# NUMERICAL INVESTIGATION OF BREAKING AND BROKEN REGULAR WAVE FORCES ON A SHOAL-MOUNTED CYLINDER

JAN VAN GORSEL[1], AKSHAY PATIL[2], JEREMY BRICKER[1], STUART PEARSON[1], ALISSON RABY[3], DARSHANA DASSANAYAKE[4], ALESSANDRO ANTONINI[1]
[1]*Faculty of Civil Engineering and Geosciences Delft University of Technology,*
*jan_v_gorsel@outlook.com, J.D.Bricker@tudelft.nl, S.G.Pearson@tudelft.nl, A.Antonini@tudelft.nl*
[2]*Stanford University, alpatil@stanford.edu*
[3]*University of Plymouth, alison.raby@plymouth.ac.uk*
[4]*University of Sri Jayewardenepura, darshana.dassanayake@sjp.ac.lk*

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## INTRODUCTION

Shoal-mounted cylindrical structures such as lighthouses assist in the navigation of vessels, and act as warning systems. Many of these iconic lighthouses are continuously subjected to extreme sea-wave action, made acute by the effects of climate change [1], [2]. Studying the complex hydrodynamic loads acting on such structures surrounded by rocks or emerged shoals can provide valuable insights for addressing their structural integrity, and how much longer these heritage structures can withstand such harsh environments. In this work, the effectiveness of a finite volume-based numerical framework to predict wave loads on such structures is assessed. The proposed numerical investigation is supplemented by the STORMLAMP (STructural behaviour Of Rock Mounted Lighthouses At the Mercy of imPulsive waves) project's experimental data [3] that has been used as a benchmark case to validate the proposed computational framework.

## METHODS

The numerical wave tank (NWT) consists of the finite volume framework OpenFOAM® and the waves2Foam toolbox [4]. The recently developed Volume of Fluid (VOF) based isoAdvector algorithm [5] is used to model the multiphase nature of the flow and resolve the sharp discontinuities in the propagation of broken waves. Additionally, to limit the over-production of turbulent kinetic energy (TKE) under breaking waves, the stabilization closure developed by [6] was preferred. To reduce the computational cost and maintain the nonlinear nature of the shallow water waves, the numerical domain consists of an NWT coupled to a nonlinear potential wave model (i.e., OceanWave3D, [7]) as demonstrated by [8] and [9]; this coupled NWT can be seen in Figure 1. The computational grid is generated using snappyHexMesh for both the 2D and 3D NWT. The preliminary 2D model - without the cylindrical structure - is used for the mesh sensitivity analysis and compared to the water surface elevation of the experimental data for validation. The validation indicates that a numerical grid characterized by 15 cells per wave height and an aspect ratio of 1 is sufficient to properly resolve the wave kinematics and therefore the same grid set-up is also applied for the 3D model. Given the 3D NWT's symmetric nature, a symmetry boundary condition along the centre of the domain is applied while the lateral domain walls are modelled through a slip boundary condition, and the bottom boundary is modelled by a wall function prescribed rough no-slip wall.

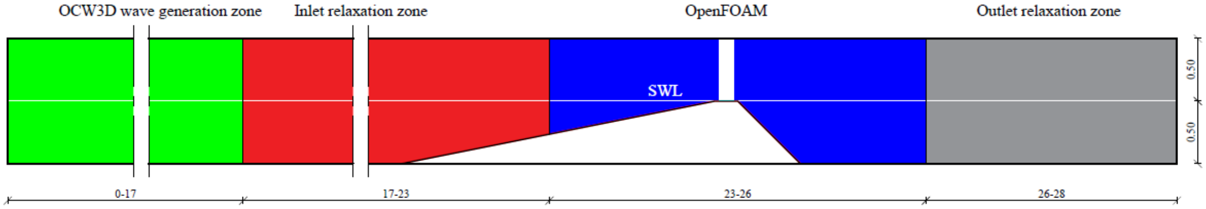

**Figure 1: Schematization of the numerical domain used in this investigation indicating the different parts in streamwise direction (in meters) in the NWT. The white horizontal line represents the still water level in the NWT.**

## RESULTS

The comparison of the 2D numerical surface elevation against the experimental results show good agreement, with a minimum Pearson Correlation Coefficient (PCC) of 0.8 for the time-series analysis and a maximum value of 1 for the ensemble-averaged surface elevation. The surface elevation analysis is complemented with the Root Mean Square Error (RMSE) normalized by the local mean wave height, and shows a maximum value of 0.30, suggesting good agreement in the frequency domain (see Figure 2a). Comparison of the ensemble averaged surface elevation in the time-domain can be seen in Figure 2b, which shows satisfactory agreement between the two datasets. Figure 2c presents the numerical ensemble-averaged force time series compared with the experimental results, in which the ensemble means, and enveloping (1 standard deviation) error bands have been aligned considering the mean peak value and are normalised with the experiment peak value. Figure 2c confirms that the proposed NWT set-up can predict not only the surface