Wave Transmission and Force on Nearshore Rapidly-Installable Breakwater

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1. Introduction

It is essential to maintain and improve port and harbor facilities and to develop mitigation measures against coastal hazards caused by storms and tsunamis because the utilization and development of the coastal regions are likely to increase in the near future. The cost and ease of construction are also important for coastal structures. Accordingly, the concept of nearshore rapidly-installed breakwater (Shore-RIB) has been developed by Melby and Resio (2002) and tested in a wave flume. Shore-RIB, which can be removed and reused at another site, consists of water-filled high-tenacity high-strength fabric tubes held by an anchored fabric shroud. In designing such breakwaters, it is essential to predict the wave reflection and transmission coefficients, wave forces, and structure response. A numerical model is developed here to predict the irregular wave breaking and transmission and the wave force on the submerged and emerged Shore-RIB structures. The computed results will be used to optimize the Shore-RIB configuration so as to increase wave energy dissipation and reduce the wave transmission and force.

2. Experimental Setup and Numerical Model

The physical model of two-tube Shore-RIB configuration is shown in Fig.1 where R_c is the crest elevation above the still water level and positive for the emerged structure. The governing equations of the developed numerical model are based on the instantaneous mass and momentum equations expressed as

$$\frac{\partial h}{\partial t}+\frac{\partial}{\partial x}(hu)=0 \qquad (1)$$

$$\frac{\partial}{\partial t}(hu)+\frac{\partial}{\partial x}\left(hu^2+\frac{1}{2}gh^2\right)=-gh\tan\theta-\frac{1}{2}f|u|u \qquad (2)$$

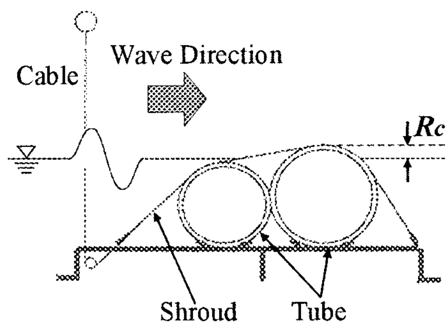

Fig.1 Two-tube Shore-RIB

in which t=time; h=instantaneous water depth; u=instantaneous depth-averaged horizontal velocity; g=gravitational acceleration; and f=bottom friction factor. Eqs.(1) and (2) are solved numerically in the time domain using the explicit dissipative Lax-Wendroff finite difference method based on a finite-difference grid of constant space size and constant time step after the normalization of (1) and (2) (Kobayashi and Wurjanto 1989).

The incident irregular wave train measured for 560s at the toe of the Shore-RIB structure is used as input to the numerical model. The tensioned fabric shroud is assumed to be a solid bottom in the following computations. So far, comparisons are made for 6 tests out of the 62 tests by Melby and Resio (2002) for which the spectral significant wave height H_{mo}=7.7-13.5cm and the spectral peak period T_p=1.2-2.7s.

3. Computed Results and Comparisons with Data

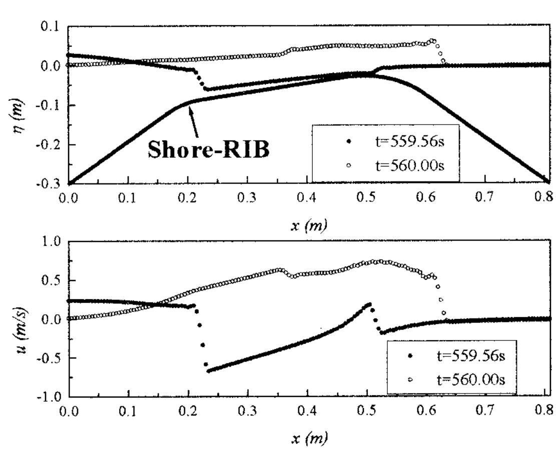

Fig.2 Spatial variations of η and u

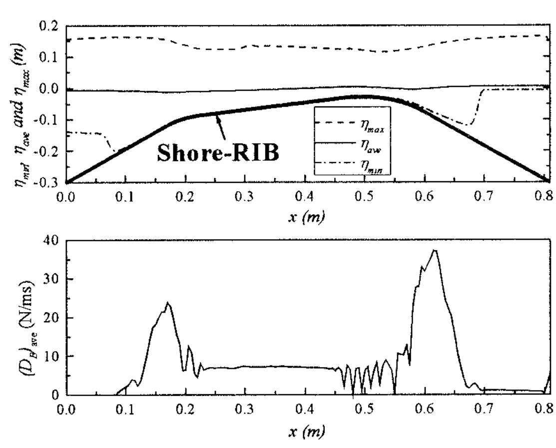

Fig.3 Spatial variations of statistics of η and energy dissipation rate

Fig.2 shows the computed cross-shore variations of the free surface elevation η and the horizontal velocity u as a function of the horizontal coordinate x at time t=559.56s (wave run-down on the slope between the two tubes) and t=560s (landward propagation of a breaking wave). Fig.3 shows the cross-shore variations of the maximum, average and minimum values of η during 560s and the time-averaged wave energy dissipation rate $(D_B)_{ave}$ due to wave breaking. The mean water level is higher landward of the structure due to wave setup. The wave energy dissipation is large at the seaward and landward ends of the slope between the two tubes.

Fig.4 compares the measured and computed wave transmission coefficients $(K_t)_{mo}$ based on the spectral significant wave heights as a function of the normalized crest height R_c/H_{mo} for the one-tube and two-tube configurations. The numerical model slightly underpredicts $(K_t)_{mo}$. Both measured and computed $(K_t)_{mo}$ linearly decrease with increasing R_c/H_{mo}. The value of $(K_t)_{mo}$ for the one-tube structure tends to be slightly larger than that of the two-tube structure.

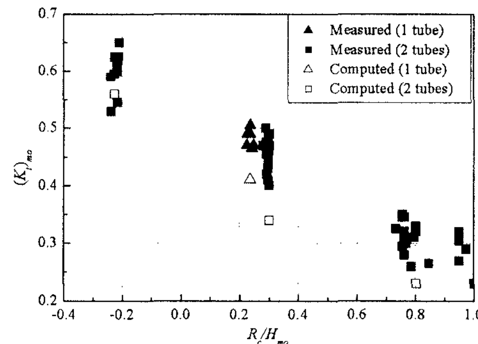

Fig.4 Transmission coef. v.s. R_c/H_{mo}

The computed horizontal wave force acting on the entire Shore-RIB is used to predict the measured tension force on the fabric shroud which exhibited sudden increases due to snapping and a gradual drift due to the shift of the tube(s) to the equilibrium location. Fig.5 shows the maximum, mean and minimum values of the computed horizontal wave force. The horizontal wave force is obtained by integrating the wave-induced pressure over the structure. The computed maximum horizontal force has found to be expressed as

$$\frac{(F_h)_{\max}}{\rho g H_{mo}^2} = 3.0 + 0.5\frac{R_c}{H_{mo}} \qquad (3)$$

in which $(F_h)_{max}$=maximum horizontal force.

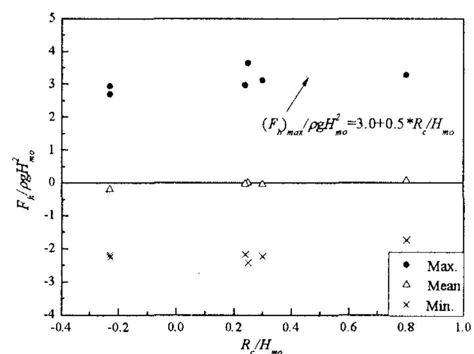

Fig.5 Wave force v.s. R_c/H_{mo}

Fig.6 shows the comparison of measured and predicted T_{max}, which expresses the maximum fabric tension, for each of all 62 cases. The structure of Plan-1 consists of 1 tube that is free to roll and slide under the fabric shroud, and the tube in Plan-2 is fixed to reduce tube movement. Two tubes are fixed on the seabed for Plan-3. $(T_{max})_{\text{measured}}$ is the measured normalized fabric tension whereas $(T_{max})_{\text{predicted}}$ is the predicted normalized fabric tension which depends on the computed horizontal wave force. The agreement is relatively good. Due to the excursion of the tube under the fabric shroud, the maximum fabric tension is larger for Plan-1 than for Plan-2 and Plan-3 with limited tube movement.

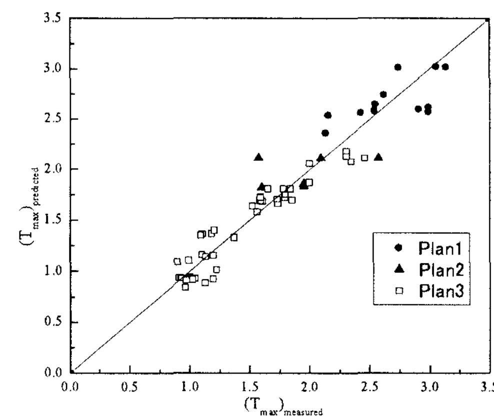

Fig.6 $(T_{\max})_{\text{measured}}$ v.s. $(T_{\max})_{\text{predicted}}$

4. Conclusion

1) The numerical model shows that the time-averaged wave energy dissipation rate due to wave breaking is large at the seaward and landward ends of the slope between the two tubes.
2) The transmission coefficient $(K_t)_{mo}$ decreases linearly with the increase of the normalized crest elevation R_c/H_{mo}.
3) The maximum normalized horizontal wave force increases slightly with R_c/H_{mo}.
4) The maximum fabric tension force can be predicted fairly accurately.
5) The excursion of the tube under the fabric shroud increases the fabric tension.

References

Kobayashi, N. and Wurjanto, A. (1989). "Wave transmission over submerged breakwaters." *J.Wtrwy. Port Coast. And Oc. Engrg*., 115(5), 662-680.

Melby, J.A. and Resio, D.T. (2002). "A nearshore rapidly-installed breakwater." *Proc.28th Coast. Eng. Conf*., ASCE (presented).