5.6 BREAKWATERS

Breakwaters are structures constructed on coasts as part of coastal defense or to protect an anchorage from the effects of both weather and long shore drift.

• A structure protecting a shore area, harbor, anchorage or basin from wave disturbance.

• A barrier that breaks the force of waves, as before a harbor.

Breakwater types

There are several types of breakwaters, the different types can be divided into two categories. Rubble mound breakwaters which are made out of large heaps of loose elements, and monolithic breakwaters which have a cross section acting as one block, for instance a caisson.

The following breakwater types have been implemented: conventional rubble mound breakwater, caisson breakwater and the vertically composite breakwater. For each of these structures a class is defined with which a conceptual design can be made.

Conventional Rubble Mound

As mentioned in the introduction a rubble mound breakwater is made out of large heaps of loose elements, the armour layer of these types are made with either rock or concrete armour units such as Xbloc or XblocPlus. Both types of armour layer can be used to design a breakwater.

Design of breakwater with Rock as armour layer

Makes a conceptual design for a conventional rubble mound breakwater with rock as the armour layer, for one or several limit states. The following computations are performed:

- The armour layer is designed with the Van der Meer formulas for deep and shallow water (van der Meer, 1988; van Gent et al., 2003).
- The underlayer is designed by using the rules for the underlayer
- A filter layer is designed if one is needed, depends on **Dn50_core**

- The toe is designed with the toe stability formula of Van der Meer (1998).
- The crest freeboard is computed with the formula from EurOtop (2018)
- The required width of the scour protection with Sumer and Fredsoe (2000)
- If a **Soil** is specified, a slip circle analysis is performed

Composite (vertical)

The caisson type and vertical composite breakwater are included in one design class as they are basically the same structures. The main difference is the water depth immediately in front of the caisson. In this package the classification criteria from Eurotop (2018) is used, which classifies a vertical breakwater as vertical if dh>0.6dh>0.6, else the breakwater is classified as a vertically composite breakwater.

Design of (composite) vertical breakwater

Makes a conceptual design of a vertical or composite vertical breakwater, with a caisson on a rubble mound foundation. The following computations are performed:

- The necessary size of the armour layer of the foundation is designed with the modified Tanimoto formula (Takahashi, 2002).
- The required stone size for the core of the foundation
- The water depth in front of the caisson is computed based on the dimensions of the foundation and water depth
- The crest freeboard is computed with the formulae from EurOtop (2018), **vertical()** is used, which automatically classifies the breakwater so that the correct formula is used.
- The required width of the caisson is computed with the extended Goda formula (Takahasi, 2002).
- The required width of the scour protection with Sumer and Fredsoe (2000). Note that a scour protection is only added if the width of the foundation is not sufficient.
- If a Soil is specified the bearing capacity of the soil will also be checked with Brinch Hansen (1970).

Breakwaters

• Breakwaters are structures constructed on coasts as part of coastal defense or to protect an anchorage from the effects of both weather and long shore drift.

• A structure protecting a shore area, harbor, anchorage or basin from wave disturbance.

• A barrier that breaks the force of waves, as before a harbor.

• Breakwater are the structures constructed to enclose the harbours to protect them from the effect of wind generated waves by reflecting and dissipating their force or energy. Such a construction makes it possible to use the area thus enclosed as a safe anchorage for ships and to facilitate loading and unloading of water by means of wave breakers.

Need of Breakwater

• Breakwaters are built to provide shelter from waves to manipulate the littoral/sand transport conditions and thereby to trap some sand entrance inside the Anchorage Area

• A breakwater is a large pile of rocks built parallel to the shore. It is designed to block the waves and the surf. Some breakwaters are below the water's surface (a submerged breakwater).

• Breakwaters are usually built to provide calm waters for harbors and artificial marinas.

• Submerged breakwaters are built to reduce beach erosion. These may also be referred to as artificial "reefs."

• A breakwater can be offshore, underwater or connected to the land. As with groins and jetties, when the long shore current is interrupted, a breakwater will dramatically change the profile of the beach. Over time, sand will accumulate towards a breakwater. Down drift sand will erode.

• A breakwater can cause millions of dollars in beach erosion in the decades after it is built.

Types of Breakwaters

- Detached breakwater (breakwaters can completely isolated from the shore)

  Head land breakwaters

  Near shore breakwaters

- Attached breakwater (Breakwaters can be connected to the shore line)

  Low crested structure

  High crested structure

- Rubble mound structure
- Composite structure
- Using mass (caissons)
- Using a revetment slope (e.g with rock or concrete armor units)
- Emerged breakwaters
- Submerged breakwaters
- Floating breakwaters

DETACHED Breakwater

Breakwaters without any constructed connection to the shore. This type of system detached breakwaters are constructed away from the shoreline, usually a slight distance offshore .they are designed to promote beach deposition on their lee side appropriate in areas of large sediment transport

Head land breakwaters(HB)

A series of breakwaters constructed in an "Attached" fashion to the shoreline & angled in the direction of predominant waves - the shoreline behind the structures evolves into a natural "crenulate" or log spiral embayment.

Nearshore Breakwaters

Nearshore breakwaters are detached, generally shore-parallel structures that reduce the amount of wave energy reaching a protected area. They are similar to natural bars, reefs or nearshore islands that dissipate wave energy. The reduction in wave energy slows the littoral drift, produces sediment deposition and a shoreline bulge or salient feature in the sheltered area behind the breakwater. Some longshore sediment transport may continue along the coast behind the nearshore breakwater

Rubble mound breakwater

- Rubble mounds are frequently used structures.
- Rubble mound breakwater consists of armour layer, a filter layer & core.
- It is a structure, built up of core of quarry run rock overlain by one or two layers of large rocks. Armour stone or precast elements are used for outer armour layer to protect the structure against wave attack. Crown wall is constructed on top of mound to prevent or to reduce wave
- A breakwater constructed by a heterogeneous assemblage of natural rubble or undressed stone.
- When water depths are large RBW may be uneconomical in view of huge volume of rocks required.
- Built upto water depth of 50m.
- Not suitable when space is a problem. If the harbor side may have to be used for berthing of ships, the RBW with its sloping faces is no suitable for berthing.
- These type of breakwaters dissipate the incident wave energy by forcing them to break on a slope and thus do not produce appreciable reflection.

ADVANTAGES OF RMBW

- Use of natural material
- Reduces material cost
- Use of small construction equipment
- Less environmental impact
- Easy to construct

• Failure is mainly due to poor interlocking capacity between individual blocks

• Unavailability of large size natural rocks leads to artificial armour blocks.

Disadvantages of RMBW

• Needs a considerable amount of construction materials.

• Continuous maintenance is required.

• Sometimes there are difficulties in erection, as the rock weight increases with the increase of wave heights.

• Can’t be used for ship berthing

VERTICAL BREAKWATER

• A breakwater formed by the construction in a regular and systematic manner of a vertical wall of masonry concrete blocks or mass concrete, with vertical and seaward face.

• Reflect the incident waves without dissipating much wave energy.

• Wave protection in port/channel

• Protection from siltation, currents

• Tsunami protection

• Berthing facilities

• Access/transport facility

• Normally it is constructed in locations where the depth of the sea is greater than twice the design wave height.

Vertical Wall Breakwaters - Types

Conventional type

The caisson is placed on a relatively thin stone bedding. Advantage of this type is the minimum use of natural rock (in case scarce) Wave walls are generally placed on shore connected caissons (reduce overtopping)

Vertical composite type

The caisson is placed on a high rubble foundation This type is economic in deep waters, but requires substantial volumes of (small size) rock fill for foundation

Horizontal composite type

The front slope of the caisson is covered by armour units This type is used in shallow water. The mound reduces wave reflection, wave impact and wave overtopping Repair of displaced vertical breakwaters Used when a (deep) quay is required at the inside of rubble mound breakwater

Block type

This type of breakwater needs to be placed on rock sea beds or on very strong soils due to very high foundation loads and sensitivity to differential settlements

Piled breakwater with concrete wall

Piled breakwaters consist of an inclined or vertical curtain wall mounted on pile work. The type is applicable in less severe wave climates on site with weak and soft subsoils with very thick layers. Manfredonia New Port (Italy)

Sloping top

The upper part of the front slope above still water level is given a slope to reduce wave forces and improve the direction of the wave forces on the sloping front. Overtopping is larger than for a vertical wall with equal level.

Perforated front wall

The front wall is perforated by holes or slots with a wave chamber behind. Due to the dissipation of energy both the wave forces on the caisson and the wave reflection are reduced

Semi-circular caisson

Well suited for shallow water situations with intensive wave breaking Due to the dissipation of energy both the wave forces on the caisson and the wave reflection are reduced

Dual cylindrical caisson

Outer permeable and inner impermeable cylinder. Low reflection and low permeable Centre chamber and lower ring chamber fills with sand Combi-caisson

Disadvantages of vertical wall breakwaters

• Sea bottom has to be leveled and prepared for placements of large blocks or caissons.

• Foundations made of fine sand may cause erosion and settlement.

• Erosion may cause tilting or displacement of large monoliths.

• Difficult and expensive to repair.

• Building of caissons and launching or towing them into position require special land and water areas beside involvement of heavy construction equipments.

• Require form work, quality concrete, skilled labour, batching plants and floating crafts.

PARAMETERS FOR THE CONSTRUCTION OF A BREAKWATER

When a breakwater is to be built at a certain location, and the environmental impact of such a structure has already been evaluated and deemed environmentally feasible, the following parameters are required before construction can commence:

• a detailed hydrographic survey of the site;

• a geotechnical investigation of the sea bed;

• a wave height investigation or hindcasting;

• a material needs assessment; and

• the cross-sectional design of the structure.

Geotechnical investigation

A geotechnical investigation of the sea bed is required to determine the type of founding material and its extent. The results of this investigation will have a direct bearing on the type of cross-section of the breakwater. In addition, it is essential to determine what the coastline consists of, for example:

• soft or hard rock (like coral reefs or granite);

• sand (as found on beaches);

• clay (as in some mangrove areas); and

• soft to very soft clay, silt or mud (as found along some river banks, mangroves and other tidal areas).

Basic geotechnical investigations

Basic geotechnical investigations normally suffice for small or artisanal projects, especially when the project site is remote and access poor. A basic geotechnical investigation should be carried out or supervised by an experienced engineer or geologist familiar with the local soil conditions. The following activities may be carried out in a basic investigation using only portable equipment:

• retrieval of bottom sediments for laboratory analysis;

• measurement of bottom layer (loose sediment) thickness;

• approximate estimation of bearing capacity of the sea bed

The equipment required to carry out the above mentioned activities consists of :

A stable floating platform (a single canoe is not stable enough, but two canoes tied together to form a catamaran are excellent)

Diving equipment

A Van Veen bottom sampler (may be rented from a national or university laboratory)

A 20 mm diameter steel pricking rod and a water lance (a 20 mm diameter steel pipe connected to a gasoline-powered water pump).

Simply picking up samples from the sea bed with a scoop or bucket disturbs the sediment layers with the eventual loss of the finer material and is not a recommended method. The sediments thus collected should then be carefully placed in wide-necked glass jars and taken to a national or university laboratory for analysis. At least 10 kilograms of sediment are normally required by the laboratory for a proper analysis

Sometimes, a good hard bottom is overlain by a layer of loose or silty sand or mud. In most cases this layer has to be removed by dredging to expose the harder material underneath. To determine the thickness of this harder layer, a water lance is required. This consists of a length of steel tubing (the poker), sealed at the bottom end with a conical fitting and connected to a length of water hose at the top end. The water hose is connected to a small gasoline-powered water pump drawing seawater from over the side of the platform. The conical end has four 3 mm diameter holes drilled into it.

The diver simply pokes the steel tube into the sediment while water is pumped into it from above until the poker stops penetrating. The diver then measures the penetration. This method, also known as pricking, works very well in silty and muddy deposits up to 2 to 3 metres thick. It is not very effective in very coarse sand with large pebbles.