Concepts for gravity base foundations
Motivation

- Cost effective production
- Capacities are available
- Local manufacturing
- Suitability for sandy and rocky soils
- Avoiding acoustic emission
Content

- Comparison of concepts
- Criteria for economic (gravity base) foundation
- Structural behavior
- Conclusion and future development
Current concepts of offshore foundations

- Monopile/Gravity base foundation mainly in water depths < 10 m
- Greater water depths possible
- All turbine sizes possible
Current concepts of offshore foundations

Water depth of installed gravity base foundation

- Max. water depth
- Mean water depth

Water depth [m]

Time [a]

- 2000
- 2002
- 2004
- 2006
- 2008
- 2010
- 2012

2000
2002
2004
2006
2008
2010
2012

Water depth [m]
Current concepts of offshore foundations

Rated Power of Offshore-Windturbines on gravity base foundation

- Max. Rated Power
- Mean Rated Power

Time [a]

Rated Power [MW]
Criteria for economic foundations

Manufacturing

- Onshore prefabrication
- Serial production
- Cost advantages of concrete

Steel-Caisson: 380,000 €
Concrete structure: 315,000 €
Monopile: 420,000 €

Price comparison according to [1]

[1] Sorensen et al.: Middelgrunden 40 MW offshore wind farm, a prestudy for the danish offshore 750 MW wind program
Criteria for economic foundations

Serial Production and preparation for transport
Criteria for economic foundations

Transport

- Transport of individual components
- Transport of complete Offshore-Windturbines
- Floating/Transport on pontoons
Criteria for economic foundations

Transport

- Transport of individual components
- Transport of complete Offshore-Windturbines
- Floating/Transport on pontoons
Criteria for economic foundations

Transport

- Cost advantages by lightweight constructions
- Submersible barge
Criteria for economic foundations

Soil preparation

- No inhibit time (rammed structures), but preparation of the soil
## Limited time window

<table>
<thead>
<tr>
<th>Significant wave height</th>
<th>Period of time</th>
<th>Duration [d]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Year Jan - Dec</td>
<td>132 52 23 12</td>
</tr>
<tr>
<td></td>
<td>Summer Apr - Sep</td>
<td>89 37 18 11</td>
</tr>
<tr>
<td></td>
<td>Winter Oct - Mar</td>
<td>43 15 5 1</td>
</tr>
<tr>
<td>2</td>
<td>Year Jan - Dec</td>
<td>276 128 77 53</td>
</tr>
<tr>
<td></td>
<td>Summer Apr - Sep</td>
<td>161 77 49 34</td>
</tr>
<tr>
<td></td>
<td>Winter Oct - Mar</td>
<td>115 51 28 19</td>
</tr>
<tr>
<td>3</td>
<td>Year Jan - Dec</td>
<td>334 161 103 74</td>
</tr>
<tr>
<td></td>
<td>Summer Apr - Sep</td>
<td>178 87 57 42</td>
</tr>
<tr>
<td></td>
<td>Winter Oct - Mar</td>
<td>156 74 46 32</td>
</tr>
</tbody>
</table>
Criteria for economic foundations

Scour protection

Geometry:

Flow velocities:

Shear stress at the bottom:
Criteria for economic foundations

Scour protection

Construction of a scour protection [2]

Limit shear stress according to the grain size [2]


Dipl.-Ing. Bosco Schmidt
Detailed knowledge of the loads must be available to determine the structural behavior.
Structural behavior of gravity base foundation

Action effects on foundations

- Wind data
  - Wind velocity
  - Wind direction
- Wave data
  - Wave height
  - Waveperiod
- Waterlevel
- Flow
  - Flow velocity
  - Flow direction

PDF of action effects
Structural behavior of gravity base foundation

Action effects on foundations

- Wind data
  - Wind velocity
  - Wind direction
- Wave data
  - Wave height
  - Waveperiod
- Waterlevel
- Flow
  - Flow velocity
  - Flow direction

PDF of action effects

- Wind velocity [m/s]
  - Histogram
  - Rayleigh-distribution
  - Gumbel-distribution

- Wave height [m]
  - Histogram
  - Rayleigh-Distribution
  - Gumbel-Distribution
Structural behavior of gravity base foundation

Action effects on foundations

- Wind data
  - Wind velocity
  - Wind direction
- Wave data
  - Wave height
  - Waveperiod
- Waterlevel
- Flow
  - Flow velocity
  - Flow direction

PDF of action effects

Wave height [m]

- Histogram
- Rayleigh-distribution
- Gumbel-distribution

Wind velocity [m/s]

- Histogram
- Rayleigh-distribution
- Gumbel-distribution
Structural behavior of gravity base foundation

Action effects on foundations

PDF of extreme action effects

- Fractiles
  - $H_{\text{max},50} = 19.01$ m
  - $V_{\text{ref}} = 42.06$ m/s

- Statistical values of action effects
  - Mean value
  - Standard deviation

- Consideration of scattering loads
Structural behavior of gravity base foundation

Scattering action effects

- Probability of failure
- Sensitivities
- Optimization of the foundation

Calculation model

Failure area according to [3]

Hansen, M.: Zur Auswirkung von Überwachungsmaßnahmen auf die Zuverlässigkeit von Betonbauteilen
Structural behavior of gravity base foundation

Axial symmetric gravity base foundation (predesign)
Structural behavior of gravity base foundation

Wave simulation

- Three-dimensional Reynolds-averaged Navier-Stokes equations
- Turbulence closure model: k-omega SST
- Wave generated by stream function theory
Structural behavior of gravity base foundation

Wave simulation

- For gravity base foundations the Morison equation is not always applicable

- Numerical simulation of wave or tide induced flow around the structure with a CFD model

- Project the resulting pressure on the mesh of a numerical mechanical model of the foundation

- Calculate stress and deformation with a suitable constitutive model
Structural behavior of gravity base foundation

Wave simulation
Structural behavior of gravity base foundation

Structural mechanical model

- Three-dimensional geometry of the foundation is taken into account
- Linear elastic approach for first assessment
Structural behavior of gravity base foundation

Structural mechanical model

- Results of stress and deformation at different wave positions
Conclusion

- 3D-CFD-Model
- Economic foundation design
- This requires a precise knowledge of the loads
- Integrated design
Future development

- Concepts for fatigue design under wave loads
- Coupling of soil and the structural mechanical model
- Transient analyses under wave loads

Thank you for your attention!