DI04006071: Railway, Harbour & Tunnel Engineering

Lecture 4.30: Selection of Berthing Structures, Jetties, Fenders, Piers, Wharves, and Dolphins

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Civil Engineering

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Introduction to Berthing Structures I

Berthing structures are specialized marine structures designed to facilitate the safe approach, mooring, and servicing of vessels. Their primary function is to provide a stable interface between land and water transport, accommodating cargo handling and passenger transfer while resisting static and dynamic loads from ships and the marine environment.

Key Points

- Provide a secure tie-up facility for vessels during loading and unloading.
- Must withstand berthing impacts (kinetic energy of approaching ships).
- Subjected to environmental loads including waves, currents, wind, and seismic activity.
- Categorized primarily into continuous (wharves, piers) and isolated (dolphins) structures.

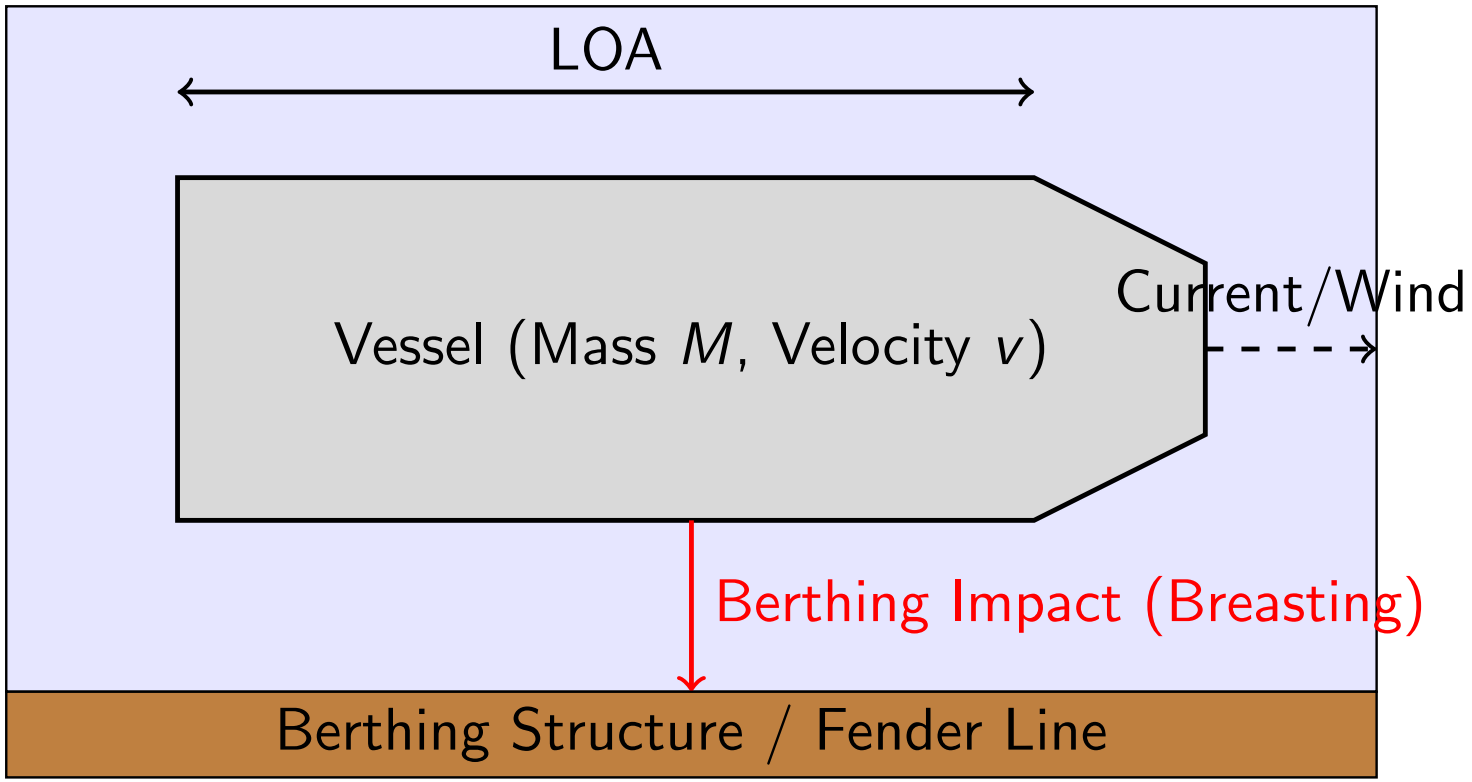
Factors Influencing the Selection of Berthing Structures I

The selection and conceptual design of a berthing structure depend on a complex interaction of environmental, operational, and geotechnical factors. A thorough site investigation is mandatory to determine the most technically feasible and economically viable structural form.

Key Points

- Bathymetry and Dredging: Natural water depth and the cost of capital and maintenance dredging.
- Vessel Characteristics: Deadweight tonnage (DWT), draft, length overall (LOA), and approach velocity.
- Geotechnical Conditions: Soil bearing capacity, depth to bedrock, and liquefaction potential.
- Environmental Forcing: Tidal range, wave climate, wind rose, and local current velocities.

Kinematics of Vessel Berthing I



Kinematics of Vessel Berthing II

Key Points

- Kinetic energy of the vessel is absorbed by the fender system and the structure.
- Approach velocity and angle of impact dictate the design breasting forces.
- Hydrodynamic mass (added mass of water) must be accounted for in energy calculations.

Comparison of Primary Berthing Structures I

The structural form chosen depends heavily on the orientation of the shoreline relative to deep water and the specific cargo handling requirements.

Comparison of Primary Berthing Structures II

Key Points

- | Feature | Wharf (Marginal) | Pier (Projecting) | Jetty |
- |———|———————|———————-|———-|
- | Alignment | Parallel to shore | Perpendicular/oblique | Perpendicular (extended) |
- | Water Depth | Requires dredging near shore | Reaches natural deep water | Reaches natural deep water |
- | Berthing Sides | Single side | Both sides | Often both sides/specialized |
- | Earth Retaining | Yes (often bulkheads) | No (open structure) | No (open structure) |
- | Ideal For | General cargo, containers | Passengers, liquid bulk | Liquid/dry bulk, hazardous |

Wharves and Piers: Detailed Considerations I

Wharves, or marginal wharves, are constructed flush with the shoreline, acting as both a berthing facility and a retaining wall for the backup land. Piers project out into the harbour basin, requiring less dredging but offering less backup space directly adjacent to the berth.

Key Points

- Wharves are ideal when deep water is close to the shore or when extensive land reclamation is feasible.
- Open-piled wharves use a suspended deck over a revetted slope, reducing earth pressure.
- Solid wharves (sheet pile, caissons) are used in suitable soil but must withstand massive lateral earth pressures.
- Piers maximize the number of berths per meter of shoreline as vessels can dock on both sides.

Jetties: Deep Water Access I

A jetty is an open structure projecting from the shore into deep water, primarily used when the required draft for vessels cannot be achieved near the shore without prohibitive dredging costs. They are commonly associated with specialized bulk terminals.

Key Points

- Consist of an approach trestle connecting the shore to the main loading platform.
- Often completely open-piled to minimize interference with coastal sediment transport.
- Structural design is governed by longitudinal forces from conveyor belts, pipelines, or vehicle braking.
- Typically integrated with breasting and mooring dolphins to handle vessel loads.

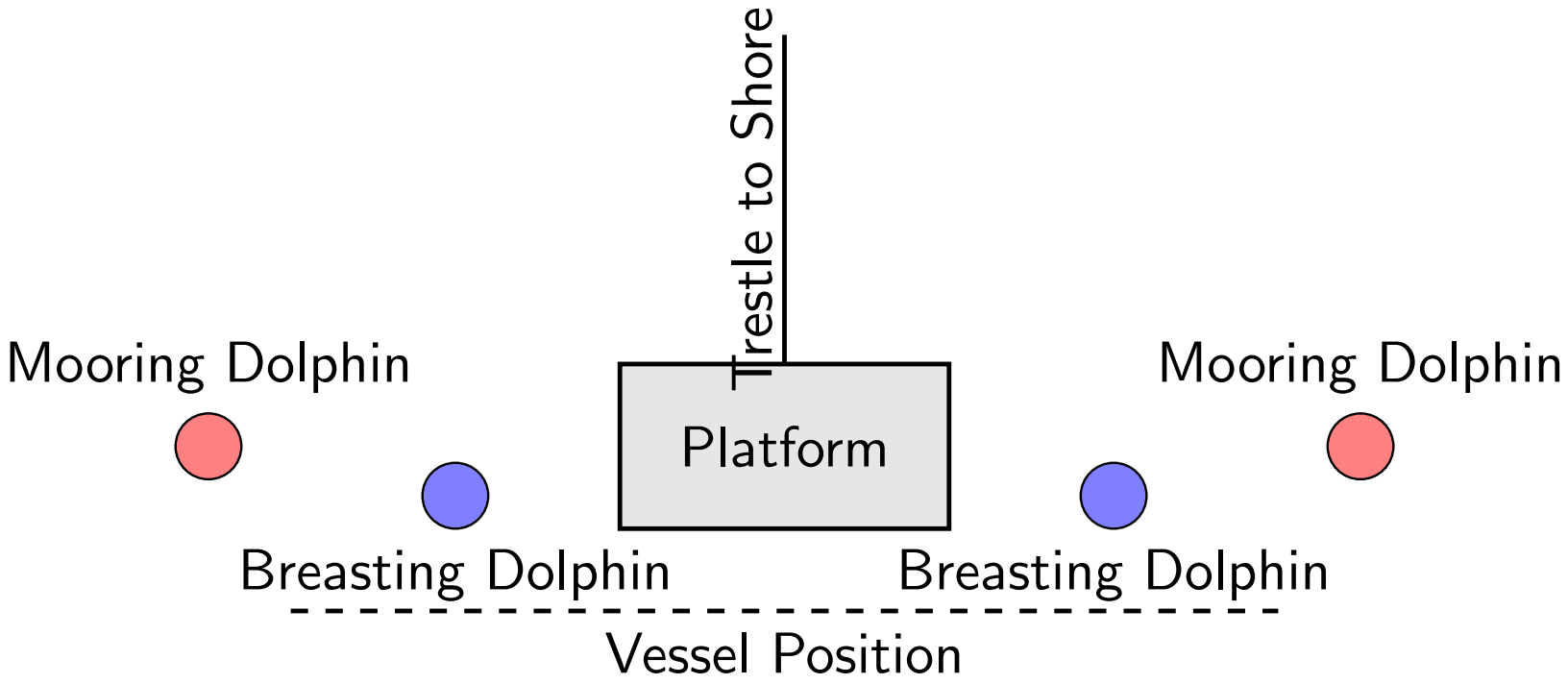
Dolphins: Isolated Load-Bearing Structures I

Dolphins are independent marine structures designed specifically to take berthing impacts (breasting dolphins) or mooring line pulls (mooring dolphins). They offer a highly cost-effective alternative to continuous berthing structures when only point loading and securing are required.

Key Points

- Breasting Dolphins: Placed adjacent to the loading platform. Designed to absorb the kinetic energy of the berthing ship and transmit breasting forces to the foundation.
- Mooring Dolphins: Placed aft and forward of the berth. Designed exclusively to handle tension forces from mooring lines to keep the vessel stationary.
- Constructed using flexible pile clusters, rigid caissons, or heavy concrete blocks on batter piles.

Typical Layout of an Offshore Berth I



Typical Layout of an Offshore Berth II

Key Points

- Central loading platform supports pipelines, loading arms, or cranes but takes NO berthing forces.
- Breasting dolphins take transverse berthing loads and longitudinal friction forces.
- Mooring dolphins are set back to provide favorable angles for mooring lines (typically \$15ˆ\{}circ\$ to \$45ˆ\{}circ\$).

Fenders and Energy Absorption I

Fenders are the interface between the berthing structure and the vessel. Their fundamental purpose is to absorb the kinetic energy of the approaching ship, converting it into strain energy, while keeping the reaction force on both the hull and the structure within allowable limits.

Key Points

- Solid Rubber Fenders: Cone, cell, and arch types. High energy absorption with relatively low reaction forces.
- Pneumatic Fenders: Air-filled rubber cylinders. Excellent for vessels with low hull pressures (e.g., LNG carriers) and areas with large tidal variations.
- Foam-Filled Fenders: Polyurethane foam core. Non-deflating and highly durable.
- Timber/Pile Fenders: Traditional flexible systems, reliant on the elastic bending of piles.

Fender Selection Criteria I

Selecting the appropriate fendering system requires balancing energy capacity, reaction force, and operational constraints.

Fender Selection Criteria II

Key Points

- | Criteria | Consideration / Impact |
- |———-|———————-|
- | Normal Energy (E_N) | Derived from vessel displacement, velocity, and eccentricity. |
- | Abnormal Energy (E_A) | Accidental impacts; usually factored as 1.5 to $2.0 \{}times E_N$. |
- | Hull Pressure | Must not exceed the allowable yield stress of the ship's hull plating. |
- | Stand-off Distance | Gap required between ship and structure to prevent overhang clashes. |
- | Tidal Range | Large tides may require vertical frontal frames or floating fenders. |

Summary of Berthing Structures Selection I

The selection of berthing structures is a multi-disciplinary challenge integrating geotechnical, structural, and coastal engineering principles to ensure safe and efficient maritime operations.

Key Points

- Site topography, bathymetry, and cargo type primarily dictate whether a wharf, pier, or jetty is selected.
- Dolphins provide an economical solution for isolated loading points, decoupling berthing forces from the loading platform.
- Fender systems are critical for energy dissipation, protecting both the vessel hull and the marine structure.
- A holistic design approach considering lifecycle costs, environmental loads, and vessel evolution is essential.