CONFINED-CREST IMPACT: THE INFLUENCE OF THE TOE BERM ON THE IMPULSIVE LOAD CONDITIONS

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INTRODUCTION

Composite vertical breakwaters are coastal structures used to defend port basins from waves in intermediate and deep water conditions. In order to safely use the inner side of harbors, it is important to limit wave overtopping. Parapet walls are used for this purpose. To improve the hydraulic efficiency of the parapet wall with a fixed crown wall height, the wall can be shaped giving rise to a recurved overhand toward the sea. Its function is to deflect back the incident waves. Recently, it has been shown that the interaction between non-breaking waves and recurved parapet can induce impulsive pressures due to the confinement of the incident wave crest deflected seaward by the overhanging structure. The new physical phenomenon has been called "Confined-Crest Impact (C-CI)" as shown by Castellino et al. 2018. This physical phenomenon can induce "unexpected" structural failure (Dermentzoglou et al., 2020). More recently, Castellino et al. (2021) extended the Goda's formulae, which define the maximum pressures along a vertical breakwater, considering the "C-CI" induced by the presence of a recurved parapet. The conducted studies have concerned a vertical breakwater without any berm at the toe of the caisson. The purpose of this research is to extend this last work to a composite vertical breakwater based on a foundation berm.

METHODS

For the definition of the geometrical characteristics of the berm, the "Parameter Map" provided by PROVERBS manual (Oumeraci et al. 2001) has been taken into account (as shown in Figure 1).

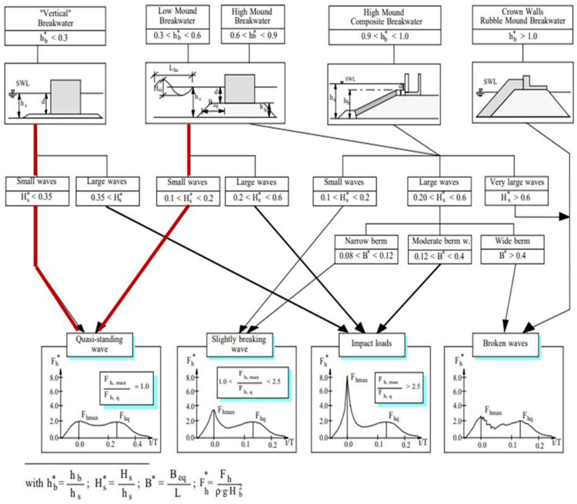

Figure 1 - Parameter Map (PROVERBS, 2001).

In this research work, the conditions that have been investigated are highlighted in Figure 1 by the red path. The study has been carried out numerically using OpenFOAM®, the solver adopted interFOAM which resolves the Reynolds averaged Navier-Stokes equation for multiphase flow (air and water). The wave generation and absorption has been solved by using IHFOAM (Higuera et al., 2013a).
The numerical experiments have been carried out in a wave flume 220 m. Due to the non-breaking wave conditions, no trained or entrained air occur. Only regular waves have been performed, this implies the simulation of a low number of waves (on average 20). Based on the range of parameters that defines composite vertical breakwaters (PROVERBS, 2001- "Parameter Map"), those that falls into the "quasi standing" loading conditions have been chosen (see Figure 1). Fourteen configurations have been analyzed, seven with a recurved parapet and the remaining with a plane parapet wall. The numerical results obtained on the plane parapet wall have been used to evaluate the pressures, forces and wave overtopping with respect to the related recurved parapet configuration. An example of the geometry is shown in Figure 2. The berm height varies between 2.0 m and 22.5 m, the wave height between 4 and 8 m and the wave period between 8 s and 13 s. The same simulations are performed in absence of the toe berm.

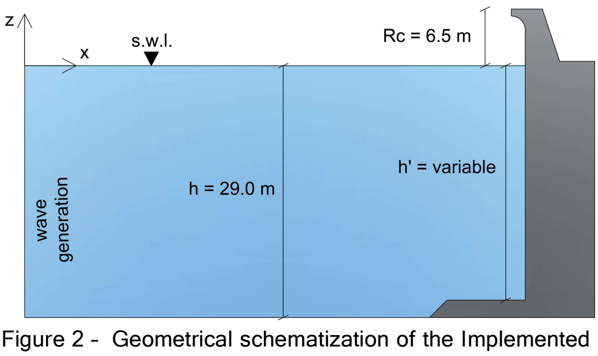

Figure 2 - Geometrical schematization of the Implemented geometries.

RESULTS

The first numerical results are shown in terms of total forces obtained with and without the toe berm (see Figure 3). Starting from the upper left plot, hb1 corresponds to a berm height of 2 m, hb3 to 14.5 m, hb5 to 19.5 m and hb7 to 22.5 m. The geometrical configuration hb1 give rise to no force increase. On the contrary, the "C-CI" gives a higher value as the berm height increase. This is mainly due to the shoaling effect induced by the berm.

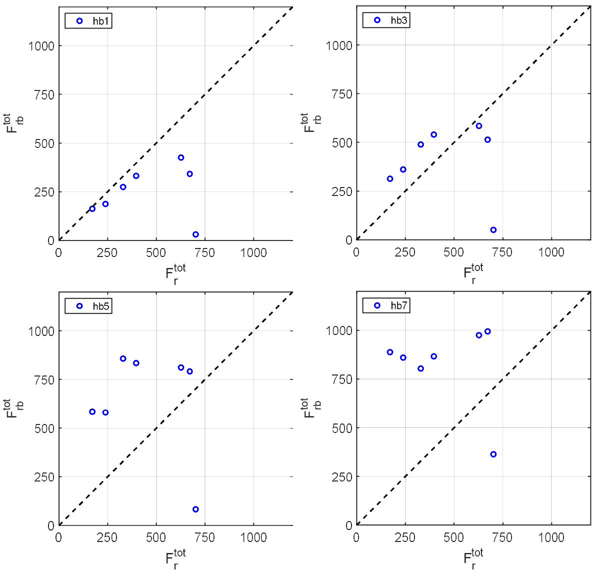

Figure 3 - Total forces on the configuration with the berm (vertical axis) and without the berm (horizontal axis).

As shown by Castellino et al. (2021), the induced effects on the pressure values by the "C-CI" can be summarized in three key points:

- $\tilde{p}_1$ = pressure increment on the s.w.l.
- $\tilde{p}_2$ = pressure increment on the initial part of the recurve
- $\tilde{p}_3$ = pressure increment on the tip of the recurve

The $\tilde{p}_3$ values can be represented as a function of the non-dimensional parameter:

$$\frac{H}{L^2} \cdot l \cdot \frac{h}{h'}$$

where H is the wave height, L is the wavelength, l is the overhang, h the water depth at the toe of the berm and h' is the water depth at the toe of the vertical structure. The results are shown in Figure 4.

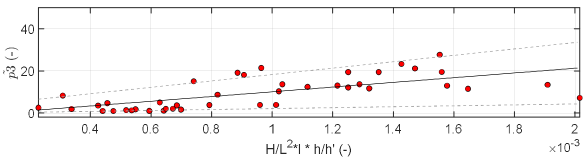

Figure 4 - Non-dimensional pressure increment $\tilde{p}_3$.

Further results concerning the dimensional analysis and the extension of the "C-CI" for vertical breakwaters with a submerged berm and the detailed analysis of the simulations will be presented at the conference.

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