PHYSICAL EXPERIMENTS ON OVERHANGING PARAPETS UNDER NON-BREAKING WAVE CONDITIONS

Alessandro Antonini, Technical University of Delft, a.antonini@tudelft.nl
Dimitrios Dermentzoglou, Technical University of Delft, d.dermentzoglou@tudelft.nl
Ermano de Almeida, Technical University of Delft, e.deAlmeida@tudelft.nl
Bas Hofland, Technical University of Delft, b.hofland@tudelft.nl
Daniele Celli, University of L'Aquila, daniele.celli@univaq.it
Davide Pasquali, University of L'Aquila, davide.pasquali@univaq.it
Marcello di Risio, University of L'Aquila, marcello.dirisio@univaq.it
Myrta Castellino, “Sapienza” University of Rome, myrta.castellino@uniroma1.it
Paolo de Girolamo, “Sapienza” University of Rome, paolo.degirolamo@uniroma1.it

INTRODUCTION

The use of sea-wall and storm-wall structures within valuable landscape or urban areas often imposes rather restrictive limits in terms of structures height. A viable solution to address the safety against overtopping and the architectonical requirements is the use of recurved parapets. However, this type of structure is exposed to large impulsive loads that have been recently described and named as confined-crest impact, (C-CI), (Castellino et al., 2018) and caused several failures such as those in Strand (South Africa), Pico Island (Portugal) and Civitavecchia (Italy), (Castellino et al., 2021; Dermentzoglou et al., 2020; Martinelli et al., 2018). Accordingly, tools to properly design these curvilinear structures and to carry out comparative assessments between the induced advantage in terms of overtopping and increased structural complexity due to its shape and the C-CI are required. This work aims to identify practical design tools and provide benchmark data for the validation of the CFD model presented in the abstract n. 1643: “Castellino et al., Numerical experiments on overhanging parapets under non-breaking wave conditions”.

METHODS

A series of non-breaking regular and irregular waves experiments have been performed at the TU Delft Hydraulic Engineering Laboratory to investigate the contrasting behaviour of the overtopping phenomena and the exerted impulsive wave load on recurved parapets. Three different geometries have been investigated (Figure 1); vertical wall (S_1) as a reference case; crownwall with a recurved face (S_2) that was not yet investigated in-depth, and rectilinear parapet (S_3). Should be noted that the seaward overhanging of S_2 and S_3 configurations is the same with respect to the vertical wall.

Figure 1 - Tested geometries

RESULTS

Initial regular wave tests have been performed to investigate the fundamental hydraulic performance of the parapets. The preliminary results show a sensible reduction of individual overtopping volumes for S_2 and S_3 when compared with classical vertical wall, Figure 2 lower panel. However, the improvement in hydraulic performance due to the crown wall shapes also involves downsides in terms of loading conditions, Figure 2 upper panel.

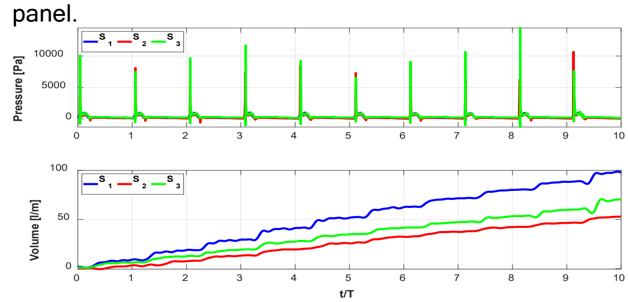

Figure 2 - Example of pressure (upper panel) and overtopping (lower panel) records for regular wave case: H=0.19m - T=2.8s

In Figure 3 left panel, the ratio between the peaks pressure (P) measured on the recurved parapets (S_2 and S_3) and the maximum quasi-static pressure measured on the vertical wall (S_1) are shown as function of the Ursell number. In Figure 3 right panel, the individual overtopping volume (V) reduction in term of ratio between the measured volume for S_2 and S_3 and the one measured for S_1 is presented as function of the Ursell number.

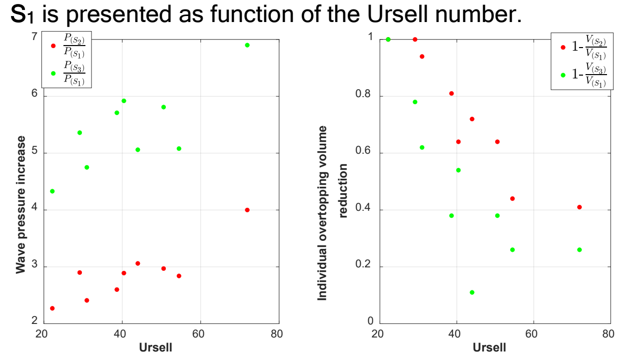

Figure 3 - (left) peak pressure increase vs Ursell number; (right) reduction factor of individual overtopping volume vs Ursell number.

Reduction in terms of individual overtopping volume shows a rather strong negative correlation with the Ursell number describing the local incident wave nonlinearity, Figure 3 right. No overtopping is detected for Ursell numbers smaller than 30, while an almost linear decrease in hydraulic efficiency is shown within the dataset.
Increase in peak pressure between 2 to 4 (S_2) and 4 to 7

(S_3) times the maximum quasi-static pressure, i.e. S_1, are detected, while some positive correlation with the Ursell number is also captured by the results. The strong correlation between the Ursell number, the pressure and overtopping measurements highlights the importance of the local wave conditions and the underlying non-linearity. With the increase of the Ursell number, higher wave crests reach the structures, the moved water mass, cause of the overtopping volume, is mainly concentrated within the wave crest and the vertical velocities, i.e. the leading parameter for the impulsive wave pressure, are higher. Hence, by contrast with other practical design experiences (e.g. Eurotop, van der Meer et al. (2018)) for a proper design of the recurved parapet, we suggest a detailed analysis of the local wave condition.

The structure S_3 can be seen to reduce the overtopping volume more than the shape S_2, however, its additional geometrical complexity might hamper its realisation therefore a detailed investigation of the incident loading conditions must be carried out to properly assess the overall (technical and economic) convenience of the solution.

At the conference the results of the parametric analysis performed on a wide range of wave conditions (regular and irregular), aimed to describe the different physical phenomena underlying the C-CI and the effects of the wave characteristics on the overtopping and impulsive loads are presented. Moreover, a comparison between the design process based on the peak pressure and the wave load impulse will be discussed.

REFERENCE

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.

Castellino, Sammarco, Romano, Ruol, Franco, De Girolamo (2018). Large impulsive forces on recurved parapets under non-breaking waves. A numerical study. Coastal Engineering, 136: 1-15.

Dermentzoglou, Castellino, De Girolamo, Portovi, Schreppers, Antonini (2020). Crownwall failure analysis through finite element method. Journal of Marine Science and Engineering, 9(1).

Martinelli, Ruol, Volpato, Favaretto, Castellino, De Girolamo, Franco, Romano, Sammarco, (2018). Experimental investigation on non-breaking wave forces and overtopping at the recurved parapets of vertical breakwaters. Coastal Engineering, 141: 52-67.

Van der Meer, Allsop, Bruce, De Rouck, Kortenhaus, Pullen, Schuttrumpf, Troch, Zanuttigh, (2018). Eurotop, 2018. Manual on wave overtopping of sea defences and related structures.