Runup of Double Solitary Waves on a Vertical Wall

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ABSTRACT

As tsunami wave may evolve into a wave train consisted of several isolated solitary waves during its propagation in the offshore area. In order to clarify the interaction mechanism between this wave train and coastal structures, well-designed run-up experiment and numerical simulation of double solitary waves were carried out. It turns out that, with regard to double solitary waves with same height, run-up amplification coefficient of the latter wave is less than the leading one when the relative wave crest distance is reduced to a certain threshold value. The detailed velocity field and energy budget were obtained using the numerical model.

KEY WORDS: Double solitary wave; runup; vertical wall; numerical simulation; flume experiment.

INTRODUCTION

It has been a traditional subject to understand the propagation of a solitary wave over a constant depth region and its runup against a sloping beach or a vertical wall because of importance of evaluating potential inundation and impacts of tsunami on coastal structures.

Synolakis (1987) developed an analytical solution for nonbreaking waves on a plane beach based on the nonlinear shallow water equation. Li & Raichlen (2001) proposed a nonlinear solution to the classical shallow water equation by using a hodograph transformation and reported an experimental study on runup process of nonbreaking and breaking solitary wave. Fuhrman and Madsen (2008) proposed the reduced surf similarity parameter for solitary waves, the beach slope divided by the offshore wave height to depth ratio, which provides good coherency with experimental breaking and runup data and analytical nonbreaking runup expressions.

The full nonlinear and highly dispersive Boussinesq equations were used by Zhao et al.(2012) to investigate the evolution and run-up of solitary waves and N-waves on plane beaches. They discussed variations of the potential energy and the kinematic energy during the run-up and rundown on a plane beach. Further, Zhao et al.(2013) carried out numerical simulation of tsunami waves propagating on the continental shelf with an extremely gentle slope. It is interesting to note that, from the numerical results obtained by the Boussinesq model, the N-shape tsunami waves could evolve into long wave trains, undular bores or solitons near the coastal area for the cases of different initial wave heights. Recently, Chan and Liu (2012) extended the analytical approach of Madsen and Schäffer (2010) to study the runup formulae of a train of solitary waves and concluded that, for the runup of two solitary waves where a wave is followed by one with a larger amplitude, the maximum runup is slightly smaller than that of a single solitary wave. Xuan et al. (2013) reported an experimental study of runup double solitary wave on a plane beach. Even though much work has been done about the overtaking or head-on collision of two solitary waves theoretically, particularly at the multi-solitary wave solution of the KdV equation, there are few works on experimental study on runup of a wave train of multiple soliton–like waves against a vertical wall. The detailed information about the velocity field during the period of runup of the multi-solitary waves and the energy budget are not clear.

This paper investigates the runup of the double solitary waves against a vertical wall experimentally and numerically. First, the runup of double solitary waves with different wave height on a vertical wall are computed and compared with the measured data. Second, the details of the velocity field are obtained through numerical simulation. Finally, the changes of the potential energy and the kinetic energy are discussed.

EXPERIMENTAL SETUP

We carried out experiments on the runup characteristics of two solitary waves in the wave flume of the MOE Key Laboratory of Hydrodynamics in Shanghai Jiao Tong University. The facility consists of a wave flume (65m long×1.8m deep×0.8m wide), a piston-type wave generation system and a wave elevation measurement system. As shown in Fig.1, left side of the wave flume equipped with the piston-type wave generator is installed at the left end of the wave flume and the paddle is moved horizontally in a prescribed trajectory by means of