Analysis of Loads and Design of Passenger Boat Berthing Structure in Water Metro Terminal

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Abstract - *Kochi water metro project envisages the development of 16 identified routes, connecting 10 islands in the inland waterways along a network of routes that span 76 km. The project intends to bring in a fleet of 78 fast, fuel efficient, air-conditioned ferries plying to 38 jetties, 18 of which will be developed as main boat hubs, while the remaining 20 will be minor jetties for transit services. More than 100,000 islanders are expected to benefit from the Water Metro, complete with modern watercrafts. In the present dissertation the passenger boat berthing structure was analyzed which a part of water metro terminal. The various load conditions are assessed in the best possible way to construct a new berthing structure. All the suitable and useful data was adopted from the proposed site location at Vytilla.*

***Key Words*: Berthing Structures, Dead Load, Live Load Wind Load, Seismic Load, Earth Pressure, Current Load, Berthing Load, Mooring Load.**

1.INTRODUCTION

Kochi is the first city in the country to have achieved such a milestone whereby water transport has been integrated as a feeder service to the metro. It is also for the first time in India that such a significant level of investment is being brought in for improving water transport. This project deals with the analysis of loads and design of passenger boat berthing structure in water metro terminal along the inland waterways. The berthing structures are constructed for the berthing and mooring of vessels to enable loading and unloading of cargo and for embarking and disembarking of passengers, conveyances etc. The orchestrating and design of berthing structures depend on sundry factors. In the present project, the boat terminal at Vytilla is considered. Here the berthing structure is constructed in the inland water ways. The different kinds of the loads acting on the berthing structure are studied. The influence factors which effected on the structure were taken into consideration such as soil characteristics of the proposed location, environmental conditions and range of traffic. The length of the proposed berth is 24m.

2. DESIGN PARAMETERS OF BERTHING STRUCTURES AND TERMINAL

2.1 Place of Construction

Vytilla is one of the locations identified for the development of a boat terminal. The structure should be placed at the easy accessible place of the proposed site. As a State Water Transport (SWT) jetty is present in the site a suitable location is identified without obstructing the operations of SWT.

2.2 Types of Berthing Structure

After determination of the location for structure, have to select the kind of structure for construction and the factors controlling the selection of the kind of structure are depending on the conditions of water flowing and Geotechnical properties of soil. Classifications of berthing structure are basically Piers and Wharfs.

1) Wharf - A berthing structure which is parallel to shore line. It is generally adjacent to the shore, and may not be very near to shore.
2) Pier - A berthing structure which project into water that means perpendicular to shore. This structure need not be exactly perpendicular to shore; it may be with some angle to shore. These structures also are like T or L shape. Here we are adopting pier which are perpendicular to the river bank.

2.3 Layout of Pier

The layout of piers at each boat terminal depend on the following considerations:

1. Number of piers needed and phasing
2. Size and types of boats to be handled
3. Availability of waterfront (with suitable water depths) and backup land
4. Environmental conditions like waves, current
5. Proximity of the navigational route being used by other vessels

3. WAY OF SELECTION TO CONSTRUCT BERTHING STRUCTURES

1. Material availability
2. Construction cost.
3. Method of construction
4. Dimension and mass of vessels

4. LONGITUDINAL DIMENSION OF BERTH

As per Cl. 3.3.2 of AS3962, pier lengths are to be taken same as the overall length of the longest boat length (L) that may use the piers.

Total length of the passenger boat L = 22m
Clearance provided = 2m
Therefore, Total length proposed for the berth = 24m.

5. WIDTH

Minimum width of finger = 0.9 m as per AS3962. Considering double berthing minimum required width is 1.8 m. However, considering ferry service requirement including fixing of bollards and gangway, width of pier is provided is 5.0 m.

6. SHORE PROTECTION WORKS

From the view of soil profile of these location following types of shore protection could be possible.
1. Pile and Slab wall with tie back anchor wall/Sheet piling
2. Flexible structure like Rock Bund / Revetment
3. Fixed structure like gravity wall

7. ANALYSIS OF INDUCED LOADS

As per IS 875 part-1, the building is coming under the category of assembly building. So loading for assembly building is provided here.

7.1 Dead Load

Self-weight of the various components such as slab, beams, pile cap and piles are coming under this loading.

Dead load on slab = 0.20 x 25 = 5 kN/m2

Dead load on beams
Longitudinal beams = 0.5 x 0.3 x 25 = 3.75 kN/m2
Transverse beams = 0.5 x 0.3 x 25 = 3.75 kN/m2

7.2 Live Load

As per IS: 875 (part-2) -1987, the loadings for assembly building is taken. Loading of 5kN/m2 is provided.

7.3 Wind Load

Wind contributes primarily to the lateral loading on a pier. Wind load is given as per IS: 875 (Part-3)-1987.

As per IS: 875(Part-III) Clause: 5.

Design wind speed $V_z = V_b \times K_1 \times K_2 \times K_3$

V_b = 39 m/s
K_1 = Probability factor=1.06
K_2 =Terrain, height and structure size factor=1
K_3 =Topography factor=1

V_z = 39 x 1.06=41.34 m/s

Design wind pressure = $.6 \times V_z^2 = .6 \times 41.34$
= 1025.39 N/m²
= 1.025 kN/m²

7.4 Seismic Load

As per IS: 1893(Part-1): 2002, cl: 7.5.3

Design seismic base shear $V_B = A_H \times W$
A_H = horizontal seismic coefficient

$$A_H = \frac{Z}{2} \times \frac{S_a}{g} \times \frac{I}{R}$$

Z = zone factor = 0.16 (zone III)
I = Importance factor = 1.5
R = response reduction factor = 3
Average response acceleration coefficient,
$\frac{S_a}{g} = 2$
$A_H = 0.08$
W = seismic weight of the structure = 337 kN

Design seismic base shear V_B = 0.08 x 337
= 26.96 kN

7.5 Earth Pressure

$P_a = K \times \gamma \times h$
K = coefficient of earth pressure = 1
γ = unit weight of soil = 19 kN/m²
γ_{sub} = 19-9.81 = 6.19 kN/m²
h = height of the structure = 26 m
P_a = 1 x 6.19 x 26 = 160 kN/m²

7.6 Current Load

Loads because of current-pressure because of flow will be connected to the zone of the vessel beneath the water line when completely stacked. The boat is for the most part berthed parallel to the current with powerful currents and where berth arrangements really goes astray from the bearing of the current, the likely force should be considered by any familiar method and taken into account.

$F = \frac{wv^2}{2g}$
W = unit weight of water = 1.025 tonnes/m³
V = velocity of current = 1 m/s
g = acceleration due to gravity = 9.81 m/s²
F = 0.522 kN/m²
F/ metre length = 0.6x 0.522 = 0.31 kN/m

7.7 Berthing Load

When an approaching vessel strikes a berth a level power follows up on the compartment. The magnitude of this power depends on the kinetic energy that can be ingested by the fendering framework.

As per IS 4651;

Berthing energy $E = \frac{W_D V^2}{2g} \times C_m \times C_e \times C_s$
W_D = displacement tonnage = 44 T
V = berthing velocity = 0.3 m/s
C_m = mass coefficient = $1+\frac{\pi}{4}\left(\frac{D^2 LW}{W_D}\right)$
D = draft of the vessel = 0.9 m
L = length of the vessel = 22m.
W = 10.25 kN/m³
W_D = 44 T
C_m = 4.26

C_e = eccentricity coefficient = $\frac{1+(\frac{l}{r})^2 \sin^2\theta}{1+(\frac{l}{r})^2}$

For $\frac{l}{r}$ = 1, θ = 0.51°
C_e = 0.5
C_s = 0.9 (cl 5.2.1.4)

$E = \frac{44x0.3^2}{2x9.81}$x4.26x0.5x0.9
= 0.386 kN/m²

7.8 Mooring Load

The mooring burdens are the lateral loads brought about by the mooring lines when they pull the boat into or along the dock or hold it against the powers of wind or current. The most extreme mooring burdens are because of the wind compels on uncovered range on the open side of the boat in light condition.
Bollard pull = 98.1 kN (10T)

Assuming 4 bollards to be taken, then load on each bollard = $\frac{98.1}{4}$ = 24.525kN

Horizontal component = 24 cos 45
= 17.34 kN

8.DESIGN

8.1Design of Beam

- Grade of concrete = M30
- Grade of steel = Fe415
- Cover =50 mm
- Span = 6m
- Size of beam = 300mm x 500mm
- Size of the bar =16 mm
- Shear reinforcement = 2 legged 8 mm dia bars at 240 mm c/c

8.2 Design of Deck Slab

- Grade of concrete = M30
- Grade of steel = Fe415
- Thickness of slab = 200mm
- Clear cover = 50 mm
- Effective Length along short span = 4.35m
- Effective Length along long span = 5.35 m
- Main Reinforcement = 12 mm diameter bars at 260 mm c/c

- Distribution reinforcement = 12 mm diameter bars at 300 mm c/c

8.3 Design of Pile

- Grade of concrete = M40
- Grade of steel = Fe415
- Clear Cover = 75 mm
- Diameter of the pile = 600mm
- Diameter of longitudinal reinforcement bar = 16 mm
- Number of longitudinal reinforcement bars = 12
- Diameter of helical reinforcement bar = 10 mm
- Spacing of helical reinforcement = 150 mm c/c

8.4 Design of Pile cap

- Grade of concrete = M40
- Grade of steel = Fe415
- Clear Cover = 75 mm
- Size of pile cap = 0.8 m x 0.8 m x 0.5 m
- Reinforcement = 4 numbers of 12 mm diameter bars (cage reinforcement)

CONCLUSION

Different factors are to be considered while analyzing and designing the berthing structure. Lateral loads on the berthing structures are more eminent than those on land– based structures. Congruous environmental data, traffic forecasting and soil data ought to be received from the proposed site location, typical load distribution is induced on the shore line structures. The structure was analyzed and designed satisfying various loading conditions and dimension analysis for economical aspect was additionally taken care of without exceeding the structural safety. Before going for designing or orchestrating a berthing structure, all the present and future optimistic conditions regarding traffic data, hinterland expansion and industrialization of that particular hinterland are to be studied, which additionally play a major role in shaping the project inception at the first place.

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