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Spatial variability in the yield stress of mud at Port of Hamburg, Germany

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1. Introduction

Natural mud typically consists of clay minerals, water, sand, silt, and a small amount of organic matter of different origin and composition. For practical reasons, the nautical bottom was until recently defined as a critical fluid density (McAnally et al., 2007). However, there is another criterion (i.e., yield point) which is quite important for the ports where the organic matter content is significantly varying as a function of location within the port. For these ports, only density is not enough to predict the rheological characteristics of mud and the nautical bottom ought to be defined on the basis of yield stresses of mud (Wurpts and Torn 2005; Shakeel et al., 2019; Shakeel et al., 2020). The objective of the present study is to analyse the spatial variability in yield stress of mud from Port of Hamburg, Germany and to define a nautical bottom based on yield stress.

2. Experimental

Natural mud samples were collected from different locations (Figure 1a) and depths of Port of Hamburg, Germany using 1 m core sampler (Figure 1b). The obtained samples were then subsampled into different layers on the basis of their consolidation stage. The bulk density of the mud samples was estimated by the oven drying method. The organic matter content (TOC) of mud samples was determined using an ISO standard 10694:1996–08. The Thermo Scientific HAAKE MARS I rheometer with concentric cylinder geometry was used to perform the rheological measurements. Stress ramp-up test, at a sweep rate of 1 Pa/s, was carried out to analyse the yield stress of mud samples.

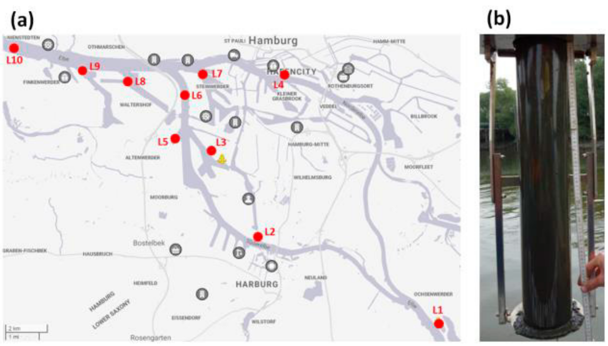

Figure 1: (a) Selected locations in the Port of Hamburg, Germany for collecting mud samples, (b) sample collector (Frahmlot).

3. Results and discussion

The correlation between the density and yield stress of mud for different locations of Port of Hamburg is shown in Figure 2. It is clear from Figure 2 that the yield stress vs density curve is a strong function of sampling location. A modified power law was used to fit the experimental data of yield stress as a function of density for different locations, given as:

$$\tau = a \cdot ((\rho - \rho_w)/\rho_w)^b \quad (1)$$

where ‘a’ and ‘b’ are two fitting parameters. It was found that the parameter ‘b’ was not varying significantly and, therefore, a fixed value of 2.4 was used for parameter ‘b’. The power law fitting was performed with just one fitting parameter ‘a’, as shown in Figure 2.

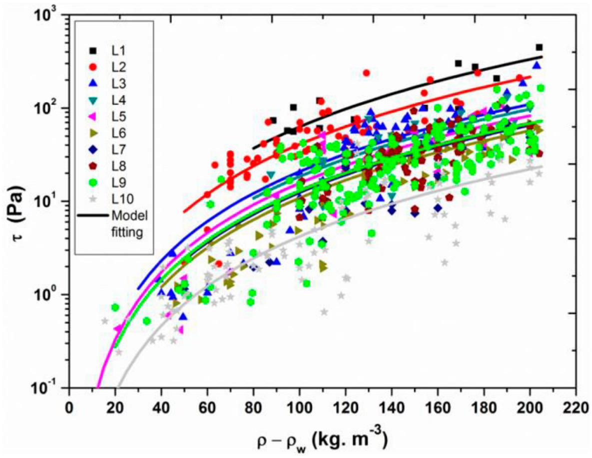

Figure 2: Yield stress as a function of excess density for different locations of Port of Hamburg, Germany. The solid lines represent the power law fitting (Eq. 1) with one fitting parameter ‘a’ and the fixed value of parameter ‘b’ (2.4). ρ_w represents the density of water.

In order to further analyse the effect of organic matter content on the yield stress of mud samples, the fitting parameter ‘a’ was correlated with the TOC content (data not shown). The result showed a strong correlation between the fitting parameter ‘a’ and the TOC for different locations.

4. Conclusions

This study confirms that the yield stress of mud samples from Port of Hamburg, Germany is significantly varying along the port, due to the variation in organic matter content. It is also identified that the yield stress value of 50 Pa can be used as a criterion for nautical bottom for the considered port.

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