Structural concepts for minimum facility platforms for Marginal field development in western offshore, India

A collaborative project
By
IIT Madras and IEOT, ONGC
Outline

- Conventional Wellhead Platforms
- Existing Marginal platforms
- Minimum Facility Platforms
- Basic Requirements
- Environmental Conditions
- Installation by Jackups
- Concepts
- Technical Feasibility
- Cost Comparison
- Conclusions
Field Map Western Offshore, India

Marginal Fields around Mumbai High and Bassein Fields

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OIL LINE
GAS LINE
OIL FIELD
GAS FIELD
OIL & GAS FIELD
SOUR FIELD
HIGHLY SOUR FIELD
SWEET OIL/GAS

Field Map Western Offshore, India

Concepts for Marginal Field Development – Western Offshore

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Department of Ocean Engineering
Indian Institute of Technology Madras-36
CONVENTIONAL WELL PLATFORM CONFIGURATIONS

**SINGLE PILE CONFIGURATION**
- Main Pile of
  - 60 INCH
  - 68 INCH
  - 72 INCH
  - 84 INCH
  - 90 INCH

**SKIRT PILE (ONLY) CONFIGURATION**
- Skirt Piles of
  - 84” SKIRT WITH 48” LEG
  - 84” SKIRT WITH 60” LEG
  - FULL BRACING 84” SKIRT WITH 60” LEG

**SKIRT & MAIN PILE CONFIGURATION**
- Combinations of
  - 54” SKIRT WITH 48” MAIN PILE
  - 54” SKIRT WITH 54” MAIN PILE
  - 60” SKIRT WITH 54” MAIN PILE
Concepts used in other regions in the industry

UK
Norway
Australia
PROPOSED CONCEPTS FOR WESTERN OFFSHORE

Mono Pile Concepts

Jacket Type Concepts

Braced Conductor legs

Guy Supports structure
Mono Pile Concepts

Mono pile concepts involve driving of large diameter pile and supporting the deck from the single leg. This can be augmented by additional skirt piles in order to reduce large bending of mono piles. The mono pile houses 3 or 4 conductors inside thus reducing the wave loads.

Another alternative to this is to have conductors outside the mono pile.
Jacket type concepts involve 3 or 4 legs with conductors inside the jacket framing. The jacket legs are either battered or vertical. Three alternate scheme are proposed are shown in figure.

The above concepts can be extended to water depths exceeding 30m and has the flexibility of increase in number of wells or topside configurations.
Braced Conductor Leg Concepts

In this concept, four conductor cum legs are braced to form a frame which will be fixed to the seabed by skirt piles.

The advantage of these concepts is that the wave loads is reduced considerably since the jacket legs and framing near water level is reduced.
Guy support Structures

4(a) 4 Legged Jacket with Hollow Base Steel Caisson

4(b) 4 Legged Jacket with Steel Caisson with Each Legs

4(c) Mono Pile with Guy Wires

The slender structure as proposed earlier are transversely supported by guy wires to reduce lateral deflection and bending stresses. Further the support reaction in terms of pile loads will be reduced considerably.
**Focus of the development**

- Understanding the requirements of marginal field.
- Developing new concepts to suit the west coast environmental parameters.
- Pile Loads and configurations will govern the economics of the concept.
- Pile Load distribution from past experience shows that:
  - Dead Load: 25%
  - Facilities (Equipment): 20%
  - Wave + current Load: 50%
  - Wind Load: 5%
- Installation costs for offshore platforms play a major role and hence installation by means of unconventional methods may need to be reviewed.
  - Smaller Crane barges
  - Pipe lay Vessel with cranes
  - Jackups
  - Self installation methods

<table>
<thead>
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<th>Item</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Engineering</td>
<td>5%</td>
</tr>
<tr>
<td>Structure</td>
<td>25%</td>
</tr>
<tr>
<td>Equipment</td>
<td>25%</td>
</tr>
<tr>
<td>Installation</td>
<td>50%</td>
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</tbody>
</table>
### Conventional Wellhead Platforms
- Design life varies from 25 - 30 years.
- No. of wells varies from 4 - 16.
- Water depth ranges from 20m - 100m.
- Two level deck with the dimension of 20m x 40m.
- Large space (40’ x 20’) for CTU operation.
- Separate Helideck is provided.
- Platform crane provided.
- Boat landing is provided.
- Total topside weight is in the order of 2000 - 2500 Tonnes.
- Modular rig such as Sundowner VI or VII is allowed.
- Unmanned platform with temporary two or four man bunk house.

### Marginal Field Wellhead Platforms
- Design life varies from 5 - 10 years.
- No. of wells varies from 2 - 4.
- Water depth ranges from 20m - 60m.
- Two level deck with the dimension of 20m x 20m.
- No separate Helideck is provided. Main deck can be used as helideck.
- **No Pedestal crane provided.**
- V notch ladder type Boat landing is provided.
- Total topside weight is less than 750 Tonnes.
- No Modular rig is allowed.
- Unmanned platform.
- No temporary bunk house provided.
Limiting Parameters

- Access to wells for drilling by jackup from north face, the skirt piles or projection of substructure on the north face to be avoided.

- The soil conditions and environmental parameters in shallow water is substantially different from conditions exist in many other parts of world

- Large deflection shall be avoided as the platform supports well heads.

- Dynamics of the slender platform shall be kept in mind to avoid resonant vibrations and subsequent fatigue related issues.

- Installation robustness to avoid delay in projects during execution
Installation by Jackup rigs

- The cost optimization by means of unconventional installation spread was considered to be an option such as use of Jackups.
- Due to limitations on size of jackets / deck modules, jackups are not suitable. Height limitation due to vertical movement of jackup legs will be a constraint.
- Jackup foot print during installation may hamper future drilling activities.
- Hence use of small derrick barge / pipe lay vessels with crane capacity of 1200 Tonnes is found to be suitable for this type of installation.
REPRESENTATIVE SITE

Environmental conditions at C-series location has been considered for this study. The location selected has some of the difficult parameters to be used in design such as wave, current and geotechnical conditions. Similar conditions are expected at other marginal field. It can be observed that the top 30m is a soft clay offering very less pile capacity.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1 year return</th>
<th>100 year return</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave height (m)</td>
<td>10.366</td>
<td>17.073</td>
</tr>
<tr>
<td>Wave period (sec)</td>
<td>10.4</td>
<td>13.90</td>
</tr>
<tr>
<td>Surface current(m/sec)</td>
<td>1.341</td>
<td>1.768</td>
</tr>
<tr>
<td>Water depth (m)</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Wind speed (km/h) (1-hr.Avg)</td>
<td>77</td>
<td>138</td>
</tr>
</tbody>
</table>
WAVE AND CURRENT 1 YEAR RETURN PERIOD (OPERATING)

- H: 4.573 m, T: 6.50 sec, Current: 0.853 m/sec
- H: 4.878 m, T: 6.70 sec, Current: 1.28 m/sec
- H: 5.488 m, T: 6.80 sec, Current: 1.463 m/sec
- H: 10.366 m, T: 10.40 sec, Current: 1.341 m/sec
- H: 8.537 m, T: 9.20 sec, Current: 1.28 m/sec
- H: 4.878 m, T: 6.80 sec, Current: 1.249 m/sec
- H: 4.878 m, T: 6.80 sec, Current: 0.223 m/sec
WAVE & CURRENT 100 YEAR RETURN PERIOD (EXTREME STORM)

- **H**: 8.537 m
  - **T**: 14.00 sec
  - **Current**: 1.28 m/sec

- **H**: 10.671 m
  - **T**: 10.80 sec
  - **Current**: 1.798 m/sec

- **H**: 16.678 m
  - **T**: 13.80 sec
  - **Current**: 1.128 m/sec

- **H**: 17.073 m
  - **T**: 13.9 sec
  - **Current**: 1.768 m/sec

- **H**: 17.378 m
  - **T**: 14.00 sec
  - **Current**: 1.615 m/sec
### Mono Pile without Guy Wire

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td>Topside Weight</td>
<td>750 Tonnes</td>
</tr>
<tr>
<td>Jacket Weight</td>
<td>330 Tonnes</td>
</tr>
<tr>
<td>Installation</td>
<td>Crane Vessel</td>
</tr>
<tr>
<td>Offshore Work</td>
<td>Crane Barge</td>
</tr>
<tr>
<td>Number of piles</td>
<td>1 Main Pile</td>
</tr>
<tr>
<td>Pile Diameter</td>
<td>142”</td>
</tr>
<tr>
<td>Penetration</td>
<td>80m</td>
</tr>
<tr>
<td>Pile Weight</td>
<td>350 Tonnes</td>
</tr>
<tr>
<td>Estimated Total Weight</td>
<td>1430 Tonnes</td>
</tr>
<tr>
<td>Estimated Offshore Time</td>
<td>6 Days</td>
</tr>
<tr>
<td>Estimated Cost</td>
<td>US$ 16M</td>
</tr>
</tbody>
</table>

**Risk**: Large deflection  
**Additional MSF required**
Topside Weight : 750 Tonnes
Jacket Weight : 370 Tonnes
Installation : Crane Vessel
Offshore Work : Crane Barge

Number of piles : 1 Main & 2 Skirt Piles
Pile Diameter : 142” (Main) 60” (Skirt)
Penetration : 80m
Pile Weight : 630 Tonnes

Estimated Total Weight : 1750 Tonnes
Estimated Offshore Time : 12 Days
Estimated Cost : US$ 22M

Risk : Fatigue at brace junction
Additional MSF required
**Concepts for Marginal Field Development – Western Offshore**

<table>
<thead>
<tr>
<th>Topside Weight</th>
<th>750 Tonnes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jacket Weight</td>
<td>300 Tonnes</td>
</tr>
<tr>
<td>Installation</td>
<td>Crane Vessel</td>
</tr>
<tr>
<td>Offshore Work</td>
<td>Crane Barge</td>
</tr>
<tr>
<td>Number of piles</td>
<td>1 Main &amp; 2 Skirt Piles</td>
</tr>
<tr>
<td>Pile Diameter</td>
<td>60”</td>
</tr>
<tr>
<td>Penetration</td>
<td>80m</td>
</tr>
<tr>
<td>Pile Weight</td>
<td>470 Tonnes</td>
</tr>
<tr>
<td>Estimated Total Weight</td>
<td>1520 Tonnes</td>
</tr>
<tr>
<td>Estimated Offshore Time</td>
<td>12 Days</td>
</tr>
<tr>
<td>Estimated Cost</td>
<td>US$ 21M</td>
</tr>
</tbody>
</table>

**Risk**
- Fatigue at brace junction
- Additional MSF required
- Conductors exposed to damage

**Braced Mono Tower (Outside Conductor)**

- Critical fatigue Joint
Topside Weight: 750 Tonnes
Jacket Weight: 460 Tonnes
Installation: Crane Vessel
Offshore Work: Crane Barge

Number of piles: 4 Main Piles
Pile Diameter: 60”
Penetration: 80m
Pile Weight: 640 Tonnes

Estimated Total Weight: 1850 Tonnes
Estimated Offshore Time: 15 Days
Estimated Cost: US$ 25M

Risk: Increased pile loads due to limited dimensions of jacket base
4 Legged Jacket Structure with Batter piles

- Topside Weight: 750 Tonnes
- Jacket Weight: 490 Tonnes
- Installation: Crane Vessel
- Offshore Work: Crane Barge
- Number of piles: 4 Main Piles
- Pile Diameter: 60"
- Penetration: 80m
- Pile Weight: 640 Tonnes
- Estimated Total Weight: 1880 Tonnes
- Estimated Offshore Time: 15 Days
- Estimated Cost: US$ 25M
- Risk Level: No major issues
### 3 Legged Jacket Structure

- **Topside Weight**: 750 Tonnes
- **Jacket Weight**: 350 Tonnes
- **Installation**: Crane Vessel
- **Offshore Work**: Crane Barge

#### Details:

- **Number of piles**: 3 Main Piles
- **Pile Diameter**: 60”
- **Penetration**: 88m
- **Pile Weight**: 510 Tonnes

#### Estimated:

- **Total Weight**: 1610 Tonnes
- **Offshore Time**: 15 Days
- **Cost**: US$ 23M

**Risk Level**: Large Pile loads at south pile, Installation difficulty
Braced Leg Jacket (4 Piles)

- Topside Weight: 750 Tonnes
- Jacket Weight: 500 Tonnes
- Installation: Crane Vessel
- Offshore Work: Crane Barge
- Number of piles: 4 Skirt Piles
- Pile Diameter: 60”
- Penetration: 77m
- Pile Weight: 530 Tonnes
- Estimated Total Weight: 1780 Tonnes
- Estimated Offshore Time: 15 Days
- Estimated Cost: US$ 24M

Risk Level:
- Conductor legs exposed for damage
- MSF is required
- Fatigue at brace junction
<table>
<thead>
<tr>
<th>Concept</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topside Weight</td>
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<tr>
<td>Jacket Weight</td>
<td>450 Tonnes</td>
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<tr>
<td>Installation</td>
<td>Crane Vessel</td>
</tr>
<tr>
<td>Offshore Work</td>
<td>Crane Barge</td>
</tr>
<tr>
<td>Number of piles</td>
<td>3 Skirt Piles</td>
</tr>
<tr>
<td>Pile Diameter</td>
<td>60”</td>
</tr>
<tr>
<td>Penetration</td>
<td>77m</td>
</tr>
<tr>
<td>Pile Weight</td>
<td>400 Tonnes</td>
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<tr>
<td>Estimated Total Weight</td>
<td>1600 Tonnes</td>
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<tr>
<td>Estimated Offshore Time</td>
<td>12 Days</td>
</tr>
<tr>
<td>Estimated Cost</td>
<td>US$ 21M</td>
</tr>
</tbody>
</table>

Risk Level:
- Conductor legs exposed for damage
- MSF is required
- Fatigue at brace junction
- Large pullout loads on south pile
4 Legged Jacket with Hollow Base Steel Caisson (with Guy Wire)

Topside Weight : 750 Tonnes
Jacket Weight : 440 Tonnes
Caisson Weight : 400 Tonnes
Installation : Crane Vessel
Offshore Work : Crane Barge

Estimated Total Weight : 1590 Tonnes
Estimated Offshore Time : 18 Days
Estimated Cost : US$ 25M

Risks
- Installation of guy systems
- Installation of large caisson
- Damage to guy wires
- Approach by boat
- Large anchor forces
### 4 Legged Jacket with Steel Caisson with Each Legs (with Guy Wire)

<table>
<thead>
<tr>
<th>Description</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topside Weight</td>
<td>750 Tonnes</td>
</tr>
<tr>
<td>Jacket Weight</td>
<td>480 Tonnes</td>
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<tr>
<td>Caisson Weight</td>
<td>250 Tonnes</td>
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<tr>
<td>Installation</td>
<td>Crane Vessel</td>
</tr>
<tr>
<td>Offshore Work</td>
<td>Crane Barge</td>
</tr>
</tbody>
</table>

- **Estimated Total Weight**: 1480 Tonnes
- **Estimated Offshore Time**: 18 Days
- **Estimated Cost**: US$ 24M

**Risks**
- Installation of guy systems
- Damage to guy wires
- Approach by boat
- Large anchor forces
### Mono Pile with Guy Wire

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td>Topside Weight</td>
<td>750 Tonnes</td>
</tr>
<tr>
<td>Jacket Weight</td>
<td>330 Tonnes</td>
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<tr>
<td>Installation</td>
<td>Crane Vessel</td>
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<tr>
<td>Offshore Work</td>
<td>Crane Barge</td>
</tr>
<tr>
<td>Number of piles</td>
<td>1 Main Pile</td>
</tr>
<tr>
<td>Pile Diameter</td>
<td>142”</td>
</tr>
<tr>
<td>Penetration</td>
<td>80m</td>
</tr>
<tr>
<td>Pile Weight</td>
<td>350 Tonnes</td>
</tr>
<tr>
<td>Estimated Total Weight</td>
<td>1430 Tonnes</td>
</tr>
<tr>
<td>Estimated Offshore Time</td>
<td>15 Days</td>
</tr>
<tr>
<td>Estimated Cost</td>
<td>US$ 22M</td>
</tr>
</tbody>
</table>

**Risk:**
- Installation of guy systems
- Damage to guy wires
- Approach by boat
- Large anchor forces
## Weight Comparison

<table>
<thead>
<tr>
<th>S. No</th>
<th>Description</th>
<th>Jacket (MT)</th>
<th>Pile (MT)</th>
<th>Total (MT)</th>
<th>Recommendation</th>
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<tbody>
<tr>
<td>1a</td>
<td>Mono pile</td>
<td>330</td>
<td>350</td>
<td>680</td>
<td>Feasible for 1-2 conductors</td>
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<tr>
<td>1b</td>
<td>Braced Mono tower (Inside Conductor)</td>
<td>370</td>
<td>630</td>
<td>1000</td>
<td>Recommended</td>
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<tr>
<td>1c</td>
<td>Braced Mono tower (Outside Conductor)</td>
<td>300</td>
<td>470</td>
<td>770</td>
<td>Recommended with large diameter mono pile</td>
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<tr>
<td>2a</td>
<td>4 Legged Jacket Structure</td>
<td>460</td>
<td>640</td>
<td>1100</td>
<td>Recommended</td>
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<tr>
<td>2b</td>
<td>4 Legged Jacket Structure with Batter Piles</td>
<td>490</td>
<td>640</td>
<td>1130</td>
<td>Recommended</td>
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<tr>
<td>2c</td>
<td>3 Legged Jacket Structure</td>
<td>350</td>
<td>510</td>
<td>860</td>
<td>Not Recommended</td>
</tr>
<tr>
<td>3a</td>
<td>Braced Legs (4 piles)</td>
<td>500</td>
<td>530</td>
<td>1030</td>
<td>Recommended</td>
</tr>
<tr>
<td>3b</td>
<td>Braced Legs (3 piles)</td>
<td>450</td>
<td>400</td>
<td>850</td>
<td>Not Recommended</td>
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<td>4a</td>
<td>4 Legged Jacket with Hollow Base Steel Caisson (Guy Wire)</td>
<td>440</td>
<td>400</td>
<td>840</td>
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<tr>
<td>4b</td>
<td>4 Legged Jacket with Steel Caisson with Each Legs (Guy wire)</td>
<td>480</td>
<td>250</td>
<td>730</td>
<td>Not Recommended</td>
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<tr>
<td>4c</td>
<td>Mono pile with Guywire</td>
<td>330</td>
<td>350</td>
<td>680</td>
<td>Not Recommended</td>
</tr>
</tbody>
</table>

Variation of weight among the concepts is limited to 10 to 20% except for mono pile.
COST COMPARISON

1a 1b 1c 2a 2b 2c 3a 3b 4a 4b 4c
Mono Pile concepts Jacket concepts Braced conductors Guy wire concepts

Cost (US$ M)

0 5 10 15 20 25 30
Technical Feasibility

- Design of Mono pile and braced mono pile system has limitations on the deck foot print size. The concept can be adopted if the topside dimensions can be limited to less than 20m x 20m.

- Braced conductor leg concept can be implemented with sufficient conductor protection system which may alleviate the safety issue. The limitations on the deck foot print applies to this option also.

- Guy support structures require pile foundations for wire anchor system which will be costly. Further, guyed wire support systems not recommended based on installation and safety issues due to potential failure of guy wires.

- Hence an optimized conventional jacket will prove to be a potential candidate both in terms of safety and installation even though cost is slightly higher.

- Installation by jackup rigs shall be considered carefully only for water depths less than 30m.
Conclusions

- Mono pile with braced skirt pile system offers economical solution and can be installed by small derrick or pipe lay barge as the weight of each component is less than 650 Tonnes. Hence this can be implemented in upcoming marginal fields with water depth not exceeding 50m.

- For other marginal fields where water depth is greater than 50m, optimized jacket concepts are recommended.

- Braced conductor legs can be used with sufficient leg protection and fatigue design.
Thank you
## Deflection for Various options

<table>
<thead>
<tr>
<th>Options</th>
<th>Option Description</th>
<th>X - deflection (mm)</th>
<th>Y - Deflection (mm)</th>
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<tbody>
<tr>
<td></td>
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<td>Operating</td>
<td>Storm</td>
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<tr>
<td>1a</td>
<td>Monopile</td>
<td>282</td>
<td>1125</td>
</tr>
<tr>
<td>1b</td>
<td>Braced Mono tower (3 piles)_Inside Conductor</td>
<td>64</td>
<td>212</td>
</tr>
<tr>
<td>1c</td>
<td>Braced Mono tower (3 piles)_Outside Conductor</td>
<td>163</td>
<td>3783</td>
</tr>
<tr>
<td>2a</td>
<td>4 Legged Jacket Structure</td>
<td>85</td>
<td>486</td>
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<tr>
<td>2b</td>
<td>4 Legged Jacket Structure With Batter Piles</td>
<td>80</td>
<td>301</td>
</tr>
<tr>
<td>2c</td>
<td>3 Legged Jacket Structure</td>
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<td>674</td>
</tr>
<tr>
<td>3a</td>
<td>Braced Legs (4 piles)</td>
<td>160</td>
<td>363</td>
</tr>
<tr>
<td>3b</td>
<td>Braced Legs (3 piles)</td>
<td>175</td>
<td>476</td>
</tr>
<tr>
<td>4a</td>
<td>4 Legged Jacket with hollow base steel caisson</td>
<td>39</td>
<td>100</td>
</tr>
<tr>
<td>4b</td>
<td>4 Legged Jacket with steel caisson with each legs</td>
<td>14</td>
<td>42</td>
</tr>
<tr>
<td>4c</td>
<td>Monopile with Guywire</td>
<td>20</td>
<td>99</td>
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</tbody>
</table>