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Wave Transmission Characteristics of Fixed and Floating Breakwaters

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SUMMARY Transmission of regular waves past fixed breakwaters and floating breakwaters are studied in detail in a laboratory wave flume. The performance characteristics of these breakwaters are presented and discussed.

1 INTRODUCTION

Ocean waves pose many challenges to marine engineers engaged in onshore and offshore operations. It has become necessary to go in for more and more wave protection devices at present due to the rapid developments in the exploration of the natural resources of the ocean - the protection of tanker terminals and construction of various offshore structures. However, the wave effects can be minimized, dissipating the wave energy, by providing suitable breakwaters.

The primary functions of fixed or submerged breakwaters is to protect the sheltered area of the harbour from severe wave action by attenuating the waves as they pass over the barrier. In many locations, submerged breakwaters (fixed) offer a potentially economic solution to the coastal engineering problems.

Floating breakwaters are necessary when sheltering of areas from sea waves is required for a short time, to carry out a specific task in the calm zone. The important features of floating breakwaters include mobility, short erection time, freedom from silting, scour and foundation problems and comparatively less initial and maintenance costs, especially for offshore construction works. One of the main advantages of the floating structures is its indifference to tidal level changes.

In this paper experimental results of hydrodynamic characteristics of fixed and floating breakwater models studied in a wave flume with fixed breakwaters placed at different depths of submergence and floating breakwater anchored to the flume bed are discussed and compared.

2 REVIEW OF EARLIER WORKS

Stoker (1957) obtained theoretical solutions for the transmission of waves over a fixed horizontal plate based upon linear wave theory. He gave the following relationship for the transmission and reflection coefficients.

$$K_T \text{ (Transmission Coefficient)} = \frac{H_T}{H_I} = \frac{1}{\left[1+\left(\frac{\pi B}{L}\right)^2\right]^{0.5}} \qquad (1)$$

$$K_R \text{ (Reflection Coefficient)} = \frac{H_R}{H_I} = \frac{\pi BL}{\left[1+\left(\frac{\pi B}{L}\right)^2\right]^{0.5}} \qquad (2)$$

where H_T, H_I, H_R are transmitted wave height and incident wave height and reflected wave height respectively. B: the length of breakwater model and L: the wave length. The theory considers the relationship

$$(H_T/H_I)^2 + (H_R/H_I)^2 = 1 \qquad (3)$$

indicating that the incoming wave energy is equal to the sum of the transmitted and reflected wave energies and hence no dissipation of energy is considered. Sendil and Graf (1975) modified Stoker's theory by inserting a non-dimensional constant as the correction factor given by

$$K_T = \alpha\left[1 + \left(\frac{\pi B}{L}\right)^2\right]^{-0.5} \qquad (4)$$

Based on experiments Sendil and Graf(1975) found α to be a function of the incident wave steepness (H_I/L) and relative plate position (h/d). Dick and Brebner (1968) conducted experiments with submerged breakwaters with a water depth of 2 feet, and depth of submergence varying from 0.10 to 0.60 feet. When the transmission coefficient was plotted against wave number spectrum $(2\pi d/L)$, d being depth of water for various values of depth of submergence (h/d), K_T was found to increase with increase in depth of submergence. A theoretical curve was also given for an infinitely deep water. It was also inferred that the value of K_T increases with increase in (h/d) for a given value of (L/B).

Model tests performed by Wiegel et al (1962) showed that with floating sheets of plastic material a wave attenuation upto 50 percent could be obtained with relative breakwater length (B/L) equal to 2 to 3. Extensive experiments were performed by Sendil and Graf (1975) with floating plates. The experiments were carried out with wave heights ranging from 0.21 to 8.17 cms, wave periods from 0.6 to 4 secs and the lengths of floating plates were 61, 91 and 122 cms. Considerable scatter was found when they plotted Transmission Coefficient against relative plate length. Studies on Wave-Maze flexible floating breakwaters were conducted by Morgan Noble et al (1976). The basic-component of this breakwater consists of used truck tyres, some of which were filled with material such as polystyrene or polyurethane, to provide floatation. It was concluded that the effectiveness of the wave-maze in attenuating waves of short periods and steepness greater than 0.04. With breakwater widths approximately equal to one half the wave length, upto 80 percent of the wave energy was attenuated.

Though several investigators have reported the transmission characteristics of fixed and floating breakwaters no attempt has been made to compare the behaviour of these two breakwaters in attenuating the incident wave height. It is felt by the authors that a comparative report between these breakwaters would be quite useful to design engineers engaged in the design of wave protection devices.

3 EXPERIMENTAL STUDIES

Experiments on fixed and floating breakwater models were performed in a wave flume of crossection (0.9 m x 0.9 m) and length 26 m at the Hydraulic Engineering Laboratory, Indian Institute of Technology, Madras. The details of the experiments are reported by Balasubramanian (1976), Sundar (1977) and Sundar and Dakshinamoorthy (1978). Regular waves were generaged in the wave flume by means of a plunger type of wave generator of parabolic section. The fixed breakwater was placed at still water level and at different depths of submergences. However, results only for depth of submergence equal to zero has been reported in this paper. Wave period ranged from 0.8 secs to 2.0 secs. The ranges of d/L, B/L were 0.01 to 0.14 and 0.1 to 1.30 respectively. Incident wave heights developed in the laboratory ranged from 5 cms to 16 cms. The floating breakwater model consisted of a wooden plank,was anchored to the concrete bed of the flume by means of mooring wires of lengths approximately twice depth of water.

4 ANALYSIS AND DISCUSSION OF RESULTS

The transmission coefficient of a fixed breakwater with a certain depth of submergence may be written as a function of the following quantities.

$$K_T = f(\rho, L, h, g, u, d, B, \mu) \quad (5)$$

where ρ: mass density, u: horizontal particle velocity, μ: viscosity and other terms as defined earlier.

A dimensional analysis of the variables in (5) yielded the following relationship.

$$K_T = f(H_I/L,\ h/d,\ H_I/h,\ H_I/d,\ H_I/B,\ B/L,\ d/L,\ Re,\ Fr) \quad (6)$$

where Re is Reynold's Number and
Fr is Froude number.

When h = 0 for fixed breakwater it has been concluded by Sendil and Graf (1975) that

$$K_T = f(H_I/L,\ d/L,\ B/L) \quad (7)$$

which is also applicable for floating breakwater.

The effects of parameters in these experimental studies are shown in Figures 1-6. Although a direct comparison cannot be made between the present results and those of Dick and Brebner (1968) from Figure 1, it is evident that the variation of the transmission coefficient with $2\pi h/L$ in the case of a submerged breakwater model, is similar to that in the case of a vertical breakwater in deep water. Further it should be noted that the present experimental study was done in intermediate depth of water. Figure 2 shows present experimental values plotted against the theoretical values given by Stoker (1957) for depth of submergence equal to zero. An equation of the form y =(mx + c)can be easily proposed. The proposed equation for transmission coefficient which is a modified form of Stoker's equation for zero submergence is given by

$$K_T = \frac{1}{2.33}\left[\frac{1}{\left[1+\left(\frac{\pi B}{L}\right)^2\right]^{0.5}}\right] + 0.15 \quad (8)$$

The comparison of present experimental results for a fixed breakwater model with zero depth of submergence and that of Sendil et al (1975) experimental results are presented in Figure 3. It is seen in both cases, as incident wave steepness increases the correction factor α decreases. Hence (4) represents a useful relation between K_T, B/L and α. Figure 4 is the outcome of plotting the values of the transmission coefficient against values of relative floating breakwater lengths for different incident wave steepness. From the plot it is concluded that wave attenuation increases with the increase in incident wave steepness which is in accordance with the theory. Transmission coefficient decreases with increase in the incident wave steepness and when the incident wave steepness exceeds 0.04 attenuated wave less than 50 percent of

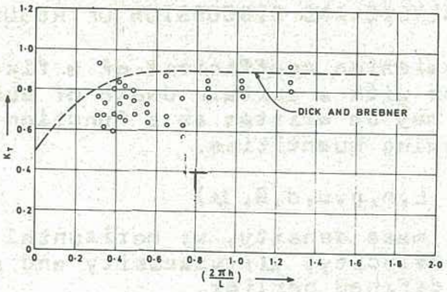

Figure 1 Comparison of Dean's Theory with experimental results (h/d=0.0)

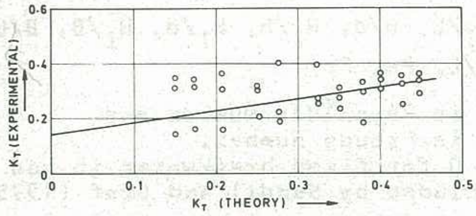

Figure 2 Comparison of Stoker's Theory with Experiments, h/d = 0.0

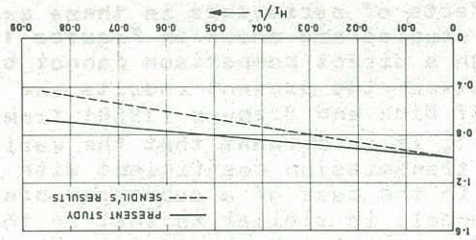

Figure 3 Comparison of Experimental Results with Sendil's Result, h/d = 0.0

the incident wave in accordance with Morgan et al (1976) is seen in Figure 5. The comparison between the transmission characteristics of fixed and floating breakwaters tested along with the theoretical curve proposed by John (1949) is presented in Figure 6. It is seen that the transmission coefficient values of fixed breakwaters is less than that of floating breakwaters d/L remaining constant. Floating breakwaters riding over the waves without attenuating them may be the reason for its lesser attenuation compared to fixed breakwater.

5 CONCLUSIONS

It is found that the horizontal fixed breakwater is more effective in attanuating waves than a vertical breakwater at the same relative depth of submergence. A modification of Stoker's theory for zero submergence based on experimental results is proposed for fixed breakwaters. Sendil's modified form of Stoker's equation can be used in the prediction of wave transmission provided prior knowledge of the correction factor α is available.

The length of the floating breakwater definitely has a great effect on the transmission coefficient. For greater length of breakwater wave attenuation is more. Regarding wave steepness it was found that wave attenuation is greater in case of steeper waves and is less in case of flatter waves.

Fixed type breakwaters are more effective in attenuating the incident waves compared to floating type breakwaters.

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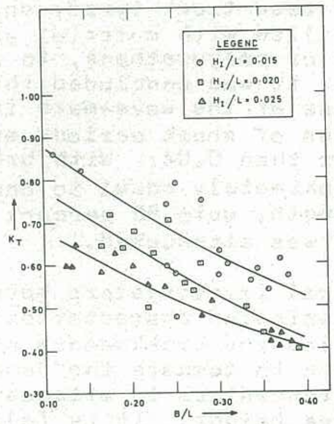

Figure 4 Transmission Coefficient Versus Relative Breakwater Length (F.B.W.)

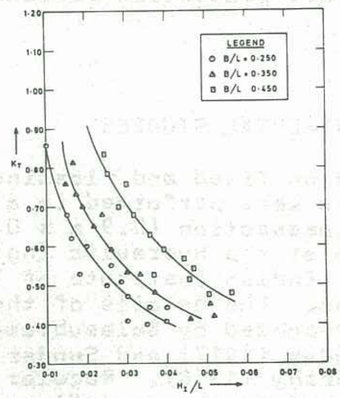

Figure 5 Transmission Coefficient Versus Incidant Wave Steepness (F.B.W.)

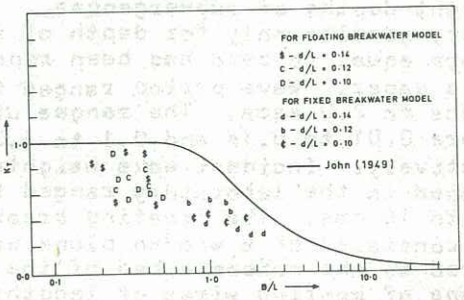

Figure 6 Transmission Coefficient Versus Relative Breakwater Length (fixed and floating)

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