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Numerical and Physical Modelling of Wave Overtopping Over a Porous Breakwater

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ABSTRACT

This paper illustrates the application of the non-linear shallow-water numerical model, AMAZON, to study the mean wave overtopping discharge at a porous breakwater protecting a Portuguese harbour. The results are compared to physical model data collected at the National Civil Engineering Laboratory, Portugal. The implications are considered of using two different inputs immediately seaward of the structure: firstly, AMAZON input is the incident wave trains obtained from the laboratory tests; secondly, AMAZON input is the incident wave trains obtained using a numerical model to transform the spectra conditions at the wave-maker in the physical model tests to AMAZON's seaward boundary.

KEY WORDS: Rubble-mound breakwater; mean overtopping discharge; AMAZON non-linear shallow-water numerical model; model tests.

INTRODUCTION

At present, the most-widely used tools for predicting wave overtopping of coastal structures are wholly empirical/semi-empirical formulae based on physical model tests (e.g. Besley, 1999; Hedges and Reis, 2004; Pullen *et al.*, 2007). Physical model tests remain the most reliable method for determining overtopping. They are used for prototype case studies, as well as providing data for the development, calibration and validation of the other prediction methods. The use of artificial neural networks is also proving to be a promising way forward (Wedge *et al.*, 2005; Coeveld *et al.*, 2005).

In recent years, due to the continuous increase in computer power, numerical models of overtopping have been developed and their use is becoming increasingly attractive (Ingram *et al.*, 2004; Lara *et al.*, 2006; Shao *et al.*, 2006). They can provide coastal engineers with wave run-up and overtopping predictions without the time and cost associated with physical experiments and field observations. The numerical models include those based on the non-linear shallow-water (NLSW) equations. These models, in spite of their limitations (mainly relating to the shallow water assumptions and the fact that they do not explicitly account for porous flow) are already being used for the purposes of design and flood forecasting, since trains of several thousand random waves are simulated rapidly. One example of NLSW models is AMAZON (Hu and Meyer, 2005), which has been validated and extensively used to study the overtopping of dikes.

In the present work, the NLSW model AMAZON is applied, together with physical model tests, to study the overtopping of a porous breakwater protecting a Portuguese harbour. In connection with plans to repair the breakwater, wave overtopping of the proposed cross-sections is analysed. Firstly, the physical model results are used to check AMAZON's applicability to porous structures. Secondly, a comparison is made between the AMAZON results calculated using incident wave trains obtained: i) from the physical model tests, at the location of AMAZON's seaward boundary; and ii) by transforming to the location of AMAZON's seaward boundary the spectra adopted at the wave-maker in the physical model tests. The latter procedure was chosen since this is the expected procedure in engineering applications, for which available data are usually the wave climate offshore. The evaluation of the input spectra obtained from the two different approaches is also presented.

Following this introduction, the paper starts by a brief description of AMAZON. Then the case study is presented along with the physical model tests carried out at the National Civil Engineering Laboratory (LNEC), Portugal. Next, the AMAZON results are shown, compared to the physical model data and discussed. Finally, conclusions are drawn and suggestions are made for future developments of AMAZON.

THE NUMERICAL MODEL AMAZON

AMAZON was developed at Manchester Metropolitan University (Hu, 2000). It is based on solving the non-linear shallow-water (NLSW) equations, which are a simplification of the Reynolds equations by depth integration. The equations are solved using a high-resolution finite volume method that is second-order in time and space. The MUSCL-Hancock scheme (van Leer, 1979; van Albada *et al.*, 1982) employed is a Godunov-type method that uses a monotonic reconstruction of the conserved variables to obtain values at cell interfaces that prevent spurious oscillations in the solution. Solutions to