2D LES of breaking waves on seawalls with recurved parapets

Andreas T. Asiikkis1, 5, Charalambos Frantzis2, 3, Dimitris Stagonas4, Antonis I. Vakis5, Dimokratis G.E. Grigoriadis1, *

1 Department of Mechanical and Manufacturing Engineering, University of Cyprus, Nicosia, Cyprus
2 Electricity Authority of Cyprus, Nicosia, Cyprus
3 Cyprus Marine and Maritime Institute, Larnaca, Cyprus
4 Department of Civil and Environmental Engineering, University of Cyprus, Nicosia, Cyprus
5 Computational Mechanical and Materials Engineering, University of Groningen, Groningen, the Netherlands
* Corresponding author

ABSTRACT

The utilization of recurves on vertical seawalls reduces overtopping without drastic increases in the structures’ freeboard. As part of ISOPE22 blind test challenge, an in-house developed computational fluid dynamics code is used to simulate the breaking of waves on a vertical seawall and the interaction of the violent up-rushing flow with the recurve. The code combines recent advances which speed-up the solution of Poison’s equation, with an immersed boundary method and a Large Eddy Simulation model. The comparison of the numerical results with the experimental data provided by the organisers shows a satisfactory reproduction of the wave conditions in the flume and a non-negligible underestimation for the predicted peak pressures. This, with a computational cost of approximately 2 hours per wave period.

KEY WORDS: Braking Waves; Seawalls; Wave-Structure Interactions; Computational Fluid Dynamics (CFD); Numerical Wave Tank (NWT).

INTRODUCTION

During storms the interaction of waves with seawalls often leads to green water and impulsive overtopping. Recurves placed at the top of the seawall deflect seawards the up-rushing water thereby reducing overtopping without drastically increasing the freeboard. Following field failures with recurves being toppled by the wave action, numerical and experimental investigations on the interaction of such super-structures with non-breaking (Castellino et al., 2021), and breaking waves (Stagonas et al., 2020), have highlighted the importance of accurately predicting wave induced loads.

Recent experimental works, e.g. Dong et al. (2021), Ravindar & Sriram (2021a), and Stagonas et al. (2014) among others, highlight a complex relationship between the super-structure’s design characteristics and the wave induced loads. For example, chamfered parapets and recurves were shown to experience impulsive loads induced by non-breaking waves, the magnitude of which increases drastically when the waves break at the wall. For the latter conditions, the shape of the recurve was also shown to affect the loading conditions at the wall as well. The present blind test challenge calls for simulations of regular waves breaking on a vertical seawall equipped with a recurve.

In principle, numerical investigations of wave-structure interaction are associated with a high computational cost and are challenged by the complex nature of the phenomenon. Martin et al. (2021) utilized the numerical toolbox OpenFOAM to model 2D and 3D impacts of solitary waves on a vertical wall using the assumptions of both incompressible and compressible fluids. Using the mesh-less program DualSPHysics which utilizes a particle-based method, Ma et al. (2021) performed simulations of the same case as in the experiments of Kisacik et al. (2012), without considering the presence of air (i.e., single-phase flow) and using a weakly compressible model for the water. Similar simulations were performed by González-Cao et al. (2019) who compared the accuracy of DualSPHysics and IHFOAM which is a mesh-based method. Their results indicated that the IHFOAM performed better compared to DualSPHysics. In addition, they concluded that the accuracy of capturing the free-surface elevation was higher compared to the impact forces due to the stochastic nature of wave impacts. Other numerical studies can be found in (Castellino et al., 2021; Liu et al., 2019).

In this paper, a newly developed Numerical Wave Tank (NWT), namely the LESIT described by Frantzis et al. (2020), is used to reproduce the large scale experimental conditions of Stagonas et al. (2020) and compare numerical predictions of the wave conditions in the flume and wave induced pressures at the structure with the measurements. In the remainder, the numerical methods utilized to solve the full set of the Navier-Stoke equations and the numerical set-up of the experiment are outlined first. The convergence study is presented before the numerical results are illustrated and compared with the experimental measurements provided by the organisers. Soon after, the results and the computational performance of the NWT are critically discussed. Finally, the conclusions of the study are drawn, and future work is outlined.