CERIS Civil Engineering Research and Innovation for Sustainability

Laboratory investigation on the motion of sediment particles in cohesionless mobile beds under turbulent flows

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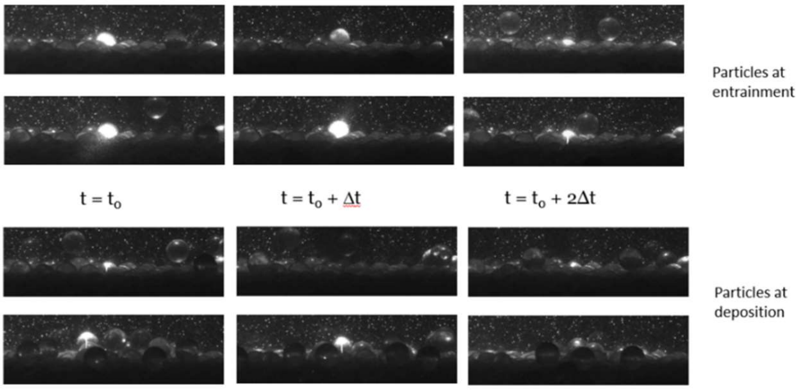
Summary

The general goal is to improve the current understanding of the kinematics and dynamics of bedload transport in turbulent open-channel flows with rough beds and turbulent flow conditions. Particular objectives ensue: (i) characterize the reciprocal influence of bedload transport and turbulent flow dynamics in the inner region; (ii) advance the knowledge of the mechanics and kinematics of particle entrainment and deposition and to characterize them stochastically; (iii) advance knowledge of diffuse processes in bedload transport; and iv) investigate the relation between lagrangian and eulerian quantities describing bedload motion. The experimental work, designed to address gaps in existing literature and to highlight the contribution of fundamental grain and fluid mechanics, involved conducting laboratory tests in a granular bed composed by simple granular media subjected to a steady-quasi-uniform turbulent open channel flow and characterized by increasing values of bedload discharge.

Important innovations in measuring capabilities had to be developed prior to the commencement of the laboratory tests: a) a particle counting system was developed up to prototype stage, allowing for the collection of very large times series of bedload transport rate with grain-scale resolution; b) Particle Tracking algorithms, based on digital image processing tools, were specifically designed for the laboratory experiments, allowing for Lagrangian tracking of sediment particles and (Eulerian) determination of bedload fluxes; c) Image analysis tools were developed to automatically identify the solid and fluid parts in frames acquired by the Particle Image Velocimetry system, allowing for the quantification of the time and space-averaged void function in mobile bed conditions. The results showed that: (i) the shear rate in the overlapping layer well fits a linear reach characterized by a flow-dependent von Kármán parameter lower than the constant k=0.4. A comparison between results obtained in case of bed composed by artificial particles and natural sand-gravel mixtures, shows that, for equal transport rates, the roughness height obtained in the latter case is much greater than in the previous, underlining the influence of the bed diversity and organization on the definition of the log-law parameters. (ii) Prevalence of sweep and outward interactions are observed for sediment entrainments, while ejection and inward quadrants are associated with deposition. No consistent variation of streamwise velocity fluctations with particle exposure is observed in the former case. The mechanisms promoting sediment dislodgment are identified considering of fluid-particle interactions, sediment collisions and the influence of the natural bed particle morphology. Evidence of the contribution of bed topography on sediment disentrainment is found. (iii) Statistics of a large sample of particle velocities reveal that entrainment events are associated with a fast increase on ensemble average particle velocity followed by a more gradual acceleration. On the contrary, a progressive loss of velocity possibly due to frictional contacts with the bed, followed by a sudden velocity drop caused by local morphology, is seen for deposition events.

Keywords

Bedload measurement, log-law parameters, entrainment, deposition, bedload diffusion.



Still images of bedload particles at entraiment and deposition.