Runup of double/triple solitary waves on plane slope

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This abstract presents an experimental study on runup of double/triple solitary waves on a plane slope in a wave flume. Time series of the surface elevation and waterline movement are measured. With regard to a train of three solitary waves with same height, the runup amplification coefficient of the individual wave varies and the runup coefficient of the second wave is smallest among them. Details of experimental results and numerical simulations of runup of double/triple solitary waves will be presented.

1 Generation of triple solitary waves

We carried out experiments on the runup characteristics of double/triple solitary waves in the wave flume of the MOE Key Laboratory of Hydrodynamics at 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. A 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 a hydraulic servo-system. At the right end of the wave flume, a slope beach is installed to eliminate the wave reflection. There are total 9 wave gauges along the wave flume, as shown in Fig. 1. The maximum wave runup is recorded by two high-speed cameras with 100FPS recording speed and 1024×1024 resolution.

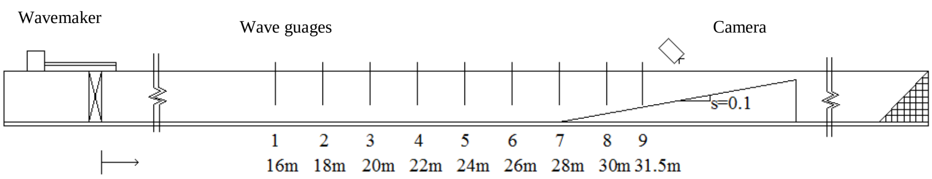

Figure 1 Experimental setup

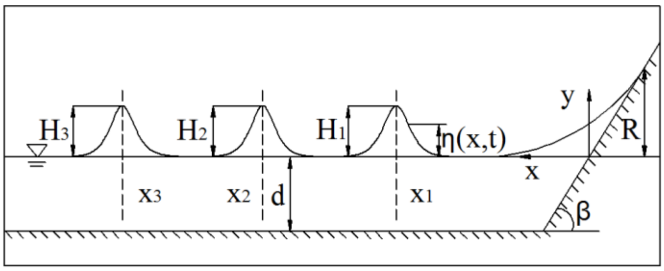

Figure 2 Sketch of definition

Lo et al. (2013) and Nimish et al. (2015) reported an experimental investigation on run-up and back-wash process of single and double solitary waves on a plane beach. In order to implement the experiments of runup of multi-solitary waves, as shown in Fig. 2, the modified Goring's method (Goring, 1978), proposed by developed Malek-Mohammadi and Testik (2010), is used to generate a wave train of three solitary waves. Actually, this modified Goring's method was used to generate two successive two solitary waves with different amplitudes (we refer to Double Solitary Waves) by Xuan et al. (2013). Following Grimshaw's solution of the third order solitary wave, the target wave train consisting of three solitary waves with different phase difference can be constructed and, then, the time series of the displacement of the wavemaker can be obtained. The time series of the surface elevation measured by the wave gauges, for the case of the relative wave amplitude H/d=0.1, are plotted in Fig. 2. In the figure, the solid line represents the double solitary wave, the dashed line denotes the triple solitary wave and the parameter ε represents the phase difference among waves.

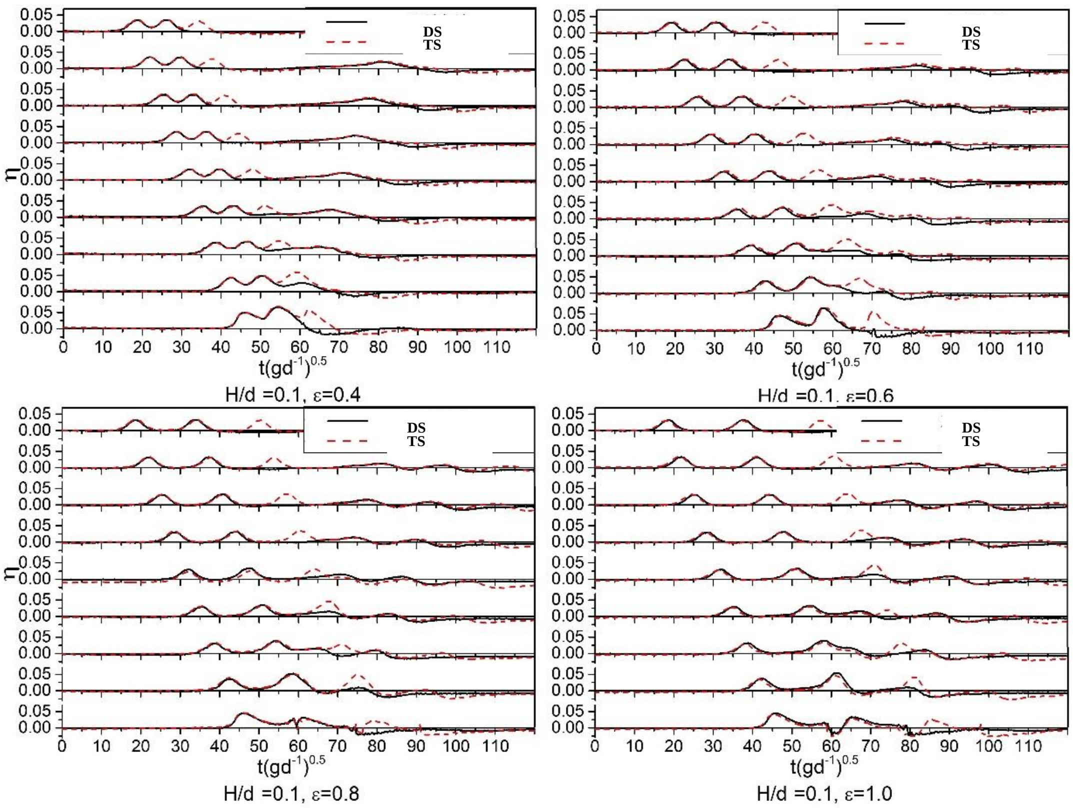

Figure 2 Time series of surface elevation

2 Results and discussion

The runup amplification coefficient of a solitary is defined as the ratio of the maximum runup to the wave amplitude R/H. The distance between two peaks of the neighbouring solitary waves δL is proportional to the phase difference parameter ε. For the case of double/triple solitary waves with identical amplitude, the same referred amplitude is adopted to calculate the runup amplification. The measured runup amplification coefficients for individuals are presented in Fig. 3.

It is found that influence of the leading solitary wave is obvious to the following wave due to strong swash current appearing in the stage of rundown of the first wave. The relationship between the runup amplification coefficient of the second waves and initial phase difference will change with the increase of the relative amplitude of incoming wave. However, the runup amplification coefficient of the third wave increases with the increase of initial phase difference and the relationship is independent of the relative amplitude of incoming wave. Basically, the runup amplification coefficient of the first waves is larger than that of the second wave, while the runup amplification coefficient of the third wave is larger than that of the second wave.

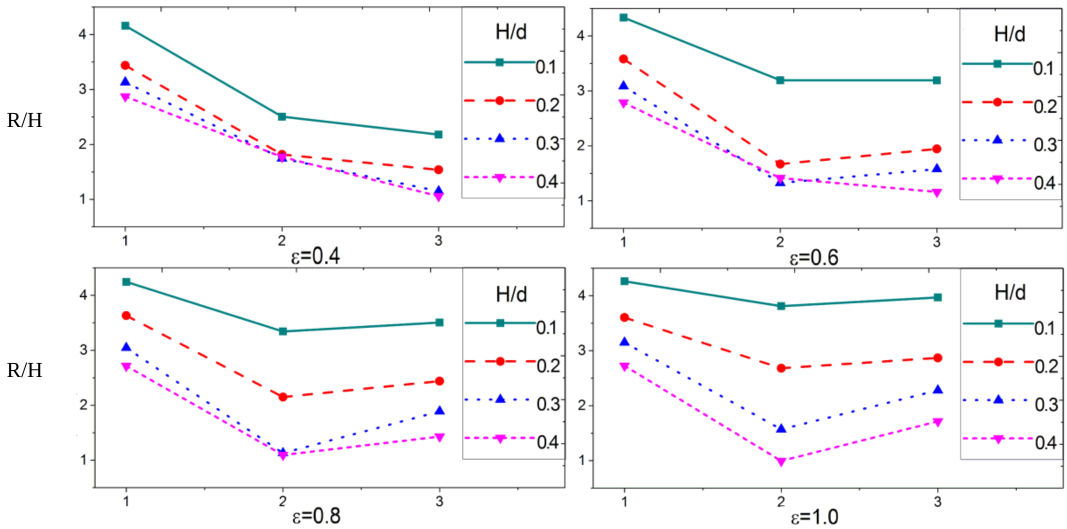

Figure 3 Runup amplification of individual wave

In order to understand the mechanism of the variation of the runnup amplification of individual waves, numerical simulations of runup of double solitary waves and triple solitary waves are carried out. Based on the computed velocity field and the wave profile by the RANS equations based numerical model, the kinetic energy and potential energy of the water in the computational domain can be obtained.

Fig.4 depicts the time series of the kinetic energy, potential energy and total energy of the double solitary waves with identical amplitude during the period of runup and rundown on a plane slope of the slope angle 30 for the cases of three different phase difference of initial linear superposition of waves. There are three peaks in the time series of the potential energy and three troughs in that of the kinetic energy. The first and third peaks of the potential energy appear at the time when the first solitary wave and second solitary wave reach the maximum runup respectively. The highest peak of the potential energy appears when the second solitary wave propagating from left to right meets the first reflected solitary wave from the beach. The kinetic energy is basically equal to zero at the head-on collision time. When the initial position of these two solitary waves separate with large distance between two peaks for cases of ε=1.0 and 0.8, the variation of the energy budge of these two solitary waves in the process of each runup are identical, which means that the influence of the first runup and rundown on the second runup can be ignored. If we look at the bottom panel of Fig. 4 for the case of ε=0.6, where the distance between two peaks is seventeen times as large as water depth, it can be seen that these two runup processes of the double solitary overlap partly and the maximum potential energy for the second runup is smaller than that of the first runup. It confirms the maximum runup of the second wave is smaller than that of the first wave.

We also found that the total energy of the double solitary waves decreases during the process of runup and rundown. Basically, the total energy decreases with time which might be induced by the turbulent dissipation because the numerical model is based on the RANS equations and VOF method.

It can be expected that, within the time window of runup and rundown process of a solitary wave on a slope, the energy loss due to turbulent dissipation is small comparing with total energy of the waves.

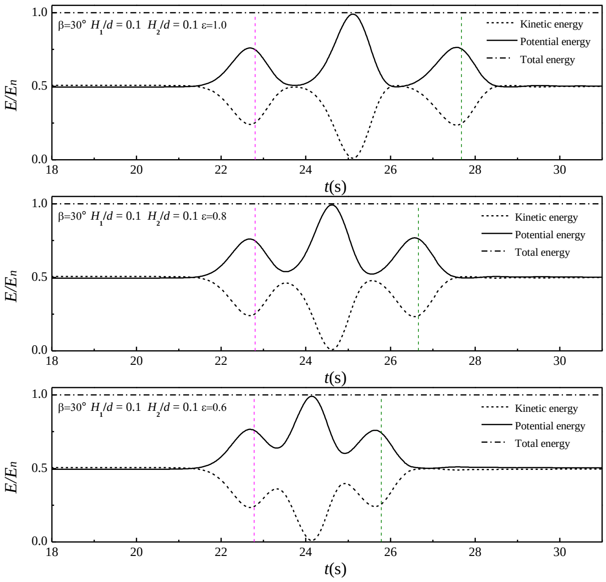

Figure 4. Time series of potential energy and kinetic energy during run-up and rundown process.

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