Examination of Wave Pressures on Breakwater over Steep Beach

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ABSTRACT

This study conducted a laboratory test to examine the wave pressure on a vertical breakwater over a steep beach with slope of 1:5. In the experiments the time history of wave pressure and surface elevation at the breakwater are observed. The pressure distributions on the vertical wall are compared with previous empirical formulas. The results show that the wave breaking is likely to occur on the steep beach, the maximum wave pressure may be underestimated about two to five times when Goda’s pressure formula was employed. According to the experimental results, a modified pressure formula is presented in this study to estimate the wave pressures on the vertical breakwater over the steep beach.

KEY WORDS: Wave pressure; vertical breakwater; steep beach; wave breaking.

INTRODUCTION

The caisson breakwater with upright section was commonly used in a harbor construction. The vertical breakwaters may be subjected to a large amount of wave force action during the storm. Thus the sufficient assessment of the wave pressure force on a breakwater is an essential part in the design process. The pressure formula proposed by Hiroi (1919) was widely employed by engineers in Japan and Taiwan before two decades for breaking waves. While the pressure formula for standing waves introduced in Sainfluo (1928) was adopted for nonbreaking waves. Nowadays the pressure formula presented in Goda (1985) has been employed as the standard formula for the design of vertical breakwaters which is applicable to nonbreaking waves to breaking waves.

This pressure formula was early presented in Goda (1973), that was extended from Ito et al. (1966) through the use of more laboratory data of Goda and Fukumori (1972) and theoretical considerations of Goda and Kakizaki (1966). Many cases of sliding and nonsliding of vertical breakwaters were examined for the formula. After that, the formula was modified in Tanimoto et al. (1976) by considering the effect of oblique wave approach. These results were concluded in Goda (1985) for the design of vertical breakwaters assuming the existence of a trapezoidal pressure distribution along a vertical wall.

Goda’s formulas of wave pressures were also adopted as standard formulas for the design of the strength of vertical breakwaters in Taiwan. The formulas were fairly applicable for a breakwater built on a gentle slope beach such as it is smaller than 1:10. However, parts of beaches in eastern coast of Taiwan that faces the Pacific where beaches are very steep, say 1:5. The wave pressure forces on a breakwater over such beach are underestimated when the Goda’s formulas were employed, thus a higher value of safety factor against sliding of the breakwater was considered in the design. For the realistic estimation of the wave pressure on a vertical breakwater over a steep beach, this paper conducted laboratory tests to examine the applicability of the previous empirical formulas for such beach.

EXPERIMENTAL SETUP

The experiments were conducted in a two-dimensional wave flume that was 100 m in length, 2 m in width and 2 m in height. The sidewalls of the flume were constructed with reinforced concrete, and included strengthened glass plates at the observation sections. A piston-type wave generator system, controlled by a D/A converter and a personal computer, was mounted at the end of the flume. A model of the vertical breakwater on the steep bed was installed at the observation area of the flume. A sketch of the experimental setup is shown in Fig. 1. Regular waves were considered in the experiments. The height of the breakwater is enough to ensure nonovertopping waves at the breakwater.

Five pressure transducers (P1 – P5) were inserted in the front face of the vertical breakwater for measuring the wave pressures distribution; and three transducers (P6 – P8) were set in the bottom of the caisson for measuring the uplift pressure. There are several capacitance-type wave gauges used for measuring the incident wave (ch1), wave reflection from breakwater (ch7, ch8) and the wave height at the breakwater (ch10), respectively.

The water depth \( h \) in front of the breakwater was fixed at 0.35 m. The wave period \( T \) varied from 1.5 sec to 2.5 sec, and incident wave heights \( H \) varied from 0.11 m to 0.35 m. Thus the corresponding relative depth \( b/L \) at the breakwater ranged between 0.079 to 0.141. The steepness