

Numerical analysis of wave transformation over low-crested impermeable breakwater

Zhong Peng and Qingping Zou

Centre for Coastal Dynamics and Engineering, School of Engineering, University of Plymouth
Plymouth, Devon, UK

ABSTRACT

In this paper, a VOF-type model based on 2D Reynolds-Average-Navier-Stokes equations was applied to investigate irregular waves transformation over low-crested impermeable breakwater. The model considers wave reflection, transmission, breaking, and turbulence generation. Three different water depths were tested in order to examine the influence of the breakwater freeboard. The predicted surface elevations are compared with laboratory data set collected during DELOS project. Generated waves through an internal wavemaker are in a good agreement with measurements at the incident side. The measured surface elevation at the transmission side is reproduced well for submerged breakwater, but underestimated slightly by the numerical model for both zero freeboard case and emerged case. This numerical model reproduces the transformation of wave spectrum over the breakwater well. The predicted wave skewness and asymmetry at the transmission side are in a good agreement with measurements and empirical equations. The transformations of wave skewness and asymmetry over low-crested impermeable breakwater are also investigated.

KEY WORDS: Low-Crested Breakwater; skewness; asymmetry; VOF; RANS; transformation.

INTRODUCTION

A Low-Crested Breakwater (LCB) provides a number of advantages with respect to conventional structures, for example, uninterrupted views of the sea from the beach with low-crests. Improved understanding of waves interaction with LCB is crucial to the assessment of the functionality and stability of this type of defence scheme.

The complexity involved in the wave interaction with LCB has led a great majority of investigators to resort to laboratory experiments, which focus on the prediction of wave transmission, reflection and energy spectrum evolution (d'Angremond et al., 1996; Van der Meer et al., 2005). On the other hand, Lin and Liu (1998) and Liu et al. (1999) proposed a model based on the complete Navier-Stokes equations and the Volume of Fluid (VOF) method (hereinafter RANS-VOF model), which allowed the calculation of the velocity field in the whole computational domain of average free surface flow. Hsu et al. (2002) improved the RANS-VOF model using volume average method (hereinafter VARANS-VOF model) for permeable breakwaters. Garcia

et al. (2004b) examined the near-field flow at low-crested permeable breakwaters under regular wave attack. The VARANS-VOF model is proven to reproduce the interaction of monochromatic waves with LCB for different incident wave conditions and structural properties. Garcia et al. (2004a) applied this model to a near-prototype scale submerged permeable LCB and achieved a satisfactory level of agreement with measurements. Lara et al. (2006) demonstrated the capability of Volume average RANS-VOF model to reproduce irregular waves interaction with submerged permeable LCB for both the small scale and large scale set-ups. Results show that wave transmission over LCB will induce a reduction of the total wave energy, but a redistribution of the remaining energy from the low frequencies to high frequencies. However, the irregular waves were generated using the parameters of a given target spectrum as input data, without a direct comparison of surface elevation data with measurements. Wave asymmetries at both sides were not investigated. In the present paper, the RANS-VOF model will be used to investigate wave transformations over an impermeable LCB by reproducing measured time series of the first gauge at the incident side. The influence of three types of structure freeboards is examined. Laboratory data sets of oblique wave transmission over LCB collected in the DELOS project (the European Union project: Environmental Design of LOW-crested coastal defence Structures) are used to verify the numerical results of wave transformation.

EXPERIMENTS

Three-dimensional wave transmission tests were conducted in the multidirectional wave basin (18.0 m × 12.0 m × 1.0 m) during the DELOS project at Aalborg University, Denmark. Detailed descriptions about this project can be found in Kramer et al. (2005) and Wang (2003) and DELOS website (<http://www.delos.unibo.it/>).

The data sets were measured from ten fixed gauges. Five of them (gauge 1 to 5) were located at the incident side near the wave generator and the other five gauges (gauge 6 to 10) were located at the transmission side near the artificial beach. In the current study, since the model can only simulate 2D waves and flows, only six gauges were used. Their locations were at 1.54m, 1.94m, 2.1m, 5.88m, 6.28m and 6.44m from the wavemaker (see sketch in Fig. 1). Each record was sampled at 40Hz and is 90-second long. The impermeable LCB model (0.3m height) was tested for three different freeboards (-0.05m, 0m and 0.05m) or three different water depths (0.25m, 0.3m and 0.35m). The total number of different irregular wave conditions was 20 for normal and 64 for oblique incident waves to LCB. The focus here is only on the