IV International Workshop on Modern Trends in Geomechanics
G. Viggiani, D. Salciarini, F. Silvestri, C. Tamagnini, G.M.B. Viggiani
(Eds) Assisi, May 16–18, 2016

EXPERIMENTAL AND NUMERICAL STUDY OF DEBRIS FLOW

M. Cabrera[1], A. Leonardi[2], F.K. Wittel[3], H.J. Herrmann[4], and W. Wu[5]

[1] Institute of Geotechnical Engineering
University of Natural Resources and Life Sciences (BOKU), Austria
e-mail: miguel.cabrera@boku.ac.at
[5]e-mail: wei.wu@boku.ac.at

[2]Institute for Building Materials
Swiss Federal Institute of Technology, Switzerland
e-mail: aleonardi@ifb.baug.ethz.ch
[3]e-mail: fwittel@ethz.ch
[4]e-mail: hans@ifb.baug.ethz.ch

Keywords: Debris flows, Rotating drum, Centrifuge.

Summary. Debris flows are among the most dangerous geo-hazards in mountain regions, with a gradation that varies from the smallest clay particles to the largest boulders. Debris flows are often the outcome of landslides in partially or completely saturated earth slopes. The flow dynamics involved during its motion and deposition are mainly dictated by the terrain characteristics and the mechanical behaviour of the debris material. Furthermore, the mechanical behaviour of the evolving particle-fluid mixture is highly inhomogeneous, making it difficult to handle in experiments and simplify in numerical models. In this paper, we present a summary of the recent results of a particle-fluid mixture in a large rotating drum and in a geotechnical centrifuge model.

In the rotating drum, the conditions leading to the formation of a granular-front are studied with a monodisperse suspension of clay balls immersed in a kaolin-water dispersion. In the drum, by varying the angular velocity, the particles settling time is disturbed, enforcing the recirculation of the material along the drum. At a sufficiently high angular velocity, the particles accumulate in the front of the flowing mixture resembling the process observed in a natural debris flow. This process of granular front formation is simulated by combining the lattice Boltzmann method (LBM) for the fluid phase and the discrete element method (DEM) for the solid phase (see Fig. 1). In experiments, the drum is partially filled with a viscous dispersion and a fixed particle concentration, occupying less than 2% of the available volume. Then, the particle concentration is monotonically increased after a sequence of rotations. The good agreement between the experimental and numerical models allows us to identify the phase-separation pattern to be dependent on two factors: the fluid recirculation and a dimensionless time ratio between the settling and recirculation time of the particle phase.

In the geotechnical centrifuge, the flow dynamics of a monodisperse suspension of glass beads immersed in a kaolin-water dispersion is studied (see Fig. 2). In this experiment, by increasing the angular velocity, a centrifugal acceleration field enhances the gravity-driven processes in the flowing mass. The orientation of the model defines the magnitude and direction of the Coriolis acceleration, resulting in dense or deflected flows in an augmented acceleration field. Moreover, the non-linear behaviour of the fluid phase is studied as a function of a scaling factor proportional to the centrifugal acceleration. In this analysis, by increasing the fluid viscosity in the mixture, the time scale at which the particle interactions occur is enlarged, counterbalancing the augmented inertia in the particles. These experiments suggest that in the study of a particle-fluid mixture in an augmented acceleration field, the particle and fluid mechanical behaviour should directly represent the behaviour observed in a debris flow. Furthermore, the scaling principles of the kinematics of mass flows in a centrifugal acceleration field are found to be augmented by a factor of $N^{0.5}$.

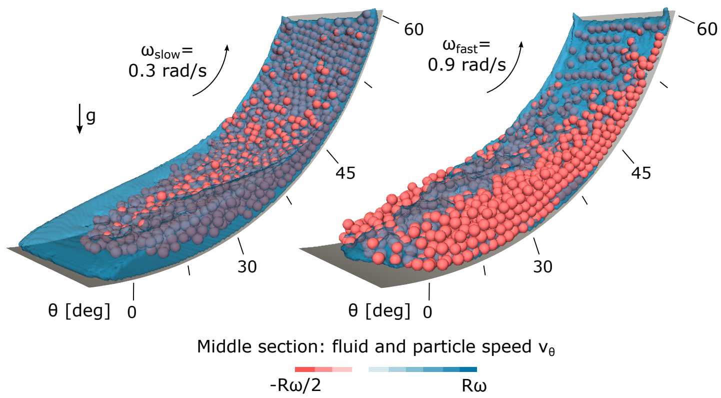
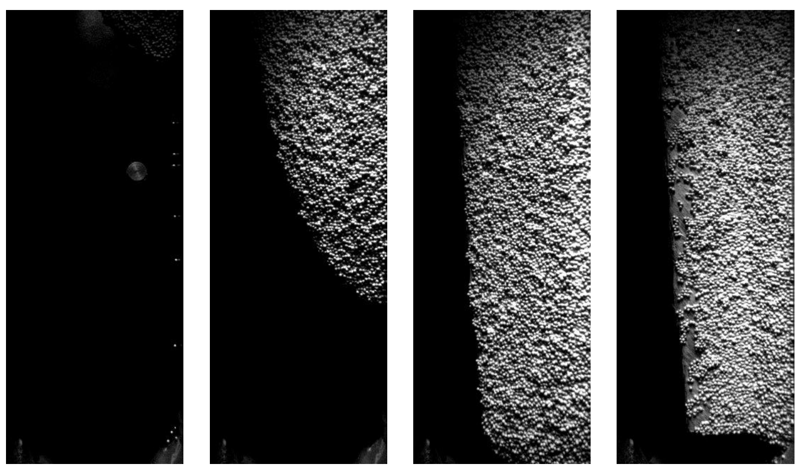


Figure 1: Snapshots of the DEM-LBM simulations (particle content of 31%). The formation of a granular front is induced by an increase in the angular velocity of the drum. A detailed description of the DEM-LBM method and its implementation is presented by Leonardi in Ref. [2].



(a) $t = 0.002$ s (b) $t = 0.0198$ s (c) $t = 0.120$ s (d) $t = 0.990$ s

Figure 2: Snapshots of the free surface flow of glass beads immersed in a kaolin-water dispersion at $20g$ and slope angle of 30°. The time of each snapshot is relative to the time of release. A detailed description of the Centrifuge experimetnal model and its results is presented in Ref. [1]

REFERENCES

[1] M. Cabrera. *Experimental modelling of granular flows in rotating frames*. PhD thesis, University of Natural Resources and Life Sciences, Vienna, 2016.

[2] A. Leonardi. *Numerical simulation of debris flow and interaction between flow and obstacle via DEM*. PhD thesis, ETH Zurich, Switzerland, 2015.