PART 3

DESIGN OF COASTAL WORKS

CHAPTER 13

SPANISH PRACTICE IN HARBOR DESIGN

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Up to a relatively short time ago maritime works, especially costly works of harbor protection, were designed merely by intuition or by misleading comparisons with other works seemingly identical, but lacking the application of appropriate scientific analysis.

Just as in what might be termed "land" design there were solutions, or methods for arriving at reasonably approximate calculations for the majority of practical cases, in "maritime" design all, or almost all, was yet to be developed. Most of the existing texts dealing with the subject were simple summaries with comments upon works previously constructed. According to the good or bad fortune experienced, efforts were made to explain the reasons for the success of some, or the failure of others, but there was a lack of the required methods for calculation according to engineering techniques.

It must be stated that following the development of the original formula in 1933 for the calculation of rock fill dikes by Castro and Briones, the Spanish contribution to maritime design was continued with the initial application of the system of wave front pattern to the port of Motrico in the designs composed by Iribarren in 1932 (1)* and in 1936 (2), where the reflections were also taken into account.

This fundamental method of wave-front pattern**, later called "refraction" by others, by means of which the direction and characteristics of waves may be determined with sufficient practical approximation in any area whose depth contours are known, was first published by Iribarren, January 1941 (3)***. In this article a study also was made of the lateral wave expansion**, later called "diffraction" by some engineers.

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*Numbers refer to references. A complete set of these papers was provided at the Third Conference on Coastal Engineering and are on file for loan purposes at the Hydrodynamic Laboratory, Massachusetts Institute of Technology, Cambridge, Mass. (Editor's Note: Since considerable editorial changes have been made in the author's original manuscript, the reader is encouraged to consult the original paper when certain statements are challenged.

**We prefer to continue using our own definitions regarding the undulating movement of gravity-waves, in which we are highly interested, to those dealing with other vibratory movements such as those of light and sound. For although there is indeed some similarity, they also differ with the waves.

***The English translation of the title is "Harbor protection works - wave front pattern". This article was published in English by "The Dock and Harbour Authority" November and December 1942 (4). In French by "Annales des Ponts et Chaussees", September - October 1945. In Portuguese by "Technica", 1945. It is necessary to point out that the date of publication of an article is that of the original and not of the translation in other countries.

The Spanish report by Iribarren and Nogales presented at the XVII International Congress of Navigation in 1949 (5), constitutes a more recent, more up-to-date study of the subject. It is recommended that this report be read, whether in French or in English, by all interested in the subject. Sections of this publication are presented as follows:

In Section (a) Wave characteristics, a discussion is presented on the determination of the "maximum" wave. This wave height is somewhat higher than the one which may occur in any sea or ocean as a function of the fetch, and, if a closer approximation is desired, of the wind pattern. The results obtained in this presentation coincide, with a suitable margin of safety, with those published later by the U.S. Navy Hydrographic Office in "Wind Waves and Swell: Principles in Forecasting".

In Section (b), Wave front pattern, the method of calculating the wave front pattern of the maximum wave is presented. By this method the direction of the waves can be determined for any point where construction work is planned.

Section (c), Height of the wave, deals specifically with the determination, as a first approximation, of the maximum possible wave height at any point in the wave front pattern.

Section (d), Special cases, lateral expansion, deals with the expansion or diffraction of waves. This phenomenon is of utmost interest, especially in the determination of the extent of harbor protection. This procedure in the second degree of approximation was presented in a later publication (6). It is of interest to note that an extensive test is being conducted, and it is expected that the results will be available in the near future. It appears that the author's method of considering diffraction and the resulting change of wave height along the crest is an accurate method.

Section (e) is devoted to the application of the methods to the Port of Palma in Majorca, and section (f) treats of the problem of diffraction at a breakwater gap. Section (g), deals with the reflection of waves, and section (h) deals with this same problem, in the first approximation, but with the breaking of the waves. In addition it treats the problem of the critical slope between incipient breaking and reflection of waves which also is published elsewhere (7,8).

Chapter II of Reference 5 deals with the variation in the height of the wave on the hypothesis of conservation of energy. It proves the acceptability of the first approximation in studies involving the wave front patterns.

Chapter III of Reference 5 starts with the study, in a preliminary manner pending further work, of the wave front patterns in the second approximation. The problem recently has been presented under the title

"Wave front patterns in the second degree application" (6)*. These studies in second approximation are now being revised and will be published shortly.

Chapter III of Reference (5) also deals with the different ways in which swell is produced in both deep water and shallow water. Also awaiting early publication is a study which confirms the increase of the period of the swell as it advances from the sea toward the shore. This increase of period is generally of little importance in regard to the wave front patterns studied, particularly for relative shallow waters where harbor works are projected. This work shows that the swell produced by the wind in deep water is composed mainly of two complex wave trains whose bisector of their directions is the wind direction, as well as that of the advance of the protuberances, or short crested waves.

The wave front patterns in the first approximation, at a reduced margin of safety, constitute in effect a simple but proportionate and orderly plan of analysis. It does not consider the actual complex movement of the sea, but considers the characteristics and direction of advance of the maximum protuberance, which are of interest for the practical calculation of maritime works.

If it is so desired, one may determine separately the wave patterns from the two mentioned wave trains whose directions of advance tend to coincide with the line of maximum slope of the bottom as the depths in the direction of propagation are reduced. The length of the crest, or protuberances, formed by the coexistence of both wave trains, consequently is increased. This may have some relation with the lateral expansion or diffraction of the waves, thus increasing the angle of penetration of the waves towards the inside of the harbor in an identical form to that of the first approximation, which is generally and but for some exceptional cases, sufficient for practical applications.

In Chapter IV of Reference (5) a study of the currents and oscillations of the surge action inside of harbors is presented. This problem also is discussed in Reference (9). These surge actions were defined as the movements which were produced in the sea during storms of much longer period than the waves. The surges might even exceed a period of three or four minutes. After determining that these movements may be amplified, impairing the usefulness of the inside of the harbors, due to resonance, and after proving in a manner that can be calculated, that the period of oscillation pertaining to a dock or zone within the harbor is a function mainly of its length and depth, it is therefore concluded that by varying the length when planning the work of a harbor, or the depth generally by means of dredging after it is constructed, the period of the oscillation

*Regarding this question the article by Fernando Rodriguez Perez published in the Revista de Obras Publicas, July 1946 also should be consulted.

or surge action in the sea can be controlled, thus reducing greatly the dangerous currents or surge action. This has been done successfully in several Spanish ports. By means of calculations it is shown also that the apparently smooth slopes of the beaches may permit reflections of the surge action. An explanation is presented on how these waves might originate from the beats of the wave groups to which their periods approximate.

Chapter V of Reference (5) is concerned with the study of the conditions of access to the harbors. This factor usually is contrary to that of its protection, since to improve the former means making the latter worse, or vice versa. It is necessary to study them jointly in such a way as to make both conditions, that is, protection and access to the harbor, if not perfect at least acceptable.

After calculating the maximum possible wave characteristics relating to the section of the coast under consideration, it is necessary to calculate upon this basis, the cross-sections of the dikes of protection. This protection can be constituted by means of the reflection and consequent dissipation of the waves and their energy to the sea, or by means of their breaking. Publications have been made relative to the calculation of both types of dikes. One is concerned with calculations for vertical walls (10, 11), and the other is concerned with rock-fill dikes (12, 13). Both were published in 1938 by Iribarren by the Bermejillo Press, Pasajes, Spain.

In the first of these which concerns vertical dikes, the diagram of the pressure of wave reflection is determined, which is a basis for the calculation of the stability of the structure. This diagram, whose approximation to real values has been proven in practice, is unique in that it is only one that, in accordance with experience*, as the steepness increases, the amplitude of movement on the wall also increases, becoming indeed much larger than double the incident wave height.

In the second of the above publications, which concerns the formula for the calculation of rock-fill dikes, a method is presented for determining the weight of natural stones or artificial blocks, which are necessary for the stability of the structure. This weight is a function of the height of the wave, the side slope of the dike, and the density of the material which constitutes the stones or blocks. A generalization of the formula for the calculation of rock-fill dikes and the verification of its coefficients was published in 1950 (15, 16, 17). Besides presenting a method of calculation for generalizing the formula to apply to the submerged zones of the structure, verification data are presented from observations on the breakwater at the port of Argel. A new statement of this formula appears in the following chapter.

*See the illustrations 13 and 21 in Reference (14)

For some years past in the School for Highway, Waterway and Port Engineering in Madrid, there has been taught the method of determining the height of the protecting works or of their parapets, their width at the top, the thickness of the protective covering, and the grading of the sizes of the stones. Also considered are the influence of the angle or direction at which the waves approach the breakwater and other construction details of such important and generally costly work of protection of the harbors*, as well as of wharves.

All that has been discussed above, and much more that cannot be given here in detail, will be included in a publication entitled "Tratado de Obras Maritimas" (Treatise of Maritime Works) whose first volume is now being printed.

The sand deposits carried by currents constitute one of the gravest dangers to many harbors. This interesting problem has been studied especially in regard to swell, whose action was less known than that of sand moving forces of other origin. As a result of this study an article on currents and the sweeping of sand due to swell has been published (18, 19, 20). Although the main or direct purpose of these studies was to determine the form of the work for harbor protection in order to avoid or diminish the danger of sand deposits, they also may be applied in the opposite sense; that is, to produce sand at the beaches or shores (21). This study demonstrates that, as the bottom configuration affects the form of propagation and characteristics of the waves that may be determined from the wave front patterns, the waves exercise in turn a decisive influence upon the shape of a movable sandy bottom. The form of the bottom may be modified in certain cases by changes in the wave characteristics which are induced by proper location of proposed structures.

Another study in progress, based mainly upon the deformation of waves in shallow water, deals with the subject of sand deposits. The results of this study, though nearer to the physical reality of this phenomenon, differ but little, in general, from those obtained by means of the process mentioned above.**

We consider the application of small scale models to maritime design problems as highly delicate, primarily because of their complexity, but also because of the excessive scale reduction which is necessary in the majority of cases. In the complex model, however, certain details can be treated separately with models of larger scale. Of interest in connection with model studies is the wave generating apparatus of the Harbor Laboratory of the School for Highway, Waterway, and Harbor Engineers (22).

*The article "Diques de abrigo en puertos" by M. Martinez Catena published in Revista de Obras Publicas, July to October 1941, should be consulted.
**The following articles should be consulted: Una comprobación de la utilidad de los planos de oleaje en el proyecto de obras para la regeneración de Playas" - Revista de Obras Públicas - September 1947 and "Notas para el proyecto de las obras para defensa y regeneración de costas-Comprobaciones en el litoral N.E. de la Península" Revista de Obras Públicas - August and September 1948, whose author is Aurelio Gonzalez Isla.

This mechanism permits the wave period to be continually changed as well as the motion of the upper and lower "throw" of the wave flap, by means of which may be produced in a continuous manner and without interruption all kind of waves - from those of pure oscillation to those of translation

Recently a study of the violent and accidental pressures produced by waves breaking on a structure was submitted to the "International Committee for the Study of Waves". It was shown that the causes of these pressures, as well as their importance, are due to their relatively small duration (23). Usually structures must be designed for ordinary pressures which are more prevalent, though less violent, by the method presented at the School for Highway, Waterway and Harbor Engineers in Madrid. Diagrams for ordinary pressures of breaking waves are to be included in the first volume of "Tratado de Obras Maritimas" mentioned above.

It should be noted that all the above mentioned studies are of highly practical character, and due mainly to the complexity and initial variability of the real waves, no pretension is made to a utopian theoretical precision, but instead to plain practical approximations. Besides the practical studies discussed above, mention is also made of a more speculative phenomenon - the oscillatory-centrifugal theory of tides (24).

We are grateful for this invitation to summarize the Spanish practice in harbor design. Although this summary is quite short, it is hoped that it will help to,establish fruitful collaboration with our colleagues in the United States. In regard to these complex subjects one cannot, nor must, improvise anything. The collaborations that tend to revise or suppl ment methods, like those which confirm the ideas discussed above, are very important. During the short time at our disposition it has been possible for us to prepare a paper on a new confirmation of the formula for calculation of rock-fill dikes. This paper constitutes the following chapter. It is interesting to note that starting from the study made by Kaplan (25) we have fully reconfirmed our formula which dates from the year 1938.

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