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ORIGINAL ARTICLE

Investigating the effect of wave parameters on wave runup

A.I. Diwedar

Researcher, Hydraulics Research Institute, National Water Research Center, Egypt

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Abstract The research presents the results and findings of an experimental work to investigate the influence of wave condition on the wave runup and rundown of rough armoured rubble mound breakwater. This work has been supported by the Hydraulics Research Institute (HRI). An experimental program was designed including more than 70 tests. A physical model with a scale of 1:20 was constructed in the coastal laboratory of HRI. Measuring devices were arranged, and measurements were undertaken and analyzed from which the impact of wave height, wave period so as the steepness on the resulting wave run-up so as the rundown, on rough armoured rubble mound breakwater, was recognized. The experiments were executed in the domain of dimensionless wave steepness that ranged between 0.01 and 0.07 while the measured dimensionless run-up varied between 1.26 and 2.24. The results were used to validate selected existing equations. Based on the results, it was clear that the wave steepness has a great effect on the run-up.

1. Introduction

Wave runup is defined as the distance between the mean sea level and the highest point of wave crest that touches the structure. Wave rundown is the vertical lower level reached by backwash of a wave on a coastal structure. The wave runup level is one of the most important factors affecting the design of coastal structures such as dikes, revetments, and breakwaters ([1–3]). Wave runup is one of the main physical processes which are taken into account in the design of the crest level of sloping coastal structures.

Information about runup is used to predict the damage that can happen to the inner structure slope. Wave runup is affected by the geometrical and structural characteristics as structure side slope, the surface roughness, the permeability and porosity of the slope. Hydraulic parameters also affect the runup value, as wave steepness, wave height and the angle of wave attack, oblique waves produce less runup rather than perpendicular waves. The relative wave runup decreases with increasing wave steepness especially in smooth and rough impermeable models according to Shankar and Jayaratne [4].

The most widely used method to predict the wave runup is the regression method (RM) developed by Van der Meer et al. [3], used to predict runup on rock armoured breakwater. This empirical model is also recommended by different manuals and guidelines in coastal engineering such as USACE [2].

Wave runup phenomenon was studied extensively in the past by Allsop et al. [5], Saville [6]. Recent summary works include Dentale et al. [7], De Walle [8], EurOtop [9], Juhl and Sloth [10], Kobayashi [11], Koraim et al. [12], Rasmeemasmuang et al. [13], Stockdon et al. [14], and De Waal et al. [15].

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Nomenclature

Notations

T_p	peak period (s)
H_s	significant wave height (m)
F_r	Froude number (–)
V	mean velocity of the flow (m/s)
g	gravity acceleration (m/s^2)
h	local water depth (m)
ξ_{0m}	surf similarity parameter based on mean wave period (–)
H_i	incident wave height (at toe of structure) (m)
H_{m0}	spectral significant wave height at the toe of structure based on the mean irregular wave period T_m (m)
L_0	deep water wavelength (m)
L_{m0}	deep water wavelength based on the mean irregular wave period T_m (m)
H_{m0}/L_{m0}	wave steepness (–)
R_u	wave runup (m)
R_d	wave rundown (m)
$R_{u2\%}$	runup level exceeded by 2% of the incident waves (m)
R_u/H_{m0}	dimensionless wave runup (–)
R_d/H_{m0}	dimensionless wave rundown (–)
θ	breakwater slope (degrees)

Most of these studies were focusing on wave runup on smooth and impermeable and less work was focusing on rough and permeable structures.

De Rouck et al. [16] stated that preliminary prototype measuring campaigns (1993–1996) indicated clearly higher wave runup values than the values found by laboratory testing and reported in the literature. The uncertainties in empirical formulas inevitably increase the factor of safety and the construction costs ([17]). Therefore, recently, more studies have been carried out to develop more accurate models for wave runup calculation. Erdik et al. [18] proposed a new runup model using TAKAGI–SUGENO Fuzzy approach for predicting the wave runup. An improvement of the prediction accuracy of wave runup on rubble-mound using Artificial Neural Network (ANN) method was proposed by Erdik et al. [19].

Predictions of wave action on slopes, and various wave and water depth induced processes in the surf zone rely on two principal parameters: wave steepness and surf parameter ([20]). Wave steepness has great effects on the wave runup; SubbaRao et al. [21] argued that wave steepness is inversely proportional to wave runup. Shankar and Jayaratne [4] argued that wave steepness proves to be a good parameter for describing the combined effect of wave height and period on wave runup.

According to Battjes [22], surf similarity parameter is also an important parameter in determining the runup and it is calculated using the following equation:

$$\xi_0 \frac{\tan\theta}{\sqrt{\frac{H_i}{L_0}}} \tag{1}$$

where:

ξ_0: surf similarity (–)
θ: angle of structure front slope to the horizontal (breakwater slope) (degrees)
H_i: incident wave height at the structure (m)
L_0: wavelength in the deep water (m)

The runup level could be reduced by using berm structure, permeable and rough structure slope. Steep structure slope produces high runup level due to the surging waves. Van der Meer et al. [3] evaluated the effects of various structural and hydraulic parameters on wave runup using a large number of laboratory tests. They analyzed the effect of the permeability, the slope angle, the spectral shape, significant wave height and mean wave period separately. They concluded that the most significant factors influencing runup phenomenon on rock armoured slopes, are the permeability of the structure and the surf similarity parameter.

2. Objectives

Different parameters affect the wave runup and rundown, some are related to structure characteristics and others are due to wave conditions. Therefore this research was initiated with the following objectives:

- Determining the effect of wave run-up on the rough armoured rubble mound breakwater.
- Analyzing the relation of run-up to the wave conditions in terms of steepness, surf similarity and the wave heights.
- Using the experimental results to develop a design methodology to give more accurate forms.

3. Methods

In order to achieve the above objectives, a methodology was designed. A physical model tool was used in this study as the physical model is a helpful tool to get in-depth understanding of the phenomena and the interaction between the structure and the waves and to investigate the influence of wave condition on the wave run-up and rundown on rough armoured rubble mound breakwater. The experimental program was designed that included more than 70 tests. A physical model with a scale of 1:20 was constructed, measuring devices were arranged, and measurements were undertaken and analyzed from which the impact of wave height, wave period so as the steepness on the resulting wave run-up, was recognized.

3.1. Model scale

Geometrical scale of 1:20 is selected for the present investigation, where Froude scaling technique is adopted for physical