MANAGING RISK DNV

Geotechnical Analysis Requirements

Copenhagen Offshore Wind 2005

Tove Feld
October 2005

Overview

- Procedures for soil investigations
  - Different Elements in Soil investigations
- Requirements to the geotechnical analysis
- Importance of planning and execution
  - Time schedule for SI
- DNV´s experiences
- Conclusion/Recommendation
  - The value of adequate soil investigations

Soil Investigations

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Soil Investigations may be divided into:

- Geological Studies
- Geophysical Surveys
- Geotechnical Soil Investigation

Extent and Type of Soil Investigations

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Depends on:

- Type, size and importance of wind turbine support structure (Turbine or substation)
- Complexity of soil and seabed conditions
- Actual soil deposits
- Positioning and installation tolerances shall be accounted for

Soil Investigations

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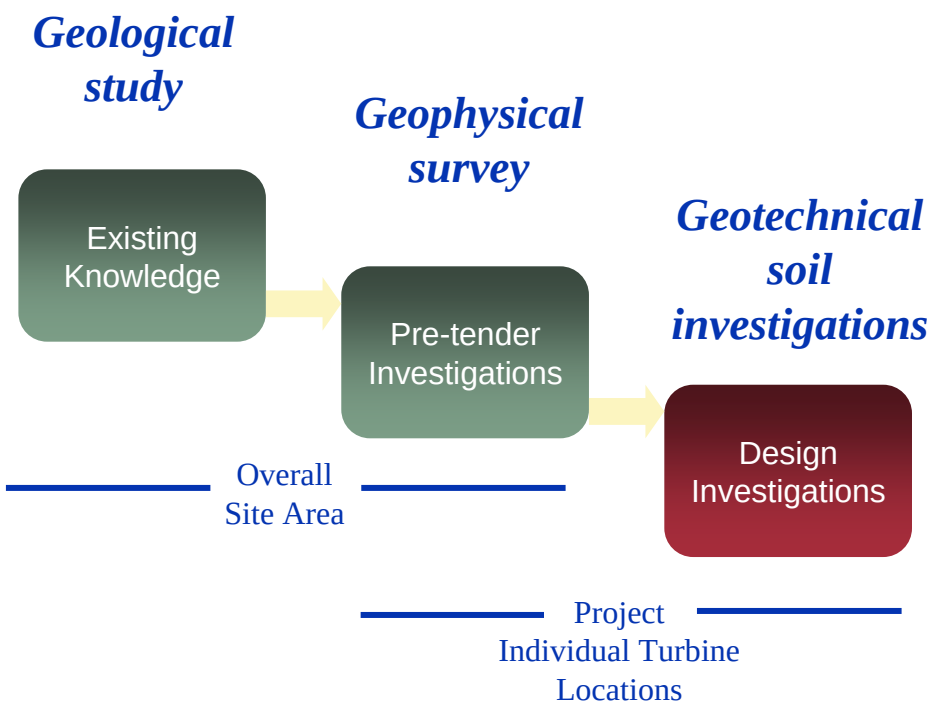

Soil investigations normally comprises

- Site geology survey
- Topography survey of the seabed
- Geophysical investigations for correlation with soil borings and in-situ testing
- Soil sampling with subsequent laboratory testing
- In-situ test, e.g. Cone Penetration tests (CPT)

Design Investigations

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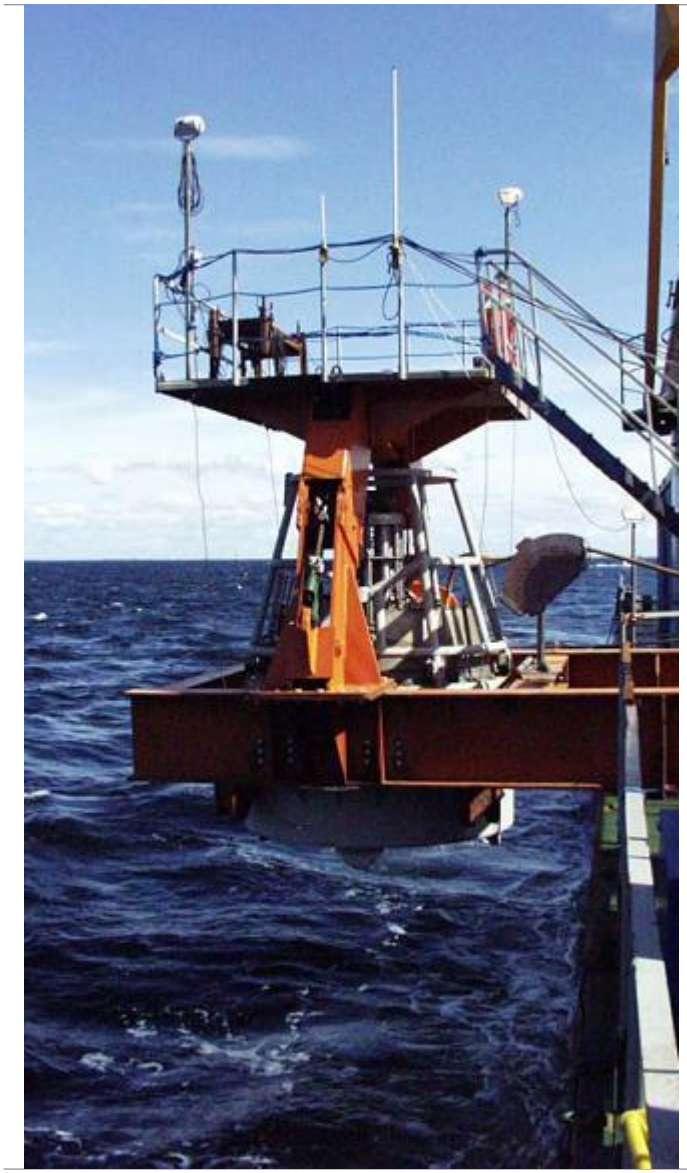

- Current preferred practice:
  Borehole and/or CPT at each turbine location
- Calm geology, from seismic investigations may lead to minor investigation program
  - Depending on the spatial variability of the soil the soil parameters and the robustness of the design approach
- For calibration of the CPTs, a minimum of one CPT should be performed in close vicinity to one of the soil borings.
- Extend and type of investigation depends on chosen foundation concept

Soil Investigations DNV-OS-J101

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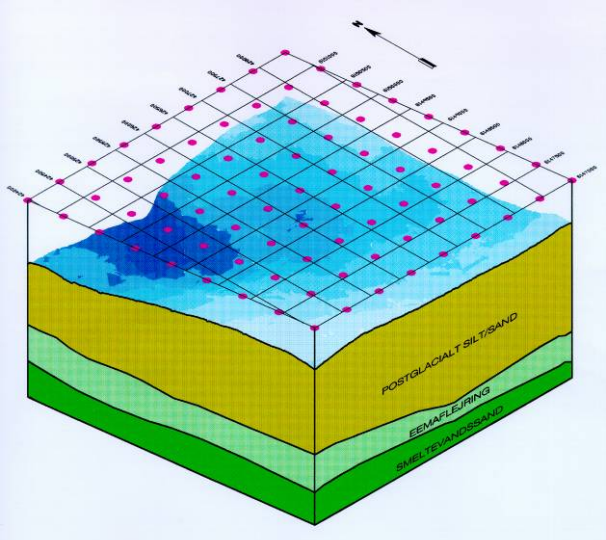

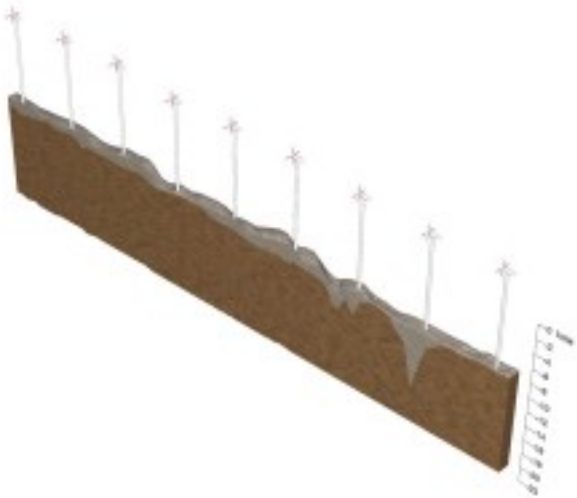

- Soil investigations (SI) shall provide relevant information about soil to a sufficient depth

e.g. possible *weak formations* below will *not influence the safety or performance* of the wind turbine, the support structure nor the foundation

- The sufficient depth of soil investigations depends on foundation type

Investigation Type & Depth DNV-OS-J101

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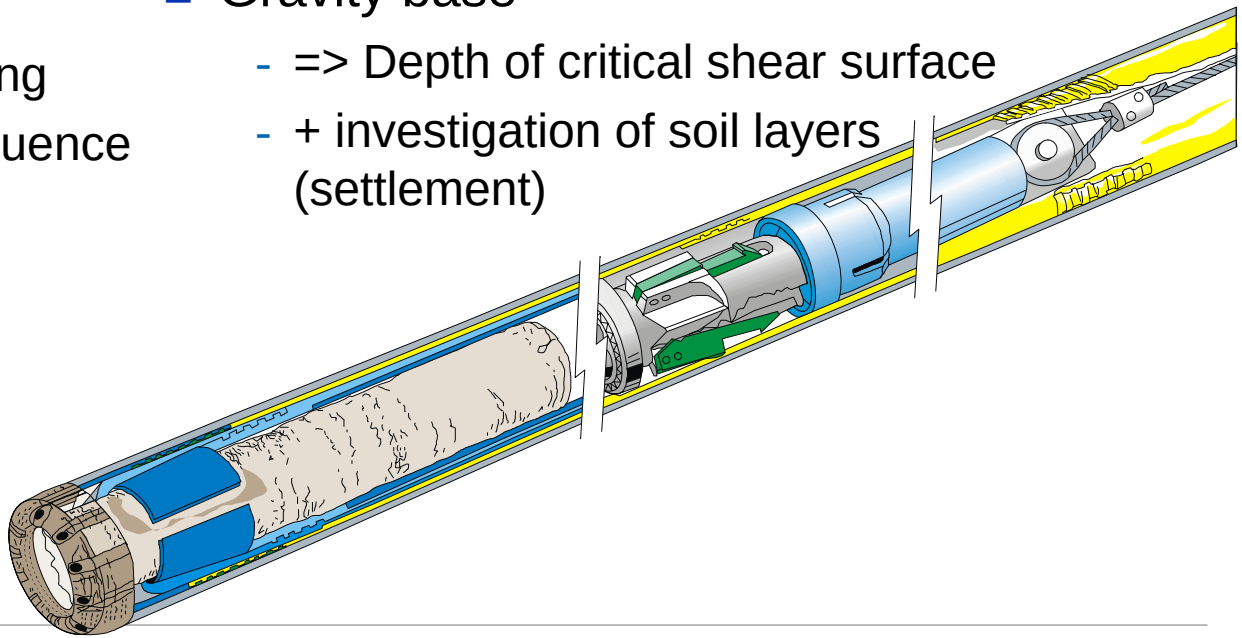
- Laterally Loaded Piles
  - SI: combination of CPTs and Borings w/ Sampling
  - Investigation Depth
    - Slender & flexible piles (jacket type) => Depth ~10 pile diameter (10 OD)
    - Monopiles => Penetration Depth + ½OD

- Axial Loaded Piles
  - SI: CPT & nearby Boring
  - to pile tip + zone of influence

- Gravity base
  - => Depth of critical shear surface
  - + investigation of soil layers (settlement)



In-situ Tests, Sampling and Laboratory Tests

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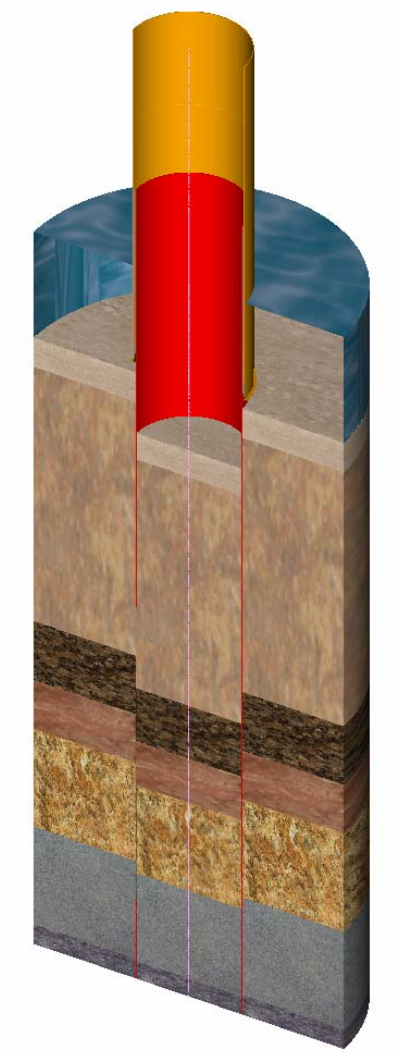

Provide geotechnical data for important layers

- Soil classification and geological description
- Strength and deformation parameters (analysis dependent)
- In-situ conditions
- Lateral extent and lateral soil property variation of layers
- Laboratory test program shall be sufficient to perform detailed design

Time schedule for SI

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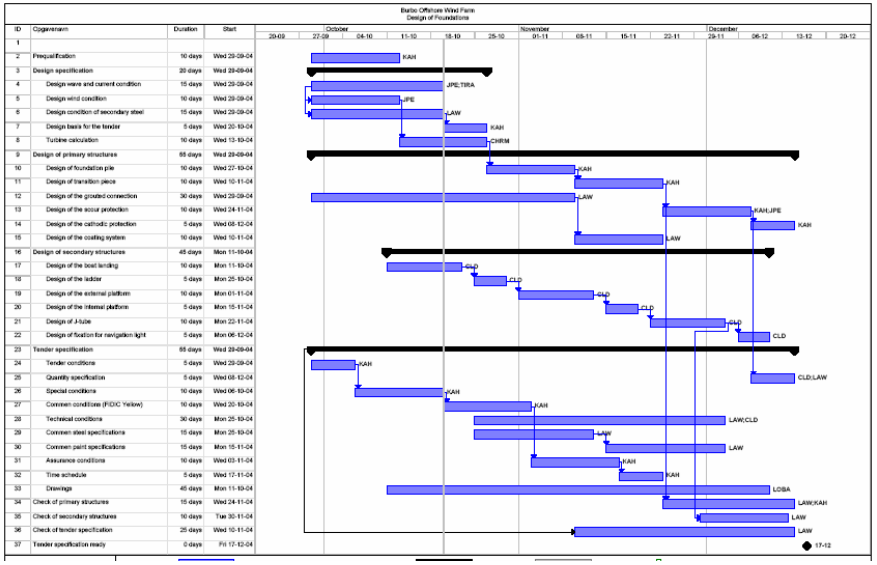
- It is essential that the right information is available at the right time.
- Steel orders placed before final SI are carried out/evaluated
- Soil investigations are often key items for project discussion, and plays an important role in the entire project evolution.
- Information shall be achieved in a process closely related to the project evolution – SI part of overall project Schedule



- Sometimes poor or inadequate soil investigations are performed resulting in the requirement to carry out additional soil investigations.

Ideal Time Schedule for Project

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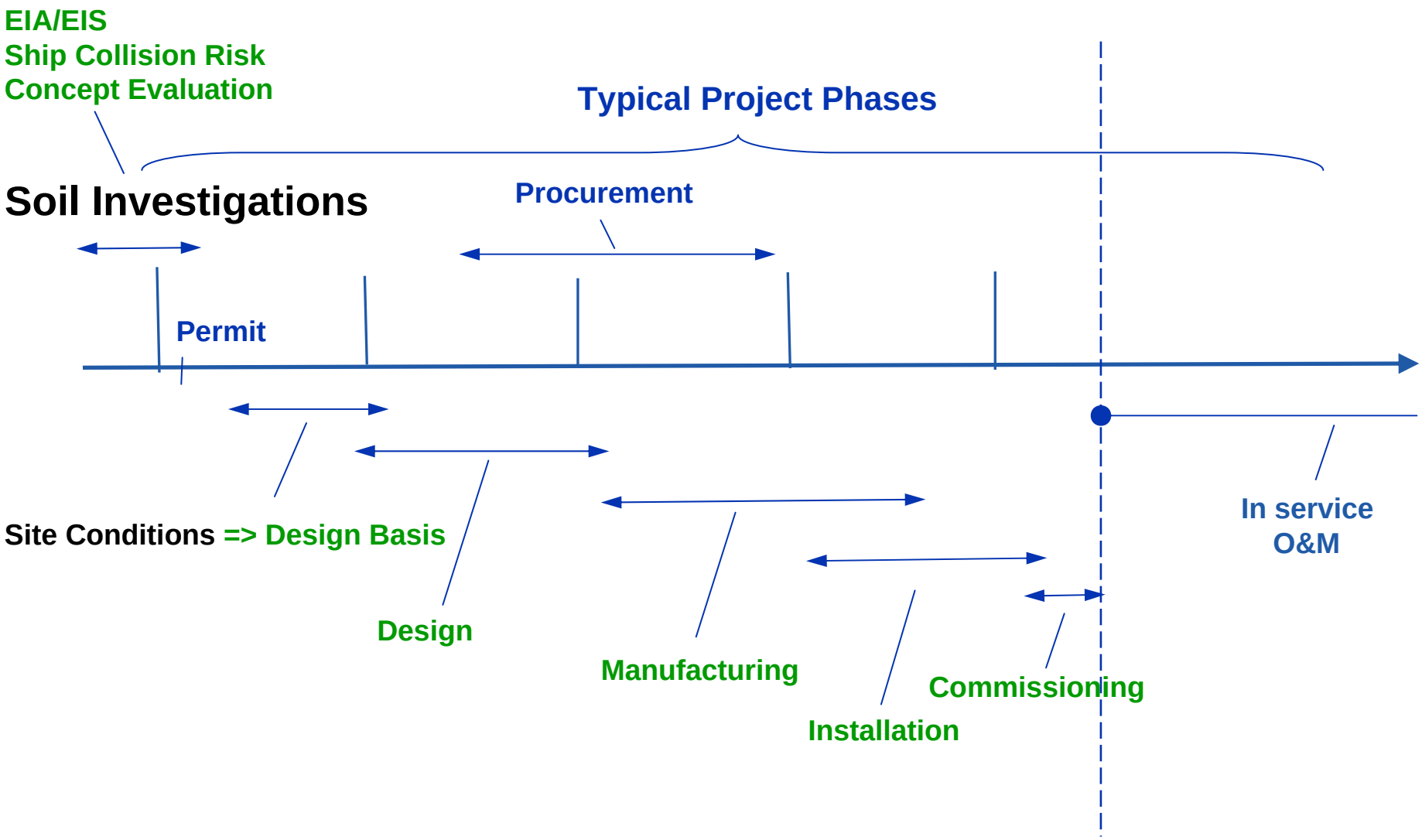

Design Basis

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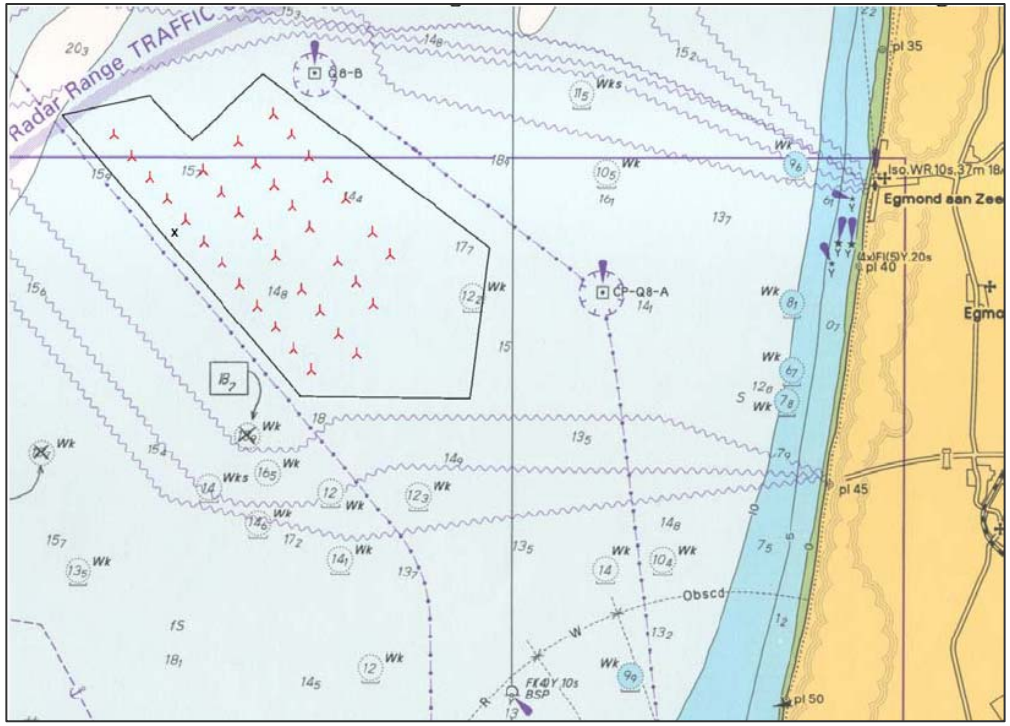
- Site Conditions
- Codes, Standards and Requirements
- Design Methodology
- Site Specific Wind Turbine Approval
- Grid Connection
- Installation and Commissioning
- Operation and Maintenance



Experience - Soil Conditions

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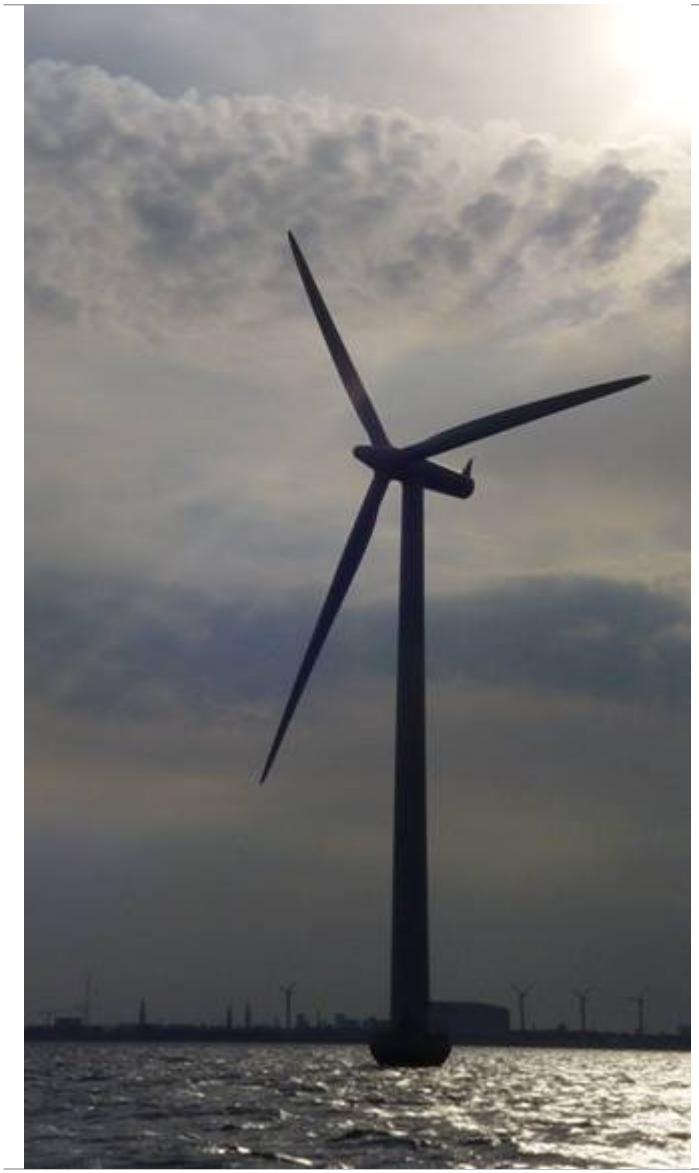

- Soil conditions - One of the most common items causing disputes:
  - Dependent on who is responsible for the ground conditions and associated potential deviations and project risks
- Owners/Developers/Contractors have carried out additional soil investigations
  - to reduce the uncertainties related to the ground conditions
  - and thereby obtaining a more optimized design.
- The presence of boulders and cobbles in glacial till and bedrock formations hot issue
  - The presence of these should be included in the design evaluation
  - design driver from an installation perspective.

Experience Background

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- DNV has verified more that 25 offshore projects and the corresponding soil investigations.

- Normally, the executed soil investigation program consists of
  - a geological desk study
  - a comprehensive geophysical survey
  - one or several rounds of geotechnical site investigations.

- The minimum requirements for a soil investigation program are given in DNV-OS-J101, BSH and IEC.

Summary - Recommendations

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- Soil conditions greatest importance
  - very often the causal factor in disputes between parties involved
- Soil investigations should reveal a geological model
  - based on geological studies, geophysical and geotechnical investigations
- From a cost and time perspective the importance of thorough soil investigations is crucial
- Soil investigation program sufficient for design and construction purposes
  - the complexity of the site is to be considered
  - extend and type of investigation depends on chosen foundation concept
- Certification is recommended to commence ASAP
  - early consensus beneficial impact on the project costs, minimising the risks of a costly redesign

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