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Predicting the wave overtopping rate at berm breakwaters

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ABSTRACT

In this paper, new formulae are presented to estimate the wave overtopping rate of mass-armoured berm breakwaters. In addition to the effects of dimensionless crest freeboard and crest width, the formulae consider the influences of water depth at the toe of the structure and structure slope on the overtopping rate through simple dimensionless parameters. The performances of the new formulae were then compared with those of the existing empirical prediction formulae. Statistical indicators such as Root Mean Square Error (RMSE) showed that the new formulae are better predictors than the existing ones.

KEY WORDS: Wave overtopping; mass-armoured berm breakwater; empirical formulae.

INTRODUCTION

Breakwaters are built to protect coastal region from wave action and consequently flooding and erosion (Lara et al., 2008). Safety in a harbour can depend on the wave overtopping rate at breakwaters and therefore their appropriate design is critical (Van der Meer and Bruce, 2014). The mean wave overtopping must be less than the allowable rate under the design and operating conditions to ensure the safety of people, land and property behind the breakwater (Goda, 2009). Additionally, Zviely et al. (2015) reported that excessive wave overtopping can lead to extensive damage in port infrastructure and moored vessels. Thus a reliable estimation of wave overtopping rate is essential to reduce the risk associated with the failure of the breakwaters.

In recent decades several methods have been put forward to predict the wave overtopping rate, with empirical prediction formulae being the most commonly used. The formulae were developed by fitting dimensionless parameters to physical model test data (e.g. Jafari and Etemad-Shahidi, 2012). The most widely used empirical formulae to estimate the overtopping rate at berm breakwaters are those of Van der Meer and Janssen (1994), Lykke Andersen (2006) and EurOtop (2007). With the advent of increased computing power, soft computing techniques have been used also to estimate the overtopping rate (e.g. Etemad-Shahidi et al., 2016; Etemad-Shahidi and Jafari, 2014; Victor and Troch, 2012; Verhaeghe et al., 2008; Van Gent et al., 2007). Artificial Neural Network (ANN) models provide a universal method of prediction of wave overtopping at a wide range of coastal structures. However, they are not as transparent as the empirical formulae and provide less insight into the wave overtopping process.

The aim of this study was to develop simple and accurate prediction formulae to estimate the wave overtopping rate of mass-armoured berm breakwaters. The mass-armoured berm breakwaters can be classified into Hardly Reshaping (HR), Partly Reshaping (PR) and Fully Reshaping (FR) based on their reshaping behaviour (Sigurdarson and Van der Meer, 2012). The data obtained from the physical model tests of Lykke Andersen (2006) and Bãtãcui and Ciocan (2013) were utilized to develop the formulae. The formulae take into account the differences in the overtopping rates from the HR/PR and the FR cross sections. In addition to the effects of the variables such as crest level and crest width, the formulae also take into account the influences of berm width, berm level, water depth at the toe, structure slope and wave steepness on the overtopping rate.

SELECTION OF DATA

To examine the behaviors of wave overtopping on berm breakwaters a total of 487 small scale data points with measured overtopping rates (q) > 10^{-6} $m^3/m/s$ were selected from the experiments of Lykke Andersen (2006) and Bãtãcui and Ciocan (2013). The Lykke Andersen (2006) data represented mass-armoured berm breakwaters, which encompassed the stability conditions from hardly reshaping to fully reshaping. The stability number of the tested cross sections H_0, varied from 0.96 (HR) to 4.86 (FR) where H_0 is defined as:

$$H_0 = \frac{H_{m0}}{\Delta D_{n50}} \tag{1}$$

Here, H_{m0} is the significant wave height, Δ is the relative reduced mass density given as:

$$\Delta = \frac{\rho_s}{\rho_w} - 1 \tag{2}$$

where ρ_s and ρ_w are the mass densities of stone material and water, respectively. D_{n50} is the median diameter of armour. Overtopping was