Coastal Engineering Technical Note

SEAWALLS - THEIR APPLICATIONS AND LIMITATIONS

PURPOSE: To describe the functional applications, limitations, and the general design concepts of seawalls. This note is intended to provide a brief, general discussion of seawalls for Corps personnel who do not have a background in the functional design of coastal structures, and to provide useful information for answering inquiries from the general public concerning the construction and use of seawalls.

FUNCTIONAL APPLICATIONS: Seawalls are used to protect a backshore area against wave action. They may retain a low fill but they are intended primarily to withstand and to deflect or dissipate wave energy. A seawall is self-supporting, while a structure placed against an embankment is a revetment regardless of size. Revetments are discussed in CETN-III-9. In locations exposed mainly to low waves, sheet-pile structures may be used as seawalls; however, where seawalls are exposed to moderate to very severe waves, rubble-mound toe protection should be provided. The use of sheet-pile structures is discussed in CETN-III-7 (Bulkheads). Moderate to severe wave climates necessitate more protection by such structures as massive concrete walls, the primary subject of this Coastal Engineering Technical Note (CETN). Rubble-mound seawalls can function in the most severe wave climates. They can be designed to dissipate wave forces and absorb heavy pounding without damage. Rubble-mound structures are wide; and consequently, can be used only where sufficient land exists to accommodate them.

FUNCTIONAL LIMITATIONS: Seawalls protect only the land immediately behind them, offering no protection to fronting beaches. Also on a receding shoreline, recession will continue on the adjacent shore and may even be accelerated by the construction of a seawall. If nearby beaches were being supplied with sand by the erosion of the area protected by a new seawall, the beaches will be starved and will experience increased erosion.

Therefore, if a beach is to be retained adjacent to a seawall, additional structures may be necessary.

Seawalls generally reflect wave energy which causes increased scour immediately in front of the wall. Wave runup and overtopping of the wall may scour the backfill. Vertically-faced impermeable sheet-pile or massive concrete walls create the most reflection and produce the most damage to the fronting beach. Rubble-mound structures are more permeable and significantly less reflective, sometimes being used as wave absorbers in front of vertical bulkheads and seawalls. A seawall should be considered only for a shoreline where loss of the fronting beach is an acceptable consequence or where the seawall will be located so high on the beach that it will be exposed to waves only during extreme and rare storm surges.

STRUCTURAL ASPECTS: Most sheet-pile seawalls are structurally similar to earth-retaining sheet-pile bulkheads, although the simple cantilever type is not recommended for seawalls. The structural aspects of sheet-pile structures are discussed in CETN-III-7 (Bulkheads). Concrete seawalls are the primary subject of this CETN. The structural aspects of rubble-mound structures are thoroughly discussed in the *Shore Protection Manual* (SPM) and only briefly covered here.

1. Foundation. Generally, seawalls are gravity structures constructed of quarrystone rubble or massive concrete. They depend on their weight to resist overturning and to develop sufficient friction with the underlying soil to maintain their position. A cross section of a rubble-mound seawall is presented in Figure 1. Figure 2 illustrates features of a simple concrete gravity structure. To increase the resistance against overturning, the base of the concrete seawall is built wide and to add the effect of the weight of the backfill, the rear face is sloped. Concrete seawalls may require pile foundations, as shown in Figure 3, to support them in weak soils or to protect them against horizontal movement. All types of seawalls can be strengthened against landward movement by placing backfill against the wall's landward side.

2. Toe Protection. Erosion at the toe of the seawall may undermine the structure's foundation and cause the wall to tilt seaward. Conversely, loss of backfill will create a cavity into which the wall can tilt landward. Toe protection usually consists of a layer or layers of quarrystone large enough to not be removed by wave forces and an underlying layer of granular material

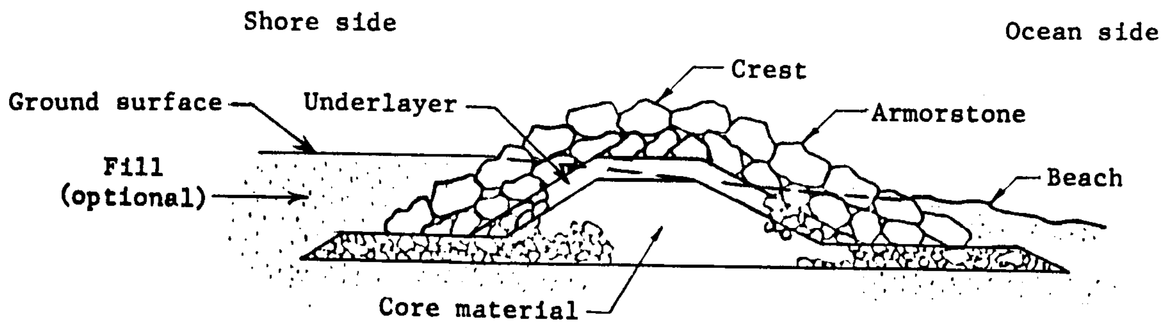

Figure 1. Rubble-Mound Seawall

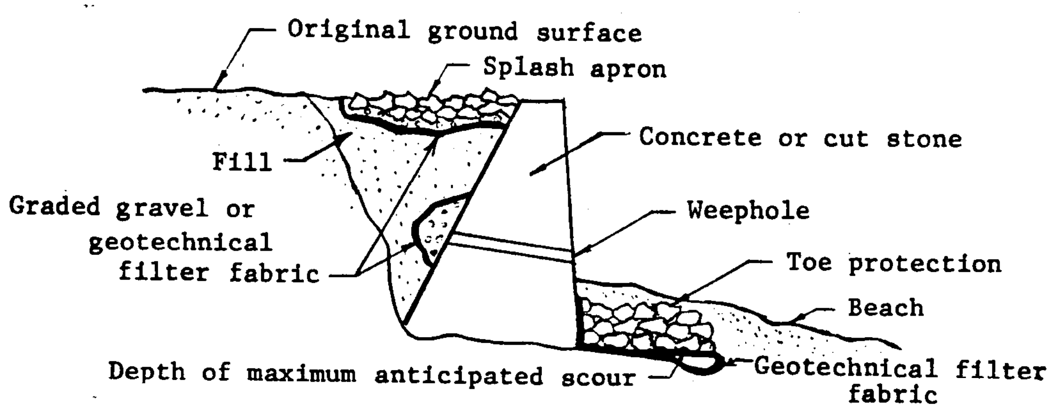

Figure 2. Concrete or Masonry Seawall

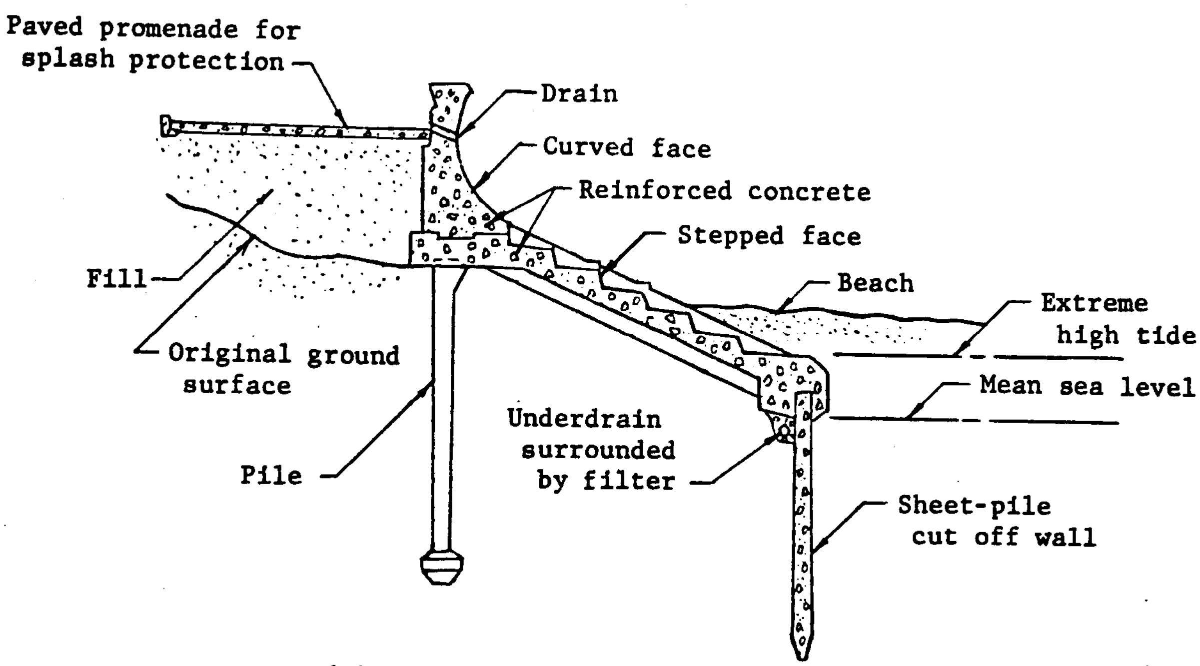

Figure 3. Reinforced Concrete Seawall with Combination Stepped and Curved Seaward Face

or geotechnical filter fabric to prevent soil from being washed through voids in the quarrystone. If the seawall is built on soft or sand soil, a sheet-pile cutoff wall, driven deep enough to prevent scour from undermining the wall, may be required at the toe as shown in Figure 3. In severe wave climates both quarrystone and cutoff wall may be required. Ground water accumulated behind the wall may create an upward hydraulic pressure or even an upward flow at the toe which may remove soil there. The cutoff wall lessens the pressure at the toe, and the quarrystone blanket and filter prevent the removal of soil. Weepholes in the seawall, as shown in Figure 2, allow ground water to flow out rather than accumulate.

3. Backfill Protection. Soil behind the seawall may be scoured by overtopping waves and by flow of ground water through joints, cracks, and holes in the structure. Loss of soil to overtopping waves can be prevented by paving the ground surface behind the wall, as shown in Figure 3, or by placing a quarrystone splash blanket there similar in design to the scour apron at the toe. Scour by ground water flow can be controlled by placing geotechnical filter fabric or a granular soil filter behind weepholes as shown in Figure 2.

4. Wave Deflecting Features. The depth and width of a seawall's base and the dimensions of the shoreward sides should be chosen to insure stability under local foundation and scour conditions, but the height of the seawall and the shape of the seaward face should be chosen to provide the desired type protection. A concrete seawall's face may be vertical, near-vertical, curved, stepped, or a combination of these. The choice of shape depends on the character of the property to be protected, the topography of the site, and the combination of extreme tide range and wave conditions. A vertical or near-vertical wall is easiest to construct, but it is also the most reflective and the most prone to overtopping. A concave curved face, with the top edge turned seaward, can deflect spray upward and seaward away from the wall to reduce overtopping. A step-faced seawall dissipates wave forces to some extent, reducing wave reflection, runup, and scour effects. For this reason, as well as for the easy access it provides, a step-faced seawall is suitable for sites with a wide fronting beach exposed to moderate wave action. Figure 3 shows a combination of two types of faces designed for sites with a large tide range. The lower part is step-faced to dissipate waves at low tide, while the upper part is curved to deflect waves at

high tide. Seawalls with shaped faces are complex structures requiring the forming of complicated reinforced concrete shapes, and generally, the placement of foundation piling.

MATERIALS: Note: Timber, steel, and concrete sheet-piles are compared in CETN-III-7 (Bulkheads). Rubble-mound seawalls are the most damage resistant and the most easily repaired; but they may require the most land area and, being the heaviest of the types, may produce foundation settlement leading to unacceptable loss of structure height. Concrete seawalls can be built in a variety of shapes to suit their function and specific site conditions; but their foundation must be designed to prevent settlement and the resulting cracking of the rigid structure. A simple structure, such as that in Figure 2, may be built of grouted cut stone; but the material and skilled masons may not be available economically. Masonry walls must be carefully founded, built, and maintained to prevent the cracking of joints, the subsequent unraveling of the stones, and the eventual loss of the supporting backfill.

DESIGN CONSIDERATIONS: Note: Design considerations for sheet-pile structures are listed in CETN-III-7 (Bulkheads).

1. If the seawall fronts a beach which cannot be sacrificed, a beach fill and additional protective structures may be necessary. If unhindered access to the beach is desired, stairs should be designed as part of the structure.

2. A seawall foundation must be adequate to prevent settlement and the resulting loss of the seawall's height and structural integrity. The bases of gravity structures may be widened to spread their load on the underlying soil, and massive concrete seawalls may be placed on foundation piles.

3. A seawall must be stable against wave forces. Resistance to wave forces can be developed by providing gravity structures with adequate weight and base width. Massive concrete seawalls may gain additional lateral support from foundation piles and any type of structure may be strengthened substantially by fill maintained against its landward side. Seawall design for wave forces is discussed in the SPM.

4. Overtopping, increased by wave reflection, may erode the area behind the seawall, negating the structure's purpose; may scour the backfill, removing support against wave forces; or may increase the weight of the

backfill by saturation, leading to structural stability problems such as overtopping, sliding and uplifting. Overtopping may be decreased by increasing the height of the seawall, by deflecting splash with a curved seaward face, or by decreasing runup with a wave-absorbing sloped face of quarrystone or concrete steps. The scour may be reduced or even eliminated by armoring the ground surface behind the seawall with quarrystone or a concrete slab, and by providing means of draining overtopped water off the surface of the slab or from beneath the quarrystone.

5. A seawall should be designed to reduce and withstand scour at its toe. Rubble-mound and step-faced concrete structures with rough, sloped seaward faces reduce wave reflection and the scour it creates. The undermining of rubble-mound and massive concrete seawalls by scour can be prevented by sheet-pile cutoff walls and/or quarrystone scour aprons placed at their toes.

6. The removal of soil at the seaward toe of the seawall, by ground water flowing under the structure and the loss of backfill by flow through it, must be eliminated. Drains in the backfill and means to control overtopping will reduce the volume of ground water at the back of the seawall; while drain holes in the seawall, backed by filter material, will allow drainage through the structure itself without loss of soil. A cutoff wall at the seawall's toe can control flow under it, and a toe protection apron can prevent the loss of soil if flow occurs.

7. The seawall must be safe against failure due to flanking. This can be prevented by tying the seawall ends to adjacent structures or turning them back into the existing upland.

MATERIAL SELECTION: Note: Material selection for sheet-pile structures is discussed in CETN-III-7 (Bulkheads).

1. Quarrystone of suitable size and structural properties for use in seawall construction is not available in all areas, but concrete is available throughout the United States. Quarrystone structures provide good habitat for marine organisms; while sheet-pile, masonry, and massive concrete seawalls provide less desirable habitat. Therefore, where available, quarrystone may be preferable to other material for those seawalls to be located in environmentally sensitive areas.

2. The construction of a rubble-mound or massive concrete seawall involves the use of a variety of heavy construction equipment and requires access to the site for the equipment. Sheet-pile seawalls and cutoff walls are built

using pile drivers which also require sufficient access and work areas. Skilled labor is necessary for construction using sheet-piles, masonry, and massive concrete. All these materials are likely to be costly.

3. Maintenance is necessary to control the spalling of concrete and cracking of masonry joints. Repairs are easier for rubble-mound structures and more difficult for grouted masonry structures.

REFERENCES:

Shore Protection Manual. 1984. 4th ed., 2 vols, U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, U.S. Government Printing Office, Washington, D.C.

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