Sediment laden flows in dredging engineering

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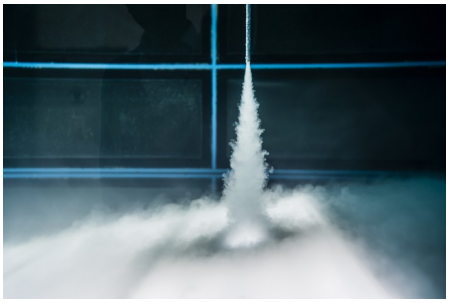
Reliable prediction of sediment transport is important for a wide range of applications in dredging engineering (transport of soil from A to B in a maritime environment). The challenge is to cover a large range of scales and unite many fluid and soil mechanical phenomena. For this reason the Dredging Engineering group of Delft University of Technology develops multiphase models and performs dedicated experiments for validation. The seminar will highlight a set of typical applications starting with very dilute flows towards dense granular flow near the maximum packing limit: turbidity plumes, erosion of sand at high flow velocities and dilative slope failure (unstable breaching).

Turbidity plumes

The modeling of turbidity plumes is very important for the assessment of the environmental impact of dredging activity. This is an issue during traditional dredging operations for example below the overflow of a hopper dredge, but becomes even more critical for future deep-sea mining activities. Large eddy simulations (LES) with a drift-flux approach for the sediment mixture have been executed to study the physics of turbidity plumes in cross flows and near the impingement point at the sea bed. The results of these simulations can serve as boundary conditions or used for the development of sub grid models for regional scale models. The dredging laboratory developed a novel test facility for turbidity plumes, where the development of concentration and velocity profiles can be monitored simultaneously. It is found that the presence of a phase fraction with a small settling velocity has significant impact on the development of the plume compared to the non-settling cases with saline water. Many interesting particle deposition patterns were observed during the tests.



Erosion of sand at high flow velocities

In dredging engineering high pressure water jets are used for the hydraulic excavation of sand. High speed velocities are also present during the catastrophic event of levee failures. Erosion at these high flow velocities is poorly understood and empirical relations obtained at low flow velocity (Shields parameter less than one) can over predict the erosion rate by orders of magnitude. In a recent study based on the two-phase flow equations for mass, momentum and the turbulent kinetic energy of the fluid carrier phase we found a possible explanation for the scaling anomaly between low and high velocities of the eroding flow. New closures based on recent experiments both with sediment lifts (see picture) and with freely erodible beds in a flume will be presented.

Dilative slope failure

Under water slopes can temporary become steeper than the natural angle of repose by the dilatancy of the soil matrix and the resulting negative excess pore pressure. As ambient water flows in, the slope gradually collapses, which is in contrast to short time scale soil mechanical failure phenomena like static liquefaction. In certain conditions dilative slope failure can progress and cause significant shore line damage (see picture) or destroy the foundation of hydraulic structures. The dredging engineering group developed a model based on a rheological description of the soil, which is fully compatible with the modeling of turbidity flows that develop above the bed and can enhance the erosion rate of the slope. The model is compared with new experiments. It is observed that static liquefaction events and dilative slope failure events can occur after each other, creating a rather dangerous chain of events that requires further attention.