WAVE OVERTOPPING AT VERTICAL WALLS WITH LARGE FREEBOARDS AND VARIABLE WATER DEPTH

Leopoldo Franco, Roma Tre University, Rome, Italy, leopoldo.franco@uniroma3.it
Tom Bruce, University of Edinburgh, Edinburgh, UK, tom.bruce@ed.ac.uk
Claudia Cecioni, Roma Tre University, Rome, Italy, claudia.cecioni@uniroma3.it
Yuri Pepi, Ghent University, Ghent, Belgium, yuri.pepi@ugent.be
Jentsje van der Meer, Van der Meer Consulting BV, Akkrum, Netherlands, jm@vandermeerconsulting.nl

INTRODUCTION

Vertical walls serve a vital role in safeguarding coastal areas and harbors from the extreme wave conditions. These structures are typically designed for installation in deep waters (often as caissons) where conventional wave overtopping prediction methods have proven effective. Vertical walls are more common as coastal protections. However, as waves approach shallower shores, the dynamics change significantly. The onset of wave shoaling and breaking introduces impulsive conditions that pose a challenge for existing prediction methods.

Notably, existing overtopping prediction methods, such as EurOtop (2018), as updated to include insights from Van der Meer and Bruce (2014), primarily apply to impulsive conditions when $R_c/H_{m0} < 3$. Here R_c is the freeboard and H_{m0} the significant wave height at the toe of the structure. However, extrapolations beyond this point lack empirical validation, leaving a significant gap in our understanding. Moreover, well-established overtopping graphs by Goda (2000) indicate the potential for overtopping even with very large freeboards and impulsive waves as shown in Figure 1 in the red box. Note that h/H'_0 in the graph is the relative water depth using the *deep water wave height* and h_c in the graph is equal to R_c.

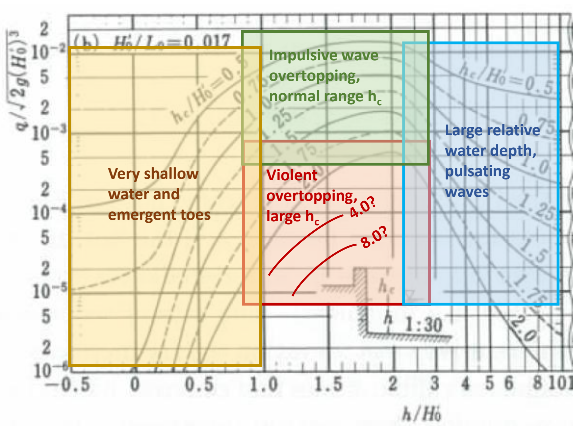

Figure 1 - Mean overtopping at a plain vertical wall under various regimes of overtopping, based on Goda (2000).

AIM OF THE RESEARCH

This research aims to deepen our understanding of wave overtopping phenomena under extreme conditions, with a particular focus on investigating mean discharge and individual wave overtopping volumes. This paper will present the follow up of the work the WOW21 project (Wave Overtopping at Walls) presented at the last ICCE 2022 in Sydney.

The primary goals of this research are as follows:

(i) Validation: Validate the observations of Goda's overtopping graphs, especially for the $h/H_{m0\ deep}$ range of 3-10 (blue box in Figure 1) using new, ongoing tests with a horizontal bottom.

(ii) Explore Extreme Conditions: Investigate wave overtopping under extreme and impulsive conditions, specifically those associated with very large freeboards, where traditional prediction methods are not available (extending the understanding of wave overtopping behavior up to $R_c/H_{m0} = 10$).

(iii) Individual Wave Overtopping Volumes: Address the significant gap in the existing literature regarding the distribution of individual wave overtopping volumes at vertical wall, especially in impulsive conditions (Koosheh et al., 2021). This aspect is particularly crucial, given the field evidence of vertical walls with large freeboards that continue to experience wave overtopping.

PHYSICAL MODELS

The research has been performed in two physical models consisting of a vertical wall with two different foreshore slopes, one with a slope of 1:50 and the other at 1:10 (refer to Figure 2 for the cross-sections of the flumes and see in Figure 3 two pictures during tests). The tests were carried out in Roma Tre University's wave flume (20m x 0.6m in 1.0m water depth and at University of Edinburgh's flume (20m x 0.4m x 0.7m depth), respectively with a 1:50 and a 1:10 foreshore slopes. A total of 183 initial tests were done across these two flumes, systematically varying the water depths at the vertical wall toe. This range spanned from 0.30 m to an emerged toe at -0.05 m, providing comprehensive coverage of potential conditions. The experimentation also entailed a systematic examination of two wave heights ($H_{m0\ deep}$) with three steepnesses: 0.01, 0.03, and 0.05.

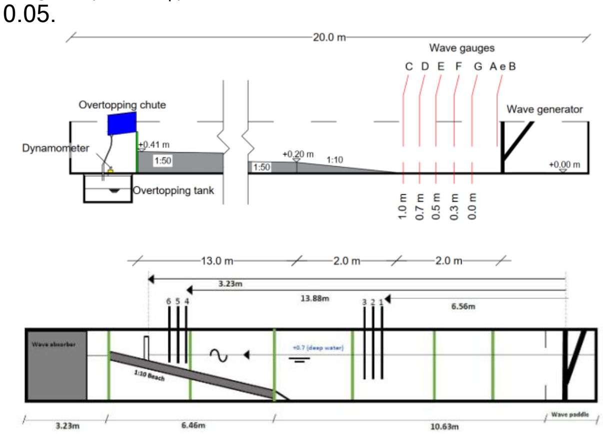

Figure 2 - Vertical sections of wave flumes in Rome (top) and in Edinburgh (bottom) and position of wave gauges and the device for measuring the overtopping volumes

Figure 3 - Pictures of high freeboard vertical wall model in Edinburgh (left) and an overtopping event during test in Rome (right).

Additional experiments are ongoing at Roma Tre University (see Figures 4-5), where the vertical wall is over an horizontal bottom (so no influencing foreshore). This expanded research program includes tests with one wave height and three different steepness levels, effectively covering the entire range of h/H_{m0} from 3 to 10. This broader investigation not only addresses a significant gap in the existing research, but also serves as a validation of Goda's findings for horizontal bottoms and large water depths.

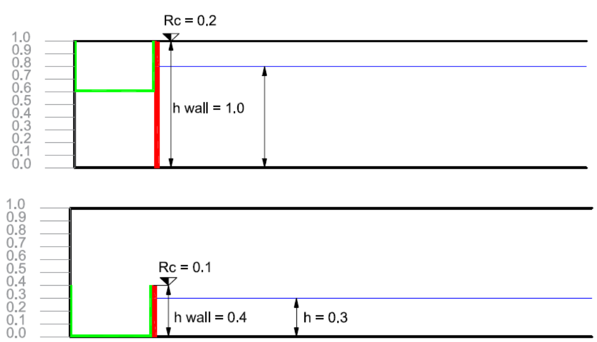

Figure 4 - Schematic sections of two configurations of the wave flume (thick black), vertical wall (red) and collection tank (green).

Figure 5 - Picture during new tests with horizontal foreshore in Rome.

This extensive investigation in two flumes in Rome and Edinburgh covers a range of foreshore slopes and water depths. It contributes to better insights and prediction methods regarding wave overtopping at vertical walls with large freeboards and impulsive conditions. The critical assessment of the performance of existing empirical formulas for quite deep water and the extension of analysis of wave overtopping volumes offer the potential for more accurate and reliable predictions of wave overtopping behavior. Full results will be presented at the conference.

REFERENCES

Goda (2000): Random seas and design of maritime structures. World Scientific, Volume 15.

Koosheh, Etemad-Shahidi, Cartwright, Tomlinson, Van Gent (2021): Individual wave overtopping at coastal structures: A critical review and the existing challenges, Applied Ocean Research, Volume 106, 102476.

Ngxabani (2021): Violent and impulsive wave overtopping at vertical walls, Master thesis IHE Delft.

EurOtop (2018). Manual on wave overtopping of sea defences and related Structures. An overtopping manual largely based on European research, but for worldwide application. Van der Meer et al.

Van der Meer, Bruce (2014): New physical insights and design formulas on wave overtopping at sloping and vertical structures. J. Waterway, Port, Coastal & Ocean Eng, 140.