Geophysical Research Abstracts
Vol. 18, EGU2016-17186, 2016
EGU General Assembly 2016

Experimental study of sediment particle diffusion on a granular bed.

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Particle diffusion in a cohesionless granular bed, hydraulically fully rough, subjected to a steady-uniform turbulent open-channel flow is investigated.

Experiments were carried out under conditions of weak bedload transport in a 12.5 m long and 40.5 cm wide glass-sided flume recirculating water and sediment through independent circuits at the Laboratory of Hydraulics and Environment of Instituto Superior Técnico, Lisbon.

The flume bed was divided in two reaches: a fixed reach comprising 1.5 m of large boulders, followed by 3.0 m of smooth bottom (PVC) and 2.5 m of one layer glued 5.0 mm diameter spherical glass beads; a mobile reach 4.0 m long and 2.5 cm deep filled with 5.0 mm diameter glass packed beads.

Particle velocities were obtained introducing 5.0 mm diameter white-coated beads in the flow. Particle motion was registered from above using a high-speed camera AVT Bonito CL-400 with resolution set to 2320 x 1000 $px^2$and frame rate of 170 fps. The field of view recorded was 77.0 cm long and 38.0 cm wide, covering almost all the width of the flume. Image processing allowed detecting and locating the centre of mass of the particles with sub-pixel accuracy. Particle trajectories were reconstructed by tracking the beads in the images; particle velocities were obtained as bead displacement over time interval between two consecutive frames (1/170 s).

The computation of lagrangian statistics of particle velocities for a Shields parameter θ=0.014, Froude number Fr=0.756, boundary Reynolds number Re*=182.9 and run duration of 20 min (during which 1218 particle trajectories were collected) provided information about particle diffusion within the local and intermediate range of temporal and space scales. Mean particle velocities, second, third and fourth order moments were obtained for both longitudinal and transverse velocity components.

A relatively large ballistic range, approximately two particle diameters, was observed, mainly due to the simple bed topography of the laboratorial configuration. This long ballistic range can be confirmed by the relatively slow decay, in both flow directions, of the values of the Lagrangian velocity autocorrelation function, in accordance to classic lagrangian dispersion theory.

By the evaluation of the variance, superdiffusion was found for time scales between 0.09 s and 1.1 s for the longitudinal velocity component (x) and in the range 0.1-0.6 s for the transverse component (y). Normal diffusion ranged from 1.1 s to 3 s and from 0.6 s to 3 s, respectively in x an y direction. A very small range of anisotropic diffusion was thus observed at intermediate time scales.

The skewness and kurtosis excess coefficients appeared are different from zero only for small time scales. From 1.0 s to 2.0 s skewness and kurtosis excess are close to zero for both velocity components. This is in accordance with the perceived normal diffusion at these scales.

This work was partially funded by FEDER, program COMPETE, and by national funds through Portuguese Foundation for Science and Technology (FCT) project RECI/ECM-HID/0371/2012 and by Project SediTrans funded by the European Commission under the 7th Framework Programme.