# The Influence of Different Ramp Slopes on the Amount of Water Discharge in an OBREC: Preliminary Numerical Results in the Port of Ancona

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## INTRODUCTION

We investigate the effect of different ramp slopes on the functioning of Overtopping Breakwaters for the Energy Conversion (OBREC hereafter). Typically, an OBREC comprises various components, including ramps, a reservoir, a conveying system, and a turbine. Cavallaro et al. (2020) suggest that the OBREC performs optimally and offers high economic viability in regions with mild or less intense wave climates. The efficiency of ramps for these wave energy converters (WECs) is analyzed in this paper.

## MATERIALS AND METHODS

Such devices have a reservoir to collect water which overtops through ramps. The FLOW-3D (Flow Science, 2023) CFD model was used to evaluate the wave-structure interactions. The wavemaker of this model was driven by waves generated by the FUNWAVE-TVD model (Shi et al., 2011). Table 1 shows, for a selected value of the joint probability density function, the main characteristics of the waves approaching from the NNE direction.

**Table 1.** Characteristics of sea waves coming from NNE direction.

| | | NNE |
|---|---|---|
| **Density 0.005** | $H_s$ (m) | 2.74 |
| | $T_m$ (s) | 6.67 |
| | $T_p$ (s) | 7.87 |
| | $\alpha_{p,h1}$ [°] | 35.00 |

To compare different slopes, a geometry like the real-scale breakwaters in the Port of Ancona was drawn using AutoCAD, and the corresponding STL files were utilized in FLOW-3D. The actual slope of the breakwater is 34°, and the water depth at the structure toe is ~6 m. For construction and practical purposes, the frontal ramp consists of a combination of two slopes: the first is 34°, extending 6 m from the seabed (water depth) across all models, and the second varies between 18° and 34° over the 2-m freeboard. The details are provided in Figure 1.

The numerical domain is 132 m long, 1 m wide and 10 m high. The cell size is 0.05 m in both x and z directions, while it is 1 m along the y direction, giving the total 528,000 cells. The volume of overtopped water was calculated beyond the ramp over a simulation time of 150 seconds. The setup and input wave energy are shown in Figure 2.

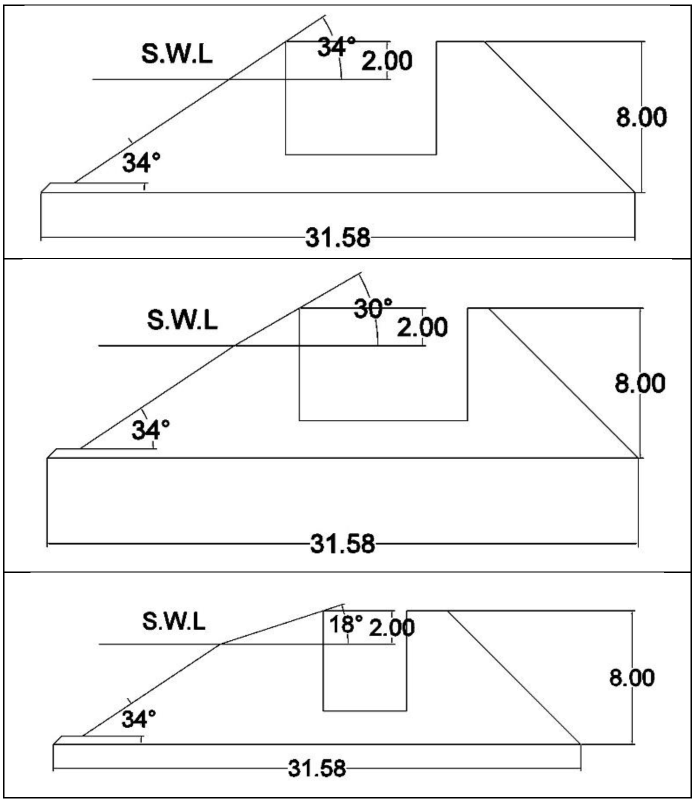


**Figure 1.** Samples for different ramp slopes upon the still water.

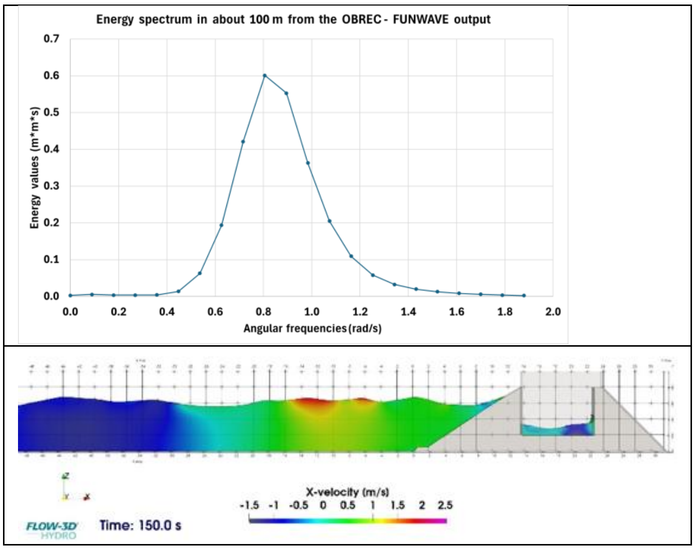


**Figure 2.** Numerical setup in FLOW-3D and wave energy spectrum as the wave maker boundary in FLOW-3D.

**RESULTS**

The comparison of overtopped volumes for different configurations, along with the free surface fluctuations recorded by a gauge located 30 m from the OBREC, are shown in Figure 3.

Based on the obtained results, the ramp slopes in freeboard significantly change the amount of water discharge: the 30° slope leads to the highest volume (10.57 $m^3$) and slopes of 26° and 34° provide volumes equal to 10.22 $m^3$. The gentle slopes of 18° and 22° lead to water discharges around 8.63 and 9.69 $m^3$, respectively.

Based on EurOtop (2018), the highest overtopping for short wind waves is achieved for slopes between 1:2 to 1:3 (i.e., 26° to 18°), while for longer waves, gentle slopes give a large overtopping due to surging waves (non-breaking waves). It should also be noted that, in the current study, only the freeboard slopes have been changed.

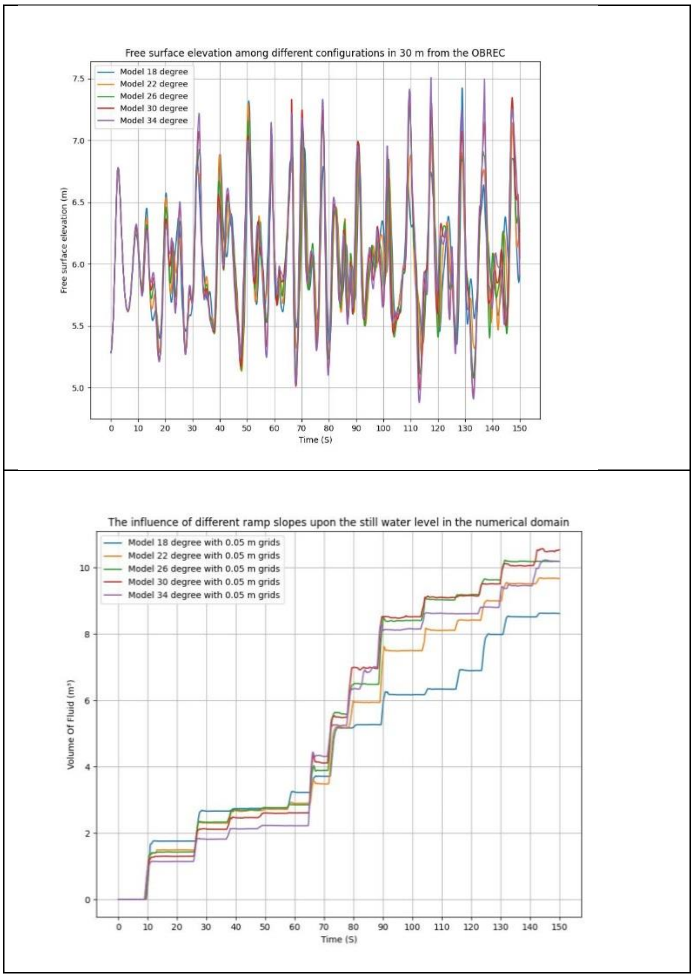


**Figure 3.** Effect of freeboard ramp slopes on water discharge and free surface elevation.

**CONCLUSIONS**

From the results of the overtopping tests, it is observed that freeboard slopes can influence the overtopped water discharge of about 20%, passing from the minimum to the maximum water volumes. Slopes of 26°, 30° and 34° show similar overtopped volumes. Detailed findings regarding the performance of the real-size ramp on the designed breakwater will be presented at the conference, particularly in relation to the OBREC installation at the Port of Ancona in Italy.

**ACKNOWLEDGEMENTS**

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