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Vertical size-segregation in bedload sediment transport : from grain scale to continuum models

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Bedload sediment transport (transport of particles by a flowing fluid along the bed by rolling, sliding and/or saltating) has major consequences for public safety, water resources and environmental sustainabilty. 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, most studies have concentrated on the spontaneous percolation of fine grains into immobile gravels. However when the substrate is moving, the segregation process is different as statistically void openings permit downward percolation of larger particles, a process also known as 'kinetic sieving'.

In order to gain understanding of this process, bedload transport numerical experiments of two-size particle mixtures were carried out, using a coupled Eulerian-Lagrangian fluid-discrete element model developed at Irstea and validated with experiments (Maurin et al. 2015, 2016). It is composed of a 3D discrete element model (based on the open source code Yade), describing each individual particle, coupled with a one dimensional Reynolds average Navier Stokes model (Chauchat 2017). A 3D 10% steep domain (angle of 5.71°) consisting at initial time of a given number of layers of 4 mm spherical particles deposited on top of a 6 mm particle bed, were submitted to a turbulent, hydraulically rough and supercritical water flow and let evolved with time. Shields numbers (dimensionless water shear stress) of 0.1 and 0.3 were considered.

For a given Shields number, the elevation of the center of mass of the infiltrated fine particles has been shown to remarkably follow the same logarithmic decrease with time, whatever the number of fine layers initially deposited. This decrease is steeper for a higher Shields number.

These numerical experiments were also analysed in the framewok of a continuum theoretical model for the segregation of binary mixtures based on a kinematic approach (Thornton et al. 2006). Modelling bedload size sorting at the particle scale and upscaling in continuum models should improve our knowledge of sediment transport and river morphology.

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