Numerical Investigation of Breaking Waves Impact On a Vertical Wall With a Large Recurved Parapet

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ABSTRACT

The present work describes the numerical approach used for the assessment of breaking waves impact on a vertical wall with a large recurved parapet, for which experiments were performed in Coastal Research Centre (ForschungsZentrum Küste, FZK), Hannover, Germany (Ravindar et al., 2018, 2019, 2021).

To perform these computations, the compressible multi-phase solver within the OpenFOAM numerical toolbox is presently combined with the waves2FOAM libraries to generate waves and resolve the Navier Stokes equations. Moreover, in these considered solvers, the free surface is treated using the Volume of Fluid (VoF) method and the pressure-velocity equations are solved thanks to the PIMPLE algorithm.

Different wave gauges and pressure probes are present in the experimental configuration that are used either as input parameters for our simulations and for the validation of our numerical results by numerical-experimental cross-comparisons.

KEY WORDS: OpenFOAM; relaxation zones; breaking waves; impact pressure; compressibility effects.

INTRODUCTION

Coastal structures are built to prevent land erosion and flooding. They can appear in different shapes, among which vertical breakwaters and sea walls are frequently used. However, these structures can be severely damaged when subjected to violent sea state conditions. Oumeraci et al. (1993) reported that breaking waves are the most significant cause of this damage but, on the other hand, they state that the prediction of design wave load conditions remains difficult. This means that accurate investigation of waves loading is a key factor for a safe design of coastal infrastructures.

Extreme wave loadings have been underlined both theoretically (e.g. Cooker & Peregrine, 1990) and experimentally (e.g. Kirgkoz 1982; Oumeraci et al. 1993; Hattori et al., 1994 and Bullock et al., 2007). Most of these studies gave a general classification of breaking wave loads on vertical and sloping sea walls. Besides, it has been proven that the shape of breakwaters has a large influence on the so-called wave impact pressure exerted on the structure, and the wave over-topping as well (Hull and Müller, 2002). In fact, nowadays, with the sea level rise due to global warming, rather than increasing the sea wall height, many researchers and engineers show that adding a parapet could be more efficient in mitigating the wave over-topping through discharging a part of seawater back into the sea.

Some early physical and empirical studies were carried-out by Owen & Steel (1992), Cornett et al. (1999) and Kortenhaus et al. (2001, 2003) to investigate the efficiency of different types of parapets (plain or recurved). Recently, more laboratory-based research work has been made in this context (e.g. Ravindar et al., 2019, 2021; Ravindar & Sriram 2021; Stagonas et al., 2020) focusing on the forces and the impact pressure at the structures with a recurved retrofitting.

Stagonas et al. (2020) and Ravindar et al. (2020, 2021) have performed two sets of experiments on the vertical wall attached with recurved parapets. The model scale (1:8) experiments conducted in a shallow wave flume at the Department of Ocean Engineering, Indian Institute of Technology (IIT) in India, and the quasi-prototype scale (1:1) carried out at Large Wave Flume (Großer Wellen Kanal, G.W.K.) in Hanover, Germany. Different parapets (with different angles of extension) and wave conditions were tested, and all experiments consider a single monochromatic wave field, which will lead to breaking owing to the presence of a sloping beach in front of the vertical wall. The small-scale (1:8) configuration was scaled using the Froude scaling method which unfortunately creates scale effects due to its limitations. For this reason, the large-scale experiments (1:1) with, to the author point of view, more reliable results avoiding scale effects will be preferred for the purpose of this paper.

The experimental facilities are usually expensive and limited, as a result, a detailed parametric study is not always feasible. However, with the significant advances of High-Performance Computing, several parametric simulations could be carried out and validated with experiments, using different Computational Fluid Dynamics (CFD) tools. Particularly, the open-source library OpenFOAM based on the Finite Volume Method (FVM) and using the Volume of Fluid (VoF) approach has been applied to investigate various problems related to coastal and offshore engineering. The good capabilities of this software were demonstrated by Morgan et al., (2010), Liu et al., (2019) and more recently by Molines et al., (2020) who numerically modelled