Coastal Structures: Types, Functions and Applications

US Army Corps of Engineers
Presentation to Shoreline Erosion Task Force
August 15, 2012
Hartford, CT
Session Objectives

Coastal Structure Types & Functions: Understand fundamental concepts of coastal structures and how they provide protection.
SOFT v.s. HARD
(Erodable v.s. Nonerodable)

Beachfill
Dunes
Marshes
Bioengineered

Seawalls
Revetments
Breakwaters
Jetties
Groins
Bulkheads

geotubes are in between
What Do Coastal Structures Do?

- **Protect infrastructure** from flooding due to high water levels, erosion, and impact from waves and currents
- **Protect boat traffic** by reducing waves and wave impact
- **Stabilize navigation channels** by reducing sedimentation, inlet migration
- **Reduce erosion** by stabilizing shorelines/beaches
- **Enhance recreation, beauty**
Advantages of Hard Structures v.s. Soft

- Withstand larger forces
- Resist erosion - consider hard structures if erosion > 3 ft/yr
- Less footprint area
- Reduce renourishment needs/costs
  - Help extend available sand resources
- Function in deep water
- Transition to existing shore over short distances
- Tend to last longer
Coastal Structures
Functional Areas

1. Coastal **armoring structures** resist waves, scour, overtopping

2. Beach or soil **stabilization structures** hold upland sediment, retard alongshore transport

3. **Navigation structures** resist waves, currents, sedimentation
1. Coastal Armoring Structures

• Seawalls
  Largest
• Revetments
  Medium
• Bulkheads
  Smallest

More is more
Seawalls

- Prime objective is to protect upland infrastructure from flooding, wave impact and overtopping

- Secondary function is to hold fill (bluff, shoreline) in place

- Generally massive. Often high. Often long.

- High wave energy application

O’Shaughnessy Seawall, San Francisco, CA
Seawalls

• Often concrete
• May be rubblemound or other materials
• Tend to be free-standing with backfill, gravity or pile supported
• Scour protection integral

Galveston seawall, TX
Galveston Seawall during construction, 1905. Built following Galveston Hurricane of 1900. (image from Wikipedia)
Seawalls
Typical cross-sections
(EM1110-2-1614)
Seawalls

Waves breaking over Sea Bright NJ seawall

Curved concrete seawall La Jolla, CA

Curve directs waves away from infrastructure
Seawall
Hereford Inlet, NJ

Wall added for overtopping protection
Seawalls

When would you want major armoring?

- Very valuable upland infrastructure
- Harsh wave conditions, high surge
- Cannot provide protection further offshore, for example with an offshore breakwater
People understand flooding, but what exactly is “wave attack”? 

Wave attack is impact from waves. Water is heavy, plus waves have forward velocity. To illustrate:

1 cubic foot = 7.48 gallons

2 cubic feet = 128 pounds

1 cubic foot = 64 pounds
Rule of Thumb

Repeated impact from 3-ft waves during a storm can destroy a small house.
Heavier seawall materials can withstand wave impact

<table>
<thead>
<tr>
<th>Material</th>
<th>1 cubic foot =</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>145 pounds</td>
</tr>
<tr>
<td>Rock</td>
<td>165 pounds</td>
</tr>
<tr>
<td>Steel</td>
<td>490 pounds</td>
</tr>
<tr>
<td>Sand (dry)</td>
<td>100 pounds</td>
</tr>
</tbody>
</table>
Wave Impact on the Structure

- Waves impact the face of structure
- Overtopping also impacts the top & back of the structure
- Scour impacts the toe
What is overtopping?

Overtopping is water that splashes above and landward of the line of protection.

Lajes, Azores Breakwater (image from Jeff Melby)
What does overtopping do?

Impact from overtopping water can cause direct damage to upland infrastructure, and can remove material from behind structures, causing structure failure. Overtopped water floods behind line of protection.

ASHAROKEN 15 Mar 2010

Removes unprotected soil from behind structure, fails structure

Damage reaches to far side of roadway
Scour: loss of material at the toe

Wave form is traveling forward

But water particles go in circular paths

Structure stops forward motion of wave, reflects it back, increasing wave height

Movement water digs out sand - bottom scours

Friction from sloping bottom slows down water particles, wave steepens (may break)
Scour

- Common experience of scour – standing still at waters edge, waves dig out around your feet, you sink.

Rule of Thumb:
Scour depth will equal reflected wave height

Scour protection likely to be comparable in size to upper part of seawall
Coastal Armoring: Revetments

- Purpose is to protect the shoreline against erosion
- Function by reinforcing of part of the beach profile
- “Medium” cross-section size. Can be long.
- Generally built on existing slope
- Often rubblemound
Revetments

Materials: Rock, concrete

Layered on existing slope
How to Build a Rubblemound Structure

Digression #2:

Water

Existing Bottom
How to Build a Rubblemound Structure

1. Excavate if needed

2. Place geotextile to control loss of fines, spread load

3. Place bedding stone to smooth bottom, provide gradation
How to Build a Rubblemound Structure

Place large toe stones
How to Build a Rubblemound Structure

Place core stone
How to Build a Rubblemound Structure

Place armor stone
Revetments
Materials: Other

Gabion Revetment
Cape May Pt, NJ

Geotube® revetment
Revetments

Fort Fisher, NC before

Fort Fisher, NC after

Road protection

Photos: Williams Dennis SAW
Bulkheads

- Objective is to retain upland soil
- Function is reinforcement of the soil bank
- Steel, concrete, timber, vinyl, composite
- “small”
Bulkheads

Anchored

Anchor pile

Tie rod

Sheeting
Bulkheads
Cantilever
Bulkheads

Bulkheads: “Every homeowner for himself!”

Coney Island, 1990
Bulkheads

Timber bulkhead at Bradley Beach, NJ under direct wave attack

Rock placed at the base of the structure to prevent scour, sometimes placed to reinforce bulkhead.

Tie-back section to landside closure
Types of Coastal Structures

1. Coastal armoring structures

2. Beach or soil stabilization structures

3. Navigation structures
Beach or Soil Stabilization Structures

- Nearshore breakwaters
- Groins
- Reefs and sills (“perched beach”)
- Containment dikes
Nearshore (Detached) Breakwaters

- Purpose is to prevent shoreline erosion
- Function is reduction of wave energy in lee and reduction of longshore transport
- Parallel to shoreline
- Allow some alongshore transport
Nearshore (Detached) Breakwaters
Presque Isle, PA
Nearshore Breakwaters
Maumee Bay State Park

Lake Erie
• Purpose is to reduce beach erosion, or terminate a beach fill

• Function by trapping or slowing down longshore transport.

• Generally perpendicular to shoreline

• Designed to both hold back sand and allow transport, to reduce downdrift impacts
Groins

- Not jetties!
- Trap % of longshore transport, if transport exists
- Most effective when combined with beach fill
- Usually constructed in groups or groin fields
- Terminal groins anchor beach or limit sand into navigation channel
- Types include notched, permeable, adjustable, T/L/Y shaped
- Varied types of construction materials
Groin Geometries

(Figure: CHL Website)
Groins

Overhead view of a rock groin showing the underwater extent of the structure
Groin Field

Long Branch and Deal, NJ 1987

Allenhurst, Loch Arbour, Asbury Park, NJ 1987
Groins

Coney Island terminal groin (w/beach)
How does sand travel in water?

- Rolling along the bottom (bed load)
- Floating in the water column (suspended)
- Saltation, or hopping

Sand travels mostly between depth of closure and landward limit of flow
How does sand move past a groin?

Sand can only travel where the water flows

1. Around seaward end
2. Over
3. Through
4. Around landward end
To add permeability to a groin:

- Lower the crest
- Shorten seaward extent
- Shorten landward extend
- Use material with voids

To reduce permeability:

- Raise the crest
- Lengthen seaward extent
- Lengthen landward extend
- Eliminate voids
Reefs and Sills

- Purpose is to limit beach erosion
- Reef breakwaters function by reducing waves at the fill toe
- Submerged sills are used to slow offshore movement of sand, shorten fill profile
- Often used inside groin compartments
Reefs and Sills

Used with or without beach fill.
Double-T Units & Scour Apron
Placement of Double T Unit
“Beachsaver” Units

Patented shape®
Other Technologies

• Holmberg Beach Technologies
• Sand Rx, Sand Castle Technologies
• Beach/Dune Dewatering
Containment Dikes

- Stabilize perimeters of marshes, disposal islands

Poplar Island Restoration, Chesapeake Bay, MD
Branch Box Breakwaters
Types of Coastal Structures

- Coastal armoring structures
- Beach stabilization structures
- **Navigation structures**
Navigation Structures

- Breakwaters
- Jetties

Repair of North Jetty Yaquina, Oregon (2000)
- Smaller vessels are more affected by waves

- Larger vessels are more affected by currents

- Faster moving vessels are less at risk than slower moving vessels

- Vessels generally have to slow down and turn to enter channels
Navigation Breakwaters

- Purpose is to shelter harbor basins and entrances against waves and currents primarily for boat traffic
- Function by dissipating and reflecting wave energy

Marina del Rey, CA
Jetties
Acting as breakwaters

Source: Heidi Moritz, Portland District
Breakwaters and Jetties
Ventura Harbor, CA
Jetties

Barnegat Inlet, NJ
(new south jetty)

• Purpose is to reduce sedimentation of channels

• Shelter harbor basins and entrances against waves and currents

• Limit inlet migration
Jetties
As with groins, geometry can vary

Spur Jetties Siuslaw River, OR
Concrete units may be cost effective vs. large stone
Core-Loc units at Manasquan Inlet Jetty, NJ
Floating Breakwaters

- Purpose is to shelter harbor basins and mooring areas
- Reduce waves by reflection and breaking

Floating Breakwater RIBS System
Combination of Structures (Systems)

Chicago, 31st Beach

Submerged Breakwater
Groins
Beach fill
Revetment with walk way
Construction of first hydraulically pumped beachfill at Coney Island NY, 1922

Essayons!