CHAPTER 15

SOME ASPECTS OF SHORE PROTECTION IN BOSTON HARBOR

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INTRODUCTION

At the end of World War II, the newly created Port of Boston Authority was faced with embarking upon an extensive belated shore protection program. The funds for the projects were approved by the State Legislature based on pre-war estimates and with the proviso that the affected town or city must pay an equal amount towards the total cost of such work. In the face of rising costs of labor and materials, it was obvious that appropriations were inadequate to permit construction of the proposed seawalls unless a more economical type could be found. This was primarily the reason, along with a natural desire to gain more knowledge and obtain basic design criteria, that the Authority made a comprehensive study of existing shore structures along the Atlantic coast.

I personally became so wrapped up in the subject that I spent one whole summer traveling around on my own time during week-ends. It is a very fascinating subject, I assure you, because of its endless and unknown problems which tax one's ingenuity and knowledge for a solution.

The survey and study indicated a wide range of thinking as to basic concepts of shore protection engineering, design and construction materials. I do not wish to be critical, but the survey did indicate a need for more dissemination of the latest engineering concepts and more thought to the individual problem. There was a noticeable lack of periodic beach condition surveys after construction of shore protective measures. Without such surveys, it appears impossible to evaluate the protective maintenance action. The following aspects were noticeably lacking in consideration:

(1) Measures for stabilization of beach.
(2) Coordination and correlation of sectional measures into the over-all picture.
(3) Selection of materials for economy and proper function.
(4) Over-topping of seawalls by impinging waves.
(5) Attrition of wave energy as much as possible before meeting a more or less vertical barrier.

"PERMEABLE" SEAWALL

GENERAL CONSIDERATIONS

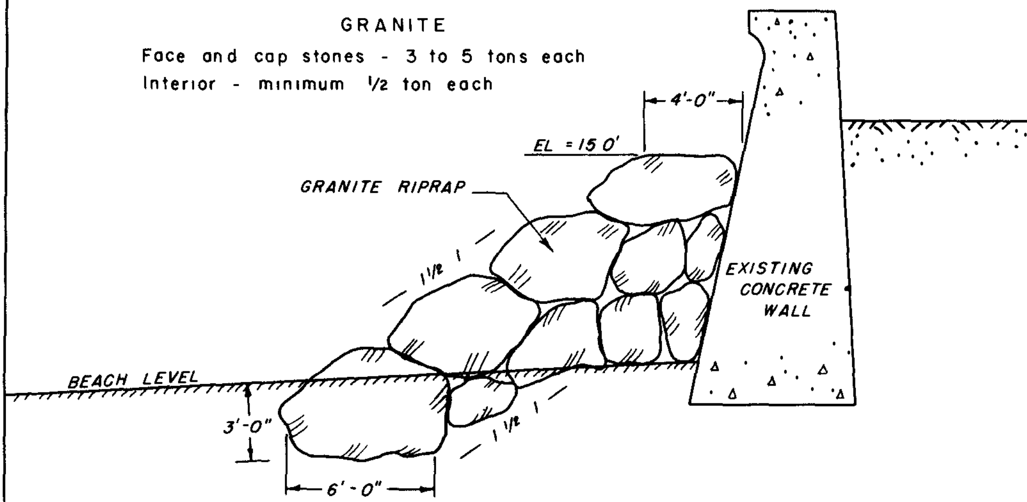
As the economic justification for shore protection is often dubious, it becomes necessary to design a seawall at the lowest cost possible, consistent with satisfactory performance. In our attempt to find a suitable type of seawall to be followed in the program of shore protection in Boston Harbor, the following standards were established for evaluation:

(1) Low cost
(2) Minimum maintenance
(3) Pleasing appearance
(4) Flexibility
(5) Low wave over-topping consistent with low wall crest

The so-called permeable type of seawall satisfied all these requirements. The low cost is achieved by the use of rip-rap stone in the base. This is plentiful and very reasonable, varying from \$3.50 to \$5.00 per cubic yard measured in place. The cost of placing the rip-rap is very low, as the stone is placed entirely by crane with a skilled operator. The crane also accomplishes the excavation immediately ahead of the wall, therefore eliminating costly cofferdams and the pumping involved with a rigid type of seawall regardless of the tidal conditions. It also permits the performance of the work in the winter months when construction activity is very small and during inclement weather, a factor which is reflected in the competitive bids received on the work. The plain concrete cap can be either precast or cast in place, at the discretion of the contractor. The quality of the concrete is normally much better, as it is poured under more satisfactory conditions and does not come in contact with the seawaters in any way during the curing period. The cost of the concrete is about \$25.00 per cubic yard in place. Excavation generally costs about \$1.00 per cubic yard.

Flexibility is achieved because of the fact that the wall is made up of many individual components, and therefore it would not be adversely affected by differential settlement and horizontal movement as would a rigid concrete seawall. One very interesting and unusual attribute of this type of wall is in connection with shores having poor foundation soil condition, such as peat and silt underlying granular beach material. Since the structural stability and integrity of the wall are unimpaired by reasonable settlement or movement, it has been used under such conditions satisfactorily. The only differences in construction are a 12 inch layer of quarry chips as a blanket over the entire foundation of the wall before placing the rip-rap and the excavation of the foundation is sloped uniformly from toe to heel. A typical cross-section of the seawall is shown on Figure 1.

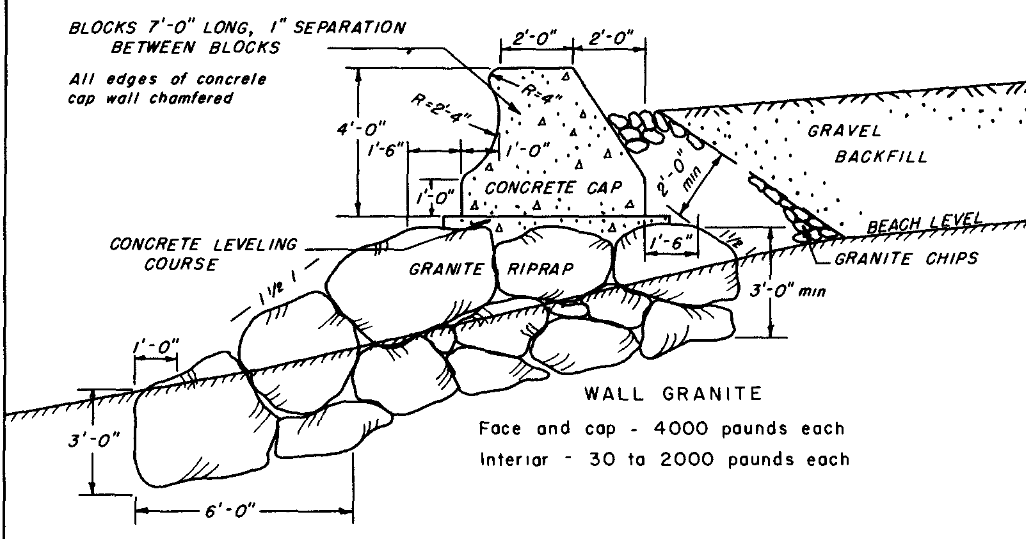
The two-tone color combination of the rip-rap base and the concrete cap, along with the pleasing lines of the cap, makes the wall appear very attractive as shown on Figures 3, 4, and 5. The maintenance is low, as the abrasion of the wall by the coarse beach material carried by the impinging waves is best resisted by the granite rip-rap. The concrete which is not so resistant is above the abrasion zones. The wall with the slots in the cap and voids in the base permits seepage of ground water behind the wall, thus eliminating any heaving of the wall as result of freezing and thawing of entrapped water.



TYPICAL CROSS-SECTION

SEA WALL REINFORCEMENT IN BOSTON HARBOR

FIGURE 1



TYPICAL CROSS-SECTION

PERMEABLE SEA WALL IN BOSTON HARBOR

FIGURE 2

Fig. 3.

Fig. 4.

Views of "Permeable Seawall" constructed at North Weymouth, Massachusetts. Note groins on beach.

Fig. 5. "Permeable Seawall".

Two conditions which made the problem difficult were the great water depth variation at the barrier and the necessity to locate the structure on geographical and economic considerations. The main tidal variation is 9½ feet, with Spring tides of about 12 feet. In the layout the shore barrier is placed as high on the beach as possible and still permit a smooth and easy shore configuration coordinated in the comprehensive long range protection program.

A great deal of thought was given to mitigating overtopping of the seawall consistent with low wall crest height for economical and effective coastal protection. There are a number of factors that were taken into consideration in attaining a more effective design, namely, the use of a rough sloping barrier base for changing the horizontal wave momentum into a vertical component in order that attrition may result from opposing gravitational pull, and a curved re-entrant face of the cap to turn back the diminished remaining force of the wave. Another factor which has been observed to cause attrition of wave energy is a rough surface and voids in the rip-rap face. The wave, as it moves up the slope, encounters flow resistance from the rough surface and from the gushing in and out of water in the voids. A system of groins will also reduce wave energy by setting up turbulence in the wave flow, besides maintaining beach slopes.

DESIGN

Unfortunately, at the time of the design of this type of seawall we did not have the intensely interesting and helpful article of Eduardo de Castro entitled "Rock Fill Dams and Dikes" which was translated by Mr. D. Heinrich of the University of California, edited by Dr. M. A. Mason of the Beach Erosion Board, and published by the Board Bulletin in Volume 3, dated January 1, 1949.

The effective height of the wall was determined basically to cut down the over-topping during wave attack to non-damaging proportions. However, a minimum satisfactory wall crest was very desirable as it greatly affected the economics and determined whether or not criticism would be forthcoming from owners of developed shore areas on account of blocked seaward view. The first section of wall constructed was designed in accordance with the "Cycloidal" theory and compared with observations made of the performance of existing structures in the Harbor. After this section was completed and evaluated for performances, it became the criterion for all subsequent sections in the harbor. The height of the wall for any particular location would be referred to the test section and varied to take into consideration differences of fetch, direction and magnitude of the expected most severe storms, distance of wall up on beach slope from point of breakers and steepness of beach slope. With the great variation in water level from both gravitation and storms, the wave analysis becomes very difficult. In all cases the normal maximum conditions are used, such as a 12 foot maximum

Fig. 6.

Fig. 7.

Views of typical seawall reinforcement with granite rip-rap. Note groins on beach.

Fig. 8. Typical rip rap beach groin.

tide, instead of the highest recorded water level of 15 feet above mean low water in Boston Harbor.

The toe at the slope of the rip rap base is placed at least 3 feet below the beach level in order to prevent failure of the wall from erosion and to anchor it securely from displacement caused by breaking waves. The slope of the rip rap face has been found to be most satisfactory between the limits of $1\frac{1}{2}$ and 2 horizontal to 1 vertical and tangent to the curved re-entrant face of the concrete cap. The exterior stones of the rip rap base should be as large as possible and securely interlocked against movement. The interior mass should be compact, consisting of stones large enough to block the interstices in the face.

The fill at the back of the wall should have a vertical layer consisting of a well assorted mixture of quarry chips or grout to develop passive pressure capable of resisting horizontal and overturning forces besides providing excellent drainage. No evidence of damage from wave impact in water filled interstices has been observed.

A necessary adjunct of this seawall is a system of rip rap groins. These groins project about $3\frac{1}{2}$ feet above the beach, and are relatively short in length, about 100 feet. The cost is about $5.00 per linear foot.

REINFORCING VERTICAL CONCRETE SEAWALLS

There were a number of old plain cement concrete seawalls with a vertical face which showed evidence of bad scour at the base from the abrasive action of coarse beach material carried along with impinging waves. This condition was so bad that failure of the wall was imminent unless immediate repairs or corrective measures were taken. Under severe wave attack considerable over-topping of the wall was observed. There was also another condition which had to be taken into consideration - evidence of lowering of the beach from erosion.

The corrective action consisted of a rip rap base in front of the wall on a $1\frac{1}{2}$ to 1 slope extending up to the level of maximum high water, with a system of rip rap groins to stabilize the beach (Figures 2, 6, 7, and 8). The rip rap base reinforcement not only was more abrasion-resistant, but it presented a more energy absorbing face along with less base turbulence. The reinforced wall observed now undergoing severe wave attack shows considerably less over-topping.

CONCLUSION

Under conditions such as we have in Boston Harbor the "permeable" type of seawall has been found satisfactory in every respect. About 4 miles have been completed since 1947, and a commitment has been made for the construction of 8000 feet next year. Continuous observations are being made to uncover unanticipated functional characteristics and to improve upon our present design criteria. The economic approach in the engineering design for the use of low cost local construction materials is well illustrated.