Research Area D

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Specific Problems in Using Organic Harbor Mud as Construction Material

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1 Project Description

In 2005 / 06, the second largest harbor construction project in Germany was carried out as a pilot study in using dredged harbor mud as construction material. Situated in Bremerhaven at the mouth of the river Weser, a shallow harbor basin was redesigned to meet the following goals:

- Generation of required storage space for car export
- Deepening of the basin to accommodate deep sea car-carrier
- As short as possible construction phase
- On-site disposal of the dredged sediments to avoid disposal costs

During the construction phase, 7 m of harbor mud (TOC: 3 - 5 w%) were pumped behind a sheet piling, accumulating to max. 16 m of soft soils. Special care was taken to reduce water intake of the mud during dredging and relocation. A geotextile, preventing density induced mixing, capped and separated the mud layer from the following 4 m of sand layers. An ~0.8 m spaced vertical vacuum drainage (effect. length >1,200 km) was installed to accelerate consolidation (**Fig. 1**).

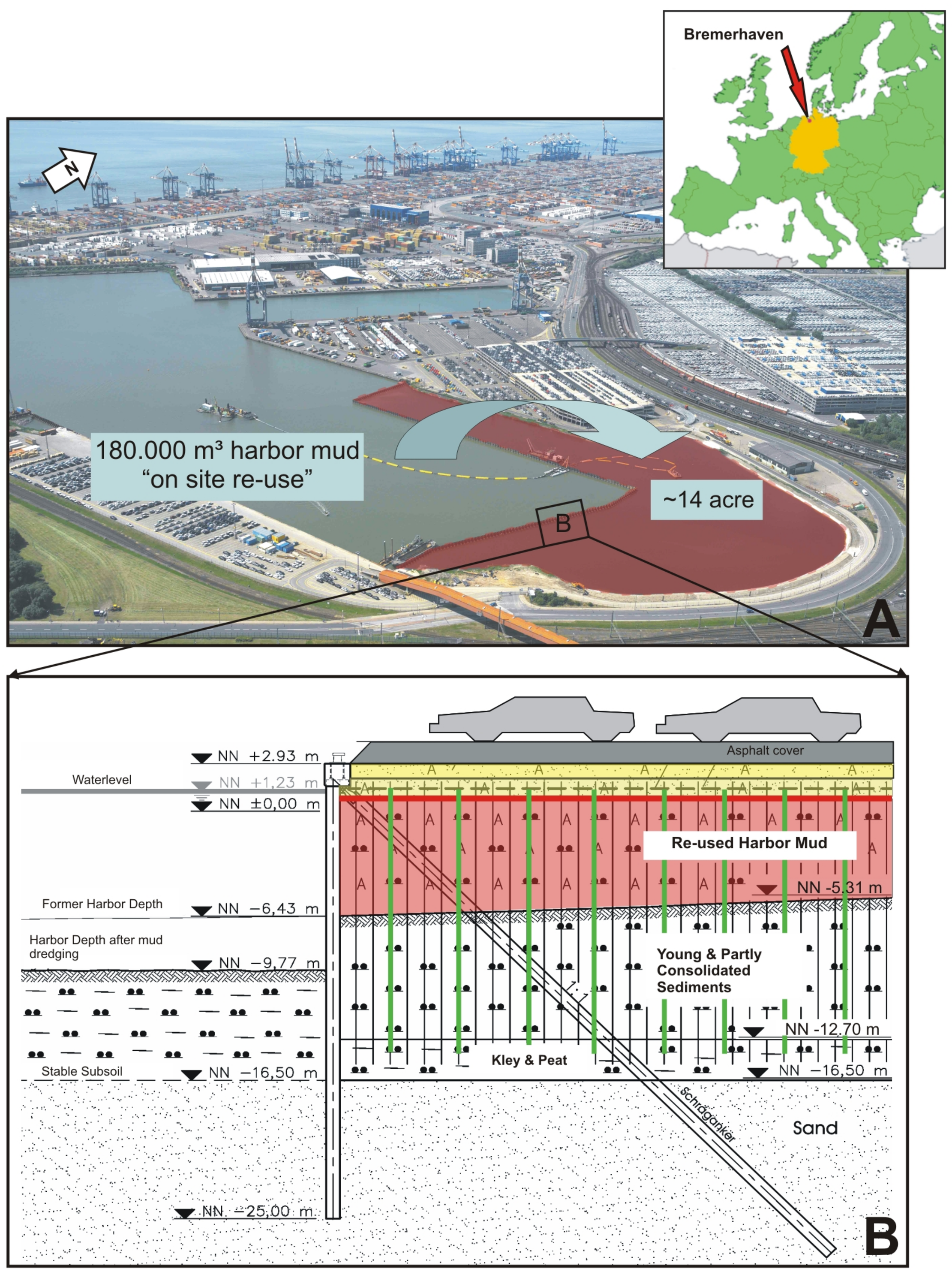

Fig. 1: Location of the 'East Harbor Basin' at Bremerhaven, northern Germany. **(A)** Organic rich, contaminated mud is dredged from basin and relocated to fill a former basin part. **(B)** Cross section of finished RoRo-car carrier pier, showing re-used harbor mud (red) beneath a geotextile (thick red line) and various sand layers (yellow). Vacuum drainage system sketched in green.

2 Ground Movement

Despite preventive measures, intense vertical mud-layer movements of up to 2 m occurred and could only partly be explained by semi viscose and thixotropic material properties (**Fig. 2**). Furthermore, mentionable amounts of in-situ gas generation was observed from the mud layer (**Fig. 3**).

Fig. 2: **(A)** Vertical mud movements led to hump formation and local failure of the geotextile. **(B)** Degassng voids in syringe sample.

3 Gas Quantification

The observed gas composition (avg.) is CH_4 > 98%, CO_2 less than atmospheric and various intermediate liquid & gasious decomposition products < 0.5% (e.g. dimethylsulfide).
Headspace sampling from sediment cores was the first attempt to quantify the methane content of the mud. **Fig. 3A** shows that methane (blue) can only be measured up to its solubility limit (purple). Free gas is undetectable with this method (green). A new volumetric appoach using equal volume sampling and gas pycnometry turned out to be a better appoach toward total gas content (disolved and free phase). Compared to **Fig. 3B**, the severe overestimation of Methane from dryed mud samples becomes clear.

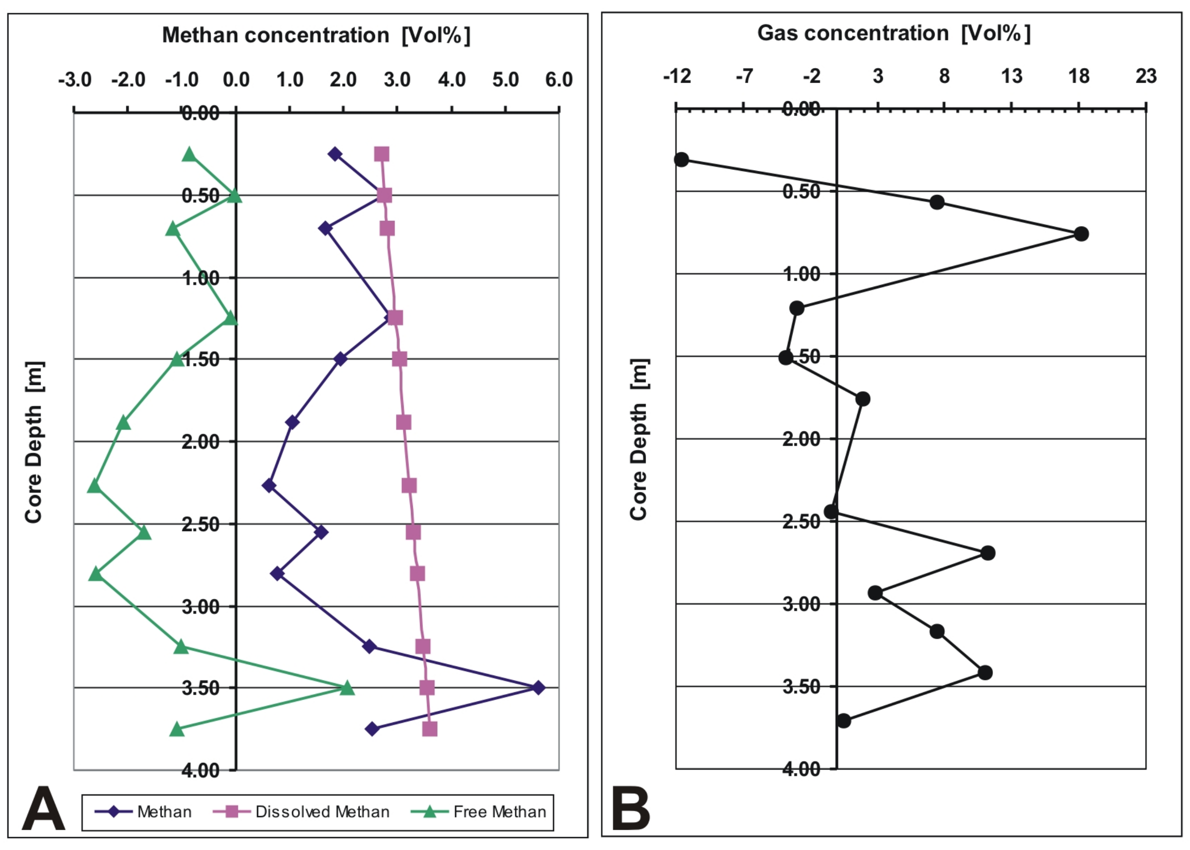

Fig. 3: **(A)** Methane concentrations from headspace samples from mud cores . **(B)** Volumetric methane concentrations calculated from dryed ~5 ml syringe core samples.

4 Consolidation Testing & Modeling

To study mud consolidation behaviour, hydraulic conductivity and gas formation in a comprehensive context, a large scale oedometer with attached permeameter and gas trap was designed.
Fig. 4A shows, that each increase in loading leads to a distinct short-term gas export event. A constant gas generation rate seems to be approached at a total stress of 8 kPa. A 2D Finite Elemet Model was run for a cross section over the filled basin revealed long primary consolidation times (~9 months) due to the mud's very low hydraulic conductivity values (~10^{-7} m/s), **Fig. 4B**. Despite special constructional measures the unfavourable mud properties lead to extended consolidation times and expenditures.

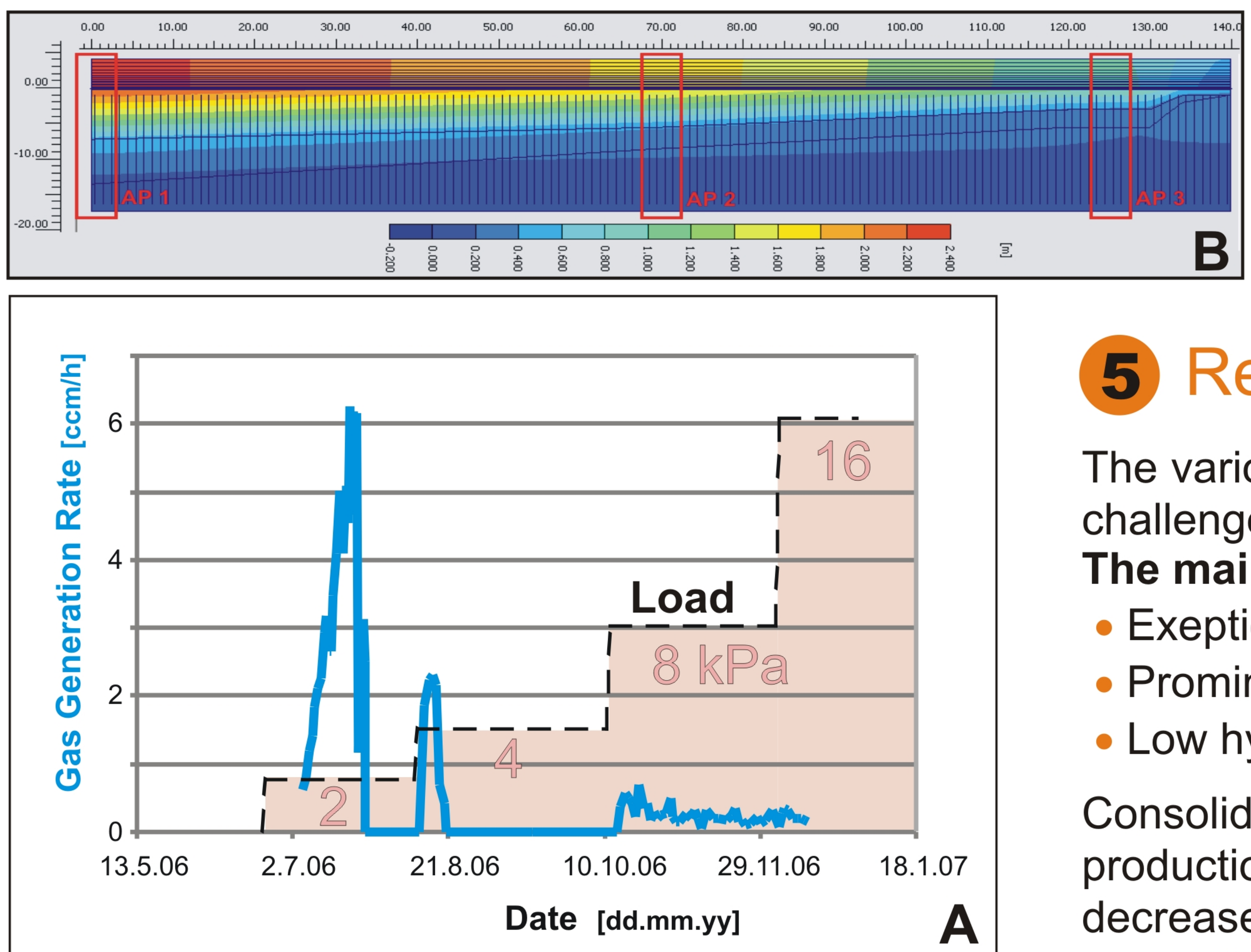

Fig. 4: **(A)** One-dimensional compression lab test with Oedometer, 22 cm diameter. **(B)** FEM: settlement values after full primary consolidation; creep was not included.

5 Results

The various field and lab observations (not all presented here) reveal the challenge in using organic harbour mud as construction material. **The main difficulties** result from:

- Exceptionally low initial shear strength (0.2 - 0.6 kPa)
- Prominent thixotropy
- Low hydraulic conductivity leading to long consolidation time

Consolidation is further affected by organic decay which leads to gas production leading to an increase in drainage path tortuosity and a decrease in water permeability of the geotextile. Lab oedometer testing suggests that the first loading steps free adsorbed gas. As consolidation preceeds, adsorption capacity diminishes and gas production rate approaches the observed free gas export.

Coastal Dynamics and Human Impact

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