Anchoring FOWTs in shallow to deep water.

Roderick Ruinen - Director

Mooreast Europe B.V.
Presentation Outline

• Introduction
• Drag Embedment Anchors
• Torpedo Piles
• FOWT Challenges
Anchoring Solutions
Seabed Conditions

- Anchor efficiency greatly influenced by seabed conditions
- Large variety of seabed conditions encountered offshore:
  - Soft to hard clays
  - Loose to dense sands
  - Rocks and gravel
- In general, soft soil is typical for deep water, hard soils in shallow water
<table>
<thead>
<tr>
<th>Seabed Conditions</th>
<th>Soft clay</th>
<th>Hard clay</th>
<th>Sand</th>
<th>Cemented</th>
<th>Rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driven pile</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Suction pile</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Drag embedment anchor</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Torpedo pile</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X*</td>
<td></td>
</tr>
</tbody>
</table>

* Loose to medium dense
Drag Embedment Anchors
Overview

• Suitable for a wide range of soil conditions
• Used for temporary and permanent mooring
• Used in catenary moorings
  In soft soils small uplift angles possible
• 1000’s of drag embedment anchors in use since the 1970’s
Installation

• Anchor pulled (dragged) into the seabed
• Installation load typically intact design load
• Depending on the installation load, installation using:
  • AHTS
  • Surface tensioner
  • Subsea tensioner
Recovery

• Anchor can be recovered after design life
• Recovery force dependent on seabed conditions and installation load
• Pull backwards on the mooring line
Torpedo Piles
Overview

• Suitable for soft to medium clay soil conditions
• Used mostly for permanent mooring
• Suitable for catenary and taut leg moorings
• Since the 1990’s over 2000 torpedo piles installed
Overview

- Anchor sharing possible
  Multiple mooring lines connected to single anchor
Installation

- Deployed from AHTS
- Dropped from predetermined height above seabed
- Accurate positioning
Recovery

- After design life, anchor recovery is possible
- Using AHTS, torpedo pile is pulled out of the seabed
FOWT Challenges

• Wind farm with multiple FOWT is located on a large expanse of seabed:
  • Variations in seabed conditions possible
  • Contact anchor designer at early stage of project:
    Optimize the requirements for the soil investigation
    Optimize the type and number of anchor most suitable for the encountered seabed conditions
FOWT Challenges

• Wind farm with multiple FOWT required large number of anchors
  • Standardize the anchor size
    Anchors can be fabricated ahead of time
    Simplifies installation
  • Delivery schedule in collaboration with installation contractor
Thank You