GRANULAR RHEOLOGY IN BEDLOAD TRANSPORT

R. Maurin[1,2], J. Chauchat[3,4] & P. Frey[1,2]
[1] *Irstea, Grenoble, UR ETGR, 2 rue de la papeterie, BP 76, 38402 Saint-Martin-d'Hères, France*
[2] *Univ. Grenoble Alpes, Irstea, F-38000 Grenoble, France*
[3] *Univ. Grenoble Alpes, LEGI, F-38000 Grenoble, France*
[4] *CNRS, UMR 5519, LEGI, F-38000 Grenoble, France*

Key words Sediment transport, Bedload, granular flow, two-phase flow, granular rheology.

Considering a granular bed submitted to a surface fluid flow, bedload transport is classically defined by opposition to suspension as the part of the load in contact with the granular bed, i.e. in rolling, sliding or small jumping motions. The granular rheology in bedload transport is characteristic of the granular bed response to the fluid shear stress, and is therefore fundamental both in term of transport rate and for upscaling in the framework of two-phase continuous modelling. Using a validated coupled fluid-Discrete Element Model for bedload transport [1], the granular rheology is characterized by computing locally the granular stress tensor as a function of the depth for a serie of simulation varying the Shields number, the particle diameter and the specific density. The obtained results are analyzed in the framework of the $\mu(I)$ rheology and show a collapse of the data for a wide range of inertial numbers. The effect of the interstitial fluid on the granular rheology is shown negligible, supporting recent work [2] suggesting the absence of a clear transition between the free-fall and the turbulent regime. In the low inertial numbers limit, signatures of non-local granular behavior are observed. Meanwhile, the collapse as a function of the inertial number for both the solid volume fraction and the shear to normal stress ratio is observed up to unexpectedly high inertial numbers ($I \sim 3$) in regions showing an important dependency on the restitution coefficient. At higher inertial number, a transition to a granular gas behavior is suggested by the results and is seen to depend on the parameters of the configuration sampled. These results, on the one hand show the relevancy in modelling the granular phase in bedload transport using the $\mu(I)$ framework, and on the other hand challenge the existing conceptions and parametrizations of the $\mu(I)$ rheology. By pragmatically fitting the expression of the latter with the results obtained, a parametrization of the $\mu(I)$ rheology is proposed for bedload transport, and tested using a 1D two-phase continuous model [3, 4]. The latter is shown to reproduce accurately the granular depth profiles, and the classical behavior in terms of dimensionless sediment transport rate as a function of the Shields number. The proposed rheology therefore represents an important step for upscaling in the framework of two-phase continuous modelling of bedload transport.

References

[1] Maurin, R. and Chauchat, J. and Chareyre, B. and Frey, P., A minimal coupled fluid-discrete element model for bedload transport,*Physics of Fluids*, **27** 113302. (2015)
[2] Izard E. and Bonometti T. and Lacaze L., Simulation of an Avalanche in a Fluid with a Soft-sphere/Immersed Boundary Method Including a Lubrication Force,*The Journal of Computational Multiphase Flows*, **6**:391-406. (2014)
[3] Chauchat, J., A comprehensive one-dimensional two-phase flow model for steady uniform sheet-flow based on dense granular flow rheology,*submitted to Journal of Hydraulic Research*
[4] Revil-Baudard, T. and Chauchat, J., A two-phase model for sheet flow regime based on dense granular flow rheology,*Journal of Geophysical Research: Oceans*, **118**:619–634. (2013)