mm. The sphere is dragged through a given sample fluid at specified rotational speeds. From the measured rotation velocity and torque, shear stress and shear rate are calculated. Subsequently Bingham and Herschel Bulkley parameters can be derived for different material mixtures.

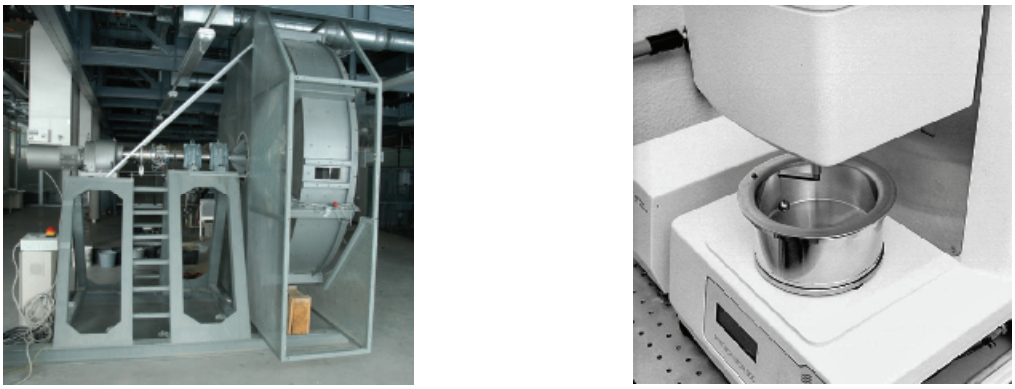

Fig. 1: Left: vertically rotating flume (VRF); right: ball measuring system (BMS)

The debris flow material tested was taken from a fresh deposit in the Scalära torrent near Trimmis/Chur in Eastern Switzerland and analysed by Schatzmann (2005).

1 Institute of Mountain Risk Engineering, BOKU – University, Peter Jordanstr. 82, 1190 Vienna, Austria (Tel.: +43-1-47654-4372; Fax: +43-1-47654-4392; email: roland.kaitna@boku.ac.at)

2 Swiss Federal Research Institute WSL, Zuercherstrasse 111, CH-8903 Birmensdorf, Switzerland (email: dieter.rickenmann@wsl.ch)

3 Basler & Hofmann Ingenieure und Planer AG, Bachweg 1, CH-8133 Esslingen (Tel.: +41-44387-1522, Fax.: +41-44387-1500; email: markus.schatzmann@bhz.ch)

RESULTS

It is found that for material mixtures with a high content of fines a rheologic description of the flow properties is possible (e.g. Coussot 1994; Parson et al. 2001). For the free surface flows in the rotating drum it is possible to derive Bingham parameters of viscous mudflows of different viscosities using simple one dimensional analysis within certain limits of accuracy. Independent measurements in the BMS rheometer are in good agreement with the rheometric curves derived from drum experiments. The tests have been restricted to mixtures including sediment particles less than 5 mm in diameter. Fig. 2 gives an example of rheometric curves derived from drum experiments and BMS – rheometer measurements for debris flow material of varying sediment concentration.

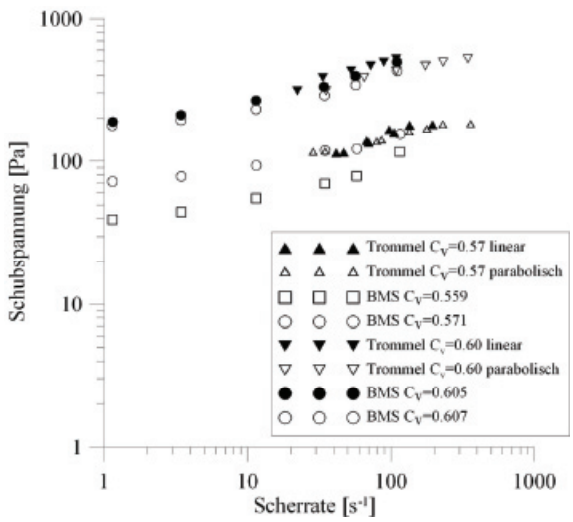

Fig. 2: Example of rheologic curves of debris flow material of different sediment concentration (Cv) derived from VRF experiments and BMS measurement.

CONCLUSION

A vertically rotating drum has been developed to investigate the flow behaviour of large particle fluids, i.e. debris flow material. The results obtained for debris flow material mixtures were compared with measurements in the BMS rheometer, another novel instrument for the analysis of large particle fluids. In order to estimate rheologic parameters to be used in debris flow hazard assessment, future experiments should be carried out with mixtures including particles with maximum grain sizes up to several centimetres.

REFERENCES

Coussot P (1994) Steady, laminar flow of concentrated mud suspensions in open channel. *Journal of Hydraulic Research* 32(4): 535 – 559

Müller M, Tyrach J, Brunn PO (1999) Rheological characterization of machine-applied plasters. ZKG International 52: 252-258

Parson JD, Whipple KX, Simoni A (2001) Experimental study of the grain-flow, fluid-mud transition in debris flows. *Journal of Geology* 109: 427-447

Schatzmann M (2005) Rheometry for large particle fluids and debris flows. Dissertation No 16093, ETH Zurich, Switzerland.

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