EXTENDING THE H&R WAVE OVERTOPPING MODEL TO VERTICAL STRUCTURES

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1. Introduction

Since 1998, Royal HaskoningDHV (RHDHV) has been developing coastal flood forecasting and warning systems in the UK for the Environment Agency (EA) and the Scottish Environment Protection Agency (SEPA) and in the Republic of Ireland for Dublin City Council (DCC). The latest development was the new Firths of Forth and Tay coastal flood warning system for SEPA, which has been in operation since November 2012. These systems aim to give those at risk valuable time to protect their families, homes and businesses, by providing advance warning of flooding.

In developing all systems, RHDHV has analysed the suitability of several methodologies/tools for predicting wave overtopping (Lane et al., 2008; Naysmith et al., 2013), such as the AMAZON numerical model (Hu, 2000; Reis et al., 2011), empirical formulae from the EA Manual (Besley, 1999) and the EurOtop Manual (Pullen et al., 2007) and the H&R semiempirical model (Hedges & Reis, 1998, 2004; Reis et al., 2008). The H&R overtopping model, designed especially to predict low wave overtopping rates, proved to be the most robust and reliable, since AMAZON was not as efficient, resulting in higher development costs, and the other empirical methodologies significantly overpredicted low overtopping rates. Overprediction would lead to false warnings being issued and result in a warning system that the public would soon distrust. AMAZON was chosen only for more complicated defence/beach profiles.

Since the H&R model was found to suit the nature of flood forecasting practice, it was recommended by RHDHV to extend this model to vertical structures, not included in its calibration and validation. This paper will describe the first results of this extension and the further developments planned.

2. The H&R Model

Hedges & Reis (1998) introduced a semiempirical model (the H&R model) based on an overtopping theory for regular waves developed by Kikkawa et al. (1968), who had assumed that a seawall acted as a weir whenever the incident water level exceeded the seawall crest level and that the instantaneous discharge was described by the weir formula. The H&R model extended the concept to random waves. It can be written as follows:

$$\begin{cases} Q = A\sqrt{gR_{max}^{3}}\left[1-\dfrac{R_c}{\gamma_r R_{max}}\right]^{B} & \text{for } 0 \le \left[\dfrac{R_c}{\gamma_r R_{max}}\right] < 1 \\ Q = 0 & \text{for } \left[\dfrac{R_c}{\gamma_r R_{max}}\right] \ge 1 \end{cases} \quad (1)$$

where Q is the mean wave overtopping discharge per unit length of seawall, A and B are empirical coefficients, g is the gravitational acceleration, R_{max} is the maximum run-up on a smooth slope induced by the random waves during a storm, γ_r is the reduction factor to account for slope roughness/permeability, and R_c is the seawall freeboard. The precise value of R_{max} during any particular storm cannot be known *a priori*: an estimate of its value has to be made. Unless $R_{max}>R_c/\gamma_r$, there is no overtopping apart from wind-blown spray.

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Coefficients A and B have been evaluated using the results of hydraulic model tests. Hedges & Reis (1998) originally used Owen's data for that purpose (Owen, 1980). More recently, Mase et al. (2003) modified and extended the H&R model to account for Japanese data on run-up and overtopping, which covered front slopes as shallow as 1:20. Furthermore, new estimations of R_{max} can be found in Mase et al. (2003). The new equations for A and B have subsequently been validated with the data of Hawkes et al. (1998) for uniform seaward slopes of 1:2 and 1:4 and the SHADOW data (Bay et al., 2004) for relatively high discharges over slopes of 1:2, 1:10 and 1:15. The range of conditions covered by the calibration and validation tests can be found in Reis et al. (2008).

3. Extension to Vertical Structures

Extending the H&R overtopping model to vertical structures is planned to encompass:

1. A thorough review of the data for vertical and steep slopes in the CLASH database (Steendam et al., 2004) to check if there are sufficient data for both calibration and validation of the model;
2. A reflection on any additional wave conditions and/or structure geometries, beyond those already in the CLASH database, which might need testing;
3. Composite (numerical and physical) modeling of additional wave conditions and structure geometries.

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