ON THE BENEFICIAL USE OF SOFT MUD – CASE STUDY MARKER WADDEN PROJECT

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INTRODUCTION

LAKE MARKERMEER AND PROJECT MARKER WADDEN

Let’s start with a video!

http://magazine.boskalis.com/issue04/marvelous-marker-wadden
INTRODUCTION

SIMILARITIES BETWEEN MARKER WADDEN PROJECT AND OIL SAND INDUSTRY

- Reclamation is required from an environmental and regulatory perspective.
- The project is an example of how to reclaim an area using large quantities of soft material for which dewatering and strength development is a rather slow process.
- Handling large volumes requires a cost-effective work method: limit use of additives, limit multiple operational rehandling steps, smart use of natural processes.
- The spatial scale of the Marker Wadden (300 – 500 ha) is comparable to typical oil sands ponds (diameter of ~2-4 km, 300 – 1000 ha).
DESIGN

- Borrowing pit
- Rock revetment
- Siltation trench
- Recreational port
- Sandy Beaches
- Underwater dams
DESIGN – KEY ISSUES

Water level Markermeer

Requirements:
- Final elevation levels
- Strength requirements (goose accessibility)

Reclamation  Consolidation  Dewatering  Drying / crust formation  Final
DESIGN – KEY ISSUES

CRUST FORMATION AND EFFECT OF VEGETATION
SETTLING COLUMN TESTS (BOSKALIS LAB) AND SEEPAGE INDUCED CONSOLIDATION (SIC) TESTS (DELTARES)

- Determine consolidation relations, i.e. compressibility and permeability relations that are required for consolidation modelling.

- Representative clay material from Lake Markermeer.
DESIGN - LARGE SCALE TESTING

CONTAINER TESTS

- Determine if scale effects can play a role.
- Three containers with the following dimensions: $l \times w = 5.9\,\text{m} \times 2.3\,\text{m}$ and $h = 1.9\,\text{m}$ were filled with representative clay material from Lake Markermeer.
- One container was filled completely at the start of the experiment, other two initially filled half and later with an additional filling layer.
NUMERICAL MODELLING OF CONSOLIDATION

- DELCON model. 1D model for self-weight consolidation of mud developed by Deltares.
- Input: relations between void ratio, permeability and effective stress. Based on outcome of column tests and SIC tests.
- Test filling strategies and determine the sensitivity of the outcomes for initial parameters.
- Focus on elevations and density development.
- Effect of crust formation on consolidation behavior was analyzed in terms of extra bed level lowering, based on model developed by TU Delft.
OPERATIONAL WORKING METHOD
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ADAPTIVE MANAGEMENT DURING CONSTRUCTION

DECREASE UNCERTAINTIES DUE TO MONITORING AND ADDITIONAL MODELLING
ADAPTIVE MANAGEMENT DURING CONSTRUCTION

FIELD MONITORING AND ADDITIONAL MODELLING

- Once or twice a week to monitor the consolidation behavior of the material in the compartments.
- Density profiles from the fresh bed to the original bed were taken at various locations inside the compartments, using a MudBug device.
- ‘Bed’ levels with single beam and multibeam.
- Additional DELCON modelling:
  - Improve predictions
  - Determine final heights
MARKER WADDEN AS AN EXAMPLE FOR RECLAIMING OIL SANDS TAILINGS PONDS

SIMILARITIES AND DIFFERENCES

- Although characteristics of the soft clay material in the Markermeer are different from the oil sands tailings, the same physical processes occur → same theory and tools can be used for predictions.

- Similar operational work method can be applied and adaptive management of operations is needed to continuously optimize that work method. → monitoring needed!

- Differences in reclamation depth: 5 m in the Markermeer – 10’s of m in oil sands ponds
  - Work method cannot exactly be copied as consolidation times would be too long
  - Sand capping techniques between filling layers
  - Proven technique in multiple dredging projects
  - Needs advanced engineering and dredging expertise
  - Strategy of Marker Wadden project as example
CONCLUSIONS

- Building with soft muddy material is possible without the use of chemical additives, in an economical and safe way.

- The Marker Wadden project can be considered as a good example for the oil sands industry how to reclaim large deposits of soft mud:
  - reclamation large quantities of soft material at relatively low costs
  - the same physical processes occur and the same design tools are applicable
  - an integrated and iterative design process is needed, incorporating state-of-the-art design tools/engineering, operational experience (adaptive management), cost and safety

- Difference in reclamation depth requires measures (like sand capping between filling layers) to reduce consolidation time.
Thank you for your attention!

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