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Conceptual design for investigations on natural cohesive sediments from the Weser estuary

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For An Improved Understanding Of Estuarine Sediment Transport – Research project FAUST

The complexity of fine sediment dynamics in tidal estuaries arises from the large number of parameters that influence the processes for the formation of temporally and spatially variable bottom conditions. The project FAUST (06/2018-06/2021) addresses basic challenges in modelling sediment exchange at the water / soil interface. By means of sampling natural sediments from the Weser and Elbe estuary, parameters for erosion, deposition and consolidation behavior are determined performing phys. experiments. The project is based on the common idea that flocs form and sink predominantly during slack water. As a result, a bottom near stationary suspension is formed which even begins to consolidate. At the onset of flood-/ebb-currents, the stationary suspension already increased its erosion resistance. Full resuspension might therefore be hindered during the next tidal phase and accumulation occurs over several tidal phases. From the investigations carried out model approaches for the description of the dynamics of cohesive sediments shall be derived specifically for the German estuaries. This poster presents the first stages of the project.

Sampling Setup

Natural sediments at Weser and Elbe estuaries within the navigational channel at ETM and slack time are taken.

Fig. 2 Sampling natural sediments from the Elbe & Weser ETM, here at HH harbor in 2019

Characterize the cores:
- Corn size distribution
- Loss on ignition
- Water content
- Salinity
- Density profile

Fig. 1 Sediment core sampler developed by TUHH, IRCE (2019)

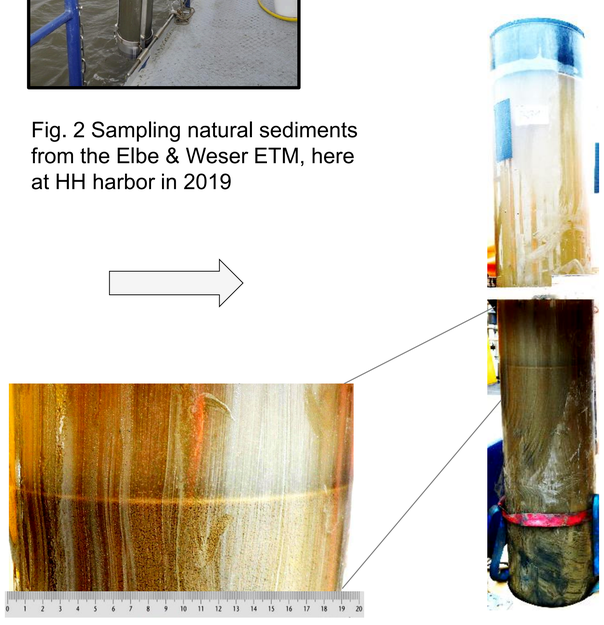

Fig. 3 Natural samples from navigation channel during slack time

Motivation

Major German estuaries (e.g. Weser & Elbe) are subject to a suspended matter dynamic:

- Estuarine turbidity maximum (ETM) leads to accumulation of fine cohesive sediments
- Expensive maintenance dredging (> 10^3 m^3 of sediment) required for navigable water depths
- In spite of decades of research, there is no generally valid model approach for bottom exchange
- Widely used model approaches (e.g. Partheniades-Law) and common parameterization is not satisfactory to simulate observed fine sediment dynamics
- Estuary-specific and extended parameterization is required for deposition and erosion formulas

Consistent set of devices:
- The soil sampler
- The erosion chamber
- The settling tube

are made for Ø 20 cm samples and 120 cm height.

Investigate influence parameters to the erosion thresholds:
- Consolidation time
- Salinity
- Forcing (static, dynamic, …)
- ….

Experimental Setup

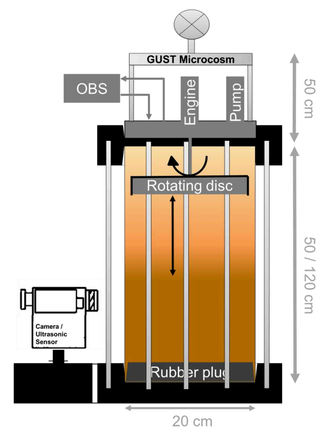

Fig. 4 Adapted GUST (1997) erosion chamber using reproduced & natural samples

Determination of erosion thresholds

Reproduction of representative samples

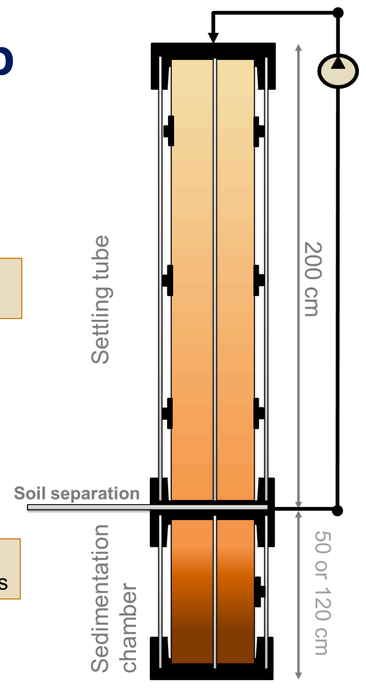

Fig. 5 Settling tube with homogenization and separation of deposited bed

Settling experiments

The settling column is separated into two sections:
- Section one: mixing and settling zone
- Section two: sedimentation and consolidation

Settling exp. are carried out to determine settling velocities, deposition rates and bottom forming behavior under set boundary conditions (initial concentration, salinity,…).
The sedimentation chamber, see Fig. 5, is movable to analyze reproduced naturelike samples in further erosion studies with the erosion chamber.
Preliminary settling experiments have been carried out with Elbe sediment. Results suggest bottom forming and consolidation within the first hour after start of calm conditions, see Fig. 6. This supports the projects hypothesis.

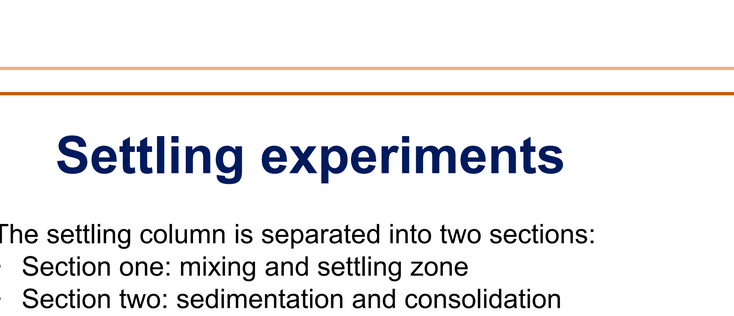

Fig 6. Examples from settling experiments at TUHH

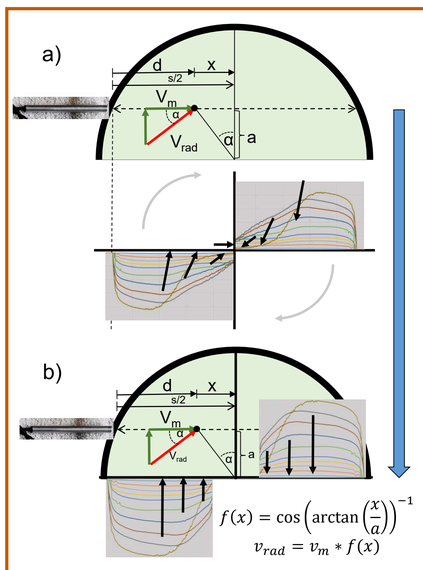

Fig. 7 Methodology of ultra-sonic measurements for flow field determination

Gust erosion chamber: flow field determination

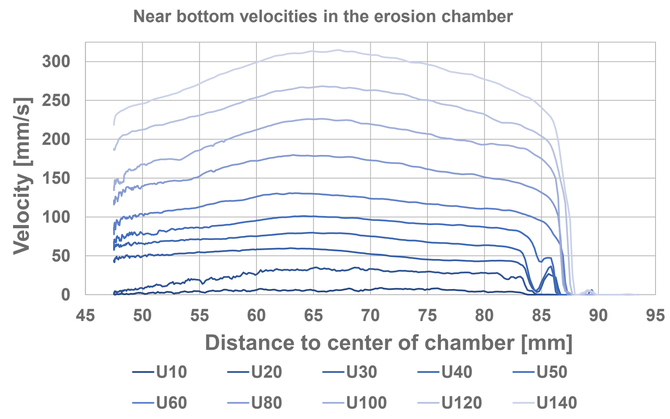

Fig. 8 Velocities v_{rad} along the diameter axes for modes of rotation (U)

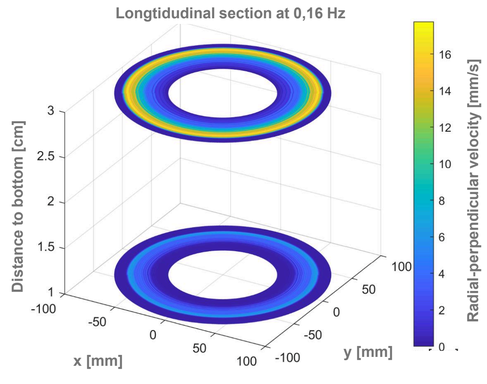

Fig. 9 Radial velocities in different heights above ground under the rotating plate

Because high concentrations in suspension may lead to viscous flow, we perform a new determination of shear inducing velocities at the water soil interface, compare Gust & Müller (1997). Using ultrasonic sensors (US) the flow field of the erosion chamber has been scanned, e.g. Fig. 7 a). Velocities $v_m$in direction of the sensors along the measurement axes are determined and transformed to v_{rad} using $f(x)$. Velocities v_{rad} are perpendicular to the radius. Fig.8 exhibits a quite uniform velocity (v_{rad}) profile along the radius for 10 states of flow within the chamber. Fig.9 demonstrates v_{rad} in two longitudinal sections respective 1 cm and 3 cm above bottom.

Take Home Messages

Project FAUST aims to model bottom exchange by:

1. Sampling natural cohesive sediment cores
2. Characterizing cores of natural sediment
3. Focusing Weser & Elbe estuaries
4. Reproducing naturlike sediment density profiles
5. Performing lab experiments on erosion, deposition and consolidation
6. Determining estuary specific parameterization for application in numerical models

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