WAVE TRANSMISSION OVER LOW-CRESTED POROUS BREAKWATERS

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INTRODUCTION

Low-crested (LC) rubble mound breakwaters are used for coastal protection. The main advantage of these structures is their mild aesthetic impact on the natural environment. As the waves approach and transmit over these structures, significant hydrodynamic processes occur in their proximal area, such as wave breaking, wave reflection, wave overtopping and transmission (Garcia et al., 2004). Many researchers have studied the hydrodynamics of flow in the vicinity of such structures, as well as the influence of their geometrical characteristics on the flow field. However, in most studies, the structures are either emerged or submerged, while the case in which the crest level of the breakwaters is at the still water level (SWL) has to be further investigated.

METHODOLOGY

In the present study, the 2D-vertical flow over three layouts of zero-free-board (ZFB) breakwaters, with their crest level at the SWL, was simulated by means of a Navier-Stokes solver. The breakwater geometry, the sea bed and the free surface were interfaces immersed in the numerical grid. The implementation of the boundary conditions was based on the Immersed Boundary method (Balaras, 2004). A two-phase flow approach was considered and the level set method was used to track the free-surface evolution.

RESULTS

The numerical model was validated for three cases. The first case corresponds to wave propagation and breaking over a constant slope beach of 1/35. In Fig. 1, the numerical results for the vertical distribution of the undertow current at two positions inside the surf zone are compared with the corresponding profiles obtained from the experiments in Ting and Kirby (1994). It is observed that the undertow current is captured adequately.

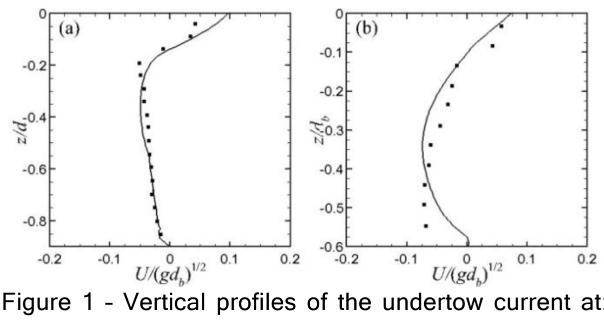


Figure 1 - Vertical profiles of the undertow current at: (a) h/h_b = 0.965 and (b) h/h_b = 0.668, where $h = d + \overline{\eta}$ is the water depth, d is the SWL water depth, $\overline{\eta}$ is the wave setup, and h_b refers to breaking. The lines correspond to the numerical results while the symbols to the experiments in Ting and Kirby (1994).

Regarding the second case, which refers to wave propagation over a submerged trapezoidal bar, comparisons of the free-surface elevation between the numerical results and the experimental data in Beji & Battjes (1994) at five locations over the bar during five wave periods are presented in Fig. 2. A good agreement is demonstrated.

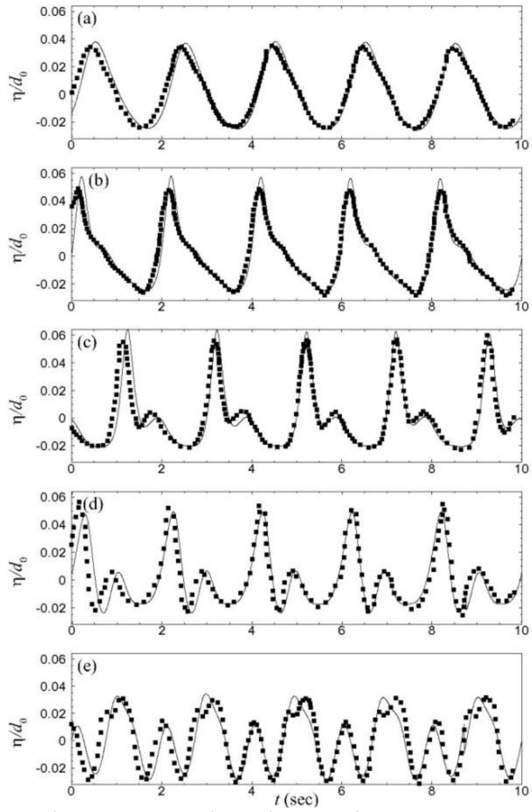


Figure 2 - Variation of the free-surface elevation during five wave periods at five locations over a submerged bar. These five locations correspond to the stations 2, 3, 4, 5, and 6 of the experimental work in Beji & Battjes (1994). The lines correspond to the numerical results while the symbols to the experiments.

The last case refers to wave propagation and breaking over a wide-crested submerged porous structure Snapshots of the free surface elevation during 2 wave periods, after 20 wave periods of simulation, are shown in Fig. 3, and in comparison to the experimental data of crest and trough elevations in Garcia et al. (2004). The numerical model captures adequately the main characteristics of wave propagation over the submerged breakwater.

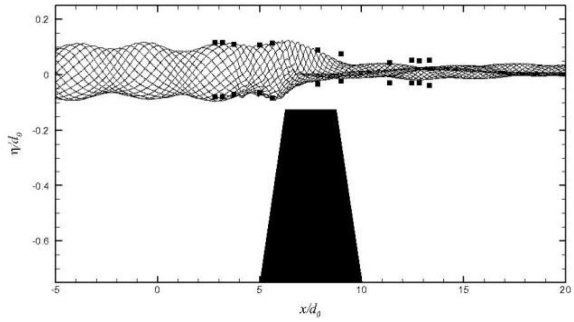
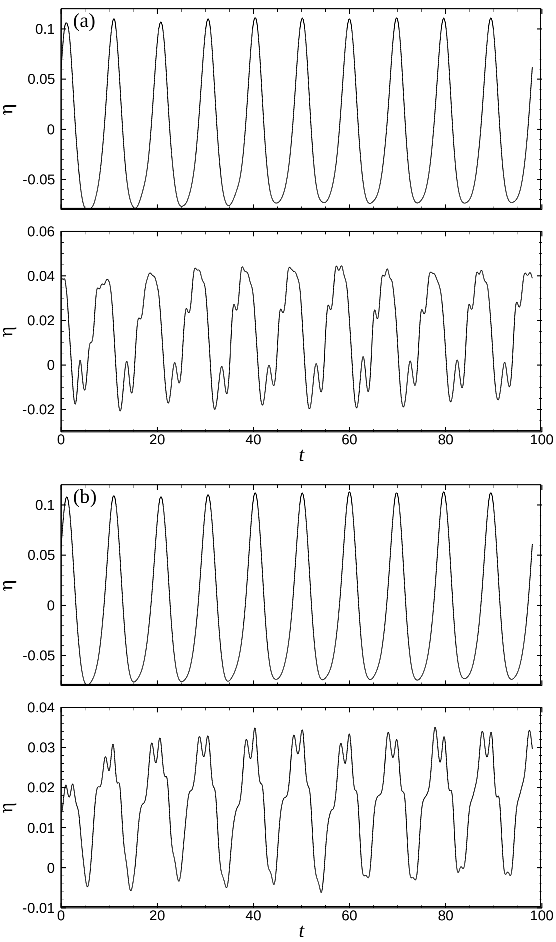


Figure 3 - Envelope of the free-surface elevation of waves passing over a submerged porous structure. Symbols correspond to the experiments in Garcia et al. (2004).

For the ZFB breakwaters of the present study, three different layouts were examined in order to reveal the effect of crest width on the hydrodynamics of wave reflection and transmission, as well as the flow behavior in the vicinity of the crest of these structures. In all cases, the structures were modeled as porous media (Liu et al., 1999), while the slopes were equal to 1/2 at both the seaward and the leeward sides. The crest width was set equal to d, $2d$ and $3d$, respectively, where d is the SWL depth at the breakwater seaward toe. The incident wave characteristics were H/d = 0.2, $T\sqrt{(g/d)}$ = 9.8 and λ/d = 9. The Reynolds number based on d was Re = 8×10^5. The results of the numerical model, which include free-surface elevation, reflection and transmission coefficients, velocity and vorticity fields and undertow current distribution, reveal the effect of the structure crest geometry on the flow and wave pattern. In Fig. 4, the free-surface elevation during ten wave periods for the three different layouts at two locations is illustrated. The first location is upstream of the breakwater while the second location is at the leeward toe of the breakwater. It is observed that less energy is transmitted to the leeside of the breakwater as the crest width increases. In addition, it is worth mentioning that for the cases with crest width equal to d and $2d$ (Fig. 4a and Fig. 4b, respectively), nonlinear phenomena are profound in the leeward side of the structure. In Table 1 transmission and reflection coefficients for the three different setups are presented. It is indicated that the transmission coefficient decreases linearly with the crest width.



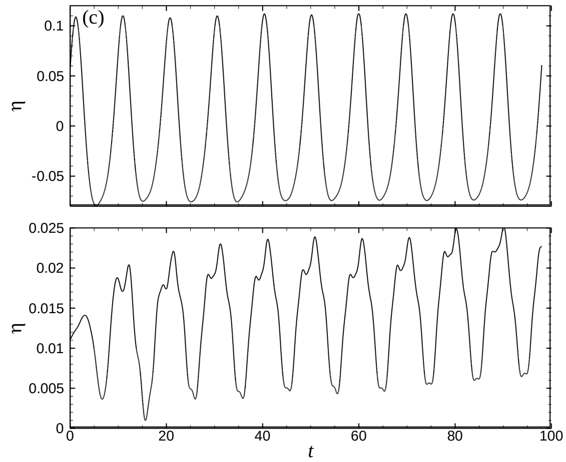


Figure 4 - Variations of the free surface elevation during twelve wave periods for the three different setups of the LC breakwaters: (a) d, (b) $2d$, and (c) $3d$, at two different locations: the seaward side of the breakwater (up) and the leeward toe (down).

Table 1. Reflection and transmission coefficients for the three cases of ZFB breakwaters.

Case	Crest Width	Reflection Coefficient	Transmission Coefficient
a	d	0.171	0.416
b	$2d$	0.167	0.238
c	$3d$	0.167	0.127

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