A Proposed Approach for Two-dimensional Run-up Modeling

Jeffrey A. Oskamp and Ahmed “Jemie” A. Dababneh
RIZZO Associates
Pittsburgh, Pennsylvania, USA

ABSTRACT

A method was developed to combine the application of empirical run-up equations with two-dimensional hydrodynamic modelling to characterize inundation of waves. A synthetic wave field is developed for input to the hydrodynamic model. The height of the synthetic wave field is calibrated to ensure that the run-up height in the model matches the run-up height indicated by an empirical run-up equation for specified design incident wave conditions. The calibrated synthetic wave field is used as the input to a detailed model that simulates inundation around structures. The model output can provide information about inundation depths and velocities, which support a detailed evaluation of loadings exerted on inundated structures.

KEY WORDS: Waves; Inundation; Run-up; Modeling; Coastal; Two-dimensional.

INTRODUCTION

As computer technology advances, new methods are becoming available to solve hydrodynamic problems in nearshore areas. However, even though it is now possible to simulate wave propagation in the surf zone with a significant degree of accuracy, such simulations remain computationally intensive.

State-of-the-art modelling software for characterizing nearshore wave dynamics is typically based on Boussinesq-type equations, e.g., FUNWAVE-TVS (Tehranirad et al., 2011). Recently, a somewhat less computationally intense method has been proposed based on an extension of the Non-Linear Shallow Water (NLSW) equations (Zijlema and Stelling, 2008). The NLSW equations are commonly used for many over-land flow flooding applications, including tsunami inundation analysis (Zijlema et al., 2011). The inclusion of the non-hydrostatic pressure term in the NLSW equations provides increased accuracy necessary for simulating waves in the surf zone (Zijlema et al., 2008; Smit et al., 2013). However, the computational burden of a non-hydrostatic NLSW equation model remains significantly higher than a hydrostatic NLSW equation model (approximately three times higher for cases considered in this study).

This paper proposes a less computationally intensive method for characterizing wave run-up effects by applying the NLSW equations and neglecting non-hydrostatic pressure. This paper suggests that reasonable results for run-up inundation may be obtained using the hydrostatic NLSW equations as long as the model is calibrated to account for processes that are not captured in the model.

This method provides a more detailed understanding of wave run-up than the traditional empirical wave run-up equations (e.g., Mase [1989], Van der Meer and Stam [1992], van Gent [2001], and Stockdon et al. [2006]), allowing for determination of wave run-up inundation extents behind structures and the associated hydrodynamic and hydrostatic forces.

The proposed method involves a synthesis of numerical hydrodynamic modelling with traditional coastal engineering wave run-up equations. A hydrostatic NLSW equation model (which, as discussed above, accounts for some, but not all of the physical processes present in the nearshore zone) is coupled with run-up heights estimated from empirical run-up equations. The empirically based run-up heights can be used to calibrate the hydrostatic NLSW equation model to compensate for the effect of physical processes not fully characterized.

This paper outlines a methodology for two-dimensional wave run-up analysis that is…

- More informative than empirical run-up equations, particularly with the ability to provide information about inundation extents behind buildings/structures and velocities near structures to compute hydrodynamic forces;
- Less computationally intensive than existing Boussinesq and non-hydrostatic NLSW equation models; and
- Less expensive than physical modelling.

As a validation, inundation results from this proposed method (for a scenario involving wave inundation around a structure) are compared with results from a non-hydrostatic NLSW equation model. To facilitate comparison between the hydrostatic NLSW equation model and the non-hydrostatic NLSW equation model, the SWASH model (Simulating WAves till SHore [Zijlema et al., 2011]) is used for both halves of the comparison. The SWASH model is a NLSW-equation-based model with the capability of switching on and off the non-