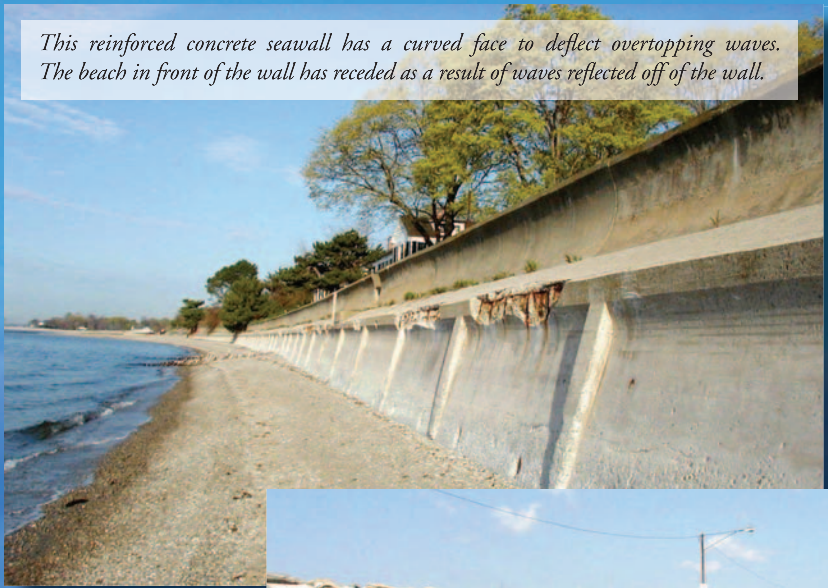
Shore Protection Structures

By Jim DeStefano & John Roberge

Shorelines are dynamic landforms. With every passing wave, and each changing tide, the profile of the shoreline changes. The sands and cobbles that make up a beach are in constant motion. On a calm day, the shoreline changes are barely perceptible, but during a storm the change can be dramatic.

Some sections of the shoreline will erode and recede with time, while others will accrete and grow. Often the changes are seasonal, with the shoreline eroding in the winter and accreting in the summer. On an undeveloped waterfront site, these natural changes to the shoreline seldom pose a problem.

When a home or building is built near a naturally eroding shoreline, an engineered solution is often sought to halt the erosion. If a shore protection structure is designed without an understanding of the wave climate and coastal processes at the site, the structure can accelerate rather than arrest erosion.



This reinforced concrete seawall has a curved face to deflect overtopping waves. The beach in front of the wall has receded as a result of waves reflected off of the wall.

This graded rip rap revetment protects a harbor entrance

This steel sheet pile bulkhead lines the shore of a small boat marina.

Seawalls

Seawalls are the most common form of shore protection structure and also the least effective. Unlike a natural beach that gently dissipates wave energy as a breaking wave rolls up the shore, the vertical face of a seawall will reflect and concentrate the energy of a breaking wave on the beach directly in front of the wall. This concentrated wave energy can rapidly erode and scour the sands in front of the wall, eventually undermining the wall's foundation.

"…the vertical face of a seawall will reflect and concentrate the energy of a breaking wave…"

On a high-energy site where significant wave activity is anticipated, stone riprap should be placed in front of the wall to protect the toe of the wall from erosion and to help dissipate wave energy.

A seawall is subjected to loads very different from an inland retaining wall. A wave breaking against the face of a seawall can exert hydrodynamic pressures in excess of 500 psf.

Seawalls need weep holes and porous backfill that can rapidly relieve unbalanced hydrostatic pressures. If a wave overtops a wall, the retained soil can become saturated. When the wave recedes, the unbalanced hydrostatic pressures will push the wall outward.

If a seawall is constructed of reinforced concrete in a saltwater environment, precautions need to be taken to protect the reinforcing from corrosion and to protect the concrete from sulfate deterioration. The use of epoxy coated reinforcing steel and micro-silica admixtures has become standard practice in waterfront structures.

Bulkheads

Bulkheads are a common type of shore protection structure. Bulkheads are constructed of either steel sheet piles or preservative treated timbers. Bulkheads are often used when deep water must be maintained up to the shoreline for boating or shipping.

Bulkheads are classified as either cantilever or anchored. Cantilever bulkheads are common when the exposed height of the bulkhead is less than 10 feet. A cantilever bulkhead relies on the embedment of the sheet piling for stability. Where a taller wall is needed, or where shallow bedrock limits the depth of sheet pile embedment, anchored bulkheads are used. Anchored bulkheads are braced by walers and tie rods secured to concrete deadmen or anchor piles positioned behind the wedge of soil retained by the bulkhead.

Bulkheads are only suitable for low-energy protected sites where large waves are not anticipated. These types of structures have very little resistance to wave action. Sheet piling can be driven with an impact hammer, but is more commonly installed with a vibratory hammer. In sandy soils, jetting is sometimes used. When steel sheet piles are used, the sheets should be coated to protect them from corrosion. Epoxy paints or hot dip galvanizing should be considered. Aluminum sheet piles are also available. Aluminum offers superior corrosion resistance, but is unable to withstand high driving stresses associated with penetrating dense soils or obstructions.

This timber bulkhead protects a low-energy shoreline.

"The armor stone must be of adequate size and gradation…"

Revetments

The most effective type of shore protection structure for a high-energy site is a sloped stone revetment. A revetment will dissipate the energy of breaking waves without reflecting them. The more irregular the stone surface is, the more effective it will be at dissipating energy. It is important to resist the urge to neatly lay flat stones to form a smooth slope. The slope of a revetment will typically have a vertical rise to horizontal run ratio between 1:4 and 1:2. In no case should a revetment be steeper than 1:1.5.

A revetment is usually constructed of at least two layers of large armor stones laid over a bed of smaller stones. The armor stone must be of adequate size and gradation to prevent individual stones from being lifted and moved by waves. Either quarry stone of uniform size or graded rip rap is used for the armor stone. The stone should be a dense, durable, crystalline stone such as granite, gneiss, or basalt.

Large toe stones should be provided at the base of a revetment to prevent scour and undermining of the slope. A filter layer consisting of geotextile and smaller stones is needed below the armor stones to prevent soil from washing out through the revetment. Where large durable stones are not available, revetments are sometimes built of precast concrete blocks. The concrete blocks do not interlock as well as stone and their smooth surfaces are less effective at dissipating wave energy.

Alternatives

Non-structural solutions for shore protection are generally preferred from an environmental standpoint.

Most shore protection structures require permits from a State environmental agency and the U.S. Army Corps of Engineers. The task of obtaining these permits can be daunting. Often a permit applicant will be required to demonstrate that non-structural solutions are not feasible before a structure is approved.

On certain sites, vegetation can be used to stabilize the shoreline. Planting dune grasses or other salt tolerant plant species that develop dense root networks can be effective at arresting or reducing erosion.

Beach nourishment involves building up a beach with sand that is either imported from off-site or hydraulically dredged from offshore. The sand particle size and gradation must be chosen carefully to prevent the new sands from eroding rapidly. Beach nourishment is usually only feasible if a significant portion of the shoreline can be nourished. This often involves the cooperation and participation of several property owners.

"…vegetation can be used to stabilize the shoreline."

When all shore protection efforts fail, as a final resort, homes and buildings can be relocated further inland and nature can be allowed to resume control of the shore.■

Penfield Lighthouse in Long Island Sound is protected by quarry stone revetments

Dune grass vegetation has been planted as a non-structural erosion control measure

John Roberge and Jim DeStefano are the principals of Coastal Engineering Partners located in Fairfield, CT.