FLORIDA SEA GRANT PROGRAM

SEAWALL AND REVETMENT EFFECTIVENESS, COST AND CONSTRUCTION

by COURTLAND A. COLLIER

Jointly Sponsored By

State of Florida
Department of Natural Resources

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Marine Research · Education · Advisory Services
A Sea Grant Program for Florida

As a companion to this report, a Florida Sea Grant publication concerning the use of vegetation in protecting and restoring dunes is in progress. Together these two reports are intended as complimentary approaches to the stabilization of Florida's shoreline.

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SEAWALL AND REVETMENT EFFECTIVENESS, COST AND CONSTRUCTION

Courtland A. Collier

INTRODUCTION

This publication is designed to give owners of waterfront property an easily understood reference guide explaining the types of shore protection structures that are commonly available and the relative merits and costs of each. A section is also included on permitting procedures to aid in understanding the pertinent government regulations and jurisdictions.

FLORIDA'S SHORELINE

Florida has 8,426 miles of tidal shoreline, the longest of the 48 contiguous states. The value of Florida's shoreline, that desirable area where land and sea meet, has increased rapidly in recent years as various interest groups compete for the right to develop or use the rapidly dwindling supply of undeveloped shore. Developers find the shoreline well suited for residential, commercial, or industrial development while citizen groups seek to reserve key portions of the shore for public use or preservation in its natural state. Instances are common of fifty foot lots on the ocean, miles from the nearest town, that sold for $40 to $50 a front foot in 1960, and about $200 a foot in 1970, and are now selling for over $400 a foot in the mid-seventies. Thus, as the value of shore property increases, the protection of the shoreline becomes proportionately more important.

SHORELINE STABILITY

The shoreline of Florida, whether sandy beach, marsh, or rock, responds to nature's forces of wind, waves, currents, and tides. The result is a shoreline that constantly changes. These changes are part of a natural process that has been occurring since the shoreline was first created and are caused primarily by the forces of moving water and air transporting particles of soil from place to place. As the velocity of the water or air increases, more and larger grains of sand or earth are carried from, or parallel to the shoreline. For instance, on Florida's sandy beaches the high energy winter waves and currents usually wash more sand off the beaches and dunes than into them and depletion and erosion occurs.

Milder summer swells normally wash more sand toward the beaches resulting in replenishment and buildup of sand. The summer shoreline in Florida is typically from 10 to 40 feet seaward of the winter shoreline (Ref.1). As the beach sand dries, an onshore wind may carry the grains to dunes which serve as natural reservoirs of sand. The grains accumulate at the dunes as they reach a steep windward slope or the sheltered lee. If the summer wind velocity is not sufficient to carry the grains beyond the obstacle, they remain there until winter storms bring higher waves or wind attacking the built-up sand dunes, further transporting the migrating grains either back into the sea or to some other land location. If the dunes are removed by man, the wind or wave forces attack whatever replaces the dunes, often resulting in severe property damage of man-made construction.

Since all shorelines are in a state of constant change, a "stable" beach is one that maintains a reasonable balance between periods of erosion and replenishment. Sand moves not only between the beach and sea but also is carried by waves and currents parallel to the beach in a process called littoral drift. Sand grains removed from one beach by wave backwash are carried to another beach up or down shore. In the case of Florida's east coast the prevailing winds and currents carry most of this off-shore sand toward the south. From the Georgia border to Palm Beach as much as 300,000 to 500,000 cubic yards pass down the coast every year through littoral drift.

The predominant drift on Florida's lower Gulf Coast is also southward, with local exceptions around some inlets, and amounts to about 50,000 to 100,000 cubic yards per year. On Florida's upper Gulf Coast the littoral drift is mostly westward at about 100,000 to 200,000 cubic yards per year.

Erosion and accretion also affect shorelines composed of other materials. In many parts of Florida marshy shorelines exist, such as along the shores of the Everglades, and along the Gulf Coast from Crystal River to the Apalachicola. Vegetation along these shorelines acts to reduce erosion. The root system of plants provides some anchorage to the soil and protection against erosion by wind and waves. Where mangrove trees grow along the shoreline, their intertwining underwater root systems typically serve as collection areas for migrating sand, soil particles, and debris. Over a period of years considerable accretion may occur and cause the resulting land area to extend gradually outward into what was once part of the sea.

Natural shorelines composed of rock resist erosion forces quite well. Even these areas, however, do not have a permanent shoreline. The continuous battering of waves and tidal movements gradually take their toll, although the changes from year to year are hardly noticeable.

In areas where natural offshore reefs, bars, or shoals occur, erosion producing wave forces may be weakened significantly. Where the water depth to the bottom is shallow enough, the coral reefs, sand bars, or other underwater ridges act as barrier reefs causing the waves to break offshore and dissipate their energy before reaching the shore. Shore erosion is thus reduced or prevented by the action of natural subsurface energy dissipators.

In summary, a number of forces affect shoreline stability. Most of the natural changes in shoreline are slow and require a period of time to become noticeable. Man-made structures near the shore make these changes more apparent by establishing reference points of some value. Each year as the sea moves closer to the structure, the owner becomes understandably concerned over potential losses due to beach erosion. In the past the construction of these structures frequently involved removal of the dunes which were the shoreline's natural defense system, thereby accelerating the erosion and ultimate destruction of the man-made improvement.

DESIGN CRITERIA FOR HARDENING THE SHORELINE

Where existing shorelines are subject to erosion or are otherwise unsuitable in their existing condition, the problem area of the shore may be stabilized by construction of a hardened lining, such as a seawall, revetment, or bulkhead.

1. Objective

Hardened shore protection structures are typically designed to meet one or more of the following objectives:

A. Protect artificially filled land areas that extend seaward from the existing shore.
B. Save an eroding shoreline or protect one that is subject to erosion under adverse weather conditions.
C. Maintain a boat landing or stable shore next to deep water, as at a dock or at a ship channel traversed by a short bridge.

2. Limitations

These hardened shore protection structures typically protect only the land directly behind them. Usually they will not protect the shore in areas immediately up or down the shoreline or the beach seaward of them. When such structures are built on an eroding shoreline, erosion will normally continue on adjoining shores. In addition the loss of materials immediately in front of the protection structure frequently accelerates since the structure tends to concentrate the wave energy in a more confined area.

3. Placement and Size

A. Location

Wherever a bulkhead law is enforced, the structure can be located no further seaward than the officially designed bulkhead line. When located landward of a beach, it should usually be viewed as a line of last defense from the sea and located as close as practical to the improvement it is supposed to protect. This is because many hardened structures aggravate rather than relieve the erosion problem if the waves reach them.

B. Length of Hardened Protection

Since the hardened structure usually protects no more than the land behind it, it should extend the full length of the property to be protected. In addition, wing walls should be carried a reasonable distance inland, since the abutting property is subject to erosion and the water may come in behind the frontal structure.

C. Height of Hardened Protection

The elevation of maximum wave run up at any given location is a function of water depth, tide, slope of sea bottom, fetch, barometric pressure, wind velocity, and shape of the seawall face. Consultants specializing in this field should be engaged to determine the characteristics of each location.

D. Depth of Hardened Protection

Hardened structures must be protected against scour caused by the downward component of wave energy encountering the face. As a rule of thumb (Ref. 4, p. 213), the maximum depth of scour may be approximated as 0.8 of the water depth to the natural sea bed. For example, if the controlling depth of the water at the face of the structure is 10 feet, scour might occur under heavy wave action down to a depth of 8 feet below the natural sea bed, or 18 feet below the design high water surface.

4. Materials for Seawalls and Revetments

In selection of materials for waterfront protection structures, the warm moist marine atmosphere of Florida must be taken into consideration.

A. Concrete

A rich stiff concrete mix properly placed and vibrated at the time of construction will produce a finished concrete structure less permeable to water. The Portland Cement Association recommends a water/cement ratio of 0.44 to 0.40 which corresponds to between 6-1/2 and 10 sacks of cement per cubic yard depending on other factors. Three inches or more of dense concrete cover is recommended over all reinforcing steel to provide protection against corrosion in warm marine environments (Ref. 5).

B. Steel

When exposed to warm moist atmosphere of marine environment, steel corrodes and gradually loses cross section. The greatest loss occurs in the splash zone between mean high tide and the upper limit of wave contact.

For example, Figure 1 shows steel sheet piling extracted after about 12 years of service at Boynton Inlet near Palm Beach. Close inspection reveals that portions embedded in the sea bottom show some loss, while the areas exposed to the spray zone have severely deteriorated. The sheet piles carry the remains of a bitumen coating applied at the time of installation.

If the abrasive action of sand and water is allowed to continually expose fresh steel, the pile life may be less than 10 years. Therefore coatings of plastic, bitumin, concrete, or others are recommended from the sea bottom line to the top of the pile in order to retard corrosion. Electrical cathodic protection is also effective in some cases. If the rust is left undisturbed and the steel is made of a chemical composition resistant to marine environments, and is of sufficient thickness, the life may extend to 35 years and more without additional protection (Ref. 4, p. 351). Several manufacturers have introduced steel sheet piling designed

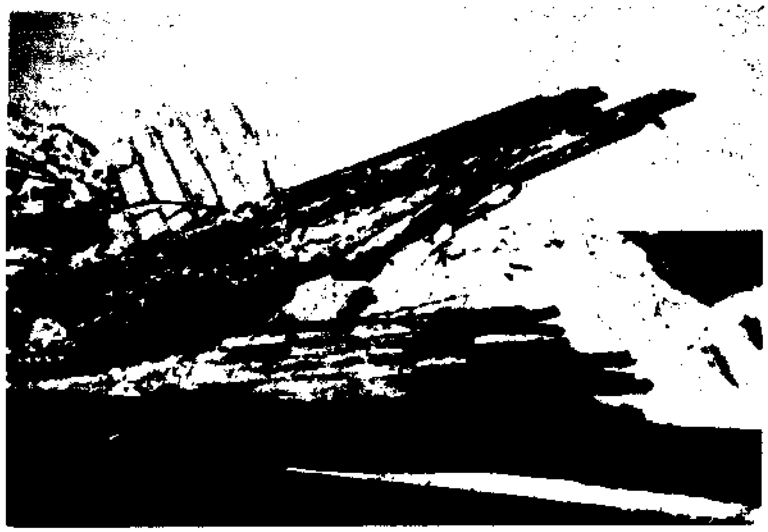


Fig. 1. Steel sheet pile corrosion after 12 years service

especially for use in marine environments. Tests by one manufacturer indicate the thickness of steel remaining after nine years' exposure is approximately double that of conventional A-328 steel piling (Ref. 6).

C. Timber

If properly designed and installed, timber can prove quite durable in a marine environment (Fig. 2). Timber piles over 1000 years old have been found in good condition under the streets of Venice, Italy.

In a warm marine environment, timber is subject to attack in three forms: (i) decay and rot, (ii) insects, and (iii) marine borers.

(i) Decay is caused by a low form of plant life called fungi. In order to grow, fungi require moisture, air, favorable temperatures, and food. The moisture condition must be damp, but too much or too little water will kill the fungi. Air is available to depths of 2 or 3 feet below ground surface in sufficient quantities to support the fungi. Fungi will not grow in very high or very low temperatures but thrive on moderate to warm temperatures. Wood provides the food for the fungi, which usually find the best combination of moisture, air, temperature, and food in the zone from 3 feet below the ground surface to a few inches above ground. Protection consists of poisoning the food supply with a good penetrating wood preservative.

(ii) The three principal insect types that attack wood are subterranean termites, dry wood termites, and wharf borers. The subterranean termite requires contact with the ground and moisture to sustain life. The dry wood termite flies and does not require moisture and is more frequently found above ground level. Wharf borers do not live below water level but prefer timber not far above high water or timber subject to periodic salt spray. Protection from insects consists of impregnation by a suitable toxic agent.

(iii) Marine borers consist of several hundred species of invertebrates divided into two groups, the Molluscan group and the Crustacean group (Figs. 3 and 4). The Molluscans, including the teredo or ship worm, enter the timber through minute holes and destroy the interior of the timber member without visible disturbance to the outer surface. The Crustaceans, including the limnoria, destroy the outside of the timber and leave easily seen gaps in the surface of the timber. Protection from the marine borers consists of impregnation with a creosote-coal tar solution and/or casing the timber between the mud line and the maximum high tide line with a protection coating of material impermeable to the borers (Ref. 7).

As an example of damage inflicted by the teredo in Florida, a temporary work trestle consisting of 450 untreated pine piles was constructed at Ponce de Leon Inlet midway down Florida's east coast in 1968. Within three months the teredo infestation rendered the trestle unsafe for work and it was removed (Ref. 8).

Fig. 2. A wooden bulkhead installed in 1928, still in good condition after 46 years of service, just south of Boynton Inlet in Palm Beach

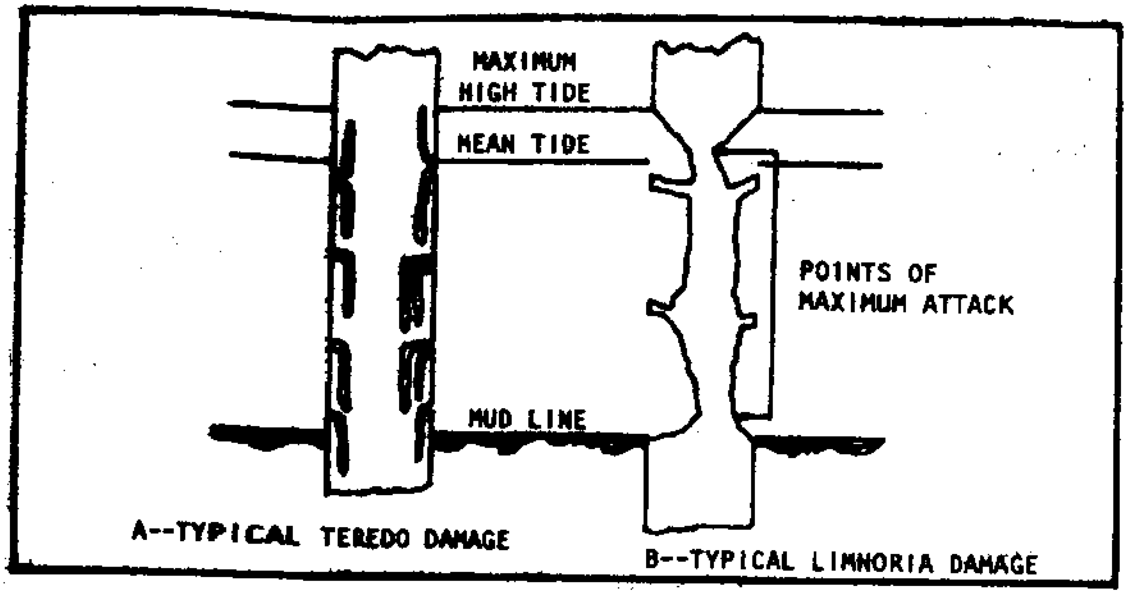


Fig. 3. Typical pile damage by marine borers

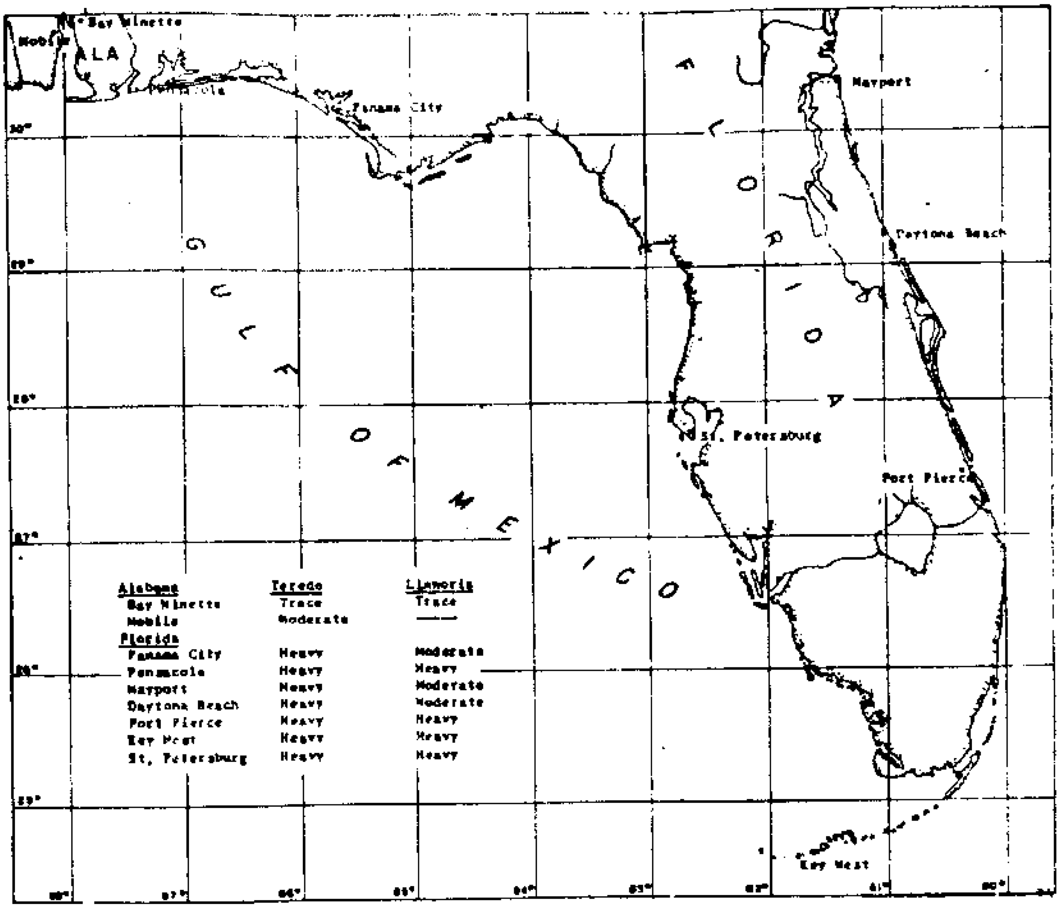
D. Combinations

Since timber is more durable below the sea bottom, some successful installations have used combinations of wood below the bottom with concrete tops forming a combination piling.

E. Stones

Angular stones provide interlock and are less likely to move under wave action than rounded surfaces. Stones used in marine structures should resist weathering and disintegration under normal conditions of use. Stones with higher density (specific gravity) are preferred if a choice is available. Revetments constructed of rock, rubble, or similar units have the advantage of free articulation. If the revetment should move or settle, these units are free to move and adjust with it and lose little of their effectiveness. Repairs are usually simple and inexpensive--just add more rocks or other units.

Several types of native rock are available in Florida. In the St. Augustine area, coquina rock has been quarried for over 400 years and used in a variety of structures from fortress walls to decorative fire places. Coquina rock has proved durable for marine installations and was recently used for constructing a groin at Marineland on Florida's Atlantic Coast. Present sources of supply are said to be almost exhausted, however, and new quarries have yet to be uncovered. The current price is $16 to $40 per ton in the quarry plus about $6 to $8 per ton for hauling and placing.



Alabama	Teredo	Limnoria
Bay Minette	Trace	Trace
Mobile	Moderate	——
Florida		
Panama City	Heavy	Moderate
Pensacola	Heavy	Heavy
Mayport	Heavy	Moderate
Daytona Beach	Heavy	Moderate
Port Pierce	Heavy	Heavy
Key West	Heavy	Heavy
St. Petersburg	Heavy	Heavy

Fig. 4. Areas of Infestation by marine borers in Florida

In the Tampa area, native limestone is sometimes available. When limestone is being mined for road base material, cherty boulders too hard for the crusher are set aside for use in revetments. Recently a jetty at Clearwater was constructed of this material at a cost of about $21 to $24 per ton. The supply of this material is limited.

Hard igneous rock is not available in peninsular Florida in commercial quantities, so it must be hauled in from out-of-state. On a recent revetment at Sebastian Inlet (about midway down Florida's east coast), rock was hauled by rail from Birmingham, Alabama. It then had to be reloaded into trucks and hauled 12 miles from the nearest railroad siding to the job site.

Current 1974 costs for large igneous rocks suitable for revetments is about $8 to $9 per ton FOB the destination siding. Costs of reloading, hauling by truck, and placing at the job site must be added and may result in costs of $25 per ton or higher in places (Ref. 9).

5. Information for Design of Waterfront Structures

A. "Shore Protection and Design," Tech. Report No. 4, 3rd Ed., U. S. Army Coastal Engineering Research Center, 1966 (no longer in print, but available at many libraries).

B. "Shore Protection Manual, Vols. 1, 2, & 3," U. S. Army Coastal Engineering Research Center, Superintendent of Documents, Washington, D.C. 20402, 1973 (replaces Tech. Report No. 4).

C. "Anchored Bulkhead Design by Numerical Method," F. E. Richart, Jr., Vol. XIV, No. 8, Florida Engineering and Industrial Experiment Station, University of Florida, Gainesville, Florida 32611, August 1960.

D. Design and Construction of Ports and Marine Structures, Chapter 4, Alonzo De F. Quinn, McGraw-Hill, 1961.

E. Port Engineering, Chapter 3, "Planning and Layout of Ports: Breakwaters, Jetties and Piers," Per Bruun, Gulf Publishing Company, 1973.

F. "Proceedings of the Twelfth Coastal Engineering Conference," 1970 (several papers).

G. "Proceedings of the Thirteenth International Conference on Coastal Engineering," 1972 (several papers).

H. "Woven Plastic Cloth Filters for Stone Seawalls," by James W. Dunham and Robert J. Barrett, Vol. 100, No. WW1, Feb. 1974, Proceedings, American Society of Civil Engineers, 345 E. 47 St., New York, N.Y. 10017.

SEAWALLS, SLAB AND SHEET PILE WITH ANCHORED TIE-BACKS

Both seawalls and bulkheads are referred to as seawalls in this publication to avoid the confusion of overlapping nomenclature. There are two basic types of seawalls. The most widely used consists of a vertical face of either precast concrete slabs (Fig. 5) or steel sheet piles (Figs. 6 & 7) driven into the sea bottom to secure the toe. The top is secured by anchor rods connecting the wall to anchors placed back a safe distance landward. The second type consists of massive free-standing gravity structures with curved, vertical or inclined faces designed to withstand the full force of the oncoming waves.

1. Precast Concrete Slab Seawall

Hardened shore protection with a vertical seaward face may be installed in a relatively short time by using precast concrete slabs jetted into place or driven with a vibratory or impact hammer (Fig. 5). A concrete cap is usually cast on top of the slabs to serve both as a structural tie and to improve the finished appearance. Tie-backs are usually needed to prevent the wall from tipping seaward. Also, adequate penetration of the piles or slabs into the sea bottom is necessary to prevent the toe from sliding seaward. If wave action occurs against the vertical face, scour erosion at the toe of the wall may be expected. The wave energy breaking against the vertical face is deflected both upward and downward. The downward component of the deflected wave scours the sea bottom at the toe of the wall. Hardened toe protection may be required to prevent toe failure.

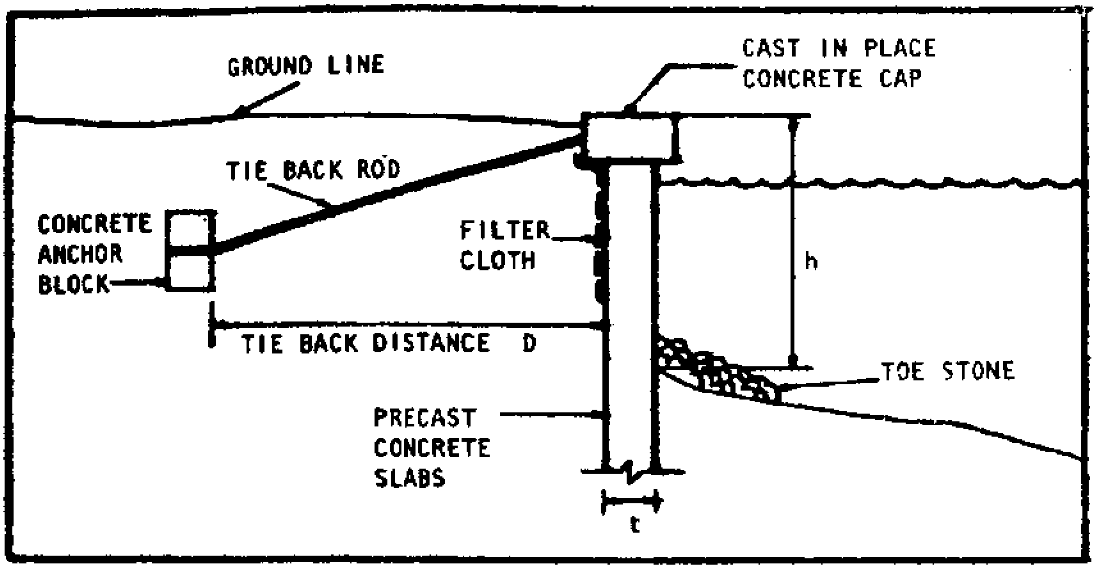


Fig. 5. Typical dimensions of precast concrete seawalls for protected waters

Description	Design depth of water at seawall For protected waters only (for exposed locations consult professional design engineers.) 1' to 1.5'	3'	4'
Dimensions Height, h	4.5' to 5.5'	6.5'	7' to 8'
Slab piling length Slab thickness t	10' to 12' 5 1/2"	14' 7"	16' to 18' 8"
Cap size * Tie back rod diameter Tie back distance D Distance between anchor rods	10" x 16" 1" 12' to 14' 10'	12" x 18" 1 1/8" 16' 12'	16" x 20" 1 1/4" 20' 12'
Anchor block size Seawall installed cost *** $/lineal foot (without toe stone)	12"x18"x3'8" $30	12"x18'x5' $50	12"x24"x5' $80
** Toe stone, tons/lineal ft. *** Toe stone, $/lineal ft.	0.5 $13	1 $25	1.5 to 2 $38 to $50

* Tie back rods should be heavily coated or wrapped to resist erosion.
** Toe stone protection is normally required wherever wave action is expected.
*** Costs are 7/74, Tampa, for quantities of 1000 l.f. or over. (Ref. 9)

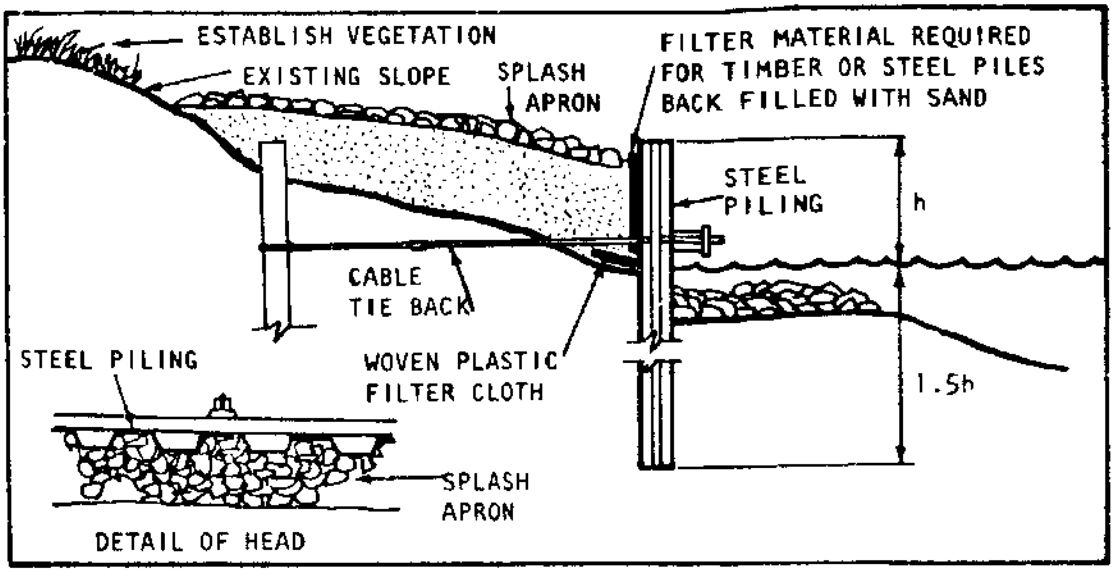


Fig. 6. Steel sheet pile seawall

A steel bulkhead serves to armor the bank. The face must be designed to absorb all wave energy. Severe scour occurs at the bulkhead line. The sheeting depends upon penetration and tie backs for its stability. The structural design of sheet piling is highly specialized and not subject to standard plans. For this reason the service of a qualified engineer is essential. Key design considerations are foundation conditions, penetration of the piling, height and alignment, and scour protection. Sufficient access must be available for pile driving equipment.

Piles should be carefully located as shown on the drawings and driven in a plumb position, each pile interlocked with adjoining piles for its entire length, so as to form a continuous diaphragm, throughout the length of each run of wall. The contractor should drive all piles as true to lines as practicable and should provide suitable temporary wales or guide structures to insure that the piles are driven in correct alignment.

Continued

Fig. 6, Continued

Description	Design depth of water 50' offshore (ft.)		
	3 - 4	5 - 6	7 - 8
Dimensions			
Height (h)	5	8	10
Piling length	13	20	25
Toe protection apron length	2 x 2	4 x 4	5 x 5
List of Materials (per ft.)			
Steel Pile (ft.)	13	20	25
Waler (ft.)	1	1	1
Fill material (yds.)	.9	2.0	3.0
Toe protection (yds.)	.15	.60	.95
Cost $/lin.ft.	220	280	330

(Ref. 10)

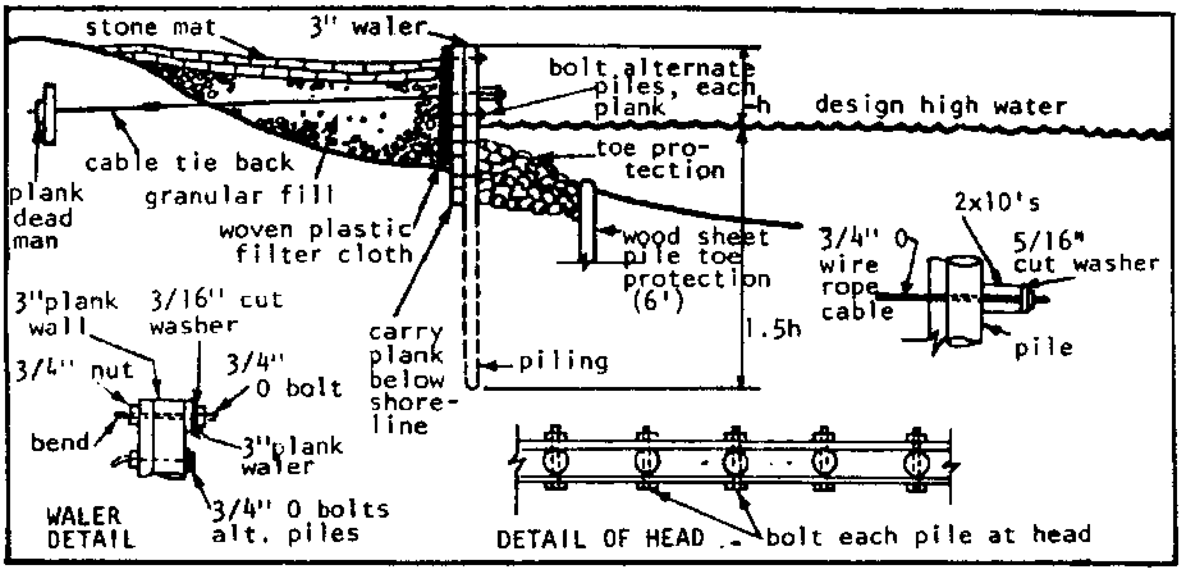


Fig. 7. Wood sheet pile seawall

Timber walls are constructed of plank sheeting with round piles. They consist of two rows of 3-inch plank sheeting and a row of round piling with heavy horizontal walls between the planks and the piling. They must be tied back to anchor piling. The most common cause of failure of sea walls is undermining of material from the bottom of the toe of the structure, resulting in inadequate penetration of piling. The pressure of the soil and water on the back side can then tip the sturcture. The tie-backs provide additional strength to resist this force. Timber bulkheads also require positive toe protection.

The piling and sheeting are driven with the aid of a jet from a small pump. The use of this design is controlled by subsurface foundation conditions. It is suitable for sand or sand and gravel shores where the sand deposit is 12-15 feet below the bottom. Wooden structures must be securely fastened together with bolts.

Continued

Fig. 7, Continued

Description	Design depth of water 50' offshore (ft.)		
	3 - 4	5 - 6	7 - 8
Dimensions			
Height (ft.)	5	8	10
Diameter of Piles (in.)	6	8	10
Pile Length (ft.)	13	20	25
Wall plank thickness (in.)	3	3	3
Toe protection wt (lbs.)	70	140	200
List of Materials (per ft.)			
Piling	5.3	8.0	9.3
Waler	1	1	1
Wall Plank (s.f.)	6	9	11
Filter Blanket (s.f.)	9	12	16
Toe Stone (c.y.)	.33	.7	.95
Fill Material (c.y.)	.9	2.0	3.0
Cost $/lin.ft.	60	80	120

4. Guidelines for Construction and Maintenance of Seawalls (Ref. 10)

RULE 1

PROVIDE ADEQUATE TOE PENETRATION AND PROTECTION FOR THE TOP OF THE STRUCTURE SO THAT IT WILL NOT BE UNDERMINED.

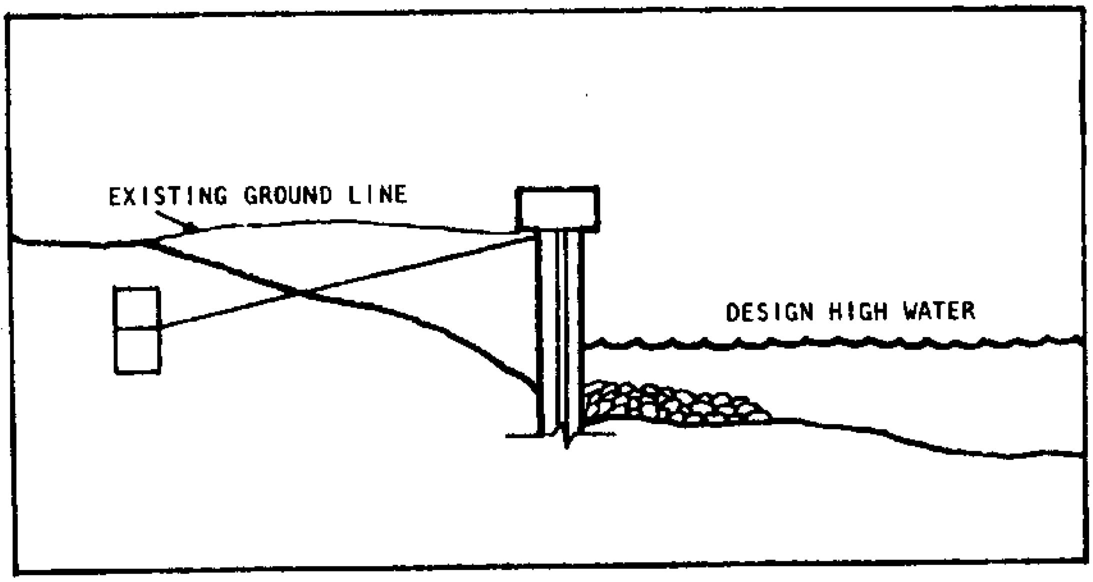


Fig. 8. Adequate toe penetration needed

CHECK FOR SIGNS OF FAILURE

Most failures of shore protection works results from "toe failure", or erosion under the lowest part of the structure. Failure of the bulkhead can be prevented with adequate toe protection. Toe protection must be substantial enough to prevent the original ground under it from washing through the toe protection blanket, and extend far enough seaward of the structure to prevent undermining. Check for signs of failure such as seaward movement of the wall, erosion behind or at the toe, or at the end of the structure.

RULE 1 Continued

RULE 1 Continued

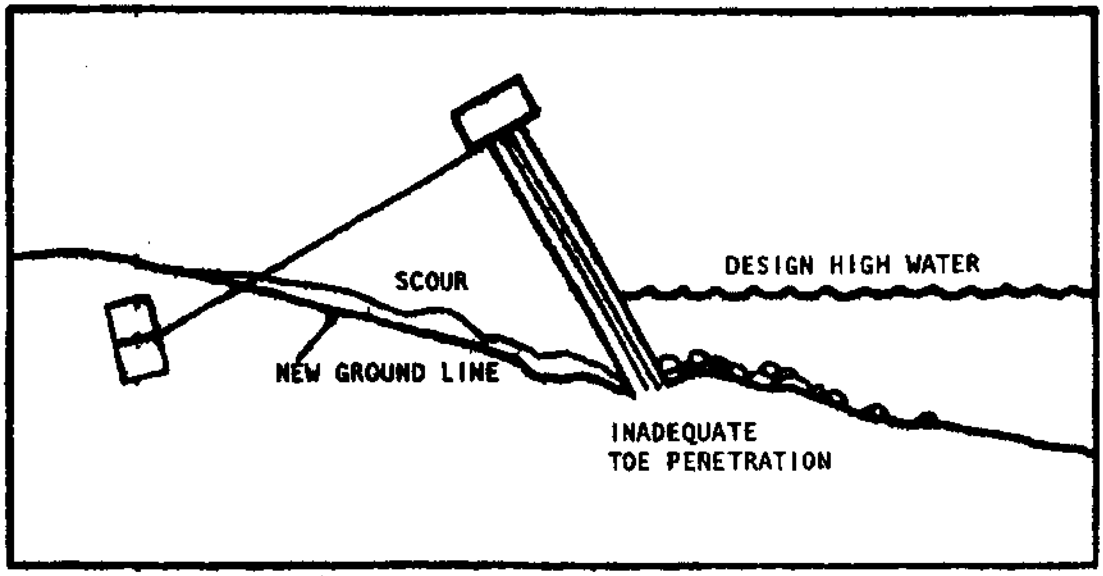


Fig. 9. Failure due to inadequate toe penetration

MAINTENANCE OR REPAIR PROCEDURE

Re-establish support by underpinning, tie backs systems of anchor piling, walers and tie rods. Place larger stone or rock-filled mattress at toe of structure to prevent scour. Backfill where necessary.

RULE 2
PROVIDE ADEQUATE ANCHORAGE

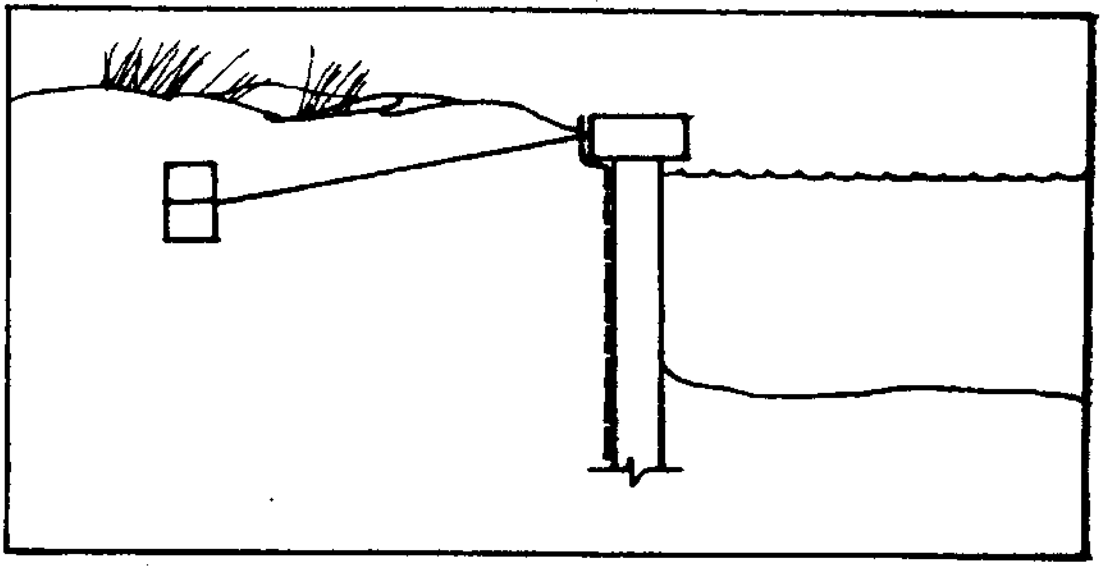


Fig. 10. Adequate anchorage needed

The pressure of the earth pushes the seawall seaward. Anchors that are too light or too close to the wall will pull out, permitting the wall to fall seaward. Tie-back rods that are too light or exposed to corrosion will break. Anchor design is an engineering specialty requiring an expert knowledge of soil mechanics. Check for signs of failure such as top of wall moving seaward, pockets or cracks forming in earth behind the seawall.

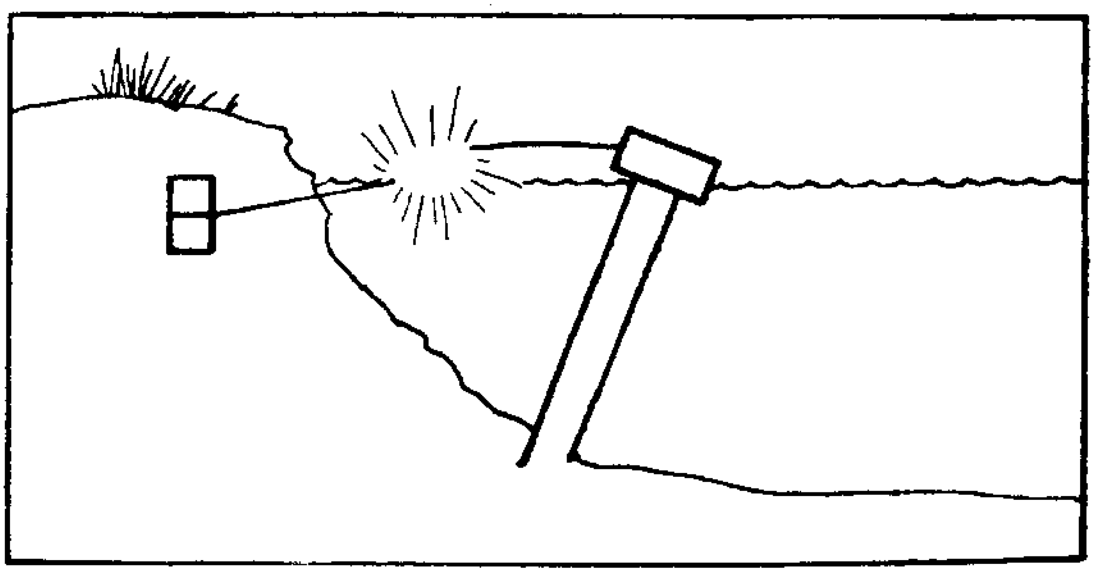


Fig. 11. Failure due to inadequate anchor tie-bar

Anchor blocks that are too light may be weighted by pouring more concrete on seaward side of anchor. Anchor blocks that are too close may be anchored back by placing a second large heavy anchor a safe distance landward and tying it to the existing system. If the tie-back rods are too small, add new tie rods, well wrapped and coated for protection against corrosion.

RULE 3

PREVENT LOSS OF EARTH BEHIND THE WALL

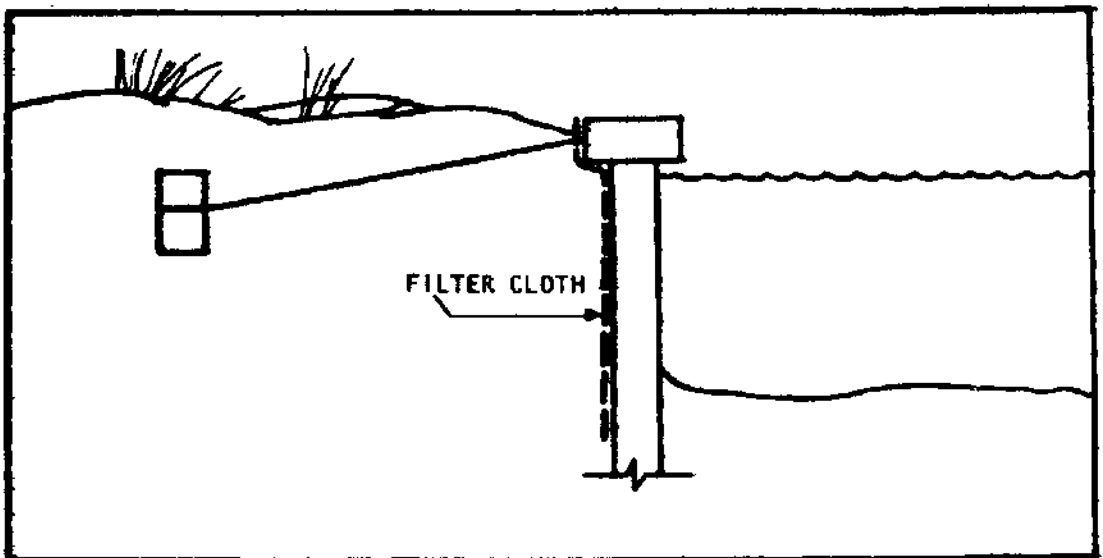


Fig. 12. Adequate earth support needed behind wall

The earth behind the wall provides support. If the supporting earth is washed out by storm water and/or other seepage, the wall collapses landward. Check for signs of failure such as pockets forming in the earth near joints.

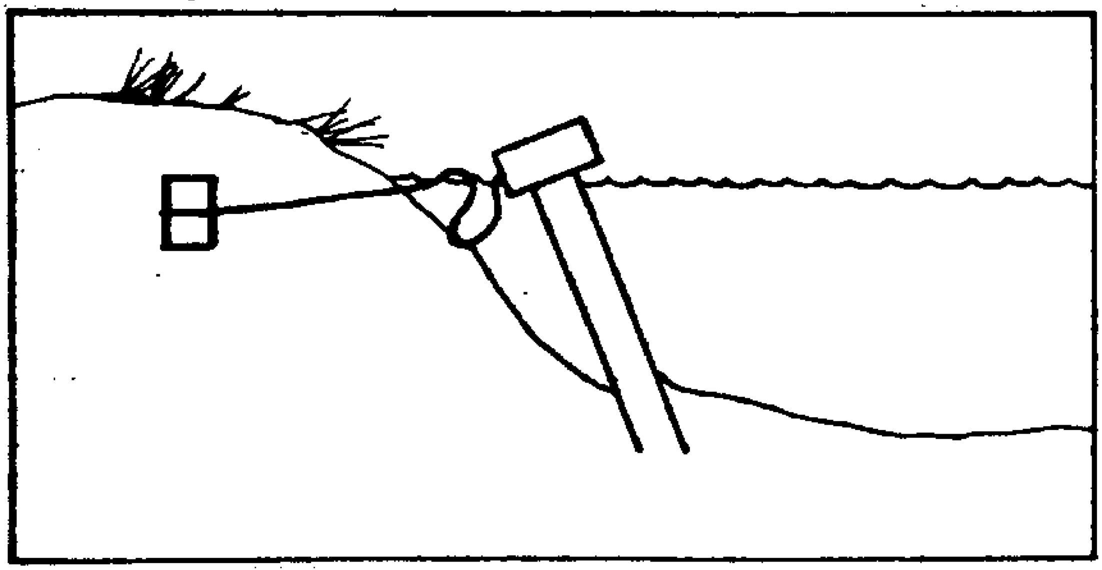


Fig. 13. Failure due to loss of earth support

MAINTENANCE AND REPAIR PROCEDURE

Install filter cloth to intercept migrating soil. This permits water to pass and prevents buildup of water pressure, but retains the soil for support.

RULE 4

SECURE BOTH ENDS OF THE SHORE PROTECTION WORKS AGAINST FLANKING.

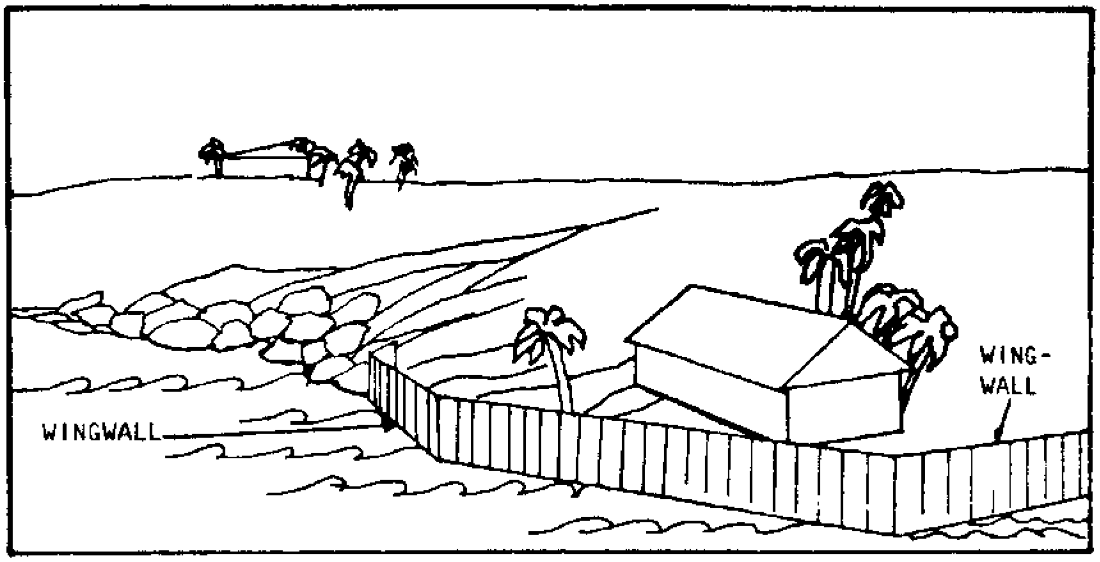


Fig. 14. Adequate end anchorage needed

CHECK FOR SIGNS OF FAILURE

Erosion will continue adjacent to the works. If an existing structure has been flanked, such as the one shown in Fig. 15, correct it by placing additional material at the ends and tying the works directly into the shore. Check for signs of failure such as seaward movement of the ends and erosion at the end of the structure. The illustration below shows the result of not constructing wingwalls and tying the ends of the structure into the shore.

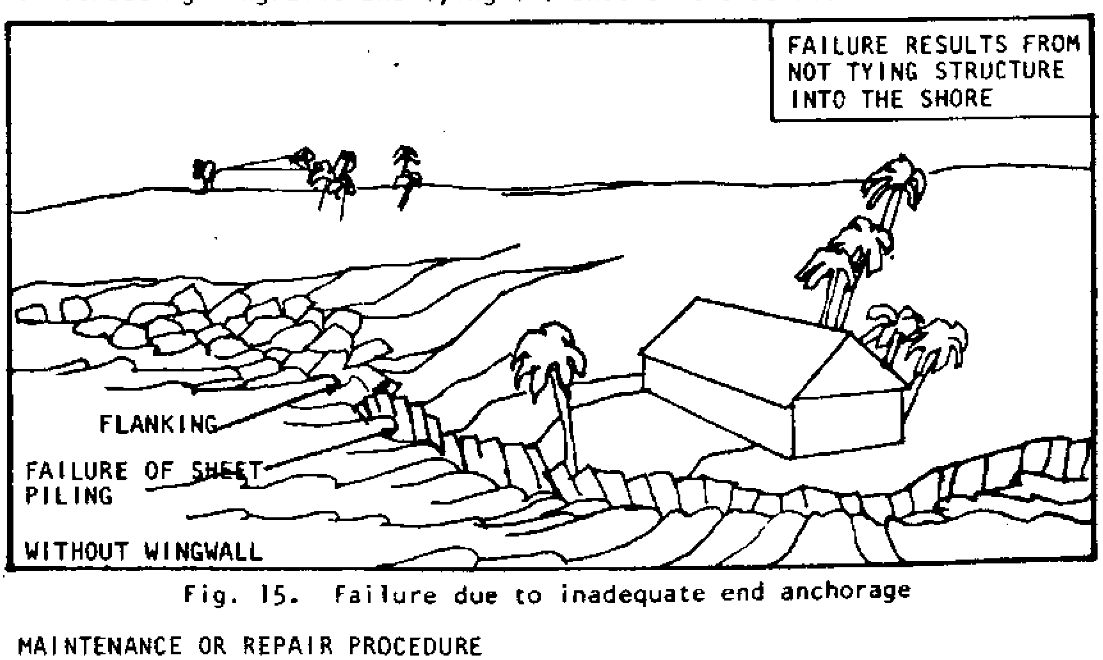


Fig. 15. Failure due to inadequate end anchorage

MAINTENANCE OR REPAIR PROCEDURE

Place additional material at the ends and tie structure directly back into the shore. (Ref. 10)

RULE 5
CHECK FOUNDATION CONDITIONS.

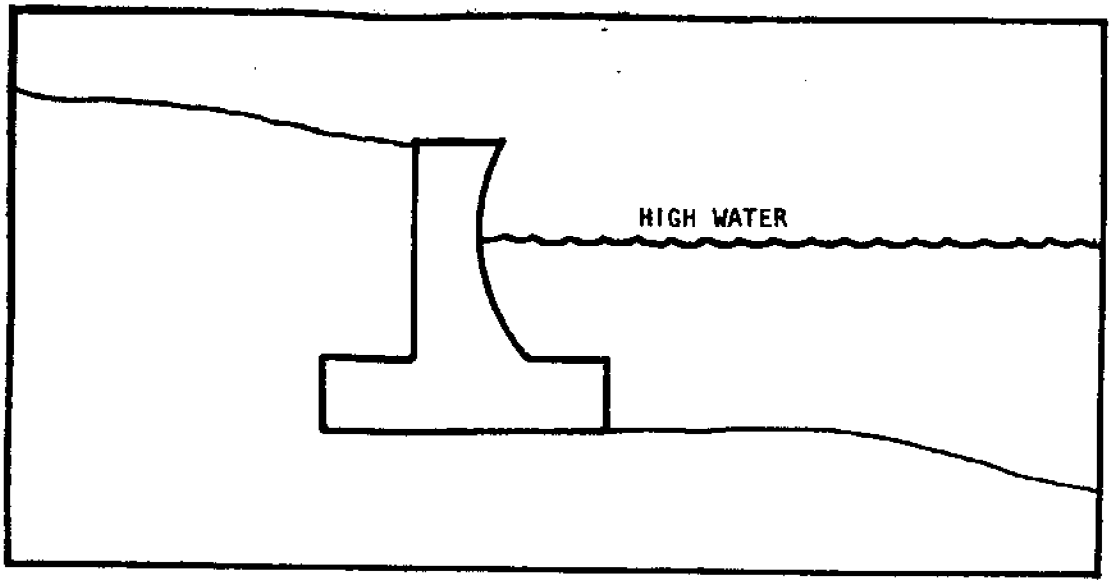


Fig. 16. Firm foundations are essential

CHECK FOR SIGNS OF FAILURE

Soft foundation material may result in excessive settlement of the structure. Soft underlayers may allow all or part of structure to slide. Check for settlement and excessive displacement. Hydrostatic pressure due to groundwater seepage may cause seaward movement of some types of impermeable walls.

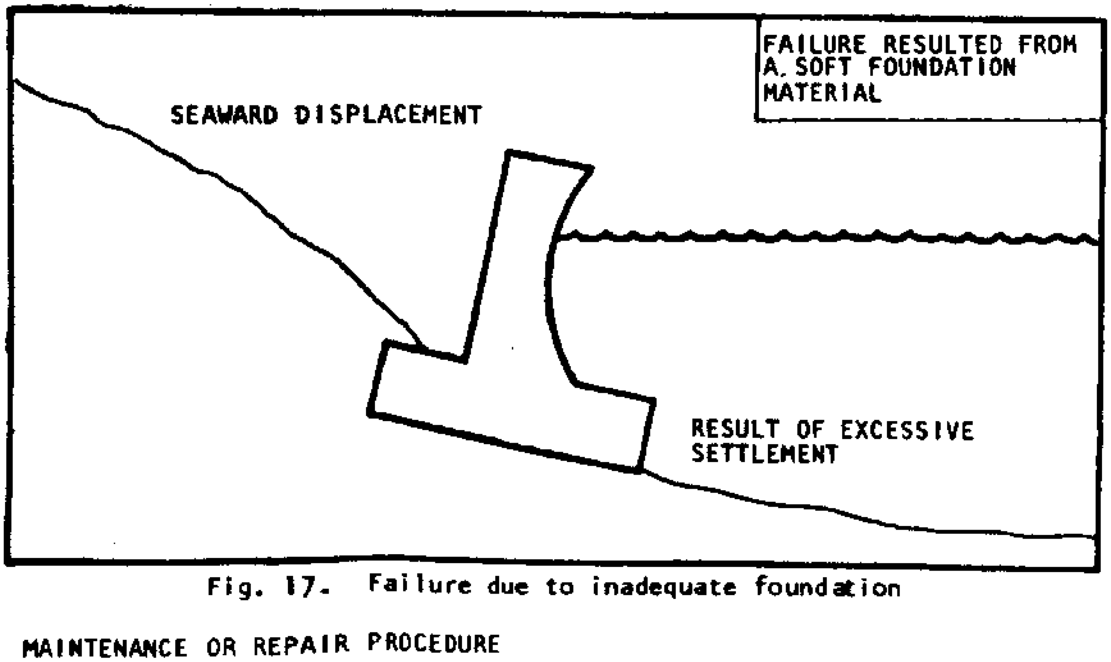


Fig. 17. Failure due to inadequate foundation

MAINTENANCE OR REPAIR PROCEDURE

Re-establish support by construction underpinning, foundation protection and backfilling. If the structure was impermeable and failure was caused by foundation seepage, add or reopen weep holes. (Ref. 10)

5. Examples of Seawall Failures

A. Violation of Rule 1, Adequate Toe Penetration and Protection

The anchor rods for this wall were adequate, but the toe of the wall had insufficient depth of penetration into the earth (Figs. 18 and 19). The pressure of the embankment caused the toe to swing seaward and the bank collapsed into the resulting cavity. Also shown is the formwork and reinforcing steel for replacement precast concrete slabs (Fig. 20). These will be jetted into place and a cap poured on top.

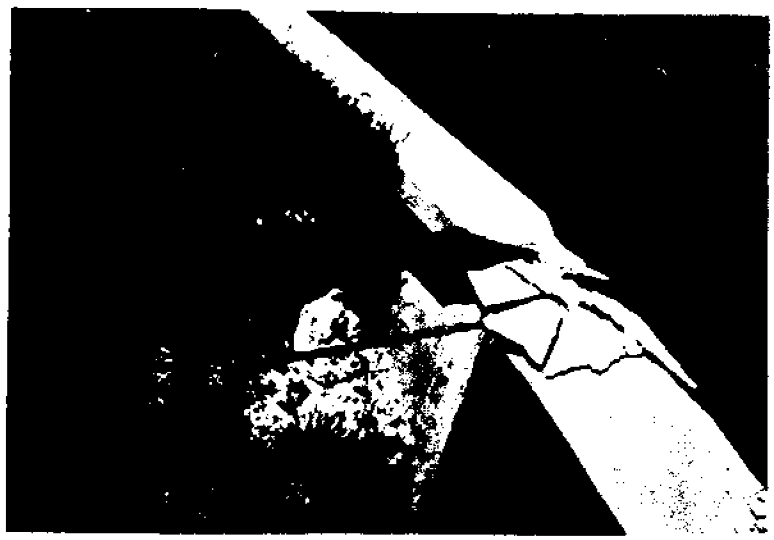


Fig. 18. Failure due to insufficient toe penetration

Fig. 19. Toe failure

Fig. 20. Replacement slab

B. Violation of Rule 2, Adequate anchorage

These tie-back rods (Fig. 21) were attacked by corrosion and eventually failed. This permitted the bank to push the top of the wall seaward, and the whole mass of earth and wall slid seaward. Rods should be of adequate size, thoroughly wrapped, coated or otherwise protected against corrosion, and firmly anchored to a well designed wall cap.

Fig. 21. Failure of anchor tie-back rod

C. <u>Violation of Rule 3</u>, Prevent Loss of Earth Support Behind Wall

In Fig. 22, depressions are beginning to form in the earth behind the wall as rain and storm drainage washes the material through the joints of the wall or under the wall. If this loss continues, the wall may collapse landward due to complete loss of supporting backfill.

Fig. 22. First signs of loss of supporting backfill

Fig. 23 below shows a similar seawall in a more advanced stage of failure due to loss of supporting backfill landward of the wall.

Fig. 23. Advanced stage of loss of supporting backfill

MASSIVE FREE-STANDING GRAVITY SEAWALL

Due to the expense and complexity of this type of seawall, installations are usually funded by the government or a large corporation. The cost ranges from $300 to over $1100 per lineal foot and requires the design expertise of experienced marine structures engineers. However, for the benefit of readers interested in this type of shoreline protection the following brief review is provided.

Massive free-standing gravity seawalls consist of two functional parts, the stem and the base.

1. The Stem

The stem receives the full force of the oncoming wave. The face of the stem may consist of any of a wide variety of surfaces. The face may be a plane surface either vertical or inclined; a curved surface, either concave, convex, or compound; an irregular surface, such as stepped, checkerboard, or other. The texture of the face may vary from smooth to extremely uneven.

A. Vertical Face

Where docking or mooring is required, the vertical face is naturally preferred in order to reduce the horizontal distance from ship to landing. Vertical faces are usually the quickest and least expensive to construct.

B. Convex and Sloped Faces

Structures with convex or sloped plane faces deflect more wave energy upward, and less energy is available for bottom scour around the toe of the structure, providing greater protection against toe failure.

C. Irregular Faces

Structures with irregular surfaces, such as rubble, or stepped faces act to diffuse the wave energy and have proven effective in minimizing both toe scour and overtopping. A stepped face also provides people with easier access to the beach or water. Interlocking blocks are sometimes used to give an indented checkerboard appearance or a stairstep pattern or other irregular face.

D. Concave Faces

Concave surfaces have been used successfully to minimize overtopping and bottom scour where the face profile is correctly designed. Where high wave conditions are expected a curved reeintrant top over a stepped face is a typical design possibility. The design of seawalls to resist wave forces is an area of professional specialization and should not be attempted by the novice (for sample calculations see Ref. 15, Vol II).

The five mile long Bayshore seawall at Tampa, Florida, is still as beautiful and serviceable as it was when it was first built in 1938. This reentrant face protects the shore from the tropical storms that sweep in with hurricane force from the south. Figs. 24 and 25 illustrate details of the design. In recent years there has been some minor spalling and some locations under the sidewalk have required mud jacking to compensate for minor amounts of fill washed out by stormwater filtration (Ref. 11).

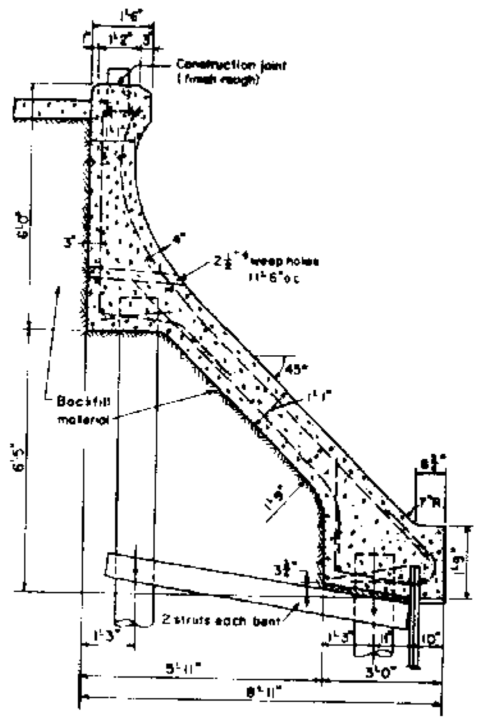


Fig. 24. Section of Bayshore seawall, Tampa, Florida

(Courtesy of Portland Cement Association)

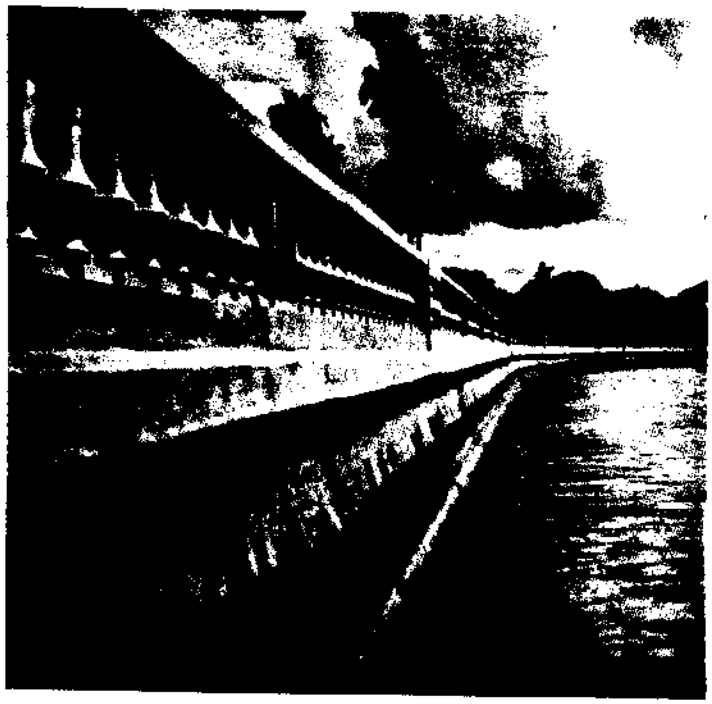


Fig. 25. View of Bayshore seawall,
Tampa, Florida, built in 1938

(Courtesy of Portland Cement Association)

2. Base

When failures do occur in seawalls, they are frequently encountered at the base. Material supporting the base may seem stable under quiet sea conditions and yet become very unstable under high wave conditions due to the rapidly fluctuating water depths and jet-like currents. For this reason special care is necessary in design of the bases. The following protective features are sometimes added:

A. On massive gravity structures, bearing piles may be needed to prevent settlement and provide stability to the base.

B. On large structures special sheet pile cutoff walls under the base may be used to prevent loss of foundation material due to undermining by wave scour and by seepage under the foundation of overtopping sea water and rain water runoff.

C. On waterfront structures of all types enlarged toes may be needed to protect against scour and undermining of the base. These toes consist of extension of the base of the wall seaward, either at or below the sea bottom. Toes may be constructed of concrete, rock, or other tough durable material. Enlarged toes should be considered especially where the water depth is less than twice the height of the maximum wave expected.

3. Bedding Layer for Gravity Structure

The type of base selected depends not only on wave forces, but also on the hardness and compressibility of the sea bottom. Problems of settlement associated with a soft bottom are typically dealt with by one of the following approaches:

A. Accept the settlement, and build a flexible structure out of stone or other articulating components. A filter mat, such as a plastic filter cloth, is often placed between the sea bottom and the base to reduce scouring and settlement.

B. Punch through the soft material to a firmer base by use of piles. These piles may consist of cellular sheet pile cofferdams, or individual concrete, steel, or wood bearing piles.

C. Remove the soft compressible material and replace with a firmer base such as sand or gravel.

REVETMENTS

1. Functions of Revetments

Revetments are usually the least expensive hardened protection available. They consist simply of a light armor facing of blocks, rocks, or other hard material on the natural sloping shore. The revetment functions as a wave energy dissipator by deflecting the wave upward along its sloping surface. The rougher the slope, the faster the wave energy is dissipated. Water receding down the slope from a previous wave often helps diffuse the energy of a newly uprushing wave. Since the revetment purposely deflects wave energy upward, provision should be made for overtopping, as it is usually not economical to construct the revetment to the height of the highest possible wave. Both wave overtopping and storm runoff act to saturate the soil behind the revetment, and adequate drainage of the soil in this crucial area is important. Soil that does not drain well tends to lose stability, become soft and possibly slide seaward carrying the revetment structure with it. The revetment as a complete structure usually has little strength of its own but relies on the underlying soil for stability. It is a surface coating designed to be supported by the shore it protects. The armor coating is made up of individual units such as precast concrete blocks, natural stones and boulders, bags filled with sand-cement mixture of grout, or some durable facing material. The revetment typically relies only on gravity interlocks between individual armor units to hold it together. In the absence of cemented joints the revetment is typically flexible and can adjust to minor settlement without failure.

Since the joints in the revetment facing are usually open and not watertight, special care must be taken to prevent scour of supporting shore material as the returning splash and rain water flows back to the sea. A filter mat is normally located between the natural soil and the revetment, designed to retain the solids as the water flows through. Past practice was to construct this filter of carefully screened sand and rock in successive layers. Now, however, the more economical woven plastic mats are used almost universally. A good filter must not impede the flow of water, or a pressure head may build up which could lift the armor units from their seats. On the other hand, the filter must not pass fine sand grains or the supporting material may be scoured from underneath the revetment.

On rare occasion revetments may be constructed of impermeable materials, such as asphalt or bitumen grouted stone. Careful design is required to prevent excessive water pressure from building up on the landward side of this type of structure.

2. Precast Concrete Checkerboard Revetment

The precast concrete revetment is expensive but performs well when installed under favorable conditions (Fig. 26). A typical installation consists of 3' x 3' squares of interlocking concrete, alternating 10" and 14" in thickness. Under the block is a bedding layer of 3/4" stone about 10" to 12" thick underlain by a plastic filter sheet.

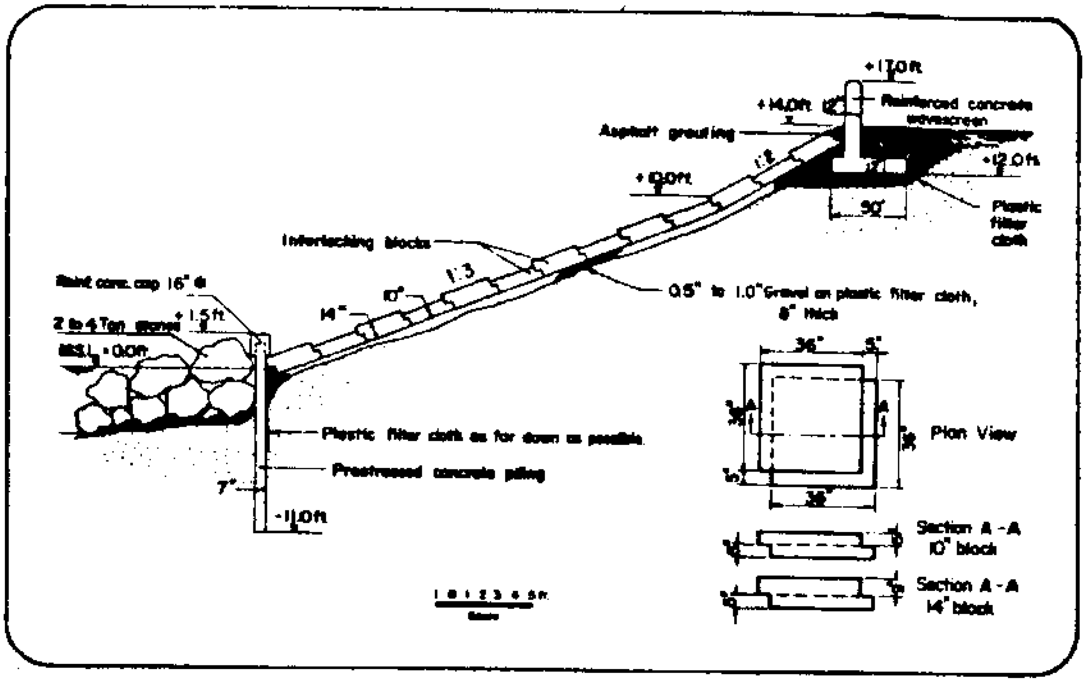


Fig. 26. Interlocking concrete-block revetment at Jupiter Island, Florida (Ref. 12)

Some failures of this type revetment have occurred on Florida's Atlantic Coast. While expert opinion is divided regarding the exact cause of these failures, the possible contributory factors are listed as follows:

A. The supporting sand underneath the revetment may have settled and compacted due to the static and dynamic loading of pounding wave forces. Possible preventive measures: precompact the underlying sand to a specified density.

B. The gravel under the concrete slabs may have squeezed out through the joints between the slabs. Possible preventive measure: specify larger gravel size, closer tolerances on joints, or use another layer of filter cloth between the gravel and the concrete slabs.

C. The gravel may have broken into smaller sizes under the wave pounding forces, thus facilitating loss of gravel through the joints. Possible preventive measure: specify a stronger rock material or use filter cloth between gravel and concrete slabs.

D. The interlocking keys of the concrete slabs may have fractured, causing the blocks to become displaced. Possible preventive measure: design stronger interlocking keys.

E. Supporting sand may have leached out through exposed toe areas. Possible preventive measures: maintain adequate sand cover over the toe areas, provide adequate sheet pile and rock protection for toe areas, place filter cloth to prevent sand loss.

3. Stone Revetment

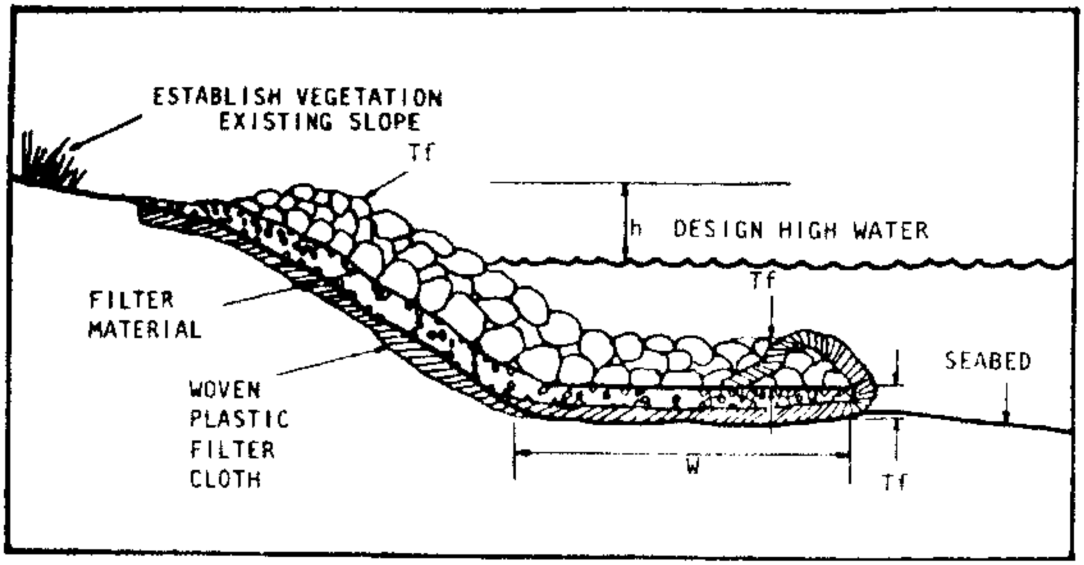


Fig. 27. Stone revetment (Ref. 10)

Stone revetment is the preferred method of shore protection. It is economical and suitable for all types of erosion problems when stone is available in sufficient size and quality. The key design considerations are the dimensions, foundation treatment, and stone size. Construction is not complicated and no special equipment, other than a crane and trucks, is needed.

Notes:

1. Slope should be compacted and graded to 1:2 or flatter.
2. Place a gravel, small rock, filter blanket, and/or woven filter cloth on the prepared slope.
3. Place rock carefully with a crane, rock should have a three-point bearing.
4. Insure rock sizes are well mixed. Larger and smaller rock should not be visibly segregated.

MAINTENANCE REQUIREMENTS

This structure is subject to displacement. The effectiveness of the structure will be impaired by thinning of the protective layer or settling of the structure. Restoration of the rock slope protection to the designed top elevation, equivalent thickness, and reduction of voids in the facing should be accomplished when needed. The list of materials and general costs information is given in the following tabulation.

Description	Design depth of water 50' offshore (ft)		
	3 - 4	5 - 6	7 - 8
Dimensions			
Thickness (ft)	2	4	5
Average Wt of Stone (#)	200-500	750-2000	2000-5000
Height of structure (ft)	4	6	8
Toe Protection Width (ft)	2	4	5
Filter material	Woven Cloth		
List of Materials (per ft)			
Stone (ton)	1.89	4.94	7.36
Filter (sq ft)	13	19	22
Cost $/Lin ft	30	80	110

4. Gabion Revetment

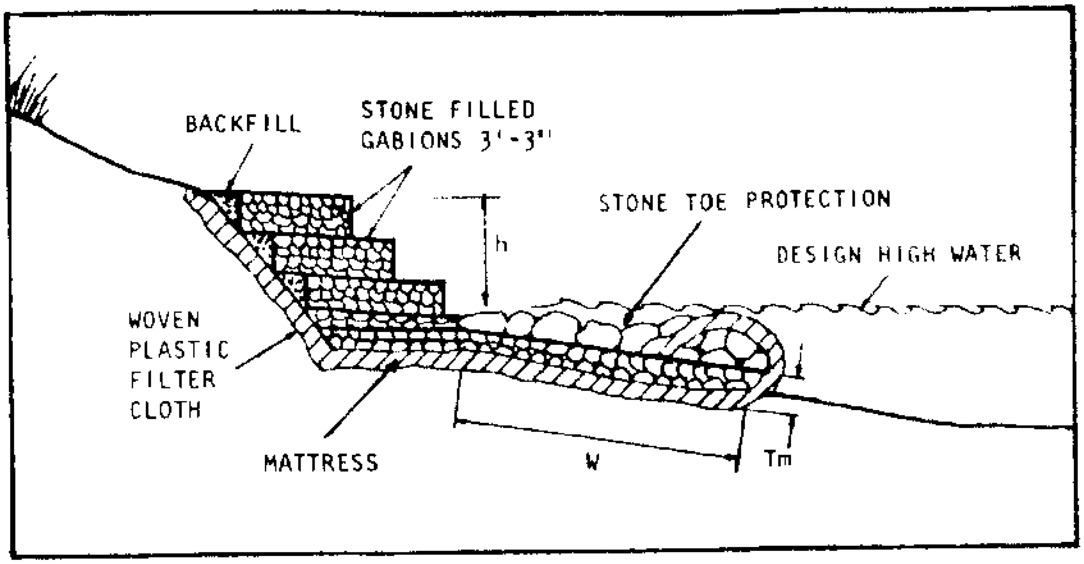


Fig. 28. Gabion revetment (Ref. 10)

A gabion is a steel wire mesh basket available commercially. Revetments can be constructed from stone filled gabions by groups of individuals without special construction equipment. Gabion structures can be built to any height required. A step design is suggested to reduce wave runup. The manufacturer's instructions should be followed closely. The structure should rest on an 18" thick gabion mattress to protect against scour. This type of construction is applicable to all shore-protection problems.

Notes:

1. Gabions can be filled with any stone material larger than the mesh.

2. Gabion structures maintain their strength even if the foundation settles somewhat.

3. Stagger the joints between baskets the same way the joints between courses in a brick wall are staggered to make a stronger structure.

4. For longer protection, anchor the seaward end of the mattress with large stone or anchor screws.

5. The mattress should extend as far from the toe as 1½ times the design depth.

Continued

Figure 28, Continued

MAINTENANCE REQUIREMENTS

The life of gabion protection depends on the durability of the wire. Replace broken wires with galvanized or plastic coated wire. The baskets occasionally are moved during severe storms, but can often be replaced after the storm. Such movement indicates foundation failure or scour at the toe. Repair all storm damage as quickly as possible.

Description	Design depth of water 50' offshore (ft.)		
	3-4	5-6	7-8
Dimensions			
Height (ft)	5	7	9
Apron length (ft)	2	5	7
Filter material	Woven Cloth		
Materials (per ft)			
Gabions (#)	1	3	4
Gabions-Stone filled (yd^3)	0.2	0.7	0.9
Gabion type mattress (yd^3)	0.2	0.4	0.7
Cost $/Lin ft	30	60	80

5. <u>Grout Filled Bag Revetment</u>

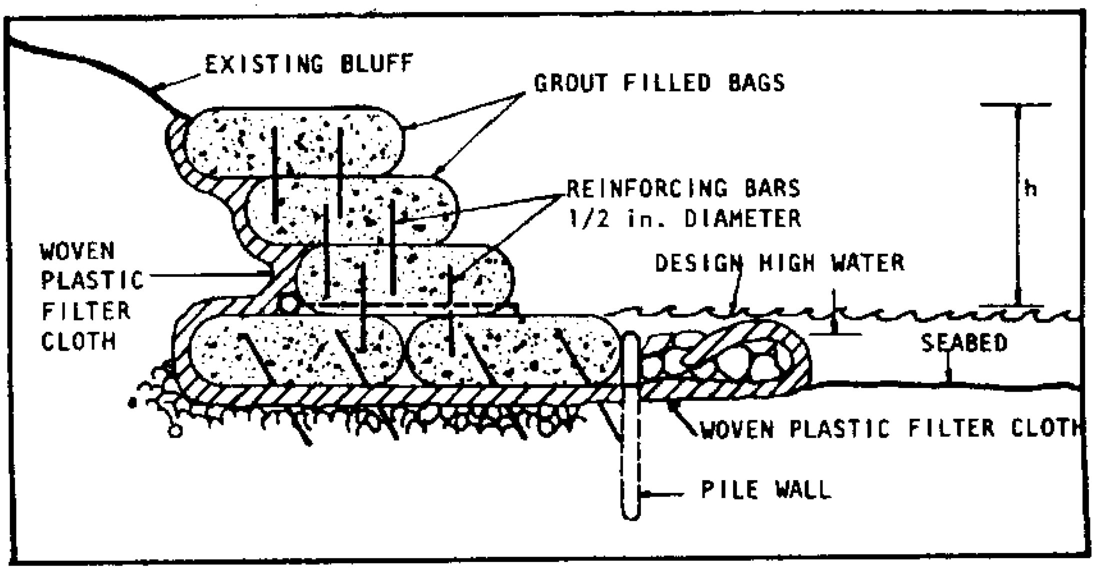


Fig. 29. Grout filled bag revetment (Ref. 10)

Large grout filled nylon bags (20' x 5' x 1.6") may be used to protect eroding shorelines. This type of structure is adaptable to all types of slopes. Bags should be placed parallel to the shore with reinforcing bars installed both vertically and horizontally as shown in the section below. This type of structure may be applicable where access is limited and rock is not readily available. No special material is needed other than the bags and construction is not complicated. A grout pump is required to fill the bags. Prices in the table below were computed with the assumption that ready-mix grout will be used, but a concrete mixer could be substituted at the site.

Maintenance Requirements

Remedial work on this type of structure is not easily accomplished. Special attention should be given to the protection. Uneven settlement or undermining might cause fracture or collapse. If excessive scour causes toe stone to settle, more material should be added. This type of structure is readily adaptable to add-on construction. Additional structure height can be easily accomplished if necessary. A lean mixture of sand cement consisting of as little as 3 bags of cement per cubic yard of mix is pumped into the bags with a portable concrete pump.

A typical bag when empty measures 5' by 10' and weighs about 5-1/2 pounds each. The bags may be filled in place on the beach by a 3" centrifugal bilge pump dredging 2-1/2 cubic

Continued

Figure 29, Continued

yards of beach sand into the mixer with the cement, then into each bag which gives the bag a dimension of about 9-1/2' x 4-1/2' x 1-1/2'.

Description	Design depth of water 50' offshore (ft.)		
	3 - 4	5 - 6	7 - 8
Dimensions			
Height of Structure (ft)	6.4	8.0	11.2
(Bags)	(5)	(6)	(8)
List of Materials (per ft)			
Grout (Yds. 3)	1.5	1.8	2.4
Reinforcing bars (lbs.)	10	12	16
Filter Cloth (Sq. Ft.)	18	21	26
Cost $/Lin. ft.	90	100	130

6. Guidelines for Construction and Maintenance of Revetments

The basic rules for constructing revetments are illustrated as shown below.

Rule I
USE MATERIAL THAT IS HEAVY AND DENSE ENOUGH THAT WAVES WILL NOT MOVE INDIVIDUAL PIECES OF THE PROTECTION.

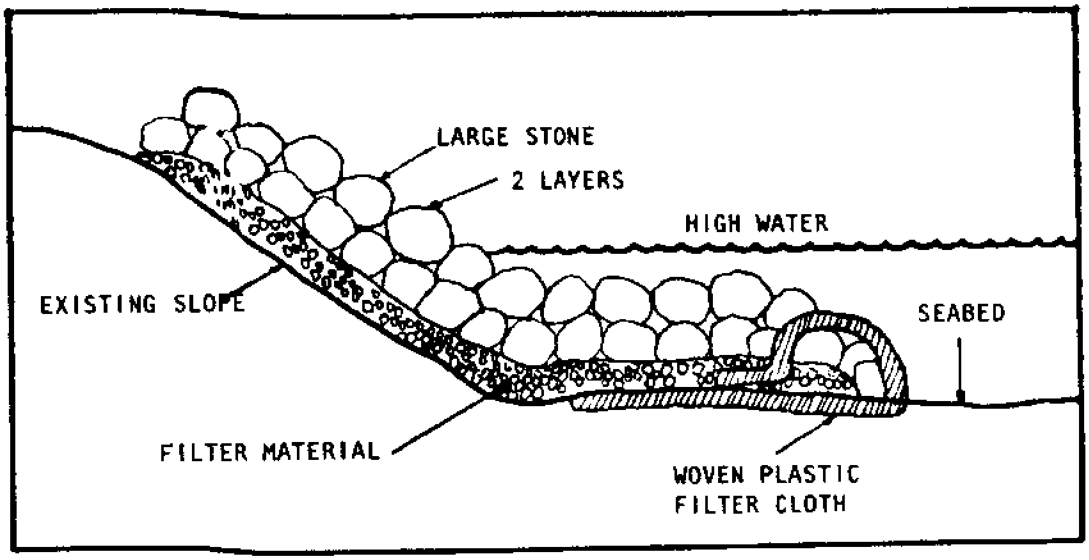


Fig. 30. Heavy dense units needed (Ref. 10)

CHECK FOR SIGNS OF FAILURE. A cause of common failure is to use undersized material; waves have tremendous power and can move a lot of material in a short time. Small stones, or pieces of concrete, will be moved around and carried away by small waves. Larger waves will do it even faster. The bank revetment shown in Fig. 31 was constructed of undersized stone that was carried down the slope by large waves. Excessive settlement, increase in voids, loss of filter material, erosion behind, or at the end of the structure can result due to the use of small stone; a layer or two of filter material may be required between underlying ground and the protective material.

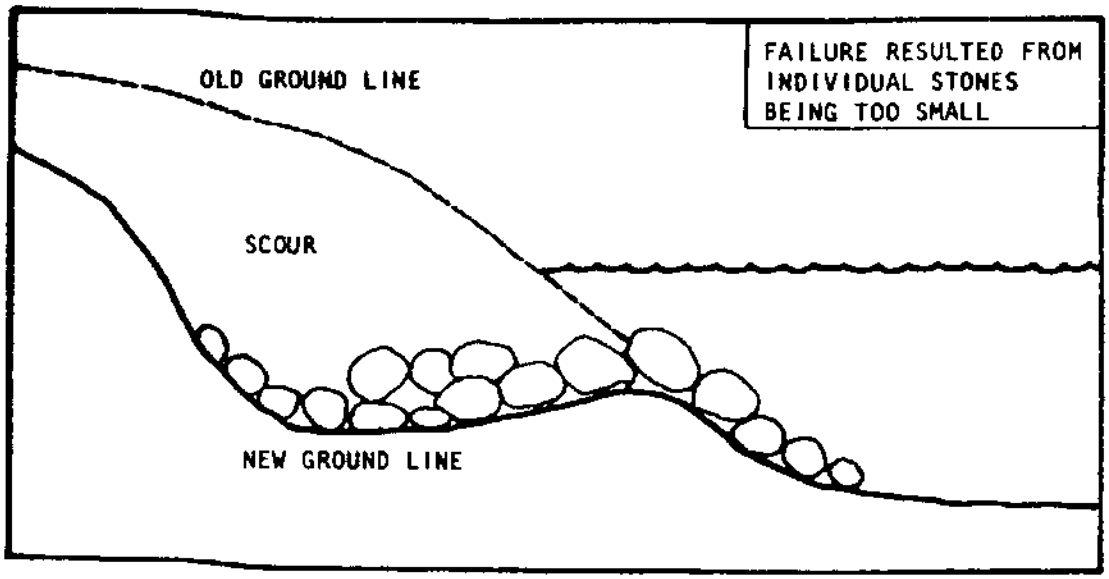


Fig. 31. Failure due to too small units (Ref. 10)

MAINTENANCE OR REPAIR PROCEDURE

Place additional stone at toe, restore to original elevation, section, and thickness, reduce excessive void ratio, back fill behind structure, extensive upgrading in size of material may be required.

RULE 2

BUILD REVETMENT HIGH ENOUGH THAT WAVES CANNOT OVERTOP IT (SPRAY OVERTOPPING IS ALL RIGHT, BUT NOT "GREEN" WATER)

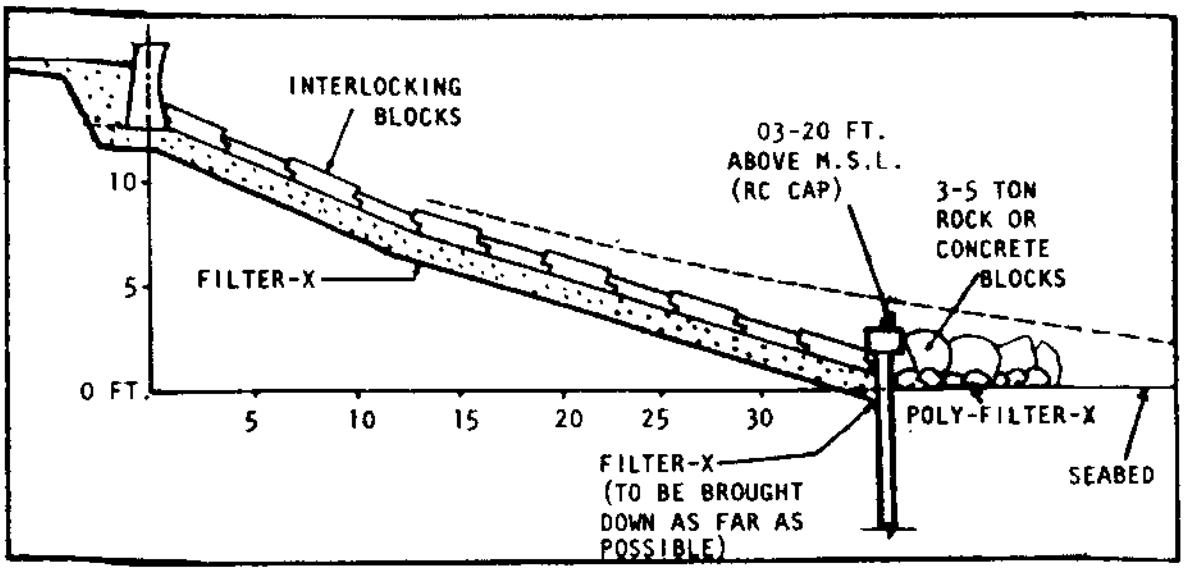


Fig. 32. Prevent serious overtopping (Ref. 10)

CHECK FOR SIGNS OF FAILURE

Many failures have happened because the structure was not built high enough and erosion could then continue behind the structure as if it were not there. Check for depressed or broken blocks, excessive movement, and erosion behind or at ends of structure.

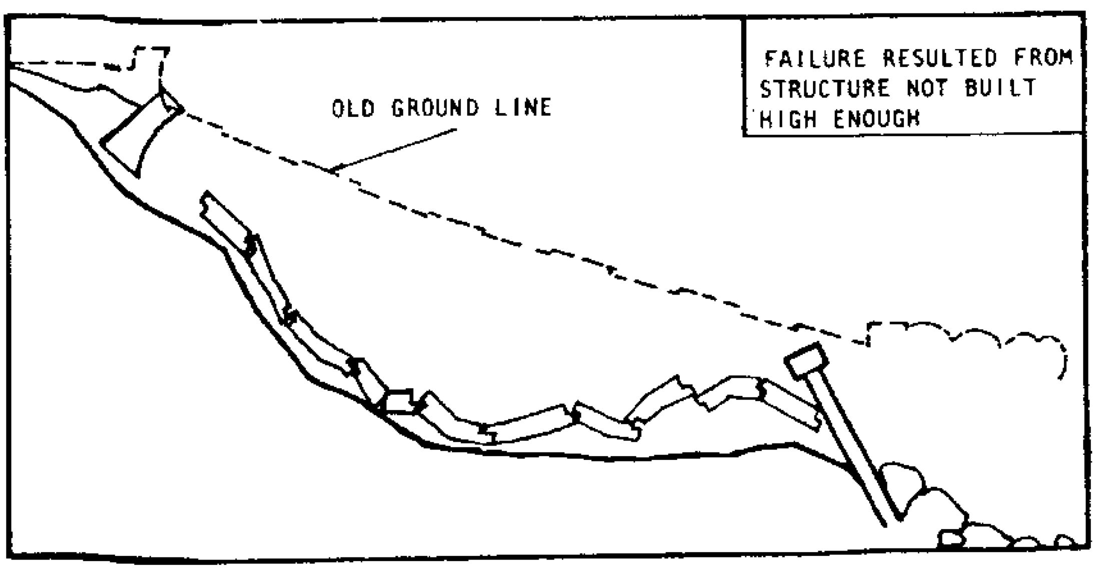


Fig. 33. Revetment failure (Ref. 10)

MAINTENANCE OR REPAIR PROCEDURE

Restore to higher elevation, back fill behind structure, add filter cloth, and splash apron.

RULE 3

MAKE SURE THAT VOIDS BETWEEN INDIVIDUAL PIECES OF PROTECTION MATERIAL ARE SMALL ENOUGH THAT UNDERLYING MATERIAL IS NOT WASHED OUT BY WAVES.

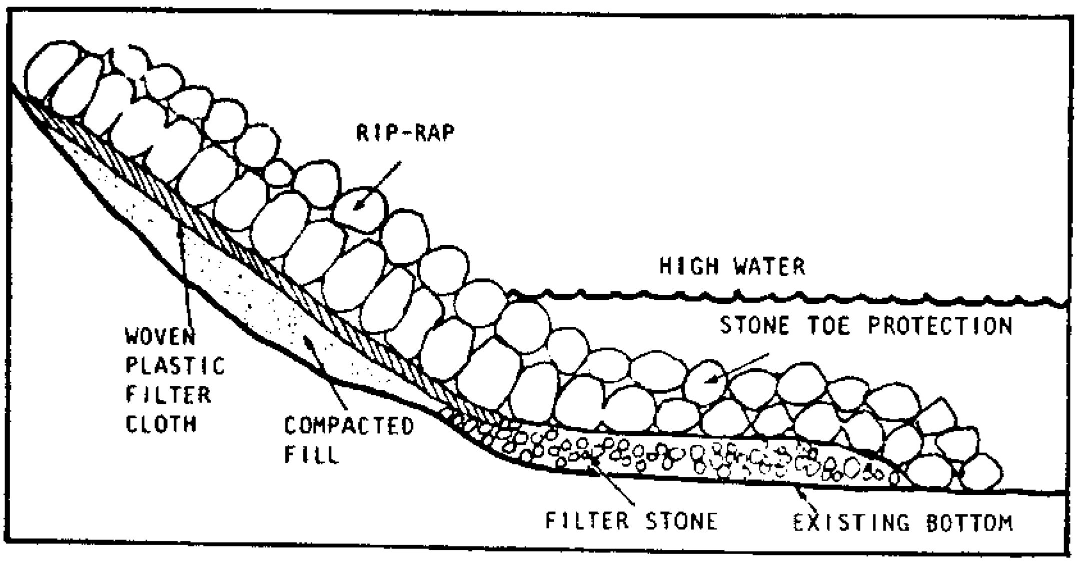


Fig. 34 Prevent loss of supporting material (Ref. 10)

CHECK FOR SIGNS OF FAILURE

A filter material such as woven plastic filter cloth must be placed on a highly erodible embankment to prevent the fine materials from washing through the voids in the structure. The protection material must be thick enough to make a long passage for dissipation of wave energy prior to reaching the underlying materials. As seen in Fig. 35, woven plastic filter cloth was not included. As a result fine material was washed out by waves.

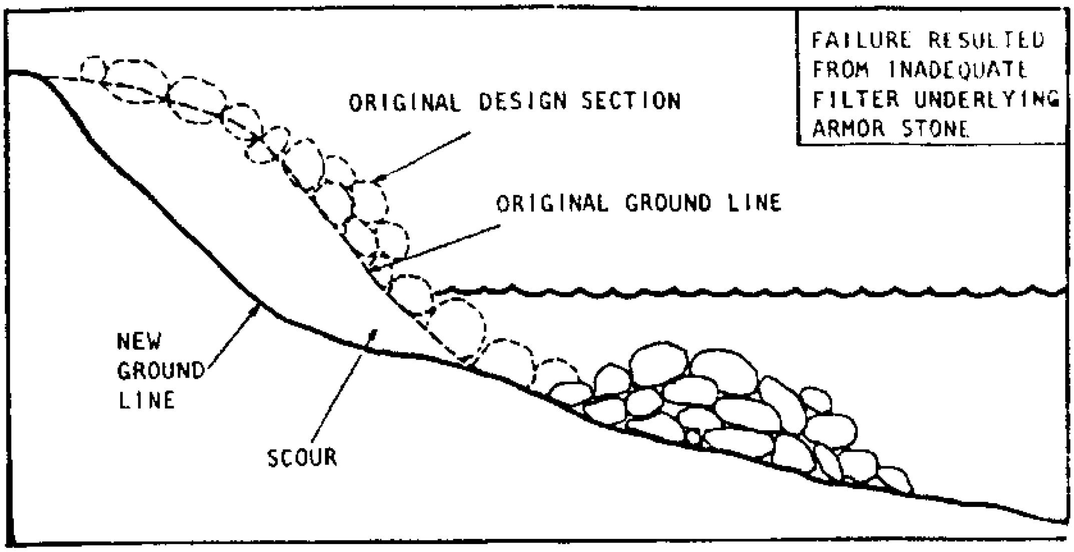


Fig. 35. Failure due to loss of supporting material (Ref.10)

MAINTENANCE OR REPAIR PROCEDURE

Rebuild to original elevation, use at least two layers of stone, use a stone filter or woven plastic filter cloth, fill behind structure.

7. Examples of Revetments in Florida

On Florida's gulf coast the sloped checkerboard revetment has been quite successful when properly installed. Pictured after 10 years of use is the revetment at the south west tip of Mullet Key, constructed in 1964 (Fig. 36). The installation consists of a deep toe wall, headwall with a slight reentrant curve, and plastic filter mats overlain with gravel and topped with precast interlocking checkerboard squares.

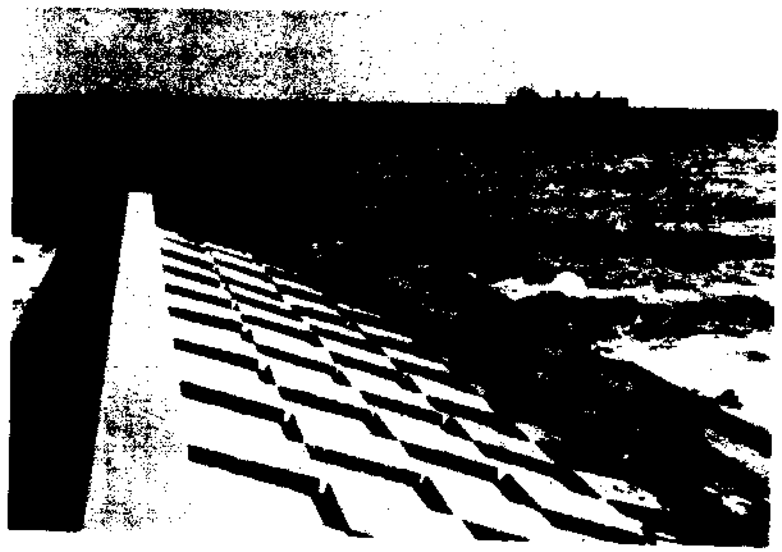


Fig. 36. Interlocking concrete block revetment, constructed in 1964

Along the eastern shore of Clearwater Harbor is a smaller sloped checkerboard revetment protecting a multi-unit residential complex (Fig. 37). This also has a toe wall which is largely covered with beach sand even though the installation is less than a year old. This revetment allows much easier access to the beach and water than does a vertical wall. The cost was approximately $300 lineal foot.

Fig. 37. Concrete block revetment partially covered with beach

A revetment constructed during summer 1974 at Sebastian Inlet as a protection for the McLarty State Museum is shown in Fig. 38. The underlying material is ordinary white beach sand common to the area. It was shaped to the profile shown under the filter stone. Sheets of green plastic filter cloth were then laid over the sand and pegged into place with steel pegs. A bedding layer of small filter stone was placed over the cloth to a thickness of one foot. Large boulders were then placed by crane to a depth of about 5 feet and the whole area covered over with sand. The boulders cost about $25 per ton in place (Ref. 9).

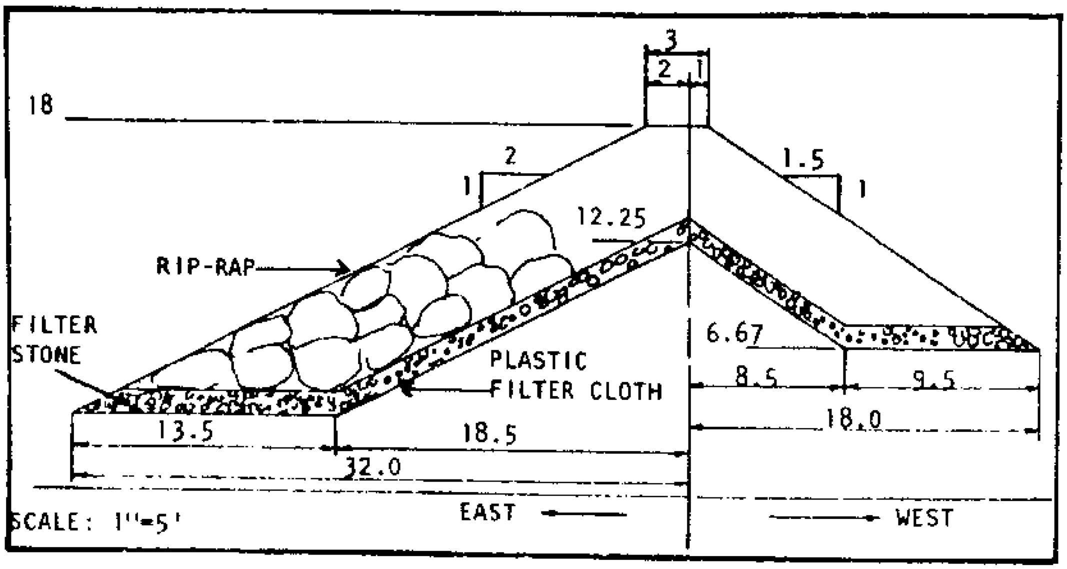


Fig. 38. Revetment protecting McLarty State Museum

HOW TO ESTIMATE CURRENT LOCAL COSTS OF SHORELINE PROTECTION STRUCTURES

Costs of construction vary with two major factors and a number of minor ones. The two major factors are (1) time and (2) location. Preliminary estimates of costs may be derived by finding costs of recent similar structures and then bringing the costs up-to-date by multiplying by time and location modifiers.

1. Time Modifier

A number of indexes are published reflecting the change of construction costs (usually upward) with the passage of time. The most easily available are the "Construction Cost Index" (CCI) and "Building Index" (BCI). These are published weekly in the Engineering News-Record by McGraw-Hill, Inc. (Ref. 8). See Fig. 39.

CONSTRUCTION SCOREBOARD

LATEST WEEK

COST INDEXES ENR 20-cities 1913=100	Apr. 3* index value	Change from last month %	Change from last year %
Construction Cost	2135 0	+ 0 3	+ 8 9
Building Cost	1269 0	+ 0 3	+ 7 8
Common labor (CC)	4204 9	+ 0 4	+ 9 3
Skilled labor (BC)	1928 4	+ 0 3	+ 8 0
Materials	866 4	+ 0 3	+ 7 5

*Official April Indexes

Reprinted from Engineering News-Record, April 10, 1975,

Fig. 39. ENR's Construction Scoreboard

For example, an average cost of $30 per lineal foot in June 1970, when the CCI stood at 1369, could be updated to April 3, 1975, when the CCI reached 2135, by using the ratio (2135/1369) x $30/lineal foot = $47/lineal foot. Using the BCI yields almost the same results.

A convenient compilation of indexes is published monthly in Construction Review, Table E-1, by the U. S. Department of Commerce (available through the Superintendent of Documents, U. S. Government Printing Office, Washington, D.C. 20402, $11.50/year). See Fig. 40.

Fig. 40. Construction Cost Indexes (Table E-1 from Construction Review) (1967 = 100)

Period	Department of Commerce composite cost index*	American Appraisal Company	Associated General Contractors*	"Boeckh Indexes," P&E Division—The American Appraisal Company, Inc.: Residences	Apartments, hotels, and office buildings	Commercial and factory buildings	Engineering News Record: Building	Engineering News Record: Construction	Environmental Protection Agency, sewer
				Annual indexes					
1969	114.1	116	114	116.2	116.1	114.5	117.7	118.7	111.
1970	121.5	124	126	122.4	124.4	123.1	124.4	128.9	120.
1971	130.5	138	n.a.	132.8	135.0	133.9	140.5	146.8	134.
1972	138.7	151	n.a.	145.8	145.4	144.8	155.2	162.9	149.
1973	152.1	167	n.a.	159.2	154.0	154.4	168.6	176.6	160.
1974	173.0	177	n.a.	172.0	168.4	171.0	178.3	188.2	180.
				Monthly indexes					
1969: January	109.5	112	110	112.4	111.9	111.0	113.8	113.6	108
February	110.0	113	111	113.7	113.2	111.9	114.8	114.9	109.
March	110.9	114	111	115.0	114.1	112.3	116.1	115.7	109
April	111.8	114	111	114.8	113.5	112.7	117.6	116.[illegible]	109
May	112.8	114	112	115.2	113.9	112.5	117.8	117.6	109
June	113.7	115	114	117.0	115.8	114.3	118.9	120.0	110
July	114.9	117	116	116.9	117.0	115.4	119.0	119.8	112.
August	115.5	117	116	118.1	116.1	115.9	119.0	120.2	113
September	116.1	117	116	117.6	118.1	116.0	118.5	120.1	111
October	117.0	118	116	117.2	118.6	116.9	118.7	121.4	113
November	117.3	118	116	117.9	119.3	117.1	119.3	121.9	114.
December	117.4	118	117	118.6	119.6	117.7	119.5	122.0	114
1970: January	117.2	119	117	119.0	119.8	118.5	119.5	122.3	115.
February	117.2	119	117	119.4	120.2	118.6	119.3	122.5	115.
March	118.0	119	118	119.6	120.9	119.4	119.5	122.8	116.
April	119.6	121	119	119.8	121.1	119.6	121.0	124.2	117.
May	120.3	123	120	120.3	122.0	121.1	122.8	125.7	118.
June	121.6	124	124	120.6	122.2	121.2	123.6	127.9	119
July	122.3	127	127	123.6	125.3	124.3	126.3	132.1	122.
August	122.5	127	130	123.9	125.5	124.4	126.7	132.5	122.
September	122.9	127	130	125.1	128.3	126.8	127.6	132.9	123.
October	123.7	128	133	125.3	128.5	127.0	128.4	133.9	124.
November	124.3	129	136	126.1	129.4	127.9	129.0	135.0	124.
December	127.4	130	137	126.2	129.9	128.4	128.9	135.0	125.
1971: January	124.7	131	139	126.4	130.7	128.8	130.2	136.[illegible]	126.
February	124.8	131	139	126.6	131.0	129.0	130.6	137.0	126.
March	126.3	133	139	128.5	131.9	130.3	134.4	139.6	127
April	128.3	134	141	129.7	133.2	130.9	136.2	141.2	129.
May	129.9	137	142	129.7	132.7	131.7	138.8	144.2	132.
June	130.6	138	146	130.3	133.3	132.0	140.6	147.2	134.
July	132.0	141	149	135.6	136.5	135.2	141.8	149.3	135.
August	132.7	143	150	136.3	137.2	136.1	143.4	150.9	136.
September	132.7	143	n.a.	137.5	138.5	138.1	147.4	153.2	138.
October	133.0	143	n.a.	137.5	138.5	138.1	147.2	153.5	139.
November	133.0	142	n.a.	137.5	138.5	138.1	147.4	153.6	142.
December	133.8	145	n.a.	137.5	138.5	138.1	147.9	154.6	143.
1972: January	134.7	146	n.a.	141.4	141.8	140.6	149.1	155.6	144
February	135.1	147	n.a.				150.8	156.6	145.
March	135.9	148	n.a.	143.3	143.5	143.1	151.5	157.2	145.
April	136.7	148	n.a.				152.1	158.9	146.
May	137.0	150	n.a.	145.0	144.6	144.2	153.7	161.5	148.
June	137.5	150	n.a.				155.0	163.9	149.
July	137.9	151	n.a.	147.3	146.6	146.1	155.8	164.9	149.
August	138.7	152	n.a.				156.4	165.4	150.
September	140.0	152	n.a.	148.6	147.5	146.9	157.9	166.2	151.
October	141.9	154	n.a.				158.4	167.0	152.
November	143.0	155	n.a.	149.5	148.3	147.9	160.1	168.1	153.
December	143.7	155	n.a.				161.4	169.1	153.
1973: January	144.0	157	n.a.	149.8	148.6	148.3	163.2	171.1	154.9
February	145.0	161	n.a.				164.9	172.2	156.1
March	147.0	165	n.a.	156.3	151.6	152.6	167.3	173.7	157.3
April	148.7	166	n.a.				168.0	174.4	157.9
May	150.2	167	n.a.	160.1	153.7	155.1	168.9	175.0	159.8
June	151.4	167	n.a.				168.5	176.5	160.4
July	153.2	168	n.a.	160.7	154.5	155.3	168.3	177.0	161.5
August	154.7	169	n.a.				169.3	178.7	161.5
September	155.9	170	n.a.	163.9	157.8	157.7	170.2	179.6	162.1
October	156.4	170	n.a.				171.2	180.0	163.0
November	157.5	170	n.a.	164.4	157.8	157.7	171.0	180.1	163.7
December	159.0	170					171.4	180.5	165.5
1974: January	161.4	170	n.a.	165.7	158.9	159.3	171.0	180.6	166.1
February	163.6	171	n.a.				170.8	180.6	167.5
March	166.1	174	n.a.	167.4	162.5	163.0	171.0	182.9	169.1
April	168.4	175	n.a.				174.2	182.6	172.1
May	170.7	176	n.a.	168.6	165.8	167.7	174.2	182.6	174.8
June	172.8	177	n.a.				177.5	185.6	180.5
July	175.0	178	n.a.	175.0	170.2	174.3	182.4	189.9	184.5
August	177.0	179	n.a.				183.6	193.2	188.1
September	178.9	181	n.a.	177.1	175.3	179.6	183.1	194.5	188.7
October	180.0	181	n.a.				184.5	195.5	191.2
November	180.7	180	n.a.	177.9	177.4	182.4	183.4	195.0	193.1
December	182.7	180	n.a.				183.8	195.3	194.9
1975: January	184.4	181		178.0	178.3	182.8	183.8	195.8	196.9
February							187.2	198.1	

See footnotes at end of table.

Fig. 40, Continued

(1967 = 100)

Period	Bureau of the Census New One Family Houses	Federal Highway Administration	George A Fuller Company	Bureau of Reclamation	Turner Construction Company	Handy-Whitman Public Utility: Buildings	Handy-Whitman Public Utility: Gas plant	Handy-Whitman Public Utility: Electric light and power plants	Bell System Telephone Plant, Telephone and telegraph: Buildings	Bell System Telephone Plant, Telephone and telegraph: Outside plant
	Annual indexes									
1969	113.6	111.8	116	110	116	113	110	110	112.6	111.1
1970	117.4	125.6	127	118	129	121	117	119	123.0	123.8
1971	123.2	131.7	n.a.	128	143	133	125	128	134.6	130.2
1972	131.0	138.2	n.a.	137	154	144	134	135	146.7	139.8
1973	144.8	152.4	n.a.	145	162	158	140	144	153.4	146.8
1974				163	188					
	Quarterly indexes					Semi-annual indexes				
1966 1st quarter	94.1	92.9	98	n.a.	96	n.a.	n.a.	n.a.		
2nd quarter	97.1	97.2	98	n.a.	97					
3rd quarter	96.2	98.7	98	n.a.	98	n.a.	n.a.	n.a.		
4th quarter	96.7	94.2	98	n.a.	99					
1967 1st quarter	99.3	96.0	99	98	99	n.a.	n.a.	n.a.		
2nd quarter	98.5	95.3	99	99	100					
3rd quarter	99.8	104.9	101	101	100	n.a.	n.a.	n.a.		
4th quarter	100.5	100.8	102	102	102					
1968 1st quarter	103.4	101.8	107	102	103	n.a.	n.a.	n.a.		
2nd quarter	104.7	103.3	103	104	105					
3rd quarter	105.1	101.4	107	105	107	n.a.	n.a.	n.a.		
4th quarter	107.4	113.1	108	106	109					
1969 1st quarter	110.7	105.1	111	107	111	114	111	110		
2nd quarter	113.3	110.6	115	109	114					
3rd quarter	114.9	115.1	116	112	117	116	113	115		
4th quarter	116.5	116.6	120	113	119				Indexes available on basis only	
1970 1st quarter	116.4	116.4	121	115	121	120	120	119		
2nd quarter	118.9	121.2	126	116	125					
3rd quarter	116.7	134.0	128	120	129	126	116	122		
4th quarter	117.9	130.2	134	122	132					
1971 1st quarter	119.8	124.1	136	124	136	132	125	128		
2nd quarter	122.9	133.4	147	126	140					
3rd quarter	124.5	135.5	n.a.	129	143	140	132	132		
4th quarter	125.7	133.5	n.a.	131	147					
1972 1st quarter	128.1	135.5	n.a.	133	149	143	133	135		
2nd quarter	129.3	133.7	n.a.	137	152					
3rd quarter	131.2	141.2	n.a.	139	153	149	136	137		
4th quarter	135.6	144.4	n.a.	140	155					
1973 1st quarter	138.2	137.8	n.a.	141	159	158	140	143		
2nd quarter	144.1	145.9	n.a.	144	161					
3rd quarter	148.0	155.1	n.a.	147	163	166	143	151		
4th quarter	149.2	167.8	n.a.	149	165					
1974 1st quarter	152.0	187.4	n.a.	152	170	194	159	172		
2nd quarter	157.3	201.4	n.a.	156	189					
3rd quarter	161.4	209.7	n.a.	164	195					
4th quarter			n.a.	178	[1]200					

[1] An implicit price deflator, computed by the Bureau of the Census, which is the ratio of the estimate of total new construction put in place in current dol[lars] seasonally adjusted, to the corresponding estimate in 1967 dollars. In form, the index is a weighted harmonic mean of the deflators used for various catego[ries of] construction and, hence, of the basic cost indexes which make up these deflators), with weights proportionate to the value-put-in-place estimates seasonal[ly adjusted] for these categories. Since this "implicit price deflator" is in the form of a changing weight index, it measures the combined result of cost changes as well [as] changes in the weights of different types of construction in the current-dollar construction activity aggregrate. n.a.—Not yet available. [1]Revise[d]

Sources for each column as stated.

Table E-1 Supp.—Regional Price Indexes of New One-Family Houses Sold, Including Value of Lot. 1963 to 1973

(1967 100)

Year	United States	Northeast	North Central	South	West
1963	90.2	90.7	89.4	91.6	91.1
1964	91.1	87.4	88.4	92.4	94.0
1965	93.2	91.3	91.4	94.6	94.0
1966	96.6	95.2	96.0	97.0	97.4
1967	100.0	100.0	100.0	100.0	100.0
1968	105.1	108.2	105.7	104.0	103.4
1969	113.6	117.7	115.7	111.4	111.6
1970	117.4	124.1	116.2	116.7	114.9
1971	123.2	134.4	119.8	124.6	117.4
1972	131.0	143.8	126.6	131.1	125.5
1973	144.8	154.7	138.9	142.9	142.4

Source, Table E-1 and E-1 Supp.: U.S. Department of Commerce, Bureau (Construction Review, Jan./Feb. 1975, pp. 62-63)

2. Location Modifier

The effect of location may be reasonably accounted for by using "localizers" such as those published by McGraw-Hill Information Systems Company in their current annual "Dodge Construction Systems Costs" (Ref. 16). In the 1975 issue, for instance, Miami is listed with a factor of 1.02 while Jacksonville has a factor of 0.88. Thus, an installation in the Miami area is expected to cost approximately 1.02/0.88= 1.16 times as much as a similar installation in Jacksonville (Figs. 41 and 42).

Locality Adjustments	
Jacksonville, Fl	.88
Miami, Fl	1.02
Tampa, Fl	.93

Fig. 41. 1975 Dodge Construction Systems Costs (Ref. 16)

Similar factors are available from other sources of construction estimating data such as the current annual "Building Construction Cost Data" (Ref. 17) and the "Boeckh Building Valuation Manual" and bi-monthly supplement "Building Cost Modifier" (Ref. 18).

It should be emphasized that these modifiers are valid only for rough approximations of cost. Local contractors and engineers should be consulted for up-to-date local costs taking into account the individual characteristics of a particular site.

City Cost Indexes

Division	Jacksonville, Fl			Miami, Fl			Tampa, Fl		
	Mat.	Inst.	Total	Mat.	Inst.	Total	Mat.	Inst.	Total
Forms	100	85	89	100	98	98	96	85	88
Reinforcing	100	83	95	97	99	98	100	91	97
Cost in place concrete	100	73	91	100	100	100	100	90	96
Masonry	85	81	82	89	94	93	95	88	89
Metals	100	86	92	108	97	102	100	95	97
Carpentry	100	90	95	100	98	99	100	86	93
Moisture protection	100	80	92	100	97	99	99	84	93

Fig. 42. Means 1975 City Cost Indexes (Ref. 17)

ALTERNATIVES TO HARDENING THE SHORELINE

Three alternative approaches are available for protecting shorefront structures threatened by eroding shorelines:

(1) Relocate the threatened structure back a safe distance from the shoreline. Develop a balance of natural forces such as dunes and vegetation which will act as a natural defensive system.

(2) Build up the beach by artificial beach nourishment.

(3) Reduce the force of on-shore waves by groins or off-shore reefs or breakwaters resulting in beach accretion.

SUMMARY OF SHORE PROTECTION METHODS
(Adapted from Ref. 10)

	Shore Conditions	
	Any erodible condition	
	Offshore Conditions	
Protection Method	Flat to moderate offshore slope	Steep offshore slope
Relocation of structures behind natural defense systems	X	X
Artificial nourishment	X	
Beach accretion devices		
groins	X	
offshore breakwaters	X	
Armor the shoreline		
revetments		
stone; interlocking concrete block; bags filled with sand-cement mix; or gabions	X	X
Seawalls		
flat sheet pile of conc., steel or wood	X	X
massive gravity wall	X	X

1. Protecting Shorefront Structures by Relocation

Threatened structures may be relocated behind a natural defensive system if there is a suitable site available and a house-moving contractor is able to move the structure (Fig. 43). Shore systems often may be balanced by providing replenishment of the dune and vegetation system. Detailed design information on dune stabilization and enhancement is available in a Sea Grant report entitled Protection and Restoration of Beaches and Dunes Using Vegetation.

2. Rebuilding the Shoreline by Artificial Beach Nourishment

Where erosion of valuable beach shoreline occurs, artificial nourishment could be considered as one means of restoration. The advantages of artificial beach nourishment over hardened structures are:

A. the beach after treatment is still suitable for recreation,

B. nourishment does not adversely effect downstream areas,

C. if a design failure occurs, there are no large broken pieces of concrete or steel to be disposed of.

One major obstacle to many beach nourishment proposals is the problem of acquiring large quantities of sand of suitable type and size. In years past these sand deposits were often available from inland sounds, bays or adjacent land. However, in recent years there has been increasing concern with the ecology of inland bays and the nearby land has frequently been developed. Most future sources will probably have to be obtained from offshore sea bottom areas.

3. Cost of Beach Nourishment

The cost of sand for beach nourishment depends largely upon the source of the material and the method and distance of transport. For sand hydraulically dredged from nearby sources and transported short distances by pipe line, the cost can be as low as $1.00 per yard (Corps of Engineer charge in Jacksonville for dredged material, 1975). If the material must be excavated from borrow pits, transported and spread, an order of magnitude cost may be estimated as follows:

Cost of purchasing borrow pit	$0.25/cy
Excavation and loading	.10/cy
Hauling, round trip	.20/cy/mile
Spreading	.05/cy

Thus for a nourishment project located 5 miles from the borrow pit (10 miles round trip), the total cost would approximate $2.40/cubic yard ($.40/cy for purchase, excavation, spreading, and $2.00 for hauling). A rule-of-thumb estimates that for each 1 foot of visible recession of shoreline, the beach has lost 2 cubic yards per shoreline foot. Thus, for a mile of shore that has experienced 50 feet of erosion, a nourishment project replacing 528,000 cubic yards of sand is required (5280 ft/mi x 50 recession ft. x 2 cy/shoreline ft./recession ft. = 528,000 cy/mi).

4. Protecting the Shore with Beach Accretion Structures - Groins and Offshore Breakwaters

As the force of offshore waves is dissipated by groins or off-shore breakwaters, the suspended sand grains carried by these waves typically lose their forward velocity and gradually sink to the bottom. If the groins and offshore breakwaters are properly designed and installed, they will therefore function as beach accretion structures.

A. Groins

Groins are long, low finger-like structures that jut out from the shore and dissipate or deflect the erosive energy of water currents and waves before they can reach vulnerable areas of the shoreline.

Groins may be used to either maintain a beach with its present profile by deflecting or dissipating erosive currents and waves or build up a beach by trapping littoral sand passing along in the shallows seaward of the beach. Groins consist of low barrier walls extending seaward and, while usually intended to protect the shore, may often lead to shore erosion if not properly designed, installed, and maintained. If the upstream side of the groin is not filled with sand at the time of construction, a part of the natural littoral flow of sand along the coastline is usually intercepted by the groin and retained on the upstream side. The usual result is a build-up of sand on the upstream side with a consequent erosion on the downstream side. If the groin is too long, the sand carried around the end of the groin tends to become lost in deep water rather than provide nourishment for downstream beach areas (Ref. 4, pg. 221). See figures 44 and 45.

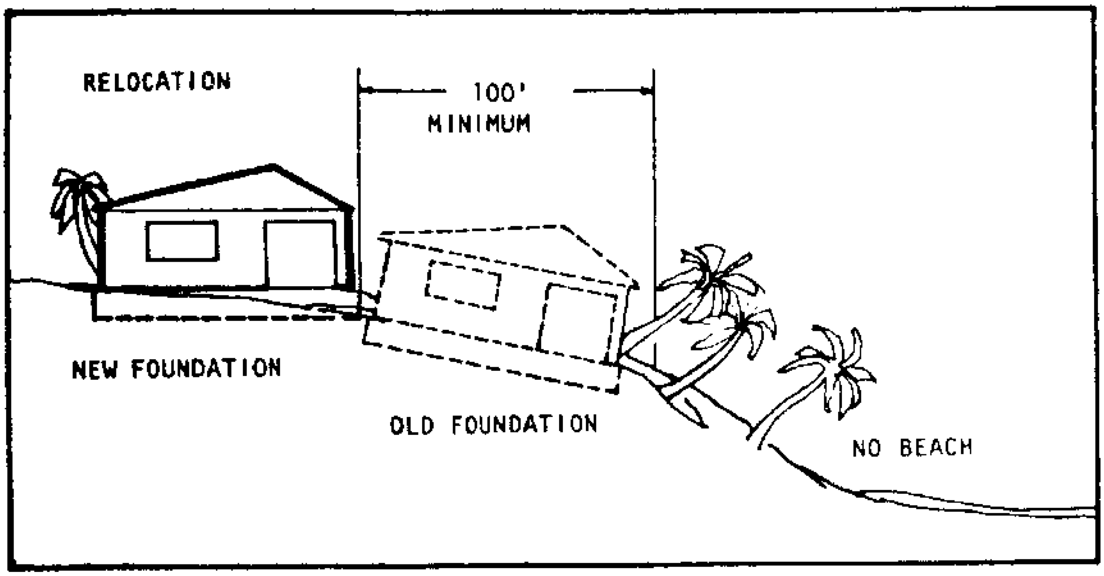


Fig. 43. Saving a Structure by Relocation

This alternative provides for the permanent relocation of homes subject to destruction by erosion induced foundation failure. Relocation is accomplished by home movers. The important planning consideration is the rate of erosion. Key design considerations are the condition of the home, foundation and utilities, access and obstructions, length of move, new foundation and utilities.

Notes:

Move 100' minimum or comply with state set back requirements.

Home moving is a highly specialized activity requiring a qualified home mover.

Recession Rates

Long term quantitative data on the rate of recession of the shore may be obtained from historic records of the area or the state. Early surveys and plat maps may contain survey points and a plot of the shoreline as of the date of the survey. Utilizing these existing data, a new topographic map can be prepared showing the historic location of the shoreline and the present location. The distance between the old and existing location documents the amount of recession in the period of record.

The average cost of moving a typical home is about $8,000, excluding the cost of land. This cost includes house moving ($3,500), new foundation ($3,500), and utilities and service ($1,000). The cost of a new lot varies considerably depending on location.

Continued

Figure 43, Continued

RELOCATION

Relocation is an alternative that cannot be overemphasized. Erosion is a natural geologic process that is extremely difficult to stop. The alternatives to build shore protection or to relocate must be weighed against the consequence of failure. Depending on the type of structure you might consider, it may cost the same to relocate as it would to build shore protection. Should a protective structure fail, then your investment in the structure is lost and your home or cottage is still in danger.

ADVANTAGES

It is permanent. In the long run it may be the best method of protection.

Adaptable to short reaches of shoreline.

Can be accomplished by the individual through contract with a house mover.

DISADVANTAGES

Special skills and equipment required.

Area must be available for relocation of the house.

Does not stop erosion.

COST/LIN. FT. - $80/ LF for 100' LOT

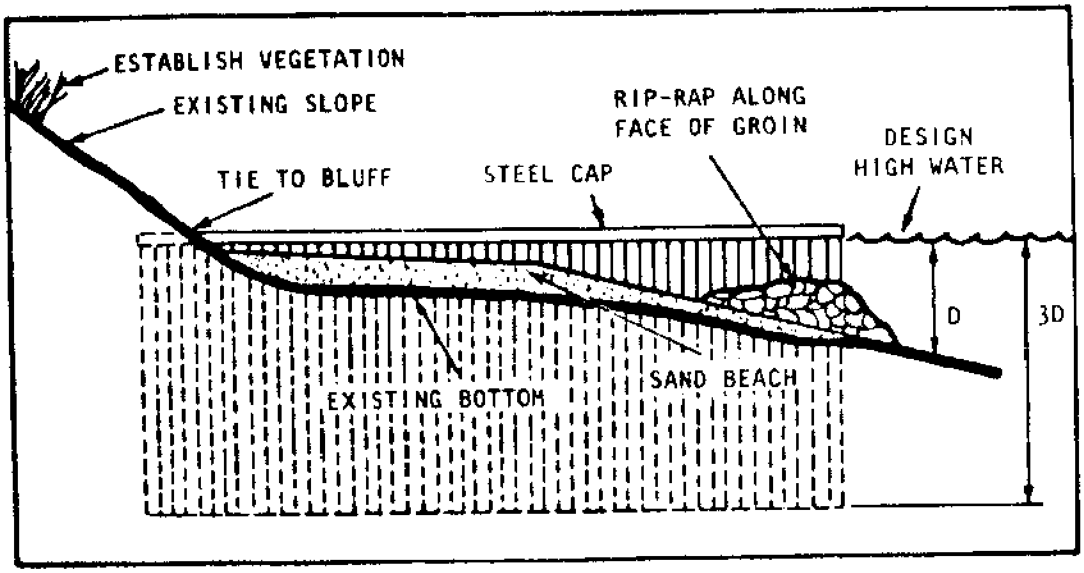


Fig. 44. Impermeable Groin

Protection of the shoreline by groins assumes sand is available and is moving along the shoreline. Groins can have the undesirable effect of damaging downdrift shores. The layout of groins is very important. Groins should be kept low, only one foot above the expected high water, and short, terminating at the 3 foot depth. Groins must be protected from flanking by tying them well into the bank. The maximum length of groins should not exceed 100 feet. If possible groins should be artificially nourished by placing sand on the updrift side of each groin.

Caution. Groins are shore protection structures that interfere with shore processes and entrap beach materials. Their use demands extreme caution to preclude major downdrift erosion. Consider them only in areas of substantial sand movement. Make them low so they will be overtopped by waves during storms. Groins should be constructed in stages, starting at the extreme downdrift end of the area to be protected. Study the effects of the single groin carefully before completing the layout of the groin field.

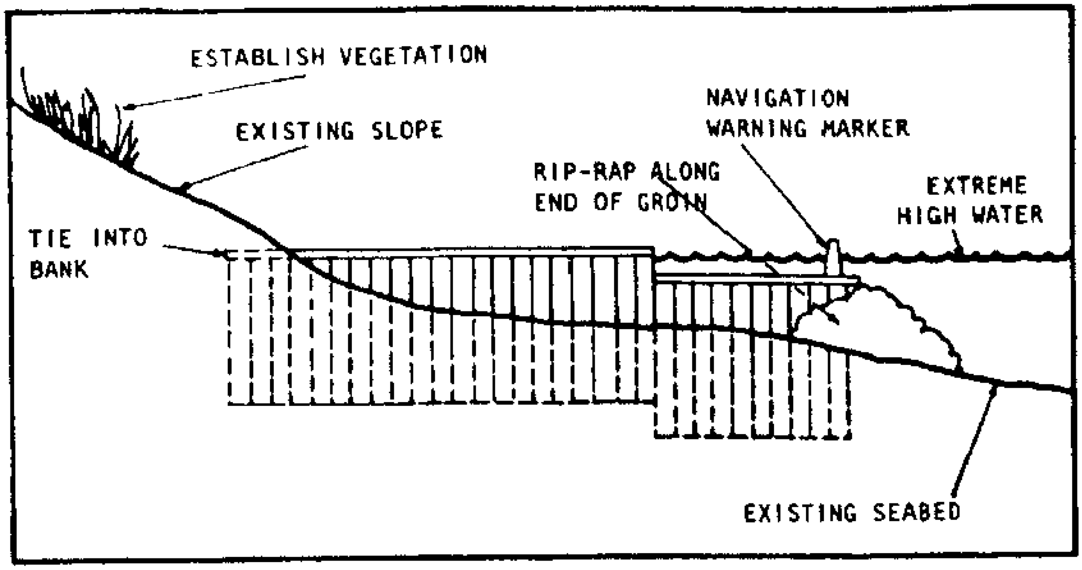


Fig. 45. Step down groin

ADVANTAGES

Resulting beach protects upland areas and provides recreational benefits.

Moderate first cost and low maintenance cost.

DISADVANTAGES

Extremely complex coastal engineering design problem. Qualified coastal engineering services are essential. Groins rarely function strictly as intended.

Areas downdrift will probably experience erosion.

Unsuitable in areas of low littoral drift (Sand movement).

Subject to flanking, must be securely tied into bluff.

COST/LIN. FT. - $140 to $160 (STEEL)

Continued

Figure 45, Continued

	Design depth of water 50' offshore (ft.)		
Dimensions	3 - 4	5 - 6	7 - 8
Steel Piling (length) (ft.)	115	65	
Steel Piling (wetted length)(ft)	100	50	Not
Depth (ft.)	15	15	Recom-
Groin Spacing (ft)	200	100	mended
List of Materials(per groin)			
Sheet Piling (tons)	27	16	
Timber Walers (tons)	3	2	
Stone Filter Blanket (tons)	90	90	
Stone Rip-rap (tons)	140	140	
Cost $/Lin. Ft.	140	160	

B. <u>Offshore Breakwaters</u>

Since the transport of water borne sand is largely dependent upon wave energy, any structure that reduces wave energy will usually reduce sand transport as well. Therefore, a breakwater barrier constructed offshore that reduces wave action at the shore also permits more sand grains to sink to the bottom as the water wave velocity diminishes. The result is an accumulation of sand in areas shoreward of the breakwater, sometimes extending completely from the shore out to the breakwaters (Ref. 4, p. 238). However, compensating downstream erosion may also occur if this new deposit of sand interrupts a littoral replenishment flow of sand from an upstream source (Ref. 4, p.276; Ref. 14).

Silvester and Ho (Ref. 14) report on this type of structure installed off a beach near Singapore. At this project the installed structures and resulting deposits are called "headlands." Each is essentially a breakwater of about 100 feet in length placed about 200 feet offshore, not quite parallel to the shore, and spaced about 800 feet apart. Two different types were constructed:

(1) gabions consisting of stone filled cages of 71 cubic feet capacity slung into position during low tide, ranging in elevation from 2 ft. below LWL to 1 ft. above HWL, involving an overall height of 13 ft. (Fig. 46).

(2) rip-rap constructed in the dry by overfilling the area, then excavating and dewatering. The dimensions are approximately the same as the gabions.

It was estimated the gabions cost about 50% as much as an equivalent revetment wall, while the rip-rap cost about 75% as much as the revetment. The rip-rap was preferred finally because of the rising price of PVC coated steel used in the gabions, and the problem of damage to the gabions caused by people searching for shellfish taking refuge inside the gabions (Ref. 4, page 307).

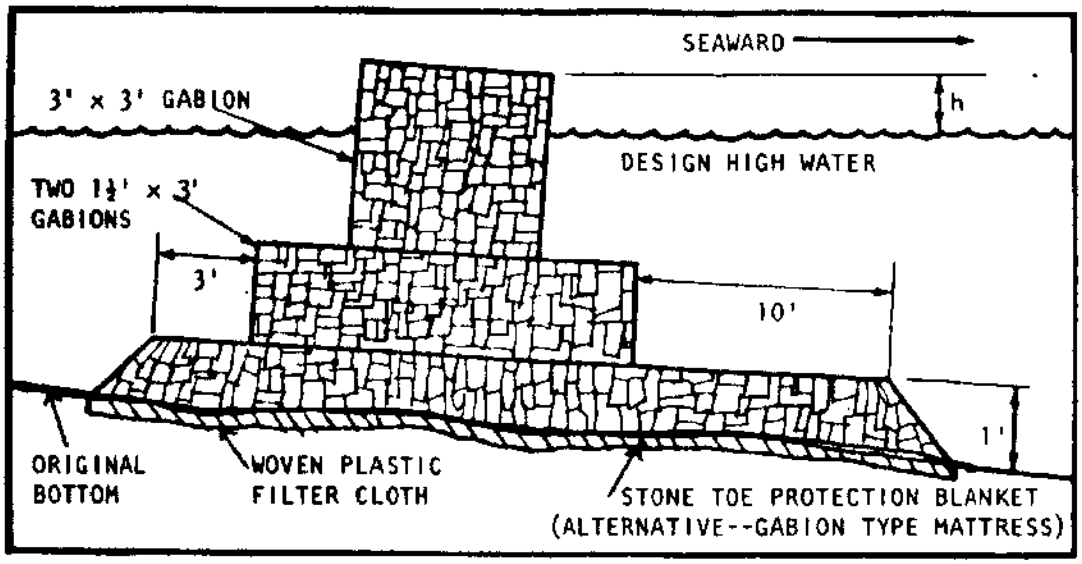


Fig. 46. Offshore Breakwater

Offshore breakwaters are an acceptable method of shore protection for flat or moderate offshore slopes. The design wave is based on water depth 50 feet seaward of the structure.

Offshore breakwaters can be constructed of any material capable of withstanding the wave energies impinging on them, including stone, gabions, steel, wood, and concrete shapes. A toe protection blanket is essential. Offshore breakwaters may be low structures to allow passage of wave energy or they can be high structures to completely block waves. They should be built in shallow water nearshore for reasons of economy. They can be continuous for long distances or segmented with passages between them to allow exchange of water.

Caution. Offshore breakwaters interfere with shore processes; their use demands extreme caution to preclude major downdrift erosion. Consider them only in areas of substantial sand movement. Make them low so they will be overtopped by waves during storms. Offshore breakwaters are difficult and expensive to maintain.

	Design depth of water 50' offshore (ft.)		
Dimensions	3 - 4	5 - 6	7 - 8
Height (ft)	1.5	2.0	
Apron length (ft)	10.0	10.0	Not
List of Materials			Recom-
Gabion-Stone filled (yd^3)	0.7	0.7	mended
Stone toe protection (yd^3)	0.6	0.6	
Cost $/Lin. Ft.	80	100	

Continued

Figure 46, Continued

ADVANTAGES

Beneficial effect can extend over a considerable length of shoreline.

Maintains or enhances recreational value of a beach.

The structure is not subject to flanking. It can be built in separate reaches.

Gabions can be constructed on shore and transported to site by ordinary earth moving equipment.

Tends to build a natural beach between the breakwater and the shore.

DISADVANTAGES

May modify beachline and cause erosion in downdrift areas.

Structure is subject to foundation and scout failures; floating plant and heavy equipment may be required for construction.

Gabions may be damaged by floating ice or logs.

Extremely difficult to repair.

COST/LIN. FT. - $80 to $100

PERMITTING PROCEDURE FOR WATERFRONT CONSTRUCTION

Permits must be obtained for most types of waterfront construction, usually from all three levels of government, the local, county or city, the state, and the federal government. In Florida, there are four principal agencies involved on the state level:

1. The Trustees of the Internal Improvement Trust Fund (TIITF)
2. The Department of Natural Resources (DNR)
3. The Department of Pollution Control (DPC)
4. The Game and Fresh Water Fish Commission (GFWFC)

In addition, the U. S. Army Corps of Engineers (USACE) has jurisdiction over all navigable waters for the federal government while county and city governments have local jurisdiction over all development within their boundaries. Each level of government must be consulted. A permit from one does not imply permission from the others. Figure 47 indicates the primary concerns of each.

The typical step by step procedure for obtaining a Coastal Construction Permit for seawalls, breakwaters, groins, etc. below the mean high water line is as follows:

1. The applicant submits plans for approval to the county or city in which the project is located and obtains approval.

2. The applicant submits the locally approved plans to the Lead or Contact agency or agencies designated in Fig. 47, "Environmental Permitting Matrix":

    A. a field investigation of the proposed project is initiated;

    B. riparian owners within 1000 feet of the project are notified and given opportunity to comment; and

    C. notices are sent to the other state agencies designated under Agency Involvement in the Permitting Matrix

3. Every Friday, the Trustees of the Internal Improvement Trust Fund sponsor a meeting in Tallahassee with representatives of the state agencies concerned with waterfront development. Should problems arise, the applicant may attend any of these meetings for advice and counsel regarding the proposal.

4. If the problems can be resolved satisfactorily, the proposal receives approval and a permit.

5. The applicant sends the proposal to the Army Corps of Engineers. The Corps advises other federal agencies and interested parties and provides opportunity for comment. Upon meeting Corps requirements, a construction permit is issued.

6. The project is constructed and a certificate of completion is filed with

FIG. 47. ENVIRONMENTAL PERMITTING MATRIX *

ACTIVITIES	AGENCIES: Dept. of Natural Resources ** — Beaches & Shores	Dept. of Natural Resources ** — Survey & Management	Trustees of the Internal Improvement Trust Fund	Game & Fresh Water Fish Comm.	Dept. of Pollution Control	Dept. of Transpor-tation	Div. of State Planning	U.S. Army Corps of Engineers	U.S. Coast Guard	U.S. Navy
Coastal Construction										
Hydrology		X					●	X	●	
Dredge & Fill	●	●	X	●	●			X		●
Boat Ramps	●	●	X	●	●	●		X		
Biological Concerns		X	●	X	●			X		
Marina Licenses	●	●	X		●			X		
Artificial Fishing Reefs		●	X		●			X	X	●
Water Quality		●	●	●	X			X		
Sanitary Facilities					X					
Bicycle Trails						X				
Catwalks		●	X			X		X		
Navigability		●	X		●			X	X	
Aids to Navigation			X					X	X	●

* The information contained in this matrix is intended for use as a general guide, and the actual permitting responsibilities are subject to change if agency organizations are restructured by the 1975 Florida Legislature

** The Division of Recreation and Parks and the Division of State Planning are not listed in this matrix since they are not permitting agencies, however, each has a concern for each of the activities and is available for assistance upon request.

X Lead or Contact Agency

● Agency Involvement

the appropriate agency.

The various agencies that review the project will each look at it from a different viewpoint since each is responsible for protecting the State's interest in a different area of concern. The agencies and their respective areas of concern are described below.

1. The Trustees of the Internal Improvement Trust Fund (TIITF)

This department is charged with managing all state owned lands not under the jurisdiction of other agencies. The state owns all land that lies below the mean high water level and that has not been previously transferred to private ownership. Therefore, the TIITF exercizes proprietory rights, and jurisdiction over all such land is concerned with any development that affects it either directly or indirectly. Direct jurisdiction of the TIITF is limited to areas below the mean high water line. However, in managing the state's property below this line, they are naturally concerned with damage that could occur as a result of development above this line. In addition the TIITF has regulatory jurisdiction over privately owned submerged lands under navigable bodies of water. A simplified permitting procedure has been implemented for small projects, defined as costing less than $5000 and involving less than 5000 cubic yards of material. These may be processed through any of the TIITF six field offices. The TIITF evaluates applications on the basis of proposed affect in three areas of concern:

A. natural resources including aquatic life habitat

B. navigation

C. rights of nearby riparian owners.

In areas where a natural shoreline currently exists, the TIITF prefers retention of the natural shore. If hardening of the shoreline is required, a sloping rock revetment may be accepted. Where dredge and fill have already altered the natural shore, vertical structures are acceptable providing no further damage or degradation of the area will result.

In addition to looking after their own concerns, the TIITF also acts as a clearing house for the concerns of other state agencies with jurisdiction over waterfront development. It sends copies of the application to the other agencies, receives comments and recommendations from them, and hosts Friday meetings where all concerned can meet with the applicant and discuss problems involved with each proposal. Often modifications to the project can be agreed upon during these meetings and a permit subsequently issued. (If no agreement is reached, the proposal may be appealed to the Governor and Cabinet and from hence to the Courts.) When all appropriate state agencies are satisfied, the TIITF issues either an "exemption permit" (for projects of less then $5000 and 5000 cy) or a permit for coastal construction. The average time from application to permit is about 5 weeks on successful "exemption permit" projects. On larger projects about 4 to 8 months is required including a 3 month initial period for accumulating comments and recommendations from other state agencies and concerned individuals.

2. Department of Natural Resources (DNR)

This department is concerned with the protection of Florida's natural resources on both privately and publicly owned property.

The Bureau of Beaches and Shores of the DNR requires a permit for any coastal construction undertaken upon state lands below the mean high water line of any body of tidal water. Coastal construction is defined as any activity likely to have a material physical effect on existing coastal conditions or natural shore processes. All activity undertaken specifically for shore protection purposes must have a permit, as well as all other structures and physical activity which by their nature and design might have similar effects. This includes groins, jetties, moles, breakwaters, seawalls, revetments, causeways, and artificial nourishment or other deposition or removal of beach material. Docks and similar structures are also included if of a solid or highly impermeable design.

3. Department of Pollution Control (DPC)

This department is concerned with environmental quality in the areas of air and water pollution, solid waste, and noise. Regarding waterfront development, they are concerned with maintaining water quality, especially turbidity, during construction as well as for the subsequent operational life of the development. They are especially concerned with protection of aquatic habitats from the damaging effects of increased runoff resulting from development.

The DPC reviews all applications submitted to the TIITF. The DPC may then

A. issue a certificate of water quality,

B. waive the requirement for a certificate, or

C. refuse a certificate.

If the certificate is refused, counseling is available on measures required to gain acceptance.

4. Game & Fresh Water Fish Commission (GFWFC)

This department is concerned with management and protection of wildlife and fresh water aquatic life. Any project affecting habitat of fish and wildlife will receive careful review and comment.

Concerning bulkheads and seawalls, the general policy of the department is based on the following guidelines:

A. all bulkheads should be placed at or above the mean high water line

B. existing shoreline vegetation, if any, should remain undisturbed to protect the existing shoreline;

C. where shoreline vegetation does not now exist, it should be cultivated by constructing suitable growth areas waterward of the bulkhead;

D. rubble rip-rap bulkheads may be acceptable in some locations instead of vegetation.

5. Federal Permit

After receiving a permit from the local government and the State of Florida, applicants must obtain a federal permit from the Department of the Army, whose primary concern is the effect of the proposed construction on public rights of navigation in navigable waters. Applications should be made to the U. S. Army Corps of Engineers at the appropriate district office listed below:

For Florida west of the St. Marks River:

The District Engineer
U. S. Army Engineering District, Mobile
P. O. Box 1169
Mobile, AL 33601

For Florida north of Fernandina Beach:

The District Engineer
U. S. Army Engineer District, Savannah
P. O. Box 889
Savannah, GA 31402

For the remainder of Florida:

The District Engineer
U. S. Army Engineer District, Jacksonville
P. O. Box 4970
Jacksonville, FL 32201

16. Other

Applicants should also check to insure their proposal complies with local zoning regulations, building codes, and similar requirements of the city, county and/or special local district.

SUMMARY OF SEAWALLS AND REVETMENTS

SUMMARY OF SEAWALLS AND REVETMENTS

Vertical Seawalls of Flat Slab or Sheet Piles with Toe Penetration and Tie-Backs to Anchor

	General - Seawalls	Precast Concrete Slab	Steel Sheet Pile	Wood Sheet Pile	Massive Free-Standing Gravity Seawall
ADVANTAGES	a) Relatively fast construction time. b) Provides good protection for eroding or unstable shoreline. c) Low maintenance costs. d) Widely used. Experienced designers and contractors are available. e) Vertical face provides for easy mooring or lifting facilities for boats, or deeper water close to shore for fishermen.	a) See all advantages listed under "General - Seawalls." b) Concrete is usually more durable for the same or less cost.	a) See all advantages listed under "General - Seawalls." b) Steel has more strength per pound, requiring less tonnage of material transported to the job site. c) Often the only practical alternative where long piles are required. d) Steel may be driven immediately without curing, shortening the construction time. e) May be driven or jetted.	a) See all advantages listed under "General - Seawalls." b) Wood is usually the lowest cost material. c) Wood appearance blends better with natural surroundings. d) Wood is easier to cut and shape.	a) Provides protection from severe wave attack. b) Low maintenance cost. c) May provide suitable base for roadway or walkway along crest.
DISADVANTAGES	a) Structural security depends upon adequate i) toe penetration and protection ii) tie-back rod strength and anchorage iii) maintenance of supporting backfill behind the wall. b) Vertical walls induce scour at toe. c) Complex engineering design problem. d) Construction requires special pile driving skills and equipment. e) Limits access and use of beach. f) Incompatible with conditions required for some forms of natural animal and plant shore life.	a) See all disadvantages listed under "General - Seawalls." b) Concrete used in marine environment requires special skill in design and construction. c) Concrete slabs require either extra time for on-site curing or hauling heavy slabs from stock pile. d) Slabs usually jetted into place to avoid spalling or cracking under driving hammer blows.	a) See all disadvantages listed under "General - Seawalls." b) Subject to corrosion if not kept adequately coated. (Marine resistant steel composition and cathodic protection may reduce corrosion)	a) See all disadvantages listed under "General - Seawalls." b) Subject to attack by marine borers and fungi if not properly treated or coated.	a) Usually very expensive. b) Security depends upon adequate foundation and protection of foundation material. c) Downward component of deflected wave energy induces scour at the toe. d) Complex design and construction problems require special skills and equipment. e) Limits access and use of beach. f) Incompatible with some forms of natural animal and plant shore life.
COST	(All costs are estimated for a Construction Cost Index of 2100. See section "How to Estimate Current Local Costs of Shoreline Protection Structures" for information on updating.)	$43/LF to $130/LF	$220/LF to $330/LF	$60/LF to $120/LF	$300/LF to over $1100/LF

SUMMARY OF SEAWALLS AND REVETMENTS

Revetments

	General - Revetments	Precast Concrete Checkerboard Revetment	Stone Revetment	Revetment of Nylon Bags Filled with Cement Grout	Revetment of Stone-Filled Wire-Cage Gabions
ADVANTAGES	a) Usually the least expensive hardened protection for the shoreline. b) Constructed of individual articulating units able to accommodate some settlement. c) Provides sloping surface and more surface area on individual units to accommodate more forms of natural animal and plant shore life. d) Sloping surface is more acceptable to state agencies due to less adverse effect on shoreline.	a) See all advantages listed under "General - Revetments." b) Provides for access to beach over easily traversed slope. c) Indented pattern may trap sand and become covered with beach.	a) See all advantages listed under "General - Revetments." b) Natural stone provides most surface area for accommodation of marine shore life. c) Repairs often require only the addition of more stone. d) Rough surface is most effective in dissipating wave energy. Reduces wave run-up. e) Suitable for stage construction.	a) See all advantages listed under "General - Revetments." b) Requires only small equipment and mostly unskilled labor. c) Suitable for stage construction. d) Low initial cost. e) Rounded, non-hazardous surfaces f) Blends well with surroundings. g) Repairs are easy, add more bags.	a) See all advantages listed under "General - Revetments." b) No special equipment required. Suitable for do-it-yourself. c) Flexible, easily repaired. d) Low first cost.
DISADVANTAGES	a) The light armor facing depends for stability upon the underlying base. b) If surface is not sufficiently rough to dissipate the wave energy, the upward deflection of the sloping face may cause overtopping. c) If the filter fails, the underlying material is easily lost through the open joints. d) An underlying cushion of gravel over the filter cloth is required to prevent puncture by sharp projections on rough units or to prevent uplift under smooth units.	a) See all disadvantages listed under "General - Revetments." b) Units are light weight and depend on keying action for stability under wave attack. c) Gravel layer is required between concrete and filter to prevent uplift. d) Loss of supporting material may require disassembly of revetment to restore contour. e) Severe wave attack along Florida's east coast has led to some failures.	a) See all disadvantages listed under "General - Revetments." b) Hard dense igneous rock is not native to Florida and must be imported in scarce gondola cars causing extra expense and scheduling problems. c) Sharp projecting surfaces make beach access difficult and hazardous. d) Underlying gravel over filter cloth is required or rock may sink. e) Heavy equipment required for construction.	a) See all disadvantages listed under "General - Revetments." b) Smooth surfaces do not interlock. (Reinforcing rod dowels may be installed to compensate.) c) Smooth rounded surfaces may become slippery and hazardous for pedestrian footing.	a) Wire cage gabion subject to corrosion if coating not maintained. b) High level of maintenance effort often is required.
COST	(All costs are estimated for a Construction Cost Index of 2100. See section "How to Estimate Current Local Costs of Shoreline Protection Structures" for information on updating.)	$300/LF to $500/LF	$30/LF to $110/LF (about $25/ton)	$90/LF to $130/LF	$30/LF to $80/LF

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