WAVE FORCES ACTING ON VERTICAL STRUCTURES WITH RETREATED WALL: NUMERICAL MODELLING WITH OPENFOAM®

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INTRODUCTION

Composite vertical breakwaters are monolithic structures which are mainly used to protect harbor basins, especially in relatively deep-water conditions. Currently, design criteria of composite vertical breakwaters are mainly based on the Goda's formulae (Goda, 2010), including impulsive breaking conditions proposed by Takahashi (1996). More recently, Oumeraci et al. (2001) has provided guidelines for the design of composite vertical breakwaters and seawalls under breaking and non-breaking conditions within the framework of PROVERBS (PRObabilistic design tools for VERtical BreakwaterS); these guidelines also include methods to estimate wave impact magnitude and duration on vertical breakwaters.
Given the considerable size of such structures, whose height is often on the order of tens of meters, it is of strong interest to study solutions and configurations that allow to reduce the magnitude of wave loads. Even a relatively small local reduction of wave-induced pressures acting on the structure can provide significant advantages and benefits in terms of reduction of forces. The engineering optimization of vertical breakwaters requires a deep understanding of the processes involved in the wave-structure interaction, whose physics is rather simple. Even tough vertical breakwaters are relatively common structures, which have been widely used in the last decades, further research is needed to achieve the objective of an effective optimization.
One possible solution often used to attempt reducing wave loads and overtopping is the retreated crown wall. In this configuration, the crown or wave wall is translated backwards, away from the seaside edge of the caisson. An example of this solution is represented in Figure 7.1 of the EurOtop manual (EurOtop, 2007), depicting the Civitavecchia vertical breakwater (Italy). The aim of this structural modification lies in obtaining two main effects: I) the time shifting between the trunk and wall forces, i.e., the peak loads on these two elements occur at different time instants; II) the modification of pulsating nature of the wave-structure interaction hydrodynamics. In fact, the retreated wall configuration introduces extra turbulent dissipations that would contribute to wave overtopping reduction.
It is worth to highlight that there no exist specific criteria, nor guidelines, for the design of vertical breakwaters with retreated wall. Indeed, the design of such structures is currently performed mostly on the basis of experimental and numerical studies that aim at investigating wave actions and the hydraulic performance of the breakwater. Recently, Romano & Bellotti (2023) provided a first experimental insight into the increase/reduction of wave loads on vertical breakwaters with retreated crown walls placed in relatively deep-water. The paper deals with a 2D physical model study of wave-induced forces on a composite vertical breakwater, where the position of the crown wall has been varied during the tests. As a general result, the experimental evidences suggest that, at least for the four configurations tested, the global forces and moments acting on the caisson vary significantly depending on the wall position.
These general considerations are supported and explained by the detailed analysis of the wave-structure interaction phenomena presented in the paper. In fact, this analysis suggested that several physical/geometrical drivers play a role on the force increase/reduction as a function of the wall position, namely: I) time shifting between impacts on caisson trunk and wall; II) unloading of the water column acting on the trunk due to overtopping of the seaside edge of the caisson; III) increase of the forces on the wall due to occurrence of impulsive loads. The synchronous analysis of the forces highlighted that these physical/geometrical drivers can have both a concordant and antithetical action among them, then resulting in increasing or decreasing, respectively, forces acting on the structure, if compared with the flushed wall configuration. Thus, they found that there are particular combinations of caisson wall retreats and wave parameters for which the global loading conditions are globally equal/higher than that experienced for the flushed wall configuration under the same sea states.
As long as experimental tests have shown a complicated physics of the wave-structure interaction, numerical modelling can provide a valuable assistance in understanding the phenomena involved in the problem. The new tools offered by the Computational Fluid Dynamics (CFD) methods represent a valuable means for shedding light on the unresolved aspects.
In this paper, a numerical study of the wave loads acting on vertical breakwaters with both flushed and retreated wall is presented. The study is carried out by using the opensource framework OpenFOAM® (IHFOAM, Higuera et al.,2013). The main objective of this study lies in comparing the nature of loads acting on the vertical structure induced by these two wall configurations under different wave conditions. The numerical model is validated against both literature (Goda, 2010) and experimental data (Romano & Bellotti, 2023). Therefore, a parametric analysis by varying both wave and structural parameters is carried out by using both regular and irregular wave conditions. An example of the numerical results related to the wave-structure interaction for two wall configurations (one flushed and one retreated) is shown in Figure 1. The study has highlighted a number of interesting features, such as the transition from pulsating to impulsive loads and a wave

range in which the use of a retreated wall worsens the magnitude of loads on the structure, confirming and extending the experimental results of Romano & Bellotti (2023). New results and an in-depth analysis of the wave-structure interaction physics will be shown at the Conference.

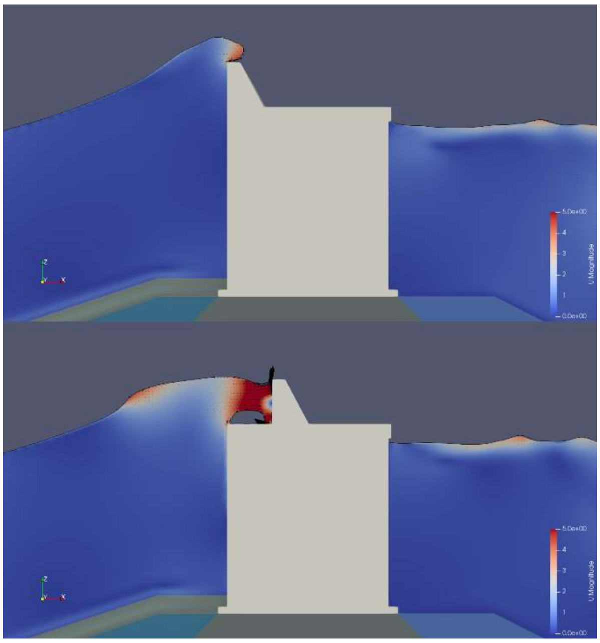

Figure 1 – Wave-structure interaction of both flushed (upper panel) and retreated (lower panel) wall during one of the numerical simulations.

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