SIZE EFFECT ON WAVE FORCES ACTING ON A SPHERICAL ARMOR UNIT ON A SUBMERGED BREAKWATER

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1. INTRODUCTION: The problem of estimating the wave force acting on an armor unit is of considerable engineering importance due to its practical application in ocean engineering. Henceforth, a thorough knowledge on the fundamental characteristics and the generating mechanism of the wave forces acting on an armor unit is essential for an accurate estimation of wave force. Thus, this paper presents the pertinent characteristics of the wave forces acting on a spherical armor unit of different sizes on a submerged breakwater.

2. EXPERIMENTAL PROCEDURE: Laboratory investigations of wave forces acting on a spherical armor unit of a submerged breakwater were carried out using an indoor wave tank. Three different types of submerged breakwater (D = 3.0, 2.47, 1.94 cm) were installed in this experiment, where D is the spherical armor unit diameter for each type of submerged breakwater. Regular waves were generated using three different periods (T = 1.0, 1.4, 1.8 s) and for each period, four different values of wave height(H_I = 3.0, 5.0, 7.0, 10.0 cm) were assigned. The incident wave height was adjusted so that both breaking and non-breaking waves attacked the submerged breakwater. In each trial, horizontal and vertical water particle velocities (u and w), water surface profile, and horizontal and vertical wave forces (Fx and Fz) for non-embedded and embedded conditions were measured.

3. EXPERIMENTAL RESULTS AND DISCUSSIONS: In the estimation of wave force, Morison's equation is employed and the correlation coefficient, r, is used to determine the range of applicability of the Morison's equation. The Morison's equation is not applicable when r is less than 0.9 [1], since the difference between the calculated and the measured wave forces is not negligible. For different values of D/d, the range of the applicability of the Morison's equation, as shown in Fig.2, is verified to be applicable for non-embedded condition when $x/L \leq 0.0$ and almost not applicable for embedded condition [2].

Figure 3 gives the variation of the dimensionless maximum wave force, $Fx_m/\rho gHD^2$, with the dimensionless distance, x/L, where ρ is the density of water, g is the gravitational acceleration, H is the wave height at measuring point, x is the horizontal distance measured from the leading crown-edge, L is the wavelength and subscript m indicates the maximum value. The magnitude of the dimensionless maximum wave forces increases with D/d. And regardless of the value of D/d, where d is the depth of water from the crown, large value of the dimensionless maximum wave force is concentrated around the leading crown-edge of the submerged breakwater. Thus, the vicinity around the crown-edge is confirmed to be the most critical location of the submerged breakwater [3].

The relationship between the dimensionless maximum wave force $Fx_m/\rho(u\sqrt{u^2+w^2})_m D^2$ and KC_x is shown in Fig.4. The mean value obtained for an isolated sphere [1] is also plotted in the figure. For any value of D/d, $Fx_m/\rho(u\sqrt{u^2+w^2})_m D^2$ is inversely proportional to KC_x when $KC_x < 10$ and seems to approach a constant value when $KC_x > 20$. In the range($KC_x < 10$) where the inertia force is dominant over the drag force, the dimensionless maximum wave force increases with D/d. On the other hand, in the range($KC_x > 20$) where drag force is dominant, the dimensionless maximum wave force is almost constant for $D/d = 0.35$ and $D/d = 0.28$; whereas, for $D/d = 0.43$ the magnitude of the dimensionless maximum wave forces is somewhat bigger and this can be attributed to the presence of other generating mechanism.

4. CONCLUSIONS: The results obtained from this study can be summarized as follows:

(1) Regardless of D/d, large value of the dimensionless force is concentrated around the vicinity of the crown-edge of the submerged breakwater; thus, this vicinity is confirmed to be the most critical location on the submerged breakwater.

(2) Morison's equation is applicable for non-embedded condition when $x/L < 0.0$ for $0.28 < D/d < 0.43$.

(3) For inertia-dominated wave force, the maximum wave force increases with increasing D/d.

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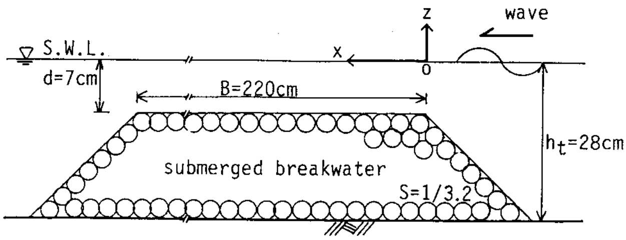


Fig.1 Schematic diagram of submerged breakwater.

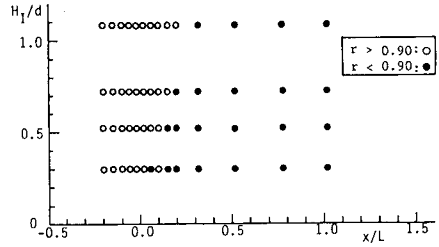
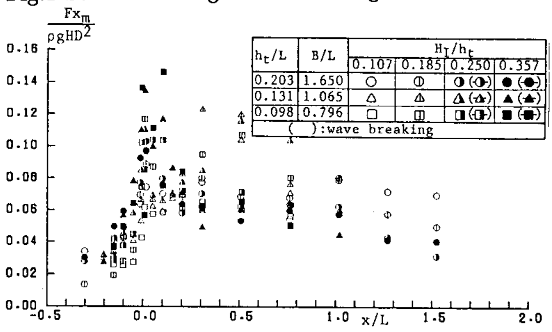
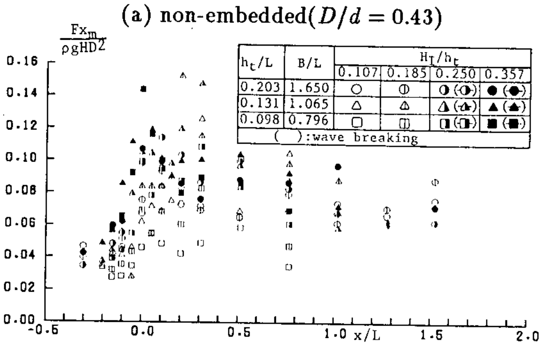


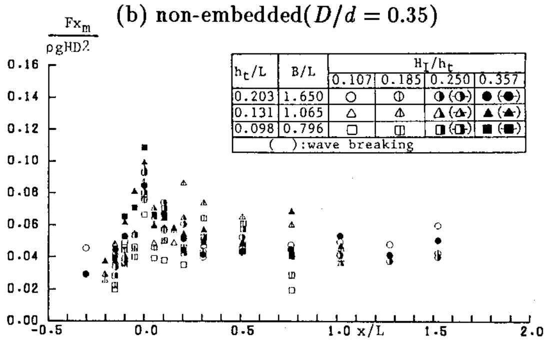
Fig.2 Variation of H_I/d with x/L (non-embedded:$D/d = 0.43$).



(a) non-embedded($D/d = 0.43$)

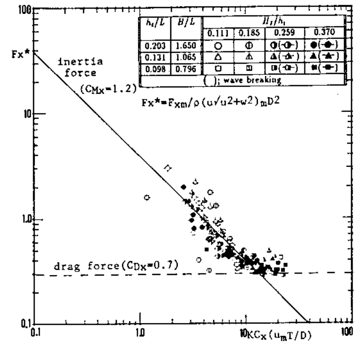


(b) non-embedded($D/d = 0.35$)

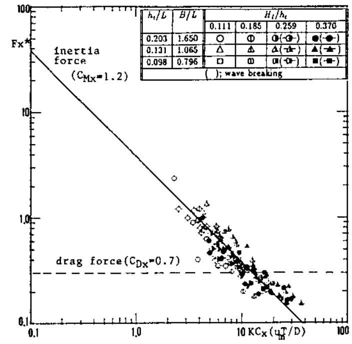


(c) non-embedded($D/d = 0.28$)

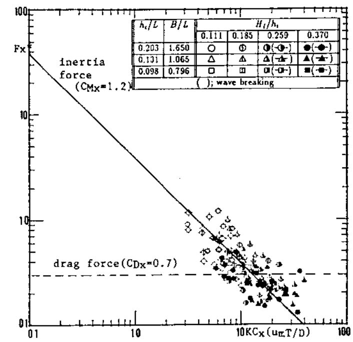
Fig.3 Variation of $Fx_m/\rho g H D^2$ with x/L.



(a) non-embedded($D/d = 0.43$)



(b) non-embedded($D/d = 0.35$)



(c) non-embedded($D/d = 0.28$)

Fig.4 Variation of $Fx_m/\rho(u\sqrt{u^2+w^2})_m D^2$ with KC_x.