Prevention of Shoreline Erosion - Coastal Defense Schemes

An Online Continuing Education Course for Engineers

Course Number: C-3013

Credit: 3 Hours / 3 PDH / 3 CPD

INTRODUCTION

Coastal structures are used in coastal defense schemes with the objective of preventing shoreline erosion and flooding of the hinterland. Other objectives include sheltering of harbor basins and harbor entrances against waves, stabilization of navigation channels at inlets, and protection of water intakes and outfalls. An overview of the various types of coastal structures and their application is given in Table 1.

a. Sea dikes

Sea dikes are onshore structures with the principal function of protecting low-lying areas against flooding. Sea dikes are usually built as a mound of fine materials like sand and clay with a gentle seaward slope in order to reduce the wave runup and the erodible effect of the waves. The surface of the dike is armored with grass, asphalt, stones, or concrete slabs.

b. Seawalls

Seawalls are onshore structures with the principal function of preventing or alleviating overtopping and flooding of the land and the structures behind due to storm surges and waves. Seawalls are built parallel to the shoreline as a reinforcement of a part of the coastal profile. Quite often seawalls are used to protect promenades, roads, and houses placed seaward of the crest edge of the natural beach profile. In these cases a seawall structure protruding from the natural beach profile must be built. Seawalls range from vertical face structures such as massive gravity concrete walls, tied walls using steel or concrete piling, and stone-filled cribwork to sloping structures with typical surfaces being reinforced concrete slabs, concrete armor units, or stone rubble.

Erosion of the beach profile landward of a seawall might be stopped or at least reduced. However, erosion of the seabed immediately in front of the structure will in most cases be enhanced due to increased wave reflection caused by the seawall. This results in a steeper seabed profile, which subsequently allows larger waves to reach the structure. As a consequence, seawalls are in danger of instability caused by erosion of the seabed at the toe of the structure, and by an increase in wave slamming, runup, and overtopping. Because of their potential vulnerability to toe scour, seawalls are often used together with some system of beach control such as groins and beach nourishment. Exceptions include cases of stable rock foreshores and cases where the potential for future erosion is limited and can be accommodated in the design of the seawall.

c. Revetments

Revetments are onshore structures with the principal function of protecting the shoreline from erosion. Revetment structures typically

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Table 1 Types and Functions of Coastal Structures

Type of Structure	Objective	Principal Function
Sea dike	Prevent or alleviate flooding by the sea of low-lying land areas	Separation of shoreline from hinterland by a high impermeable structure
Seawall	Protect land and structures from flooding and overtopping	Reinforcement of some part of the beach profile
Revetment	Protect the shoreline against erosion	Reinforcement of some part of the beach profile
Bulkhead	Retain soil and prevent sliding of the land behind	Reinforcement of the soil bank
Groin	Prevent beach erosion	Reduction of longshore transport of sediment
Detached breakwater	Prevent beach erosion	Reduction of wave heights in the lee of the structure and reduction of longshore transport of sediment
Reef breakwater	Prevent beach erosion	Reduction of wave heights at the shore
Submerged sill	Prevent beach erosion	Retard offshore movement of sediment
Beach drain	Prevent beach erosion	Accumulation of beach material on the drained portion of beach
Beach nourishment and dune construction	Prevent beach erosion and protect against flooding	Artificial infill of beach and dune material to be eroded by waves and currents in lieu of natural supply
Breakwater	Shelter harbor basins, harbor entrances, and water intakes against waves and currents	Dissipation of wave energy and/or reflection of wave energy back into the sea
Floating breakwater	Shelter harbor basins and mooring areas against short-period waves	Reduction of wave heights by reflection and attenuation
Jetty	Stabilize navigation channels at river mouths and tidal inlets	Confine streams and tidal flow. Protect against storm water and crosscurrents
Training walls	Prevent unwanted sedimentation or erosion and protect moorings against currents	Direct natural or man-made current flow by forcing water movement along the structure
Storm surge barrier	Protect estuaries against storm surges	Separation of estuary from the sea by movable locks or gates
Pipeline outfall	Transport of fluids	Gravity-based stability
Pile structure	Provide deck space for traffic, pipelines, etc., and provide mooring facilities	Transfer of deck load forces to the seabed
Scour protection	Protect coastal structures against instability caused by seabed scour	Provide resistance to erosion caused by waves and current

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consist of a cladding of stone, concrete, or asphalt to armor sloping natural shoreline profiles. In the Corps of Engineers, the functional distinction is made between seawalls and revetments for the purpose of assigning project benefits; however, in the technical literature there is often no distinction between seawalls and revetments.

d. Bulkheads

Bulkhead is the term for structures primarily intended to retain or prevent sliding of the land, whereas protecting the hinterland against flooding and wave action is of secondary importance. Bulkheads are built as soil retaining structures, and in most cases as a vertical wall anchored with tie rods. The most common application of bulkheads is in the construction of mooring facilities in harbors and marinas where exposure to wave action is minimized. Some reference literature may not make a distinction between bulkheads and seawalls.

e. Groins

Groins are built to stabilize a stretch of natural or artificially nourished beach against erosion that is due primarily to a net longshore loss of beach material. Groins function only when longshore transport occurs. Groins are narrow structures, usually straight and perpendicular to the preproject shoreline. The effect of a single groin is accretion of beach material on the updrift side and erosion on the downdrift side; both effects extend some distance from the structure. Consequently, a groin system (series of groins) results in a saw-tooth-shaped shoreline within the groin field and a differential in beach level on either side of the groins.

Groins create very complex current and wave patterns. However, a well-designed groin system can arrest or slow down the rate of longshore transport and, by building up of material in the groin bays, provide some protection of the coastline against erosion. Groins are also used to hold artificially nourished beach material, and to prevent sedimentation or accretion in a downdrift area (e.g., at an inlet) by acting as a barrier to longshore transport. Deflecting strong tidal currents away from the shoreline might be another purpose of groins.

The orientation, length, height, permeability, and spacing of the groins determine, under given natural conditions, the actual change in the shoreline and the beach level. Because of the potential for erosion of the beach downdrift of the last groin in the field, a transition section of progressively shorter groins may be provided to prevent the formation of a severe erosion area. Even so, it might be necessary to protect some part of the downdrift beach with a seawall or to nourish a portion of the eroded area with beach material from an alternative source.

Groins are occasionally constructed non-perpendicular to the shoreline, can be curved, have fishtails, or have a shore-parallel T-head at their seaward end. Also, shore-parallel spurs are provided to shelter a stretch of beach or to reduce the possibility of offshore sand

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transport by rip currents. However, such refinements, compared to the simple shape of straight perpendicular groins, are generally not deemed effective in improving the performance of the groins.

In most cases, groins are sheet-pile or rubble-mound constructions. The latter is preferably used at exposed sites because of a rubble-mound structure's ability to withstand severe wave loads and to decrease wave reflection. Moreover, the risk of scouring and formation of strong rip currents along rubble groins is reduced.

The landward end of the groins must extend to a point above the high-water line in order to stay beyond the normal zone of beach movement and thereby avoid outflanking by back scour. The groins must, for the same reason, reach seawalls when present or connect into stable back beach features. The position of the seaward end is determined such that the groin retains some proportion of the longshore transport during more severe wave conditions. This means that the groin must protrude some distance into the zone of littoral transport, the extent of which is largely determined by surf zone width. Groins can be classified as either *long* or *short*, depending on how far across the surf zone they extend. Groins that transverse the entire surf zone are considered *long*, whereas those that extend only part way across the surf zone are considered *short*. These terms are relative, since the width of the surf zone varies with water level, wave height, and beach profile. Most groins are designed to act as *short* structures during severe sea states and as *long* structures under normal conditions.

Groins might also be classified as *high* or *low*, depending on the possibility of sediment transport across the crest. Significant cost savings can be achieved by constructing groins with a variable crest elevation that follows the beach profile rather than maintaining a constant crest elevation. These groins would maintain a constant cross section and allow increasing amounts of sand to bypass as water depth increases. At some point the crest of the groin becomes submerged. *Terminal groins* extend far enough seaward to block all littoral transport, and these types of groins should never be used except in rare situations, such as where longshore transported sand would be otherwise lost into a submarine canyon.

Some cross-groin transport is beneficial for obtaining a well-distributed retaining effect along the coast. For the same reason *permeable groins,* which allow sediment to be transported through the structure, may be advantageous. Examples of permeable groins include rubble-mound structures built of rock and concrete armor units without fine material cores, and structures made of piles with some spacing. Most sheet-pile structures are impermeable. Low and permeable groins have the benefit of reduced wave reflection and less rip current formation compared with high and impermeable groins.

f. Detached breakwaters

Detached breakwaters are small, relatively short, nonshore-connected near-shore breakwaters with the principal function of reducing beach erosion. They are built parallel to the shore just seaward of the shoreline in

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shallow water depths. Multiple detached breakwaters spaced along the shoreline can provide protection to substantial shoreline frontages. The gaps between the breakwaters are in most cases on the same order of magnitude as the length of one individual structure.

Each breakwater reflects and dissipates some of the incoming wave energy, thus reducing wave heights in the lee of the structure and reducing shore er... ch material transported ... osited ... the ... nes ... lar

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... very effective ... building up beaches using ... littoral drift. Moreover, they are effective in holding artificially nourished beach material.

Optimizing detached breakwater designs is difficult when large water level variations are present, as is the case on coastlines with a large tidal range or in portions of the Great Lakes, which may experience long-term water level fluctuations.