Seawalls & Sloped Revetments

- **Seawalls.** Onshore structures with the principal function of preventing or alleviating overtopping and flooding of the land and the structures behind due to storm surges and waves.
  - built parallel to the shoreline as a reinforcement of a part of the coastal profile.
  - often used to protect promenades, roads, and houses placed seaward of the crest edge of the natural beach profile. In these cases a seawall structure protruding from the natural beach profile must be built.
  - range from vertical face structures (massive gravity concrete walls), tied walls (steel or concrete piling), and stone-filled cribwork to sloping structures with typical surfaces being reinforced concrete slabs, concrete armor units, or stone rubble.

- **Revetments.** Onshore structures with the principal function of protecting the shoreline from erosion.
  - typically consist of a cladding of stone, concrete, or asphalt to armor sloping natural shoreline profiles.

- In the Corps of Engineers, the functional distinction is made between seawalls and revetments for the purpose of assigning project benefits; however, in the technical literature there is often no distinction between seawalls and revetments.
Design Considerations

- **flanking effects**: Flanking is the local beach erosion near the structure corners, caused mainly by the wave diffraction phenomenon.
- **cross wave effects**: During storm surge period, the depth in front of the seawall is likely to be larger than that along the beach and wave reflection will occur. Consequently, more wave energy will be trapped in the trough between the seawall and the offshore bar causing stronger longshore current and the resulting down drift sand transport.
- **groin effects**: If the shoreline retreats due to littoral drift, the seawall will eventually protrude seaward and act like a groin. Although this groin effect does not remove sand from the system it increases downdrift erosion pressure.
- **sand supply cutoff**: Seawall prevents sand from the back shore region being added to the littoral system, thus, deprives the local sand supply. This will result in lower bar profile in front of the seawall during the storm period.
- **local scouring in front of seawall**: Local scouring at the toe of the structure is a common phenomenon caused either by a standing wave system (when the water and deep and the wave is not breaking) or by breaking waves.
Flanking

![Diagram of Flanking]

- Initial Shoreline
- Eroding Shoreline with Flanking
- Waves
- Seawall

a) Flanking Effect
Cross-Wave
Groin & Sand Supply Cut-off
Design Considerations

- **Strength and vulnerability**: Structure strength is the still the primary concern in design. The vulnerability is measured in terms of the steepness of the damage curve; the steeper the damage curve the more vulnerable the structure. Therefore, for structures with comparable costs, the selection should favor those with milder damage curves.

- **Flexibility**: This is associated with vulnerability. For earth retention structures, a certain degree of settlement is anticipated. A compliant structure that adjusts to the change is usually less vulnerable to catastrophic failures.

- **Material availability**: The availability of material becomes a major factor for large size projects. This may dictate the type of structure selected.

- **Construction**: Easy and fast construction usually translates into lower costs. Also, when construction time is a major factor, construction may dictate the selection of structural types.

- **Maintenance**: The cost of maintenance should be factored in at the design stage.

- **Durability**: The durability of material concerning physical, biological, sea water effects, sun light effects, etc. should be considered.

- **Others**: Such as environment impact, recreation value, aesthetic, other utilities, etc.
Design Procedure

1. Determine water level range
2. Determine wave heights (breaking, non-breaking, shoal from deepwater)
3. Select suitable armor & armor unit size
4. Determine runup to set the crest elevation.
5. Determine overtopping for low structures.
6. Design under-drainage features if they are required.
7. Provide for local surface runoff and overtopping runoff, and make any required provisions for other drainage facilities such as culverts and ditches.
8. Consider end conditions to avoid failure due to flanking
9. Design toe protection
10. Design filter and underlayers
11. Provide for firm compaction of all fill and backfill materials.
12. Develop cost estimate for each alternative.
Stone Revetment and Riprap

- The design practice same as for rubble mound breakwaters.
- More care should be exercised in filter design.
- Application of geotextile filter is common.
- Prevent toe scouring, piping, bank instability and other hydraulically related failure modes.
- Grading of the stone must be more tightly controlled than for breakwater design.
Run-up & Overtopping

"The wave runup level is one of the most important factors affecting the design of coastal structures because it determines the design crest level of the structure in cases where no (or only marginal) overtopping is acceptable. Examples include dikes, revetments, and breakwaters with pedestrian traffic." (CEM)
Under-layers

For graded riprap cover layers the minimum requirement for the under-layers (if one or more are required) is

\[ D_{15(cover)} \leq 5 \, D_{85(under)} \]

where

- \( D_{15(cover)} \equiv \text{diameter exceeded by the coarsest 85 percent of the riprap or under-layer on top} \)
- \( D_{85(under)} \equiv \text{diameter exceeded by the coarsest 15 percent of the under-layer or soil below} \).

For a revetment where the riprap and the underlying soil satisfy the size criterion, no under-layer is necessary.
Filter Criterion

- The size criterion for riprap is more restrictive than the general filter criterion given in Part VI-5-3b, “Granulated and geotextile filter stability.”
- The riprap criterion requires larger stone in the lower layer to prevent the material from washing through the voids in the upper layer as cover layer stones shift during wave action.
- A more conservative under-layer than required by the minimum criterion may be constructed of stone with a 50-percent size of about $W_{50}/20$.
  - larger stone will produce a more permeable under-layer
  - should reduce runup and increase interlocking between the cover layer and under-layer.
  - However, minimum criterion of $D_{15(cover)} \leq 5 \cdot D_{85(under)}$ is met.
- The under-layers should be at least three thicknesses of the $W_{50}$ stone, but never less than 0.23 m
- The thickness can be calculated using $r = 3(W_{50}/\gamma_a)^{1/3}$
- Because a revetment is placed directly on the soil or fill material of the bank it protects, a single under-layer also functions as a bedding layer or filter blanket.
1. Wave impact force
2. Wave dynamic force
3. Uprush force

1. Uplift force due to wave setup
2. Uplift force due to wave front
3. Downwash force
**Impact Loading**

\[ M = \frac{P}{4 \left( \frac{c}{4K} \right)^{1/4}} \]

\[ K = \frac{S d^3}{12(1 - \nu^2)} \]

\[ \sigma_b = \frac{M}{Z} = \frac{6M}{d^2} \]

\[ d = \frac{27 P^4 S}{16 \sigma_b^4 c(1 - \nu^2)^{1/5}} \]

\[ P = p \times b = 12pgH_s \tan \theta(0.4H_s) \]

**Uplift Pressure**

\[ \Lambda = \sqrt{\frac{K_F bd}{K_r}} \sin \theta \]

\[ \frac{H_s}{\Delta d} = K_c \left[ \frac{d}{\Lambda \xi} \right]^{0.67} \]
Impervious Revetments

The common damage modes of impervious revetments, such as asphalt, are

• buckling, sliding and floating under hydrostatic pressure,

• fracture under impact loading,

• piping of underlying material and subsequent collapsing.
Geotextile Design Considerations

Once the geotextile pore size requirement is determined, a number of potential problem areas should be examined that include the potential of blocking, clogging, pumping and piping. Unfortunately, none of the above can be predicted quantitatively at present.

- **Blocking** is a phenomenon where large particles seal the openings in the textile. In this case, the permeability of the filter can decrease dramatically causing pressure build-up and eventual separation of the textile layer from the base material. Geotextile is found to be susceptible to blocking when the base material is rather uniform and the ratio of d to D90 in the order of unity.

- **Clogging** is the trapping of very fine particles in the openings of the textile, also leading to a decrease of permeability and an increase in the pressure gradient. Clogging may result when water is contaminated with chemicals such as iron or detergent or other agents that tend to bind fine particles to the cloth.

- **Pumping** occurs when erodible soil in contact with free water is subject to cyclic loading, such as breaking waves. The cyclic loading acts like a pump that forces the erodible material through the filter and results in the progressive loss of bank material. The potential for pumping cannot be established through experiments. A remedial for reducing the pumping hazard is to slightly increase the textile pore size. If pumping persists, geotextile may not be suitable for the specific application and granular type of filters should be considered.

- **Piping** is the loss of bank material from underneath the toe of the filter. The potential for piping can be analyzed by such techniques as flow nets or an equivalent that produces the equal potential lines in the soil. End structures are usually installed to increase soil resistance and prevent piping. The types of end structures will be shown later.
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<thead>
<tr>
<th>COMPARATIVE PROPERTIES</th>
<th>TYPES OF POLYMER</th>
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<tbody>
<tr>
<td></td>
<td>Polyester</td>
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<td>Strength</td>
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<td>Elastic modulus</td>
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<td>Strain at failure</td>
<td>M</td>
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<td>Creep</td>
<td>L</td>
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<td>Detergents</td>
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H = High, M = Medium, L = Low
(A) Fabric sections being sewn together

(B) Fabric being pinned in place

(c) In situ heat welding operation
Armoflex blocks and mat construction

Terrafix interlocking blocks
(A) Interlocking concrete grids serve as base for plants
(B) Salt water resistance grass planted on top