DI04006071: Railway, Harbour & Tunnel Engineering

Lecture 4.31: Classification of Breakwaters and Construction Methods

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Civil Engineering

July 23, 2026

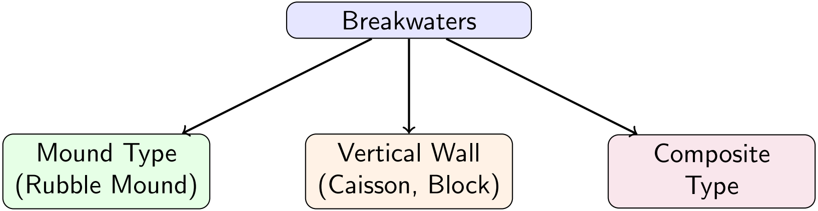
Introduction to Breakwaters I

A breakwater is an artificial offshore structure constructed to protect a harbour, anchorage, or marina basin from water waves. Breakwaters intercept coastal currents and waves, providing safe berthing for vessels and facilitating loading and unloading operations.

Key Points

- Primary function is to attenuate wave energy.
- Creates an artificial harbor with calm waters.
- Prevents coastal erosion and protects shoreline infrastructure.
- Essential for safe navigation and port operations.

Types of Breakwaters I



Key Points

- Broadly classified into three main types based on structure and interaction with waves.
- Mound types absorb wave energy.
- Vertical walls reflect wave energy.
- Composite types combine features of both.

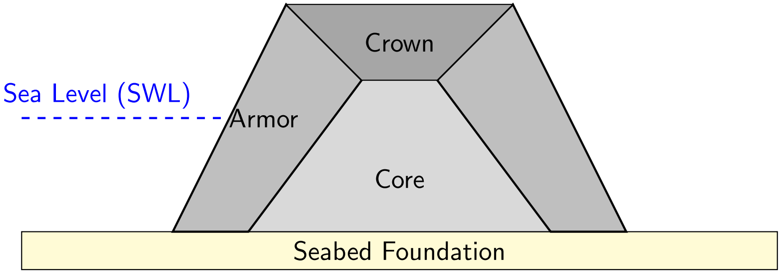
Rubble Mound Breakwaters I

Rubble mound breakwaters are constructed by dumping and shaping mounds of rubble (irregularly shaped rocks). They are designed to dissipate wave energy through friction and porous flow rather than reflecting it. They are the most common type due to their adaptability to various seabed conditions.

Key Points

- Constructed using naturally available rock or concrete armor units.
- Consists of a core, underlayers, and an armor layer.
- Highly adaptable to settlement and weak seabed foundations.
- Relatively easy to repair and maintain by adding more materials.

Cross-section of Rubble Mound Breakwater I



Cross-section of Rubble Mound Breakwater II

Key Points

- Core: Small quarry run material providing the bulk volume.
- Underlayer: Intermediate sized rocks preventing core washout.
- Armor Layer: Large rocks or concrete units (e.g., Tetrapods) resisting wave impact.
- Crown/Crest: Superstructure often paved for access.

Vertical Wall Breakwaters I

Vertical wall breakwaters are solid structures with a vertical seaward face that reflect wave energy instead of dissipating it. They are typically constructed where the seabed is firm and the water is deep. Common materials include concrete blocks, reinforced concrete caissons, or sheet piling.

Key Points

- Induces high wave reflection, causing standing waves (clapotis).
- Requires a very strong and stable foundation to prevent overturning or sliding.
- Smaller footprint compared to rubble mound breakwaters.
- Can also serve as berthing facilities on the harbor side.

Composite Breakwaters I

Composite breakwaters consist of a vertical wall superstructure resting on a rubble mound foundation. This hybrid design is utilized in deep waters where a full vertical wall would be unstable, or a full rubble mound would require an excessive amount of material.

Key Points

- Combines the wave-dissipating properties of a mound and the footprint of a vertical wall.
- Rubble mound foundation distributes the heavy load of the vertical superstructure.
- Reduces the required height of the expensive vertical caisson.
- Careful design is required to prevent wave breaking directly on the vertical face.

Comparison of Breakwater Types I

| Feature | Rubble Mound | Vertical Wall | | :— | :— | :— | | **Wave Interaction** | Absorbs/Dissipates wave energy | Reflects wave energy (Clapotis) | | **Foundation Needs** | Adaptable to weak soils | Requires strong, firm rock/soil | | **Construction Cost**| Material intensive, cheaper per unit | Lower material volume, high unit cost | | **Maintenance** | Higher maintenance (replacing armor) | Lower maintenance if stable | | **Berthing** | Not suitable for ship berthing | Suitable on the protected (lee) side |

Key Points

- Rubble mound is preferred for poor soil conditions and abundant local rock.
- Vertical walls are preferred in deep water with solid foundations.
- Selection depends on water depth, wave climate, soil bearing capacity, and material availability.

Construction Methods: Rubble Mound Breakwater I

The construction of a rubble mound breakwater is heavily dependent on the transport and precise placement of materials. It typically starts from the shore and progresses seaward. The sequence involves preparing the seabed, placing the core, underlayers, and finally the armor units.

Key Points

- Seabed preparation: Dredging unsuitable material or laying geotextile mattresses.
- Core placement: Dumping quarry run using split-hopper barges or dump trucks.
- Underlayer and Armor placement: Placed carefully using floating cranes or land-based crawler cranes.
- Interlocking of artificial armor units (like Tetrapods, Accropodes) is critical for stability.

Construction Methods: Vertical Wall (Caisson) I

Caisson breakwaters involve the use of large, hollow concrete boxes pre-cast in dry docks or slipways. They are floated to the site, sunk into position by filling them with sand or water, and then capped with concrete.

Key Points

- Pre-fabrication: Caissons are built on land or floating docks to ensure high quality.
- Foundation preparation: A rubble leveling berm is laid and perfectly leveled on the seabed.
- Towing and Sinking: Caissons are towed by tugboats and sunk by carefully flooding their cells.
- Filling and Capping: Cells are filled with sand/gravel for mass, and a concrete crown is cast in situ.

Design and Environmental Considerations I

Breakwater design must account for extreme hydrodynamic forces and environmental impacts. Engineers analyze wave heights (design wave), tidal variations, and storm surges. Environmental impacts such as alteration of coastal sediment transport and water quality must also be mitigated.

Key Points

- Hydrodynamic stability: Checking against sliding, overturning, and armor displacement.
- Toe protection: Preventing scouring (erosion) at the base of the structure.
- Sediment transport: Breakwaters can cause downdrift erosion and updrift accretion.
- Ecological impact: Creating artificial reefs while ensuring adequate harbor flushing.

Summary of Breakwaters I

Breakwaters are indispensable for port development, offering protection against aggressive wave action. Understanding the distinct classifications—mound, vertical, and composite—allows engineers to select the most appropriate type based on site-specific geotechnical and hydrodynamic conditions.

Key Points

- Rubble mounds dissipate energy and suit weak foundations.
- Vertical walls reflect energy and require strong foundations but allow berthing.
- Construction techniques range from simple dumping to complex caisson towing.
- Thorough hydrodynamic and environmental analysis is mandatory for a successful design.