Port of Kobe

Part 4
COASTAL ENGINEERING PROBLEMS

Typhoon Waves, Kobe Sea Wall

CHAPTER 69

OCEANOGRAPHIC CRITERIA FOR DESIGN OF SMALL CRAFT HARBORS

by
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The most important oceanographic criteria which are required in establishing the optimum design of a harbor complex for small craft harbors located adjacent to large bodies of water are:

1. Wave Statistics Incident to the Site.
2. Effects of Breakwaters or Jetties upon Incident Waves.
3. Design of Interior Configuration and Water Levels.
4. Littoral Processes at the Site.

WAVE STATISTICS INCIDENT TO THE SITE

One of the most important considerations required in establishing the design of a small craft harbor is the magnitude and percent occurrence of waves incident upon the site. In most cases, adequate wave data for a particular shallow water site are unavailable. Where deep water wave data are available, they then must be modified by refraction, sheltering and shoaling effects to apply directly to the design site.[2]

Although the techniques for modifying deep water wave data are linear and are applied to statistical wave parameters instead of the more detailed wave spectra, the linear process does yield useful engineering design criteria. The shallow water wave statistics developed in this manner are percent occurrence of wave height and wave period as a function of shallow water wave direction, and statistics concerning the occurrence of severe and unusual wave conditions.

EFFECTS OF BREAKWATERS UPON INCIDENT WAVES

Wave energy incident upon the breakwater is modified in two ways:

a. diffraction at the harbor entrance, and
b. propagation of wave energy through and over the breakwater.

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1. Richard C. Timme, OceanicS Division, Interstate Electronics Corporation, Anaheim, California, U. S. A.

2. Department of the Army, Corps of Engineers, "Shore Protection, Planning and Design", Technical Report Number 4.

a. Diffraction of Wave Energy at the Harbor Entrance

An examination of the shallow water wave statistics will determine the predominate wave directions and characteristics that could possibly produce undesirable wave action at the harbor entrance and within the harbor. Diffraction diagrams can then be constructed to determine the wave effects at various locations in the harbor entrance and along interior quays, walls and moles. Figure 1 shows theoretical diffraction patterns for entrance to Santa Barbara Harbor. Figure 2 shows diffraction patterns for Santa Barbara Harbor obtained in a wave tank.

b. Wave Energy Propagating Through Breakwater Sections

To assess the effects of incident waves upon the harbor design and to determine the resulting wave action within the harbor, it is necessary to determine the amount of wave energy which propagates through the breakwater section. Until recently, breakwater and jetty design considered that wave energy in the sea and swell range was eliminated from propagating through the breakwater into the harbor interior. However, recent investigations[3] have shown that considerable wave energy with relatively short periods propagate through rubble mound breakwaters in quantities that drastically affect interior harbor basins (Figures 3 and 4) and interior design. An analytical model study by Le Mehauté demonstrated the relative effects of incident waves upon dikes and rubble barriers and the transmitted wave.

The initial study at Redondo Beach and several large scale model tests by the U. S. Army Corps of Engineers for various breakwater sections and various incident wave conditions have led the way to solving this problem. However, since the amount of wave energy propagating through a breakwater section depends upon the design of the section, these studies can only be extrapolated to obtain relative effects. More precise information must be obtained by model studies of the current breakwater design or upon the prototype itself.

Figure 5 shows the relative propagation of waves H_T/H through two breakwater cross sections versus the incident wave energy.

3. National Marine Consultants, Investigations of Wave Characteristics, King Harbor, Redondo Beach, National Marine Consultant Report, 1961.
4. Le Mehauté, "Perméabilité des digues en enrochements aux ondes de gravité periodiques", La Houille Blanche, March 1958.

DESIGN OF INTERIOR CONFIGURATION AND WATER LEVELS

The design of the interior basins and entrances must consider the net effect of possible wave disturbances within the harbor; the diffracted wave energy, the wave energy propagated through the breakwater, and waves which overtop the breakwater during severe storms. Other design considerations are hydrodynamic response of the interior basins to long period wave energy, and the maximum expected water levels. Figure 6 shows wave energy propagating through a rubble mound breakwater. Figure 7 shows the interior harbor design and the effective blocking of wave energy from the basins.

WAVE RUN UP ON INTERIOR MOLES AND WALLS

The effect of short period waves (7 to 20 seconds) from diffracted wave energy or from wave energy propagated through the breakwater upon mole and basin walls with various slopes and roughness, has been investigated in model studies and observed in nature. From the results of these studies, it is possible to determine run up and overtopping probabilities for various wave conditions as a function of wall and slope geometry.[5] Calculations of wave run up are important in designing mole and wall elevations.

HYDRODYNAMIC RESPONSE OF THE BASINS TO LONG PERIOD WAVE ENERGY

Oscillation of a basin of water can create severe horizontal and vertical water motion leading to damage of floating objects within the basin. Basin oscillation is usually produced by some outside influence in the form of wave action within the large body of water to which the basin is connected.

The dimensions and shape of the basin, particular location, and type of wall construction are factors which determine how much basin oscillation will be experienced. There is no exact theoretical method for determining the extent of surge, or seiching within a harbor; however, certain basic principles can be utilized to establish optimum harbor design and thus minimize the possibility of harbor oscillation.

Relationships for determining basic resonance and higher harmonic frequencies of various harbor geometries have been discussed.[6] Usually, only the lower harmonics are important in basin oscillation, since for higher harmonics, the phenomenon becomes quite unstable and most likely would not last any significant length of time even if the higher harmonics of oscillation occurred initially.

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5. Department of the Army, op cit.
6. Vanoni, V. A., and Carr, J. H., "Harbor Surging", Proceedings of the First Conference on Coastal Engineering, October 1950.

MAXIMUM WATER ELEVATIONS EXPECTED

The optimum elevation above a mean low water datum to which moles and walkways around the harbor must be constructed in order to preclude overtopping is important. The maximum water elevation is defined as that water elevation which will occur when maximum astronomical, storm, and isostatic effects are coincident in time. Clearly, the probability of such an event occurring in any year is small; however, over a long enough period (20 to 30 years), it has a high probability of occurrence, and affects harbor design.[7]

Final design elevations of moles and walkways must also take into consideration the effect of wave and surge action as occurring upon the maximum still water level. Depending upon final harbor geometry and breakwater section, design elevations can be determined from run up calculations as discussed previously. Figure 7 shows the schematic design of Dana Point Harbor, as a result of the above considerations.

LITTORAL PROCESS AT THE SITE

Over short periods of time, shoreline configurations generally appear to be permanent unless modified by certain types of structures. Actually, however, the shoreline is a dynamic feature constantly changing locally from day to day or season to season, due to variations in the intensity and direction of wave attack. The most important variables involved in establishing the character of beaches are the waves, the sediment, the variation in tidal level, and the adjacent headlands.

The general character of a given length of shoreline at any particular time is the long term result of the waves to which it is subjected and the amount and type of material in supply.

Essentially, the movement of sand by waves at any time is in the direction of the resultant wave energy vector. If the waves approach a coastline at right angles, much of the sediment transport is either shoreward or seaward, depending upon the wave characteristics of height and length. The zone of maximum sand transport appears to be in that section of the beach which lies shoreward of the line of breaking waves. There are, however, indications that some sand transport occurs in water depths to 80 feet.

For shorelines that are subjected to oblique incident waves of various periods and directions, the littoral current may vary considerably. On the other hand, for shorelines showing a predominant direction of wave approach, the littoral current is more or less uni-directional and a net transport in one direction results.

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7. Reid, Robert, et al, Surface Waves and Offshore Structures: The Design Wave in Deep or Shallow Water, Storm Tides and Forces on Vertical Piles and Large Submerged Objects. U. S. Army Board Report, October 1953.

The important factors affecting littoral drift have been studied considerably. These studies show the principal parameters to be amount and direction of available wave energy E, angle of wave attack θ, sand grain size, and the wave steepness ratio H/L, where H is wave height and L is the wave length. For a given wave or wave train and angle of attack, experiments reveal the existence of a critical value of the ratio, H/L, at which the littoral drift is a maximum. The transport of sediment decreases as H/L increases or decreases from this initial value (0.025). Further evidence suggests that for a given wave energy and steepness, the maximum transport occurs when the angle between wave crest and shoreline is approximately 40°.

In view of the transport maximum occurring at H/L equal to 0.025, it follows that for a given energy it is not the very high choppy waves that cause a large littoral transport but rather the intermediate waves. Storm waves undeniably do remove huge amounts of sand from beaches, but the net movement due to this cause apparently is directly offshore rather than along shore. Thus, after severe storms, it is not unusual to observe waves shoaling and breaking offshore at locations where previously no such phenomenon existed. Storm or winter beaches are associated with large values of H/L - the berm retreats shoreward, the slope decreases and offshore bars and troughs exist. Ordinary or "summer" beaches, on the other hand, are associated with long low waves of small H/L. Here, the berm advances seaward as the beach builds up, the slope increases, the offshore bars and troughs level out.

Assessment of the nature of littoral transport at, and adjacent to, the harbor site is essential in order to determine the magnitude, both for economical and engineering design reasons.

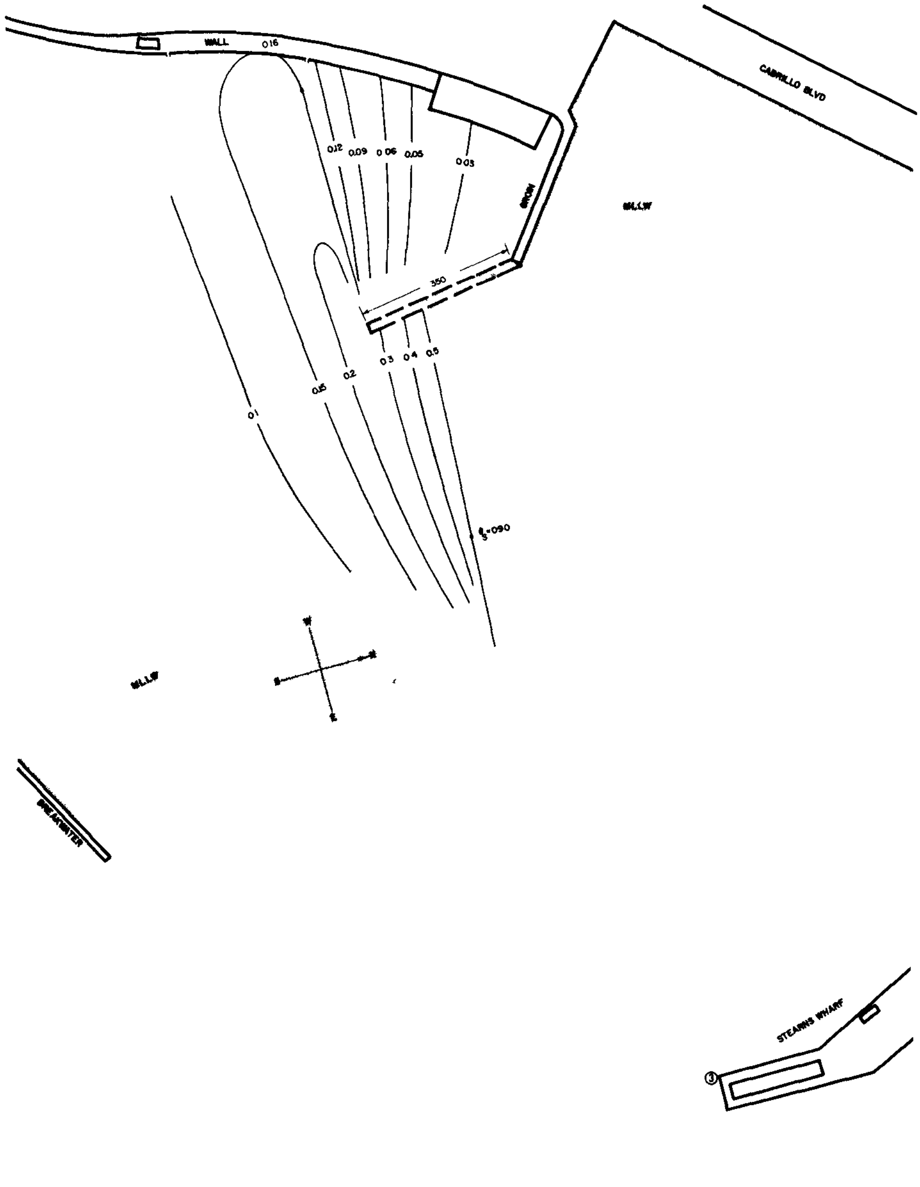


Fig. 1. Diffraction coefficients for 5.0-second-period waves, $\theta_S = 090^{o}$ (Isolines of K_D).

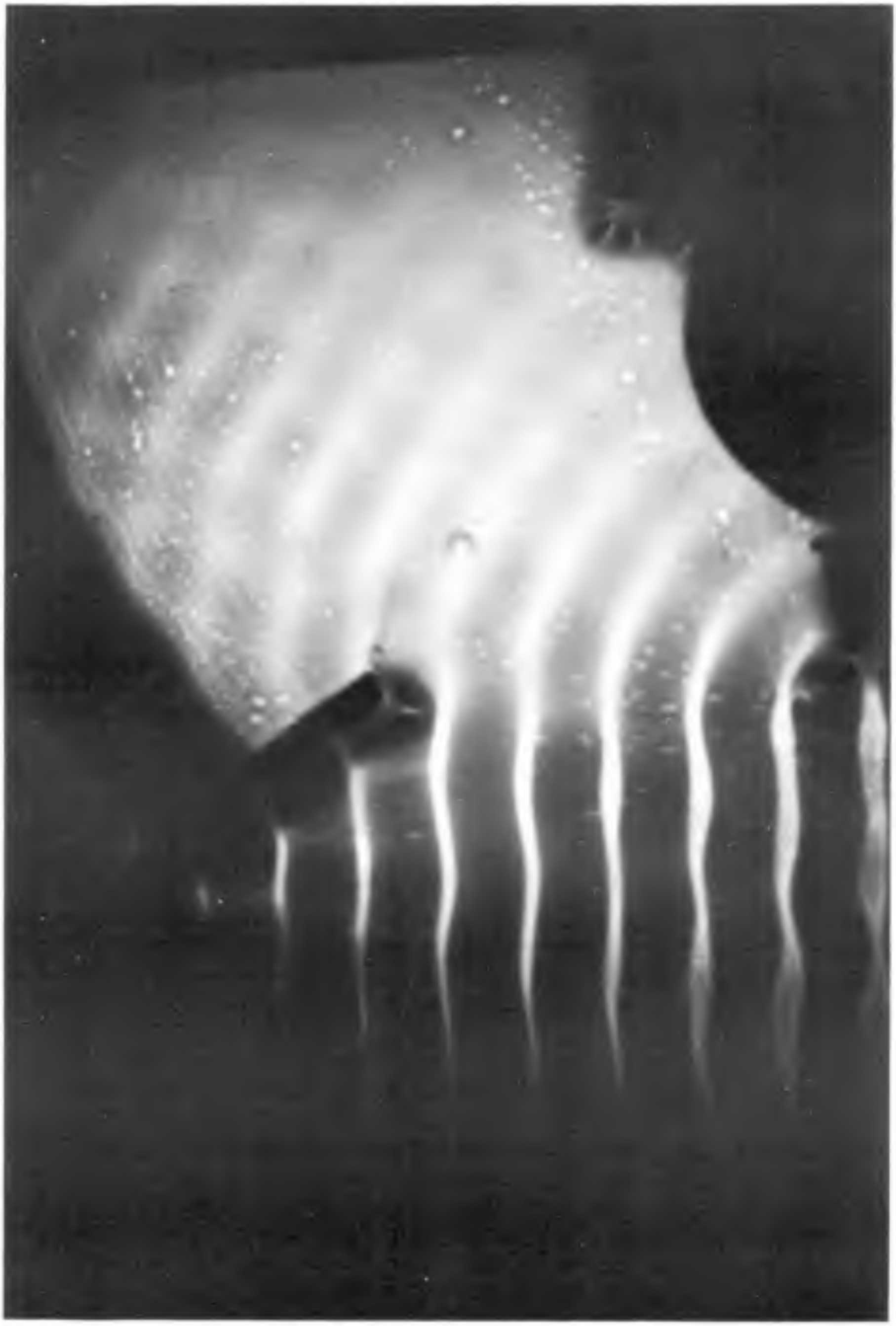


Fig. 2.

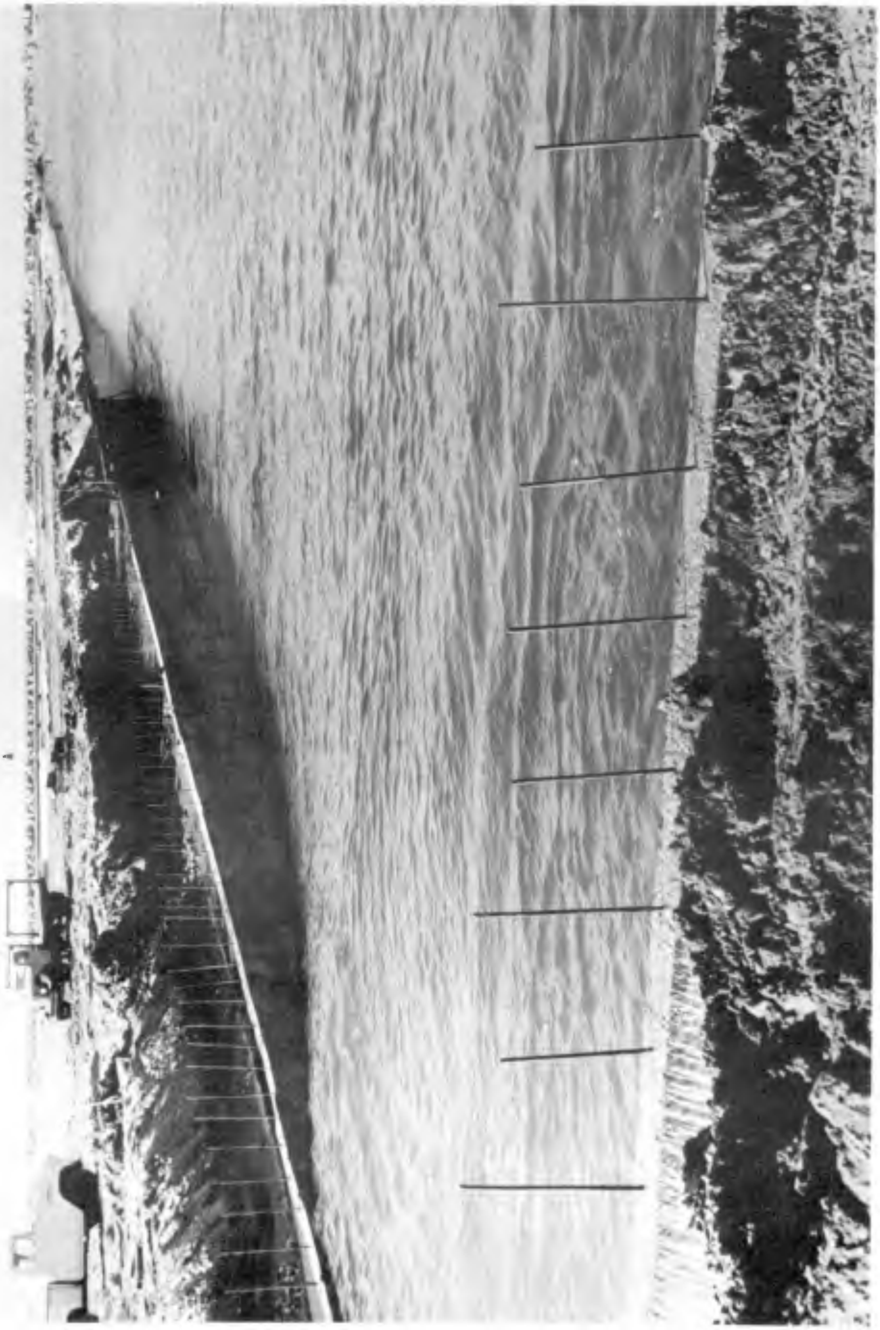
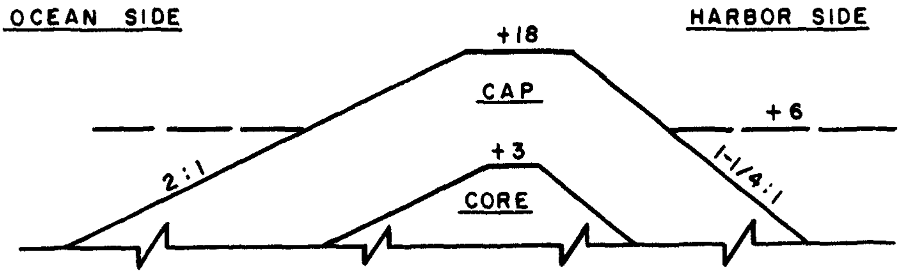
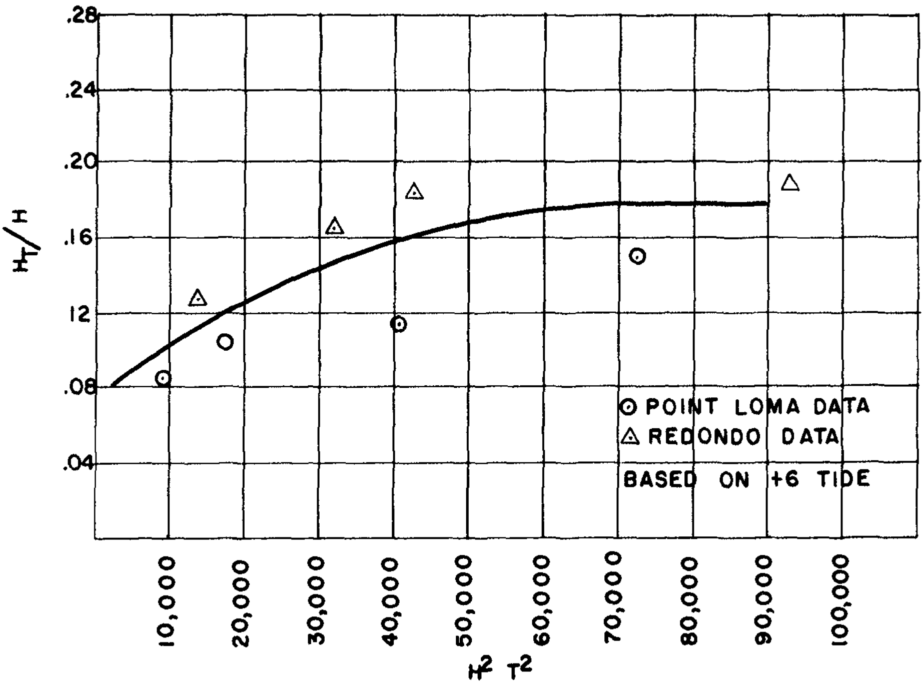


Fig. 3.

Fig. 4.



BREAKWATER SECTION II



TRANSMISSION OF WAVES THROUGH BREAKWATER SECTION VERSUS INCIDENT WAVE ENERGY

Fig. 5.

Fig. 6. Wave patterns, 9.0-sec waves 13 ft. high from S5°W. West breakwater crown at +18 ft. mllw. (U.S. Army Corps of Engineers, Waterways Experiment Station).

Fig. 7. Wave patterns, 9.0-sec waves 13 ft. high from S5°E. West breakwater crown at +18 ft. mllw. (U.S. Army Corps of Engineers, Waterways Experiment Station)