



PART 1
BASIC OCEANOGRAPHIC INFORMATION



CHAPTER 1

WAVES AND BREAKERS IN SHOALING WATER

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Wiegel and Johnson (1950) summarized useable wave theories for deep and shallow water. Mason (1950) discussed waves in shoaling water and compared theoretical predictions with measurements. The theories are shown to apply, within practical limits, to periodic systems of deep water waves, and to periodic waves progressing over a shoaling bottom to wave positions near the breaking point.

Near and at the breaking position the wave features are not predicted from theory with desired accuracies and measured characteristics are used to describe breakers. The available measurements are limited and do not show the effects of variables such as the beach slope.

Recent work at the University of California has resulted in information on the limits of applicability of the linearized wave theories as applied to wave transformation in shoaling water, and on breaker shapes and motions including the effect of beach slope.

DEFINITIONS OF TERMINOLOGY AND SYMBOLS

The description of breakers involves the use of terminology which may not be consistent in all wave and breaker studies. In order to avoid misinterpretation or confusion, the terminology and symbols as shown on Figure 1 are adopted for this discussion. Subscripts are used with the symbols to designate particular locations of the variables. Subscript *a* refers to deep water wherein the wave form is not affected by the proximity of the bottom. Subscript *b* refers to the breaker point.

EXPERIMENTAL PROCEDURE

Two sets of experiments were performed, one in which the breaker details were examined, the other in which wave height transformations in shoaling water were obtained. Both were made in the same laboratory wave channel, Figure 2, which consists of a channel one foot wide by three feet deep rectangular cross-section of smooth side walls and smooth bottom with a working length of 54 feet. Smooth, impervious plane sloping bottoms of reinforced plywood or metal sheeting were placed in the channel to give desired beach slopes. In some arrangements a seaward toe was used with a steeper slope than the normal beach to give a longer constant depth portion of the channel. All beaches were sealed at the junction of the beach bottom and side walls.

Waves were generated as a continuous periodic train by a hinged plane flap oscillating with a constant period. The period and amplitude of the

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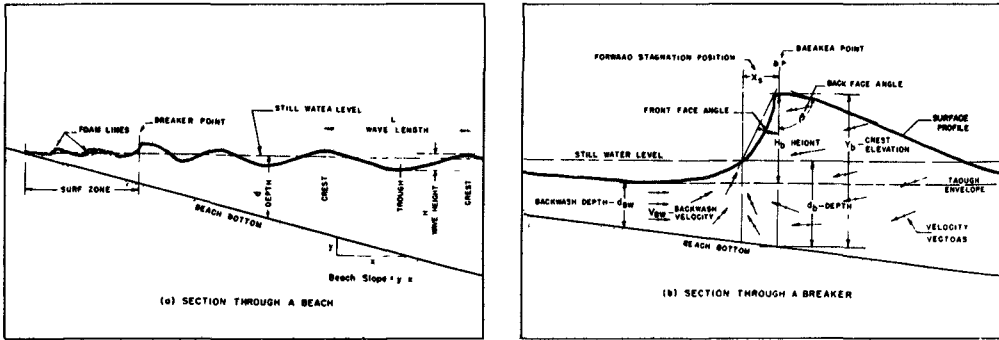


Fig. 1 Wave and Breaker Terminology.

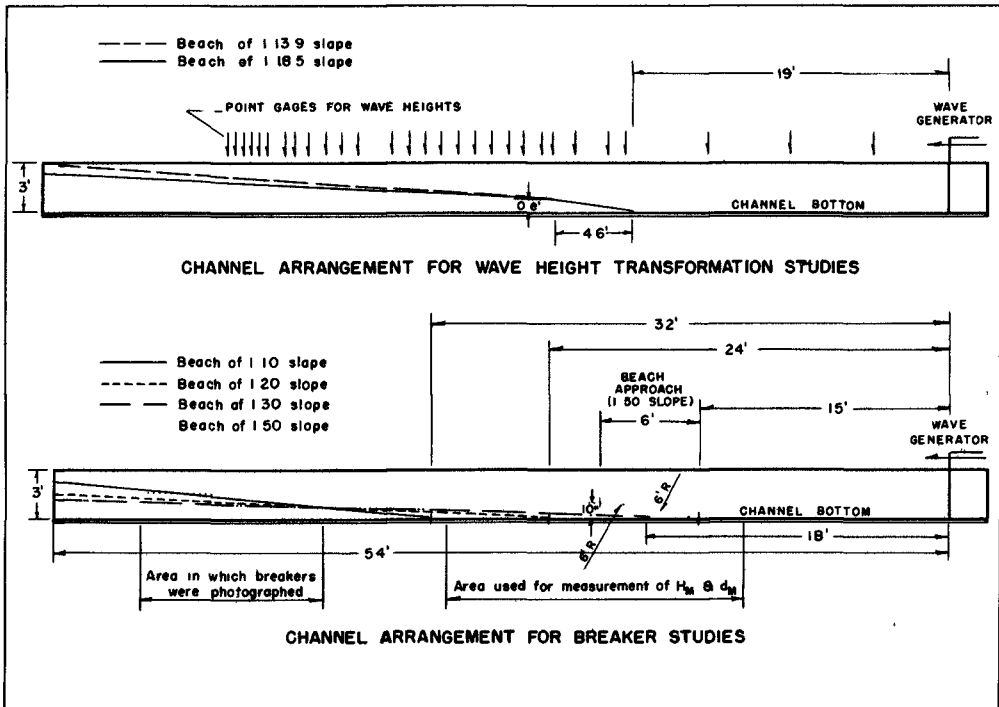


Fig. 2.

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flap were adjustable to enable a range of initial wave conditions. For the breaker studies the flap was driven through top and bottom independently adjustable cranks to permit a close approximation of a shallow water wave at the wave generator.

Measurements were made as follows:

(1) Wave height transformation studies. Crest and trough positions at various stations as diagrammed in Figure 2(a) were obtained with vertical point gages. Depth readings at each of the stations also were obtained. The wave period was obtained from the timed oscillations of the wave generator.

(2) Breaker studies. Wave heights in the constant depth portion of the channel were obtained from point gage readings of crest and trough elevation. Movies of the breaker region were taken through the glass walls of the channel with the camera axis at the still-water level. To obtain the kinematics of the water movement in the breaker, particles of a mixture of xylene and carbontetrachloride, with zinc oxide for coloring, with a specific gravity corresponding to that of the water, were introduced in the breaker region. The point to point movement of the particles then was recorded on the movies, from which each particle velocity was obtained by superposition of the projected movie frames to give distance moved and time interval of movement. Complete velocity fields were mapped for each wave for successive positions before and during breaking. The breaker surface profile transformations were also obtained by this procedure.

The limitation of the length of the laboratory wave channel restricted the investigation to beach slopes of 1:50 or steeper. In addition, in order to cover a range of characteristic waves with appreciable heights for reasonable measurements of vertical displacements, the majority of the waves were not generated as deep-water waves due to the depth limitations of the channel. The defining incident waves, characterized by the deep-water wave steepness, the ratio of the deep-water wave height to the deep-water wave length*, were evaluated from the wave heights measured in the constant depth portion of the channel with application of wave height transformation information (Mason, 1950) to obtain deep-water wave heights.

EXPERIMENTAL RESULTS - WAVE HEIGHT TRANSFORMATION STUDIES

Figures 3, 4, 5, and 6 show the measured wave heights related to the still water depth. The small amplitude linear theory corrected for channel wall and bottom frictional effects is shown to be applicable for the test conditions of Runs 1 and 7. The theory for the remainder of the laboratory waves does not predict the measured results with sufficient accuracy for laboratory experimentation. Two conditions contribute to the discrepancy.

*Deep-water wave steepness = H_0/L_0 , or H_0/T^2 where T is the wave period. With L_0 in feet and T in seconds, $L_0 = 5.12 T^2$.

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The short length of channel from the generator to the initial height measurement stations introduces some doubt that the wave form for the longer waves was completely established at the first few height measuring stations. Since these heights were used as references for the initial wave conditions, a lack of agreement between measured and predicted wave heights along the channel may be expected. In addition, the steep beach toe, as shown on Figure 2, may have produced excessive reflections, particularly for the longer waves, and consequent erroneous wave height measurements.

One feature is definitely established in the wave height transformation. The initial portion of the transformation shows a decrease of wave height as the depth becomes smaller. The small amplitude linear theory predicts a change of this nature. The theory then shows a gradual increase of wave height as the depth further decreases. The measurements follow the predicted trend of the wave height decrease with approximately the same rate of change. However, the measured rate of increase of wave height with decreasing depths is much greater than that predicted. The depth at which the disagreement becomes marked is noted on Figures 3, 4, 5, and 6. The choice of limiting depth is admittedly somewhat arbitrary. Results are shown on Figure 7. A curve is drawn through the results as a tentative limiting depth of applicability of the small amplitude linear theory.

EXPERIMENTAL RESULTS: BREAKER CHARACTERISTICS

Results obtained from the breaker studies included the complete geometry of the wave transformation in the region of breaking, and also the complete velocity field from the water surface to the beach bottom at increments of the wave and breaker position in the region of breaking. The complex nature of the transformation of a wave into a breaker, with the dependence of the transformation upon initial wave steepness and beach slope, precludes any simple presentation of the complete experimental results. Certain features pertaining to the breaker point can be correlated. These include the variables as listed on Figure 1(b). Correlations are made as a function of deep water wave steepness and beach slope.

The same limitation was present in the breaker experiments as was present in the wave height transformation experiments, i.e., most of the waves which were generated were not deep water waves in the constant depth portion of the channel. Deep water wave heights were computed from measured wave heights in the constant depth portion of the channel using the transformation results from small amplitude theory. Frictional damping of the wave train between the incident wave measurement station and the breaker was included to obtain the equivalent undamped deep water wave height. All results are shown as a function of the deep water wave characteristic, H_0/T^2 , where H_0 is the deep water wave height and T is the wave period.

Breaker heights are shown in Figure 8 for beach slopes of 1:10, 1:20, 1:30, and 1:50. The generated waves were between 0.1 to 0.4 feet high, and with periods between 0.8 to 2.5 seconds. Some scatter is noticed for the

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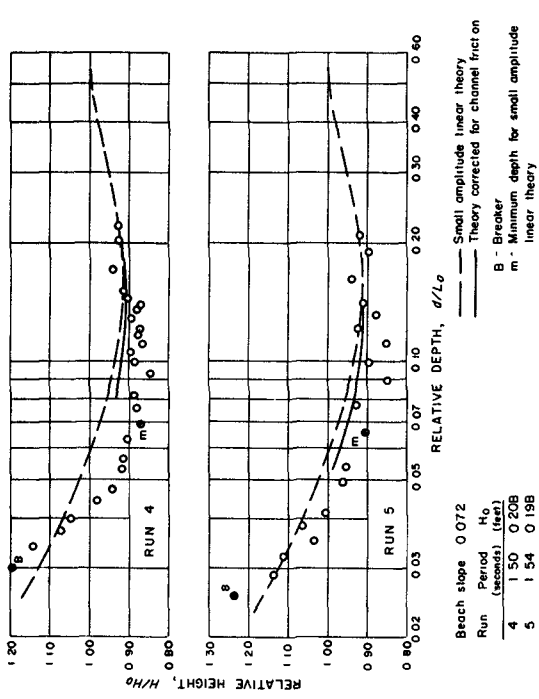


FIGURE 3

FIGURE 4

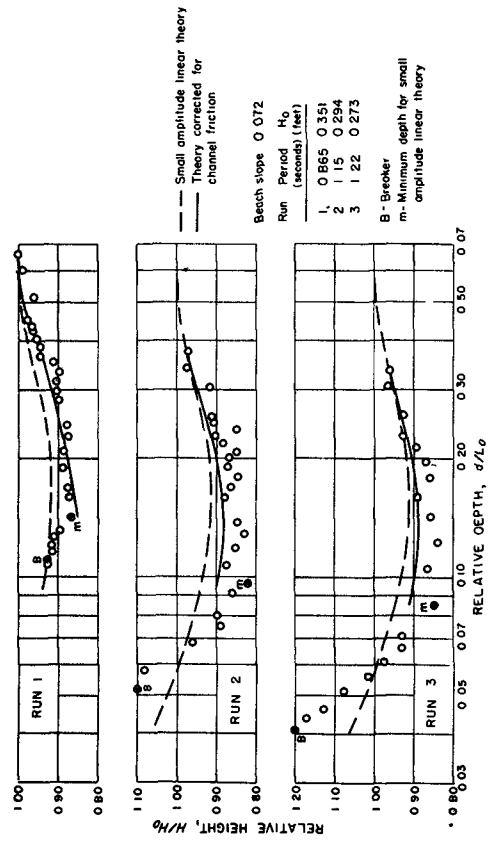
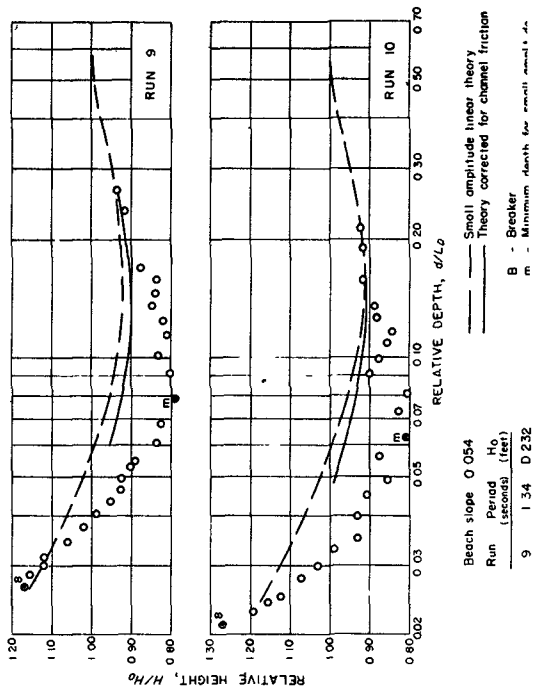


FIGURE 5

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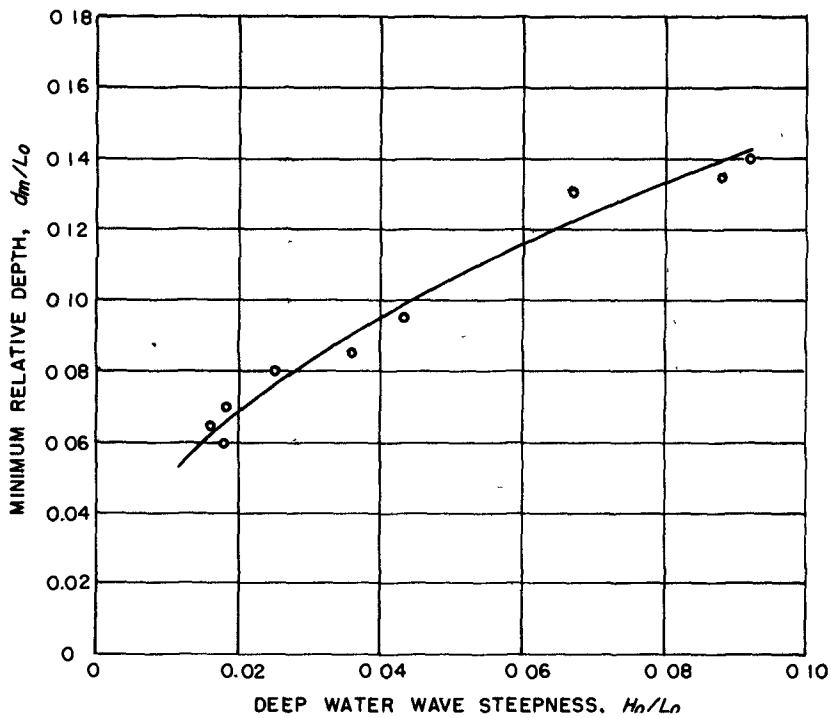


Fig. 7. Tentative limiting depth for application of small amplitude linear theory wave height transformation.

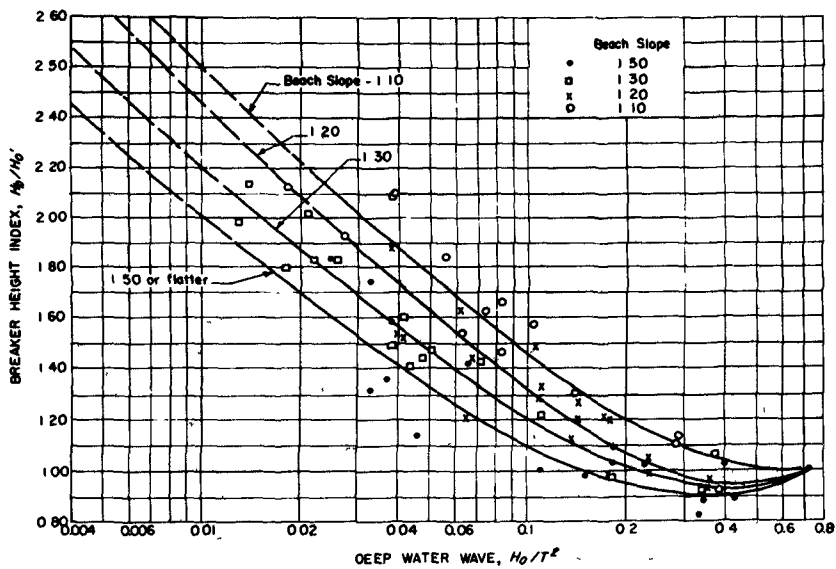


Fig. 8. Breaker height index as a function of deep water wave and beach slope.

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results of each beach slope. The scatter is larger than that accounted for by the measurement techniques. No explanation is offered at present to reconcile the scatter.

However, the beach slope effect is apparent on the breaker heights since the same range of wave trains in height and period was generated with each beach slope. Curves have been drawn as representative averages of the results from each beach slope. Breakers on the 1:10 slope are approximately 40% higher than those on the 1:50 slope.

Figures 9, 10, 11, and 12 show breaker geometrical features of depth at breaking, crest height, backwash depth, and forward stagnation position. The breaker height was used to obtain the various dimensionless geometric ratios of the curve ordinates as shown since the breaker heights were measured directly and in the same manner as the other shape variables. Although some experimental scatter is noted, the results describe continuous average curves. Curves also are shown relating the breaker shape variable to the deep water wave height by combining the curves from the plotted results with the curves of Figure 8 - for example, $d_b/H_\lambda = (d_b/H_b) (H_b/H_0)$.

Figure 13 shows the breaker face angles. Figure 14 shows the backwash velocity and the crest velocity in dimensionless form with the crest height as representative of a shallow water wave velocity evaluated from a water depth.

Some comments should be made relative to the evaluation of the results which appear in the above figures. The breaker point is, to a certain degree, a matter of judgment which depends upon the type of breaker which is formed. For "spilling" breakers, in which the crest became unstable in a mild fashion with the appearance of "white water" at the crest which expanded down the front face of the breaker, the picture preceding that in which the first white water appeared was taken as the breaker point. For "plunging" breakers, in which the crest overshot the body of the wave to project ahead of the wave face, the picture in which the front face at the crest was vertical was taken as the breaker point. For "surging" breakers, in which the front face of the wave became unstable over the major portion of the face in a large scale turbulent fashion, the picture preceding this action was taken as the breaker point. The movies, from which the results were obtained, were taken at approximately 60 frames per second. The time interval of 1/60th of a second permitted a reasonable approximation of the breaker point.

The depth, crest elevation, backwash depth, and front and back face angles were easily determined from the selected pictures. The forward stagnation point, which was determined from the particle movements, was noted to occur at approximately the intersection of the still water line and the front face of the wave. Backwash velocities were obtained by averaging all particle velocities in the region of minimum depth in the backwash. Crest velocities were obtained from the gradient of the crest position-time history. Small surface irregularities influenced the selection of the crest position in any one picture.

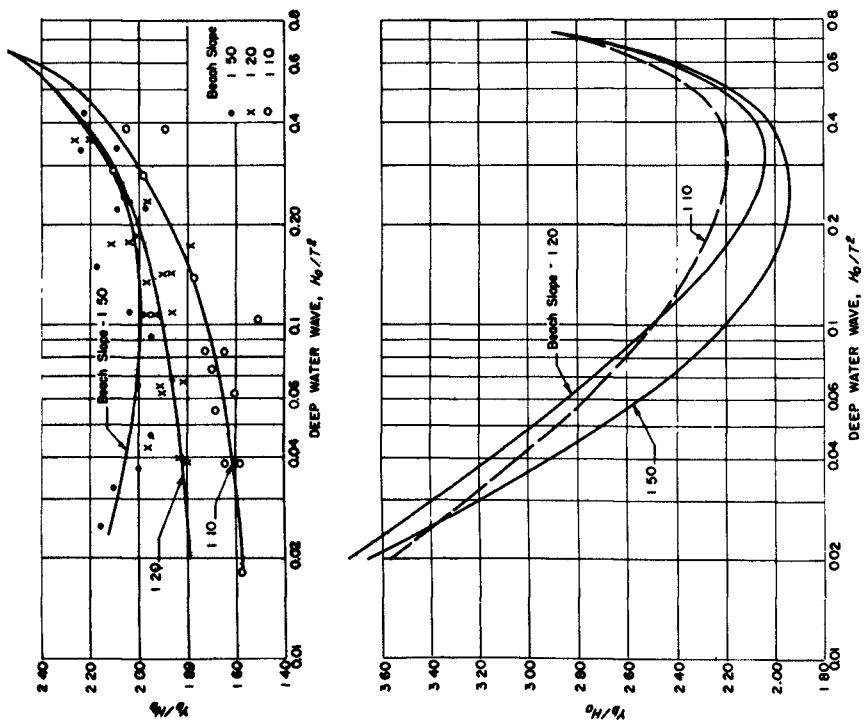


Fig. 10. Breaker Crest Index.

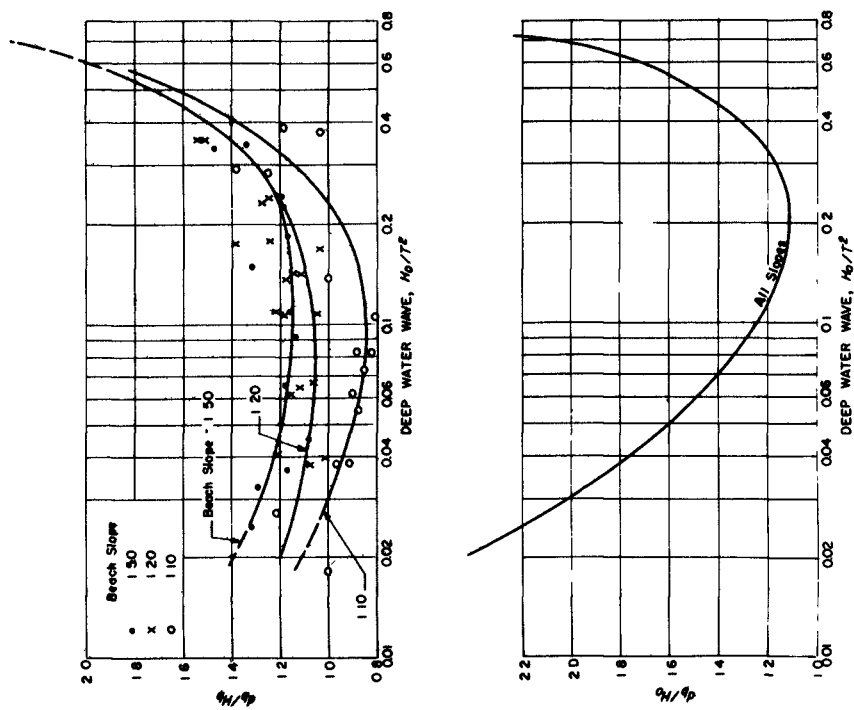


Fig. 9. Breaker Depth Index.

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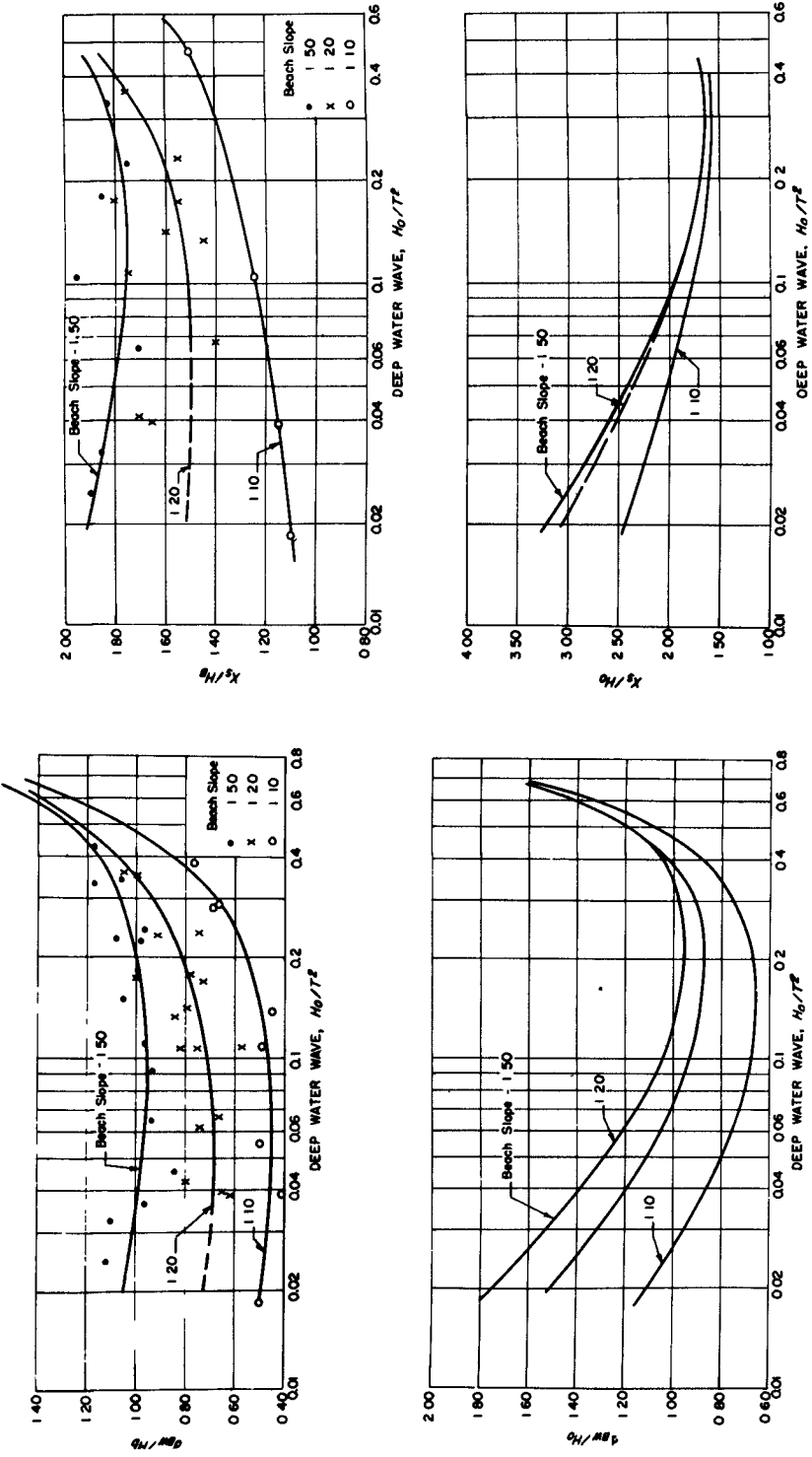


Fig. 11. Backwash depth index.

Fig. 12. Forward stagnation position index.

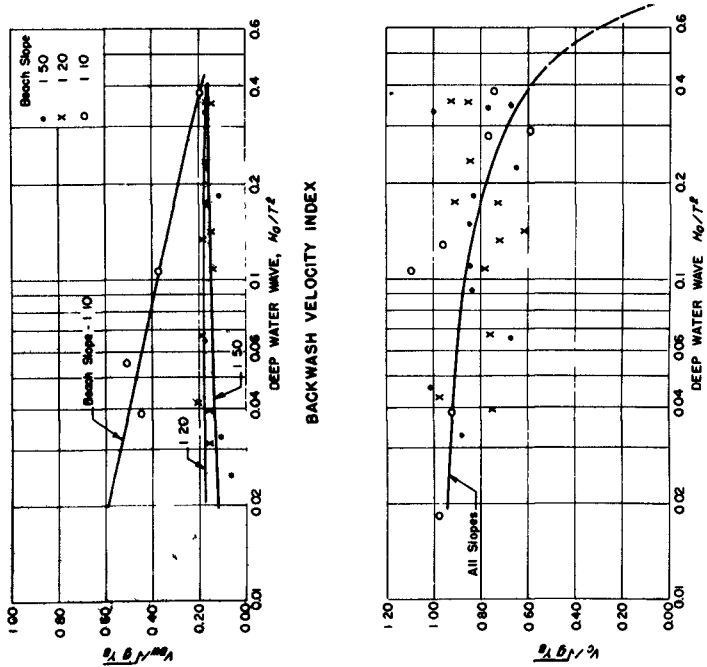


Fig. 14. Crest velocity index.

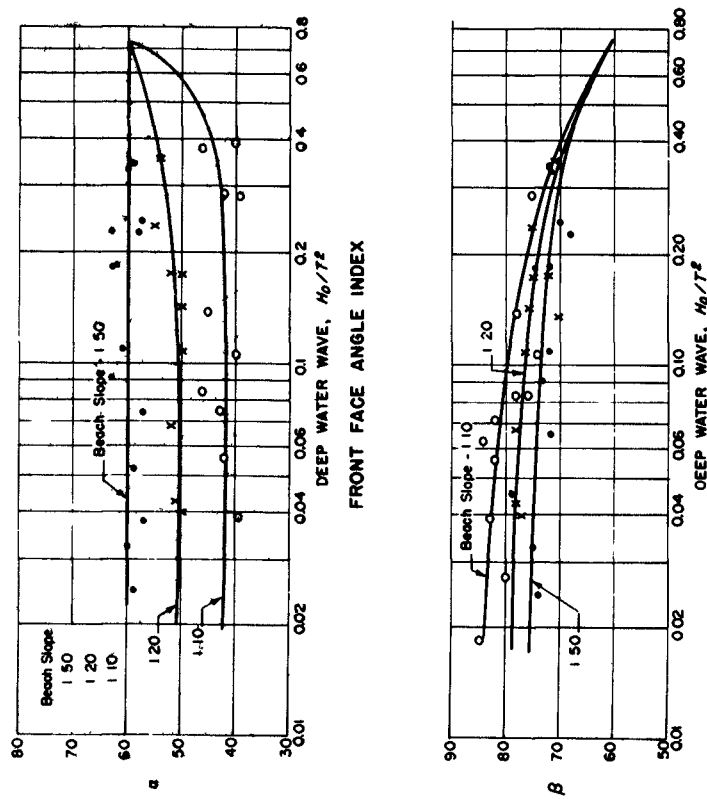


Fig. 13. Backface angle index.

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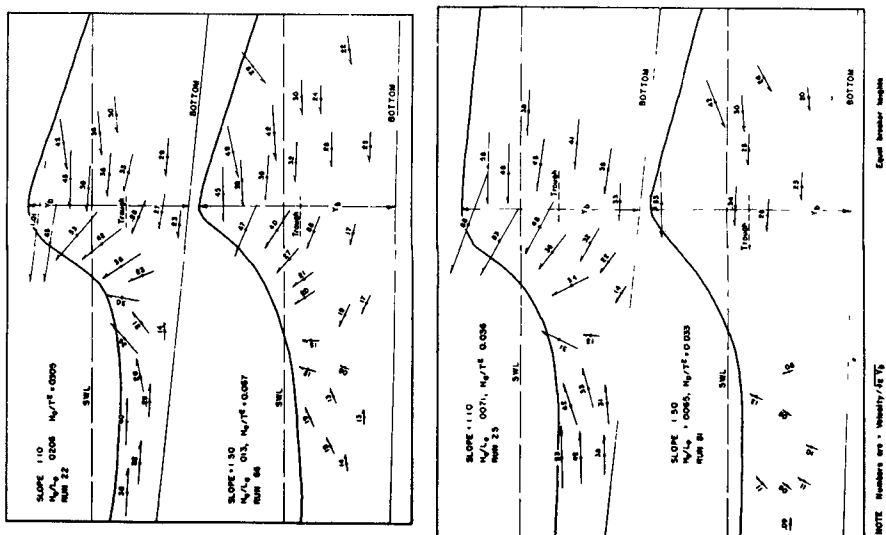


Fig. 16. Kinematics at breaker point.

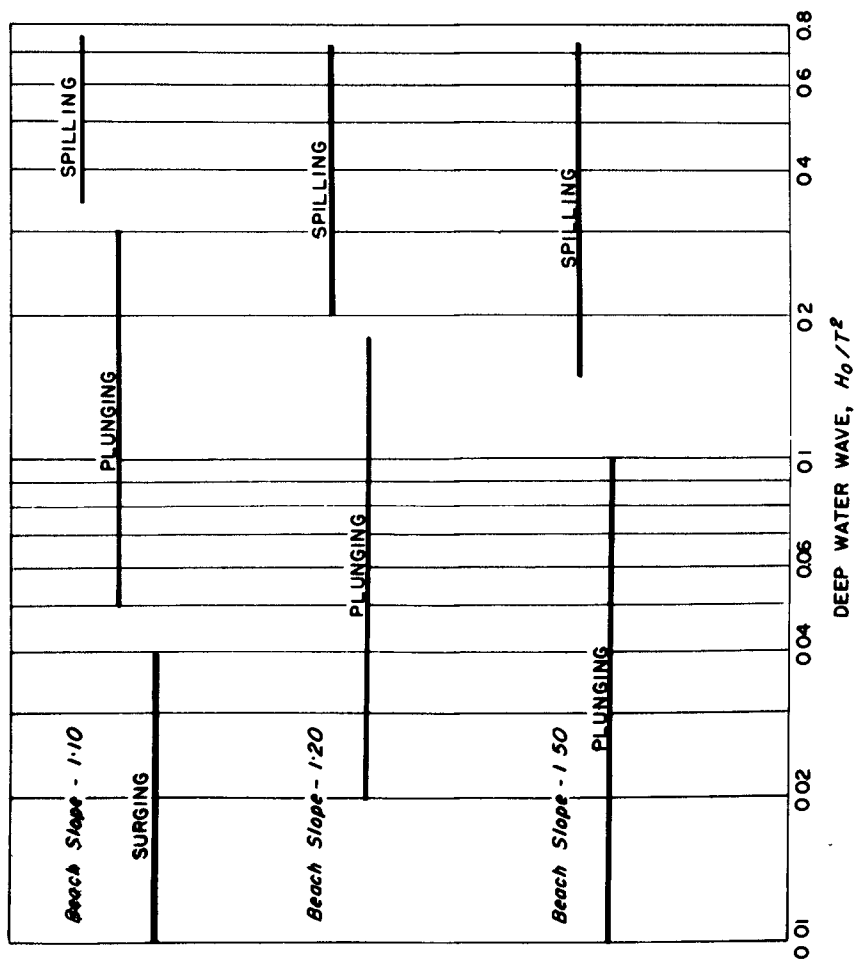


Fig. 15. Breaker type index.

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For a given wave train defined by the deep water wave height and period, on a steep beach as compared to a flat beach, the breaker is higher, breaks in the same depth of water with a higher crest elevation, has a flatter back face and a steeper front face, and has a smaller depth in the backwash with a higher backwash velocity.

The backwash, which is a function of events preceding a particular breaker, is a factor in the breaking action. High backwash velocities retard the base of the wave with a consequent tendency to promote a "plunging" breaker. At large values of deep water wave steepness, the breakers on all beaches were "spilling". At smaller values of deep water steepness the waves tend to plunge with greater tendencies on the steeper slopes. At the extreme lower values of the deep water wave steepness, particularly on the 1:10 slope, the breaker tended to "surge". A breakdown of observed spilling, plunging and surging tendencies is shown in Figure 15.

Other features of the breaker, particularly the kinematic field, may be noted in Figure 16. All breakers which were studied showed essentially the same general kinematic field, except for the differences as noted in the fore part of the breaker in terms of the backrush and forward stagnation point.

The laboratory waves were of uniform period and geometry. Natural waves seldom correspond to this condition. What effect the previous and following wave histories have upon a single wave under consideration, if the wave train is irregular, is not known. The effect of bottom friction and percolation also should be included for waves on natural beaches.

REFERENCES

- Wiegel, R.L. and Johnson, J.W. (1950), Elements of Wave Theory; Proc. of the First Conf. on Coastal Engineering, pp. 5-21.
- Mason, M.A. (1950), The Transformation of Waves in Shallow Water; Proc. of the First Conf. on Coastal Engineering, pp. 22-32.