Experimental investigation of the variability of the peak shear stress within consolidating cohesive sediment

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An experimental analysis of the variation of the peak shear stress within consolidating cohesive sediment is presented. To this end, the occurring peak shear stress of the cohesive sediment is analysed with a rotating vane based rheometer. By measuring the peak shear stress within samples with an identical initial condition at different time intervals, the temporal evolution of the peak shear stress is acquired. In addition, the influence of the considered deformation rate is examined by applying 10 different rotation speeds of the vane. The variability of the peak shear stress in function of the deformation rate and consolidation time is examined and mathematical formulations describing the dependence of the peak shear stress on both will be introduced.

Introduction

Many harbours and ports suffer from a net import of sediment, affecting the navigability and manoeuvrability of vessels entering. In order to guarantee safe access, commonly, the sediment is periodically dredged and disposed. When the sediment imported into the harbours chiefly consists of cohesive sediment, the efficient organization of maintenance dredging programs, however, is not straightforward. In particular, the rheology of consolidating cohesive sediment is known to be time dependent (e.g. Nichols, 1984; Kessel and Blom, 1998) and can strongly vary between different locations and with different local conditions (Claeys *et al.*, 2012). As such, a precise parameter which can be used as an indicator of the necessity to dredge is currently still under debate.

In the present study, we investigate the variation of the peak shear stress, i.e. the shear stress necessary to break the structure within the sediment build up during consolidation, with respect to consolidation time and deformation rate. The latter parameter is evaluated as it can be considered as a mimic of the speed of a vessel; while the first provides insight in the temporal evolution of the peak shear stress.

a.

b.

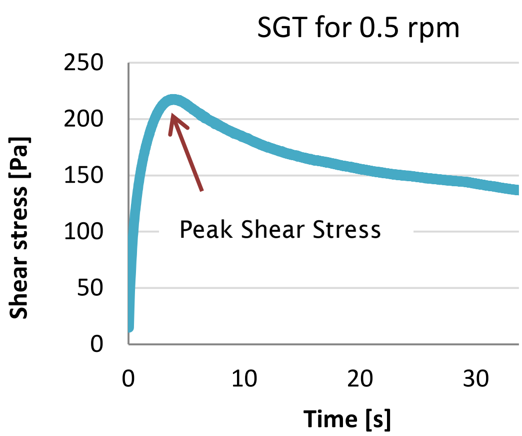

Fig. 1a. Picture illustrating the sample cups filled with cohesive sediment dredged in the harbour of Zeebrugge. Initially, the sediment has a density of 1.229g/cm^3.

Fig. 1b. Typical SGT result obtained with a rheometer and considering a constant rotation speed of 0.5 rotations per minute.

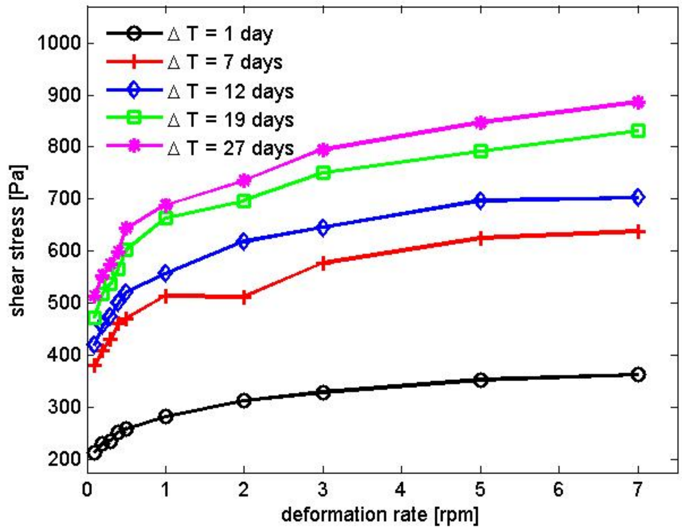

Fig. 2. The peak shear stress [Pa] (obtained by the instrument) plotted as function of the deformation rate (vane rotations per minute [rpm]) for five different consolidation times (ΔT).

Methods and materials

Within this study, we analyse the rheological characteristics of cohesive sediment dredged from the harbour of Zeebrugge. The sediment is homogenized, manipulated to a starting density of 1.229g/cm^3 and divided over 180 sample cups, see Fig. 1a. The variability of the peak shear stress is evaluated by applying a stress growth test ("SGT") on each (undisturbed) sample using a vane spindle (model: ST22-4V-40-SN11294) (Instruments, n.d.). This means that we monitor the shear stress needed to maintain a constant shear rate (~ constant revolution rate of the vane). In Fig. 1b, a typical SGT result is plotted illustrating the occurrence of a peak in the shear stress.

To investigate the influence of the deformation rate θ, 10 different rotation speeds are considered; while stress growth tests are performed on undisturbed samples at five different time intervals (ΔT).

Results

Fig. 2 illustrates the variation of the peak shear stress as function of the deformation rate after various consolidation times. In this study different deformation rates are obtained by varying the vane rotation rate. The figure indicates that different deformation rate significantly affects the required shear stress necessary to break up the sediment structure. On the other hand, Fig. 2 indicates that the increase in peak shear stress is smaller for high deformation rates than for lower values of θ, suggesting a logarithmic interdependence. Similarly, it is found that the time interval the sediment has consolidated can appreciably impact the peak shear stress.

Conclusions and outlook

The variability of the peak shear stress within consolidating cohesive sediments is analysed experimentally. It is found that both deformation rate as consolidation time significantly affect the occurring peak shear stress. In particular, the obtained data suggests that the peak shear stress increases logarithmically with deformation rate, while also ΔT is found to have a significant influence. Currently, laboratory experiments are ongoing in order to extend the dataset on the peak shear stress as function of consolidation time and deformation rate such that mathematical formulations can be confidently fitted to the data. Moreover, additional tests are presently performed to evaluate also the impact of the starting density.

References

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