A UNIFIED RUNUP FORMULA FOR BREAKING SOLITARY WAVES ON A UNIFORM BEACH

Yun-Ta Wu, National University of Singapore, ceewyt@nus.edu.sg
Philip Li-Fan Liu, National University of Singapore and Cornell University, philip.liu@nus.edu.sg
Kao-Shu Hwang, National Cheng-Kung University, kshwung@mail.ncku.edu.tw
Hwung-Hweng Hwung, National Cheng-Kung University, hhhwung@mail.ncku.edu.tw

INTRODUCTION

For coastal management, it is of great importance to understand long-wave induced runup processes and predict maximum runup heights. Long-wave in nature could take different forms, such as swells, storm surges and tsunamis. One of the fundamental waveforms is solitary wave, which has a permanent form in a constant depth. Thus, the issue of solitary wave propagation, shoaling, breaking and runup has been an active research area in coastal engineering community, using experimental, numerical and analytical approaches. Among existing runup experiments, only limited numbers of experiments were conducted in large-scale wave flume facilities because of the lack of easy access. To enhance the range of surf parameters for breaking solitary waves, new laboratory experiments were carried out in a large-scale wave flume with a 1/100 slope. Several wave conditions in the experiments were on the borderline of plunging and spilling breakers. The main objective of this paper is twofold. The first aim is to present a new dataset for solitary wave runup. The second objective aims to develop a unified empirical formula, based on the available runup data in the literature and the present new data, for the runup of breaking solitary waves on a uniform slope.

NEW EXPERIMENTS

A series of new experiments was carried out in a large-scale wave flume at Tainan Hydraulics Laboratory of National Cheng-Kung University, Taiwan. The wave flume is 300 m long, 5.0 m wide and 5.2 m in depth. A programmable dry-back piston-type wavemaker, which is hydraulically driven and equipped with an active absorption system, was installed at one end of the flume. A 1 (vertical) to 100 (horizontal) plane slope (i.e., s = 1/100) was constructed with a layer of smooth concrete, ensuring that the slope surface is uniform and impermeable. Between the wave paddle and the toe of the 1/100 slope is a constant depth region. We employed wave gauges and high-resolution cameras to record the time series of free surface fluctuations as well as the wave breaking and the runup processes, respectively. The wave conditions were designed for four different water depths, i.e., 1.75 m, 1.20 m, 1.00 m and 0.80 m, and the range of wave heights were varied from 10 cm to 37 cm. Thus, the range of wave-height-to-water-depth ratio (H/h_0) covered from 0.057 to 0.412.

RESULTS

In this study, the surf parameter for solitary wave (Lo et al., 2013), which is defined as $\xi_s = s(H/h_0)^{-9/10}$, is used to unify the runup data available in the literature and the present new data. Figure 1 shows the normalized runup heights (R/H) against ξ_s^{-1}, in which the runup data were categorized in terms of slope gradients. The theoretical breaking criterion of Synolakis (1987) is also indicated in Fig. 1 to distinguish whether waves break or not. According to the definition of ξ_s^{-1}, for a fixed water depth h_0, a larger ξ_s^{-1} means either a milder slope or a higher incident wave height. The overall trend of Fig. 1 can be categorized from the transition zone of wave breaking; increasing ξ_s^{-1} will increase R/H until reaching the largest wave height of breaking threshold and, after exceeding the breaking threshold, R/H decreases with increasing ξ_s^{-1}. We note that existing runup data was available up to ξ_s^{-1} = 29.02. New experimental runup data extends existing data smoothly to the limit of ξ_s^{-1} = 45.02. Using the least-square best fit for the breaking wave data, a new empirical formula with four coefficients is deduced with the correlation coefficient R^2 = 0.9815. Thus,

$$\frac{R}{H} = \frac{4.50(\xi_s)^{1.52}}{0.04+(\xi_s)^{1.19}}. \tag{1}$$

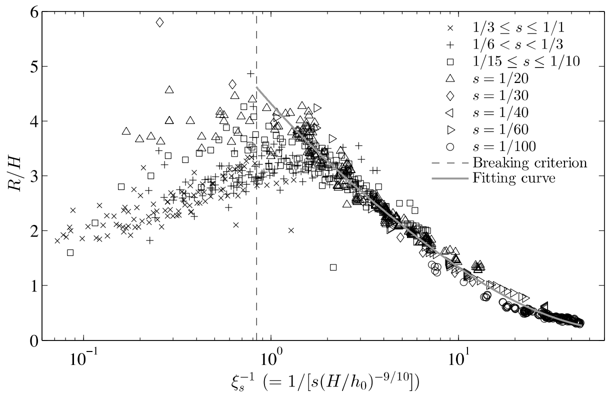

Figure 1 – Unified runup heights of solitary waves on uniform beaches

CONCLUDING REMARKS

In this study, the runup heights due to breaking solitary waves on a 1/100 slope were measured in a large-scale wave flume. The range of H/h_0 covered from 0.057 to 0.412. For the case with the largest H/h_0 value, the breaker type was on the borderline of plunging and spilling breakers. Existing runup data available in the literature were collected and discussed in detail. Using the new experimental data and the selected existing data, an empirical formula for the normalized runup, R/H, of breaking solitary waves on a uniform slope is proposed in terms of the surf parameter, $\xi_s = s(H/h_0)^{-9/10}$. This runup formula covers a wide range of slope gradient from 1/5.37 to 1/100. Moreover, the effects of slope gradients, slope materials and breaker types on the runup heights will also be discussed and presented.

REFERENCES

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