17. Explore Breakwater Alternatives

The primary objective of the breakwater is to provide the harbor with protection from wind, waves, currents, or other natural forces. Breakwaters also define the navigation channels and control the littoral processes. Evaluation of detailed site-specific design characteristics and costs enable the engineer to optimize the breakwater design.

17.10 Rubble Mound

A Rubble mound breakwater consists of a prismatic structure with sloping sides ranging from about 1.5 to 1 to 5 to 1. The rubble breakwater has a relatively impermeable central core that is protected against waves by stones or concrete armor units. Filter stone is provided between the central core and protective cover.

RUBBLE MOUND breakwaters should be considered when:

1) Wave action is substantial requiring high-energy absorption.

2) There is a breaking wave condition due to shallow water.

3) Breakwater is to be located in fairly shallow water with a solid bottom for support.

4) There is long period swell

Note 1. Periods longer than 4 seconds, wave heights greater than 4 feet, and water depths less than 30 feet are the site conditions most conducive to rubble mound structures.

Note 2. The choice between quarry stone and man-made concrete armor units depends largely on availability and cost.

Note 3. Failures of rubble-mound breakwaters due to waves are generally gradual, thereby lessening the possibility of a catastrophic incident.

Note 4. If rubble-mound breakwaters are constructed on the outside edge of an alluvial fan it is important that they are checked for global stability under seismic events.

Note 5. A tidal basin enclosed by a rubble breakwater can often be configured to provide better water quality and habitat than can be achieved with floating breakwaters and wave barriers.

REFERENCES:

1. ASCE Manual No.50. Task Committee on Marinas 2000. 1982. *Planning and Design Guidelines for Small Craft Harbors.* New York. Pg. 85-119.

2. CIRIA Special Publication 83. CUR Report 154. 1991. *Manual on the Use of Rock in Coastal and Shoreline Engineering.* Balkema, A.A.: Rotterdam/Brookfield. Pg. 7-25, 351-442.

17.11 Determine Armor Type/Weight

The selection of armor type/weight for design criteria standards is based on many factors including site-specific conditions, availability of materials, cost, and required lifetime of the structure. The choice between stone and concrete armor units (e.g., dolos, core-loc etc.) is usually determined by the height of the design wave and availability of materials.

STONE armor should be considered when:

1) Design wave conditions are relatively moderate, (less than about 15 ft).

2) Suitable rock is economically available to meet the design criteria.

CONCRETE armor should be considered when:

1) Design wave is substantial requiring greater interlocking and wave energy absorption.

2) Suitable quarried stone is not available for the rubble mound breakwater.

3) Controlling runup is a critical design criterion.

Note 1. Providing the contractor with the option of using rock or concrete may lower bid prices.

Note 2. As a rule-of-thumb, the **stone diameter** is approximately one-half the design wave height for a breaking wave when randomly placed on a 1:1.5 slope.

REFERENCES:

1. U.S. Army Corps. of Engineers, Dept. of the Army. 1984. *Shore Protection Manual.* CERC. Vicksburg, Mississippi. U.S. Government Printing Office. Vol. 1 & 2.

2. CIRIA Special Publication 83. CUR Report 154. 1991. *Manual on the Use of Rock in Coastal and Shoreline Engineering.* Rotterdam/Brookfield: Balkema, A.A. Pg.418-420.

3. ASCE Manual No.50. Task Committee on Marinas 2000. 1982. *Planning and Design Guidelines for Small Craft Harbors.* New York. Pg.136-138.

17.12 Determine Crest Height

Wave transmission, constructability, structural integrity, functional use and aesthetics all must be considered when determining the crest height. A higher crest can provide a wider platform (for any given water elevation) for shore side construction. If the crest height is lowered it may provide an improved view but may expose the harbor to overtopping of waves. The higher the crest is, the more sheltered the basin will be from winds; however, it will require a larger more costly structure.

CREST HEIGHT factors to consider include:

1) Wave conditions, (height, period, and depth of water)

2) Acceptable level of overtopping and/or transmission

3) Constructability based on equipment working from crest during high tides

3) Armor stability/lifecycle cost

5) Functional use as road access to dock or other facility

5) Aesthetics for panoramic view of open water

6) Wind Break

Note 1. On permeable structures subjected to **long period waves**, low crested breakwater heights may allow unwanted wave action in harbor due to **wave transmission.** If the core is impermeable, the wave may be transmitting through the crest. Increasing crest width may help.

REFERENCES:

1. ASCE Manual No.50. Task Committee on Marinas 2000. 1982. *Planning and Design Guidelines for Small Craft Harbors.* New York. Pg.135-136.

2. CIRIA Special Publication 83. CUR Report 154. 1991. *Manual on the Use of Rock in Coastal and Shoreline Engineering.* Balkema, A.A.: Rotterdam/Brookfield. Pg. 270-276, 351-394, 418-420.

3. U.S. Army Corps of Engineers, Dept. Of the Army. 1984. *Shore Protection Manual.* CERC. Vicksburg, Mississippi. U.S. Government Printing Office. Vol. 2. Chapter 7.

17.13 Determine Crest Width

Typically, the crest width is governed by the size of the primary armor. Other considerations include the method used to place the armor units (barge/crane or access from shore), and the functional use of the breakwater (e.g. road or crown wall on the top). By increasing the width, the rubblemound breakwater can be constructed from shore, particularly if the rock is from a local quarry.

CREST WIDTH factors that should be considered include:

1) Wave conditions, (height, period, angle of obliqueness, and local water depth)

2) Functional use

3) Construction methods and/or availability of local equipment and materials

Note 1. Crest width dimension is usually a minimum of **three armor stones** wide.

Note 2. When calculating breakwater overtopping, the **leeward side** should be designed for breaking wave impact.

REFERENCES:

1. ASCE Manual No.50. Task Committee on Marinas 2000. 1982. *Planning and Design Guidelines for Small Craft Harbors.* New York. Pg.136.

2. CIRIA Special Publication 83. CUR Report 154. 1991. *Manual on the Use of Rock in Coastal and Shoreline Engineering.* Balkema, A.A.: Rotterdam/Brookfield. Pg. 270-278, 351-394, 418-420.

3. U.S. Army Corps of Engineers, Dept. Of the Army. 1984. *Shore Protection Manual.* CERC. Vicksburg, Mississippi. U.S. Government Printing Office. Vol. 2. Chapter 7.

17.14 Determine Side Slopes

The side slopes are designed for stability given the site-specific conditions. Typically, the cost of producing quality armor rock will determine the slope angle. A more gradual slope allows use of smaller armor units, which may reduce costs and create a more stable structure. The slopes are normally not steeper than 1:1.5 and not flatter than 1:5 unless using a dynamically stable beach. The leeward slope is usually 1:1.5.

SIDE SLOPE factors that need to be considered include:

1) Wave conditions, (height, period, angle of obliqueness, and depth of water)

2) Hydraulic boundaries: tides, currents, seismic activity, sediment processes, run-up, run-down, overtopping, transmission, reflection

3) Availability of suitable local quarried stone

4) Construction methods and capacity and reach of available equipment

Note 1. A **soft foundation material** may require a more gradual slope to distribute the load.

Note 2. If the local rock produced is of good quality but smaller sizes, consider flattening the breakwater slopes to optimize use of the quarry.

Note 3. Equipment can normally drive on slopes flatter than 2.5 to 1 for placing armor and toe stone

Note 4. Slopes of 3 to 1 or flatter may begin refracting the wave. This can be used to the designers benefit for wave attenuation.

REFERENCES:

1. ASCE Manual No.50. Task Committee on Marinas 2000. 1982. *Planning and Design Guidelines for Small Craft Harbors.* New York. Pg.136.

2. CIRIA Special Publication 83. CUR Report 154. 1991. *Manual on the Use of Rock in Coastal and Shoreline Engineering.* Balkema, A.A.: Rotterdam/Brookfield. Pg. 270-278, 351-394, 418-420.

3. U.S. Army Corps of Engineers, Dept. Of the Army. 1984. *Shore Protection Manual.* CERC. Vicksburg, Mississippi. U.S. Government Printing Office. Vol. 2. Chapter 7.

17.15 Determine Layer Thickness

Wave energy is absorbed by layering several sizes of rock. A three-layer section is commonly used, but a two-layer system works well for wave heights of less than five feet. The armor layer for rock is normally about twice the thickness of the underlying filter. The layer thickness is normally two stone diameters.

LAYER THICKNESS factors that should be considered include:

1) Wave conditions, (height, period, angle of obliqueness, and depth of water)

2) Weight and grading of rock

3) Density of rock

4) Construction methods

5) Stone quality/shape

6) Breakwater slope

7) Allowable wave runup

Note 1. Clarification of **profile survey methods** and **surface definition** may be beneficial in determining slope thickness during construction.

Note 2. If a scale is used, a measure of "tons per linear foot" provides a good check on quantities. If "tons" is the measure for payment the contractor will have an incentive to key the rock more tightly than using "cubic yards in place".

Note 3. If controlling runup is critical to the design, an armor layer of 3 units thick would be beneficial.

REFERENCES:

1. ASCE Manual No.50. Task Committee on Marinas 2000. 1982. *Planning and Design Guidelines for Small Craft Harbors.* New York. Pg.137-138.

2. CIRIA Special Publication 83. CUR Report 154. 1991. *Manual on the Use of Rock in Coastal and Shoreline Engineering.* Balkema, A.A.: Rotterdam/Brookfield. Pg. 104-106, 270-278, 351-394, 418-420.

3. U.S. Army Corps of Engineers, Dept. Of the Army. 1984. *Shore Protection Manual.* CERC. Vicksburg, Mississippi. U.S. Government Printing Office. Vol. 2. Chapter 7.

17.16 Determine Toe Details

In shallow water (less than about 20 ft.) the design of the toe is subject to scour as waves break on the structure. If possible, the preferred method of design is to place a dredged trench at the toe thereby lowering the elevation at the toe. A three stone minimum width is commonly used for the toe.

TOE DETAILS that should be considered include:

1) Wave conditions (height, period, angle, depth of water, breaking, or non-breaking waves)

2) Arrangement of toe geometry

3) Construction methods

4) Weight and density of rock

5) Littoral processes and variability in thickness and composition of bed material

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Note 1. The toe may be eliminated, if the bed material is comprised of nearly the same size cobble as the rubble mound structure.

Note 2. It the bed material varies in thickness seasonally or from storm events the toe must be designed for the lowest beach elevation during the life of the structure.

Note 3. Excess "Sacrificial" toe material can be placed if toe scour is expected but pre-dredging a channel is not feasible.

Note 4. The breakwater toe should not be placed an flat or down sloping bedrock

Note 5. Placing a large breakwater toe on the inside of the basin may become a navigation hazard and should be avoided.

REFERENCES:

1. ASCE Manual No.50. Task Committee on Marinas 2000. 1982. *Planning and Design Guidelines for Small Craft Harbors.* New York. Pg. 138.

2. CIRIA Special Publication 83. CUR Report 154. 1991. *Manual on the Use of Rock in Coastal and Shoreline Engineering.* Balkema, A.A.: Rotterdam/Brookfield. Pg. 104-106, 270-278, 351-394, 418-420.

3. U.S. Army Corps of Engineers, Dept. Of the Army. 1984. *Shore Protection Manual.* CERC. Vicksburg, Mississippi. U.S. Government Printing Office. Vol. 2. Chapter 7.

17.20 Floating (Concrete, Timber, Tires, Etc.)

Floating breakwaters are generally used for harbors in low energy environments or where partial protection is already available. These structures are not suitable for open ocean applications as they have little ability to absorb longer period waves.

FLOATING breakwater should be considered if:

1) Wave conditions are minimal (wave period of less than 4 seconds).

2) Water is fairly deep (up to about 150 feet).

3) Design considerations include environmental impact.

4) Foundation for a rubble structure is poor.

5) It can serve as a heavy-duty transient dock for seasonal use

6) It is important not to interrupt natural hydraulic circulation.

Note 1. Floating breakwaters generally attenuate the waves through three processes. These include **1) Wave reflection**, (concrete box) **2)** Energy dissipation through **turbulence** (tire breakwater) and 3) disruption of **orbital wave motion** (wide shallow breakwater).

Note 2. A floating breakwater can be used in addition to a rubble mound breakwater or other structure for greater inner harbor protection.

Note 3. A floating breakwater may be designed for both **transient moorage** and wave protection.

Note 4. Floating breakwaters offer little protection for boats longer than about 60 to 80 feet

Note 4. Floating breakwaters can have a wide range of **costs** varying from log bundles, where the material may be salvaged with little to no cost, to concrete box structures that often cost more per linear foot than rubble mound structures.

REFERENCES:

1. Tobiasson, B.O. & Kollmeyer, R.C. 1991. *Marinas and Small Craft Harbors.* New York: Van Nostrand Reinhold. Pg. 187-198, 205-207, 210-211, 270.

2. ASCE Manual No.50. Task Committee on Marinas 2000. 1982. *Planning and Design Guidelines for Small Craft Harbors.* New York. Pg. 113-116, 118, 119-132.

17.30 Vertical Wave Barriers

Wave barriers can generally be categorized into two types: solid, impermeable barriers; and permeable wave boards or wave fences. Solid barriers may be constructed of sheet pile, concrete or metal cylinders, or timber piles. Permeable wave boards are usually built from wooden planks with gaps between the boards; they are designed to attenuate, but not eliminate, wave energy.

WAVE BARRIERS should be considered when:

1) Wave period is less than about 4 seconds.

2) Littoral process and barrier design meet the design criteria.

3) Barrier is subject to small tidal ranges.

4) Its' use won't reflect waves back into approach channels or onto adjacent properties.

5) It can be integrated into the design of a dock

6) Barrier is cost effective when compared to other structures.

Note 1. It is important to identify the desired wave condition inside and outside the perimeter of the harbor **early in the design stage.** Identify potential problems created by reflection, diffraction, and overtopping.

Note 2. Wave barriers may have to be designed for a higher wave (such as H1) than rubble or floating breakwaters depending on their construction

Note 3. Wave barriers should be analyzed for performance and **wave attenuation** during **low tide** conditions and **structural integrity** during **high tides**.

REFERENCES:

1. Tobiasson, B.O. & Kollmeyer, R.C. 1991. *Marinas and Small Craft Harbors.* New York: Van Nostrand Reinhold. Pg. 182-198, 205-207, 210-215, 270.

2. ASCE Manual No.50. Task Committee on Marinas 2000. 1982. *Planning and Design Guidelines for Small Craft Harbors.* New York. Pg. 56-57, 85-147.

3. U.S. Army Corps of Engineers. Dept. of the Army. 1984. *Shore Protection Manual.* CERC. Vicksburg, Mississippi. U.S. Government Printing Office. Chapter 5 & 7.

17.40 Dynamically Stable Beaches

Protecting a basin with a dynamically stable beach provides a low cost alternative that can be more in balance with natural coastal processes. Constructing with natural beaches is the direction that coastal engineering is moving but the applications can be sensitive to the site conditions.

DYNAMICALLY STABLE BEACHES should be considered when:

1) There are limited sources for large armor, but an abundant supply of coarse gravel and cobbles.

2) The waves approach the site from only one direction perpendicular to the proposed beach. (no longshore littoral transport)

3) There is a shallow offshore beach that would allow a slope of roughly 8:1 from the crest to the toe.

4) A local community chooses to construct the wave protection with limited funds.

Note 1. Although natural beaches protect most the coastlines of the world, there has been little research on how to use them for mans benefit.

Note 2. It is important that the beach has groins or jetties at both ends so that material is not lost by longshore transport or spreading.

Note 3. The slope of the beach is determined primarily by the size of material and only indirectly by the height of the wave.

Note 4. Dynamically stable beaches are particularly well suited to projects where material dredged from the basin can be used for beach material.

Note 5. Creating dynamically stable beaches follows the intent of the EPA and Army Corps of Engineers agreement for beneficial use of dredged material.

REFERENCES:

1. CIRIA Special Publication 83. CUR Report 154. 1991. *Manual on the Use of Rock in Coastal and Shoreline Engineering.* Balkema, A.A.: Rotterdam/Brookfield. Pp. 282-287.