Hypoplastic and rheological constitutive modeling of debris materials

Xiaogang Guo*†, Wei Wu* and Yongqi Wang†

* Institut für Geotechnik, Universität für Bodenkultur
Feistmantelstrasse 4, 1180 Vienna, Austria
e-mail: xiaogang.guo@boku.ac.at, web page: http://www.baunat.boku.ac.at/igt/

† Fachgebiet für Strömungsdynamik, FB Maschinenbau
Technische Universität Darmstadt
Otto-Berndt-Strasse 2, 64287 Darmstadt, Germany
e-mail: guo@fdy.tu-darmstadt.de, web page: http://www.fdy.tu-darmstadt.de/

ABSTRACT

Debris flows are dangerous natural hazards in countries with mountainous terrains. Debris materials show solid-like or fluid-like properties under different stress states. Such particular behaviours cannot be modeled only within the framework of solid mechanics or rheology. In this paper, a new model capable of describing the constitutive relation of debris materials from solid-like to fluid-like state is developed based on the framework in which solid mechanics and rheology are integrated. The new constitutive model is composed of a static and a dynamic part. The hypoplastic constitutive model is employed for the static contribution due to its simple formulation and capacity to capture some features of granular materials. Based on Bagnold's pioneering work about the flow behaviour of granular materials in 1954, a quadratic rheological model is proposed to describe the rate-dependent stresses after yielding. The changing of stresses in the entire flow process from quasi-static to high-dynamic state can be captured by this rheological model even if the material has a high volume fraction. The three-dimensional expression of this model is derived as the dynamic contribution in the new model. For the verification, the derived model taking the hypoplastic and rheological model into account is numerically examined for a channel flow by means of the smoothed particle hydrodynamics method (SPH).

ACKNOWLEDGEMENT

The authors wish to thank the European Commission for the financial support to the following projects: MUMOLADE (Multiscale Modelling of Landslides and Debris Flows), Contract Agreement No. 289911 within the program Marie Curie ITN, 7th Framework Program.