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OVERTOPPING REDUCTION BY ARTIFICAL REEFS

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1 INTRODUCTION

Artificial or Engineered reefs are primarily developed for enhancing the ecological system. In Guidelines for the Placement of Artificial Reefs (UNEP, 2009) they are described as "An artificial reef is a submerged structure deliberately constructed or placed on the seabed to emulate some functions of a natural reef such as protecting, regenerating, concentrating, and/or enhancing populations of living marine resources."

Often these artificial reefs have either a complex shape inspired by biomimicry (*e.g.* Coastruction) or a more regular shape, designed to function as modular blocks that can be easily placed on top of each other (*e.g*. Reefy). In many parts of the world, application of these engineered elements on top of existing shallow reefs may be a solution to not only enhance the ecosystem but also to increase the safety level of the hinterland. Also, in light of climate change and further increasing water levels, the artificial reefs may be a valuable alternative to reduce wave overtopping and prevent the land for extreme flooding.

To quantify the possible effect of such artificial reefs in more shallower areas, physical model testing have been performed in which both overtopping was measured with and without the use of engineered elements. Shallow water depths have been chosen here, since the reef should induce wave breaking, resulting in the wave energy to decrease. The performance of these engineered elements in relation to its submergence has been investigated and a reduction coefficient has been developed.

2 PHYSICAL MODEL

Physical model tests were performed in the Scheldt Flume at the Deltares with a length of 55 m, width of 1.0 m and height of 1.2 m. The physical model setup is illustrated in Figure 1. In the middle of the flume, the bathymetry is increased to 0.4 m using a 1:1 transition slope. The artificial reef is placed 13 m from the transition slope. At the end of the flume a 1:3 slope with an overtopping chute is located to measure the overtopping volumes. The artificial reef consists of 3D printed elements (25 cm x 25 cm with height of 15 cm) made by Coastruction, that were regularly placed in 8 rows of 4 elements with some space in between each row, resulting in a 3m long reef. In total 97 tests were performed with varying wave height H_s (0.12-0.215 m), free crest board R_c (0.145-0.345 m), wave steepness s_{op} (0.009-0.037) and wave spectra (JONSWAP and Pierson-Moskowitz). Tests were conducted with and without the reef structures to determine the effect of the reef structure on the amount of wave overtopping. In case the overtopping tank is (almost) full, the tank is emptied using a pumping system. Additionally, wave height and flow velocity measurements have been performed as described in Speth (2023). All tests have been performed with a duration of 700 waves.

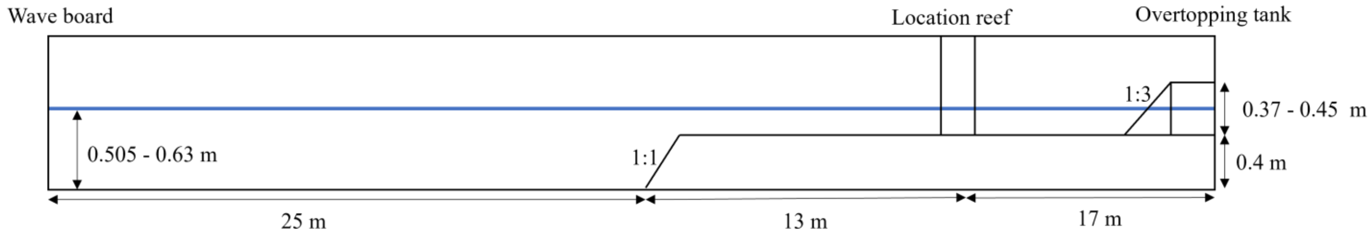

Figure 1. Physical model setup (not to scale)

3 RESULTS

The data was selected for analysis based on two criteria: the overtopping volume during the test exceeds 0.05 L and the pumping time of the overtopping tank is less than 60 s. The dimensionless overtopping discharge $q^*=q/\sqrt{gH_s^3}$ and the dimensionless crest freeboard $R_c^* = R_c/H_s$ are calculated for selected data points for the reference case (no reef) and with the artificial reef (Figure 2). The figure shows that the artificial reef results in a significant reduction of the overtopping discharge. As a first step to quantify this reduction, a formula for the reference case was determined:

$$q^* = a \cdot \exp\left(-b \cdot R_c^*\right)$$

where the parameters a = 0.11 and b = 1.89 are determined based on the best-fit with a $R^2 = 0.85$. Next, the reduction factor of the artificial reef γ_{AR} is determined using a fit of the form:

$$q^* = a \cdot \exp\left(-\frac{b}{\gamma_{AR}} \cdot R_c^*\right)$$

A reduction factor of $\gamma_{AR} = 0.697$ was determined from the best-fit with a R^2 of 0.93.

Figure 2b shows that the dimensionless overtopping discharge calculated using the fitted parameters and the reduction factor of the artificial reef compares well to the measured dimensionless overtopping discharge.

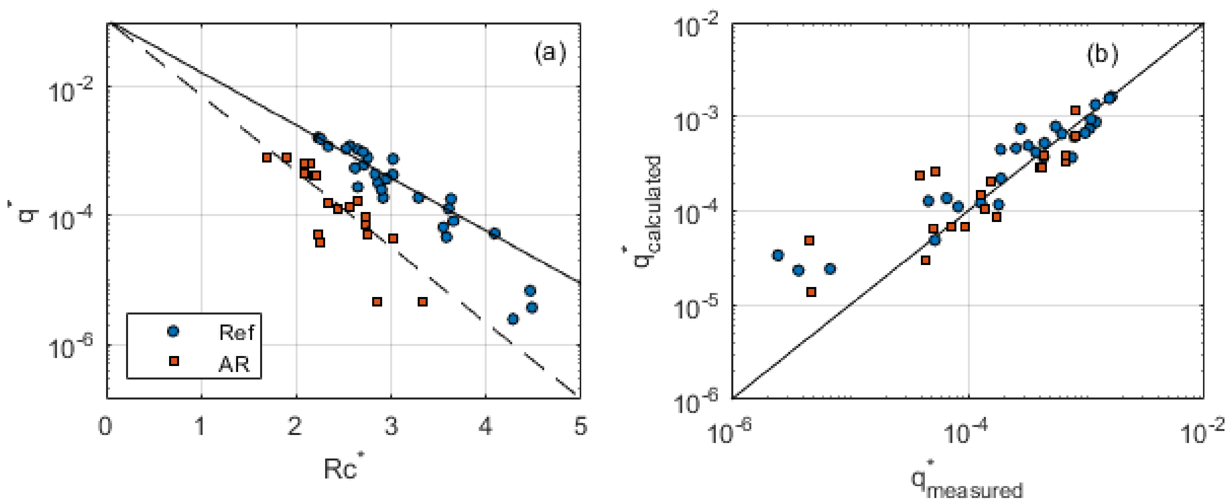

Figure 2: (a) The dimensionless overtopping discharge q* as function of the dimensionless crest free board Rc* for the measurements without (Ref) and with (AR) an artificial reef together with the corresponding fits. (b) The measured dimensionless overtopping discharge q*measured against the dimensionless overtopping discharge calculated with the new formulas q*calculated .

4 CONCLUSIONS

The physical model tests show that artificial reefs reduce the overtopping significantly. A reduction factor for the overtopping discharge was determined to account for the effect of artificial reefs in design formulas. Further research into the reduction effect of other artificial reef elements is necessary to develop a general design formula based on the characteristics of the elements such as porosity and permeability (Van Gent *et al*, 2023). It is recommended to further study the effects of artificial reefs on wave overtopping, for example study the effect on individual overtopping formulas, and other safety requirements such as structural performance of coastal structures.

ACKNOWLEDGEMENT

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