

# Effects of Breakwaters on Motions of an Elastic Floating Plate in Waves

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## ABSTRACT

An analytical method to calculate motions of an elastic mat-like floating structure in waves in a sea with breakwaters was proposed by the authors (1997, 1998). In this paper, in order to prove the validity of that method, first, the calculations corresponding to the model test for the wave-induced motions of the rectangular plate in a sea with straight breakwater are done. Second, the calculations corresponding to the field test for a rectangular mat-like floating structure 300 m long in a sea with breakwaters are done. From the comparison between the experiments and calculations, the validity of the proposed method is shown.

## INTRODUCTION

A pontoon-type floating structure 4 to 5 km long and 5 m deep was studied by The Technological Research Association of Mega-Float in Japan. This study considered the reduction of the motion of a floating structure by surrounding it by breakwaters. In order to evaluate the motion of this type of structure, it is necessary to consider the fluid dynamic force containing the breakwater's effect, and to perform analyses on the response of the floating structure to the waves by taking their elastic deformations into account. From this viewpoint, the authors proposed a numerical method to calculate the wave-induced motions of an elastic rectangular mat-like structure with breakwaters as the work of The Technological Research Association of Mega-Float in Japan (Nagata et al., 1997, 1998). Seto (1998), Utsunomiya et al. (1998) and Ohmatsu (1999) also used the numerical method to calculate the motions of an elastic mat-like structure with breakwaters. Our method used the 3-dimensional eigenfunction expansion method to calculate fluid force, and the mode expansion method to express the elastic behavior of the floating plate. Finally, the motions of the plate are calculated by using the variational principle. Our method has the advantage that the input data are small and the effect of the breakwater easily considered. However, it took a great deal of time to calculate the potential on the bottom of the plate by that of the boundary of the plate by using Green's identity formula. So in this paper, in order to decrease the computation time, we use the analytical method proposed by Ohmatsu (1997) for calculating the potential on the bottom of the plate.

In this paper, in order to prove the validity of the calculation method, first, a comparison is made between the experimental results in the tank test for a rectangular plate with a straight breakwater and the calculated results. Second, a comparison is made between the experimental results in the field test for a rectangular plate 300 m long with breakwaters and the calculated results.

## FORMULATION

### Fundamental Assumption

As shown in Fig. 1, a rectangular floating plate with a breakwater is considered. The length of the breakwater is finite, and the water depth  $h$  is constant everywhere. The plan of the plate is a rectangle with length  $2a$ , width  $2b$ , and draft  $qh$ . With an incident sinusoidal plane wave of frequency  $\sigma$ , amplitude  $s_0$  and incident angle  $\omega$  with respect to the  $x$ -axis, the floating plate is assumed to be in small motion.

We take the origin  $O$  of the coordinate system at the still water surface, the  $x$ - and  $y$ -axes in horizontal directions, and the  $z$ -axis vertically upwards. For simplicity, we focus on the vertical deformations of the plate. The deflection of the plate is approximated by an expansion in terms of the natural modes of a free-free beam in free vibrations. The vertical displacement of the plate  $w(x, y) \cdot e^{-i\sigma t}$  is then expressed as follows:

$$w(x, y) = \sum_{m=-1}^M \sum_{l=-1}^L A_{ml} \cdot \mu_m(x) \cdot \psi_l(y) \quad (1)$$

where:

$$\begin{aligned} \mu_{-1}(x) &= 1, & \mu_0(x) &= -x, & \psi_{-1}(y) &= 1, & \psi_0(y) &= y \\ \mu_{2m-1} &= \frac{1}{2} \left( \frac{\cos \lambda_{2m-1}^{(1)} x}{\cos \lambda_{2m-1}^{(1)} a} + \frac{\cosh \lambda_{2m-1}^{(1)} x}{\cosh \lambda_{2m-1}^{(1)} a} \right) \end{aligned} \quad (2)$$

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KEY WORDS: Mat-like elastic floating plate, breakwaters, wave-induced motions, calculation, experiment.