# CHAPTER 17

## WAVE DAMPING EFFECT OF SUBMERGED DIKE

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

### INTRODUCTION

Up to present, submerged dikes were mainly used as detatched breakwaters for artificial nourishment of beach or a front dikes to protect a rear main dike. However, the application of submerged dike to artificial creation of a fishing-ground has been recently taken into consideration with great interest. The following four pointe are considered as the oharacterietice of a submerged dike.

(1) Wave pressure and wave force acting on a submerged dike is emaller than those on other type breakwater because its crown ie below the still water level.

(2) Submerged dikee damp comparatively great waves, while comparatively small wavee freely pass over submerged dikes. This is the moet suitable condition for the fishing-ground. Namely, slightly wavy surface of water in the fishing-groud is rather deeirable from a view-point of fish ecology.

(3) Submerged dikes are usually conetructed at comparativel low cost because their heights are lower and wave pressure operating on them is smaller in comparison with other type breakwater.

(4) Since the water depth on the crown of eubmerged dikes is the most important facter that determinee the effect of eubmerged dikes against wave action, the wave damping effect of submerged dike variee according to chang of tidal level.

Ae for study on submerged dikes, many reeearchers have already published the results of their investigations, such as the theoretical studiee by Lamb, Jeffreys, Dean, Johnson and Fuchs, the investigation of trapezoidal and triangular underwater barriers by the B.E.B. (U.S.A.), that of rectangular barriers by Morison, that of horizontal barrier by Hein and that of submerged cylinder by Ursell. Moreover, Johnson has recently reexamined a eubmerged dike, and in Japan the report by Hosoi and Tominaga wae already publiehed. The causes of wave damping due to a submerged dike can be considered that it absorbe some of the incident wave energy by causing the waves to break. Some of the remaining energy is diseipated by reflection and friction on the crown of the submerged dike and some transmitted ehoreward. In the published reporte ae previously mentioned, the transmission coefficient has been obtained mainly by the investigatione of wave reflection due to the submerged dike. The theoretical analysis of breaking phenomena is very difficult because of its complication. However, the wave damping effect due to submerged dike is made remarkable by causing the wave to break on the submerged dike. From this point of view, thie report mainly deale with the wave damping effect due to breaking on the submerged dike and offers the experimental data for the practical use.

Moreover, in order to investigate the scale effect of experimental results, the comparison between experimental data and field data is presented.

## EXPERIMENTAL EQUIPMENTS AND PROCEDURES

### EXPERIMENTAL EQUIPMENTS

The wave channel used in this experiment is 100 m long, o.6 m wide and 1.0 m deep as shown in Fig. 1. An impermeable submerged dike of rectangular section as shown in Fig. 2 was installed on the flat bottom of this wave channel. The wave channel has a flap type wave generator at one end and a sloping wave absorber of 1/50 at another end to eliminate reflection waves. The measured amounts were the height, length and period of incident wave seaward from the submerged dike and of transmitted reforming wave inshore of it. Moreover, the distance from inshore edge of the submerged dike to a reforming point was also measured and whether the incident waves were caused to break by the submerged dike or not was discriminated. In these observations, supersonic water gauges and electric resistance type wave gauges were used. In order to know the incident wave witout influence of reflected wave by the submerged dike, the wave characteristics with no dike in position were measured. The obtained wave data were designated as the seawed wave characteristics with the submerged dike in position in case of the same condition of wave generation.

### EXPERIMENTAL CONDITIONS

The experimental conditions are as shown in Table 1.

Table 1. Experimental conditions

| | | |
|---|---|---|
| Water depth | : | 40, 50, 60, 70 cm |
| Wave height | : | 3 - 25 cm |
| Wave period | : | 1.00, 1.25, 1.50, 1.75, 2.00, 2.25, 2.50 sec |
| Dike height | : | 40, 50, 60, 70 cm |
| Dike width | : | 0.0 , 1.0, 2.2, 4.0 m |
| Dike type | : | Rectangular, impermeable |

### NOTATIONS

Symbols used in this paper are as shown in Fig. 2 and in Table 2.

## MAIN DEMENSIONLESS VARIABLES

Transformation of energy of incicident waves can be presented by the following formula.

$$Ei = Er' + Eb + Ef + Ea \quad \text{.............................} \quad (1)$$

In the previously published reports, the investigations concerning Er and Eb have been mainly presented and transformation of wave energy has been theoretically analyzed by regarding wave action over the submerged

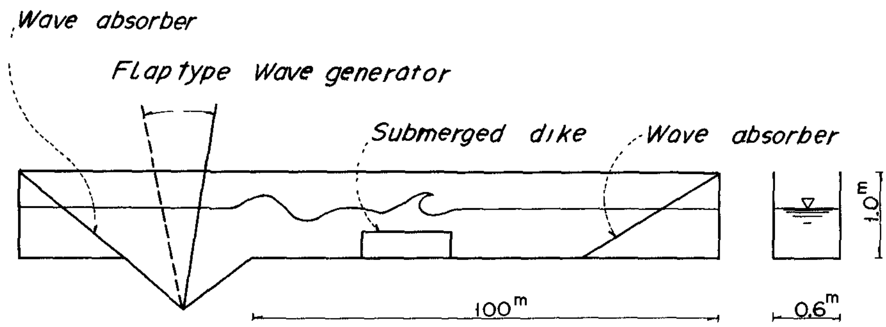


Fig. 1. Experimental equipments.

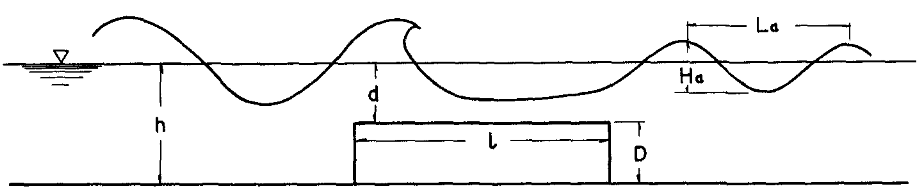


Fig. 2. Hydraulic symbols

Fig. 3, whether incident waves are caused to break by the submerged dike can be discriminated.

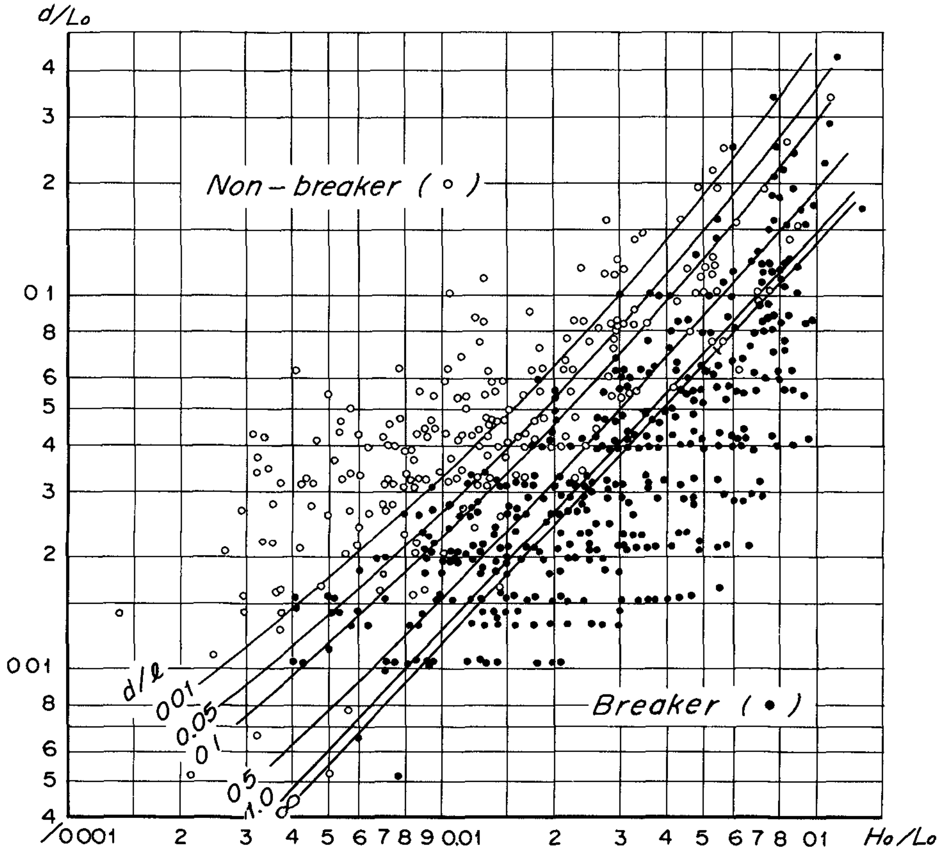


Fig. 3. Breaking conditions on submerged dike.

Table 2. Notations

| | | |
|---|---|---|
| Ho, Lo, To | : | Height, length and period of deep water wave, respectively |
| Hi, Li, Ti | : | Height, length and period of incident wave, reepectively |
| Ha, La, Ta | : | Height, length and period of reforming wave inehore from dike, respectively |
| h | : | Water depth on the bottom of the wave channel |
| d | : | Water depth on dike crown |
| l | : | Width of eubmerged dike |
| Ei | : | Energy of incident wave |
| Er | : | Energy of reflrcted wave by eubmerged dike |
| Eb | : | Dissipated energy caused by breaking on submerged dike |
| Ef | : | Dissipated energy caused by friction of crown of submerged dike |
| Ea | : | Energy of transmitted wave |
| lb' | : | Length from inshore edge of submerged dike to reforming point |

dike as potential motion in neglecting of Eb and Ef. Ae for the experimental investigations in coneideration of Eb and Ef, there are eome reports. However, these reporte present the experimental resulte within the limited extent of wave eteepnees, relative depth and dimensione of the eubmerged dike. Consequently, these results cannot be applied to general cases.

Thie paper deale with the wave damping effect of the eubmerged dike laying etress on Eb and Ef. The relation of formula (1) can be shown by the following function with variables as for waves and the submerged dike.

$$Ha = f(Hi, Li, h, D, d, l) \quad \ldots\ldots\ldots\ldots \quad (2)$$

In this function, fundamental quality of water ie not included. The variables in the formula (2) are replaced by the dimensionlees variables in the following equation.

$$Ha/Hi = \phi(d/Hi, l/Li, D/h, Hi/Li, h/li) \quad \ldots\ldots\ldots\ldots \quad (3)$$

Other dimensionless variables can be obtained from the combinatione of these dimeneionless variablee.

## BREAKING CONDITIONS ON SUBMERGED DIKE

The wave damping effect of the eubmerged dike in case of breaking is remarkably different from that in caee of non-breaking. Consequently, it is very important in the eetimation of the damping effect of the submerged dike to discriminate whether the incident wave is caused to break or not by the submerged dike. Fig. 3 shows the breaking conditions on the eubmerged dike. In this figure, wavee in the condition of the lower zone were caused to break by the submerged dike and wavee in the condition of the upper zone were transmitted without breaking. The limit between theee two zones is related to the relative width of the submerged dike, d/l. With increaeing w width the limit line moves upwards. This fact ehows that the incident wave is apt to break according to enlargement of width of the submerged dike. The condition of premature breaking due to an abrupt change of water depth is different from the breaking conditions on a natural bottom. By using

WAVE DAMPING EFFECT DUE TO BREAKING ON SUBMERGED DIKE

The transmission coefficient, Ha/H is shown in Figs. 4 - 7. These figures are obtained from the comparison of the height of incident wave and corresponding transmitted wave. Consequently, the relations of the transmission ooefficient of these figures contain the influence of various kinds of energy transformation, i.e., dissipation of wave energy due to breaking, reflection and friction. In Figs. 4 and 6, the values of the incident wave in the formula (3) are converted into those of the corresponding deep water wave by the small amplitude wave theory. The curves in Fig. 4 do not converge necessarily to unity in the ordinate because the ordinate has the dimensionless value by the height of deep water wave. Therefor, it is undesirable that these curves are used beyond the limits of the experimental data. Judging from Fig. 4, if the value of d/Ho is larger than 1.5 - 2.0, the submerged dike is ineffective in damping waves in case of its comparatively small width. Figs. 5 and 7 show the transmission coefficient in comparison with incident waves. Figs. 6 and 7 are exchanging the values of the abscissa for the parameters in Figs. 4 and 5, respectively. These figures indicate that the transmission coefficient is not so sensitive to the width of the submerged dike. This fact shows that the dissipation of wave energy through the submerged dike is mainly caused by reflection and breaking. Figs. 8 and 9 present respectively the length and the period of reforming wave inshore of the submerged dike. If the characteristics of wave outside the submerged dike is given, necessary elements of the transmitted wave can be estimated by using these results.

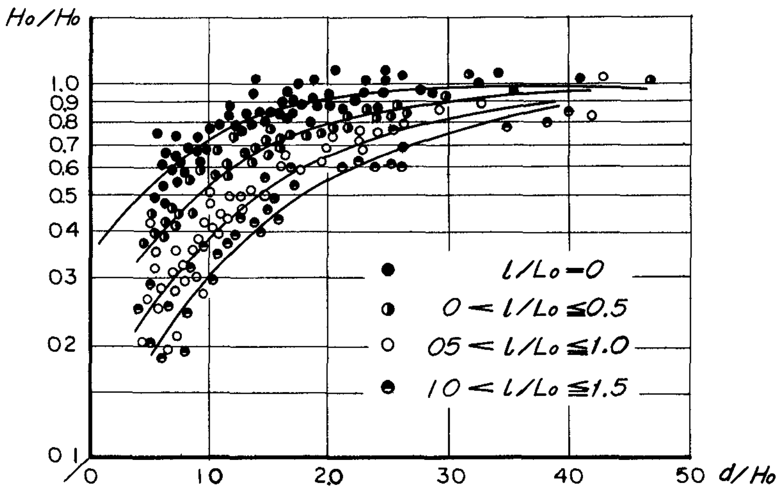


Fig. 4. Relation between transmission coefficient Ha/Ho and d/Ho in case of breaking on submerged dike.

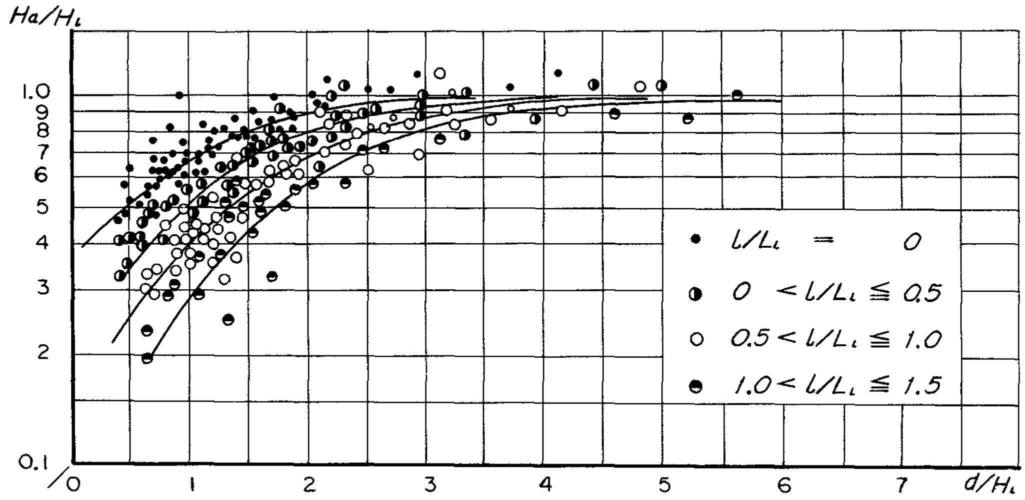


Fig. 5. Relation between transmission coefficient Ha/Hi and d/Hi in case of breaking on submerged dike.

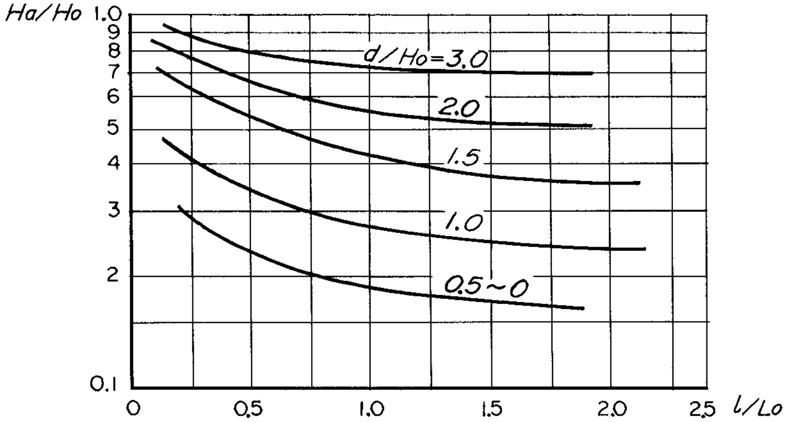


Fig. 6. Relation between transmission coefficient Ha/Ho and l/Lo in case of breaking on submerged dike.

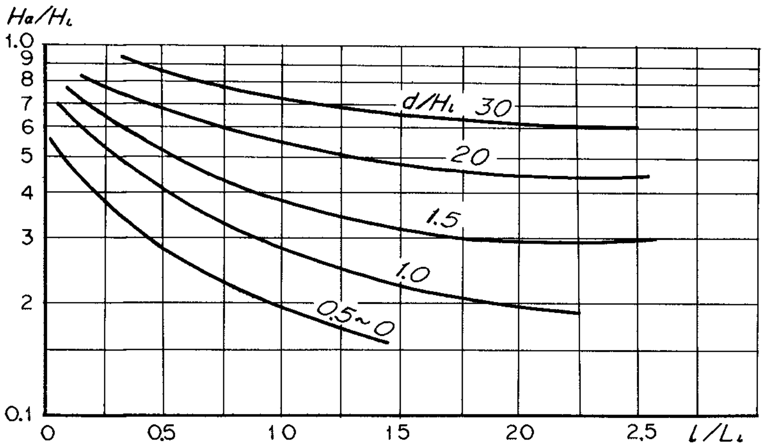


Fig. 7. Relation between transmission coefficient Ha/Hi and l/Li in case of breaking on submerged dike.

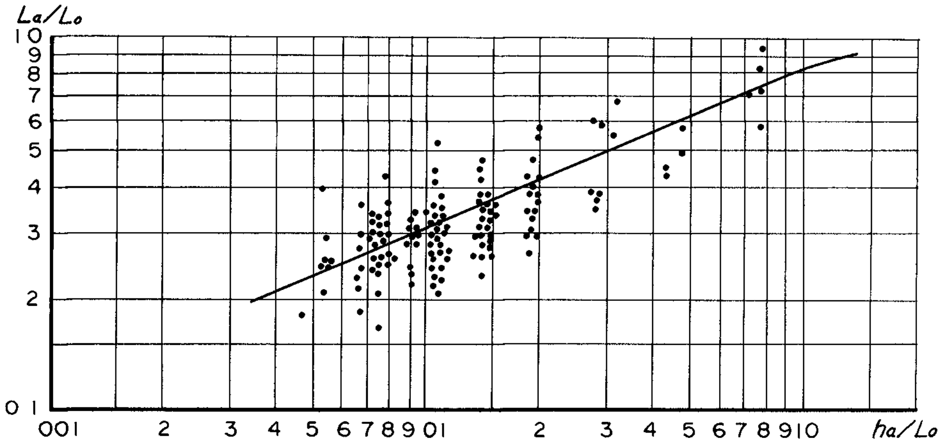


Fig. 8. Change of wave length due to breaking on submerged dike.

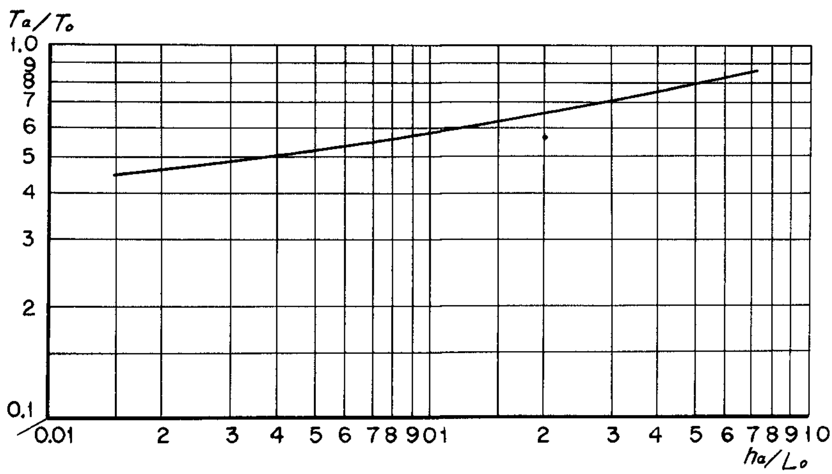


Fig. 9. Change of wave period due to breaking on submerged dike.

## DISTANCE IN PROCESS OF BREAKING

The wave caused to break by the submerged dike proceeds into the process of breaking during some distance after passing over the submerged dike in spite of increase of water depth. Shore structures, fishery facilities in particular, must be constructed in such a position to avoid the violent action of breaking waves. So it is important to estimate the position where such a breaking wave reforms to non-breaking wave. The distance from inshore edge of the submerged dike to a reforming point is given by Fig. 10.

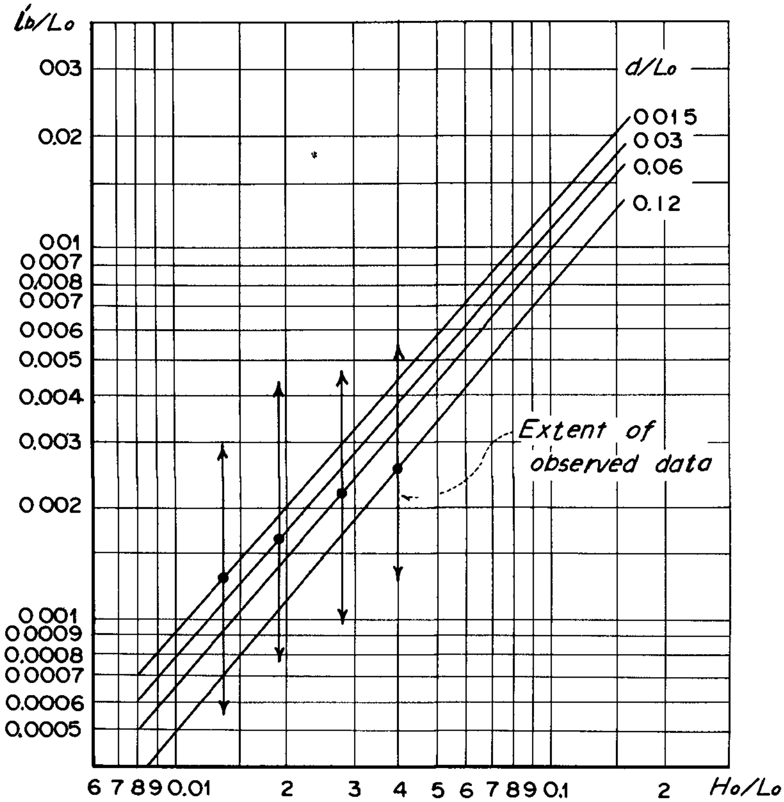


Fig. 10. Length from inshore edge of submerged dike to reforming point.

TRANSMISSION COEFFICIENT IN CASE OF NON-BREAKING ON SUBMERGED DIKE

In the case when the wave passes over the submerged dike without breaking, the wave damping effect is mainly affected by reflection and friction. Whether a given wave seaward from the submerged dike is caused to break or not can be discriminated by Fig. 3. The transmission coefficient is given by Fig. 11 in the case of non-breaking. This figure indicates that the transmission coefficient in this case is affected more by the height of the submerged dike and the water depth on dike crown than by its width. Moreover, the change of wave length in the case of non-breaking is given by Fig. 12.

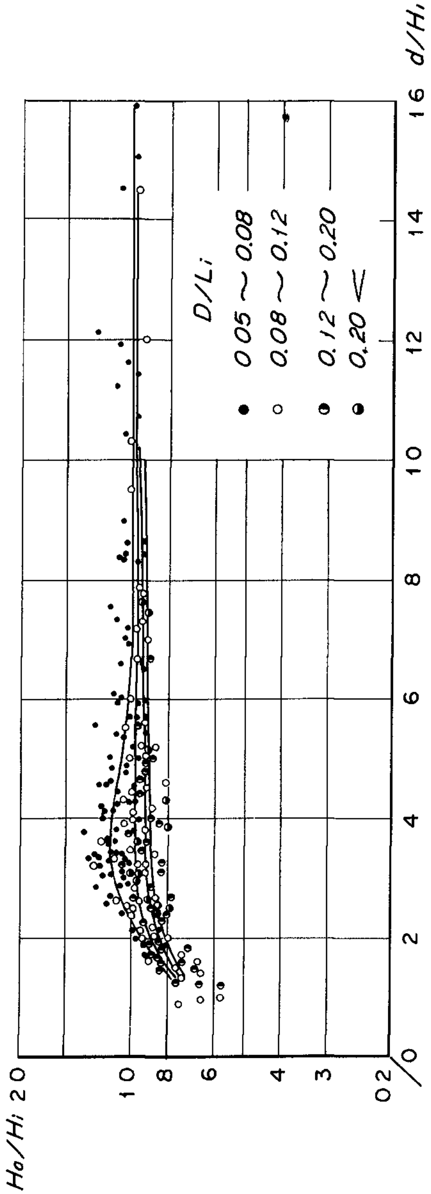


Fig. 11. Relation between transmission coefficient Ha/Hi and d/Hi in case of non-breaking on submerged dike.

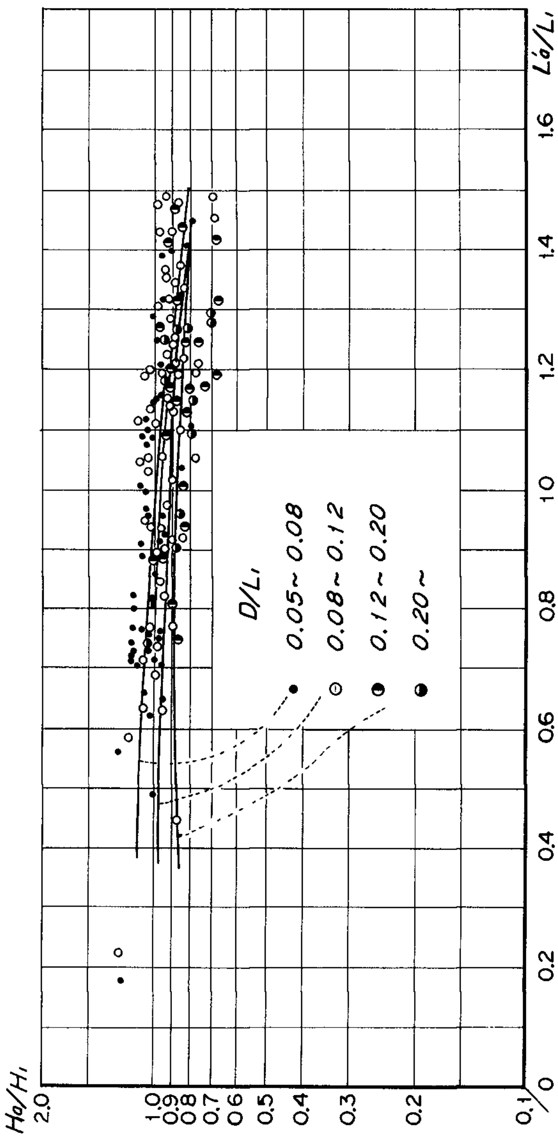


Fig. 12. Relation between incident wave length and transmission wave length in case of non-breaking on submerged dike.

INVESTIGATION ON DATA OF FIELD OBSERVATION

In order to investigate the scale effect of this experiment, the comparison between field data and experimental result is shown in Fig. 13. The field data were observed at Tokoname of Aichi Prefecture. In this figure, plotted points show the data of field observation and curve presents the experimental relation. The prototype submerged dike has been constructed for the purpose of both wave protection and foot protection of cylindrical piles. Consequently, the field data is a little affected by such piles. However, it is generally mentioned that cylindrical piles is little effecttive on transmission coefficient in the case of larger ratio of an interval of piles to a diameter of pile than about 0.2. In the field, the piles were 0.3 m in diameter and 2.0 m apart one from each other. Therefore, it may be stated that the field data do not contain the influence of piles.

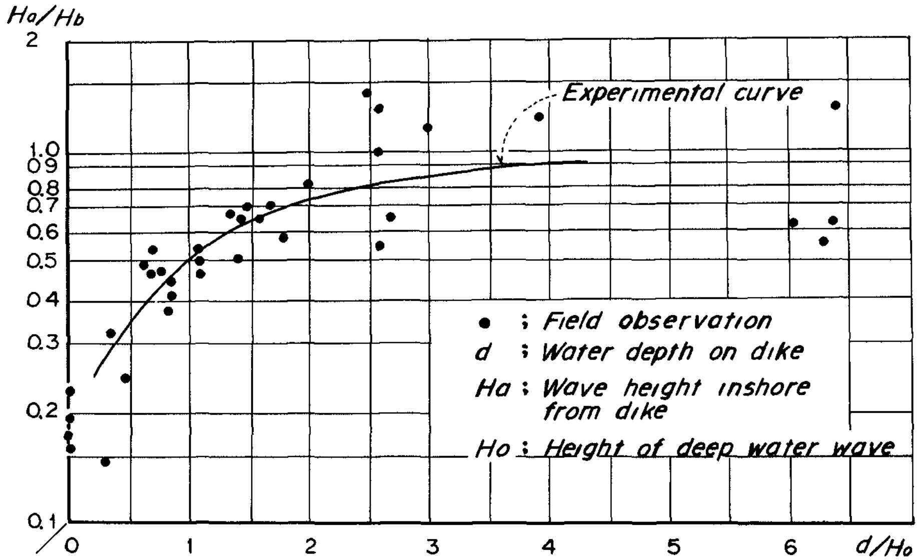


Fig. 13. Comparison between field data and experimental data.

## CONCLUSIONS

The following conclusions can be stated from this experimental investigation on the submerged dike.

1) Whether the incident waves are caused to break or not by the eubmerged dike can be discriminated.
2) In the case of breaking, the transmission coefficient of wave height can be obtained by Figs. 4 - 7.
3) In the case of breaking, the change of wave length and period is shown in Figs. 8 and 9, respectively.
4) In the caee of non-breaking, the transmission coefficient of wave height can be obtained by Fig. 11.
5) In the caee of non-breaking, the change of wave length is given by Fig. 12.

## REFERENCES


Lamb, H. (1945). Hydrodynamics; 6th Ed.

Jeffreys, H. (1944). Note on the offshore bar problem and reflection from a bar; Grt. Brrit. Minietry of Supply, Wave Report 3

Dean, W. R. (1945). Onthe reflection of surface waves by a submerged plane barrier; Grt. Brit. Ministry of Supply, Wave Report 8

Johnson, J. W., Fuchs, R. A. and Morison, J. R. (1951). The damping action of submerged breakwaters; Trans. A. G. U., Vol. 32 - 5

BEACH EROSION BOARD (1940). A model study of the effect of submerged breakwaters on wave action; Tech. Memo. 1

Ursell, F. (1947). The effect of a fixed vertical barrier on surface waves in deep water; Proc. Cambridge Phil. Soc., V. 46

Ursell, F. (1950). Surface waves in deep water in the presence of a eubmerged circular cylinder; Proc. Cambridge Phil. Soc., V. 43

Hosoi, S and Tominaga, M. (1959). Wave damping due to detached breakwater; Proc. 6th Conf. on Coastal Engineering in Japan (In Japanese)