

**ANALYSIS, PLANNING AND CONSTRUCTION TECHNIQUES FOR  
REINFORCED CONCRETE BERTHING STRUCTURES**

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**ABSTRACT**

The construction of berthing structures forms a cornerstone of modern port and harbour engineering, providing safe and efficient facilities for mooring, loading, and unloading vessels. This study presents a detailed analysis of planning and construction techniques for reinforced concrete berthing structures.

The study begins with an overview of functional requirements and engineering principles governing the design of berthing structures. It highlights the importance of site investigation, geotechnical assessment, and environmental considerations in ensuring structural stability and long-term sustainability. Planning aspects such as material selection, construction sequencing, and resource optimization are also discussed.

Various construction techniques, including cast-in-situ reinforced concrete systems, pile-supported decks, and diaphragm walls, are analysed. Critical challenges such as tidal variations, underwater concreting, corrosion resistance, and quality control are addressed. Advanced techniques such as prefabrication and slip-forming are also considered to enhance construction efficiency.

The study concludes by recommending effective planning and construction strategies to improve the safety, durability, and performance of reinforced concrete berthing structures in marine environments.

**Keywords:**

Reinforced concrete Berthing structures, Geotechnical assessment, construction sequencing, structural integrity, dynamic marine conditions, cast-in-situ, pile-supported decks ,Diaphragm walls, Slip-forming, prefabrication, demonstrate improvements.

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**1. INTRODUCTION**

Ports and harbours are critical gateways for global trade, and the efficiency of their operations depends largely on the reliability of berthing structures. Reinforced concrete berthing structures provide durable and versatile solutions for mooring, loading, and unloading vessels of varying capacities.

With the increasing size of modern ships, such as bulk carriers exceeding 100,000 DWT, the design and construction of berthing facilities require advanced engineering approaches. This study focuses on analysing planning and construction techniques for reinforced concrete berthing structures by integrating theoretical principles with practical execution strategies.

**2. METHODOLOGY**

The construction of a reinforced concrete berthing structure for high-capacity vessels is a highly integrated process that combines geotechnical, structural, and marine engineering disciplines to deliver a facility capable of withstanding immense loads and the harsh marine environment. It begins with comprehensive site characterization, where bathymetric and topographic surveys are conducted to understand seabed conditions and logistical arrangements are made to mobilize marine fleets, establish fabrication yards, and secure material supply chains. Once the groundwork is laid, detailed engineering analysis follows, involving soil-structure interaction studies based on borelogs, finite element modeling to simulate static and dynamic loads such as berthing impacts

and mooring forces, and hydraulic studies to assess the influence of waves and currents. This analytical stage ensures that the design is robust enough to accommodate both operational stresses and environmental challenges. The actual construction commences with the substructure, where vertical and raker piles are driven deep into competent soil strata to transfer loads safely. Alongside this, a reinforced concrete diaphragm wall is built using the slurry trench method, serving as both a cut-off and earth-retaining system to stabilize the landward side. Rigorous static and dynamic load tests, as well as integrity checks, validate the reliability of these foundational elements. With the substructure secured, attention shifts to the superstructure, where staging and shuttering systems are erected over water. Pre-cast beams and deck panels are carefully positioned using marine cranes to accelerate progress, followed by reinforcement placement and cast-in-situ marine-grade concrete pouring to create a monolithic deck slab. After deck completion, marine hardware is fitted that typically includes energy absorbing fender systems and high-capacity mooring bollards type hardware for safely berthing and securing mooring against tide variations. Ultimately, safeguards will be implemented to shield the structure from aggressive marine forces. The submerged steel components generally use cathodic protection like sacrificial anodes; the curing and surface treatments can prevent corrosion due to sea-water (ingress of chlorides). The methodology is multidisciplinary, sequential and holistic to enable the berthing facility to remain safe, reliable and claiming to be going to withstand be condition for over several years.

The construction of reinforced concrete berthing structures involves an integrated approach combining geotechnical, structural, and marine engineering principles. The process begins with site investigation, including bathymetric surveys and geotechnical studies to assess seabed conditions.

Detailed analysis is carried out using soil-structure interaction studies and numerical modelling to evaluate loads such as berthing impact, mooring forces, wave action, and seismic effects.

Construction starts with substructure development, where piles are driven into competent strata. Diaphragm walls may be constructed for stability. The superstructure is then developed using precast and cast-in-situ concrete techniques. Marine hardware such as fenders and bollards are installed, followed by corrosion protection measures like cathodic protection.

### 3. Equations: As Per IS 4651 (Part 3)

- a. The formula for Berthing Energy (E) is:

$$E = \frac{1}{2} MV^2 C_m C_e C_c C_s$$

Where M is the displacement tonnage of our 1 Lakh DWT vessel.

V is the velocity approach (0.1 to 0.15 m/s)

C<sub>m</sub> is the mass coefficient

C<sub>e</sub> is the eccentricity coefficient

C<sub>s</sub> is the softness (berthing) coefficient

C<sub>c</sub> is the configuration coefficient

- b. The Formula for Berth Length:

$$L_{\text{berth}} = \text{LOA} + C_{\text{fwd}} + C_{\text{aft}}$$

Where LOA = Vessel Length Overall

C<sub>fwd</sub> = Clearance at bow (typically 10–15 m)

C<sub>aft</sub> = Clearance at stern (typically 10–15 m)

Thus, berth length is vessel LOA plus clearances at both ends.

### Example for 100,000 DWT Vessel As Per IS 4651 (Part 3)

LOA = 250 m

Clearance forward = 15 m

Clearance aft = 15 m

$$L_{\text{berth}} = 250 + 15 + 15 = 280 \text{ m}$$

So, the berth should be ≈ **280 m long** to safely accommodate the vessel.

### 4. Figures and Tables

For 100000 DWT vessel the parameters and values as per IS Code 4651 part -3 (Bulk Carriers)

Table 1: Parameters and values for 100000 DWT vessel

PARAMETERS	VALUES
Vessel type	100000 DWT (Bulk)
Length Overall (LOA)	250.00 m
Beam (Breadth)	38.00 m
Depth	21.00 m
Maximum Draft	15.0 m

**Table No-2: Environmental Design Basis**

Environmental Factor	Design Consideration	Impact on Final Selection
Max Wave Height ( $H_{\max}$ )	2.5 m to 4.0 m	Dictates the thickness of the deck and pile diameter
Tidal Range	1.8 m (Typical for Vizag)	Sets the vertical clearance for the jetty deck
Current Velocity	0.5 to 1.0 m/s	Influences the difficulty of the berthing manoeuvre
Soil Type	Silty Clay / Weathered Rock	Determines if we use Piles (Open) or Caissons (Solid)
Seismic Zone	Zone II / III	Requires specialized reinforcement for earthquake safety

**Table No-3: Structural parameters & specifications and technical justification**

Parameter	Planned Specification	Technical Justification
Pile Diameter	1000 mm to 1200 mm	To handle 2500 KN lateral reaction
Bollard Spacing	25 m Centre	Even distribution of 600 T total wind load.
Dredged Slope	1:3 (Stable side slope)	Prevents underwater landslides into the berth
Fender Spacing	15 m to 20 m	Ensures 2 points of contact for a 250 m LOA

**Table No-4: Marine hardware & Function & Material**

Hardware	Function	Typical Material
Fenders	Absorb ship impact	Rubber, composite
Bollards	Secure mooring ropes	Cast steel, ductile iron
Hooks	Quick-release mooring	Steel with remote systems
Ladders	Crew access	Galvanized steel
Cleats	Tie small craft ropes	Steel, cast iron
Fairleads	Guide ropes	Steel with rollers

**Table No-5: Conditions and Recommended Structure**

CONDITION	RECOMMENDED STRUCTURE
Deep Rock Level (>30m)	Open Pile Jetty
Shallow Rock (<10m)	Gravity Quay Wall
High Siltation/Currents	Open Pile Jetty
Heavy Container Loads	Solid Quay Wall / Wharf
Liquid Bulk (Oil/Gas)	Dolphin / Island Berth

**FIGURE-1: 100,000 DWT Bulk Carrier**

## 5. CONCLUSION

The selection of berthing structures depends on geotechnical, environmental, and operational conditions. Open pile jetties are suitable for deep water and high siltation areas, while gravity-type quay walls are preferred for stable soil conditions and heavy cargo operations.

The study highlights that proper planning, accurate analysis, and appropriate construction techniques are essential for ensuring safety, durability, and cost-effectiveness. The integration of modern construction methods further enhances the performance and service life of berthing structures.

### 1 Conclusion on the Typical Use of Berthing Structures in Ports

Each type of berthing structure is chosen based on environmental conditions, soil characteristics, and operational requirements. Their typical uses can be summarized as follows:

- Quay Walls → Best for sheltered harbours with stable soil, supporting heavy cargo handling and container terminals.
- Jetties → Extend into deep water, ideal for bulk cargo and oil terminals where shoreline depth is insufficient.
- Piers → Suited for passenger traffic, fishing, and smaller vessels, especially in areas with tidal variation.
- Wharves → Economical structures for general cargo handling in estuaries or rivers.
- Dolphins → Used for mooring and berthing large tankers in exposed or deep-water conditions.
- Floating Berths → Adaptable to large tidal ranges, mainly for marinas and small craft.
- For a coastal or riverine project where you are dealing with a deep rock level and have selected an open pile jetty as the recommended structure, the operational and environmental parameters must align with the structural flexibility and the challenges of deep-piling.
- Here is a breakdown of the recommended ships and environmental conditions for this specific engineering setup.

### 1. Recommended Types of Ships

- An open pile jetty is ideal for handling vessels that require significant water depth but don't necessarily exert the massive lateral berthing impacts that a solid gravity wharf can handle.

- Oil & Chemical Tankers: Since open pile structures allow water to flow through, they are excellent for liquid bulk terminals where specialized piping can be run along the approach trestle.
  - LNG/LPG Carriers: These vessels often berth at "island" type open pile jetties to maintain safety distances from the shore.
  - Bulk Carriers (Panamax/Handymax): Suitable if the jetty is equipped with conveyor systems or traveling loaders. However, the pile design must account for the heavy vibrations of unloading machinery.
  - Ro-Ro (Roll-on/Roll-off) Vessels: If a ramp is integrated, open piles provide the necessary height clearance for tidal variations.
  - Note: For very large vessels like VLCC's (Very Large Crude Carriers), the "deep rock level" is a benefit for draft, but ensure the piles are designed for high lateral kinetic energy during berthing.
2. Recommended Environmental Conditions
- The environment must justify the use of an open pile structure over a solid quay wall.
  - Hydraulic Conditions
  - High Tidal Ranges: Open pile jetties are preferred in areas with significant tide changes because they don't block the movement of water, reducing the risk of siltation.
  - Strong Currents: Because the structure is "transparent" to the flow, it experiences much lower hydrodynamic drag compared to a solid wall. It is ideal for estuaries or river mouths with high flow velocities.
  - Low to Moderate Wave Energy: While piles can withstand waves, extreme "breaking wave" zones can cause significant uplift forces on the jetty deck.
  - Geotechnical Context
  - Deep Rock Level: This is your primary constraint. Since the rock is deep, you will likely use End-Bearing Piles.
  - Stable Overburden: You need enough soil/sediment above the rock to provide lateral stability (passive resistance) for the piles before they hit the bedrock.

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