



Designing Resilient Shorelines Through the Practice of Coastal Engineering

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DESCRIPTION

Coastal engineering is a specialized field that focuses on the planning, design, construction and management of structures and systems along coastlines. Its primary goal is to protect coastal areas from erosion, flooding and storm impacts while supporting navigation, economic activity and environmental stability. As coastal populations grow and climate related risks increase, coastal engineering has become an essential discipline for balancing human needs with the natural dynamics of the shoreline. Coasts are naturally active environments shaped by waves, tides, currents, wind and sediment movement. These forces continuously modify the shape and position of the shoreline. Coastal engineering works within this dynamic setting to reduce risks to people and infrastructure. Historically, engineering efforts focused mainly on controlling nature through hard structures designed to resist wave energy. Seawalls, revetments, groynes and breakwaters were widely constructed to defend property and harbors. While these approaches often provided immediate protection, they sometimes disrupted natural sediment transport and caused unintended erosion in nearby areas. Seawalls and revetments are among the most common coastal engineering structures. Built parallel to the shoreline, they are intended to prevent landward erosion and protect buildings and roads. Although effective in shielding what lies behind them, these structures can reflect wave energy rather than absorb it. Over time, this reflected energy may increase erosion at the base of the structure and narrow the adjacent beach. As beaches shrink, the natural buffer between the sea and land is reduced, potentially increasing long term vulnerability.

Groynes and jetties are structures built perpendicular to the shoreline to influence sediment movement. Their purpose is to trap sand moving along the coast through longshore transport, encouraging beach accumulation on one side. While this can stabilize a beach locally, it often leads to sediment starvation and erosion down the coast. This illustrates a key challenge in coastal engineering, where solving a problem in one location may create new problems elsewhere if regional processes are not fully considered. Breakwaters are typically built offshore to reduce

wave energy before it reaches the coast. By creating calmer waters behind them, breakwaters support harbor operations and encourage sediment deposition. However, they also alter wave patterns and currents, which can change natural shoreline behavior. The success of breakwaters depends heavily on careful design and an understanding of local coastal dynamics. In recent decades, coastal engineering has shifted toward softer and more environmentally integrated approaches. Beach nourishment is one such method, involving the placement of sand on eroding beaches to restore their width and protective function. Nourished beaches can absorb wave energy, reduce flooding risk and provide recreational space. Unlike hard structures, nourishment works with natural processes, though it requires repeated applications as added sand is gradually redistributed by waves and currents.

Another important trend is the incorporation of nature based solutions into coastal engineering practice. These approaches use or restore natural features such as dunes, wetlands, mangroves and coral reefs to reduce coastal hazards. Vegetated dunes can trap windblown sand and provide storm protection. Wetlands and mangroves dissipate wave energy and reduce storm surge impacts. By enhancing natural resilience, these solutions often provide multiple benefits, including habitat creation and improved water quality. Climate change presents one of the greatest challenges for coastal engineering. Rising sea levels increase the frequency of coastal flooding and accelerate erosion. Stronger storms place additional stress on existing defenses and infrastructure. Engineers must now design projects that account for uncertain future conditions rather than relying solely on historical data. Adaptive design strategies, which allow structures and systems to be modified over time, are becoming increasingly important. Human activities beyond engineering also influence coastal outcomes. Urban development, dam construction and land use changes can reduce sediment supply to the coast, undermining the effectiveness of engineering solutions. Successful coastal engineering therefore requires integrated planning that considers the entire coastal system, from river basins to offshore environments. Collaboration among

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engineers, scientists, planners and communities is essential to achieve sustainable results.

In conclusion, coastal engineering plays a critical role in protecting shorelines and supporting coastal societies. Through a combination of traditional structures, soft engineering techniques and nature based solutions, the field seeks to reduce risk while respecting the dynamic nature of coastal systems. As

environmental pressures increase, the future of coastal engineering lies in flexible, system wide approaches that work with natural processes rather than attempting to overpower them. By embracing innovation, sustainability and long term planning, coastal engineering can help create resilient coastlines that benefit both people and the environment.