Monitoring the strength development of mud layers in ports and waterways

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Introduction: Port authorities, in order to safeguard navigation within their waterways, usually spend substantial costs for maintenance of silted channels by means of hopper dredging and relocation of the dredged sediment to the open sea.

Traditionally, the surveying in ports is conducted using echo-sounders. However, it has been recognized that low-frequency echo sounding surveys are not reliable in the areas with substantial fluid mud layers and mud density gradients and, therefore, they are no longer normative [1]. This conclusion led to the development of alternative surveying strategies, which have been tested in different ports and waterways with fluid mud layers ever since. The developed measuring tools are typically designed to measure the density of mud. In some ports (e.g. the Port of Rotterdam, the Port of Zeebrugge) the density has been used as a criteria for defining the nautical bottom [2]. Moreover, the density is also an important parameter to estimate the dredged volumes that are required for maintenance dredging.

As stated in the PIANC report (XX) density alone might not be a sufficient criteria to define the nautical bottom, and yield stress should also be considered. Recent progress in the development of the shear strength (or rheology) measuring equipment enables nowadays to use these methods in waterways with fluid mud layers to assess yield stress [3]. In the present work we compare existing and rheological in-situ monitoring techniques used to monitor the development of fluid mud layers over time in the Port of Hamburg.

Methods: In this work, we tested the conventional low-frequency (38 kHz) and high frequency (200 kHz) acoustic sounding and compared it to the recordings of Graviprobe, Rheotune and rheological analysis of 'undisturbed' mud samples, that were collected on site. The Graviprobe instrument (see Fig. 1(a)) measures the cone penetration resistance while falling free in a water-mud column. The cone penetration resistance is then correlated to the undrained shear strength of the fluid mud layer. The Rheotune (see Fig 1(b)) is based on the recording of the amplitudes which are triggered by mechanical vibrations at different frequencies. The recordings can be used to get the information about the yield stress and/or density of fluid mud layers.

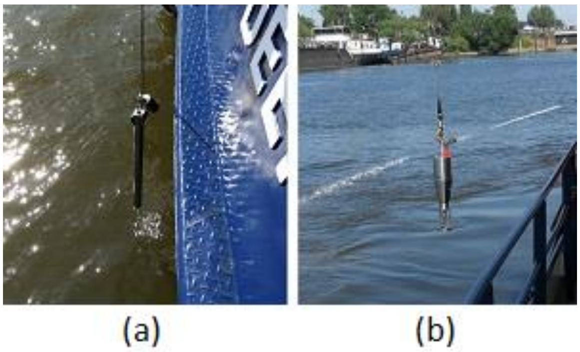

Fig. 1: The Graviprobe (a) and the Rheotune (b) testing at the Port of Hamburg.

Results: Our study shows that Rheotune and the Graviprobe data are in acceptable agreement regarding the value of the navigable depth. The differences between techniques are discussed.

Conclusion: A large variety of in-situ measuring tools are operational for characterizing the behavior of fluid mud. Based on our observations, we can conclude that these tools can provide useful information for developing new cost effective maintenance strategies in the ports and waterways with fluid mud layers.

This study is funded by Hamburg Port Authority and carried out within the framework of the MUDNET academic network. www.MUDNET.eu

References: [1] Kirby et al. (1980) *Int. Hydr. Rev* ; [2] PIANC (2014) *Harbour Approach Channels - Design Guidelines*, **121** ; [3] Kirichek et al. (2018) *Terra et Aqua* **151**:6-18.