Sludge Test Tank: a platform for nautical bottom rheology research to optimize in-situ measurement tools and reduce dredging activities

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Introduction: The harbour in Zeebrugge experiences a lot of sedimentation of fines. To ensure a safe passage for vessels, the depth of the harbour has to be maintained at a target depth. However a sludge package up to several meters can occur. At a certain depth below the top of the mud, the rigidity of the mud will cause navigational problems ('nautical bottom'). The density can be used to predict rheological parameters (like rigidity) of the mud, but the relation between density and rheology is site-specific. Also the parameter density is a static dimension that cannot be taken into consideration as a parameter for ship movement [1]. Therefore, rheological parameters, representing the forces experienced by a vessel while sailing in or just above the mud layer, are to be determined and defined. The aim of this research is to optimize in-situ rheological measurement methods to reduce dredging quantities by a more accurate predicting of the nautical bottom.

Methods: Measuring in-situ introduces many errors, due to factors beyond control, such as sampling depth, movement of the vessel, waves, wind and currents. Hence, a platform has been constructed that allows for controlled profiling of the sensors. The Sludge Test Tank (STT) has been built at Flanders Hydraulic Research (FHR) to host in-situ sludge for sediment studies (fig 1). The STT is designed and equipped for the conditioning and storage of a chosen sand-silt-clay mixture and sediment layers with different density and rheology parameters. More than 50 m³ of sludge from Zeebrugge is stored in the STT. Because of consolidation of the fluid mud, the sediment mixture shows a thixotrophic, shear-thinning behavior. A rheological transition zone can be observed, whose position in the sludge profile is changing during the compression settling time. A whole range of parameters are measured to relate the temporal evolution of the consolidation processes and rheological transition zone to sediment properties, a.o. density, rheology, pore pressures, thermo-gravimetric and sediment quality analyses.

Different rheological measuring devices were profiled vertically or towed in the STT. Results were compared with laboratory analyses of undisturbed sludge samples (Beeker sampler).

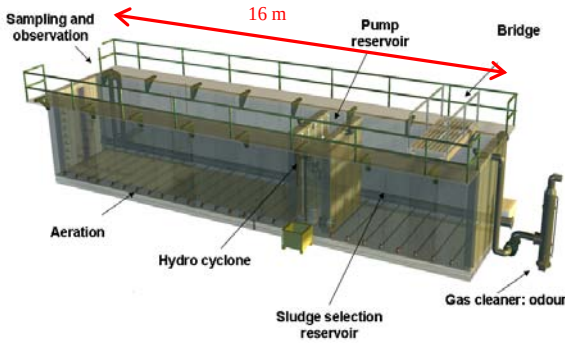

Fig. 1: Side view of the Sludge Test Tank

Results and discussion: Positive correlations are found between different sludge parameters, like consolidation speed, sludge temperature and pore overpressure. Sludge density values are linked with different sludge properties e.g. conductivity, pH and oxidation rate.

Prior to substantial consolidation of the sludge no clear correlation can be found between shear stresses and density. Due to consolidation processes, the rheology behavior of the mud changes in time. At a certain moment, depending on the composition of the mud, a clear correlation between yield stresses and density could be observed for densities higher than 1.17 g/cm³. Moreover, the relation between density and yield stress for well consolidated sludge layers was found to be similar to the relation obtained in sludge from other Flemish harbours [2]. This indicates that the influence of sediment composition on rheological behavior becomes less important as sediment volume fraction increases.

When first testing the rheological measurement methods in the STT, most instruments showed highly fluctuating values, exceeding the expected density or shear stress when entering the sludge. A second measuring campaign was needed to fine-tune the sensors and to improve the set-up conditions. By comparison of sensor output with laboratory analyses, the capacity of the sensors for measuring the density and rheological parameters could be assessed. Adequately assessing the rheological mud characteristics in the STT will allow to select suitable active dredging techniques (mud conditioning without removal).

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