Small diameter limit of cohesionless particle erosion

Mehta Ashish J.

Nutech Consultants, Inc., Gainesville, FL 32606, USA
E-mail: mehta@coastal.ufl.edu

The critical shear stress for erosion of sand by water-current or waves is commonly obtained from the Shields diagram, and in recent decades the so-called extended Shields diagram (ESD) has been used for the critical stress of finer cohesionless particles (Garcia, 2008). Presently, in mathematical modeling of waters containing both cohesionless and cohesive particles, the lower diameter limit of ESD is commonly taken as a somewhat arbitrary input parameter. As the diameter of the roughly spherical particles decreases below about 15μm, their flatness represented by the specific surface area increases, along with a concurrent increase in the ratio of the surface force of attraction to particle buoyant weight. At about 1μm this ratio is orders of magnitude larger that at 15μm, and results in the formation of cohesive microflocs (d<100μm) and/or macroflocs (d≥100μm) depending on the flow shear rate (Winterwerp and van Kesteren, 2004).

The transition from cohesionless to cohesive particle behavior occurs notionally at a single diameter d_{sc} of about 10μm. A recent analysis (Mehta and Letter, 2013) suggests that the variation of the critical shear stress of cohesive flocs with particle/floc diameter is useful for deriving a formula for d_{sc}. Above d_{sc}, ESD is a valid representation of cohesionless critical shear stress, whereas below d_{sc} the critical shear stress of cohesive sediment is obtained.

Zones representing cohesionless and cohesive critical shear stress are more conveniently described by the variation of the critical shear stress with diameter d in lieu of ESD, when all cohesionless particles have the same material density. This paper is concerned with the development of such a description, shown in Fig. 1, in which the cohesionless data are limited to quartz and silica particles. Diameters d_1 and d_2 indicate the junctions of segments of the power-law equations (not given) used to approximate the mean trends of cohesionless and cohesive critical shear stresses. The transition diameter d_{sc} makes it convenient to identify diameter ranges of cohesionless particles, dispersed (deflocculated) cohesive particles, microflocs and macroflocs.

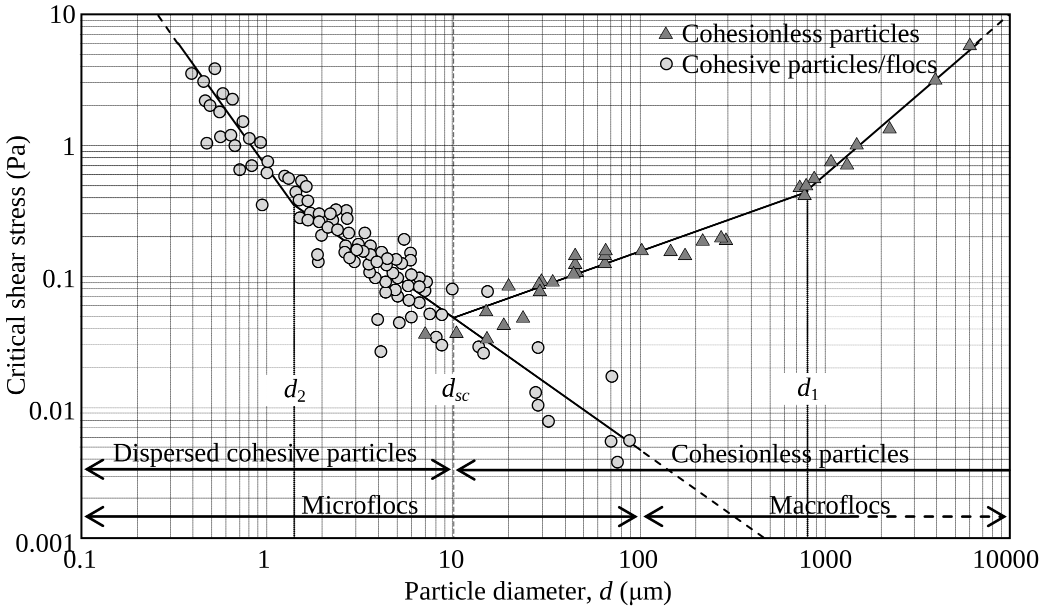

Fig. 1. Transition diameter d_{sc} defined with respect to cohesionless and cohesive sediment particles and critical shear stress for erosion.

References

Garcia M.H. (Ed.). 2008. Sedimentation engineering: processes, measurements, modeling and practice. American Society of Civil Engineers, Reston, VA. xv+1132p.

Mehta A.J. and J.V. Letter, jr. 2013. Comments on the transition between cohesive and cohesionless sediment bed exchange. Estuarine, Coastal and Shelf Science 131:319-324.

Winterwerp J.C. and W.G.M. van Kesteren. 2004. Introduction to the physics of cohesive sediment in the marine environment. Elsevier, Amsterdam. xiii+466p+app.