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Standing Wave Pressure Acting on the Mixed Type Breakwater

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1. INTRODUCTION

In the design of mixed type breakwater, the most important factor to be considered is the wave pressure. In particular, the standing wave pressure has a significant effect on the vertical wall breakwater or mixed type breakwater. Many wave pressure formulas were developed and the Goda's formula[1] was very frequently used among them by the coastal engineers due to its simplicity and accuracy. This formula, however, has a drawback not considering the bottom topography in front of the breakwater and mound configuration such as the inclination and berm length. To cope with this problem, the hydraulic experiment is commonly used to design the breakwater even though it takes so many times and costs.

In the present study, we develop a numerical model to calculate the standing wave pressure acting on the mixed type breakwater attacked by highly nonlinear waves. We also calculate the wave pressures at the front face and bottom of the caisson of the breakwater and compare the results of numerical model with those of the hydraulic experiment and Goda's formula.

2. MATHEMATICAL FORMULATION

Consider a general two-dimensional hydrodynamic problem to generate nonlinear wave. Under the assumption of irrotational flow of inviscid and incompressible fluid, the governing equation and boundary conditions are formulated as follows;

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial z^2} = 0 \quad \text{(in the domain)} \quad (1)$$

$$\frac{\partial \phi}{\partial n} = -\frac{\partial \phi}{\partial z} = 0 \quad \text{(on the bottom)} \quad (2)$$

$$\frac{\partial \phi}{\partial n} = 0 \quad \text{(on the wall)} \quad (3)$$

$$\frac{\partial \phi}{\partial n} = -\frac{\partial \phi}{\partial x} = -u(z,\ t) \quad \text{(on incidence)} \quad (4)$$

$$\frac{\partial \phi}{\partial n} = n_z \frac{\partial \eta}{\partial t} \quad \text{(on water surface)} \quad (5)$$

$$\frac{\partial \phi}{\partial t} + \frac{1}{2}\left\{\left(\frac{\partial \phi}{\partial n}\right)^2 + \left(\frac{\partial \phi}{\partial s}\right)^2\right\} + g\eta = 0 \quad \text{(on water surface)} \quad (6)$$

where, ϕ = velocity potential,
$x,\ z$ = Cartesian coordinate,
$n,\ s$ = outward normal and tangential vector,
u = horizontal wave particle velocity at x=0,
t = time,
n_z = unit vertical component of outward normal vector,
g = gravity acceleration,
η = water surface displacement

3. HYDRAULIC EXPERIMENT

The experiments are conducted in a two-dimensional wave flume of 53.0m long, 1.25m high and 1.0m wide at Korea Ocean Research & Development Institute (KORDI).

The wave pressure transducers are installed at the front face and bottom to measure the wave pressure acting on the breakwater. We conduct the experiment with the wave condition of the relative wave height H/h = 0.13, 0.21, 0.25, 0.28, 0.34 and 0.37 for the non-dimensionalized wave period $T\sqrt{g/h}$= 7.83 under the water depth h = 50cm. The wave pressure $\bar{p}$ measured is nondimensionalized as $p = \bar{p}/wH_o$.

4. WAVE PRESSURE ANALYSIS

The non-dimensionalized wave pressure p_1, p_3 and p_u at the still water level, at the bottom end of front face and bottom face, respectively, are used to compare results of the numerical model and hydraulic experiment with those of Goda's formula. Table 1 shows the comparison of the wave pressures acquired by the three different methods for the six wave conditions. It can be seen that the nondimensionalized wave pressures decrease in both numerical method and experiment while in Goda's formula the pressures increase. The latter trend may be attributed to the impact pressure that the Goda's formula bears even in the nonbreaking wave conditions. In the smaller relative wave height, the wave pressures by the present numerical method agree with experimental values better than the Goda's formula does. But as the wave height increases, their differences appeared relatively smaller. It is expected that the experimental value will conform to the value Goda's formula predicts at high wave condition causing wave breaking at the breakwater position. But here, it can be asserted that the Goda's formula provides somewhat less conservative design condition at relatively lower wave height condition.

Table 1 Wave pressures acting on mixed type breakwater by numerical method, laboratory test and Goda's formula for various wave heights.

H/h	Numerical			Experimental			Goda's		
	p_1	p_3	p_u	p_1	p_3	p_u	p_1	p_3	p_u
0.13	1.06	0.84	0.84	1.04	0.81	0.81	0.80	0.65	0.65
0.21	1.03	0.77	0.77	0.97	0.70	0.70	0.81	0.67	0.65
0.25	1.00	0.73	0.73	0.91	0.70	0.70	0.82	0.68	0.65
0.28	0.97	0.68	0.68	0.87	0.68	0.68	0.83	0.68	0.65
0.34	0.92	0.61	0.61	0.83	0.59	0.59	0.86	0.70	0.65
0.37	0.90	0.57	0.57	0.80	0.57	0.57	0.87	0.71	0.65

The sensitivity analysis is carried out to know the wave pressure change with the change of mound configuration under a single wave condition H/h = 0.28. The change of mound configuration is restricted to the berm

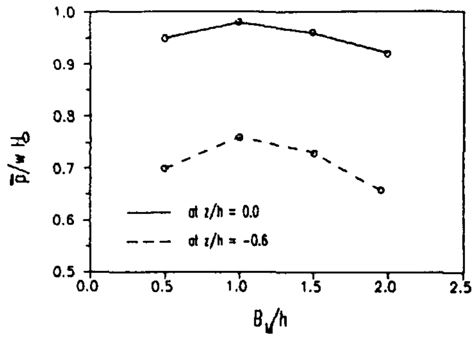

Fig.1 Wave pressure variations due to the change of berm length

length with mound inclination and height fixed. Fig.1 shows the wave pressure change with the change of berm length B_M/h = 0.5, 1.0, 1.5 and 2.0 at the still water level and bottom end, z/h = -0.6. From these results, the wave pressure becomes peak at B_M/h = 1.0 and decreases at the other berm lengths. Thus, the present numerical methods can be effectively utilized in the determination of the optimal mound inclination, height, etc. when we design the mixed type breakwater.

5. CONCLUSIONS

The wave pressure acting on the mixed type breakwater was calculated by the numerical model and compared with results of the hydraulic experiment and Goda's formula. The change of wave pressures is analyzed with respect to the change of wave heights with their nondimensionalized values. As the wave height becomes high, the wave pressure decreased both in the numerical model and hydraulic experiment, but increased in the Goda's formula.

In the non-breaking wave condition, the conservative design condition was provided by the numerical model in the case of small wave, but by the Goda's formula in the case of high wave.

REFERENCES

1. Goda, Y.: Random seas and design of maritime structures, Univ. of Tokyo Press, pp.299-305 (1985).