

COASTAL ENGINEERING

Chapter 21

ECONOMICS OF COASTAL STRUCTURES

Colonel E. E. Gesler
President, Beach Erosion Board
Department of the Army, Washington, D. C.

The engineer is constantly called upon to make an economic analysis of proposed engineering works. His analysis is just as trustworthy as his base information. In some cases experience and knowledge are so complete that an estimate can be accepted with assurance of great accuracy. The purpose of this paper is to discuss some of the factors involved in making an economic analysis of coastal structures.

The coast line of this country provides many examples of all types of structures in various degrees of preservation and effectiveness. Some of those in the best physical condition after a long period of time show little evidence of past effectiveness. At the other extreme are structures in poor physical condition and obviously ineffective. To determine whether structures have been both functionally effective in their life time and of sound construction to withstand the elements to which exposed would require very careful analysis, but such an analysis would give a measure of the expense of providing an engineering solution to the problem involved. It would provide an answer to the question of whether it was worth the cost. The designing engineer is not always in a position to make such a post mortem case study, his principal attention being given to making estimates of the future. However works of governmental units investing in such works provide material for constant appraisal of results which can be used to bolster estimates for future work. Governmental units, as private owners, are concerned with getting the maximum returns from investments. Engineers serving such masters must take cognizance of past experience in order to improve service in the future.

In utilizing works of the past, or in designing current structures, several elements must first be evaluated. These may be listed as follows:

a. What is the purpose of the structure? What is its value to the owner, assuming functional adequacy of structure? This is expressed in terms of the benefit in Corps of Engineers procedures. Obviously the value of benefits, acceptable to the owner, must exceed the cost of the structure.

b. Was or is the structure functionally adequate for the purpose? This question, insofar as coastal structures are concerned, is more easily answered for the past than stated with assurance for the future. A structure which has been in use for several years will show by its action whether it has accomplished all that had been anticipated, with minimum disruptive collateral effects. A functionally adequate structure is one that accomplishes its purpose rapidly, constantly, and with minimum additional works. It will be that structure which is located and layed out

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with reference to all known forces so that it accomplishes the purpose with the most economical structural design requirements.

c. Was or is the structural design adequate for the exposure? Again, judgment must be used in evaluating this factor. One can be charged with expensive over design as well as underdesign. Was there a calculated risk involved and was it properly evaluated?

These questions will be discussed with particular reference to studies of the Beach Erosion Board.

EVALUATION OF BENEFITS

An engineering study is undertaken when local authorities believe that an engineering solution to their problem may be justified. This presupposes that the anticipated benefits would justify the expenditure of funds. While some of the benefits may have to be reevaluated and the suggested engineer solution may open up additional benefits the basic estimate of benefits precedes the engineer study.

Beach Erosion Board studies are concerned with shore protection and collateral effects on the shore line caused by navigation structures. Benefits are therefore associated with preservation of a shore line. Since a beach is often involved, special consideration of benefits of a beach must be included in appropriate cases.

Benefits under these circumstances are classified as direct and indirect. The direct benefits are those which can be evaluated with some accuracy whereas the indirect are intangible and only related to an indeterminate degree with the engineering improvement. Direct benefits are further broken down into damage prevented, enhanced value of shore property by reason of the improvement, and, in certain cases, recreation.

The usual manner of calculating damage to shore property is to consider the value of land lost annually, due to wave action based on the value per square foot. This method assumes an unlimited area of constant value which can be eroded. In developed shore property this is not the case. A lot may be of a certain value when 100 feet deep but quite a different value per square foot after the seaward 75 feet have been eroded. Unchecked erosion may therefore introduce a further direct damage due to changed use which can also be expressed as an average annual damage. In like manner roadways and utilities may introduce special types of direct damages due to unchecked erosion. An air strip, if shortened or breached unduly, could destroy the effective use of an airfield. Thus direct damages prevented must be given individual treatment to fit each case and the amount reduced to an annual rate to facilitate comparison with other costs.

Upon the assumption that erosion can be checked, property values are enhanced to the extent that higher uses are then opened. Property values without improvements provided later by new investments are involved. With

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an assurance that further loss of land or structures will not be caused by encroachment of the sea, property may be used for more permanent or higher class uses. In the case of roads and utilities it may justify the location of more important structures along the shore line. In all these cases, enhanced value of the existing land or property only is considered. This is expressed on an annual basis by a fair rate of interest on the increase in valuation.

While a beach is classified as a protective structure it also has value as a recreational asset in most cases. In beach resort communities such as Atlantic City it represents such a valuable asset that expenditure of large sums of money can be justified in preservation of the recreational beach. The benefits of a beach must therefore be evaluated consistent with the local situation. This varies from being the central asset in the economics of the community, through a simple community recreational beach park to a beach having current value solely as a protection to the shore line. Where the beach has a value there may be justification for holding or restoring it to its optimum width for the purpose intended, whether for recreation or protection of the shore line. Benefits of stabilization of the beach width may be calculated then as for the shore property in terms of damages prevented and enhanced value per square foot of beach. Such evaluation considers the beach to have a value as property.

In determining the value of a beach for recreation consideration is further required of several factors contributing to an optimum beach such as:

- a. The material in the beach. Sand of median diameter less than .4 mm. is preferable.
- b. The slope of the beach. About 1/50 is optimum with a berm width between 100 and 200 ft.
- c. The suitability of the water. It must meet public health standards to be used as a beach and the temperature for bathing should be between 65° and 80° F.
- d. The accessibility to users. Communications must be adequate and population within using distance should be sufficient to support a beach population of one person to each 100 sq. ft. of beach above H.W.
- e. The amenities provided. Bathhouses and pavilions should be adequate for the designed beach population.

The popularity and value of a beach must be judged by its current or past use, or by analogy in relation to other beaches of the same character. Because of the many intangible factors involved, judgment must be formed

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of the probable beach population which would use the beach, regardless of how provided, and what the value would be to those using it. The factors can be evaluated by a careful survey of public opinion using recognized statistical procedures, but as a workable average, 25 cents per person per visit using the beach up to a population of one person per 100 sq. ft. of beach may be used and beyond that a flat value of 25 cents per day of use per 100 square feet of beach above high water. These estimates when adjusted for cost of operation and maintenance of a beach for recreation will permit calculation of the annual recreational benefit of a given beach. Deviations from the average should be supported by careful analysis of the factors contributing to the optimum beach.

A resort community, such as Atlantic City, presents a special problem in that the business life of the community depends upon the fame and popularity of the beach, even though relatively few visitors to the community go there for bathing, but rather to view and mingle with the bathers. The beach may not be the sole reason for the intensive business conducted in the community but the business life would wither without the beach and therefore as in Atlantic City, business will support any beach expense within reason regardless of number of bathers. A measure of the importance of a beach to business will be found in the difference in the amount of business during the bathing season and the non bathing season. Not all of this difference can be attributed to a good beach but a certain proportion may be so credited as a benefit. Depending upon the importance of the beach to the resort business, from 10 to 25% may be taken. Not all people will agree on this allocation and these figures are offered only for consideration. The effect is to place a value on the beach well beyond that which would be found in a beach park. Because of the difficulty in assessing the value of business attributable to the beach the Beach Erosion Board has favored considering this an indirect benefit.

Other indirect benefits are found in benefits to the community at large such as reduced juvenile delinquency or crime, and a more healthy and better adjusted citizenry.

DETERMINATION OF FUNCTIONAL DESIGN

A proper functional design depends upon a correct appraisal of all the forces involved. Since, on a shore front, these forces are rather complex, with daily and seasonal variations, and occasional storms of greater intensity, the best functional design must be that which meets the most general condition with a special provision for intensive storms of short duration. Even general conditions may be slowly changing with long time trends, and one section of a shore amply protected by a beach for example, may find in a term of years that accreting conditions change to erosion. Surveys over a period of years show shore line and off shore changes in areas not affected by works of man. A major portion of the Beach Erosion Board research is directed toward the analysis of forces affecting shore processes so that the relation between cause and effect will be more

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clearly understood and considered in functional design.

Beach erosion control structures must consider the movement of beach materials in littoral drift. Changes in distribution and rates of littoral drift are found even in short reaches of a beach. Evidences of these changes are noted in changing beach profile, in minor changes in beach materials, and the action of groins, which are more successful in one spot than in another. These differences are caused by irregular distribution of forces or materials and emphasize the need for a complete understanding of the forces before applying a remedy. It is evident that a single solution cannot apply to long reaches of a coast even though the average rate of littoral drift may be known. The Beach Erosion Board is investigating the affects of bottom irregularities and currents upon approaching wave trains in an effort to establish a basis for the irregular distribution of energy.

The direction of littoral drift changes along some sections of the coast due to changes in direction of approach of waves at different seasons of the year, or to affects of occasional storms. This results in building of beaches under certain conditions and erosion under others. The type of waves, whether long or short period, and low or high, also has a varying effect on the shape of a beach.

A better understanding of the manner of application of energy and the resultant action of shore materials under different conditions and over a long period of time will improve the design of methods or structures to correct unfavorable conditions. It will help settle the question, in an eroding shore, whether artificial fill, or groins of some type, length, and spacing, would give the best and most economical protection. It will indicate where jetties can be used to advantage and where they would have little effect or would cause more harm than good. It would give greater assurance that the location and type of structure would keep maintenance costs in connection with the improvement to a minimum. In short better functional design demands a more accurate definition of the applied energy and resultant action of beach materials. Increased knowledge of these factors would save much that is now being spent in measures of desperation, or in expensive improvements which ignore, for example, cyclical rises in lake levels, or points on the coast having unusual concentration of wave energy.

STRUCTURAL DESIGN FACTORS

Structural design follows correct functional design. After a careful analysis of all the functional factors develops the proper location, type, and general plan of a corrective method or structure, there remains the important problem of selecting materials and designing a structure that will withstand the forces and resist the corrosion and erosion due to exposure for a reasonable life expectancy, all things considered. It must be assumed that the most reasonable annual costs are desired.

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Expressed in money this means that the annual interest on the investment, plus amortization charges, plus annual maintenance results in the lowest annual charges.

The amount to be invested in a coastal structure should consider the probable period in which there will be no material change in the functional requirements. A study of historical changes may give a clue to the answer to this factor. Obviously there would be no point in building a structure that would either have to be moved after a period of years, or left to deteriorate without any further functional need. Some structures, such as groins, may, if properly designed and located functionally, work themselves out of any further functional use in a relatively short time. The materials chosen should be suitable for the period of probable need for the structure. The more durable, and hence the more costly, may be chosen for those elements requiring the longest life.

Having determined the desired useful life of a structure based on functional need, structural design must be based on the expected exposure and on the day to day forces acting upon the structure. Consideration must also be given to reversal of forces and to storm forces. The maximum stresses are probably developed during storms and therefore an analyses of storms in the area is necessary. A structure probably should be designed for a storm expected to occur at least once during the useful lifetime of the structure, but judgment of the affects upon related facilities will probably be required before selecting less frequent but more severe storms as a criterion. In some structures, as timber groins, it may not be economical to protect a whole field of groins against a contingency which may affect only one or two groins in minor degree. For this reason it is not reasonable to put expensive rip rap around the outer end of all timber groins because an unusual storm destroys the outer end of one groin. In the end, the assumed design stresses must be considered together with the durability of the materials in determining the proper type of structure.

The life of materials in structures along the coast depends upon the climate and the exposure. Local experience probably is the best guide, though the Beach Erosion Board is undertaking to tabulate and analyze data concerning this. The task is complicated by the fact that even in the same climate, the exposure of similar types of structures and materials may be quite different.

ANNUAL CHARGES

With or without adequate experience, the ultimate cost of a structure, as expressed in annual charges, depends upon the validity of the assumed useful life of the structure. This may vary for coastal structures, from a few years to 50 years. The Beach Erosion Board policy, in conformance with the policy of the Corps of Engineers does not extend the financing of any structure beyond an assumed life of 50 years. Even where there may be a functional need for 50 years, it may be necessary to consider replacement of the structure or elements of it, one or more times during that

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period, and the annual charges reflect that condition.

The assumed useful life of a structure affects the amortization rate directly. It therefore has an important bearing on the estimated annual charges and should be realistic if a comparison with annual benefits is to have any value. When replacements will be required during the useful life, an amount must be set up initially which will represent the present worth of the estimated future cost of the replacement. This, added to the initial cost, must then be amortized over the useful life of the structure.

The third element in computing annual charges after interest on investment and amortization, is maintenance. The cost of maintenance will depend upon the materials used in construction, and upon the exposure. Again, local experience is probably the best guide, because there will be many factors to consider, most of which are peculiar to the locality. Aside from the physical needs for maintenance, the cost will, in general, vary over the life of the structure in about the same degree as the value of benefits. Since this will be largely unpredictable, though at present rising at a rapid rate, it would probably be better to keep all estimates on the basis of present values.

Maintenance costs will be higher for meagerly designed structures than for excessively designed structures. The proper balance between initial cost and maintenance is therefore one that requires judgment. It may be desirable to consider several alternate designs in order to develop the best combination for total low annual charges. The result will give the annual charges combining the best functional design with the most economical means of carrying it out.

BENEFIT COST RATIO

The relation between the annual benefit value, and the annual charges for the improvement, gives the benefit-cost ratio, which, if substantially greater than unity, shows economic justification for the improvement. This does not necessarily mean that the improvement should be built immediately, for the owner must weigh the proposed improvement against his financial capability and the relative merits of other prospective improvements. This latter determination is usually beyond the scope of the engineer.