Investigation of Breaking Wave Action on Vertical Breakwater

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ABSTRACT

This paper investigates the breaking wave action on vertical breakwater mounted on a moderate-crested foundation bed by both physical model tests and numerical simulations. The numerical results were compared with that of physical model test, which validate the present numerical model. The characteristics of time series of breaking wave pressure as well as the relationship between the pressure and the variations of flow fields are analyzed.

KEY WORDS: Wave force; breaking wave; vertical breakwater; numerical wave flume; FEM; VOF; PIV

INTRODUCTION

Vertical breakwater is widely used in port and coastal engineering. Wave force is the one of the major loads acting on the breakwater. The wave loads induced by non-breaking wave has been well studied by many researchers such as Goda (1994), Tsai and Lee et al.(1999), Hu and Yu et al (2006), and Chiu and Lin (2007) etc. The results in that case are relatively mature and have been utilized in practical engineering. However, the mechanism of breaking wave action on vertical breakwater has not been figured out so far, since the wave breaking is very complict and violent phenomena. Through physical model tests, Grilli and Losada et al (1994) reported that for emerged breakwaters, waves may collapse over the crown, or break backward during rundown; and for submerged breakwaters, waves may break forward or backward, downstream of the breakwater. Kirkgoz and Aköz (2005) investigate the geometrical properties of waves breaking perfectly on the vertical wall of composite breakwaters, they point out that the berm width of the base structure is the major parameter affects the geometry of the breakers. Li and Liu et al (1997,1999), Martinelli and Lamberti et al (2007), and Cuomo and Allsop et al (2010) put their emphasis on the wave forces due to wave breaking. Zhang and Leung et al (2009) use centrifuge modeling technique to simulate the prototype stress levels in the foundation soil, and investigate the behavior of caisson breakwater resting on sand beds subject to breaking wave impacts. In the aspect of numerical model, the aforementioned work of Grilli and Losada et al (1994), a fully nonlinear potential model is used to simulate the wave breaking process. Nowadays, viscosity fluid model are commonly used in this subject, for example, Kawasaki (1999) present a numerical model combined a VOF method with a non-reflective wave generator to simulate the wave breaking near a submerged breakwater.

This paper investigates breaking wave before the vertical breakwater mounted on a moderate-crested foundation bed by physical model test and numerical simulation. The physical model test of this paper was conducted in the State Key Laboratory of Coastal and Offshore Engineering in Dalian University of Technology. PIV (Particle Image Velocimetry) was adopted to visualize the breaking wave field. The pressures on the seaside wall of the breakwater are recorded. A two-dimensional nonlinear wave flume is established based on finite element method and VOF (volume of fluid) technique in the numerical simulation.

PHYSICAL AND NUMERICAL MODEL

Physical Model

The flume for physical model test is 24 m in length, 0.45 m in width and 0.6 m in depth. A piston-type wave generator is located at one end of the flume, and a slope at the other end to dissipate the wave energy. The vertical breakwater model is 0.45 m in length, 0.4 m in width and 0.55 m in height.

The PIV system consists of: two laser generators are placed under the wave tank to illuminate upwards vertically to provide a thin light sheet; a high speed Powerview CCD Camera produced by TSI in USA allows the real time capture of two image sequences, 512×512 resolutions at 262 fps; Coreco camera link image acquisition card and LaserPulse synchronizer were used to control the image sampling and the synchronization of CCD camera and laser generator; the PVC powder of 150 μm grain size is used as tracer particles; the InsightTM3G software is applied for the image processing, analysis, and measurement operations.

Seven pressure transducers are installed along the middle line on the vertical wall of the breakwater model. The positions of the transducers are listed in Table 1. The sampling frequency of wave pressure transducer is 500 Hz.

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