Proceedings of the 9th International Conference on Physical Modelling in Coastal Engineering (Coastlab24)
Delft, Netherlands, May 13-16, 2024

Extended Abstract, DOI: 10.59490/coastlab.2024.775

LOW-CRESTED AND EMERGENT BREAKWATERS WITH ECO-FRIENDLY ARMOUR UNITS

SERIM DOGAC SAYAR[1], IOAN NISTOR[1], SCOTT BAKER[2], JORGE GUTIÉRREZ MARTÍNEZ[3]

1 University of Ottawa, Canada, ssayar@uottawa.ca, inistor@uottawa.ca

2 National Research Council Canada, Canada, scott.baker@nrc-cnrc.gc.ca

3 ECOncrete AQUA SL, Spain, jorge@econcretetech.com

KEYWORDS: Ecosystem Enhancement, Breakwaters, Physical Modeling, Coastal Defense, Nature-Friendly Armour Units, Nature Positive Infrastructure

1 INTRODUCTION

Artificial coastal defense systems (such as concrete armour units) frequently host less diverse aquatic populations than natural environments and feature higher concentrations of invasive species (Dafforn et al., 2009). Therefore, coastal structures need to be designed or refitted to achieve sustainable goals through the application of ecological engineering solutions applied to coastal defence structures and for the ecosystem, marine habitat, and biodiversity improvement. Ecological engineering, which integrates ecosystems with engineering principles to construct coastal structures that benefit both humans and the ecosystem, is growing as a means of reducing the adverse ecological impacts of coastal infrastructure (Mitsch & Jorgensen, 2003). Thus, creating new eco-friendly breakwater design guidelines is critical and will benefit from the multidisciplinary involvement of marine biologists and ecologists.

The purpose of this experimental modelling study was to provide data on the hydraulic performance and stability of low-crested and emergent rubble mound breakwaters (RMBW) constructed using ecologically friendly armour units under various wave conditions. The University of Ottawa, the National Research Council of Canada (NRC), and ECOncrete collaborated to develop and conduct the physical testing program.

Several breakwater models were tested to evaluate their performance, as the idea of an eco-friendly breakwater is still a new area of research. Thus, this experimental program is essential to promote environmentally-friendly armour units in the design of new coastal structures (such as Baker et al., 2018), as well as ecological retrofitting of existing coastal structures. The physical tests were conducted between June 2023 and August 2023 in the Large Wave Flume of NRC's Ocean, Coastal, and River Engineering Research Center in Ottawa, Canada. ECOncrete's Coastalock armour units were tested in various configurations at a 1/15 scale using two-dimensional low-crested and emergent RMBW models. The hydraulic performance and failure mechanisms of these environmentally-friendly breakwater models were tested under severe wave conditions.

2 EXPERIMENTAL SETUP

Model testing used Froude scaling with a scale of 1:15. A model was designed (Figure 1) in which a 1:16 slope and 1:100 foreshore bathymetry slope were combined, assuming typical nearshore conditions.

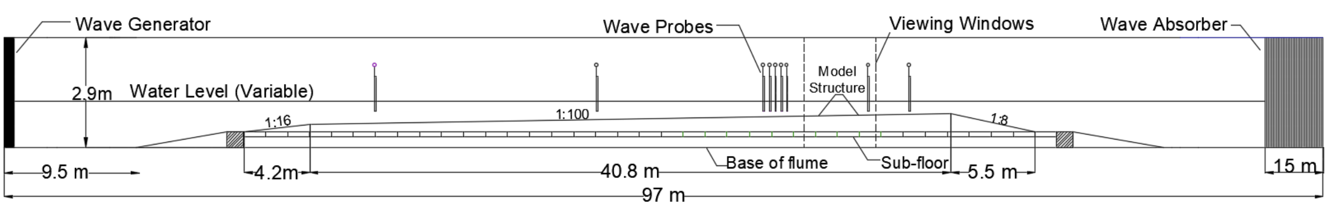

Figure 1. Experimental Setup in the Large Wave Flume at NRC-OCRE Facilities (not to scale)

Both models (low-crested and emergent RMBW) were constructed as permeable structures using core material, underlayer rocks, rock armour toe and Coastalock armour units along the sea side, crest, and lee side as shown in Figures 2 and 3. The orientation of the Coastalock units was based on the “San Diego” configuration (Molenkamp, 2022) in which the units at the bottom have their cavity positioned sideways, while the rest of the units have their cavity facing forwards, thus providing a cave and water retaining elements for the creation (in prototype) of underwater and intertidal marine habitats, respectively. Following the low-crested model tests, an emergent RMBW model, twice as high as the low-crested model (see Figure 3), was tested.

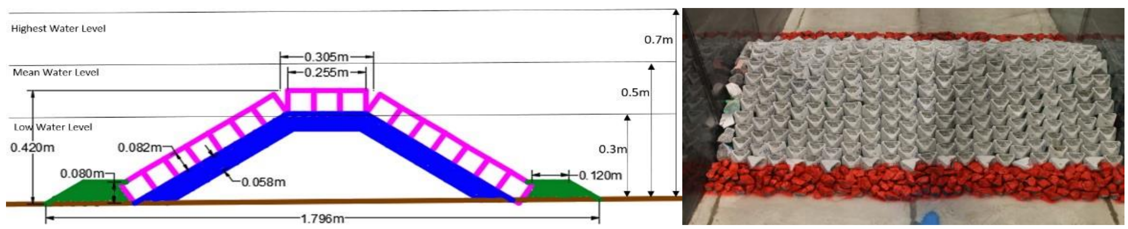

Figure 2. Low-crested Breakwater Cross-Section and Model Construction

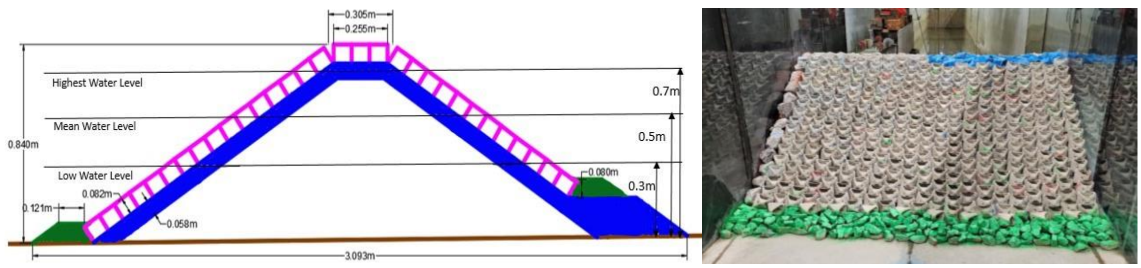

Figure 3. Emergent Rubble Mound Breakwater Cross-Section and Model Construction

During the test program, the shape and dimensions of the model cross-sections were kept constant throughout each specific test, while unit spacing and underlayer rock size were the varying parameters between the test series. Various water levels, wave heights, and wave steepness were used during the tests: wave heights ranged between Hs=1.2m and Hs=5.7m (at prototype scale) while the wave steepness ranged between s=0.025 and s=0.065.

3 TEST RESULTS AND ANALYSIS

A preliminary evaluation of the test results for the low-crested breakwater model showed significant findings. The stability analysis demonstrated that the armour units at the top part of the front slope (at the transition between the slope and the crest) were vulnerable to rocking. It was also determined that larger underlayer rocks made armour unit placement more difficult, which resulted in less-than-ideal placement and, thus, increased rocking. However, the low-crested model performed generally well in terms of stability against harsh wave conditions.

Several significant results were also obtained from the emergent RMBW model tests. It was again observed that the largest number of moving units were those placed at the top part of the front slope (at the transition between the slope and the crest) and over the entire crest. A preliminary conclusion is that a larger or modified armour unit placed on the crest may be beneficial in decreasing the number of rocking units. Moreover, the toe design was found to be critical due to the single-layer regular placement of the armour units as it was observed that displacement of the leeward toe armour may cause sliding of an entire along-slope line of armour units. However, despite significant overtopping measured during the high water level tests, the back slope units performed very well. Generally, wave overtopping, reflection, and transmission results of this model were deemed similar to those of emergent rubble mound breakwaters. Furthermore, wave transmission, reflection and overtopping results were compared to low-crested and emergent RMBW experiment data in the literature by analyzing the existing formulas (Van Gent et al.,2023; Zanuttigh and Van der Meer, 2008; EurOtop, 2018)

4 CONCLUSION

Coastalock armour unit placement, spacing, and underlayer rock size were investigated for their impact on structural stability to determine the most effective and safe design parameters and breakwater characteristics. The results of these experimental tests will offer critical information for the increasing interest in the construction of ecologically-friendly coastal structures.

Following the physical modelling study, numerical modelling is planned to model the environmentally friendly breakwater under a broad range of wave conditions using the numerical model IH2VOF (Lara et al., 2011). The next steps will also involve an evaluation of the ecological performance of these units that are currently undergoing pilot projects at the Port of San Diego (USA) and the Port of Vigo (Spain).

REFERENCES

Baker, S., Brashear, P., Tschirky, P., Marrone, J., & Larson, M., 2018. Design and Physical Model Studies of Innovative Living Breakwaters. *Coastal Engineering Proceedings*, 1, 10.9753/icce.v36.papers.59.

Dafforn, Katherine & Glasby, Tim & Johnston, Emma., 2009. Links between estuarine condition and spatial distributions of marine invaders. *Diversity & Distributions*, 15. 10.1111/j.1472-4642.2009.00587.x.

EurOtop, 2018. Manual on wave overtopping of sea defences and related structures. An overtopping manual largely based on European research, but for worldwide application. Van der Meer, J.W., Allsop, N.W.H., Bruce, T., De Rouck, J., Kortenhaus, A., Pullen, T., Schüttrumpf, H., Troch, P. and Zanuttigh, B., www.overtopping-manual.com.

Lara, J.L., Ruju, A., Losada, I.J., 2011. Reynolds averaged Navier–Stokes modelling of long waves induced by a transient wave group on a beach. *Proceedings of the Royal Society*, A 467, 1215–1242.

Mitsch, William & Jørgensen, S.E., 2003. Ecological engineering: A field whose time has come. *Ecological Engineering*, 20. 363-377. 10.1016/j.ecoleng.2003.05.001.

Molenkamp, A., 2021. Hydraulic performance of CoastaLock armour units (thesis).

van Gent, M.R.A., Buis, L., van den Bos, J.P. and Wüthrich, D., 2023. Wave transmission at submerged coastal structures and artificial reefs. *Coastal Engineering*, 184, 104344

Zanuttigh, B., Van der Meer, J.W., 2008. Wave reflection from coastal structures in design conditions. *Coastal Engineering*, 55, 771–779