EXPERIMENTAL STUDY OF WAVE FORCE ACTING ON A SPHERE ON AN ARTIFICIAL REEF

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1. Introduction

Clarifying the mechanism of wave forces on an armor unit of a reef is not only an interesting research problem but also valuable in the solution of practical and actual problems such as in the design and construction of coastal structures. The ability to analyze the wave force and other wave characteristics acting on a reef plays an important role in assessing the overall effectiveness of such structure. This paper aims to present experimentally the important characteristics of wave forces acting on a sphere on an artificial reef.

2. Experimental Procedure

Laboratory observation of waves acting on a sphere on an artificial reef was carried out using an indoor wave tank(25 m long x 0.7 m wide x 0.9 m deep). An artificial reef was installed by means of spheres of diameter, $D = 3$ cm. The waves were generated using three different periods, and for each period, four different values of wave height were assigned. For each trial, water particle velocities, water surface profile and wave forces just over the reef were measured. The locations of the velocitimeters, wave gauges and the cantilever-type wave force meters are described in Figure 1 and Table 1.

3. Experimental Results and Discussions

3.1 Time History of the Wave Force. The time histories of the wave force are shown in Figure 2 and are classified as follows:

(1) Single-peak type profile (S-type). This type is very common for F_x forces under the non-breaking wave conditions.

(2) Pulse type profile (P-type). This type of profile is affected largely by wave breaking. Most of this profile were observed in F_x forces, particularly in the range of $X/L = 0.00$ to 0.30 (L=wavelength), where breaking wave conditions occur.

(3) Zigzag type profile (W-shape). Profile of this type is noticeable for F_z forces ($T = 1.0sec$ and $1.60sec$), especially in the range of $X/L = 0.60$ to 1.20, both for breaking and non-breaking wave conditions.

(4) Zigzag type profile (V-shape). This type is very clear for F_z forces with periods of $T = 1.41sec$ and $1.60sec$ and in the range of $X/L = 0.10$ to 0.50, where breaking wave conditions occur.

(5) Double-peak type profile (D-type). This profile is usual for F_x force of period $T = 1.60sec$ under the non-breaking wave conditions and in the range of $X/L = 0.60$ to 0.80. This type is caused by the second harmonic waves generated on the reef.

3.2 Maximum Wave Force. The dimensionless maximum wave force quantities are defined by $F_{xm}/\rho gHD^2$ and $F_{zm}/\rho gHD^2$, where ρ is the density of water and g is the acceleration due to gravity. As shown in Figure 3 , $F_{xm}/\rho gHD^2$ and $F_{zm}/\rho gHD^2$ have maximum values when $X/L = 0.0$ and near $X/L = 0.7$. The locations of the maximum force correspond to the points at which the particle velocities are also maximum . The relation shows that after wave breaking, the nonbreaking force is greater than the breaking force. This may be caused by the energy loss due to wave breaking.

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 Figure 4 and 5. The relation shows that C_{Mx} is almost constant around 1.00 *to* 1.40 when K-C number increases. The values of C_{Dx} approach a constant value around 1.00 as K-C number increases, where flow separation takes place. It can be observed that our experimental values of C_{Dx} and C_{Mx} correspond well to those obtained by Iwata *et al.* (1) . It should be noted that a very low value of the correlation coefficient between the experimental and the calculated value of F_z by Morison's equation was obtained. This clearly shows that the Morison's equation is not applicable in the computation of the vertical forces on the sphere which are very near the bottom bed. This may be due to the bottom proximity effect.

4. Conclusions

In this paper, important characteristics of wave force acting on the sphere on an artificial reef have been discussed experimentally. Our results are summarized as follows:

(1) The maximum forces in each experimental run are concentrated generally around point D of the reef.

(2) Time history of the wave force are classified into five types(P-type, S-type,W-shape,V-shape,and D-type).

(3) The vertical force can not be estimated by Morison's equation.

5. Reference

(1) K.Iwata and N.Mizutani. *Experimental Study on Wave Force Acting on Submerged Sphere.* Proc. ASME, Eighth International Conference on Offshore Mechanics and Arctic Engineering , The Hague, Vol.2, 1989.

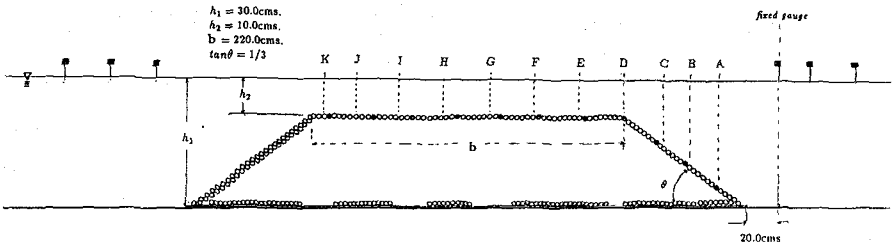

Figure 1 - Locations of Wave Force Meters.

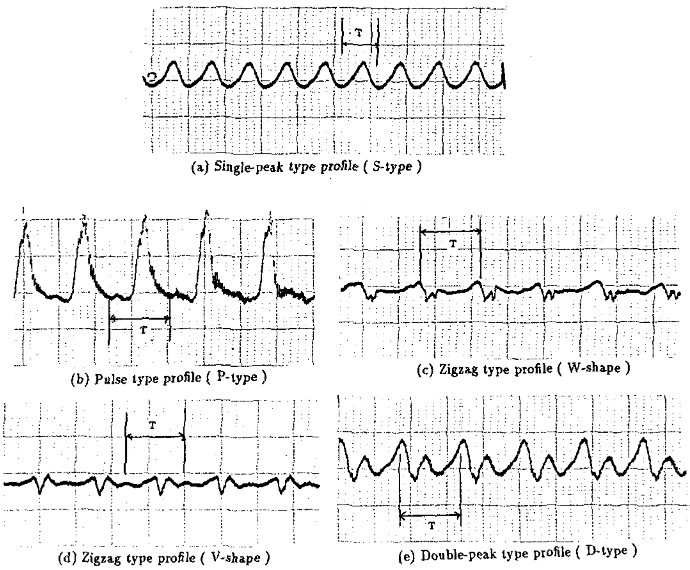

Figure 2 - Time histories of the wave force.

Table 1 - Experimental Conditions for Wave Force Measurements.

WAVE PERIOD(T,SECS.)	1.0	1.41	1.60
WAVE HEIGHT(H_I,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.)	A = -51.0	A = -45.00	A = -45.0
	B = -34.0	B = -30.0	B = -30.0
	C = -17.0	C = -15.0	C = -15.0
	D = 00.0	D = 00.0	D = 00.0
	E = 17.0	E = 27.0	E = 31.5
	F = 34.0	F = 54.0	F = 63.0
	G = 51.0	G = 81.0	G = 94.5
	H = 68.0	H = 108.0	H = 126.0
	I = 102.0	I = 135.0	I = 157.5
	J = 136.0	J = 162.0	J = 189.0
	K = 170.0	K = 216.0	K = 220.5

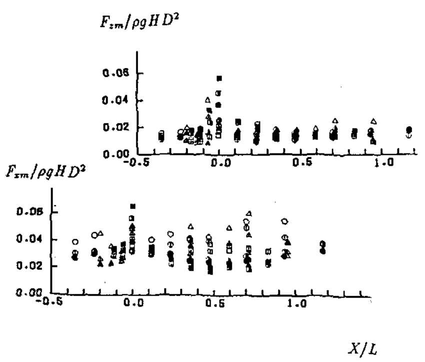

Figure 3 - Relationship between $F_{xm}/\rho g H D^2$,$F_{zm}/\rho g H D^2$ and X/L.

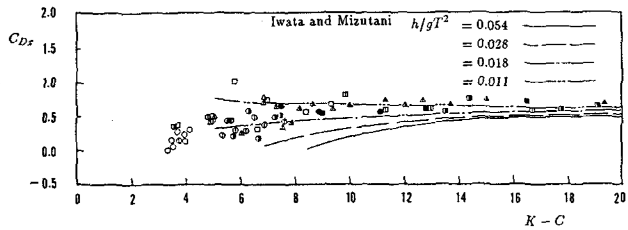

Figure 4 - Relationship between C_{Dx} and $K-C$ number.

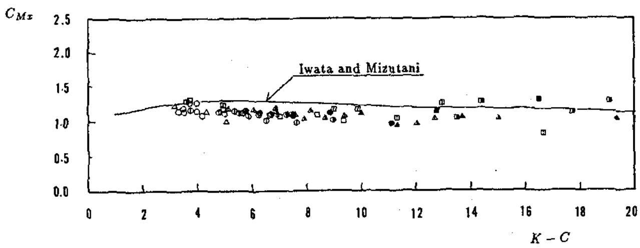

Figure 5 - Relationship between C_{Mx} and $K-C$ number.