Proceedings of the 9th International Conference on Physical Modelling in Coastal Engineering (Coastlab24)
Delft, Netherlands, May 13-16, 2024

Extended Abstract, DOI: 10.59490/coastlab.2024.786

EXPERIMENTAL COMPARISON OF THE HYDRAULIC PERFORMANCE OF OVERHANGING AND VERTICAL PARAPETS UNDER LIMITED WAVE BREAKING CONDITIONS: THE CASE OF THE NEW OFFSHORE RAVENNA LNG TERMINAL (IT)

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KEYWORDS: Wave overtopping, vertical breakwater, recurved parapet

1 INTRODUCTION

Harbors play a pivotal role in global trade, serving as vital gateways for the transportation of goods, fostering economic growth. These essential coastal infrastructures are subjected to relentless forces (e.g. wave action, storm surges, and sea level variation induced by climate change) which can jeopardize their functionality and safety. Safe working conditions are mandatory for the operability of all kinds of harbors. However, particular attention must be paid in the case of terminals dedicated to dangerous goods, as for example Liquefied Natural Gas (LNG). Composite vertical breakwaters may be efficiently used to protect this kind of terminal and have both advantages and disadvantages over rubble mound breakwaters.

This work presents the results of a 2D experimental campaign carried out to optimize, from a hydraulic point of view, the parapet wall of the new composite vertical breakwater that will be built to protect the new offshore LNG terminal located in in the North Adriatic Sea in the South-East of the Port of Ravenna (Italy). In particular, two types of parapets walls have been compared: one overhanging (recurved in the shape of one fourth of a circumference with a ray of one meter) and one vertical. For each type of parapets, three different heights were evaluated for a total of six different configurations. The typical water depth in the area where the new terminal will be built is approximately -15.0 m with respect to the MSL and the total range of the astronomical tides does not exceed one metre. The terminal is located about 8.0 km far from the coast and is positioned on a very mild seabed foreshore slope of less than 0.05°

2 THE EXPERIMENTAL CAMPAIGN

Tests were carried out in HR Wallingford's Flume 2 (see Figure 1), which is 40 m long, 1.2 m wide and with operating water depths of up to 1.6 m. The flume's wave generation is accomplished using a piston-type wavemaker and is controlled by HR Wallingford's Merlin software. The active wave absorption technique is implemented within this software and is crucial when high reflective structures are investigated, as true for the present case. The paddle can generate non-repeating random sea-states to any required spectral form.

The new Ravenna terminal has been tested under severe wave and sea level conditions characterized by a return period of 100 years (the sea state parameters are shown in Table 1). The experimental campaign has involved different parapet geometrical configurations, in terms of height and shape, listed in Table 1 (V stands for Vertical parapet wall, R stands for Recurved parapet wall and the wall freeboard Rc is the height of the parapet wall on MSL).

In Figure 1 it is possible to observe an example of the Vertical and Recurved configuration tested in the wave flume. The tests on the Vertical parapet wall allow a direct comparison to be made of the wave overtopping, of the wave transmission and of the wave forces with respect to the Recurved parapet wall.

Overtopping water was collected in a calibrated tank placed at the landward edge of the caisson breakwater in the centre of the flume. For the wave transmission coefficient, wave probes were used in order to measure water surface elevation. Concerning wave forces acting on the composite vertical breakwater, the structures were equipped with 24 pressure transducers embedded in the surface of the caisson. The output of the transducers has been integrated to derive whole body forces. The pressure transducers are designed to have a response rate up to 10 kHz in the model scale (equal to 1:35). The very high acquisition rate allows to perfectly catch impulsive conditions like those induced by the Crest-Confined Impact (C-CI) Castellino et al. (2018a, 2018b, 2021).

Table 1. Performed sea state and geometrical configurations (prototype scale).

Test	Rc (m on MSL)	Hs (m)	Tp (s)	SWL (m on MSL)
V-1	+6.5	5.5	9.6	+1.7
V-2	+8.5	5.5	9.6	+1.7
V-3	+10.5	5.5	9.6	+1.7
R-1	+6.5	5.5	9.6	+1.7
R-2	+8.5	5.5	9.6	+1.7
R-3	+10.5	5.5	9.6	+1.7

Figure 1. HR Wallingford's Flume 2 (left panels). Example of Vertical and Recurved parapet (right panels).

As a preliminary result, a comparison between the wave transmission coefficient, wave overtopping, and wave forces on the Vertical and Recurved parapet is shown in Figure 2. In the first plot of the figure, the Transmission coefficient, calculated at three distances from the structure (e.g. 50 m, 100 m, and 150 m), is reported. As a general comment, the higher is the parapet freeboard, the lower is the transmission coefficient. This perfectly matches the results on the mean wave overtopping, reported in the central panel of Figure 2. It can be observe that, for a fixed freeboard, the Recurved parapet is always subjected to half the mean overtopping discharge, confirming the high hydraulic efficiency of overhanging structures. On the other hand, particular attention must be given to the force increase due to C-CI, as shown in the right panel of Figure 2.

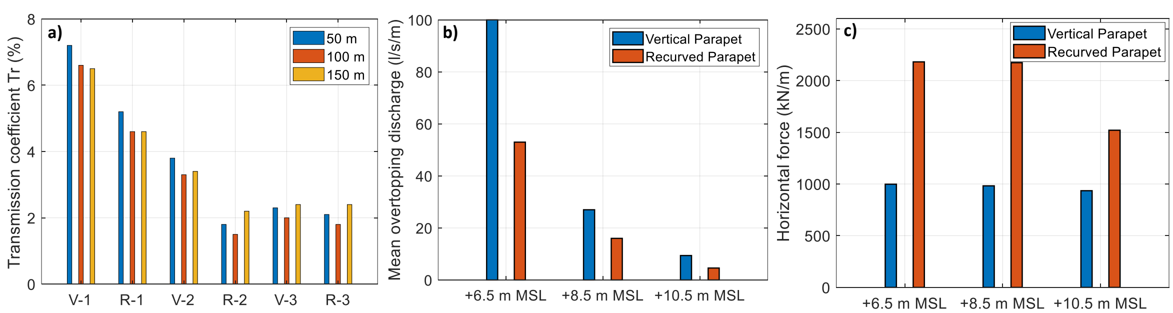

Figure 2. Panel a) Transmission coefficient, Panel b) Mean wave overtopping, Panel c) Horizontal force component.

Detailed results on the experimental set-up and techniques, together with a broader view of the achieved results compared to prediction methods, will be shown during the conference.

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