

Discrete element simulations and continuous modeling of vertical size-segregation in bedload transport

Chassagne, Maurin, Chauchat, Frey

Bedload sediment transport has major consequences for public safety, water resources and environmental sustainability. In mountains, steep slopes drive intense transport of a wide range of grain sizes implying size sorting or segregation largely responsible for our limited ability to predict sediment flux and river morphology. Concerning size sorting, when the substrate is moving, statistically void openings allows fine particles to percolate into the bed, a process called ‘kinetic sieving’.

To better understand this process, bedload transport numerical experiments of two-size particle mixtures were carried out, using a coupled Eulerian-Lagrangian fluid-discrete element model (DEM) developed at Irstea (Maurin et al. 2015, 2016, Chauchat 2017). A 3D 10% steep domain consisting at initial time of a given number of layers of 4 mm spherical particles deposited on top of a 6 mm particles bed, were submitted to a turbulent, hydraulically rough and supercritical water flow and let evolved with time. Shields numbers of 0.1 and 0.3 were considered.

For a given Shields number, the elevation of the center of mass of the infiltrating fine particles has been shown to remarkably follow the same logarithmic decrease with time, whatever the number of fine particles. In addition, the profile of concentration of fine particles is a Gaussian like function with constant width during the percolation into the bed : the entire layer percolates at the same velocity. Based on this observation, it has been showed that the segregation velocity is driven by the shear rate at the bottom of the layer.

These numerical experiments were also analyzed in the framework of a continuum theoretical model for the segregation of binary mixtures based on a kinematic approach (Thornton et al. 2006). The continuum model shows very good agreement with the DEM simulations (comparable characteristic time of segregation, exact segregation velocity) and reproduces the same properties (Gaussian like concentration profile, constant width of the fine layer).

Chauchat J. 2017. A comprehensive two-phase flow model for unidirectional sheet-flows. *Journal of Hydraulic Research*: 10.1080/00221686.2017.1289260.

Maurin R, Chauchat J, Chareyre B, Frey P. 2015. A minimal coupled fluid-discrete element model for bedload transport. *Physics of Fluids* **27**(11): 113302.

Maurin R, Chauchat J, Frey P. 2016. Dense granular flow rheology in turbulent bedload transport. *Journal of Fluid Mechanics* **804**: 490-512.

Thornton AR, Gray J, Hogg AJ. 2006. A three-phase mixture theory for particle size segregation in shallow granular free-surface flows. *Journal of Fluid Mechanics* **550**: 1-25.