Wave-transmission of very large and fixed bottom-detached breakwaters in a numerical wave flume

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ABSTRACT

Climate change and energy crisis are fueling wide concern. Coastal areas are prone to the effects of sea level rise and change of wave conditions as the results of extreme conditions and the increasing number of coastal risks. These phenomena drive coastal erosion, and the lack of alternative dwelling space leads to the higher density urban structures in coastal communities. Expanding human's activity space toward exposed offshore marine areas is a big challenge in term of scientific and technological issues. The use of floating structures, such as the Very Large Floating Structure (VLFS) (Bouchet et al., 2004), is a potential solution to expand activity space and cope with the sea level rise with a resilient approach. In the past, most of research activities have focused on the relatively small floating structures located in intermediate or shallow waters in naturally protected marine areas.

Many experimental tests for studying the transmission coefficient (K_{tr}), which presents the protection performance, were carried out (Koutandos et al., 2005; Liang et al., 2022; Wu et al., 2022), and some empirical equations for predicting K_{tr} of various structures were proposed (Macagno, 1954; Drimer et al., 1992; Hossain et al., 2001; Nørgaard & Andersen, 2012; Pezzutto, et al., 2013; Kolahdoozan et al., 2017; Ruol, Martinelli, Abarca, 2021). But it is surprising to notice that the case of floating breakwater with large draft and width, located in deep waters and working in extreme wave conditions has rarely been studied to date.

In this study, a very large and fixed bottom-detached breakwater (VLFB) with large draft (D_{FB}) and width (W_{FB}) was investigated in extreme wave conditions and offshore deep waters, with the aim to limit the wave transmission in the rear protected area. It is necessary to concentrate on investigating the K_{tr} of VLFB for filling the gap and providing more reliable prediction for future engineering development. By using Computational Fluid Dynamics (CFD) tool, Fluent, a 2D numerical wave flume (NWF) was implemented and calibrated. The influence of different numerical settings and the sensitivity analysis of mesh resolution on the relative error and wave decay of wave height were studied (Figure 1). The wave decay of the NWF was optimized and controlled within 5% in different time instants (Figure 2).

Based on the established NWF, the interaction between wave and VLFB was studied, and the sensitivity analyses of K_{tr} to wave conditions and the dimensions of VLFB were conducted. It was found that the K_{tr} of floating breakwater provided by the empirical equations , which were proposed by other researchers for predicting the K_{tr} of box-type floating breakwater (Macagno, 1953; Ruol et al., 2013), couldn't provide sufficiently accurate results for VLFB. As shown in Figure 3, with the increasing of relative draft (D_{FB}/L_w; L_w: wavelength), the predicting results of K_{tr} under the conditions of different relative width (W_{FB}/L_w) become less accurate. One of the key factors influencing the accuracy of predicting results is relative draft.

Considering the large size and high material requirements of VLFB, it is meaningful to propose an empirical equation for providing sufficiently accurate results of K_{tr} for optimizing the dimensions of VLFB, which could save the construction cost and expand activity space to the greatest extent. In conclusion, this study will provide a research reference for designing VLFB in extreme wave conditions and it could be considered as a kick-off study for further laboratory experiment studies and even engineering design.

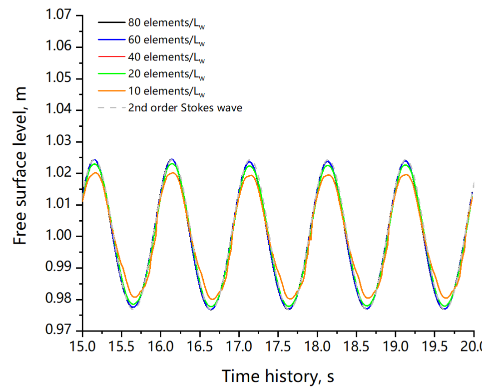


Figure 1 The influence of mesh resolution in term of computational node per wavelength on free surface level (L_w: wavelength).

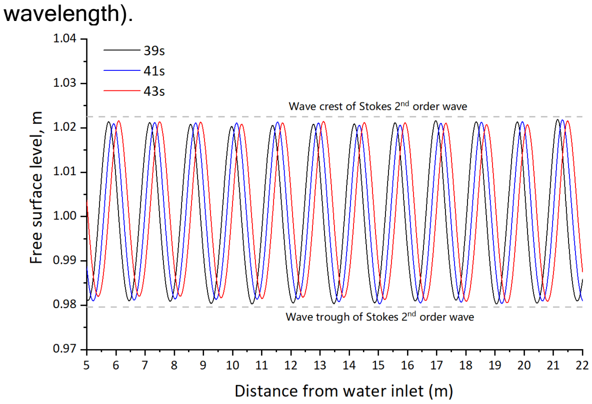
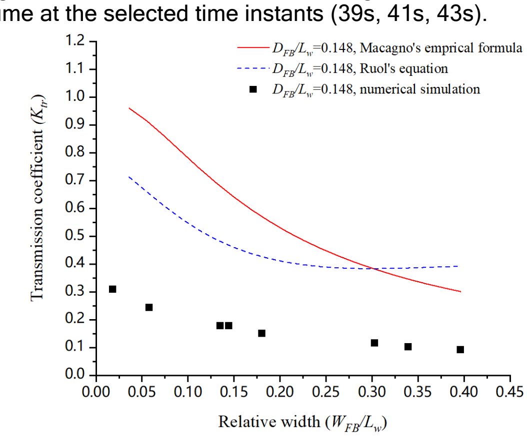
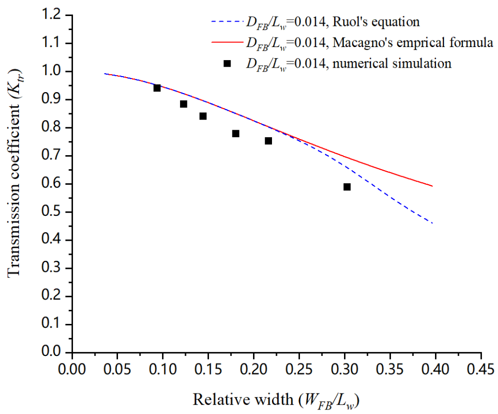


Figure 2 - The free surface level along the numerical wave flume at the selected time instants (39s, 41s, 43s).



(1) D_{FB}/L_w=0.148



(2) D_{FB}/L_w=0.014

Figure 3 - The comparison of the K_{tr} versus W_{FB}/L_w for different constant values of D_{FB}/L_w among the results from numerical simulation and previous empirical equations (W_{FB}: width of breakwater; D_{FB}: draft of breakwater).

REFERENCES

Arie Cornelis Biesheuvel (2021): Effectiveness of floating breakwaters (wave attenuating floating structures), Delft University of Technology Institutional Repository

Bouchet René, Troya Luis, Sedillot François, Peset Luis, Jaeger Jean Marc, Martareche Freéric (2004): Monaco semi-floating dyke a 352 metre long concrete caisson, Proceedings of the fib Symposium 2004 - Concrete Structures: The Challenge of Creativity, pp.109-26.

Chunyan Ji, Yuchan Guo, Jie Cui, Zhiming Yuan, Xiaojian Ma (2016): 3D experimental study on a cylindrical floating breakwater system, Ocean Engineering, ELSEVIER, vol.125, pp.38-50.

David Kriebel, Chad Bollmann (1951): Wave Transmission Past Vertical Wave Barriers, Coastal Engineering Proceedings, vol.1, pp. 2470-2483.

Drimer Nitai, Agnon Yehuda, Stiassnie Michael Aharon (1992): A simplified analytical model for a floating breakwater in water of finite depth, Applied Ocean Research, vol. 14, pp. 33-41.

Akter Hossain, Wataru Kioka, Toshikazu Kitano (2001): Transmission of long waves induced by short-wave groups through a composite breakwater, Coastal Engineering Journal, vol. 43, pp. 83-97.

Ala-Eddine Kassimi (2016): Design tool for an offshore, Delft University of Technology.

Kolahdoozan, M., Bali, M., Rezaee, M., & Moeini, M. H. (2017). Wave-Transmission Prediction of π-Type Floating Breakwaters in Intermediate Waters. Journal of Coastal Research, 33(6), 1460-1466.

Evangelos Koutandos , Panayotis Prinos, and Xavi Gironella (2005): Floating breakwaters under regular and irregular wave forcing: reflection and transmission characteristics, Journal of Hydraulic Research, vol. 43:2, pp. 174-188.

Jiaming Liang, Yong Liu, Yongkun Chen, Aijun Li (2022): Experimental study on hydrodynamic characteristics of the box-type floating breakwater with different mooring configurations. Ocean Engineering, ELSEVIER, vol. 254, pp. 111296.

Enzo Oscar Macagno (1953): Fluid mechanics – experimental study of the effects of the passage of a wave beneath an obstacle, Proceedings of the Academic des Sciences, Paris.

Macagno, E. O. (1954): Houle dans un canal présentant un passage en charge. Houille Blanche, vol. 6368, pp. 10-37.

Jørgen Harck Nørgaard and Thomas Lykke Andersen (2012): Investigation of wave transmission from a floating wave dragon wave energy converter, Proceedings of the International Offshore and Polar Engineering Conference, vol. 4, pp. 509-516.

Piero Ruol, Luca Martinelli, and Paolo Pezzutto (2013): Formula to Predict Transmission for π-Type Floating Breakwaters, Journal of Waterway, Port, Coastal, and Ocean Engineering, vol.139, pp. 1-8.

Jingping Wu, Tianlong Mei, Zaojian Zou (2022): Experimental study on wave attenuation performance of a new type of free surface breakwater. Ocean Engineering, vol. 244, pp. 110447.