Appendix – B

I. Load calculations:

A. Dead Load

1. Beam along grid A

Precast Element

<table>
<thead>
<tr>
<th>L</th>
<th>B</th>
<th>H</th>
<th>Density</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.2</td>
<td>1.5</td>
<td>25</td>
<td>7.50 kN/m</td>
</tr>
<tr>
<td>1</td>
<td>1.4</td>
<td>0.2</td>
<td>25</td>
<td>7.00 kN/m</td>
</tr>
<tr>
<td>1</td>
<td>0.2</td>
<td>1.5</td>
<td>25</td>
<td>7.50 kN/m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>22.0 kN/m</strong></td>
</tr>
</tbody>
</table>

Cast in Situ Element

<table>
<thead>
<tr>
<th>L</th>
<th>B</th>
<th>H</th>
<th>Density</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1.3</td>
<td>25</td>
<td><strong>32.5 kN/m</strong></td>
</tr>
</tbody>
</table>

2. Beam along grid D

Precast Element

<table>
<thead>
<tr>
<th>L</th>
<th>B</th>
<th>H</th>
<th>Density</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.2</td>
<td>1.5</td>
<td>25</td>
<td>7.50 kN/m</td>
</tr>
<tr>
<td>1</td>
<td>1.4</td>
<td>0.2</td>
<td>25</td>
<td>7.00 kN/m</td>
</tr>
<tr>
<td>1</td>
<td>0.2</td>
<td>1.5</td>
<td>25</td>
<td>7.50 kN/m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>22.0 kN/m</strong></td>
</tr>
</tbody>
</table>

Cast in Situ Element

<table>
<thead>
<tr>
<th>L</th>
<th>B</th>
<th>H</th>
<th>Density</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1.3</td>
<td>25</td>
<td><strong>32.5 kN/m</strong></td>
</tr>
</tbody>
</table>

3. Beam along grid E

Precast Element

<table>
<thead>
<tr>
<th>L</th>
<th>B</th>
<th>H</th>
<th>Density</th>
<th>Load</th>
</tr>
</thead>
</table>


4. Built up Column
Along grid B and C
Precast Element

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>Density</th>
<th>Load</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1.3</td>
<td>25</td>
<td>32.50</td>
<td>kN/m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>32.50</td>
</tr>
</tbody>
</table>


5. Pile cap
For 1300Ø pile

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>Density</th>
<th>Load</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
<td>0.6</td>
<td>25</td>
<td>60.00</td>
<td>kN</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60.00</td>
</tr>
<tr>
<td>Deduction</td>
<td></td>
<td>1.322</td>
<td>5</td>
<td>0.6</td>
<td>25</td>
</tr>
<tr>
<td>0.785</td>
<td>5</td>
<td>0.6</td>
<td>25</td>
<td>15.58</td>
<td>44.42</td>
</tr>
</tbody>
</table>

6. Pile cap
For 1000Ø pile

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>Density</th>
<th>Load</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
<td>0.6</td>
<td>25</td>
<td>60.00</td>
<td>kN</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60.00</td>
</tr>
<tr>
<td>Deduction</td>
<td></td>
<td>0.722</td>
<td>5</td>
<td>0.6</td>
<td>25</td>
</tr>
<tr>
<td>0.785</td>
<td>5</td>
<td>0.6</td>
<td>25</td>
<td>8.51</td>
<td>51.49</td>
</tr>
</tbody>
</table>

7. Pile cap
For 1200Ø pile

<table>
<thead>
<tr>
<th>L</th>
<th>B</th>
<th>H</th>
<th>Density</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
<td>0.6</td>
<td>25</td>
<td>60.00 kN</td>
</tr>
</tbody>
</table>

Deduction

<table>
<thead>
<tr>
<th>L</th>
<th>B</th>
<th>H</th>
<th>Density</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.785</td>
<td>5</td>
<td>0.6</td>
<td>25</td>
<td>12.99 kN</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>47.01</strong> kN</td>
</tr>
</tbody>
</table>

Beam along grid 1 to 9

Precast Element

<table>
<thead>
<tr>
<th>L</th>
<th>B</th>
<th>H</th>
<th>Density</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.2</td>
<td>1.5</td>
<td>25</td>
<td>7.50 kN/m</td>
</tr>
<tr>
<td>1</td>
<td>1.4</td>
<td>0.2</td>
<td>25</td>
<td>7.00 kN/m</td>
</tr>
<tr>
<td>1</td>
<td>0.2</td>
<td>1.5</td>
<td>25</td>
<td>7.50 kN/m</td>
</tr>
<tr>
<td>1</td>
<td>0.2</td>
<td>0.2</td>
<td>25</td>
<td>1.00 kN/m</td>
</tr>
<tr>
<td>0.5</td>
<td>0.1</td>
<td>0.2</td>
<td>25</td>
<td>0.25 kN/m</td>
</tr>
</tbody>
</table>

|      |   |    |         | **23.25** kN/m |

Cast in Situ Element

<table>
<thead>
<tr>
<th>L</th>
<th>B</th>
<th>H</th>
<th>Density</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1.3</td>
<td>25</td>
<td><strong>32.50</strong> kN/m</td>
</tr>
</tbody>
</table>

55.75

9. Precast Slab panel load on beam

Grid 1 & 9

<table>
<thead>
<tr>
<th>L</th>
<th>B</th>
<th>Thickness</th>
<th>Density</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>From 5.5m slab panel</td>
<td>1</td>
<td>5.5</td>
<td>0.3</td>
<td>20.63 kN/m</td>
</tr>
<tr>
<td>From 2.75m Canti. slab panel</td>
<td>1</td>
<td>2.75</td>
<td>0.3</td>
<td><strong>41.25</strong> kN/m</td>
</tr>
</tbody>
</table>
### Grid 2 to 8

<table>
<thead>
<tr>
<th>L</th>
<th>B</th>
<th>Thickness</th>
<th>Density</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.5</td>
<td>0.3</td>
<td>25</td>
<td>20.63 kN/m</td>
</tr>
</tbody>
</table>

### 10. Cast in situ slab load on beam

#### Grid 1 & 9

<table>
<thead>
<tr>
<th>L</th>
<th>B</th>
<th>Thickness</th>
<th>Density</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.5</td>
<td>0.2</td>
<td>25</td>
<td>16.25 kN/m</td>
</tr>
</tbody>
</table>

### Grid 2 to 8

<table>
<thead>
<tr>
<th>L</th>
<th>B</th>
<th>Thickness</th>
<th>Density</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.5</td>
<td>0.2</td>
<td>25</td>
<td>16.25 kN/m</td>
</tr>
</tbody>
</table>

### 11. Pile load

#### 1300 mm dia pile

**Submerged**

<table>
<thead>
<tr>
<th>Density</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.785</td>
<td>16.25 kN/m</td>
</tr>
</tbody>
</table>

**Above water lvl**

<table>
<thead>
<tr>
<th>Density</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.69</td>
<td>15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Density</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19.91 kN/m</td>
</tr>
</tbody>
</table>
1200 mm dia pile

Submerged

<table>
<thead>
<tr>
<th>Density</th>
<th>Load (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.785</td>
<td>1.44</td>
</tr>
<tr>
<td>0.785</td>
<td>15</td>
</tr>
<tr>
<td>1</td>
<td>16.96</td>
</tr>
</tbody>
</table>

Above water lvl

<table>
<thead>
<tr>
<th>Density</th>
<th>Load (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.785</td>
<td>1.44</td>
</tr>
<tr>
<td>0.785</td>
<td>25</td>
</tr>
<tr>
<td>1</td>
<td>28.27</td>
</tr>
</tbody>
</table>

1000 mm dia pile

Submerged

<table>
<thead>
<tr>
<th>Density</th>
<th>Load (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.785</td>
<td>1</td>
</tr>
<tr>
<td>0.785</td>
<td>15</td>
</tr>
<tr>
<td>1</td>
<td>11.78</td>
</tr>
</tbody>
</table>

Above water lvl

<table>
<thead>
<tr>
<th>Density</th>
<th>Load (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.785</td>
<td>1</td>
</tr>
<tr>
<td>0.785</td>
<td>25</td>
</tr>
<tr>
<td>1</td>
<td>19.63</td>
</tr>
</tbody>
</table>

B. Live Load

1. Cast in situ slab load on beam

As per IS 4651 part-3, uniformly distributed vertical live load 30kN/m² is considered on entire deck.

Grid 1 & 9

<table>
<thead>
<tr>
<th>L</th>
<th>B</th>
<th>Load/m²</th>
<th>Load (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.5</td>
<td>30</td>
<td>97.50</td>
</tr>
<tr>
<td>1</td>
<td>3.25</td>
<td>30</td>
<td>97.50</td>
</tr>
</tbody>
</table>

195.00 kN/m

Grid 2 to 8

<table>
<thead>
<tr>
<th>L</th>
<th>B</th>
<th>Density</th>
<th>Load (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.5</td>
<td>30</td>
<td>97.50</td>
</tr>
</tbody>
</table>

195.00 kN/m
C. Berthing Force

1 Vessel Parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel type</td>
<td>Container type</td>
</tr>
<tr>
<td>DWT</td>
<td>150000 t</td>
</tr>
<tr>
<td>DT W_D</td>
<td>180000 t</td>
</tr>
<tr>
<td>Length L</td>
<td>290 m</td>
</tr>
<tr>
<td>Height H</td>
<td>24 m</td>
</tr>
<tr>
<td>Width B</td>
<td>44 m</td>
</tr>
<tr>
<td>Draught D</td>
<td>17.5 m</td>
</tr>
</tbody>
</table>

2 Site Condition:

- Site condition = Sheltered
- Berthing condition = Difficult

Unit weight of sea water = 1.005 t/m³

3 Berthing Energy:

- Approach velocity = V = 0.1 m/s

\[ C_m = 1 + \frac{2D}{B} \quad (\text{When } DT < 20000) \]

\[ C_m = 1 + \frac{\pi/4*D^2*L*w}{W_D} \quad (\text{When } DT > 20000) \]

\[ C_m = 1.39 \quad \text{(Cl 5.2.1.2/pg8/IS4651(part-3))} \]

Berthing Angle

\[ \theta = 10 \quad \text{(Cl 5.2.1.3/tab 3/pg10/IS4651(part-3))} \]

\[ (I/R) = \cos \theta = 0.985 \]

\[ \sin \theta = 0.1736 \]
Eccentricity Coefficient

\[ C_e = 0.522 \]

*Cl 5.2.1.3./pg9/IS4651(part-3)*

Softness Coefficient

\[ C_s = 0.95 \]

*Cl 5.2.1.4./pg10/IS4651(part-3)*

According to Cl 5.2./pg6/IS4651(part-3)

\[
E = W_d \times V^2 \times C_m \times C_e \times C_s / 2g
\]

\[
= 63.274 \text{ T-m}
\]

Factor of Safety = 1.4  
*Cl 8.4.1./pg4/IS4651(part-4)*

Final Berthing Energy = \( E \times \text{Factor of Safety} \)

\[
= 88.584
\]

\[
= 885.84 \text{ kNm}
\]

No of Fender in one block = 2

Berthing Energy per fender = 0.6 x Berthing Energy

\[
= 531.5 \text{ kNm}
\]

*The selection of fenders shall be done considering each individual fender in the block will absorb 60% of the total design berthing energy corresponding to the parameters given above.*

### 3 Fender type selection:

Fender Type = MCS 1450 G 0.8

Reaction as per Manufacturer = 881 kN

Reaction Force = 920.65 kN

X-Direction-100% = 920.65 kN

Z-Direction-25% = 230.16 kN
FIGURE B: Fender block selection chart provided by manufacturer

D. Mooring Force

1 Vessel Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead Weight Tonnage (DWT)</td>
<td>150000</td>
</tr>
<tr>
<td>Length between perpendicular (LOA)</td>
<td>290 m</td>
</tr>
<tr>
<td>Width of vessel (W)</td>
<td>44 m</td>
</tr>
<tr>
<td>Height of vessel (H)</td>
<td>24 m</td>
</tr>
<tr>
<td>Molded depth of vessel (Dm)</td>
<td>24 m</td>
</tr>
<tr>
<td>Total draught (Dl)</td>
<td>17.5 m</td>
</tr>
<tr>
<td>Lighter draught (Dl)</td>
<td>8.1 m</td>
</tr>
</tbody>
</table>

Windage area

\[ Aw = 1.175 \times \text{LOA} \times (Dm - Dl) \]

\[ = 1.175 \times 290 \times (24 - 8.1) \]

\[ = 5417.9 \text{ m}^2 \]

2 Wind load calculation

Basic wind speed (favourable for mooring)

\[ V_b = 22.4 \text{ m/s}^2 \]

Probability Factor

\[ k_1 = 1 \]

Terrain, height and structure type

\[ k_2 = 0.99 \]

Topography factor

\[ k_3 = 1 \]

Ref. Design Basis/IS875 part-3
3.7 Mooring force calculation

Mooring Force = \( C_w \times A_w \times P \)

\[
C_w = 1.3 \quad \text{(Cl 5.3.2/pg11/IS4651(part-3))}
\]

\[
(C_w = 1.3 \text{ to } 1.6)
\]

\[
\begin{align*}
\text{Mooring Force} &= C_w \times A_w \times P \\
&= 1.3 \times 5417.925 \times 29.50649856 \\
&= 207823 \text{ kg} \\
&= 2078.23 \text{ kN}
\end{align*}
\]

4. Design bollard pull

Bollard pull = 207.82 t

Bollard height = 1.22 m

Beam depth = 2 m

Lever arm = \((\text{Bollard Height}/2) + (\text{Beam depth}/2)\)

\[
= 1.22/2 + 2/2
\]

\[
= 1.61 \text{ m}
\]

Moment = 334.595 t-m

\[
= 3345.95 \text{ kNm}
\]

Axial Load = 208 t

\[
= 2078.23 \text{ kN}
\]

E. Current Force

Calculation for Grid A pile :

1. General data
Diameter of pile \(= 1.3\) m

Water depth (for high tide) \(d_1 = 24.2\) m
Water depth (for low tide) \(d_2 = 15.94\) m

Marine growth \(= 50\) mm

Diameter of pile with marine growth \(D = 1.4\) m

2 Calculation

As per Cl 213.2/pg29/IRC6:2000

\[
P = 52 \times K \times V^2
\]

Where,

\[
V = \text{Velocity of current at point where pressure intensity is being calculated along c/s.}
\]

\[
K = \text{Shape factor}
\]

Mean velocity of current \(V_m = 1.1\) m/sec
Shape factor \(K = 0.66\)

Cl 213.2/pg29/IRC6:2000

For high tide:

water depth \(d_1 = 24.2\) m
Velocity of current \(V^2 = 1.21\) m/sec

Intensity of Pressure
\[
P = 41.527 \text{ kg/m}^2
\]
\[
P = 0.415 \text{ kN/m}^2
\]

Force \(= \frac{1}{2} \times P \times d_1 \times D\)
\[
= 0.5 \times 0.415272 \times 24.2 \times 1.4
= 7.034 \text{ kN}
\]

Leaver Arm \(= \frac{2}{3} \times d_1\)
\[
= 16.13 \text{ m} \quad \text{(from sea bed level)}
\]

For low tide:
water depth \( d_1 = 15.94 \) m

Velocity of current \( V^2 = 1.21 \) m/sec

Intensity of Pressure \( P = 41.527 \) kg/m\(^2\)  
\( P = 0.4153 \) kN/m\(^2\)

\[
\text{Force} = \frac{1}{2} \times P \times d_1 \times D  \\
= 0.5 \times 0.415272 \times 15.94 \times 1.4  \\
= 4.63 \text{ kN}
\]

Leaver Arm \( = \frac{2}{3} \times d_1 \)
\( = 10.63 \text{ m} \) (from sea bed level)

Calculation for Grid B pile:

1 General data

<table>
<thead>
<tr>
<th>Data</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter of pile</td>
<td>1.00 m</td>
</tr>
<tr>
<td>Water depth (for high tide)</td>
<td>16.23 m</td>
</tr>
<tr>
<td>Water depth (for low tide)</td>
<td>9.83 m</td>
</tr>
<tr>
<td>Marine growth</td>
<td>50 mm</td>
</tr>
<tr>
<td>Diameter of pile with marine growth</td>
<td>1.1 m</td>
</tr>
</tbody>
</table>

2 Calculation

As per IRC:6 - 2000,

\[
P = 52 \times K \times V^2  
\]

Where,

\( V \) = Velocity of current at point where pressure intensity is being calculated along c/s.

\( K \) = Shape factor

Mean velocity of current \( V_m = 1.1 \) m/sec

Shape factor \( K = 0.66 \)

For high tide:
water depth \( d_1 = 16.23 \) m

Velocity of current \( V^2 = 1.21 \) m/sec

Intensity of Pressure

\[
P = 41.527 \text{ kg/m}^2
\]

\[
P = 0.415 \text{ kN/m}^2
\]

\[
\text{Force} = \frac{1}{2} P \cdot d_1 \cdot D
\]

\[
= 0.5 \cdot 0.415272 \cdot 16.23 \cdot 1.1
\]

\[
= 3.706 \text{ kN}
\]

Leaver Arm \( = \frac{2}{3} \cdot d_1 \)

\[
= 10.82 \text{ m} \quad \text{ (from sea bed level)}
\]

For low tide:

water depth \( d_1 = 9.83 \) m

Velocity of current \( V^2 = 1.21 \) m/sec

Intensity of Pressure

\[
P = 41.527 \text{ kg/m}^2
\]

\[
P = 0.415 \text{ kN/m}^2
\]

\[
\text{Force} = \frac{1}{2} P \cdot d_1 \cdot D
\]

\[
= 0.5 \cdot 0.415272 \cdot 9.83 \cdot 1.1
\]

\[
= 2.245 \text{ kN}
\]

Leaver Arm \( = \frac{2}{3} \cdot d_1 \)

\[
= 6.55 \text{ m} \quad \text{ (from sea bed level)}
\]

Calculation for Grid C pile:

1 General data

Diameter of pile \( = 1.00 \) m

Water depth (for high tide) \( d_1 = 12.08 \) m

Water depth (for low tide) \( d_2 = 5.68 \) m

Marine growth \( = 50 \) mm

Diameter of pile with marine growth \( D = 1.1 \) m
2 Calculation

As per IRC:6 - 2000,

\[ P = 52 \times K \times V^2 \]

Where,

- \( V \) = Velocity of current at point where pressure intensity is being calculated along c/s.
- \( K \) = Shape factor

Mean velocity of current \( V_m \) = 1.1 m/sec
Shape factor \( K \) = 0.66

For high tide:

- water depth \( d_1 \) = 12.08 m
- Velocity of current \( V^2 \) = 1.21 m/sec
- Intensity of Pressure \( P \) = 41.527 kg/m²
- \( P \) = 0.415 kN/m²

Force = \( \frac{1}{2} \times P \times d_1 \times D \)
= 0.5 \times 0.415272 \times 12.08 \times 1.1
= 2.759 kN

Leaver Arm = \( \frac{2}{3} \times d_1 \)
= 8.05 m (from sea bed level)

For low tide:

- water depth \( d_1 \) = 5.68 m
- Velocity of current \( V^2 \) = 1.21 m/sec
- Intensity of Pressure \( P \) = 41.527 kg/m²
- \( P \) = 0.415 kN/m²

Force = \( \frac{1}{2} \times P \times d_1 \times D \)
= 0.5 \times 0.415272 \times 5.68 \times 1.1
= 1.297 kN
Leaver Arm = \( \frac{2}{3} \times d_1 \)
\[ = 3.786 \, \text{m} \quad \text{(from sea bed level)} \]

Calculation for Grid D pile

1 General data

Diameter of pile = 1.20 m
Water depth (for high tide) \( d_1 \) = 6.83 m
Water depth (for low tide) \( d_2 \) = 0.43 m
Marine growth = 50 mm
Diameter of pile with marine growth \( D \) = 1.3 m

2 Calculation

As per IRC:6 - 2000,

\[ P = 52 \times K \times V^2 \]

Where,
\[ V = \text{Velocity of current at point where pressure intensity is being calculated along c/s.} \]
\[ K = \text{Shape factor} \]

Mean velocity of current \( V_m \) = 1.1 m/sec
Shape factor \( K \) = 0.66

For high tide:

water depth \( d_1 \) = 6.83 m
Velocity of current \( V^2 \) = 1.21 m/sec

Intensity of Pressure
\[ P = 41.527 \, \text{kg/m}^2 \]
\[ P = 0.415 \, \text{kN/m}^2 \]

Force = \( \frac{1}{2} \times P \times d_1 \times D \)
\[ = 0.5 \times 0.415272 \times 6.83 \times 1.3 \]
= 1.843 kN

Leaver Arm = 2/3 * d1
= 4.553 m (from sea bed level)

For low tide:

water depth

dl = 0.43 m

Velocity of current

\[ V^2 = 1.21 \text{ m/sec} \]

Intensity of Pressure

\[ P = 41.527 \text{ kg/m}^2 \]

\[ P = 0.415 \text{ kN/m}^2 \]

Force

\[ = \frac{1}{2} * P * d1 * D \]

\[ = 0.5 * 0.415272 * 0.43 * 1.3 \]

\[ = 0.116 \text{ kN} \]

Leaver Arm

\[ = 2/3 * d1 \]

\[ = 0.286 \text{ m} \] (from sea bed level)

\[ \text{FIGURE A: } \text{Current Force application (STAAD model)} \]

F. Wave Force

Wave forces are calculated as per Shore Protection manual volume II.
Calculation for High tide Grid A:

1 Calculation of wave force on pile for service condition:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design wave Height</td>
<td>H = 2.470 m</td>
</tr>
<tr>
<td>Time Period</td>
<td>T = 6.000 sec</td>
</tr>
<tr>
<td>Operating Still Water Level (SWL)</td>
<td>MHWS = 5.800 m CD</td>
</tr>
<tr>
<td>Storm Surge</td>
<td>= 0.000 m</td>
</tr>
<tr>
<td>Allowance for sea level rise</td>
<td>= 0.000 m</td>
</tr>
<tr>
<td>Still water level</td>
<td>= 5.800 m CD</td>
</tr>
<tr>
<td>Acceleration due to gravity</td>
<td>g = 9.800 m/s^2</td>
</tr>
<tr>
<td>Finished deck level</td>
<td>= 8.500 m CD</td>
</tr>
<tr>
<td>Depth of super structure beam and slab providing</td>
<td>= 2.000 m</td>
</tr>
<tr>
<td>obstruction to wave</td>
<td></td>
</tr>
<tr>
<td>Soffit level of super structure deck beam</td>
<td>= 6.500 m CD</td>
</tr>
<tr>
<td>Design sea bed level with scour effect</td>
<td>= -15.940 m CD</td>
</tr>
<tr>
<td>Sea water density</td>
<td>w = 10.050 KN/m^3</td>
</tr>
<tr>
<td>Diameter of pile</td>
<td>= 1.3 m</td>
</tr>
<tr>
<td>Thickness of marine growth</td>
<td>= 0.05 m</td>
</tr>
<tr>
<td>Total width of pile obstruction</td>
<td>D = 1.400 m</td>
</tr>
</tbody>
</table>

2 Evaluation of drag coefficient, $C_D$:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth of SWL from sea bed level, d</td>
<td>d = 21.740 m</td>
</tr>
<tr>
<td>$d/gT^2$</td>
<td>= 0.062</td>
</tr>
<tr>
<td>$L_A/L_0$</td>
<td>= 1.000</td>
</tr>
</tbody>
</table>

\[ \text{(FROM FIGURE 7-68 OF SHORE PROTECTION MANUAL)} \]

Maximum velocity

\[ U_{\text{max}} = \left[ \frac{\pi \cdot H}{T} \cdot \left( \frac{L_0}{L_A} \right) \right] = 1.293 \text{ m/s} \]

\[ \text{Eqn 7.47/SPM (vol-2)/pg 7-140} \]

Kinematic viscosity of sea water

\[ \gamma = 0.000000929 \text{ m}^2/\text{s} \]

\[ \text{Eqn 7.45/SPM (vol-2)/pg 7-138} \]

Wave Reynolds number

\[ R_e = \frac{D \times U_{\text{max}}}{\gamma} = 1948982 \]

\[ \text{Eqn 7.45/SPM (vol-2)/pg 7-138} \]
3 Evaluation of inertia coefficient, $C_M$:

Wave Reynolds number

$$R_e = 1948982$$

$$C_M = 1.500$$

[ FROM FIGURE 7-53 OF SHORE PROTECTION MANUAL] 

4 Calculation of maximum wave force and its point of application:

$$W = 1.215$$

$$\frac{H}{gT^2} = 0.007$$

$$\frac{d}{gT^2} = 0.062$$

[ FROM FIGURE 7-78, 7-79, 7-82, 7-83 OF SHORE PROTECTION MANUAL] 

<table>
<thead>
<tr>
<th>Factor</th>
<th>$w = 0.500$</th>
<th>$w = 1.000$</th>
<th>$w = 1.215$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi_m$</td>
<td>0.197</td>
<td>0.382</td>
<td>0.461</td>
</tr>
<tr>
<td>$\alpha_m$</td>
<td>0.135</td>
<td>0.255</td>
<td>0.306</td>
</tr>
</tbody>
</table>

Maximum wave force on pile

$$F_m = \phi_m \times w \times C_D \times H^2 \times D$$

$$= 0.461 \times 1.215 \times 0.700 \times (0.007)^2 \times 0.062 \times D$$

$$= 27.72 \text{ kN}$$

Eqn 7.42/SPM (vol-2)/pg 7-118

Maximum moment in pile due to wave force

$$M_m = \alpha_m \times w \times C_D \times H^2 \times D \times d$$

$$= 0.306 \times 1.215 \times 0.700 \times (0.007)^2 \times 0.062 \times D \times 0.062$$

$$= 400.38 \text{ kN-m/m}$$

Eqn 7.43/SPM (vol-2)/pg 7-118

Height of point of application of wave force from sea bed level

$$= \frac{F_m}{M_m}$$

$$= \frac{27.72}{400.38}$$

$$= 0.069$$

Hence the wave force acts at

$$= -1.498 \text{ m CD}$$

Calculation for High tide Grid B:

1 Calculation of wave force on pile for service condition:
Design wave Height \( H = 2.470 \text{ m} \)

Time Period \( T = 6.000 \text{ sec} \)

Operating Still Water Level (SWL) MHWS \( = 5.800 \text{ m CD} \)

Storm Surge \( = 0.000 \text{ m} \)

Allowance for sea level rise \( = 0.000 \text{ m} \)

Still water level \( = 5.800 \text{ m CD} \)

Acceleration due to gravity \( g = 9.800 \text{ m/s}^2 \)

Finished deck level \( = 8.500 \text{ m CD} \)

Depth of super structure beam and slab providing obstruction to wave \( = 2.000 \text{ m} \)

Soffit level of super structure deck beam \( = 6.500 \text{ m CD} \)

Design sea bed level with scour effect \( = -9.830 \text{ m CD} \)

Sea water density \( w = 10.050 \text{ KN/m}^3 \)

Diameter of pile \( = 1 \text{ m} \)

Thickness of marine growth \( = 0.05 \text{ m} \)

Total width of pile obstruction \( D = 1.100 \text{ m} \)

2 Evaluation of drag coefficient, \( C_D \):

Depth of SWL from sea bed level, \( d = 15.630 \text{ m} \)

\[ \frac{d}{gT^2} = 0.044 \]

\[ \frac{L_A}{L_0} = 1.000 \]

( FROM FIGURE 7-68 OF SHORE PROTECTION MANUAL )

Maximum velocity \( U_{\text{max}} = 1.293 \text{ m/s} \)

Kinematic viscosity of sea water \( \gamma = 0.000000929 \text{ m}^2/\text{s} \)

Wave Reynold number \( R_e = 1531343 \)

\( C_D = 0.700 \)

( FROM FIGURE 7-85 OF SHORE PROTECTION MANUAL )

3 Evaluation of inertia coefficient, \( C_M \):

Wave Reynolds number \( R_e = 1531343 \)
4 Calculation of maximum wave force and its point of application:

\[
W = 0.954 \\
\frac{H}{gT^2} = 0.007 \\
\frac{d}{gT^2} = 0.044
\]

[FROM FIGURE 7-53 OF SHORE PROTECTION MANUAL]

<table>
<thead>
<tr>
<th>Factor</th>
<th>w = 0.500</th>
<th>w = 1.000</th>
<th>w = 1.215</th>
</tr>
</thead>
<tbody>
<tr>
<td>φ_m</td>
<td>0.18</td>
<td>0.35</td>
<td>0.334</td>
</tr>
<tr>
<td>α_m</td>
<td>0.13</td>
<td>0.245</td>
<td>0.234</td>
</tr>
</tbody>
</table>

Maximum wave force on pile \( F_m = 15.79 \) KN
Maximum moment in pile due to wave force \( M_m = 173.04 \) KN-m/m

Height of point of application of wave force from sea bed level = 10.958 m

Hence the wave force acts at = 1.128 m CD

G. Hydrodynamic Force

Grid A

1 Vessel Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dia. of pile</td>
<td>1.4 m</td>
</tr>
<tr>
<td>Water depth (for high tide)</td>
<td>22.34 m</td>
</tr>
<tr>
<td>Water depth (for low tide)</td>
<td>15.94 m</td>
</tr>
<tr>
<td>Seismic Zone</td>
<td>5</td>
</tr>
<tr>
<td>Density of water</td>
<td>10.05 kN/m³</td>
</tr>
<tr>
<td>Radius of enveloping cylinder</td>
<td>0.7 m</td>
</tr>
<tr>
<td>( \frac{d_1}{R} )</td>
<td>31.9</td>
</tr>
<tr>
<td>( \frac{d_2}{R} )</td>
<td>22.8</td>
</tr>
<tr>
<td>( C_e )</td>
<td>0.73</td>
</tr>
<tr>
<td>( \beta )</td>
<td>1</td>
</tr>
</tbody>
</table>

Tab 7/pg36/IS1893:1984
Tab 3/pg19/IS1893:1984
Importance factor 

\[ I = 1.5 \]  

Tab 4/pg19/IS1893:1984

Response reduction factor 

\[ R = 3 \]  

Tab 7/pg21/IS1893:2002

Height of structure from bed level \( h = 26.3 \) m

Time period

\[ T = 0.075 \times h^{0.75} \]

\[ = 0.87 \]

\[ Sa/g = 1.36/T \]  

Cl 6.4.5/pg16/IS1893:2002

\[ = 1.56 \]

Zone Factor 

\[ Z = 0.36 \]  

Tab 2/pg16/IS1893:2002

\[ \alpha_h = \frac{Z}{2} \times \frac{I}{R} \times \frac{Sa/g}{C4} \]

\[ = 0.140 \]

2 For high tide

Water Weight (enveloping cylinder)

\[ W_c = \frac{(\pi/4) \times 1.4^2 \times 22.34 \times 10.05}{2} \]

\[ = 345.6 \] kN.m/sec²

Cl 6.5.2.2/pg37/IS1893:1984

\[ F = C_e \times \alpha_h \times W_c \]

\[ = 35.46 \] kN

\[ C4 = 0.4286 \]  

Cl 6.5.2.1/IS1893:1984

Lever arm From bed level

\[ = 9.57 \] m

3 For low tide

Water Weight (enveloping cylinder)

\[ W_c = \frac{(\pi/4) \times 1.4^2 \times 15.94 \times 10.05}{2} \]

\[ = 246.6 \] kN.m/sec²

Cl 6.5.2.2/pg37/IS1893:1984

\[ F = C_e \times \alpha_h \times W_c \]

\[ = 25.30 \] kN
From table, \( C_4 = 0.4286 \)

Lever arm From bed level = 6.83 m

Grid B

1 Vessel Parameters

Dia. of pile \( D = 1.1 \) m
Water depth (for high tide) \( d_1 = 16.23 \) m
Water depth (for low tide) \( d_2 = 9.83 \) m
Seismic Zone \( Z = 5 \)
Density of water \( w = 10.05 \) kN/m³

Radius of enveloping cylinder \( R = 0.7 \) m
\( \frac{d_1}{R} = 23.2 \)
\( \frac{d_2}{R} = 14.0 \)

\( C_e = 0.73 \) Table-7,IS:1893
\( \beta = 1 \) Table-3,IS:1893
Importance factor \( I = 1.5 \) Table-4,IS:1893
Response reduction factor \( R = 3 \)
Height of structure from bed level=\( h = 23 \) m

Time period

\[
T = 0.075 \times h^{0.75} \\
= 0.79
\]

\( \frac{S_a}{g} = 1.36/T \)
\( = 1.73 \)

Zone Factor \( Z = 0.36 \) Table-2,IS:1893

\[
a_h = \frac{Z}{2} \times I/R \times \frac{S_a}{g} \\
= 0.1554
\]

2 For high tide

Water Weight (enveloping cylinder)

\[
W_c = \frac{(\pi/4) \times 1.1^2 \times 16.23 \times 10.05}{2} \\
= 155.03 \text{ kN.m/sec}^2
\]
\[ F = C_e \cdot \alpha h \cdot W_e \]
\[ F = 17.59 \text{ kN} \]

\[ C4 = 0.4286 \text{ Cl.6.5.2.1,IS:1893-1974} \]

Lever arm From bed level = 6.96 m

3 For low tide

Water Weight (enveloping cylinder)
\[ W_e = \left(\frac{\pi}{4}\right) \cdot 1.1^2 \cdot 9.83 \cdot 10.05 \]
\[ W_e = 93.897 \text{ kN.m/sec}^2 \]

\[ F = C_e \cdot \alpha h \cdot W_e \]
\[ F = 10.65 \text{ kN} \]

From table, C4 = 0.4286
\[ C4 = 0.4286 \text{ Cl.6.5.2.1,IS:1893-1974} \]

Lever arm From bed level = 4.21 m

Grid C

1 Vessel Parameters

Dia. of pile \( D = 1.1 \text{ m} \)
Water depth (for high tide) \( d1 = 12.08 \text{ m} \)
Water depth (for low tide) \( d2 = 5.68 \text{ m} \)
Seismic Zone \( Z = 5 \)
Density of water \( w = 10.05 \text{ kN/m}^3 \)
Radius of enveloping cylinder \( R = 0.7 \text{ m} \)
\( d1/R = 17.3 \)
\( d2/R = 8.1 \)

\[ C_e = 0.73 \text{ Table-7,IS:1893} \]
\[ \beta = 1 \text{ Table-3,IS:1893} \]
Importance factor \( I = 1.5 \text{ Table-4,IS:1893} \)

Response reduction factor \( R = 3 \)
Height of structure from bed level=h= \( h = 23 \text{ m} \)
Time period

\[ T = 0.075 \times h^{0.75} \]

\[ = 0.79 \]

\[ Sa/g = 1.36/T \]

\[ = 1.73 \]

Zone Factor

\[ Z = \boxed{0.36} \]

Table-2.IS:1893

\[ a_h = \frac{Z}{2} \times \frac{1}{R} \times \frac{Sa/g}{2} \]

\[ = 0.1554 \]

2 For high tide

Water Weight (enveloping cylinder)

\[ W_c = \left(\frac{\pi}{4}\right) \times 1.1^2 \times 12.08 \times 10.05 \]

\[ W_c = 115.39 \text{ kN.m/sec}^2 \]

\[ F = C_e \times a_h \times W_c \]

\[ F = 13.09 \text{ kN} \]

\[ C4 = \boxed{0.4286} \]

Cl.6.5.2.1,IS:1893-1974

Lever arm From bed level

\[ = 5.18 \text{ m} \]

3 For low tide

Water Weight (enveloping cylinder)

\[ W_c = \left(\frac{\pi}{4}\right) \times 1.1^2 \times 5.68 \times 10.05 \]

\[ W_c = 54.256 \text{ kN.m/sec}^2 \]

\[ F = C_e \times a_h \times W_c \]

\[ F = 6.15 \text{ kN} \]

From table,C4=

\[ C4 = \boxed{0.4286} \]

Cl.6.5.2.1,IS:1893-1974

Lever arm From bed level

\[ = 2.43 \text{ m} \]
Grid D
Vessel Parameters

Dia. of pile \( D = 1.3 \text{ m} \)
Water depth (for high tide) \( d_1 = 6.83 \text{ m} \)
Water depth (for low tide) \( d_2 = 0.43 \text{ m} \)
Seismic Zone \( Z = 5 \)
Density of water \( w = 10.05 \text{ kN/m}^3 \)

Radius of enveloping cylinder \( R = 0.7 \text{ m} \)

\( d_1/R = 9.8 \)
\( d_2/R = 0.6 \)

\( C_e = 0.73 \) Table-7.IS:1893
\( \beta = 1 \) Table-3.IS:1893
Importance factor \( I = 1.5 \) Table-4.IS:1893

Response reduction factor \( R = 3 \)

Height of structure from bed level\(=h= \)
\( h = 23 \text{ m} \)

Time period

\[ T = 0.075 \times h^{0.75} \]
\[ = 0.79 \]

\[ Sa/g = 1.36/T \]
\[ = 1.73 \]

Zone Factor \( Z = 0.36 \) Table-2.IS:1893

\[ a_h = Z/2 \times I/R \times Sa/g \]
\[ = 0.1554 \]

For high tide

Water Weight (enveloping cylinder)

\[ W_c = (\pi/4) \times 1.3^2 \times 6.83 \times 10.05 \]
\[ W_c = 91.121 \text{ kN.m/sec}^2 \]

\[ F = C_e \times a_h \times W_c \]
\[ F = 10.34 \text{ kN} \]

\[ C_4 = 0.4286 \text{ Cl.6.5.2.1,IS:1893-1974} \]

\[ \text{Lever arm From bed level} = 2.93 \text{ m} \]

3 For low tide

Water Weight (enveloping cylinder)

\[ W_c = \frac{\pi}{4} \times 1.3^2 \times 0.43 \times 10.05 \]

\[ W_c = 5.7368 \text{ kN.m/sec}^2 \]

\[ F = C_e \times \alpha \times W_e \]

\[ F = 0.65 \text{ kN} \]

From table, \( C_4 = \)

\[ C_4 = 0.4286 \text{ Cl.6.5.2.1,IS:1893-1974} \]

\[ \text{Lever arm From bed level} = 0.18 \text{ m} \]


**FIGURE C:** Application of hydrodynamic force to structure (STAAD model)

**H. Wind Force**

A. Operating Condition ::

1 Wind load calculation

Basic wind speed (favorable for mooring)

\[ V_b = 22.4 \text{ m/s}^2 \]

*Ref. Design Basis*
Probability Factor

<table>
<thead>
<tr>
<th>$k_1$</th>
<th>$k_2$</th>
<th>$k_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.99</td>
<td>1</td>
</tr>
</tbody>
</table>

Ref. Design Basis/IS875 part-3

Terrain, height and structure type

Topography factor

$$V_z = 22.4 \cdot 1 \cdot 0.99 \cdot 1$$  
$$= 22.176 \text{ N/m}^2$$  

$$P = 0.6 \cdot V_z^2$$  
$$= 295.065 \text{ N/m}^2$$  

2 Load Calculation on surface area of element

2.1 Load Calculation on surface area of element (X - direction)

a. Fender Block front face

$$2.5 \times 7 = 17.5 \text{ m}^2$$  

$$C_f = 1.2$$  

Table 24/pg43/IS 875 (part-3)

$$17.5 \times 1.2 \times 0.2951 = 6.20 \text{ kN}$$  

i.e. Load per meter = 0.89 kN/m

b. All beam & muff face + Slab face

$$58.5 \times 2.6 = 152.1 \text{ m}^2$$  

$$C_f = 1.2$$  

Table 24/pg43/IS 875 (part-3)

$$152.1 \times 1.2 \times 0.2951 = 53.86 \text{ kN}$$  

i.e. Load per meter = 0.92 kN/m

c. Pile face
\[ C_t = 1.2 \] \textit{Table 24/pg43/ IS 875 (part-3)}

<table>
<thead>
<tr>
<th>Pile Dia. m</th>
<th>Force kN/m²</th>
<th>( C_t )</th>
<th>Load/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.3</td>
<td>0.295</td>
<td>1.200</td>
<td>0.460</td>
</tr>
<tr>
<td>1.2</td>
<td>0.295</td>
<td>1.200</td>
<td>0.425</td>
</tr>
<tr>
<td>1</td>
<td>0.295</td>
<td>1.200</td>
<td>0.354</td>
</tr>
</tbody>
</table>

2.1 Load Calculation on surface area of element (Z - direction)

a. Fender Block front face

\[
1.00 \times 7.00 = 7.00 \text{ m}^2 \]

\[ C_t = 1.2 \] \textit{Table 24/pg43/ IS 875 (part-3)}

\[
7.00 \times 1.20 \times 0.295 = 2.48 \text{ kN} \]

i.e. Load per meter = 0.35 kN/m

b. All beam & muff face + Slab face

\[
48.50 \times 2.6 = 126.1 \text{ m}^2 \]

\[ C_t = 1.2 \] \textit{Table 24/pg43/ IS 875 (part-3)}

\[
126.1 \times 1.2 \times 0.295 = 44.65 \text{ kN} \]

i.e. Load per meter = 0.92 kN/m

c. Pile face

\[ C_t = 1.2 \] \textit{Table 24/pg43/ IS 875 (part-3)}

<table>
<thead>
<tr>
<th>Pile Dia. m</th>
<th>Force kN/m²</th>
<th>( C_t )</th>
<th>Load/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.3</td>
<td>0.295</td>
<td>1.200</td>
<td>0.460</td>
</tr>
<tr>
<td>1.2</td>
<td>0.295</td>
<td>1.200</td>
<td>0.425</td>
</tr>
<tr>
<td>1</td>
<td>0.295</td>
<td>1.200</td>
<td>0.354</td>
</tr>
</tbody>
</table>
B. Extreme Condition ::

1 Wind load calculation

Basic wind speed (favourable for mooring) \[ V_b = 60 \text{ m/s}^2 \]

Probability Factor \[ k_1 = 1 \]

Terrain, height and structure type \[ k_2 = 0.99 \]

Topography factor \[ k_3 = 1 \]

\[ V_z = 60 \times 1 \times 0.99 \times 1 = 59.4 \text{ N/m}^2 \]

\[ P = 0.6 \times V_z^2 = 2117.02 \text{ N/m}^2 = 2.11702 \text{ kN/m}^2 \]

2 Load Calculation on surface area of element

2.1 Load Calculation on surface area of element (X - direction)

a. Fender Block front face

\[ 2.5 \times 7 = 17.5 \text{ m}^2 \]

\[ C_f = \text{Table 24/pg43/ IS 875 (part-3)} \]

\[ 17.5 \times 1.2 \times 2.117 = 44.46 \text{ kN} \]

i.e. Load per meter \[ = 6.35 \text{ kN/m} \]

b. All beam & muff face + Slab face

\[ 58.5 \times 2.6 = 152.1 \text{ m}^2 \]

\[ C_f = \text{Table 24/pg43/ IS 875 (part-3)} \]
152.1 \times 1.2 \times 2.117 = 386.40 \text{ kN}

\text{i.e. Load per meter} = 6.6 \text{ kN/m}

c. Pile face

\[ C_f = 1.2 \]  
\text{Table 24/pg43/ IS 875 (part-3)}

<table>
<thead>
<tr>
<th>Pile Dia. m</th>
<th>Force kN/m$^2$</th>
<th>$C_f$</th>
<th>Load/m kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.3</td>
<td>2.117</td>
<td>1.200</td>
<td>3.303</td>
</tr>
<tr>
<td>1.2</td>
<td>2.117</td>
<td>1.200</td>
<td>3.049</td>
</tr>
<tr>
<td>1</td>
<td>2.117</td>
<td>1.200</td>
<td>2.540</td>
</tr>
</tbody>
</table>

2.1 Load Calculation on surface area of element (Z - direction)

a. Fender Block front face

\[ 1.00 \times 7.00 = 7.00 \text{ m}^2 \]

\[ C_f = 1.2 \]  
\text{Table 24/pg43/ IS 875 (part-3)}

7.00 \times 1.20 \times 2.117 = 17.78 \text{ kN}

\text{i.e. Load per meter} = 2.54 \text{ kN/m}

b. All beam & muff face + Slab face

\[ 48.50 \times 2.6 = 126.1 \text{ m}^2 \]

\[ C_f = 1.2 \]  
\text{Table 24/pg43/ IS 875 (part-3)}

126.1 \times 1.2 \times 2.117 = 320.35 \text{ kN}

\text{i.e. Load per meter} = 6.61 \text{ kN/m}

c. Pile face
$C_t = 1.2$ Table 24/pg43/ IS 875 (part-3)

<table>
<thead>
<tr>
<th>Pile Dia (m)</th>
<th>Force (kN/m$^2$)</th>
<th>$C_t$</th>
<th>Load/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.3</td>
<td>2.117</td>
<td>1.200</td>
<td>3.30</td>
</tr>
<tr>
<td>1.2</td>
<td>2.117</td>
<td>1.200</td>
<td>3.05</td>
</tr>
<tr>
<td>1</td>
<td>2.117</td>
<td>1.200</td>
<td>2.54</td>
</tr>
</tbody>
</table>

### II. Horizontal subgrade modulus and Soil spring constants

The geotechnical parameters, profile data of wharf, typical calculation of horizontal subgrade modulus and soil spring constant for pile grid A is given below.

**Geotechnical parameters:**

<table>
<thead>
<tr>
<th>Soil Unit</th>
<th>Elevation</th>
<th>Cohesion</th>
<th>Angle of Friction</th>
<th>Density $Y_{sub}$ (kN/m$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>From</td>
<td>To</td>
<td>C (kN/m$^2$)</td>
<td>$\phi$ (Degree)</td>
</tr>
<tr>
<td>1</td>
<td>6.86</td>
<td>5.06</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>5.06</td>
<td>0.16</td>
<td>0.00</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0.16</td>
<td>-1.54</td>
<td>5.89</td>
<td>24</td>
</tr>
<tr>
<td>4</td>
<td>-1.54</td>
<td>-15.04</td>
<td>0.00</td>
<td>32</td>
</tr>
<tr>
<td>5</td>
<td>-15.04</td>
<td>-18.14</td>
<td>39.24</td>
<td>21</td>
</tr>
<tr>
<td>6</td>
<td>-18.14</td>
<td>-27.14</td>
<td>0.00</td>
<td>38</td>
</tr>
<tr>
<td>7</td>
<td>-27.14</td>
<td>-43.44</td>
<td>49.05</td>
<td>21</td>
</tr>
<tr>
<td>8</td>
<td>-43.44</td>
<td>-48.64</td>
<td>0.00</td>
<td>38</td>
</tr>
<tr>
<td>9</td>
<td>-48.64</td>
<td>-50.14</td>
<td>46.11</td>
<td>20</td>
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</table>

**Profile and Profile data:**
<table>
<thead>
<tr>
<th>Grid Mark</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rock fill Level (m)</td>
<td>-15.94</td>
<td>-9.83</td>
<td>-5.68</td>
<td>-0.43</td>
<td>6.50</td>
</tr>
<tr>
<td>Dredge Level (m)</td>
<td>-17.80</td>
<td>-15.00</td>
<td>-13.10</td>
<td>-10.30</td>
<td>-7.50</td>
</tr>
<tr>
<td>Fdg. Level (m)</td>
<td>-44.00</td>
<td>-44.00</td>
<td>-44.00</td>
<td>-44.00</td>
<td>-20.00</td>
</tr>
<tr>
<td>Dia. of Pile (m)</td>
<td>1.30</td>
<td>1.00</td>
<td>1.00</td>
<td>1.20</td>
<td>1.20</td>
</tr>
</tbody>
</table>

Soil Spring Calculation

Pile Grid

A

Design Dredge Level along Gridline = -17.80 m
Rock fill Level along Gridline = -15.94 m
Virtual line Level along Gridline = -17.94 m
Fdg Lvl = -44.00 m

For calculation purpose virtual line is assumed to be horizontal and considered 2m below rock fill level.

1 Horizontal Subgrade Modulus:

The modulus of horizontal subgrade Reaction,

\[ K_s = A_s + B_s \times Z^n \]

Where,

\[ A_s = C_m \times C \times [c \times N_c + 0.5 \times \gamma \times B \times N_f] \]

\[ B_s = C_m \times C \times \gamma \times N_q \]

\[ Z \] = Depth of Interest

\[ n \] = Exponent to give \( K_s \), best fit

\[ C \] = Factor depending on displacement of Pile=

\[ \gamma \] = Unit weight of Soil (kN/m³)

\[ B \] = Diameter of Pile (m)

\[ C_m \] = Size Factor

\[ = 1.0 + 2 \times 0.5 \] if \( B \leq 0.45 \)
\[ = 1.0 + (0.457/B)^{0.75} \] if \( B > 0.45 \)

7 m

0.5

40

1.30

5
\[ C_m = 1.0 + 0.25 \text{ if } B > 1.2 \text{ m} \]

2 Soil Spring Constant

<table>
<thead>
<tr>
<th>Soil Unit</th>
<th>Datum (m)</th>
<th>Depth - h (m)</th>
<th>( A_s )</th>
<th>( B_s )</th>
<th>( K_s )</th>
<th>L</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>-17.94</td>
<td>0.00</td>
<td>33537</td>
<td>3662</td>
<td>33537</td>
<td>1</td>
<td>31005</td>
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<tr>
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<td>1.00</td>
<td>36266</td>
<td>34085</td>
<td>70351</td>
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<td>88998</td>
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<td>2.00</td>
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<td>172433</td>
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<td>36266</td>
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<td>138521</td>
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<td>170133</td>
</tr>
<tr>
<td>7</td>
<td>-27.94</td>
<td>10.00</td>
<td>41328</td>
<td>3557</td>
<td>52577</td>
<td>1</td>
<td>77720</td>
</tr>
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<td>7</td>
<td>-28.94</td>
<td>11.00</td>
<td>41328</td>
<td>3557</td>
<td>53126</td>
<td>1</td>
<td>69061</td>
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<tr>
<td>7</td>
<td>-29.94</td>
<td>12.00</td>
<td>41328</td>
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<td>53650</td>
<td>1</td>
<td>69743</td>
</tr>
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<td>-30.94</td>
<td>13.00</td>
<td>41328</td>
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<td>54153</td>
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<td>70397</td>
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<td>-31.94</td>
<td>14.00</td>
<td>41328</td>
<td>3557</td>
<td>54638</td>
<td>1</td>
<td>71027</td>
</tr>
<tr>
<td>7</td>
<td>-32.94</td>
<td>15.00</td>
<td>41328</td>
<td>3557</td>
<td>55105</td>
<td>1</td>
<td>71635</td>
</tr>
</tbody>
</table>
III. Pile Design – considerations

\[ d = \text{Depth of lower point of contracture from first spring} \]
\[ L_0 = \text{Unsupported length considered for calculation of bucking moment} \]
Unsupported length of pile

<table>
<thead>
<tr>
<th>Grid</th>
<th>Level of first Spring</th>
<th>Depth of lower point of contra flexure from first spring</th>
<th>Fixity depth considered (0.5d)</th>
<th>Idealized level of pile</th>
<th>Unsupported length L₀ m</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-17.94</td>
<td>9</td>
<td>4.5</td>
<td>8.5</td>
<td>30.94</td>
</tr>
<tr>
<td>B</td>
<td>-11.83</td>
<td>8.5</td>
<td>4.25</td>
<td>8.5</td>
<td>24.58</td>
</tr>
<tr>
<td>C</td>
<td>-7.68</td>
<td>9</td>
<td>4.5</td>
<td>8.5</td>
<td>20.68</td>
</tr>
<tr>
<td>D</td>
<td>-2.43</td>
<td>11</td>
<td>5.5</td>
<td>8.5</td>
<td>16.43</td>
</tr>
<tr>
<td>E</td>
<td>4.5</td>
<td>15.5</td>
<td>7.75</td>
<td>8.5</td>
<td>11.75</td>
</tr>
</tbody>
</table>

A. Typical Pile design: Grid A, Max. Moment case

1 Maximum Banding Moment Location

- Axial Force
  \[ Pu = 5684 \text{ kN} \]
- Moment
  \[ My = 2985 \text{ kN-m} \]
- Moment
  \[ Mx = 671 \text{ kN-m} \]

Considering root mean square value
\[ = 3059.5 \text{ kN-m} \]

Design Resultant moment
\[ Mu = 3059.5 \text{ kN-m} \]

Grade of Concrete
\[ fck = 40 \text{ N/mm}^2 \]

Grade of Steel
\[ fy = 500 \text{ N/mm}^2 \]

Diameter of Pile
\[ D = 1300 \text{ mm} \]

Area of Pile
\[ \pi (1300)^2 / 4 = 1E+06 \text{ mm}^2 \]

Diameter of bar assumed
\[ = 32 \text{ mm} \]

Clear cover to the outer most reinforcement
\[ = 75 \text{ mm} \]

Diameter of helical reinforcement
\[ = 12 \text{ mm} \]

\[ d' = 32/2 + 75 + 12 = 103 \text{ mm} \]

Area of Core
\[ \pi (1300 - 75)^2 / 4 = 1E+06 \text{ mm}^2 \]

\[ d'/D = 0.0792 \]

Length of Pile
\[ = 30.54 \text{ m} \]

Effective length factor
\[ = 1.2 \]

Effective length of pile
\[ L_{ex} = 36.648 \text{ m} \]
2 Slenderness moments

\[
\frac{L_{ex}}{D} = \frac{(36.648 \times 1000)}{1300} = 28.19
\]
\[
\frac{e_{ax}}{D} = \frac{(1/2000) \times 28.19 \times 28.19}{1300} = 0.4
\]

Additional moment
\[
5684 \times 0.4 \times \frac{1300}{1000} = 2955.7 \text{ kNm}
\]

Assuming % of reinforcement as,
\[
p = 2 \%
\]

\[
P_{uz}/Ag = \left(0.45 f_{ck} A_c + 0.75 f_y A_s \right)/A_g = 23.483 \text{ (Chart 63/SP:16 - 1980)}
\]
\[
P_{uz} = 31170 \text{ kN}
\]

\[
P_{bx} = (k_1 + k_2 p/f_{ck}) f_{ck} b D
\]
\[
k_1 = 0.168 \quad \text{(Table 60/SP:16 - 1980)}
\]
\[
k_2 = 0.495
\]

\[
P_{bx} = (0.168 + (0.495 \times 2/40)) \times 40 \times 1300 \times 1300 \times 1000 = 13030 \text{ kN}
\]
\[
k_x = \frac{31170 - 5684}{31170 - 13029.9} = 1.405
\]
So, \( k_x = 1 \)

(kx is limited to 1)

\[
M_{ax} = k_x \times M_{ax} = 2955.7 \text{ kN-m}
\]

Minimum Eccentricity
\[
30.54 \times 1000/500 + 1300/30 = 104.41 \text{ mm}
\]

\[
M_{ux2} = 5684 \times 104.41/1000 = 593 \text{ kN-m}
\]

Greater of \( M_{ux1} \) and \( M_{ux2} \), \( M_{ux} = 3059 \text{ kN-m} \)

Design Moment
\[
2955.68 + 3059 = 6014.7 \text{ kN-m}
\]

\[
P_{d}/f_{ck} D^2 = \frac{5684/10 \times 100000/(40 \times 1300^2)}{1300^2} = 0.084
\]
\[
M_{d}/f_{ck} D^3 = \frac{6014.68 \times 10^6/(40 \times 1300^3)}{1300^3} = 0.068
\]
p/fck = 0.051 (SP:16 -1980)
p = 2.04 %

Area of steel required = 27077 mm²

Provide:
No of Bars provided = 34 Nos
Dia of Bar = 32 mm

Ast. provided = 27344 mm² OK

B. Helical Reinforcement Design

1 Pitch

Pitch of reinforcement shall not be more than least of the following

a. Least lateral dimension = 1300 mm
b. 16 x Dia. of longitudinal reinforcement = 512 mm
c. Max spacing = 300 mm

Provided pitch = 250 mm

2 Diameter

Diameter of reinforcement shall not be less than the following

a. 1/4 Dia. of longitudinal Bar = 8 mm
b. minimum Dia. = 6 mm

Provided Diameter of helical reinforcement = 12 mm

C. Crack width check for Pile

Grid-A

Crack width is checked as per IS 456 - 2000 CL 35.3.2 and 43.1

Permissible crack width = 0.1 mm
Design surface crack width is given by,

\[
\frac{3 a_n e_n}{1 + 2 \left( \frac{a_n}{h - x} \right)}
\]

Where,

\[
e_n = e_1 - \left( \frac{h_x - x}{3E_A (d-x)} \right)
\]

Strain at level considered \((e_1)\) =

\[
\left( \frac{h - x}{d - x} \right) \left( \frac{f}{E} \right)
\]

<table>
<thead>
<tr>
<th>Number of Bars</th>
<th>=</th>
<th>34</th>
<th>Nos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter of Bar</td>
<td>=</td>
<td>32</td>
<td>mm</td>
</tr>
<tr>
<td>Diameter of Pile ((h))</td>
<td>(h) =</td>
<td>1300</td>
<td>mm</td>
</tr>
<tr>
<td>Diameter of Helical</td>
<td>=</td>
<td>12</td>
<td>mm</td>
</tr>
<tr>
<td>Clear cover to main reinforcement</td>
<td>(C_{\text{min}}) =</td>
<td>87</td>
<td>mm</td>
</tr>
<tr>
<td>Effective diameter</td>
<td>(d) =</td>
<td>1197.0</td>
<td>mm</td>
</tr>
<tr>
<td>Effective radius</td>
<td>(r) =</td>
<td>598.5</td>
<td>mm</td>
</tr>
<tr>
<td>Effective Cover</td>
<td>(C_{\text{eff}}) =</td>
<td>103.0</td>
<td>mm</td>
</tr>
<tr>
<td>Modulus of Elasticity of Steel</td>
<td>(E_s) =</td>
<td>200000</td>
<td>Mpa</td>
</tr>
<tr>
<td>Axial Force</td>
<td>=</td>
<td>5684</td>
<td>kN</td>
</tr>
<tr>
<td>Bending Moment</td>
<td>=</td>
<td>3059</td>
<td>kN.m</td>
</tr>
<tr>
<td>Concrete Strength</td>
<td>(f_{\text{ck}}) =</td>
<td>40</td>
<td>N/mm²</td>
</tr>
<tr>
<td>Depth of Neutral Axis</td>
<td>(X_u) =</td>
<td>0</td>
<td>mm</td>
</tr>
<tr>
<td>Serviceability Stress in reinforcement</td>
<td>(f_i) =</td>
<td>-45</td>
<td>N/mm²</td>
</tr>
</tbody>
</table>

(Negative sign for stress represents stress is compressive in nature-No crack formed)
Strain at level considered \( (e_1) \) = \[
\frac{(1300 - 0) \times -45}{(1197 - 0) \times 200000}
\]

= -0.000244

Radius \( R \) = 650 mm
Distance \( r_1 \) = -650 mm
Cos(\( \theta/2 \)) = -1
\( \theta \) = 6.28 radian = 360 degree

C.G. of tension steel \[2r \sin(\theta/2)/\theta\] = 2.535E-14 mm

Width of section at centroid of tension steel \( b_t \) = 650 mm
Angle between bars = 10.59 degree
Number of bars in tension = 28 Nos
Area of tension reinforcement \( A_t \) = 22518.94 mm\(^2\)

Distance from compression face to the point at which crack width is being calculated \( a \) = 1300.00 mm

Radial distance from the point considered to the surface of the nearest longitudinal bar \( a_{cr} \) = 118.9 mm

\( e_m \) = -0.0003

Design surface crack width = -0.106 Section is Uncracked OK