Selected Marine Environmental Considerations Associated With Concrete Gravity Base Foundations For UK Round 3 Projects

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MarineSpace
Making Sense of the Marine Environment™
Presentation Outline

• Context and Perceptions

• **Environmental Pressure Pathways**
  – Foundation Seabed Footprint
    • Physical
    • Functional
  – Seabed Preparation
  – Underwater Energy Emissions and Impacts

• Determinations
Context and Perceptions
Background

Presentation based upon work commissioned by
The Concrete Centre’s Gravity Foundation Interest Group (CFIG)

– Aimed at UK Round 3 and Scottish TW Projects

– Set context for CGBFs with other deep water foundation solutions

– To inform UK regulators, statutory advisors, developers and environmental consultants

– Consultation with the Offshore Renewable Energy Licensing Group (ORELG)
CGBFs in Context

- Concrete Gravity Foundations used at industry-scale in marine environment for last 50+ years
- >50 major offshore concrete structures have been built worldwide
- 300 m water depth have been installed - Troll Gas Platform
- Majority of recent platforms in water depths comparable with UK Round 3 zones
- The trend for shallower-water platform installation commenced with the Ravenspurn North platform (1989)
- The construction features of these smaller oil and gas platforms are evident in the CGBFs now being proposed

So nothing new?
CGBFs in Context

Ninian Central - 600,000 tonnes

BP Harding – 110 m water depth

Troll Gas Platform
472 m high

Thornton Bank – 40 m,
3,000 tonnes
18 m water depth
Deep Water Foundations in Context

Deep Water Foundations in Context

- **UK Round 1 and 2**
  - **Nearshore**
  - **Shallow water** ≤ 20 m BCD
  - **Steel monopiles**

- **UK Round 3**
  - **Further offshore**
  - **Deep water** > 20 m BCD ~35 m+
  - Shift in foundation ‘toolkit’
    - CGBF, Steel Jacket, Tripod, Suction Caisson, and Floating NOT monopile

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CGBFs – Perceptions and Concerns

So what is the current perception of wind CGBFs by the UK Statutory Bodies?

• ‘Mind-set’ based on UK R1 and R2 infrastructure baseline
  – Shallow water + Nearshore
  – Steel monopile + Variable scale of scour protection

• Cumulative - Array-scale - effects
  – Oil and Gas platforms vs Wind Farms
    • Single structure vs multiple structures
  – Blockage effects
  – Direct seabed habitat loss + seabed alteration
  – Underwater energy emissions and noise impacts

• Shift in ‘mind-set’ required
  – Increased direct physical footprint
Environmental Effect Pathways

Dredging / ground preparation
- Changes to bathymetry
  - Changes to local tidal currents
    - Changes to waves
      - Disposal of dredged material
      - Resuspension of fine sediment
- Vessel presence on site
  - Displacement
  - Removal of seabed sediments and habitats
- Noise
- Deposition of sediment
  - Increased turbidity
- Coast
  - Features, habitats and species of significance
  - Smothering
  - Benthos
  - Marine Mammals
    - Navigation
    - Fishing
Foundation Footprint
### Parameterisation - Structure

<table>
<thead>
<tr>
<th>Parameter</th>
<th>35m Depth 5MW Turbine</th>
<th>50m Depth 5MW Turbine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bedrock</td>
<td>Sands</td>
</tr>
</tbody>
</table>

#### PERMANENT INSTALLATION

<table>
<thead>
<tr>
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<th>35m Depth 5MW Turbine</th>
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<td></td>
<td>Bedrock</td>
<td>Sands</td>
</tr>
</tbody>
</table>

| A.1 External surface area of concrete (m²) | 2,825 | 2,739 | 3,421 | 3,338 |
|                                            | 4,675 | 4,675 | 5,800 | 5,800 |
| A.2 Elevational area from surface of sea bed to water surface (m²) | 901 | 863 | 1,201 | 1,145 |
|                                            | 1,690 | 1,690 | 2,067 | 2,067 |
| A.3 Area of concrete footprint at surface level of sea bed (m²) | 865 | 900 | 1,000 | 1,029 |
|                                            | 1,150 | 1,150 | 1,386 | 1,386 |
| A.3.b Inferred diameter at seabed (calculated from A.3) (m) | 33.2 | 33.9 | 35.7 | 36.2 |
|                                            | 38.3 | 38.3 | 42.0 | 42.0 |
| A.4 Diameter at water surface (or shape and maximum projected width if not circular) (m) | 6.5 | 6.65 | 6.36 | 6.5 |
|                                            | 8 | 8 | 7 | 7 |
| A.5 Area of scour protection if used (m²) | Assumed | 2,095 | Assumed | 2,324 |
|                                            | N/A | 3,500 | N/A | 4,005 |
| A.6 Density of wind towers (no/km²) | 1 | 1 | 1 | 1 |
|                                            | 1.23 | 1.23 | 1.23 | 1.23 |
## Foundation Seabed Footprint - Physical

<table>
<thead>
<tr>
<th>Foundation Concept</th>
<th>Foundation diameter (m)</th>
<th>Foundation footprint (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel monopile</td>
<td>8.5</td>
<td>57</td>
</tr>
<tr>
<td>CGBF</td>
<td>40</td>
<td>1,257</td>
</tr>
<tr>
<td>Steel Jacket (piled)</td>
<td>4 * 4</td>
<td>201</td>
</tr>
<tr>
<td>Tripod (piled)</td>
<td>3 * 5</td>
<td>177</td>
</tr>
<tr>
<td>Suction caisson</td>
<td>22</td>
<td>380</td>
</tr>
</tbody>
</table>
**Foundation Seabed Footprint - Functional**

- **Direct loss of seabed habitat + benthos**
- ‘Shading’ effect\(^2\) = habitat loss/alteration
  - Significant for Steel Jackets and Tripods
- Changes to nearbed water and sediment flow – alter benthos
- ‘Reef’ effect = habitat loss/alteration
  - Significant for Steel Jackets and Tripods

\(^1\)Footprint = effective seabed footprint = habitat loss or alteration

\(^2\)Seabed located beneath foundation structure but not under one of the footings
Functional Seabed Footprint and Benthic Communities

• ‘Shading’ effects from SJs and Tripods
  – Habitat in an altered state

• Complex construction surface area
  – Altered hydrography
  – Sediment particle size changes
  – Food supply/availability

• Alteration of infaunal biotopes
  – Even on seabed without physical presence of footings
Functional Seabed Footprint and Benthic Communities

• ‘Reef’ effects from SJs and Tripods
  – Habitat in an altered state

• Complex construction surface area
  – Change from sediment biotopes to ‘rocky’ biotopes
  – Deposition of faeces and pseudofaeces
  – Organic nutrification
  – Fish Aggregation
  – Predation increase on surrounding benthos
Seabed Preparation

- 70 m * 80 m * 7 m foundation pits
- 90,000 m³ per foundation
- Dredge operations a licensable activity
- Sediment plumes
  - Smothering
  - Dredge, discharge, re-dredge, back-fill
Seabed Preparation

- Foundation pits/layers not required for all solutions
- Seabed excavation = temporary habitat loss
  - direct (removal) and indirect (smothering/plume)
- Increases overall impact zone
  - Spoil mounds
- Increases risk to archaeology/heritage
- Recovery – habitat type and benthos present
  - Sands -6-24 months
  - Gravel – 8-15 years+
  - >1 m ‘capping’ layer
Underwater Energy Impacts
Underwater Energy Emissions and Impacts

• Energy Emissions
  – Sound
  – Pressure

• Source
  – Piling
  – Drill-drive-drill

• Offshore environment vs Nearshore
  – Bathymetry, Seabed bedforms/Geomorphology
Underwater Sound Emissions and Noise Impacts

• Sensitive species
  – Certain fish (incl. eggs and larvae) and marine mammals

• Disturbance
  – Displacement
  – Behaviour Alteration
  – Reduced Predation Success

• Damage, Mortality

• Population and Ecosystem-scale effects
Underwater Noise Impacts

• Habitats Directive
  – Annex IV European Protected Species - *deliberate disturbance*
    • Habitats Regulation 41
    • Offshore Habitats Regulation 39(1)(b)

• Marine Strategy Framework Directive
  – 11 Descriptors of Good Environmental Status
    • GES #11 – "*Introduction of energy including underwater noise is at levels that do not adversely affect the marine environment.*"

• Defra – Noise Register
  "...establish and maintain a ‘noise registry’ which would record in space and time activities generating noise... (allowing a determination of)...whether they may potentially compromise the achievement of GES."
Underwater Noise Impacts

• Hammering of piles
  – Steel monopiles, Steel Jackets and Tripods
    • Disturbance\(^1\) at 50 km – Beatrice OWF (2 Steel Jackets – 5MW)
    • Mortality of Herring eggs\(^2\) – Scroby Sands OWF
• No piles for CGBF
• Dredging foundation pits
  – No more noisy than background traffic\(^3\) (≤ 1 km)
• CGBF Installation
  – No more noisy than background traffic\(^4\)
• Sound mitigation technology for SJs and Tripods

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\(^1\)Bottlenose Dolphin *Tursiops truncatus* – Moray Firth SAC interest feature – Bailey *et al.* (2010). Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals.

\(^2\)Perrow, *et al.* (2011). Effects of the construction of Scroby Sands offshore windfarm on the prey base of Little tern *Sternula albifrons* at its most important UK colony.

\(^3\)Robinson *et al.* (2011). Measurement of noise arising from marine aggregate dredging operations, MALSF

\(^4\)Haelter *et al.* (2009) - Underwater noise emission during construction at Thornton Bank, Belgian Territorial Waters
Conclusions
## Relative Comparison

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CGBFs</th>
<th>Monopiles</th>
<th>Tripods</th>
<th>Steel Jackets</th>
<th>Suction Caissons</th>
<th>Floating platforms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience (No. of foundations currently installed)</td>
<td>Good (332)</td>
<td>Good (1810)</td>
<td>Moderate (86)</td>
<td>Moderate (88)</td>
<td>Low (1)</td>
<td>Trial only (2)</td>
</tr>
<tr>
<td>Water Depth</td>
<td>All</td>
<td>Shallow</td>
<td>All</td>
<td>All</td>
<td>All</td>
<td>Deep</td>
</tr>
<tr>
<td>Emplacement weather window</td>
<td>Good</td>
<td>Restricted</td>
<td>Restricted</td>
<td>Restricted</td>
<td>Moderate</td>
<td>Unknown</td>
</tr>
<tr>
<td>Maintenance required</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>Unknown</td>
</tr>
<tr>
<td>Price</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td>Availability – UK R3</td>
<td>Fav</td>
<td>Unfav</td>
<td>Fav</td>
<td>Fav</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

### Environmental Effects/Impacts

<table>
<thead>
<tr>
<th>Ground preparation (temp habitat loss)</th>
<th>H</th>
<th>L</th>
<th>L</th>
<th>L</th>
<th>M</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound emitted during installation</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Seabed footprint (habitat loss)</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>L</td>
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<tr>
<td>Scour</td>
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<td>H</td>
<td>L</td>
<td>L</td>
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<tr>
<td>Blockage effects</td>
<td>M</td>
<td>H</td>
<td>M</td>
<td>M</td>
<td>H</td>
<td>H</td>
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<tr>
<td>Reef effects</td>
<td>H</td>
<td>M</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>L</td>
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<tr>
<td>Decommissioning</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>H</td>
</tr>
</tbody>
</table>
Conclusions

For **all** foundation solutions

– A *mind shift* for regulators and their advisors

– All deep water foundations likely to have increased direct seabed footprint than UK Round 1 and 2 foundations

– Functional seabed footprint variable between foundation types

– Return of the seabed to pre-impacted baseline

– Underwater energy emissions during construction will receive even more focus than UK Round 1 and 2 projects
Conclusions

Concrete Gravity Base Foundations

– Can have a similar functional seabed footprint to other deepwater foundation solutions

– Where seabed preparation is required will initially result in larger footprints of effects than steel jackets or tripods

– Recovery from these effects is expected within the lifespan of the windfarm project

– No significant sound emissions during installation and decommissioning

– Mitigate legislative/consenting burden
  • No significant noise impacts
Further Thoughts

– Fate of foundation pit ‘spoil’ heaps
– Service vessel moorings
  • Emplacement of permanent moorings
– Accommodation platforms
– Spread of non-native invasive species
  • Foundations as ‘stepping stones’
– Fate of the artificial reefs at project end?
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• Seatower AS
• Sir Robert McAlpine
• Skanska
• Strabag Offshore Wind GmbH
• Vici Ventus
• Vinci Offshore Wind UK
• WindAtBase

A full list of The Concrete Centre Interest Group members can be found at:
http://www.concretecentre.com/wind

The full report can be downloaded from www.concretecentre.com/wind