On the effectiveness of Oscillating Water Column devices in reducing the agitation in front of vertical walls harbour structures

ON THE EFFECTIVENESS OF OSCILLATING WATER COLUMN DEVICES IN REDUCING THE AGITATION IN FRONT OF VERTICAL WALLS HARBOR STRUCTURES

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INTRODUCTION AND MOTIVATIONS

Wave reflection at harbor structures negatively affects the navigability of entrance canals and harbor tranquility. In case of rubble-mound structures this phenomenon is relatively limited if compared to vertical-wall structures. However, in case of deep waters, the use of the latter is an obliged choice due to economic reasons. Furthermore, vertical wall structures are also the preferred choice of harbor managers since they permit a better design of the berthing structures and help the effective use of space inside the harbor.
Reducing the wave reflection at vertical wall structures is thus an important measure. To date, several approaches have been presented in the literature (see for instance Huang et al., 2011, and references therein).
The effectiveness of slotted vertical perforated-walls has been studied since many years (most recently: Neelamani et al., 2017). Such kind of structure is often also adopted as frontal and internal wall of caisson breakwaters embodying one or multiple chambers (most recently: Ciocan et al., 2017).
Another alternative, so far proposed, are caissons with internal rubble mound (Altomare, C., & Gironella, X., 2014).
The so called Oscillating Water Column (OWC) concept, commonly investigated as wave energy converter (Falcão, 2010), can also represent a viable alternative to absorb the incident energy thus decreasing its reflection. However, the studies that investigate its effectiveness as anti-reflection device are quite limited (Liu and Geng, 2012, He and Huang 2016).
This work aims to contribute to the present knowledge on the effectiveness of an OWC, embodied in quay walls or harbor breakwaters, as an alternative to reduce the wave reflection at vertical wall structures.

OBJECTIVE

The objective of this work is to study the wave field in front of the OWC device and its sensitivity to the variation of the design parameters, highlighting the contribution of reflected and radiated waves.

METHODOLOGY

The work is conducted by means of Computational Fluid Dynamics (CFD) numerical modeling. The OpenFOAM® open source software package is used. A two phases, water and air, Volume of Fluid (VOF) solver and the wave generation model *waves2Foam* are used to implement a Numerical Wave Tank (NWT). The numerical results are in good agreement with the experimental data (Fig. 1).
The sensitivity to the variation of the principal design parameters is investigated, namely: i) frontal wall lip draught, ii) chamber length (along wave propagation direction), iii) pressure drop caused by the streaming of air through the orifice connecting the internal air chamber to the atmosphere. Regular wave conditions of different frequencies and wave height are tested. In particular, the possible installation of the anti-reflection OWC device on a 3-9m water depth is considered, and its effectiveness in absorbing waves having period T between 2-5s and height H between 0.1-0.7m is analyzed.

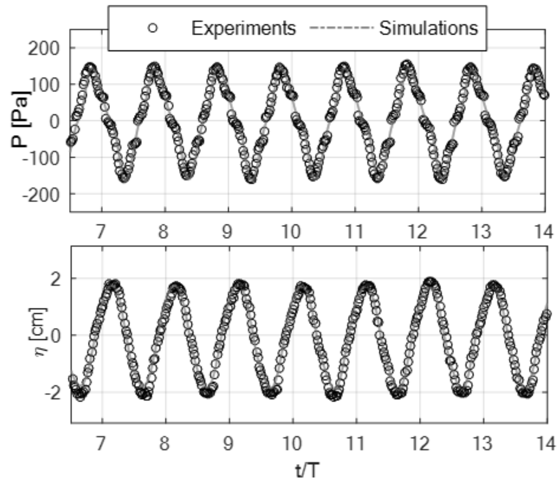

Figure 1 - Comparison between experiments and CFD simulations of air pressure (P) and water level (η) inside the OWC for an incident wave period T=3s and height H=36cm on a water depth h=4.5m (quantities in the plot are related to the physical model scale, 1:9).

CONCLUDING REMARKS

Preliminary results show that the OWC device could be efficiently applied as a measure to reduce harbor agitation (Fig. 2).

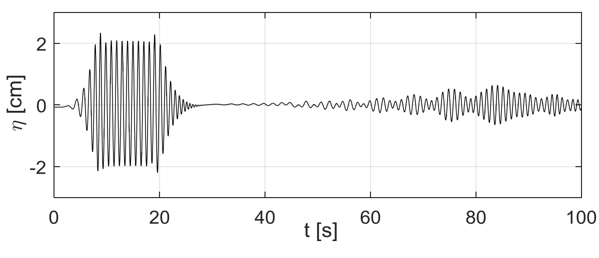

Figure 2 - Results of CFD simulations: incident and reflected waves at a wave gauge located in front of the OWC for an incident wave period T=3s and height H=36cm (quantities in the plots are related to the physical model scale, 1:9).

In general, the total amount of wave energy in front of the OWC (that is the sum of reflected and radiated field) is, as expected, strongly related to the absorbed energy. The magnitude of the radiated waves increases as the oscillation of the water column increases, while the reflected component decreases. Moreover, the effective external wave field is also affected by the phase difference between wave components.

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