

Experimental study on the wave dissipation performance and mooring force of porous floating breakwater

Y N Zheng¹, X M Liu^{1,2}, C P Chen^{1*}, Y P Jiang² and C W Zhang¹

¹School of Ocean and Civil Engineering, Dalian Ocean University, Dalian, Liaoning, 116024, China

²Tianjin Research Institute for Water Transport Engineering, Tianjin, 300000, China

*Corresponding author's e-mail: ccp@dloou.edu.cn

Abstract. Through the physical model test method, the wave dissipation performance and mooring force of porous floating breakwater under regular waves are analyzed and compared with the traditional pontoon floating breakwater. The results show that for long waves with small wave height in the tests, the transmission coefficient of porous floating breakwater is 0.5%~4% smaller than traditional floating breakwater. The porous floating breakwater cannot achieve effective wave dissipation under most conditions mainly because of the small height out of the water. The mooring force of porous floating breakwater can be reduced 3%~5.5% with splayed mooring system. The research content in this paper provides a theoretical basis for the design and engineering application of porous floating breakwater.

1. Introduction

As a wave resisting structure, breakwaters are widely used in bathing places, port fairways, yachts and wharves, and its structural form has great influence on ship navigation, water exchange, wave attenuation and wave reduction in port, coastal and offshore engineering. Traditional gravity breakwaters in deep-water areas are faced with problems such as high foundation requirements, difficult construction and high cost in very deep water. The floating breakwater is made up of floating bodies and mooring systems, which owns a lot of advantages. It is conducive to the water exchange, and has little influence on the sediment and the ecological environment. The cost is less affected by water depth, the foundation is more adaptable, and the construction and demolition are relatively convenient. It is more suitable for sea areas with high tidal range, soft soil bed and deep waters. Therefore, the floating breakwater has broad application prospects.

In recent years, many researchers proposed a lot of new type of floating body, the cage floating breakwater^[1], the square box-truss-mooring-type floating breakwater^[2], the double pontoon floating breakwater^[3], the net-board floating breakwater^[4], etc. The wave dissipation performance^[4], hydrodynamic performance^[5], the mooring force^[6] and wave pressure^[7] of floating breakwaters are mainly studied in experimental and numerical ways.

In summary, through the research of many scholars on floating breakwaters, the wave dissipation performance of floating breakwater under long wave action is the focus. In order to increase the effects on long waves, several serials of opening holes are designed on both sides of the pontoon floating breakwater to dissipate more wave energy. The type of structure can also be called porous floating breakwater. In this paper, the transmission coefficient (ratio between incident and transmitted wave height) and the mooring force of the porous floating breakwater are studied compared with the



traditional pontoon floating breakwater experimentally. The research results can provide a basis study of porous floating breakwaters under complex wave conditions.

2. Physical model test

2.1. Equipment and instruments

The experiment was carried out in a wave flume of the Tianjin Research Institute for Water Transport Engineering. The size of the flume is 68 m×1 m×1 m, equipped with wave generation machine. The wave heights are collected by three-dimensional wave probe made in Japanese, and the mooring forces are measured by piezoresistive tension sensor. The instrument and equipment satisfied the requirements of the test.

2.2. Experiment conditions and model design

Froude similitude was considered as most appropriate for the model experiment involving a floating coastal structure. The scale was set as 1:33 in accordance with the dimensions of experimental facilities and the tested wave conditions. The experimental model of porous floating breakwater is shown in Figure 1. The length, width and height of the model are 99cm, 54.5 cm and 12 cm respectively. The draught is 9.1 cm, and the total length of mooring chain is 74cm. The traditional pontoon floating breakwater is the same size as the porous one. The spring is hooked to the tension sensor to simulate the elasticity of the anchor chain, and the sketch of the experiment is shown in figure 2. The traditional pontoon floating breakwater is arranged in the same way.



Figure1. Picture of porous floating breakwater model

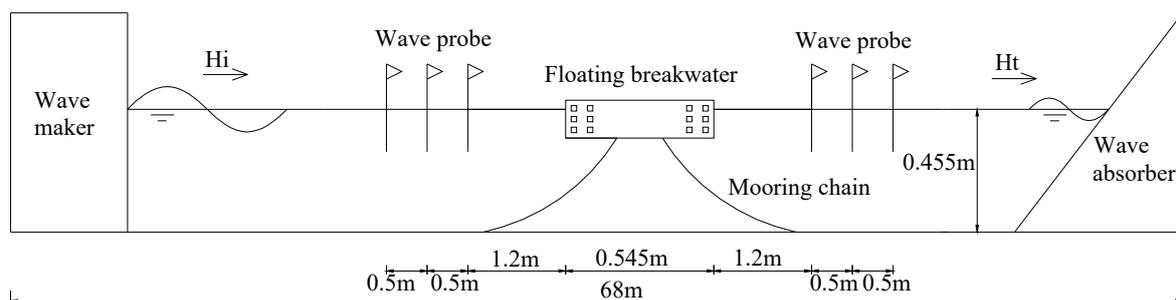


Figure 2. Sketch of the experiment

2.3. Experimental conditions

In this study, a water depth of 0.455 m is adopted for a regular wave. Given engineering practice and the wave flume condition, the experimental wave periods (T) ranges from 0.8 s-1.4 s and the experimental wave heights (H_i) ranges from 0.06 m-0.12 m. Table 1 lists the details.

Table 1. Experimental test conditions

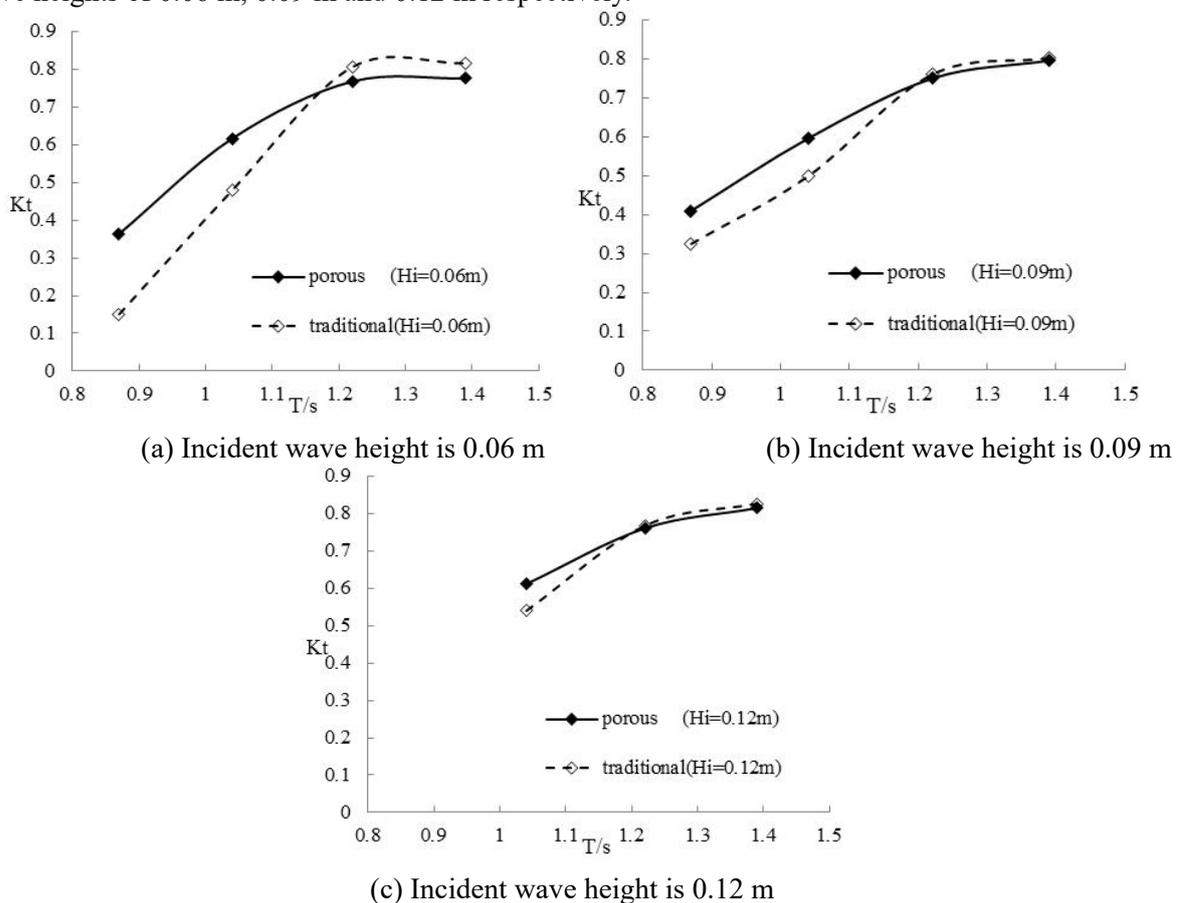
Incident wave height, H_i/m	Incident wave period, T/s
0.06	0.87,1.04,1.22 and 1.39
0.09	0.87,1.04,1.22 and 1.39
0.12	1.04,1.22 and 1.39

3. Results and discussions

The wave dissipation performance and mooring system force of the porous floating breakwater with mooring chain are studied in this experiment, and the transmission coefficient K_t and mooring force are measured and analyzed compared with those of the traditional one.

3.1. Wave dissipation performance

The wave dissipation performance of the floating breakwater can be described by transmission coefficient $K_t=H_t/H_i$, the ratio between the transmitted wave height and the incident wave height. Fig.3 shows the comparison of K_t between porous and traditional floating breakwaters with incident wave heights of 0.06 m, 0.09 m and 0.12 m respectively.

Figure 3. Comparison of transmission coefficient K_t

It can be seen from the comparison results in Fig.3 that given the same incident wave height, K_t increases with long wave, and given the same period, K_t increase with large wave height. The experimental results show that under short wave conditions, the transmission coefficient of the porous floating breakwater is larger, which indicates that the wave dissipation performance has no improvement; under long wave conditions, the transmission coefficient of the porous floating breakwater is slightly smaller than that of the traditional one, with a reduction of 0.5%~4%.

The reason is that the floating breakwater has a large draught with splayed mooring chain, and the

height out of the water surface is relatively small (only nearly 0.03 m), and a lot of waves run over the top of the breakwater, which is almost submerged in the water, therefore, the energy absorption effect of the porous structure is not remarkable. While, on the contrary, the injection of water at the opening increases the draft of the breakwater, leading to the energy which is concentrated near the water surface transmitted above the breakwater directly, and the transmission coefficient of the porous floating breakwater becomes even larger than that of the traditional one.

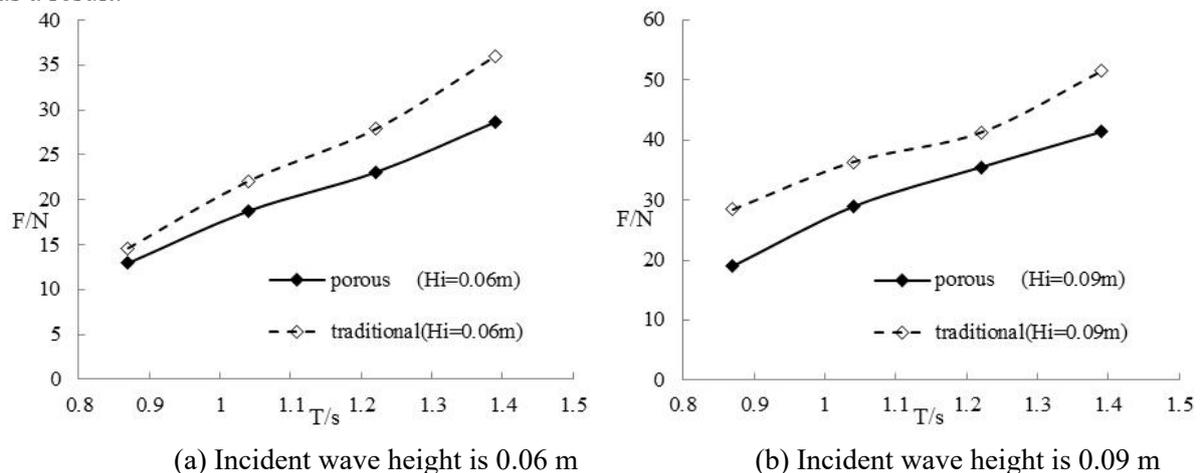
According to the wave theory for long wave, the vertical distribution range of wave energy increases, and the proportion of energy absorbed by breakwater enlarges as well. It can be seen from Fig.3 that the transmission coefficient K_t of long waves at three different wave heights is close to that of the traditional floating breakwater.

Taking the small wave as consideration, the wave amplitude is almost same as the height out of the water surface. Since most of the wave energy near the surface can be blocked by floating pontoon, the effect of wave dissipation is obvious. As the porous floating breakwater submerges near the surface with injection water, condition transmission coefficient for short wave is still larger. For long wave conditions, the rolling of the breakwater caused by the mooring chain becomes significant and the inclination of porous floating breakwater undersea enlarges the vertical wave blocking area. The transmission coefficient decreases slightly, which means the wave dissipation performance of porous breakwater is better than that of the traditional one for long wave with small wave height.

Through the analysis above, the porous floating breakwater cannot achieve effective wave dissipation under most conditions mainly because of the small height out of the water.

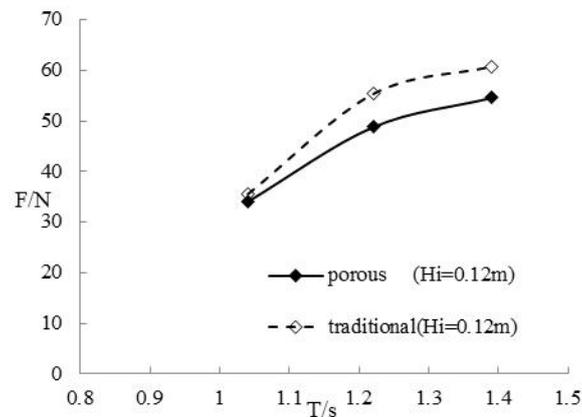
3.2. Mooring force

The mooring forces of the porous and non-porous floating breakwater at the same incident wave height and different periods are compared in Fig. 4. It can be seen from Fig. 4 that, the waves with larger height and longer period will accompany with more mooring force for porous breakwater and traditional one as well. Under the same incident wave height and period, the mooring force of traditional pontoon floating breakwater is 3%~5.5% larger than that of the porous one. The reason is that under the experimental wave conditions, the porous floating breakwater are below the water surface almost all the time, and the diving depth is deeper, so the tension of the anchor chain is small as a result.



(a) Incident wave height is 0.06 m

(b) Incident wave height is 0.09 m



(c) Incident wave height is 0.12 m

Figure 4. Comparison of mooring force F

4. Conclusions and Prospect

4.1. Conclusions

1) For the porous and traditional floating breakwater, under the same incident wave height, the transmission coefficient and mooring force increase with the increase of the wave period; under the same incident wave period, the transmission coefficient and mooring force increase with the increase of the wave height.

2) For long waves with small wave height in the tests, the transmission coefficient of porous floating breakwater is 0.5%~4% smaller than non-porous floating breakwater. The porous floating breakwater cannot achieve effective wave dissipation under most conditions mainly because of the small height out of the water.

3) The mooring force of porous floating breakwater can be reduced 3%~5.5% with splayed mooring system.

4.2. Prospect

The wave dissipation performance of the porous floating breakwater remains to be further studied with different sizes including the height above the water, the size of opening holes and also the mooring type and length of the chain etc.

Acknowledgments

This work was financially supported by the National Natural Science Foundation (NSFC) Project Nos. 31572663 and the Liaoning Provincial Department of Education Project in 2017.

Reference

- [1] Murali K., Mani J.S. (1997) Performance of cage floating breakwater. *Journal of Waterway, port, Coastal and Ocean Engineering*, 123:172-179.
- [2] Matsunaga N., Hashida M., Uzaki K.I., Kanzaki T., Urugami Y. (2002) Performance of Wave Absorption by a Steel Floating Breakwater with Truss Structure. In: *International Offshore and Polar Engineering Conference*. Kitakyushu, Japan. pp.768-772.
- [3] Ikesue S., Sugi Y.(2002) Study on the performance of a floating breakwater with two boxes. In: *International Offshore and Polar Engineering Conference*, Kitakyushu, Japan. pp. 773-778.
- [4] Dong G.H., Zheng Y.N., Li Y.C., Teng B., Guan C.T., Lin D.F. (2008) Experiments on wave transmission coefficients of floating breakwaters. *Ocean Engineering*, 35: 931–938.
- [5] Ji C.Y., Chen X., Ma X.J., Yuan Z.M. (2018) The influence of perforated plates on wave transmission and hydrodynamic performance of pontoon floating breakwater. *Journal of Hydrodynamics*, 3:522-530.

- [6] Loukogeorgaki E., Angelides D.C. (2005) Stiffness of mooring lines and performance of floating breakwater in three dimensions. *Applied Ocean Research*, 27:187-208.
- [7] Yu Y., Ding N., Lin J., Hou J.J. (2015) Wave Pressure Acting on V-Shaped Floating Breakwater in Random Seas. *Journal of Ocean University of China*, 1406:975-981.