Evaluation of Equation of Horizontal Applied Force by Wave Shapes

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1. Introduction

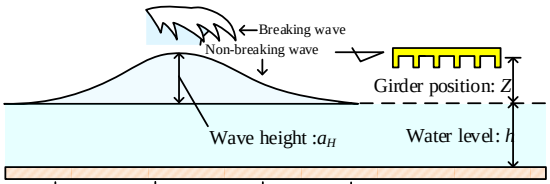
Based on the series of tsunami experiments of KIT, the horizontal acting force to girder was evaluated by equation of horizontal applied force, which was related to the wave height, girder position and the pressure area of girder. In this paper, the authors would like to discuss how the equation of horizontal applied force changed with breaking and non-breaking wave shapes.

2. Experimental Setup

As illustrated in Fig. 1, the 41m long, 0.8m wide, 0.95m high water channel was used and the slide wave making plate was set to make breaking wave and non-breaking wave. 6 wave gauges were set up along the water channel and the H6 was focused on obtaining the flow depth at the model location. Propeller velocity meter V1 was set side of girder to measure the velocity at the model location. All experiments of 3 cases were conducted by 1cm girder position change, referring to Fig. 2.

3. Experimental Results

The experimental results both of KIT and other research organizations were output in Fig. 3. Here, the horizontal axis showed dimensionless ratio which divided by the maximum of horizontal acting force *Fx*, pressure area of girder model *A* and water pressure $\rho g a_H$; the vertical axis showed dimensionless ratio which divided by the length from the center of girder model to initial water height *Z* and wave height a_H. At the same figure, when Z/a_H was higher than or equal to 0.5, $Fx/A/\rho g a_H$ increased linearly with Z/a_H decreasing; when Z/a_H was lower than 0.5, $Fx/A/\rho g a_H$ was a fixed value which was averaged by the results of case A.



Case	Wave shape	Water level h [cm]	Wave height a_H [cm]	Girder position Z [cm]
A	Breaking	5	10.3	0.7~9.7(1cm Pitch)
B		15	25.3	0.7~19.7(1cm Pitch)
C	Non-breaking		11.3	0.7~11.7(1cm Pitch)

Fig. 2 Experimental cases of KIT

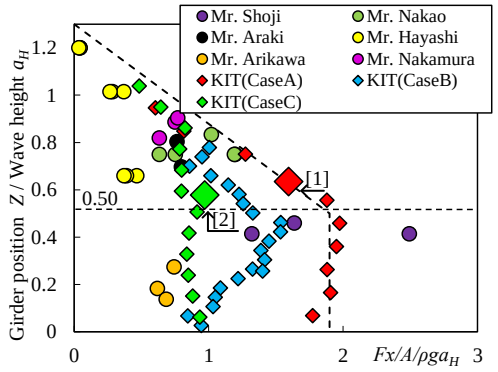


Fig. 3 Relationship between Z/a_H with $Fx/A/\rho g a_H$ (All cases)

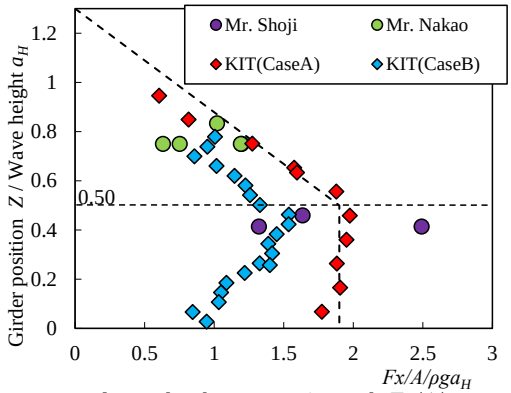


Fig. 4 Relationship between Z/a_H with $Fx/A/\rho g a_H$

(Breaking wave)

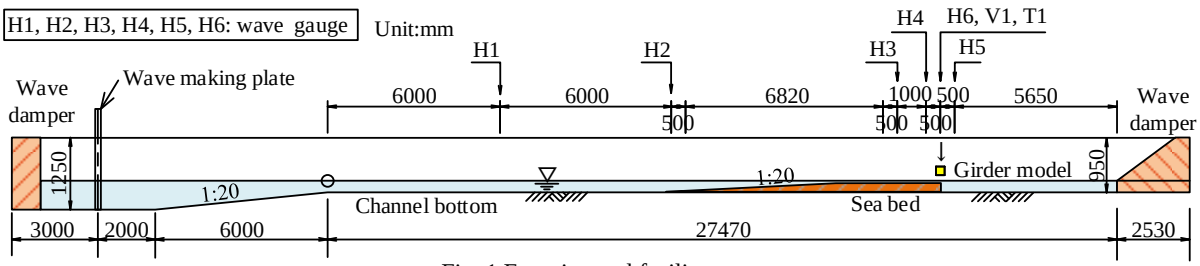


Fig. 1 Experimental facility

4. Evaluation of Equation of Horizontal Applied Force

All experiments both of KIT and other research organizations in Fig.3 were divided into two parts (breaking wave and non-breaking wave) by horizontal acting force difference. The breaking wave cases had plotted in Fig .4. At the same figure, it could be noticed that the plotted points of horizontal applied force was same almost with the large points of Fig. 3.

Fig. 5 had plotted the experimental results of non-breaking wave cases. In the same figure, it could be noticed that the plotted points of horizontal applied force was same almost with the small points of Fig. 3. When Z/a_H was equal or higher than 0.80, the black dotted line was approximated by the least-square method based on the results of case C.

When Z/a_H is lower than 0.80, the black dotted line showed the average results of points of case C. Based on the black dotted line, the horizontal proposed equation of non-breaking wave case could be summarized as below:

When $Z/a_H \geqq 0.80$, $Fx = \rho g(2.24a_H - 1.73Z)A$ Eq. (1)

When $Z/a_H < 0.80$, $Fx = 0.86 \times \rho g a_H A$ Eq. (2)

Compared breaking wave cases with non-breaking wave cases, it could be noted that $Fx/A/\rho g a_H$ of non-breaking wave trended smaller than that of breaking wave. Furthermore, the cut-off point of Z/a_H raised to 0.80 (non-breaking wave case) from 0.50 (breaking wave case).

Considered about the reason of those phenomena, the wave shapes and velocity distribution of case A and case C were plotted when tsunami acted to girder model, as shown in Fig. 6 and Fig. 7, respectively. For Fig. 6, [1] and [2] had been pointed out in Fig .3. Breaking wave jumped sharply in [1]. In Fig. 6 [2], with the same girder position of [1], the non-breaking wave acted girder smoothly. In Fig. 7, the vertical axis showed Z/a_H, the horizontal axis showed horizontal velocity measured by the propeller velocity meter V1. Average horizontal velocity of case A was 132 cm/s and average velocity of case C was 68.8 cm/s. The breaking wave led to the increasing of velocity. In authors' opinion, the difference of the average velocity would be led to the difference of horizontal applied force.

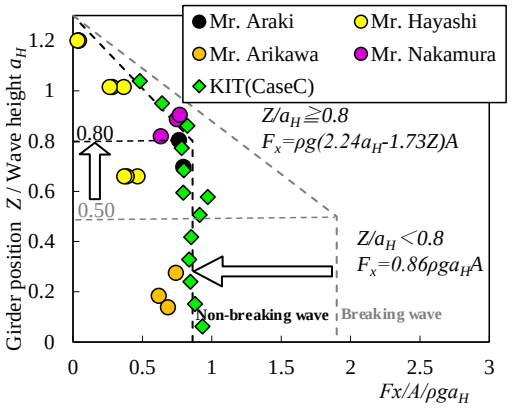


Fig. 5 Relationship between Z/a_H with $Fx/A/\rho g a_H$ (Non-breaking wave)

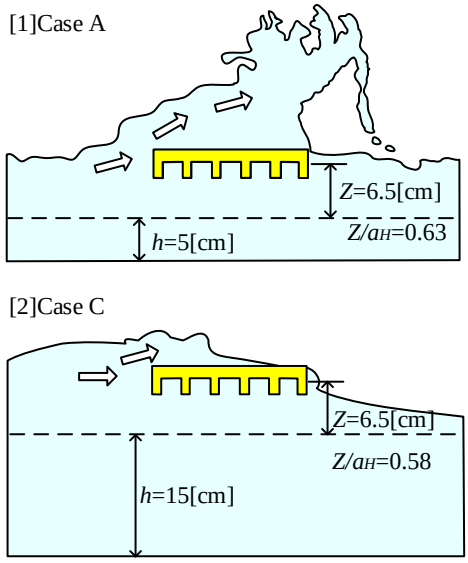


Fig. 6 Wave shape of case A & case C

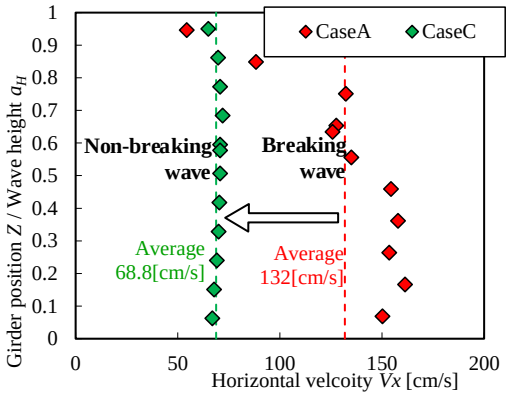


Fig. 7 Velocity distribution of case A & case C

5. Conclusions

(1) From the experimental results of breaking wave and non-breaking wave, it is confirmed that the dimensionless $Fx/A/\rho g a_H$ of non-breaking wave trended smaller than that of breaking wave.

(2) By the comparison of velocity at the girder location, the lower velocity of non-breaking wave maybe caused the dimensionless $Fx/A/\rho g a_H$ to be smaller than that of breaking wave.