Mitigation of Long Waves by means of Submerged Artificial Breakwaters Built upon a Mild–Slope Beach – A Numerical Study

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ABSTRACT

It has been a crucial issue on how to mitigate long waves by introducing artificial breakwaters. Since some tremendous and tragic tsunami hazards occurred in decade are still vivid in people’s memory, the topic related to the attenuation of long waves is of great importance. This study presents some preliminary results obtained from numerical simulations to estimate the possible mitigation of long waves by means of submerged breakwaters built upon a sloping beach. Our goal is to understand the capability and the optimal location of underwater breakwaters on reducing the run–up height due to long waves.

KEY WORDS: Long waves; solitary wave; submerged breakwater; wave breaking; wave attenuation; RANS model.

INTRODUCTION

Natural hazard caused by tsunami inundation of coastal–zone has been regarded as a crucial issue for coastal engineering community. The hydrodynamic behavior of tsunami–induced flooding inland has been better understood since the 2011 Tohoku earthquake tsunami. Although the breakwater at the Kamaishi Bay, which is the deepest breakwater in the world, was severely damaged during such tsunami event, some recent investigation showed that the breakwater can reduce the wave height of tsunami by around 25% to 40% compared to that at the Otsuchi Bay, which behaves the similar geography to the Kamaishi Bay, without the tsunami breakwater (Mori et al., 2013). Also, it was numerically confirmed that the offshore breakwater diminished 20% to 40% inundation height along the Kamaishi Bay during the 2011 Tohoku earthquake tsunami (Mori et al., 2013). Therefore, such tsunami barrier still plays an important role, in some senses, on the attenuation of tsunami waves. An insightful investigation on how to mitigate the tsunami waves by means of newly–proposed artificial breakwater is of great importance.

In this study, we propose a submerged multi–barrier system built upon a mild–slope beach as an artificial breakwater to mitigate tsunami–like long waves. Before conducting physical experiment, a numerical study is performed first to roughly estimate the optimal position of an isolated barrier and the optimal distance between two neighboring barriers. The lowest wave transmission or the minimum run–up height would be examined as a standard to judge which scenario can provide the best performance. Solitary wave has been regarded as a representation of extreme long wave and sometimes may be utilized as tsunami in some sense (Hsiao et al., 2008; Hsiao and Lin, 2010). We realize that the solitary wave is not equal to the geophysical tsunami and the solitary wave used here is to provide an ideal investigation without the effects from both preceding and subsequent waves. At present, other waveforms of tsunami–like long waves such as $N$–wave cannot be precisely generated through either physical wave flume or fully–nonlinear/dispersive wave model. The issue of solitary wave paradigm for tsunamis raised by Madsen et al. (2008) is mainly due to the concern of the resulting wave period and wavelength, which is remarkably short, as the use of a solitary wave being scaled down in a laboratory–scale. Rueben et al. (2011) used the full stroke movement of wave paddle to generate tsunami–like long waves while an error function was used as a signal to the wavemaker. Although the resulting waveform is more or less similar to the solitary wave, the wavelength as well as wave period are much larger to create longer inundation time which would be a more close approximation to the realistic tsunami (Irish et al., 2014). Such approach can be therefore used as an approximate representation of tsunami–like long waves in the next step of this study.