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Rheology and settling processes of mud for defining critical limits for navigability in the Port of Felixstowe

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Introduction: The UK's largest container port at Felixstowe, faces significant sedimentation challenges, with approximately 2.4 million m³ of sediment requiring management annually [1]. To optimize maintenance strategies and enhance navigability, Harwich Haven Authority is exploring the implementation of PIANC's nautical bottom concept [2], which relies on understanding the rheological and settling behaviour of muddy bed in the port.

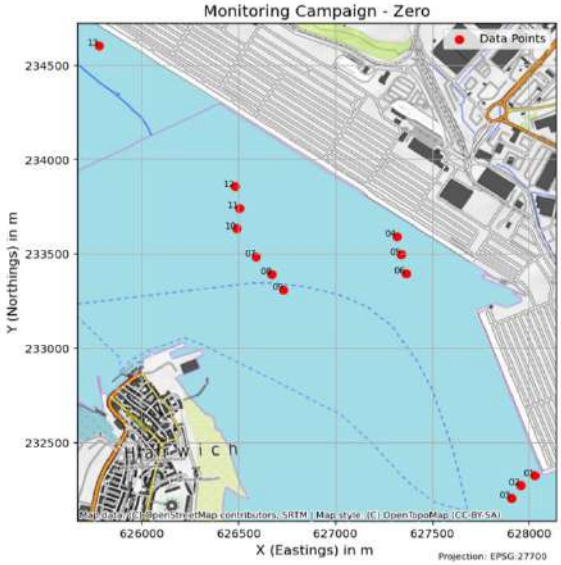

Fig. 1: Sampling and surveying locations at the Port of Felixstowe.

This study examines the shear strength (yield stress) evolution of soft mud layers by investigating their physical properties (e.g., density, organic matter, salinity, etc.), rheological behaviour such as yield stresses and thixotropy, and how these properties develop over time. By linking these temporal changes due to sediment settling and consolidation processes, the research aims to identify critical thresholds for navigability.

Methods: In this study, the analysis of both in-situ measurements and laboratory characterization on sediment samples was carried out. Sediment core samples were collected in the Port of Felixstowe using one-meter core sampler (the Frahmlot). The samples were subsampled into suspended particulate matter, fluid mud, pre-consolidated sediment and consolidated sediment at various depths per location (see Fig 1). The bulk density, particle size distribution, organic matter content, minerology, settling properties and rheology of sediment samples were determined in the laboratory. To identify the rheological characteristics of fluid mud and their development over time, in-situ measurements of density and yield stress, acoustic surveys to map the lutocline and mud-bed interface were conducted using the Rheotune and dual-frequency echosounder which are commonly used for determining the nautical bottom [3].

Results: The analysis conducted on in-situ data and collected sediment samples revealed the following results:
1) The bed of the port consisted of predominantly silt and clay with slight variation of sediment's particle size, organic matter, minerology and salinity suggesting that the density and strength variation of bed were predominantly driven by settling and consolidation of mud.
2) The analysis of settling behaviour showed a special variation in gelling concentration (structural density) of mud.
3) Strong thixotropic behaviour of mud was observed on mud with yield stresses above 50 Pa, which was in line with previous studies (e.g., [4]).

Discussion: The correlation of the in-situ and lab yield stress data could be potentially improved by generating a broad rheological dataset for calibration of the in-situ measurements.

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References: [1] Spearman and Benson (2022) *WODCON XXIII*; [2] PIANC (2014) Harbour Approach Channels - Design Guidelines; [3] Kirichek and Rutgers (2020) *Terra et Aqua* **160**:16-26; [4] Shakeel et al. (2020) J. Soil and Sed. **20**: 2553–2562.