Journal of Marine Science and Technology

Volume 18 | Issue 4 Article 13

EXPERIMENTAL STUDY ON THE INFLUENCE OF GEOMETRICAL CONFIGURATION OF POROUS FLOATING BREAKWATER ON PERFORMANCE

Huan-Yu Wang
State Key Laboratory of Coastal and Offshore Engineering, Dalian University of Technology, Dalian, Liaoning, China., dlutwhy@163.com

Zhao-Chen Sun
State Key Laboratory of Coastal and Offshore Engineering, Dalian University of Technology, Dalian, Liaoning, China.

Recommended Citation

Wang, Huan-Yu and Sun, Zhao-Chen (2010) "EXPERIMENTAL STUDY ON THE INFLUENCE OF GEOMETRICAL CONFIGURATION OF POROUS FLOATING BREAKWATER ON PERFORMANCE," *Journal of Marine Science and Technology*: Vol. 18: Iss. 4, Article 13.
DOI: 10.51400/2709-6998.1918
Available at: https://jmstt.ntou.edu.tw/journal/vol18/iss4/13

EXPERIMENTAL STUDY ON THE INFLUENCE OF GEOMETRICAL CONFIGURATION OF POROUS FLOATING BREAKWATER ON PERFORMANCE

Huan-Yu Wang* and Zhao-Chen Sun*

Key words: porous floating breakwater, geometrical configuration, transmission coefficient, mooring force.

ABSTRACT

The general aims of this paper were to present a novel floating breakwater fabricated with large numbers of diamond-shaped blocks and find out the favorable characteristics of geometrical configurations basing on wave attenuation and mooring force debasement. The research are expected to offer a little of information for the design of floating breakwater. Four sorts (with equal number of blocks) of geometrical configurations had been involved in the contrasting analyses. Various factors including water depth, relative width of the floating body and wave steepness were considered. The results had shown that the proposed porous floating breakwater revealed favorable performance and the geometrical configuration could impact wave attenuation and mooring force significantly.

I. INTRODUCTION

Over the past two decades, interest in the study of floating breakwaters has increased owing to the advantage of lower investment, environment friendly and applicability in deeper water. Floating breakwaters attenuate surface waves through the mechanisms of reflection, destruction of water particle orbital motions and viscous damping. When waves attack the structure, energy will be reflected, dissipated and induce breakwater motions. The induced body motion will subsequently generate waves in the sheltered region and restraint of the body motion will be provided by the mooring system.

Multiform floating breakwaters have appeared on the scene and many achievements have been made in this field. McCartney [9] introduced four types of floating breakwaters, including the box, pontoon, mat, and tethered, and analyzed their advantages and disadvantages. Mani [8] measured the transmission coefficients of the pontoon, mat, and tethered breakwaters. And Drimer *et al*. [3] presented a simplified design for a floating breakwater in which the breakwater width and the incident wavelength are much larger than the gap between the breakwater and the sea bed. Lao and Feng [6] calculated the floating breakwater performance in regular waves basing on the strip theory. Yao *et al*. [16] tested the transmission coefficients and the chain forces of ten types of floating breakwaters and selected the optimal type of structure. Murani and Mani [10] measured the transmission and reflection coefficients of a cage floating breakwater under wave and wave-current conditions. Sannasiraj *et al*. [12] conducted an experimental and theoretical investigation of the behavior of pontoon-type floating breakwaters and studied the motion responses, the mooring forces, and the wave attenuation characteristics. Bayram [1] conducted an experimental study of an inclined pontoon breakwater in intermediate water depths for use with small commercial vessels and yacht marinas. Williams *et al*. [15] theoretically investigated the hydrodynamic properties of a pair of long floating rectangular pontoon breakwaters, while Liang *et al*. [7] proposed the spar buoy floating breakwater and studied the wave reflection and transmission characteristics and the wave induced tension of the mooring lines. Rahman *et al*. [11] developed the volume of fluid (VOF) method to estimate the nonlinear dynamics of a pontoon type moored submerged breakwater under wave action and the forces acting on the mooring lines, for both the vertical and inclined mooring alignments. Weng and Chou [14] investigated the hydrodynamic properties of a dual pontoon floating breakwater consisting of a pair of rectangular sectional floating cylinders connected by a rigid framework.

A large degree of attenuation of wave heights and less force in the moorings should be the condition to be achieved for optimum design. To reduce the exciting force as well as the transmitted wave height from incident waves, various novel types of floating breakwater models have been tested, recently. Such as the breakwater with remodeled cross-section: rectangular breakwater with two thin side-boards [4]; large scale structures: floating pipe breakwater [5] and board-net floating breakwater [2]; porous breakwaters: freely floating porous box in shallow water [13]. The literature survey carried out clearly indicates that the problems of a porous floating body anchored

Paper submitted 06/08/09; revised 08/14/09; accepted 08/21/09. Author for correspondence: Huan-Yu Wang (e-mail: dlutwhy@163.com).
**State Key Laboratory of Coastal and Offshore Engineering, Dalian University of Technology, Dalian, Liaoning, China.*

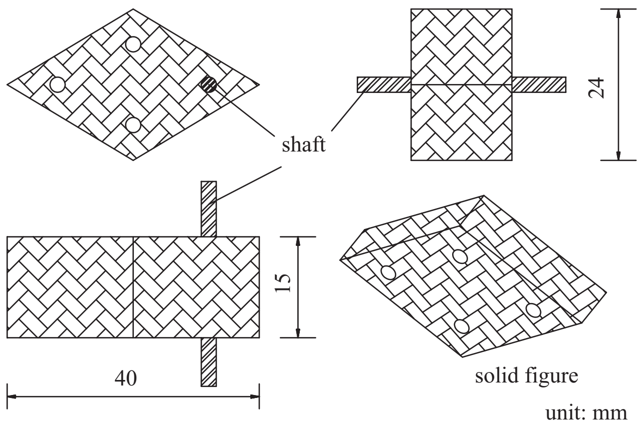

Fig. 1. The sketch of diamond-shaped block.

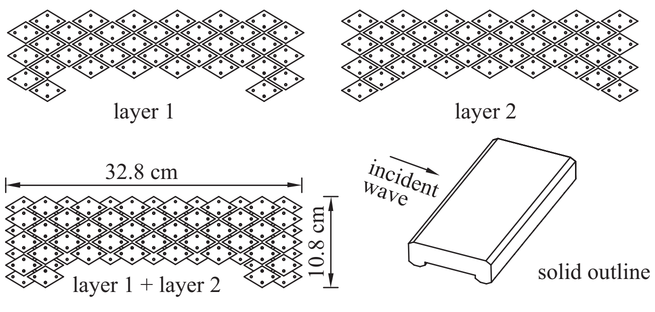

Fig. 2. The sketch of model 1.

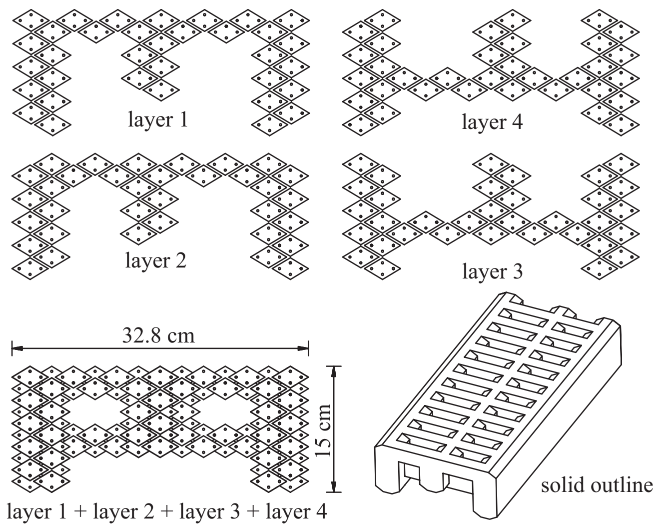

Fig. 3. The sketch of model 2.

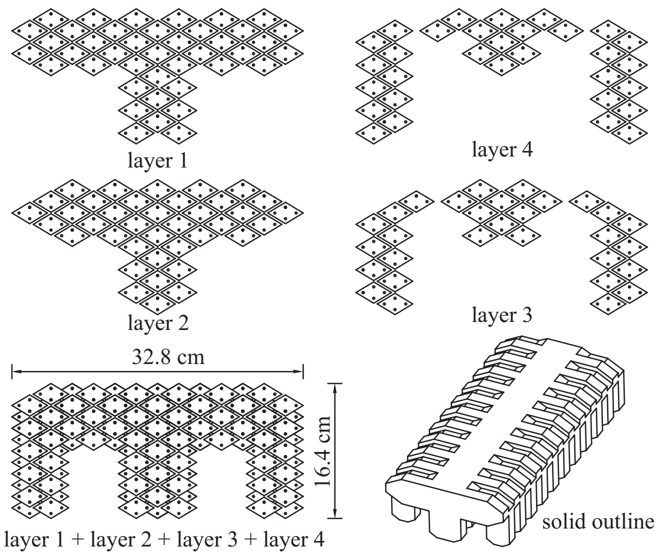

Fig. 4. The sketch of model 3.

on the sea as a floating breakwater and the influence of its geometrical configuration on wave attenuation and force in moorings have not been investigated.

Based on the aims of larger wave attenuation and less force suffered from incident wave, the influence of four geometrical configurations of the porous floating breakwaters on transmission coefficient and mooring force is investigated in this paper. With two-dimensional regular waves, the tests of the mooring porous floating breakwater made of diamond-shaped blocks are carried out in the wave flume of State Key Laboratory of Coastal and Offshore Engineering, Dalian University of Technology. The results of the transmission coefficients and the forces in the mooring systems varying with relative width or wave steepness are shown and the optimized cross-section configuration is presented.

II. FLOATING BREAKWATER STRUCTURES

The floating structures are made from perforated diamond-shaped blocks (as shown in Fig. 1). The blocks on any two adjacent layers are interlaced and connected with the shafts through the holes, and each floating breakwater model is fabricated with 44 layers of blocks. The blocks on the same layer are laid with given arrangements, and four physical models with various geometrical configurations (the total number of blocks for each model is invariable approximately) are tested for the aim of analyzing the influence of the geometrical configuration on wave attenuation and mooring force. The four arrangements are shown in Figs. 2-5, respectively. The width (B) and height (D) of each structure is presented in the respective figure, and the measured length (L_0) of each model is 0.68 m. The ratio between height and width of each model is less than 0.5, and so arranged to reduce the mooring force brought by the roll motion of the floating bodies. The four models have distinct features: model 1 is quasi-closed (except the gaps in the middle of adjacent blocks on the same layer); model 2 and 3 present semi-hollow on horizontal and vertical direction respectively; and model 4 is semi-hollow on both directions except the quasi-closed central section which can block wave energy through out the floating body on horizontal direction directly.

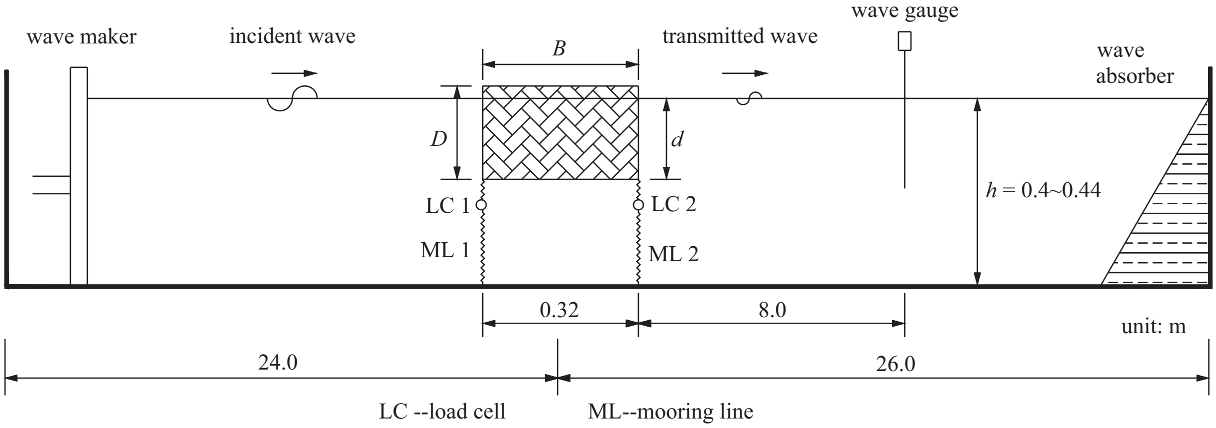

Fig. 6. The sketch of the experiment.

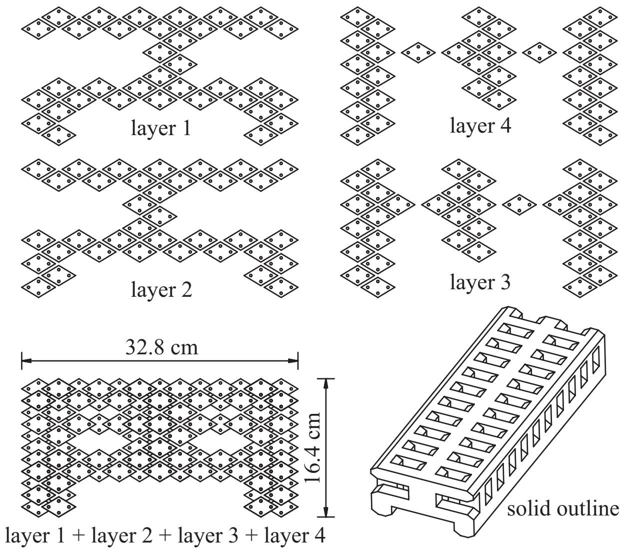

Fig. 5. The sketch of model 4.

III. EXPERIMENTS

1. Experimental Facilities and Instruments

The experiments are carried out in the two-dimensional wave flume of the State Key Laboratory of Coastal and Offshore Engineering, Dalian University of Technology. As shown in Fig. 6, the wave flume is 50 m long, 0.7 m wide, 1.0 m deep and is equipped with a hydraulically driven, piston-type irregular wave generator at one end and a wave absorber at the other. Wave parameters can be measured and analyzed with the SG200 wave measurement system. The absolute accuracy of the gauge is ±1 mm. To measure the forces acting on the mooring lines supporting the floating body that receives the wave action, two ring type load cells are connected with mooring lines. The load cells, each of 4.0 kg capacity with digital signal recorder are used for data acquiring. The elongate of the nylon mooring lines are neglected in the tests.

Table 1. Details of the wave and mooring system considered in the present study.

	Depth of water **h** (m)	Initial mooring force **F_{w0}** (normalized by $\rho g L_0 BH/2$)	Wave height **H** (m)	Wave period **T** (s)	Wave steepness **H/L** (T = 0.8~0.9s)
model 1	0.40	0	0.04	0.6~1.6	/
model 2	0.40	0			/
model 3	0.40	0			/
	0.42	0.127			0.0325~0.0910
	0.44	0.214			
model 4	0.40	0			/
	0.42	0.126			0.0325~0.0910
	0.44	0.210			

2. Experimental Contidions

In the experimental processes of all models, first adjust the lengths of the mooring lines to attain the unbent state but no tension on them when water depth is 0.4 m. While for the cases of 0.42 m and 0.44 m water depths, readjustment of the mooring lines are not done. This describes a modeling as the change of tide level, and the initial mooring forces can be decided by various water depths definitely.

The parameters of the regular wave, water depth and normalized (by $\rho g L_0 BH/2$) initial mooring force (F_{w0} denotes the initial mooring force on windward mooring line, and the leeward initial mooring force is equal to that of the windward in each case) considered in the present investigations are presented in Table 1. H and T denote the wave height without structure and wave period, respectively. ρ and g are the density of water and gravitational acceleration.

IV. RESULTS AND DISCUSSION

The results examined in the present investigations are: wave transmission coefficient K_t ($K_t = H_t/H$, H_t – transmitted wave height) and normalized (by $\rho g L_0 BH/2$) windward mooring

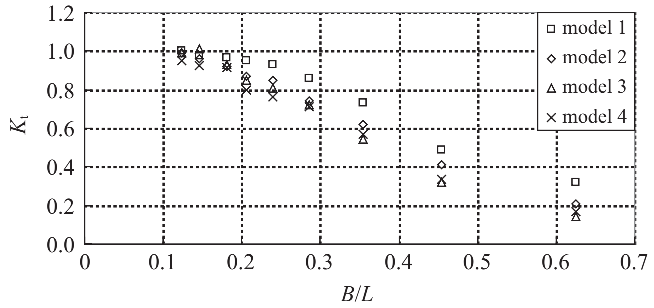

Fig. 7. The transmission coefficients (K_t) of the four models vary with B/L (h = 0.4 m).

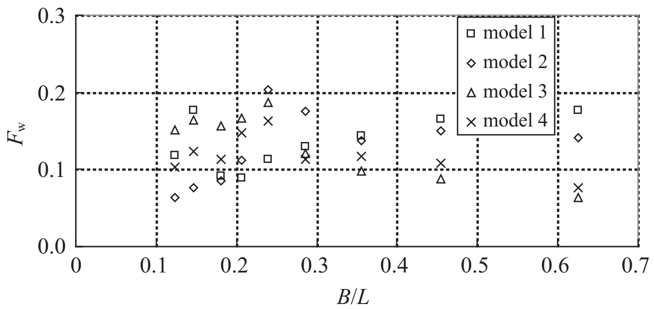

Fig. 8. The normalized (by $\rho g L_0 BH/2$) windward mooring forces of four models vary with B/L (H = 0.04 m, h = 0.4 m).

force F_w (the leeward mooring force is not presented in this paper because its values measured are less than that of the windward in all cases tested).

1. Comparison of Four Models with 0.4 m (F_{w0} = 0) Water Depth

The variations of the wave transmission coefficient with B/L (L denotes incident wavelength) for different models with 0.4 m water depth (F_{w0} = 0) are shown in Fig. 7. A wide range of values of the transmission coefficient is observed from 1.01 to 0.14 as B/L increases from 0.124 to 0.625. The performance of wave attenuation of model 1 is the worst because of its shallow draft and large assembly density (it is difficult that the wave energy is transmitted into the interior of the porous floating body with large assembly density, as a result, the efficiency of turbulence and viscous damping will be decreased). Comparing model 2 with model 1, it is found that the less transmission coefficient is achieved. It indicates that the transform of geometrical configuration can affect the performance of wave attenuation. Models 3 and 4 show us the better results on wave attenuation in all of the tested models. The values of K_t of two models are equal approximately. However, model 4 takes on a little lower K_t than model 3 as the floating bodies receive the role from the longer incident wave. The probable reason for this result is that the quasi-closed backside of model 3 plays a more notable role of "wave maker" in the sheltered region than model 4 which has a semi-hollow backside, when the structures are exposed to the longer wavelength.

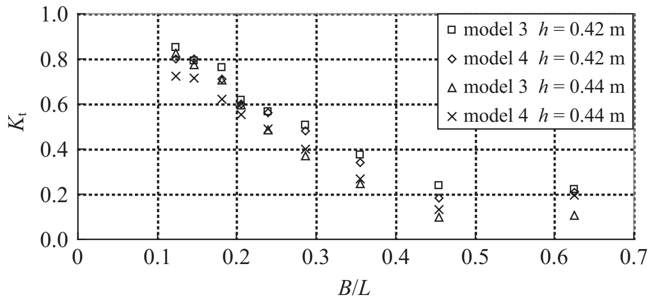

Fig. 9. The transmission coefficients (K_t) of models 3 and 4 vary with B/L (h = 0.42~0.44 m).

Figure 8 presents the results of the normalized windward mooring forces (F_w) of four models with h = 0.4 m (F_{w0} = 0) and B/L from 0.124 to 0.625. Nine tenths of F_w lies in the region from 0.1 to 0.2. The results of windward mooring forces of four models show respective trends. By and large, F_w of models 1 and 2 are going up and which of models 3 and 4 are going down with the increased B/L. The main reason is that the models have distinct capabilities of permeation, that is, stronger horizontal penetrability from models 1 (due to its lower height) and 2, and vertical penetrability from models 3 and 4. When the floating body is exposed to the longer incident wavelength (the lower B/L), the structure with stronger horizontal penetrability will suffer less wave force, contrarily, the structure with stronger vertical penetrability meeting with the shorter incident wavelength (the larger B/L) will put up better performance on receiving wave force. In sum, the models 3 and 4 present more outstanding performance on wave attenuation and not worse mooring force than models 1 and 2. In addition, F_w of model 4 varies more gently as B/L is increased. The more in-depth studies on models 3 and 4 for various water depths are presented in next section.

2. Comparison of Model 3 and Model 4 with Different Water Depths

In actual engineering, the water depth is various owing to the effect of tide. The initial forces of the mooring lines are also changed along with the water depth. It is necessary to analyze the influence of different water depths on performance. Figure 9 reveals the transmission coefficient (K_t) of models 3 and 4 varying with B/L when the water depths are 0.42 m and 0.44 m. From the figure, it is seen that the transmission coefficient is affected by the water depth obviously. The lower K_t will be achieved on account of the floating breakwater is tied tighter because of the larger water depth (except the floating body has been submerged fully). The conclusion of the contrast between models 3 and 4 is similar to that of 0.4 m water depth, that is, model 4 yields the lower K_t as the incident wavelength is increased. All the values of K_t are less than 0.4 as B/L is up to 0.35 and they decline about twenty percent compared with the results of models 3 and 4 with 0.4 m water depth (As seen in Fig. 7).

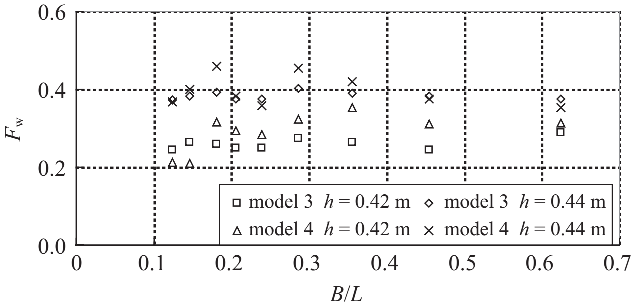

Fig. 10. The normalized (by $\rho g L_0 BH/2$) windward mooring forces of models 3 and 4 vary with B/L (H = 0.04 m, h = 0.42~0.44 m).

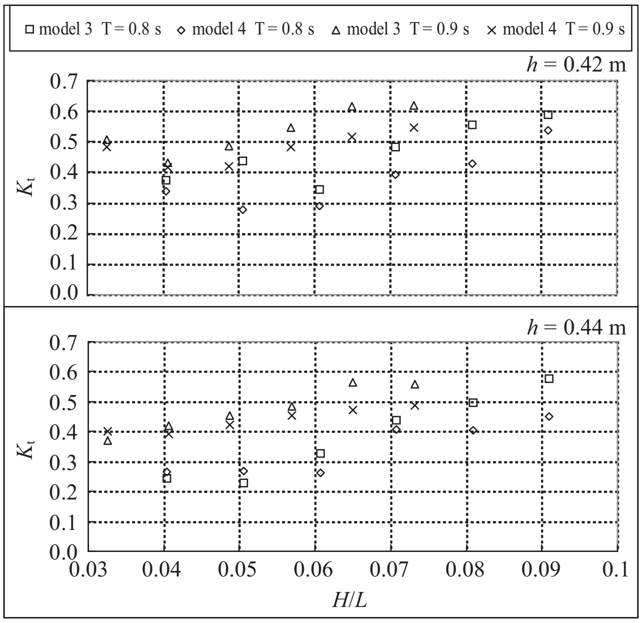

Fig. 11. The transmission coefficients (K_t) of models 3 and 4 vary with H/L (h = 0.42~0.44 m).

The normalized windward mooring forces of models 3 and 4 in different water depths varying with B/L are shown in Fig. 10. The larger windward mooring forces are acquired as water depth gets deeper. Meanwhile, the variety of F_w with increasing B/L is more gently contrasted to that of 0.4 m water depth. It indicates that incident wavelength is not a significant factor on mooring force on condition that the porous floating breakwaters such as models 3 and 4 are restricted tightly. The values of F_w in different cases get closer as B/L is increased, and the difference of F_w between models 3 and 4 is not so obvious. It implies that the crucial factor on mooring force is the penetrability on not horizontal direction but vertical direction.

The influence of wave steepness (H/L) on performance of the floating breakwaters is evaluated, here. Six values of the incident wave heights (0.04, 0.05, 0.06, 0.07, 0.08 and 0.09 m) and two representative wave periods (0.8 and 0.9 s) are adopted, and the relevant wave steepness lies in the region from 0.0325 to 0.091. Figure 11 presents the transmission

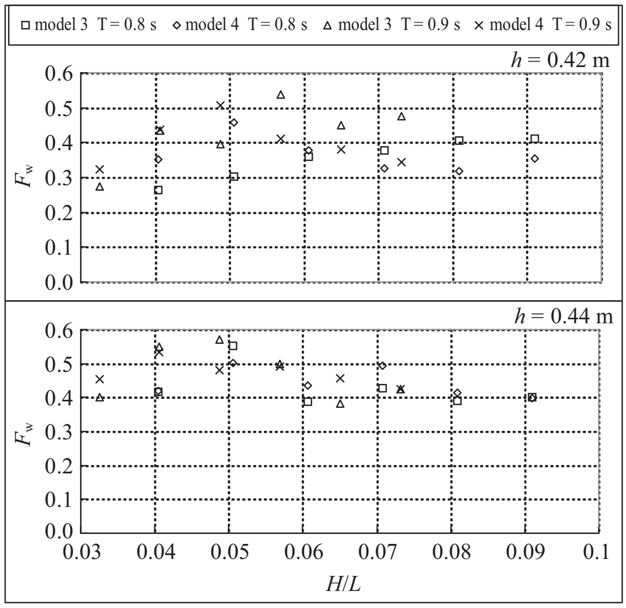

Fig. 12. The normalized (by $\rho g L_0 BH/2$) windward mooring forces of models 3 and 4 vary with H/L (h = 0.42~0.44 m).

coefficients (K_t) of models 3 and 4 vary with H/L. The graphs show an increase in K_t with an increase in H/L. The main reason for this behavior is that the larger overtopping wave on the top of the floating breakwaters is yielded when the floating bodies are exposed to the larger wave steepness. It is also observed that most transmission coefficients of model 4 are lower than that of model 3 with the variety of either wave steepness or water depths. And the difference between them is increased a little as the wave steepness is increased. It implies that the performance of attenuating wave is affected by the penetrability on horizontal direction (it is not on the horizontal direction of the whole structure like as model 2, but on the structural side-piece such as model 4, and the quasi-closed central section is crucial to hold incident wave energy back) more notably.

The normalized (by $\rho g L_0 BH/2$) windward mooring forces of models 3 and 4 vary with H/L are shown in Fig. 12. The influence of H/L on F_w is obscure, and most of the values of F_w lie in the region from 0.3 to 0.5 with 0.42 m water depth and from 0.4 to 0.6 with 0.44 m water depth, respectively. The larger water depth (larger initial force) brings the closer mooring force, and this result is similar to that from Fig. 10. The visible distinction of F_w between two models is found difficultly.

V. CONCLUSION

In this paper, a novel porous breakwater fabricated with diamond-shaped blocks is presented. And the influence of geometrical configuration of the moored floating breakwater on transmission coefficient (K_t) and mooring force (F_w) is investigated experimentally. The advantageous characteristics of configuration are offered, and it is hoped that the conclusion can bring active effect for configuration design of floating breakwater. Based on the present investigations and results obtained, the following conclusions are drawn:

- The relative width plays a crucial role in the performance of wave attenuation, and the values of K_t are decreased markedly as B/L is increased in each case examined.
- The increase of water depth will bring larger mooring force, as a result, lower transmission coefficient will be obtained for such moored floating breakwater.
- Transmission coefficient is increased with the increasing wave steepness due to wave overtopping observed in the tests. The influence of H/L on the normalized mooring force is weak, especially when the initial mooring force increases. It indicates that the absolute mooring force will increase linearly approximately with the increasing incident wave height (H).
- The geometrical configuration can impact the performance of wave attenuation and force suffered from incident wave, significantly. For the proposed porous floating breakwater, generally, moderate penetrability on the outer section and quasi-closed configuration in the central section on horizontal direction (such as model 4 not model 2) and biggish penetrability (such as model 3 or model 4) on the vertical are advantageous to wave attenuation and force debasement.

REFERENCES

1. Bayram, A., "Experimental study of a sloping float breakwater," *Ocean Engineering*, Vol. 27, pp. 445-453 (2000).
2. Dong, G. H., Zheng, Y. N., Li, Y. C., Teng, B., Guan, C. T., and Lin, D. F., "Experiments on wave transmission coefficients of floating breakwaters," *Ocean Engineering*, Vol. 35, pp. 931-938 (2008).
3. Drimer, N., Agnon, Y., and Stiassnie, M., "Simplified analytical model for a floating breakwater in water of finite depth," *Applied Ocean Research*, Vol. 14, pp. 33-41 (1992).
4. Gesraha, M. R., "Analysis of Π shaped floating breakwater in oblique waves: I. Impervious rigid wave boards," *Applied Ocean Research*, Vol. 28, pp. 327-338 (2006).
5. Hegde, A. V., Kamath, K., and Deepak, J. C., "Mooring forces in horizontal interlaced moored floating pipe breakwater with three layers," *Ocean Engineering*, Vol. 35, pp. 165-173 (2008).
6. Lao, G. S. and Feng, H., "Theoretical calculation of floating breakwater performance," *China Ocean Engineering*, Vol. 6, No. 4, pp. 415-424 (1992).
7. Liang, N. K., Huang, J. S., and Li, C. F., "A study of buoy floating breakwater," *Ocean Engineering*, Vol. 31, pp. 43-60 (2004).
8. Mani, J. S., "Design of Y-frame floating breakwater," *Journal of Waterway, Port, Coastal, and Ocean Engineering*, Vol. 117, pp. 105-119 (1991).
9. McCartney, B. L., "Floating breakwater design," *Journal of Waterway, Port, Coastal, and Ocean Engineering*, ASCE, Vol. 3, pp. 304-318 (1985).
10. Murani, K. and Mani, J. S., "Performance of cage floating breakwater," *Journal of Waterway, Port, Coastal, and Ocean Engineering*, ASCE, Vol. 123, pp. 172-179 (1997).
11. Rahman, M. A., Mizutani, N., and Kawasaki, K., "Numerical modeling of dynamic responses and mooring forces of submerged floating breakwater," *Coastal Engineering*, Vol. 53, pp. 799-815 (2006).
12. Sannasiraj, S. A., Sundar, V., and Sundaravadivelu, R., "Mooring forces and motion response of pontoon-type floating breakwaters," *Ocean Engineering*, Vol. 25, No. 1, pp. 27-48 (1998).
13. Stiassnie, M. and Drimer, N., "On a freely floating porous box in shallow water waves," *Applied Ocean Research*, Vol. 25, pp. 263-268 (2003).
14. Weng, W. K. and Chou, C. R., "Analysis of responses of floating dual pontoon structure," *China Ocean Engineering*, Vol. 21, No. 1, pp. 91-104 (2007).
15. Williams, A. N., Lee, H. S., and Huang, Z., "Floating pontoon breakwaters," *Ocean Engineering*, Vol. 27, pp. 221-240 (2000).
16. Yao, G. Q., Ma, Z. X., and Ding, B. C., "Experimental study on rectangular floating breakwaters," *China Ocean Engineering*, Vol. 7, No. 3, pp. 323-332 (1993).