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).

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:
- $p_1$ = pressure increment on the s.w.l.
- $p_2$ = pressure increment on the initial part of the recurve
- $p_3$ = pressure increment on the tip of the recurve

The $p_3$ values can be represented as a function of the non-dimensional parameter:
$$\frac{H}{L^2} \cdot \frac{l}{h} \cdot \frac{h'}{R}$$

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.

REFERENCES
Castellino, Romano, Lara, Losada, and De Girolamo (2021), Confined-Crest Impact: Forces dimensional analysis and extension of the Goda’s formulae to recurved parapets, Coastal Engineering, 163.

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