CHAPTER 63

DAMPING EFFECT OF FLOATING BREAKWATER TO WHICH ANTI-ROLLING SYSTEM IS APPLIED

by

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I INTRODUCTION

Among the recent problems in the fisheries in Japan, the development of fish farms is getting to be important. The breakwater for fish farms is required to have the functions of exchanging sea water and the preservation of fishing ground, as well as the outer facilities of fishing ground.. Various types of breakwater to meet the requirements can be considered,the floating breakwater being one of them.

When we limit the studies in the wave damping effect of a mobile breakwater, we can summarize that an effective floating breakwater should have sufficient draught under water surface and should have a comparatively large displaced water volume. In other words, the natural oscillation period of the floating body must be large enough as compared with that of the incident wave. (R. L.Wiegel '64)[1] (K. Horikawa et al. '64)[2] for practical purposes the studies on the shape and type must follow. However, if a floating breakwater is provided with a mechanism for attenuating wave, the above-mentioned criterion for the effectiveness must be largely changed.

A floating body have the possibility of three rectilinear and three rotational motions. The proposed floating body was so designed that the phase difference between the rolling motion of the body and the incident wave is as large and wide as possible, and that the phase difference can easily occur; that means, the oscillation period of the body was equal to the period of the incident wave and the body was provided with a function of effective anti-motion, in due consideration of the stability of floating body and the practical applicability of design. So we call the body an anti-rolling system inclusive of the floating body and its mechanism of the reaction. The bilge keel, the stabilizing fin, the gyro-stabilizer and the anti-rolling tank are developed in the field of ship engineering. These mechanisms might be effective when the floating body is adequate in shape even for the irregularity of wave and a complexity of the motion of the floating body.

This paper presents the results of experimental studies on the mechanism of attenuating wave and damping effect of the floating breakwater to which anti-rolling systems are applied.

II OUTLINE OF LABORATORY EQUIPMENT AND PROCEDURE

1) Laboratory Equipment

Experiments were performed in a wave tank, 30 meters long, 1.5 meters wide, and 2.0 meters high, with two glazed walls, 4 meters long each, on a side.

Regular periodic waves were generated by a flap type wave maker with a board 0.8 meters in height at water surface for the purpose of making deep water waves.

2) Model wave

The range of steepness of waves obtained is 0.007- 0.120, when the depth of water, d, is 1.50m. (wave length, L: 0.60- 7.20m, wave height, H: 0- 0.40m)

The height and the length of wave were measured by using the parallel wire resistance and the Neon tube type wave gauges.

3) Floating body (Ōgushi '64)[3] (Motora '64)[4]

The model of floating breakwater was made by steel plate and

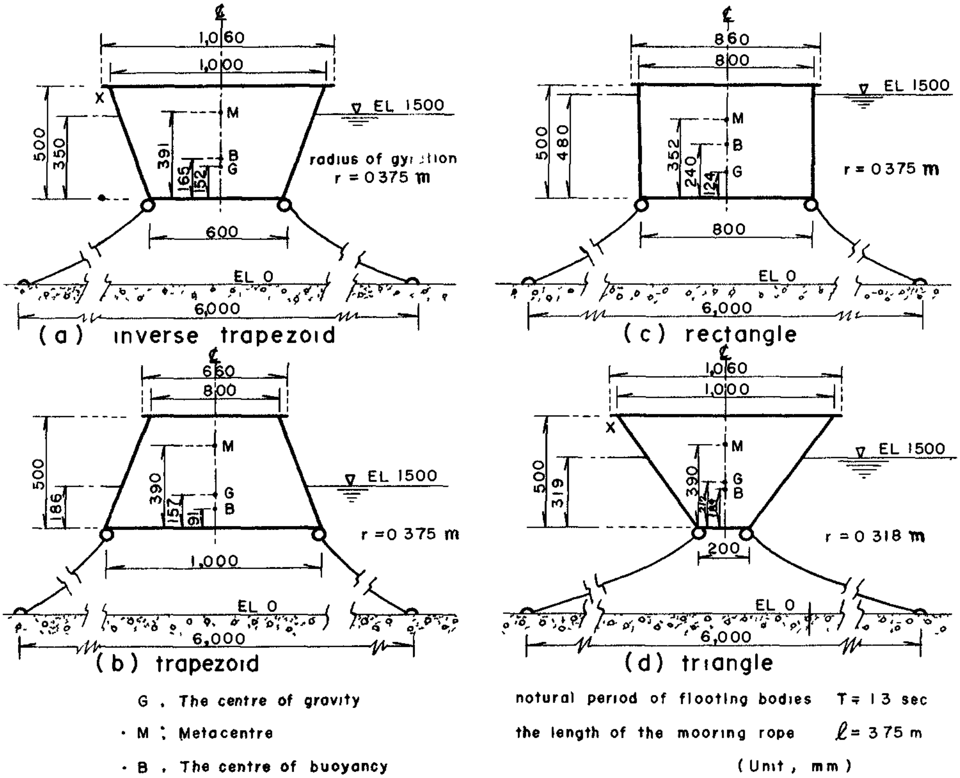

Fig. 1. Floating bodies with fundamental cross section in freely floating system.

anchored at the bottom keeping adequate height.

Four basic shapes, inverse trapezoid, trapezoid, rectangle and triangle, were adopted for the cross section of floating breakwater as shown in Fig. 1. The experiments were performed in case of freely floating system, where the length of mooring rope was 2.5 times as long as the water depth, 1.50m . And the natural oscillation period of each floating body T was constant or equal to 1.3 seconds. In other words, in the equation $T=\frac{2\pi r}{\sqrt{\overline{GM}\cdot g}}$, the height of metacentre $\overline{GM}$ is constant, where r is the radius of gyration and g is the acceleration of gravity.

The projection of the upper rim of floating body (marked with ※ in Fig. 1) was provided as a part to cause wave impaction and was useful for dissipation of energy of incident waves.

4) The series of test

(1) The mechanism of attenuating wave height at each floating body
(2) Damping effect and Reflection coefficients of each floating body

III RESULTS OF MODEL TESTS

1. The mechanism of attenuating wave (cf. Fig.3 (A)- (D))

(1) The case of inverse trapezoidal cross section

Rolling generally occurs when the floating body resonate with the incident wave period. And the floating body with this section is easy to roll for the incident waves. As the mooring cable enforces the rolling motion, a jerking force acts on the rolling body, and just then, the incident wave dashes against the front face of the floating body. At this moment, the energy of incident wave dissipates and attenuation of wave occurs.

(2) The case of trapezoidal cross section

It has also been studies by ship engineers that the floating body with the shape of trapezoidal cross section is the most stable against the rolling motion. (S. Motora '65)[5] Accordingly, the mechanism of wave damping due to attenuation for rolling motion does not occur as in the case (1). In this case a swaying motion has a largely influence on the damping effect, so that, the maximum of the damping effect appears considerably far as compared with the former case, because of the jerking action of rope due to the natural period of swaying motion or the change of the natural period of rolling motion which occurs in this case.

(3) The case of rectangular cross section

In this case, the mechanism of attenuating wave and damping effects have both intermediate characteristics between the former two cases.

(4) The case of triangular cross section

Compared with the former three shapes, the floating body with this section is easier to be agitated due to incident waves. The rectilinear and rotational motions of the floating body, due to incident wave occur remarkably at the same time. The experiment was performed in a two-dimentional wave tank, in this case. And the motion of the floating body which is composed of swaying, heaving and rolling motions, is very complicated. In consequence, it cannot be resistible to a single dominant motion, say, the rolling motion as in the case (1). Therefore, in addition to the anti-rolling motion, swaying and heaving motions also affect the moored floating breakwater. And, the influence of the rolling on the damping effect is more conspicuous in the inverse trapezoid, but is less effective in the triangluar cross section.

The same may be said of the floating body of pontoon type which was studied in the past.

The above-mentioned are the mechanism how the floating body with standard cross section attenuates the wave height. Now, there are two phenomena of wave attenuation as follows.

① The floating body must have natural periods that are large compared with the period of incident wave to which it is subjected.

② The floating body must be provided with an anti-rolling system. In this report, the system is discussed.

2. Damping effects and reflection coeffecients

(1) The case inverse trapezoidal cross section

In Fig. 2-(a) is shown the relation between the tranemission coefficient (H_T / H_I) where H_T is the transmitted wave height, H_I is the incident wave height and T/ T_w (where T is the natural oscillation period of the floating body, T_w is the wave period) or B/L (where B is average width of the floating body) with the parameter H/L (steepness) for the damping effects of the floating breakwater.

There exists the value of T/T_w for which the damping effect is maximum regardless of the value of steepness. For example, the value of H_T /H_I is nearly 0.15 at T/ T_w = 1. It appears that the floating body resonates with the incident wave period and simultaneously anti-rolling motion occurs and the damping effect is the largest at this time. The value of H_T /H_I increases in propotion as the value of T/ T_w increases within the limits $1.7 \geqq T/T_w > 1$ for $H/L \geqq 0.03$, and a similar tendency is likely to appear both for H/L = 0.02 and 0.01. It is evident that there exists a multiple peak-trough relationship between the ratio of H_T /H_I and T/ T_w although we coulon't obtain data from the series of tests. We can indicate the multiple peak-trough relationship in the study by Wiegel. (R. L.Wiegel '62)[6] Phase difference of resonance occurs several times with the increase of T/ T_w and the curve seems to be astringent to zero forming a curve of damped oscillation. There is an indication that the amplitude of the curve becomes large in accordance with steepnees of incident wave. The floating breakwater with inverse trapezoidal cross section have favorable characteristics as wave height attenuator.

Reflection coefficients can be obtained from next equation, provided that if there is no energy loss in the motion of floating bodies.

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

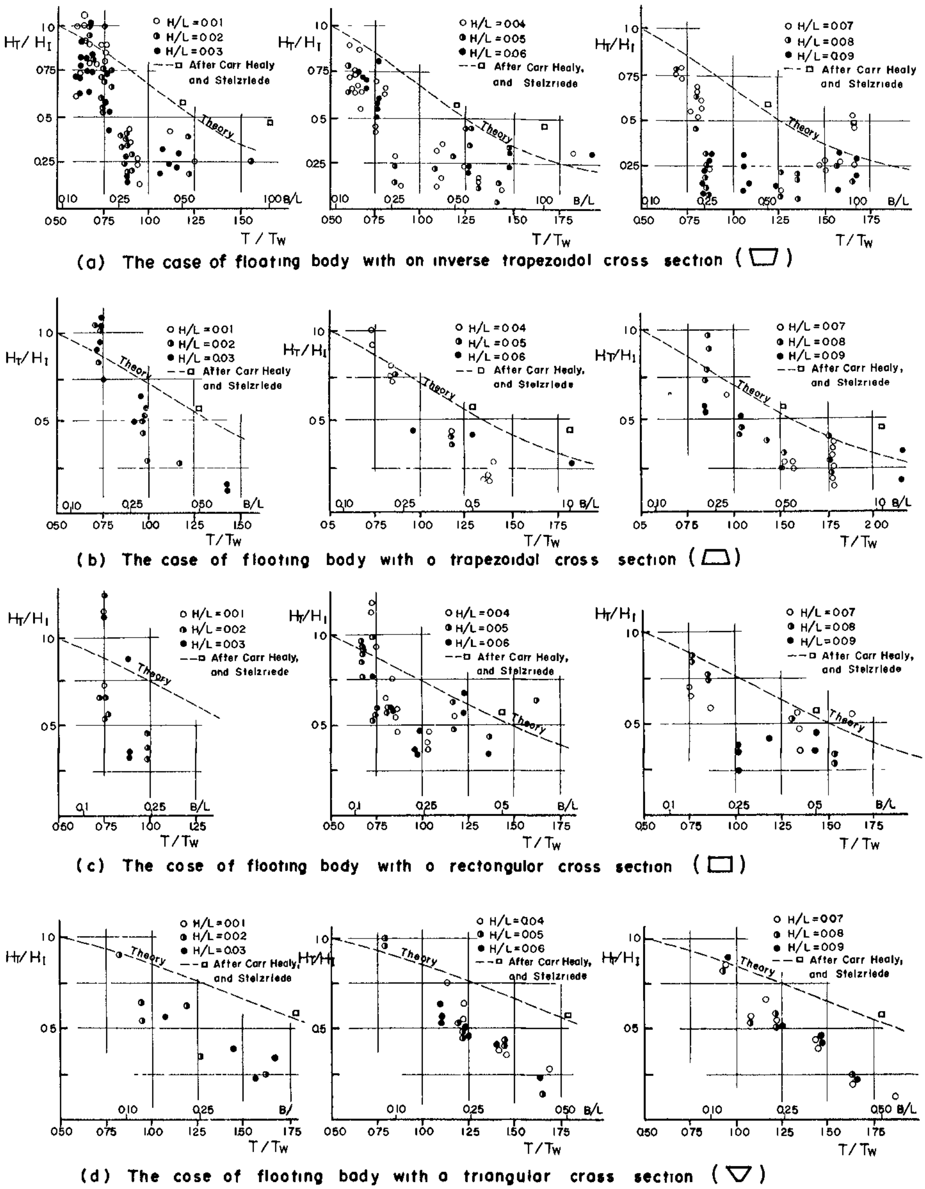

Fig. 2. Transmission coefficient $(\frac{H_T}{H_I})$ related to the value of T/T_W or B/L.

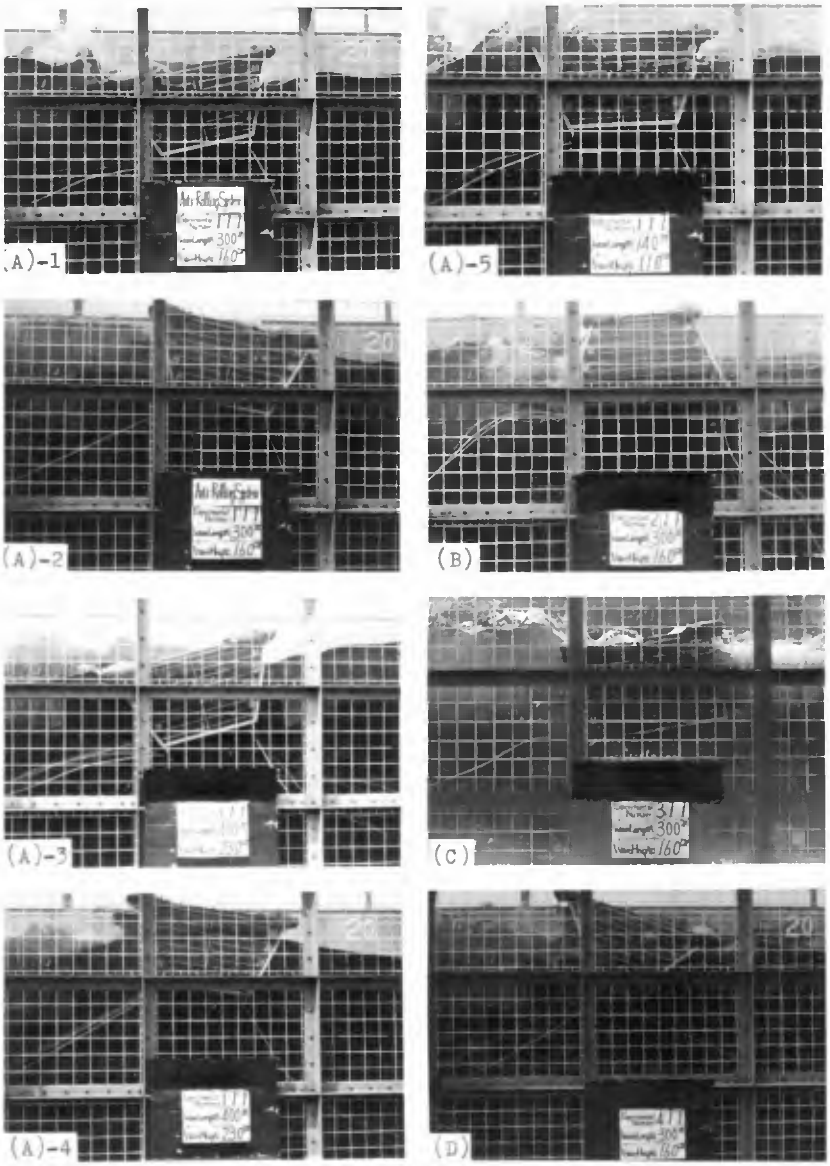

Fig. 3. The motions of the floating body due to incident wave.

(A)-1,2 Inverse trapezoid: Anti-rolling system is available ($T/T_W=1$)
(A)-3,4 Inverse trapezoid: Anti-rolling system is unavailable ($T/T_W<1$)
(A)-5 Inverse trapezoid: The floating body have natural periods that are large compared with the period of incident wave ($T/T_W>1$)
(B) Trapezoid ($T/T_W=1$)
(C) Rectangle ($T/T_W=1$)
(D) Triangle ($T/T_W=1$)

The actual reflection coefficients are about 10% smaller than the values computed from the above equation. This might be attributed to the dissipation of energy by impact to the floating body. Regardless of steepness, maximum reflection effects occurred approximately at $T/T_W = 1$. But the reflection coefficients did not have clear tendency as the damping effects. Also, it may be clear that maximum reflection effects do not accord with theoretical values, because of disturbances by the complicated motion of floating bodies.

(2) The case of trapezoidal cross section

We can see the minimum value of H_T/H_I is about 0.15- 0.20 in $T/T_W \fallingdotseq 1.5$ regardless of the values of H/L . The value of H_T/H_I is about 0.4 for the value of T/T_W is 1, so the damping effect is unfavourable as compared with the former. (cf. Fig.2- (b)) The floating body with trapezoidal cross section has the character that swaying motion is occurred by the incident wave as the above-mentioned. (the mechanism of attenuating wave height, (2)) Occurring swaying motion is the reason why the points in which the damping effect with the anti-rolling motion is maximum transfer in this case.

We can see a similar tendency more or less both in the former and in the following case. Further, it apperars that the attenuation curve also has such a tendency.

It appears that the motion of the floating body is complicated: an eddy motion, impact and run up of wave and overflowing occur in this case.

Reflection coefficients were computed in the same way as the former. The measured values are about 30- 50% smaller than the theoretical values. But the damping effect is also remarkable in this case. It seems that the energy of wave is fairly lost due to impacts or other cause. And there is also no noticeable relation between H_T/H_I and T/T_W .

(3) The case of rectangular cross section

The minimum value of H_T/H_I is 0.4 at $T/T_W = 1$ for H/L is 0.01- 0.04 and the damping effect is inferior to the case of inverse trapezoid, and then, there is the minimum value of H_T/H_I at $T/T_W > 1$ within the range $H/L \geqq 0.05$ in Fig.2- (c). In the same way, the plotted line seems to make an attenuation curve.

Reflection coefficient might have intermediate characteristics between trapezoid and inverse trapezoid. The maximum reflection coefficient H_R/H_I is 0.6 at $T/T_w \doteqdot 1$.

<u>(4) The case of triangular cross section</u>

The value of H_T/H_I is 0.7 at $T/T_w = 1.0$ and 0.3 at $T/T_w = 1.5$ as is shown in Fig.2- (d) and the damping effect of triangle is inferior to the effects of former three shapes. Within the range of $T/T_w \geqq 1.5$, the mechanism of attenuating wave is caused not because of anti-rolling system, but because the natural period of the floating body is longer than that of the incident wave.

Also, the actual reflection coefficient values are about 20- 30% smaller than the theoretical values. This may be attributed to the dissipation of energy used for the motion of the floating body.

IV CONCLUSION

In this paper, the proposed system is discussed, and the contents can be concluded as follows.

1. The floating breakwater to which an anti-rolling system is applied is found to be an effective breakwater if the shape of the anti-rolling system is adequately designed.

2. Especially, the floating body with such a cross section of which characteristic is easy to roll for incident wave, the damping effect is very remarkable, when the value of T/T_w is 1. This is well to be applied to practical use.

There still remain some other problems. These are that the rational design of the shape of floating breakwater must be established, that the characteristics of several anti-rolling systems must be studied, that the problem of mooring must be made clear, and that field tests are required.

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