DI04006071: Railway, Harbour & Tunnel Engineering

Lecture 4.28: Wind Characteristics, Tides and Currents

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Civil Engineering

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Introduction to Wind Characteristics in Harbours I

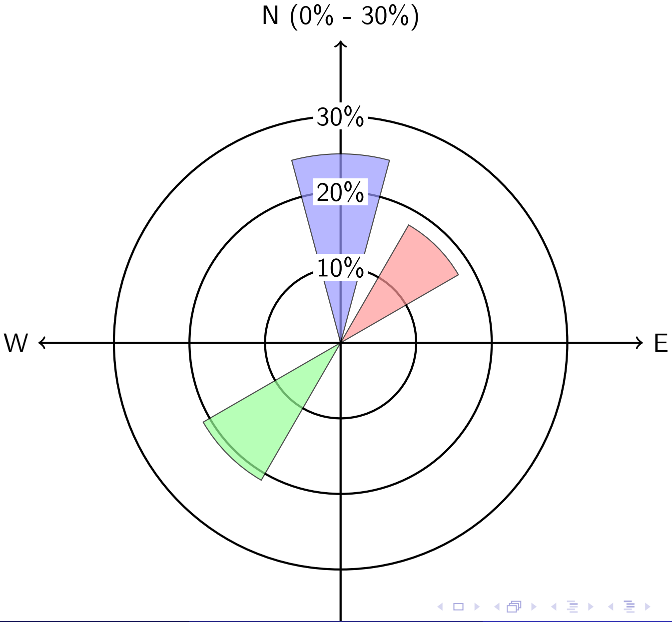
Wind is a primary meteorological factor influencing harbour design. It dictates the wave climate, impacts ship maneuverability during berthing, and determines the layout of breakwaters and port facilities. Understanding wind velocity, duration, and fetch length is crucial for calculating wave heights and designing coastal structures.

Key Points

- Wind is the primary driving force for wave generation.
- Affects vessel navigation, berthing operations, and cargo handling.
- Key parameters: velocity, duration, and fetch length.

Wind Rose Diagram I

Wind Rose Diagram II



Beaufort Wind Scale I

The Beaufort scale is an empirical measure that relates wind speed to observed conditions at sea or on land. In coastal engineering, it provides a quick assessment of potential wave conditions and operational safety levels for harbour activities.

Key Points

- Force 0 (Calm) | $<$1 knot | Sea like a mirror
- Force 4 (Moderate breeze) | 11-16 knots | Small waves, numerous whitecaps
- Force 8 (Gale) | 34-40 knots | Moderately high waves of greater length
- Force 12 (Hurricane) | $>$64 knots | Huge waves, sea completely white with driving spray

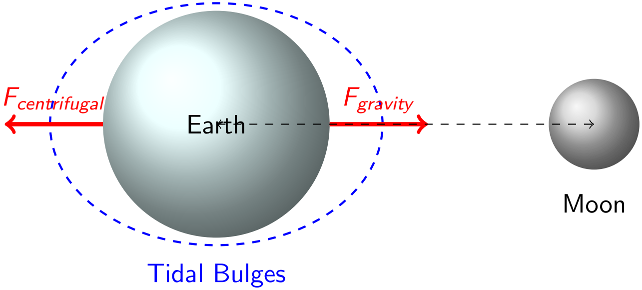
Introduction to Tides I

Tides are the periodic rise and fall of the sea surface caused by the gravitational pull of the Moon and the Sun on the Earth's oceans, combined with the rotation of the Earth. Understanding tidal variations is critical for establishing datum levels (like Chart Datum), determining dredging depths, and ensuring safe clearance for vessels navigating harbour channels.

Key Points

- Periodic vertical movement of ocean waters.
- Governed primarily by the gravitational forces of the Moon and Sun.
- Establishes essential reference levels like Mean Sea Level (MSL) and Chart Datum (CD).

Tide-Generating Forces I



Tide-Generating Forces II

Key Points

- Gravitational pull creates a tidal bulge on the side of Earth facing the Moon.
- Centrifugal force from the Earth-Moon system's barycenter creates a bulge on the opposite side.
- The Earth's rotation through these bulges creates diurnal or semidiurnal tide cycles.

Tidal Theories I

Several theories have been developed to explain the complex nature of tides. The Equilibrium Theory provides a foundational understanding based on idealized conditions, while the Dynamic Theory offers a more realistic model incorporating the physical constraints of the Earth's oceans.

Key Points

- Equilibrium Theory (Newton): Assumes a uniform, frictionless ocean responding instantly to gravitational forces.
- Dynamic Theory (Laplace): Accounts for ocean depth, land boundaries, and Earth's rotation (Coriolis effect).
- Amphidromic Points: Nodes in the dynamic theory where tidal amplitude is zero and tidal crests rotate around them.

Types of Tides I

Tides exhibit different patterns depending on geographic location and local bathymetry. The variations are classified by their daily frequency and the relative alignments of the Earth, Moon, and Sun, which modulate tidal amplitudes over a lunar month.

Key Points

- Semidiurnal Tides: Two high and two low tides of similar heights daily.
- Diurnal Tides: A single high and low tide each day.
- Mixed Tides: Two high and two low tides of unequal heights daily.
- Spring/Neap Tides: Maximum/minimum tidal ranges occurring during full/new moon (Spring) and quarter moons (Neap).

Ocean Currents in Harbours I

Currents are continuous, directed movements of seawater generated by various forces acting upon the mean flow. In coastal and harbour engineering, currents are critical as they influence sediment transport (causing siltation or scour), affect the navigation and maneuvering of vessels, and impact the dispersion of pollutants.

Key Points

- Directional flow of water within the ocean or coastal zones.
- Influences sediment transport, leading to siltation or scouring in shipping channels.
- Directly affects vessel navigation, berthing dynamics, and mooring line tensions.

Tidal Currents I

Tidal currents are the horizontal movement of water accompanying the vertical rise and fall of the tide. In coastal inlets, estuaries, and narrow straits, these currents can reach high velocities, making their prediction essential for safe maritime operations.

Key Points

- Flood Current: Landward flow associated with rising tides.
- Ebb Current: Seaward flow associated with falling tides.
- Slack Water: The moment of zero current velocity during tidal reversal.
- Critical for timing the transit of large vessels through restrictive harbour entrances.

Wind-Driven and Wave-Induced Currents I

Beyond tides, wind and waves are primary drivers of coastal currents. Wind-driven currents result from the shear stress of wind over the water. In the nearshore surf zone, wave-induced currents are dominant and are the primary agents for coastal erosion and littoral drift.

Key Points

- Longshore Currents: Flow parallel to the coast, driving littoral sediment transport (littoral drift).
- Rip Currents: Fast, narrow seaward return flows, hazardous but important for nearshore circulation.
- Wind-Driven Currents: Surface currents caused by persistent wind shear stress over the water body.

Summary I

A thorough understanding of wind characteristics, tides, and currents is foundational in Harbour Engineering. Wind data dictates structural orientation and wave climate. Tidal theories and types establish critical datum levels and navigable depths. Coastal currents govern sediment transport and vessel maneuverability, directly impacting harbour maintenance and operational safety.

Key Points

- Wind dictates wave climate and determines optimal harbour orientation via wind rose diagrams.
- Tides establish operational water levels and are governed by celestial gravitational forces.
- Currents (tidal, longshore) heavily influence sediment transport (dredging needs) and safe navigation.