CHAPTER 16

WAVE DECAYING DUE TO BREAKING

Makoto Nakamura, Hidehiko Shiraishi and Yasuo Sasaki
Hydraulics Division
Agricultural Engineering Research Station
Ministry of Agriculture and Forestry
Hiratsuka, Japan

INTRODUCTION

In the planning and design of coastal engineering works for the control of beach characteristics, a proper and effective measure against wave must be the most important problem to be solved. When the wave generated on the open sea approaches the shallow sea area, it will be transformed under the influence of sea bottom. For the construction works of coastal structures on a shoreline or in shallow water, the estimation of the rate of wave transformation is needed. In this concern, many reports were already published by the researchers,i. e, R.L.Wiegel, M.A.Mason,H.W. Iversen and T.Kishi. Moreover, the so-called Breaker Index which shows the breaking conditions has been obtained by the Beach Erosion Bord (U.S.A.), based on the data of field observations. Furthermore, these characteristics were investigated theoretically and experimentally by H.W.Iversen, Hamada, Sato and Kishi. Though these results show the wave transformation from the deep sea to a breaking point, there are few reports dealing with the wave transformation in the process of breaking and after a breaker zone. In the execution of coastal works projected in Ministry of Agriculture and Forestry such as shore reclamation works, coastal defence works and river mouth improvement, the wave inshore from a breaker zone often should be taken into consideration. In the past design of coastal structure, the wave acting on structures in the shallow water is calculated from the deep sea wave usually by using very rough estimation that wave height is reduced by about 30 per cent after a single breaking and wave period by about 10 per cent. Consequently, in order to analyze the wave decaying due to breaking, this paper treated with the wave transformation in the vicinity of a breaking point.

APPARATUS AND PROCEDURE IN EXPERIMENT

APPARATUS

The wave channel used in this experiment is 100 m long, 0.6 m wide and 1.0 m deep as shown in Fig. 1. It has a flaptype wave generator at the end and a single slope as a model of shore bottom at another end. The characteristics of waves on a single slope were detected by the water gauges of supersonic and electric resistance types. Moreover, observation was made at every 1 m within the breaker zone from the breaking point to the reforming point. At the same time, the height of wave run-up on a single slope was measured.

CONDITIONS IN EXPERIMENT

The purpose of this experiment is to investigate the wave transforma-

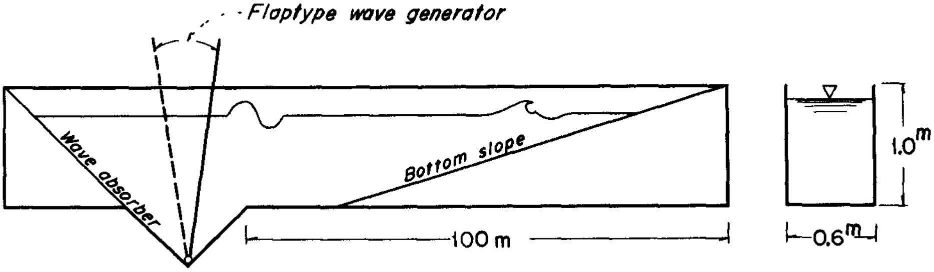

Fig. 1. Experimental equipments.

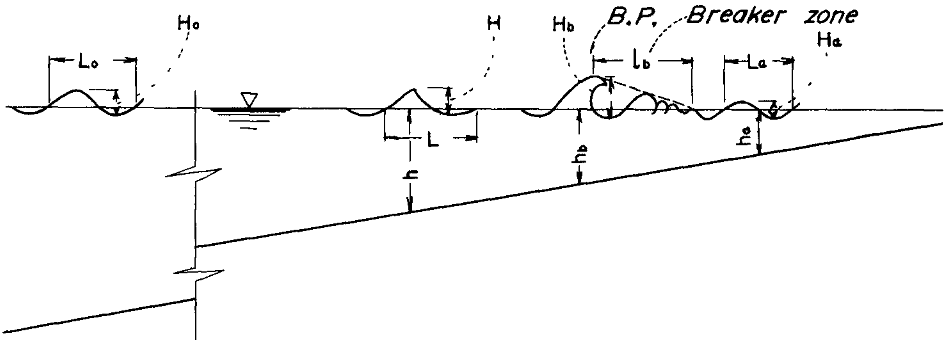

Fig. 2. Hydraulic symbols

tion taken place between deep water zone and a breaking point and to observe the length of breaker zone, the change of breaking wave height, the condition of wave reforming and the height and period of reformed wave. The conditions in the experiment are shown in Table 1. Under these conditions, about 1500 runs of experiments were carried out.

Table 1 Conditions in experiment

Bottom gradient	:	1/100, 1/50, 1/30, 1/20, 1/10
Water depth	:	40, 50, 60, 70 cm
Wave height	:	3 - 25 cm
Wave period	:	1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5 sec

NOTATIONS

Fig. 2 shows the symbols used in this paper and the pattern of wave transformation taken place between deep water zone and a shoreline. Namely, the transformation of progressive wave is caused by shoaling and breaking. The breaking wave reforms to non-breaking wave after the breaker zone. As this reformed wave progresses on a slope, the similar phenomenon is repeated at shallower area. However, in case of comparatively steeper gradient of bottom, breaking waves arrive at a shoreline without reforming.

Table 2 Notations

Ho, Lo, To	:	Height, length and period of deep water wave, respectively
H , L , T	:	Height, length and period of wave at water depth, h, respectively
h, hb	:	Water depth and breaking depth, respectively
Hb, Lb, Tb	:	Height, length and period of wave at a breaking point, respectively
lb	:	Length of breaker zone
Ha, La, Ta	:	Height, length and period of reforming wave, respectively

WAVE CHARACTERISTICS AT A BREAKING POINT

The quantitative relations between deep water wave and breaker are given by the Breaker Index by B.E.B., the experiment by Iversen and theory of solitary wave. However, the Breaker Index is shown without any connection with bottom gradient. Iversen has presented that the breaker height is influenced by bottom gradient but the breaking depth varies slightly according to that. On the other hand, the results obtained from this experiment show that the breaking conditions are related to bottom gradients as shown in Figs. 3 - 12. Namely, in these figures, the abscissas show the wave steepness and the ordinates the wave characteristics at the breaking point. Figs. 3 - 7 show the relationships between the ratio of breaker height, Hb, to the height of deep water wave, Ho, and the bottom gradients. The relationships given by B.E.B. and by Iversen are compared in these figures. Figs. 6 and 7 show the characteristics of breaker in the case of bottom gradients of 1/50 and 1/100, respectively. In these cases, the experimental data are pretty scattered and fairly smaller than the curves by B. E. B. and by Iversen. As the cause of so scattering, it is considered that slight difference of conditions of generating waves (i.e. conditions of deep water wave) affects the breaking conditions because of comparative long slope of bottom. Figs. 8 - 12 show the ratio of breaking depth to breaker height with absent marks, o and the ratio of breaking depth to length of deep water wave with present marks, o. From these figures, the following conclusions may be stated. That is, the ratio of breaking depth to breaker is nearly equal to that by Iversen. As for the ratio of breaking depth to length of deep water wave, there is an almost agreement between the experimental data and Breaker Index in the extent of steeper gradient than 1/30 but the breaking depth is fairly smaller than that of Breaker Index in the extent of gentler gradient of 1/50. These experimental results are arranged for each value of bottom gradient. So, in order to investigate the influence of bottom gradient upon Hb/Ho, its values are plotted against bottom gradient, taking Ho/Lo as a parameter, as shown in Fig. 13. As for the relation between hb/Lo and bottom gradient, Fig. 14 is also a rearrangement of the previously shown figures for the same purpose. In order to eliminate small scattering of experimental data, smooth curves are drawn. The wave characteristics at a breaking point are collectively presented again in Fig. 15 by using the approximating curves as in Figs. 13 and 14. Judging from this figure, the experimental result differs from Iversen's and B.E.B.'s relations. Consequently, the bottom gradient as well as the conditions of deep sea wave must be taken into consideration as the factors to determine the breaking conditions.

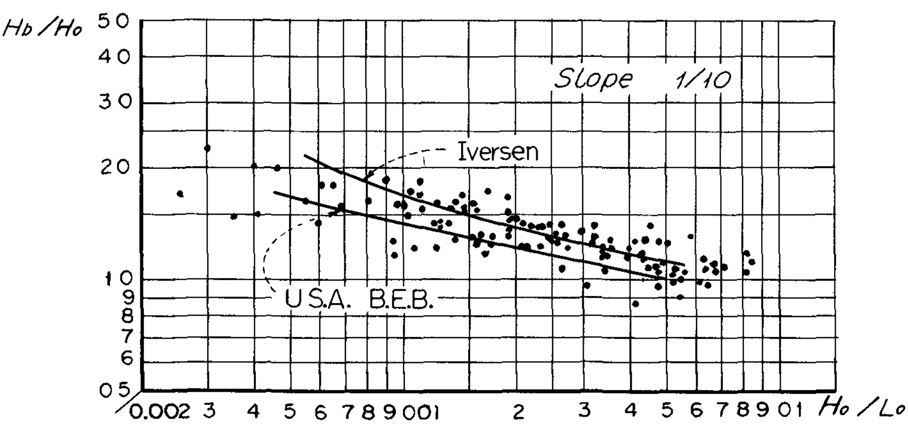

Fig. 3. Relation between Ho/Lo and Hb/Ho (Slope: 1/10).

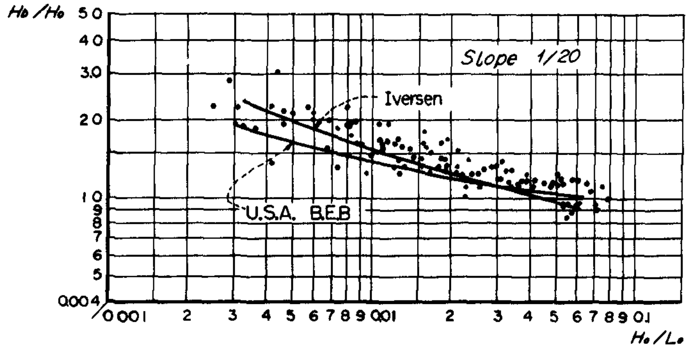

Fig. 4. Relation between Ho/Lo and Hb/Ho (Slope: 1/20).

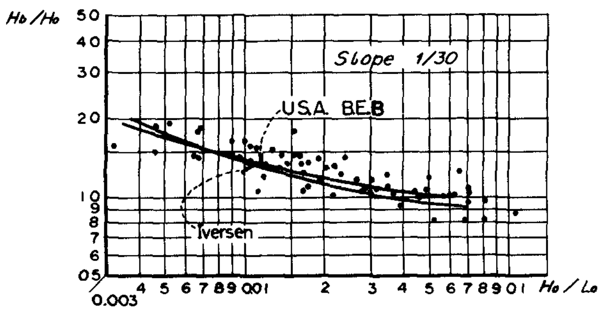

Fig. 5. Relation between Ho/Lo and Hb/Ho (Slope: 1/30).

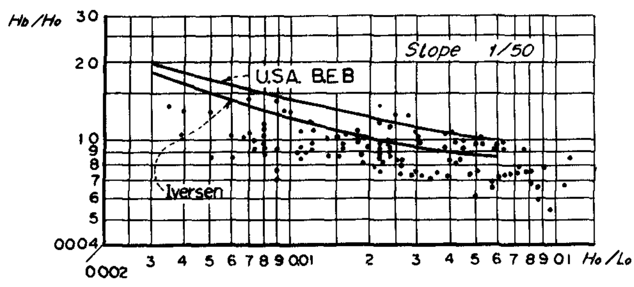

Fig. 6. Relation between Ho/Lo and Hb/Ho (Slope: 1/50).

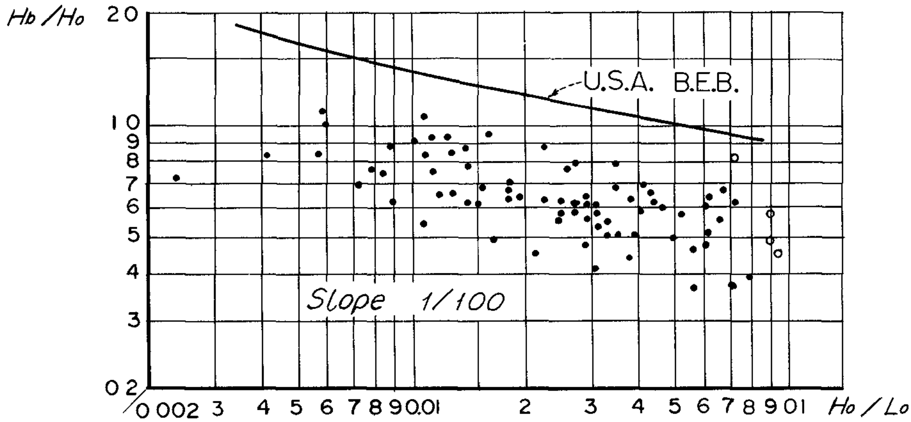

Fig. 7. Relation between Ho/Lo and Hb/Ho (Slope: 1/100).

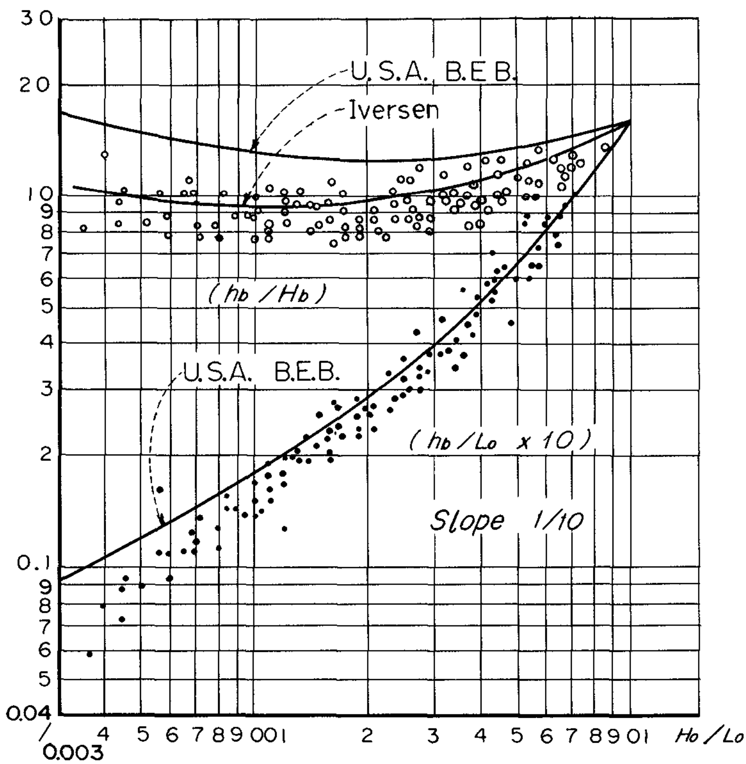

Fig. 8. Wave characteristics at breaking point (Slope: 1/10).

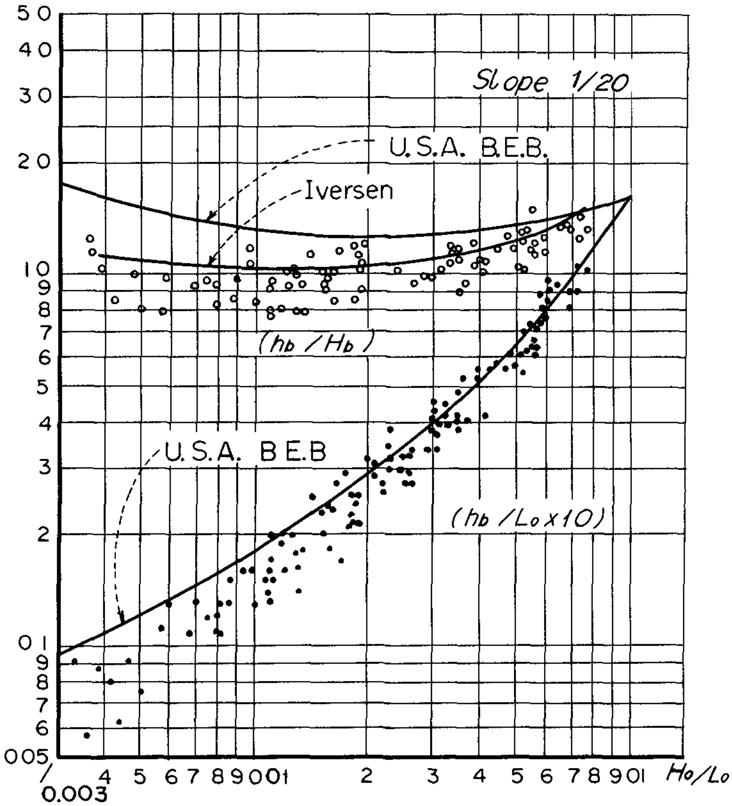

Fig. 9. Wave characteristics at breaking point (Slope: 1/20).

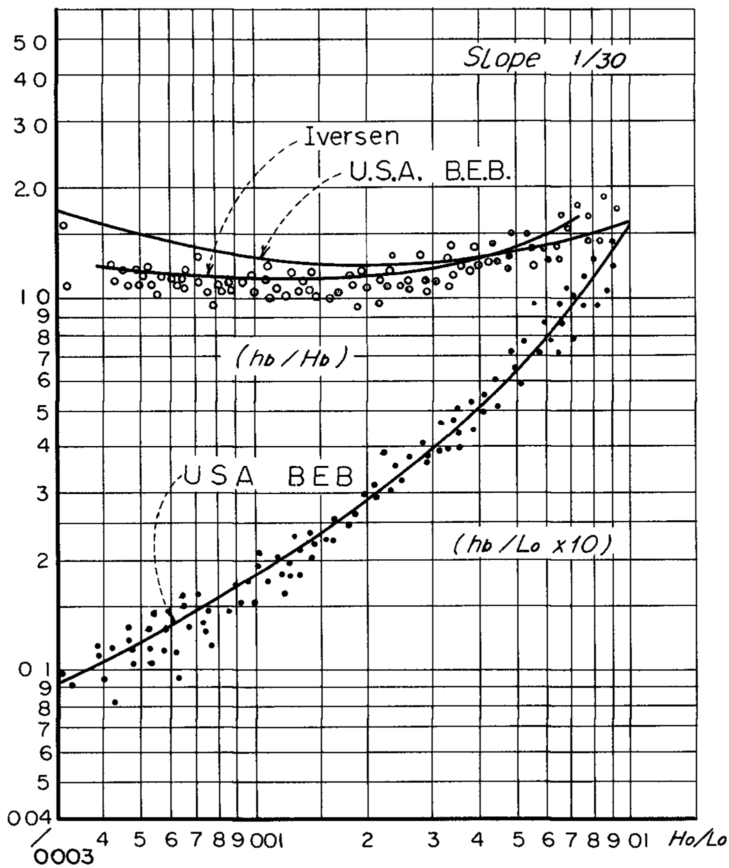

Fig. 10. Wave characteristics at breaking point (Slope: 1/30).

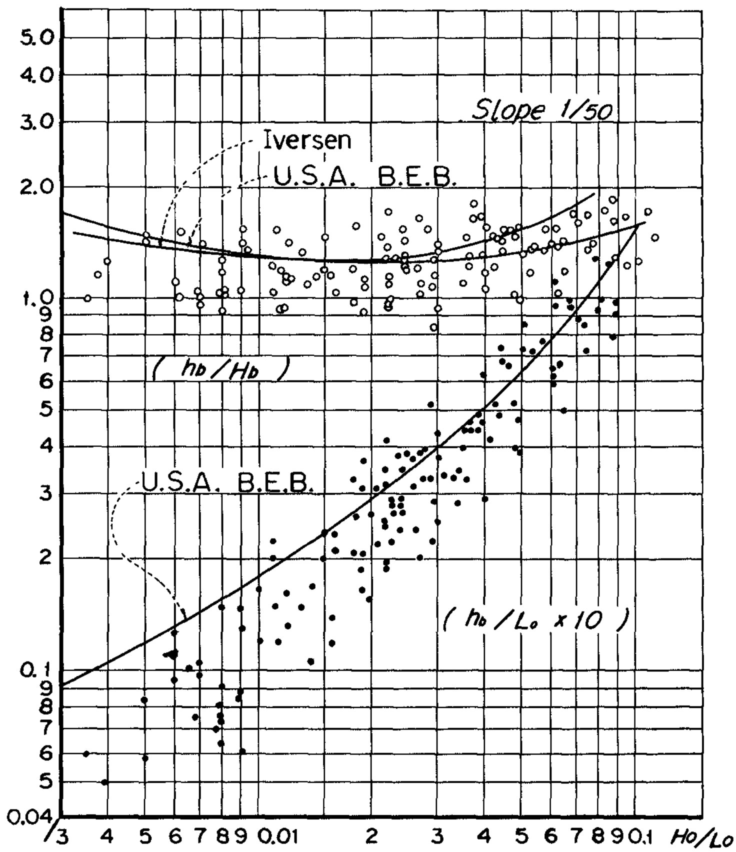

Fig. 11. Wave characteristics at breaking point (Slope: 1/50).

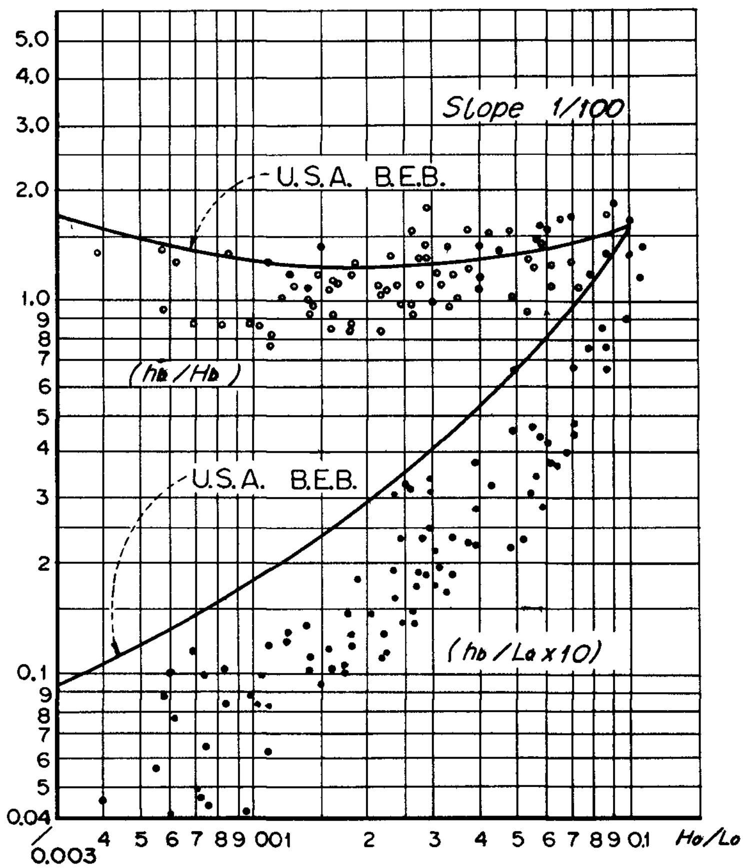

Fig. 12. Wave characteristics at breaking point (Slope: 1/100).

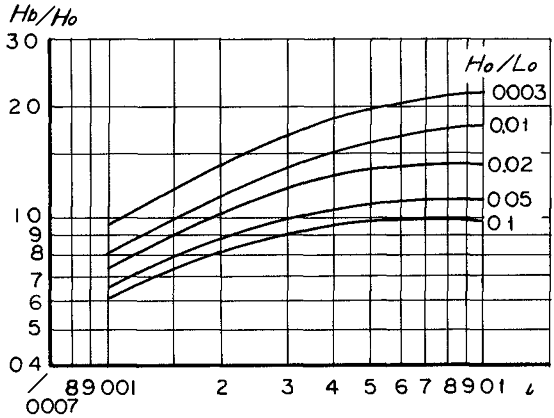

Fig. 13. Relation between slope and Hb/Ho.

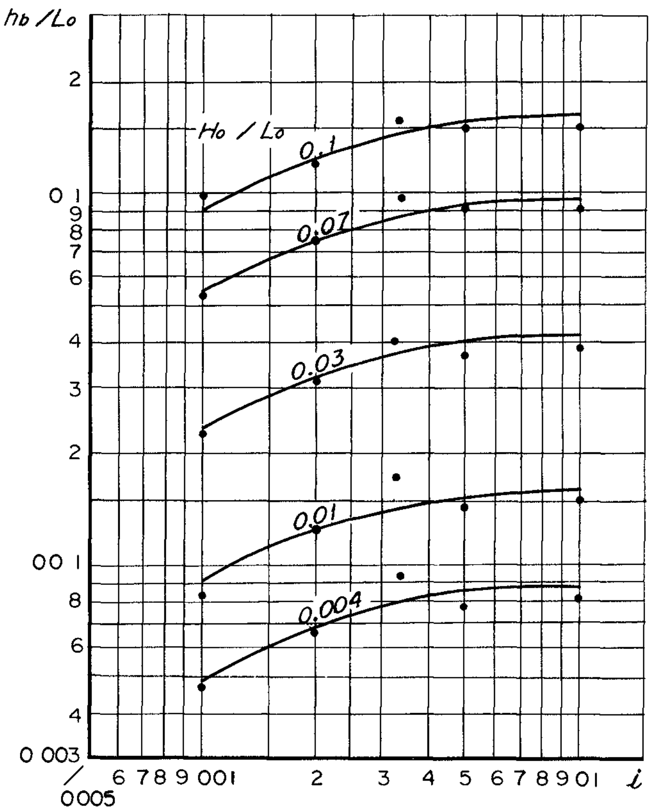

Fig. 14. Relation between slope and hb/Lo.

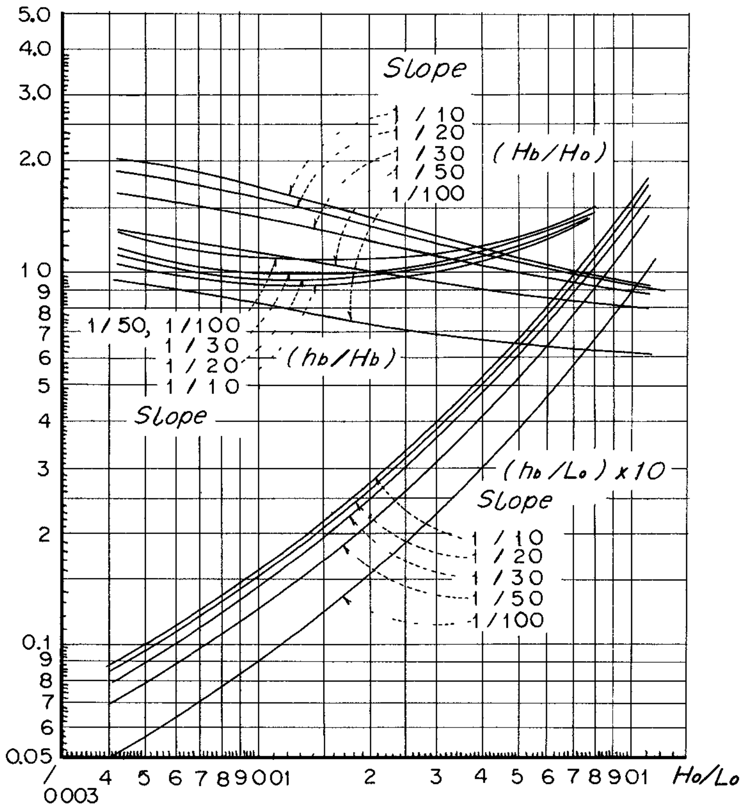

Fig. 15. Wave characteristics at breaking point.

WIDTH OF BREAKER ZONE

After progressive waves above a sloped bottom pass a breaking point, they advance in so-called breaker zone in the shape ob bore. When the bottom is 1/30 or steeper in gradient, breaking waves arrive at a shoreline in that form, while in case of 1/50 or gentler the waves reform to non-breaking wave after passing the breaker zone. Fig. 16 shows the length of a breaker zone, lb, where progressive waves are in process of breaking. From this figure, the length of the breaker zone can be calculated by using steepness of a deep water wave. If the length of the breaker zone obtained from Fig. 16 is larger than distance from a breaking point to a shoreline, it is considered that a breaking wave arrives at a shoreline without reforming and if the length, lb is within this distance, it is considered that a breaking wave reforms at the distance, lb from a breaking point.

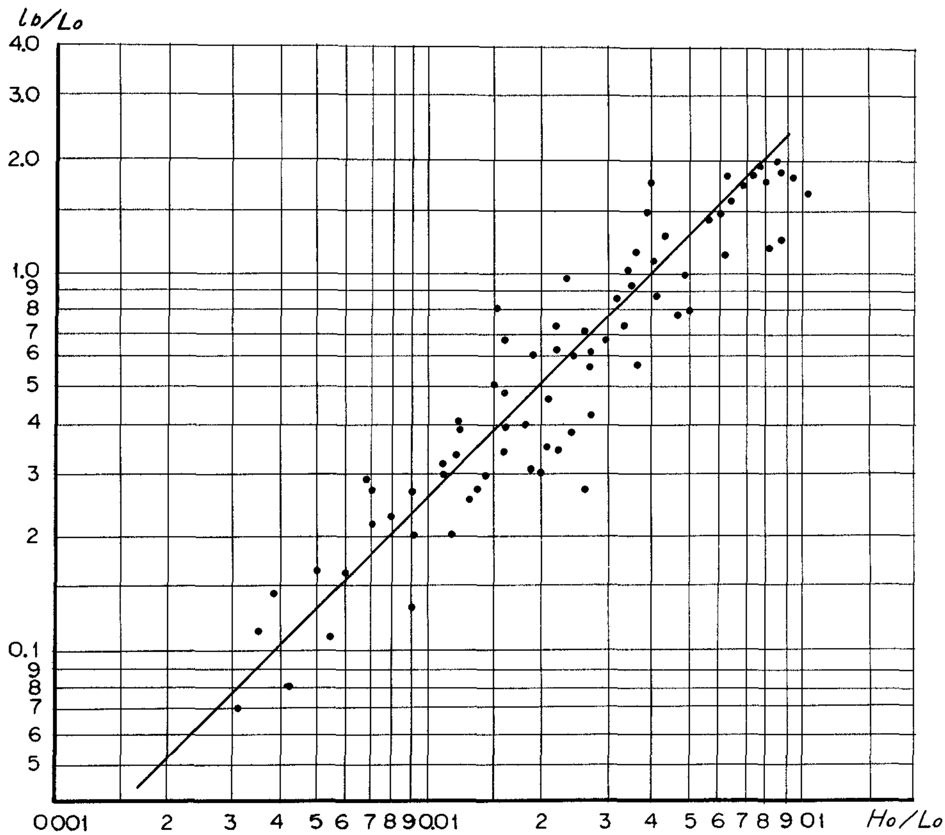

Fig. 16. Relation between Ho/Lo and length of breaker zone.

WAVE TRANSFORMATION ACCORDING TO CHANGE OF WATER DEPTH

The wave transformation occurs continuously inshore from deep water area. As some examples, Figs. 17 - 20 show the process of change of wave height in the case of bottom gradients of 1/10, 1/20, 1/30 and 1/50, respectively. That is, in these figures the abscissas show the ratio of breaking depth, hb to optional water depth, h and the ordinates the ratio of wave height, H to breaking height, Hb. Figs. 21 - 24 with steepness of deep water wave as a parameter are obtained by the similar method in case of gradients of 1/10, 1/20, 1/30 and gentler gradient than 1/30. Speaking of reforming wave after a breaker zone, it seems that the damping ratio of wave height is larger according to the increase of wave steepness, but in case of 1/50 in gradient or gentler gradient, the effect of wave steepness upon the damping ratio of wave height can be little recobnized because its effect is within scattering of data. Moreover, in order to investigate the influence of bottom gradient on the damping ratio, Fig. 25 is given. In this figure, the smooth curves approximating experimental data relatively are shown to eliminate a small scattering of data. Fig. 26 showing the change of wave height after the breaker zone is rearranged by such means. If the steepness of deep water wave, Ho/Lo is given, the breaking depth, hb and the breaker height can be obtained from Fig. 15. Using these values, wave height at any water depth can be obtained from Fig. 26. However, it must be noticed that these figures as to the change of wave height after the breaking point, are applicable within the length of the breaker zone, lb. Judging from bottom gradient, it is considered that a bottom gradient of 1/30 is the critical gradient than which breaking waves reform on gentler gradient.

Moreover, the changes of wave length and period are shown in Figs. 27 and 28, respectively. That is, Fig. 27 shows the length of reforming wave and Fig. 28 shows its period.

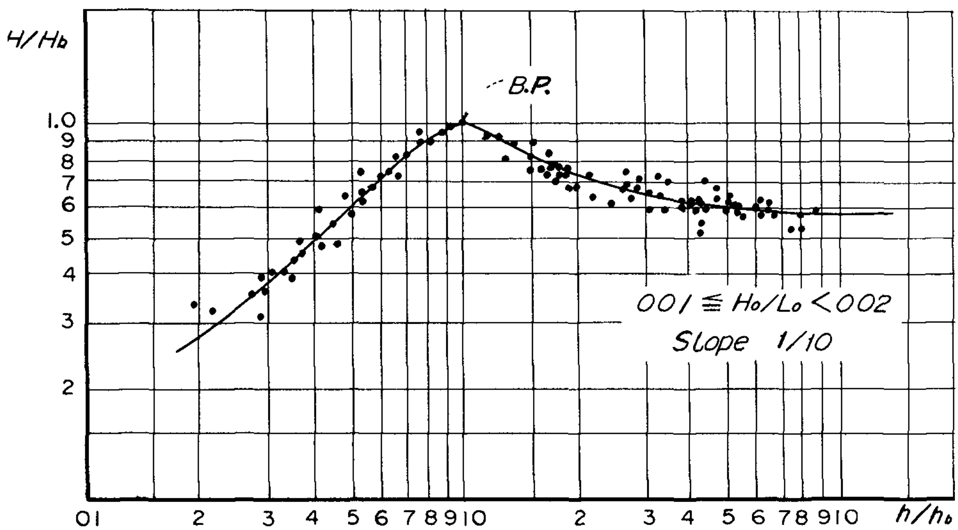

Fig. 17. Change of wave height according to water depth (Slope: 1/10).

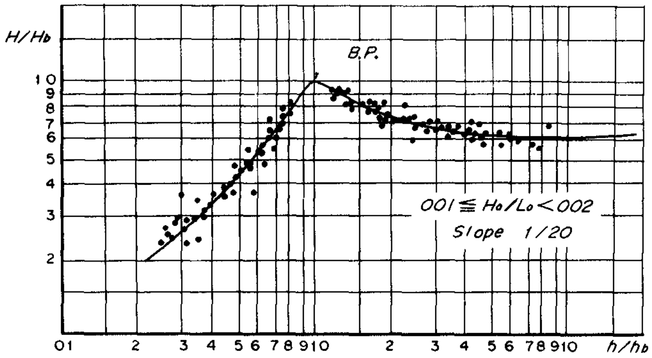

Fig. 18. Change of wave height according to water depth (Slope: 1/20).

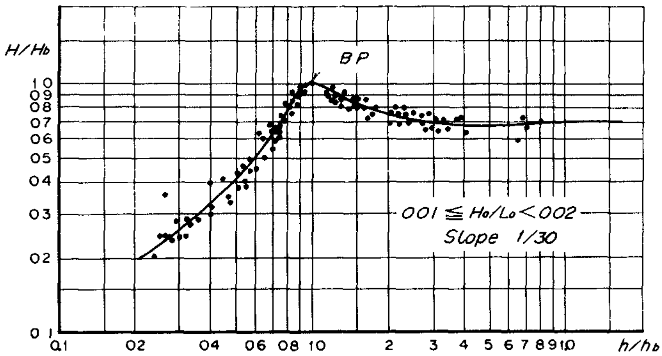

Fig. 19. Change of wave height according to water depth (Slope: 1/30).

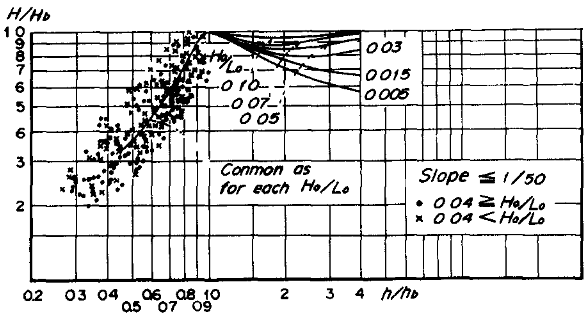

Fig. 20. Change of wave height according to water depth (Slope: 1/50).

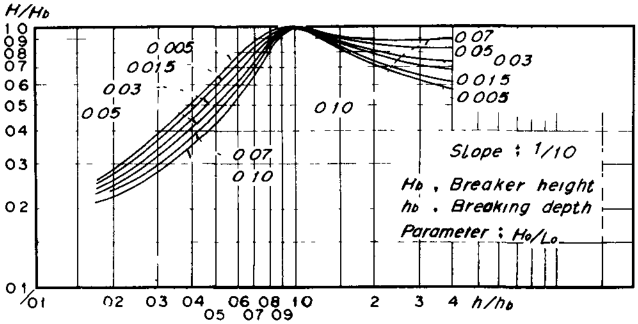

Fig. 21. Relation among h/hb, Ho/Lo and H/Hb (Slope: 1/10).

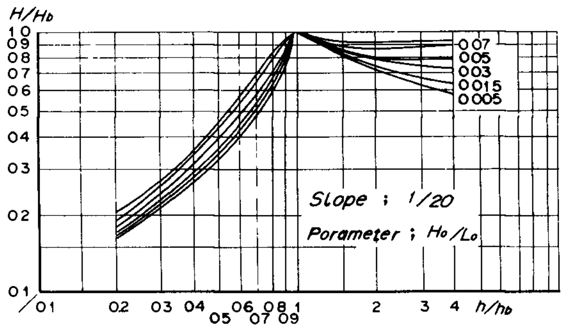

Fig. 22. Relation among h/hb, Ho/Lo and H/Hb (Slope: 1/20).

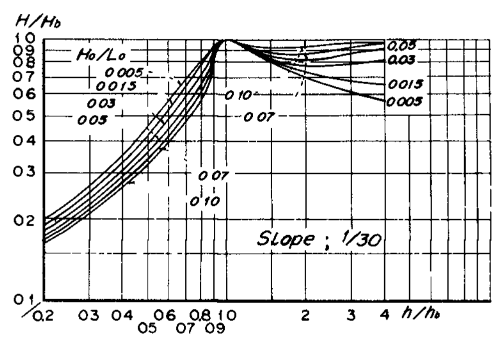

Fig. 23. Relation among h/hb, Ho/Lo and H/Hb (Slope: 1/30).

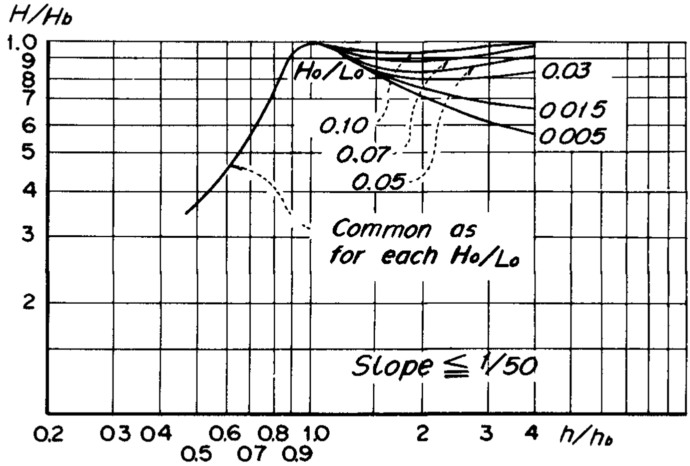

Fig. 24. Relation among h/hb, Ho/Lo and H/Hb (Slope ≦ 1/50).

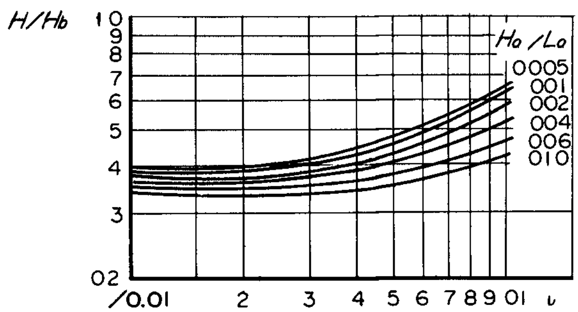

Fig. 25. Relation between slope and H/Hb.

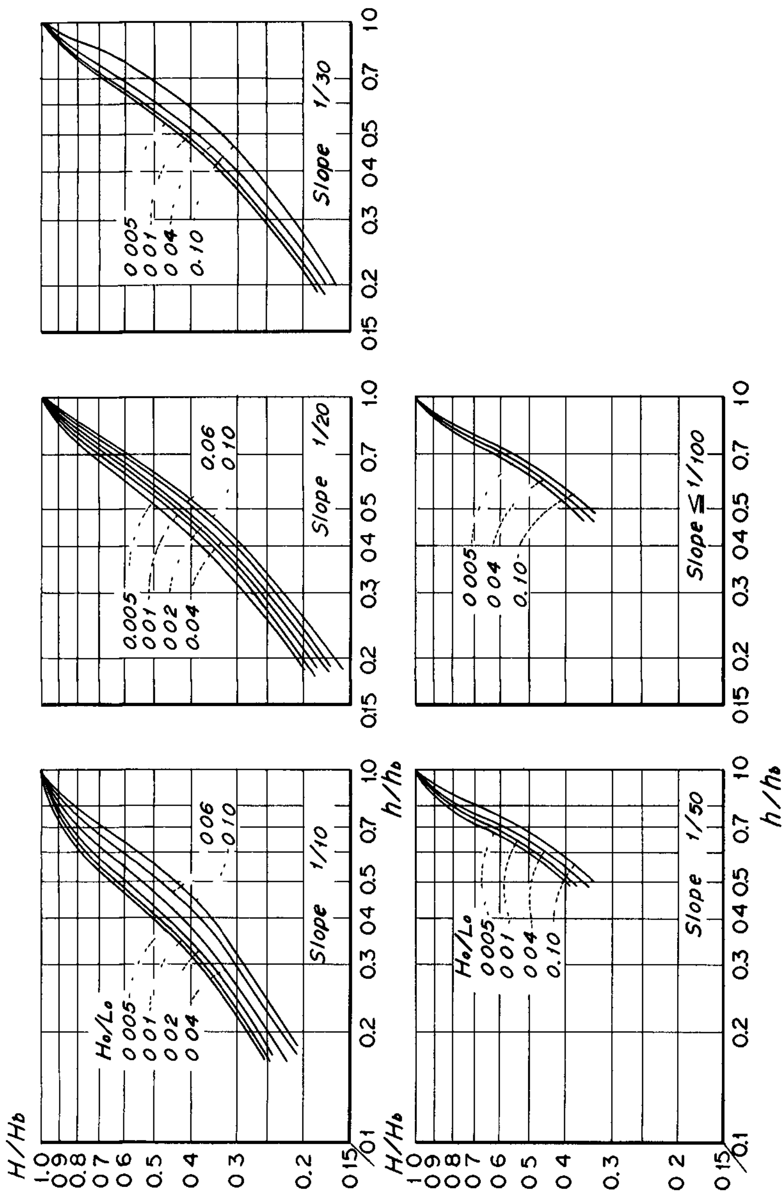

Fig. 26. Change of breaking wave height after breaking point.

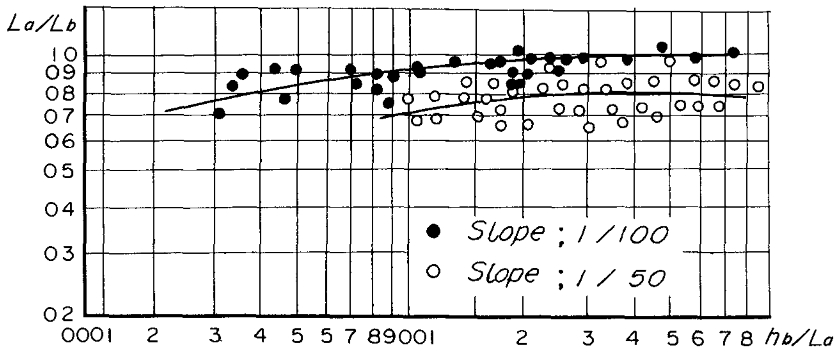

Fig. 27. Change of wave length due to breaking.

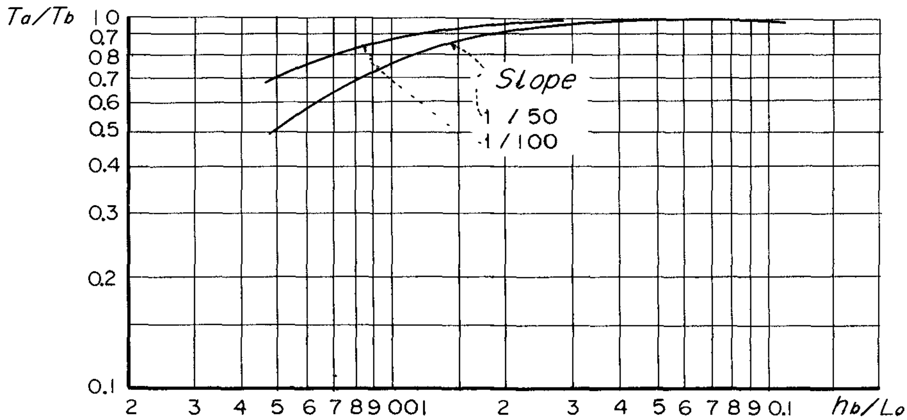

Fig. 28. Change of wave period due to breaking.

CONCLUSIONS

The experimental investigation enable the following treatments. That is,

1) The effect of bottom gradient can be used in the estimation of wave characteristics at the breaking point.
2) The wave transformation in process of breaking can be obtained.
3) The length of the breaker zone can be obtained.
4) The period of reforming wave after breaker zone can be estimated.

From these results, wave transformation from the deep sea area to the shoreline can be estimated, by extending these procedures to the series of repeated breaking.

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