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Experimental Study of the Wave Loading of a Twin-Plate Breakwater

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The twin-plate breakwater, a novel permeable breakwater, was studied experimentally in the State Key Laboratory of Coastal and Offshore Engineering in Dalian, China. The dual horizontal plates were placed in parallel with the upper one at the still water level. This study is to investigate the distribution of dynamic wave pressures and wave loads on the twin-plate breakwater under the conditions of regular waves (with the relative plate width $B/L = 0.28\sim1.43$ and relative wave height $H/d = 0.1\sim0.4$) and random waves (with the relative plate width $B/L = 0.2\sim0.66$ and relative wave height $H_s/d = 0.1\sim0.35$). Effects of the relative plate width, relative wave height, and wave steepness have been addressed. The experimental results demonstrate that the effect of the relative plate width is dominant among the above parameters. For the purpose of bulk estimation in engineering applications, we overlooked the effects of the relative plate width, relative wave height, and wave steepness and obtained the best-fitting equation to predict the maximum dynamic wave pressure and wave force on the twin-plate breakwater.

INTRODUCTION

As a functional structural part of a breakwater, the horizontal plate has been investigated since the middle of the last century. The wave-dissipating performance, reflection coefficient, wave loading, and hydrodynamic characteristics of this permeable breakwater have been explored. Various types of the plate breakwater have been studied by theoretical analysis, numerical simulation, physical modeling, and their combinations (i.e., single-plate, twin-plate, and multiple-plate types, etc.).

The early study of monolayer horizontal plates demonstrated that the horizontal plate not only dissipates waves effectively but that it also distributes the wave load more evenly on the onshore wall (Ijima et al., 1970). Patarapanich (1984a, 1984b) carried out numerical simulations to obtain the dimensionless formula of the wave loads on a horizontal plate and to provide the dimensionless vertical force and moment of the ceiling and submerged horizontal plate at various water depths. Also, Patarapanich (1984a, 1984b) pointed out that the dimensionless horizontal force was much smaller than the vertical force for plates with small thickness. However, the tidal level continuously varies in real sea states. Therefore, a monolayer horizontal plate cannot achieve the expected wave-dissipating performance at varying submerged depths. Therefore, many scholars switched to studying twin-plate breakwaters (TPBs) and multiple-plate breakwaters.

Patarapanich and Cheong (1989) and Cheong and Patarapanich (1992) conducted experiments on the transmission and reflection coefficients of an unaligned twin-plate breakwater and obtained the best wave-dissipating performance when the upper plate was located on the free surface and the lower plate was submerged at a depth of 0.15 to 0.2 times the water depth. Guo et al. (2011) carried out further experiments in investigating the dissipation performance at various submerged depths of the twin-plate breakwater. By applying the eigenfunction expansion method, Usha and Gayathri (2005) computed the reflection and transmission coefficients of the aligned twin-plate breakwater (the upper plated up to the free surface) at intermediate water depths. After comparison with the hydrodynamic responses of the submerged multiple-plate breakwater calculated by Wang and Shen (1999), it was found that the aligned twin-plate breakwater performed better than a group of submerged plates (e.g., three to six plates). Neelamani and Gayathri (2006) discussed the effects of relative plate width, relative plate spacing, steepness, and other factors on the wave dissipation performance and wave pressure of the twin-plate breakwater. The results showed that the transmission coefficient of the twin-plate breakwater can be less than 0.6 (at 98% probability) with an optimized relative plate width of 0.18∼0.84 and relative plate spacing of 0.12. Compared to the transmission coefficient of 76% for the single-plate breakwater, the performance of twin-plate breakwater is improved significantly. Based on experimental studies, Gu et al. (2017) reported that the relative plate width, relative wave height, and incident angle affect the transmission coefficient of the twin-plate breakwater significantly. Recently, researchers investigated the interaction of the breakwater and waves through the flow field simulation. Qin et al. (2019) performed numerical simulation to illustrate the flow field around the twin-plate breakwater and discuss the hydroelastic effects. Khayyer et al. (2018) simulated incompressible fluid–elastic structure interactions by using the incompressible smoothed particle hydrodynamics–smoothed particle hydrodynamics (ISPH–SPH) method. Further state-of-the-art methods can be found in the review of Gotoh and Khayyer (2018).

With random wave experiments, Gu et al. (2016) investigated the envelopes of the synchronous pressure distribution and the total vertical force on the twin-plate breakwater. It revealed that the hydrodynamic characteristics of the breakwater are subjected to various factors (i.e., the structural geometries, wave parameters, and boundary conditions, as well as their coupled effects). However, it is difficult to figure out the correlation of each factor of the hydrodynamic characteristics of the twin-plate breakwater. To simplify the problem, the wave load is assumed to be acting on rigid twin-plate boundaries. Based on the extensive experimental results under regular and random waves, this study aims to obtain

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