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Modeling flocculation processes of fine grained sediment: solving the population balance equation through a discretization and a moment methods

Zhenghui Cui (1), Hongwei Fang (1), Lei Huang (1), and Fabian A. Bombardelli (2)

(1) Department of Hydraulic Engineering, the State Key Laboratory of Hydroscience and Engineering, Tsinghua University, Beijing, China, (2) Department of Civil and Environmental Engineering, University of California, Davis, California, USA

Flocculation of suspended fine grained sediments significantly affects the floc size and settling velocity distributions, and further influences the sediment transport and morphological changes of natural environment. The flocculation processes including aggregation and floc breakup are modelled by means of a population balance equation (PBE). The present study provides and compares two different flocculation models, a size class-based (SCB) model and a mean size evolution (MSE) model that solving the PBE with the size distribution discretization and the moment methodology respectively. The role of certain factors are investigated through these models, including the environmental variables, e.g. sediment concentration and turbulent shear rate, and also particle intrinsic properties. Especially, the surface heterogeneities (F2a) of primary particles are incorporated into the expressions of floc properties, and further into the settling velocity, collision efficiency in SCB model and basic flocculation equation in MSE model. The model results compare well with the laboratory measurements, in particular in terms of the mean settling velocity, the mean floc size and the size distribution. Analysis of the results indicates that the mean floc size is related to the turbulent shear rate and sediment concentration. The increasing turbulence can increase the flocs formation, and also tear large floc apart. While the increasing concentration contribute largely to the floc breakup due to three-body collision, and a high concentration can also decrease the particles attachment, thus limit the floc growth. Additionally, the particles' surface heterogeneities also play a role, i.e. the increasing surface heterogeneities can enlarge the repulsion force during attachment process and decrease the mean floc size. The study leads to an improved understanding of flocculation, especially the role of concentration and surface heterogeneities. The model inter-comparison reveals that the SCB model is useful for studies focusing on the time evolution of floc size distributions under a highly variable condition. In contrast, the proposed MSE model can compute the evolution of mean floc size very effectively.