Laboratory Analyses On Wave Forces Acting On A Spherical Armor Unit of A Submerged Breakwater

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1. Introduction

The complete understanding of the fundamental characteristics of wave forces acting on an armor unit of a submerged breakwater is indeed an interesting research topic. This paper presents experimentally the pertinent characteristics of wave forces acting on a spherical armor unit of a submerged breakwater in relation to the previous experimental results [1].

2. Experimental Procedure

Laboratory observations of wave forces acting on a sphere on a submerged breakwater were carried out using an indoor wave tank (25 m long x 0.7 m wide x 0.9 m deep). The submerged breakwater was installed by means of spheres of diameter, $D = 3$ cm. Regular waves were generated using three different periods, and for each period, four different values of wave height were assigned. For each trial, horizontal and vertical water particle velocities (u and w), water surface profile, and horizontal and vertical wave forces (Fx and Fz) for embedded condition were measured. Contrary to our previous experiment, in the measurement of water particle velocity under the embedded condition, the velocimeter was adjusted to coincide with the center of the embedded sphere. The corresponding experimental conditions are given in Table 1 and Figure 1.

3. Experimental Results and Discussions

3.1 Maximum Velocity. The dimensionless maximum particle velocities are defined by the quantities $u_m/\sqrt{gH}$ and $w_m/\sqrt{gH}$, where g is the gravitational acceleration, H is the wave height at the measuring point and subscript m indicates the maximum value. As shown in Figure 2, the maximum dimensionless vertical particle velocities are dependent in increments of wave height. Moreover, the quantities $u_m/\sqrt{gH}$ and $w_m/\sqrt{gH}$ have almost the same tendency as in the previous experiment. These quantities peak when $x/L = 0.0$, where x is the horizontal distance measured from the crown-edge of the submerged breakwater.

3.2 Maximum Wave Force. The variations of the dimensionless maximum wave force, $F_{xm}/\rho gHD^2$ and $F_{zm}/\rho gHD^2$ with x/L are shown in Figure 3. The quantities have maximum values when $x/L = 0.0$. The locations of the maximum wave forces correspond to the points at which the particle velocities are also maximum. The present values tend to be smaller as compared to the previous experiment with greater water depths. This can be attributed to water surface proximity effect on the structure. The mechanism of surface proximity effect on the vertical wave force due to the submerged breakwater is a very important future research problem.

3.3 Drag and Inertia Coefficient. The characteristics of the coefficients of the drag and inertia forces are determined by plotting the values of C_{Dx} and C_{Mx} versus the K-C number, as can be shown in Figures 4 and 5. The relation shows that C_{Mx} is almost constant around 1.30 to 1.40 when K-C number increases. The values of C_{Dx} approach a constant value around 0.70 to 0.80 as K-C number increases, where flow separation takes place. It can be observed in the figure that the present values have almost the same tendency as compared to the formulated value for a single sphere [2]. Therefore, for insignificant effect of lift force, the horizontal wave force for embedded condition can be evaluated with Morison's equation using the drag and inertia coefficients formulated for a single sphere.

4. Conclusions

In this paper, important characteristics of wave forces acting on a spherical armor unit of a submerged breakwater have been discussed experimentally. The results obtained from this study can be summarized as follows:
(1) Large value of the dimensionless force is concentrated around the vicinity of the crown-edge of the submerged breakwater; thus, this vicinity is revealed to be the most critical location on the submerged breakwater.
(2) The reliability of the drag and inertia coefficients depends on the accuracy of measurement of the water particle kinematics.
(3) The horizontal wave force for embedded condition can be evaluated with Morison's equation using the drag and inertia coefficients formulated for a single sphere.

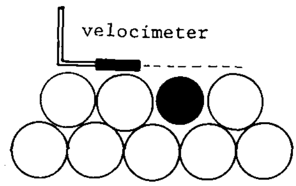
5. References

[1] Mizutani, N., Iwata, K., Rufin, Jr. T. M., and Kurata, K., Experimental Study on Wave Forces Acting on an Armor Unit of a Submerged Breakwater, *Proc., International Symposium on Natural Disaster Reduction and Civil Engineering*, pp.107-115, 1991.

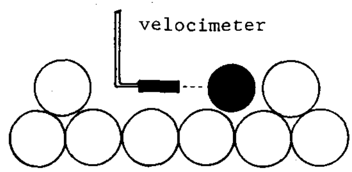
[2] Iwata, K. and Mizutani, N., Experimental Study on Wave Force Acting on a Submerged Sphere, *Proc., Eighth International Conference on Offshore Mechanics and Arctic Engineering, ASME*, Vol.2, pp.145-152, 1989.

Table 1 Experimental conditions for wave force measurements.

WAVE PERIOD(T,SECS.)	1.0	1.40	1.80
WAVE HEIGHT(H ,CMS.)	3.0 [○]	3.0 [△]	3.0 [□]
	5.0 [⦶]	5.0 [◬]	5.0 [⊞]
(*wave breaking*)	7.0 [◑]	7.0 [▲]	7.0 [◨]
(*wave breaking*)	10.0 [●]	10.0 [▲]	10.0 [■]
LOCATION OF WAVE FORCE METER(x,CMS.)	-40.5	-43.00	-43.0
	-21.0	-31.0	-28.5
	-14.0	-21.0	-14.0
	-2.0	-11.5	-2.0
	0.0	-2.0	0.0
	2.0	0.0	2.0
	4.0	2.0	4 0
	13.5	4.0	14.0
	27.0	10.5	28.5
	40.5	21.0	56.5
	67.5	31.5	85.0
	101.5	42.0	141.5
	169.0	63.5	212.0
	203.0	105.0	
		158.0	
		211.0	

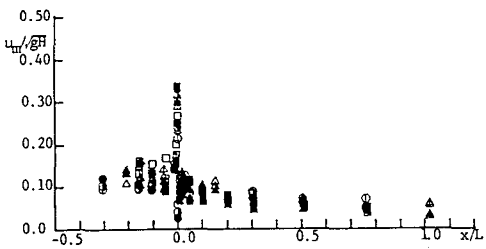


(a) previous experiment



(b) present experiment

Fig. 1 Methods of measurement of water particle velocity.



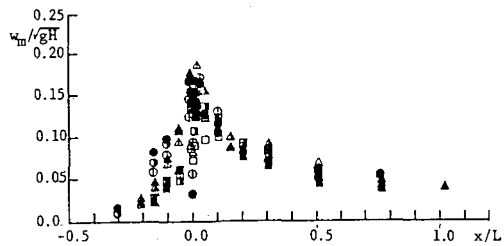
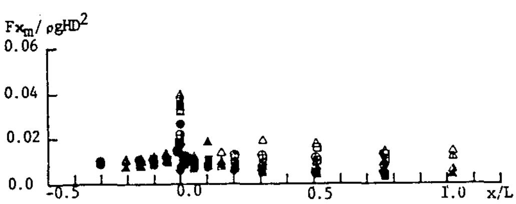


Fig. 2 Relationships between $u_m/\sqrt{gH}$, $w_m/\sqrt{gH}$ and x/L.



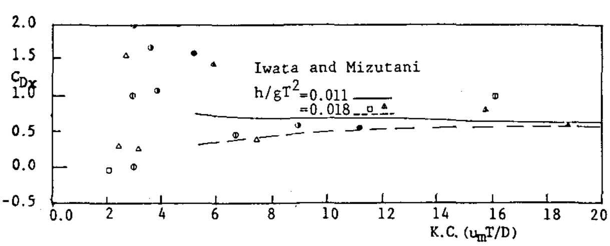


Fig. 4 Relationships between C_{Dx} and K-C number.

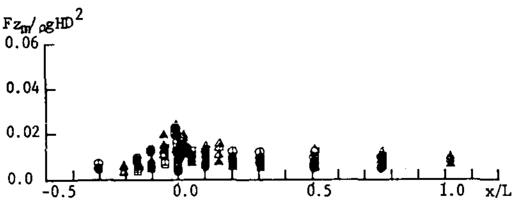


Fig. 3 Relationships between $F_{xm}/\rho gHD^2$, $F_{zm}/\rho gHD^2$ and x/L.

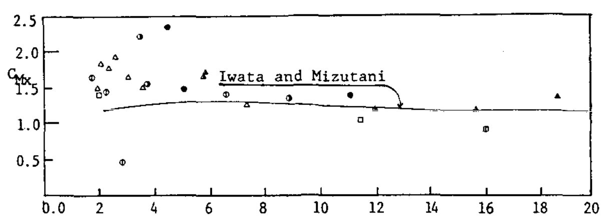


Fig. 5 Relationships between C_{Mx} and K-C number.