Study of Construction Techniques for Reinforced Concrete Berthing Structure Including Planning

G. Tirupathi Naidu[1], G.Giridhar[2], G.Hemanth[3], G.Dinesh[4], L.Nataraj[5], R.Ramu[6]

[1]Professor, Department Civil Engineering, Dr. Lankapalli Bullayya College of Engineering, Visakhapatnam, Andhra Pradesh, India.

[2]Associate Professor, Department Civil Engineering, Dr. Lankapalli Bullayya College of Engineering, Visakhapatnam, Andhra Pradesh, India.

[*3,4,5,6]UG students, Department civil engineering, Dr. Lankapalli Bullayya College of Engineering, Visakhapatnam, Andhra Pradesh, India.

Abstract

The construction of berthing structures plays a vital role in modern port and harbor engineering, ensuring safe and efficient mooring, loading, and unloading of vessels. This project, titled *"Study of Construction Techniques for Reinforced Concrete Berthing Structure Including Planning,"* focuses on analyzing, evaluating, and documenting the methodologies involved in the planning and execution of such marine infrastructure.

The study begins with an overview of berthing structures, their functional requirements, and the engineering principles governing their design. It emphasizes the importance of site investigation, geotechnical analysis, and environmental considerations in determining the feasibility and sustainability of construction. Planning aspects such as material selection and construction sequencing are examined to ensure structural stability and durability under dynamic marine conditions.

The project explores various construction techniques, including cast-in-situ reinforced concrete berthing structures, pile-supported platforms, and diaphragm walls. Various different factors has to considered for construction of marine structures, such as tidal variations, underwater concreting, corrosion resistance, and quality control measures. The role of advanced technologies such as slip-forming, prefabrication, and modern equipment for underwater works is highlighted to demonstrate improvements in efficiency and construction quality. Overall, this study addressing practical construction issues and recommending suitable techniques and planning strategies to ensure the safety, durability, and sustainability of reinforced concrete berthing structures in marine environments.

Keywords: Reinforced concrete Berthing structures, Geotechnical analysis, Structural stability, Marine conditions, Cast-in-situ, Pile-supported platforms, Diaphragm walls, Slip-forming, Corrosion resistance.

1. Introduction

The rapid growth of global trade and the increasing size of marine vessels have significantly influenced the development of port infrastructure. Berthing structures play a crucial role in facilitating safe docking, loading, and unloading operations. Historically, natural harbors were used for anchorage; however, modern ports require advanced engineered structures to accommodate large vessels such as bulk carriers and container ships exceeding 100,000 DWT.

With advancements in construction technology, the design and execution of berthing structures have evolved to incorporate modern materials, analytical tools, and efficient construction techniques. This study focuses on the planning and construction methodologies of reinforced concrete berthing structures to improve structural performance and operational efficiency

2. Methodology

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

Construction begins with the substructure, where vertical and raker piles are installed to transfer loads to deeper strata. Diaphragm walls may be constructed using slurry trench methods for stability. The superstructure is then developed using precast and cast-in-situ techniques to form the deck slab.

Finally, marine hardware such as fenders and bollards are installed, and protective measures like cathodic protection are applied to enhance durability.

Equations(**As per IS 4651-Part 3**)

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)

Cm is the mass coefficient

Ce is the eccentricity coefficient

Cs is the softness (berthing) coefficient

Cc is the configuration coefficient

3. 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 Besis

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 rein-forcement 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's & 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 (>30 m)	Open Pile Jetty
Shallow Rock (<10 m)	Gravity Quay Wall
High Siltation/Currents	Open Pile Jetty
Heavy Container Loads	Solid Quay Wall / Wharf
Liquid Bulk (Oil/Gas)	Dolphin / Island Berth

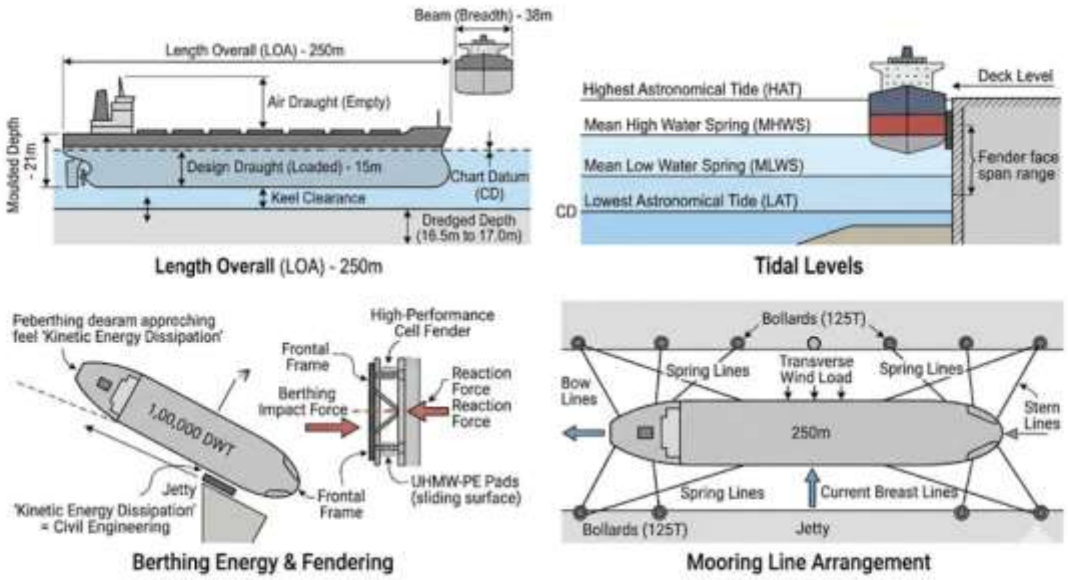

FIGURE-1 Vessel Dimension and characteristics

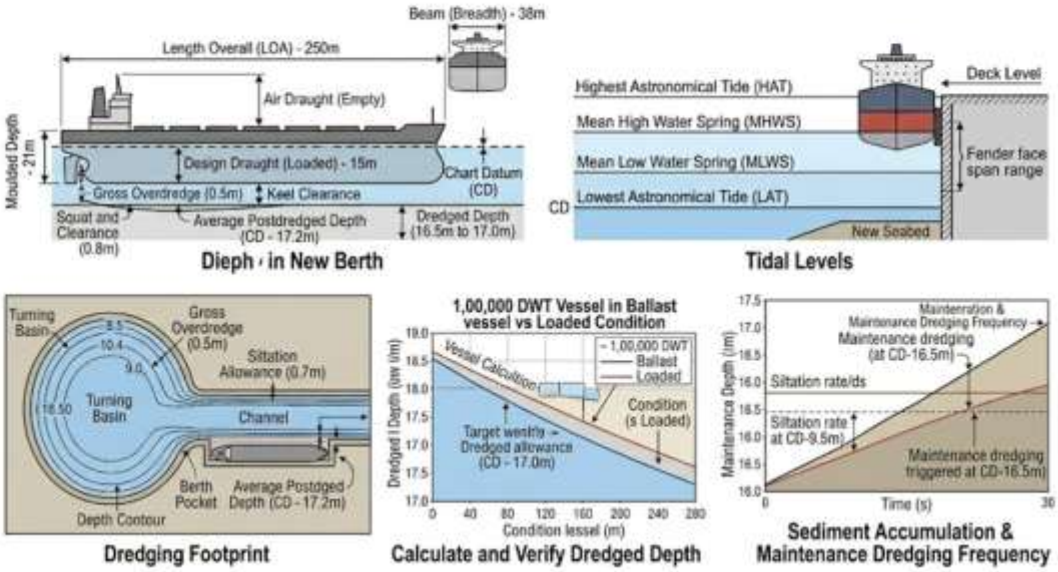

FIGURE – 2 Determination of Dredged Depth

FIGURE- 3 Bulk Carriers

4. Conclusion

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.

2 Conclusion: Selection Criteria for Berthing Structures

The selection of a specific berthing structure is not universal; it depends on a balance of geotechnical, environmental, and operational criteria.

1. Geotechnical & Environmental Criteria

- Soil Type: Piled Systems (Open structures) are used in regions with silty clay, where long piles (up to 50m) derive strength from skin friction. Gravity-Based Systems (Caissons) are selected when hard rock is present near the dredged level, as piles cannot be easily driven into rock.
- Hydraulic Transparency: In areas with significant siltation or sand movement, an Open Pile Jetty is preferred because it allows water to flow through, maintaining seabed equilibrium. A solid wall would cause massive siltation.
- Seismic Activity: Piled structures offer more flexibility to dissipate earthquake energy (specifically in Zones II/III) compared to rigid gravity walls.

2. Operational Criteria

- Cargo Type: Continuous Wharves or Quays are mandatory for container and dry bulk operations where cranes must move the entire length of a 250m ship. Island/Dolphin Berths are sufficient for liquid bulk (oil/gas) since cargo is transferred via pipelines.
- Vessel Size: For a 1,00,000 DWT vessel, the structure must accommodate a 15m maximum draft (requiring a ~18m dredged depth) and provide high-capacity mooring (125T-150T bollards).
- 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.

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