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REEFENSE: DESIGN OF A POROUS MODULAR HYBRID REEF FOR COASTAL PROTECTION

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1 INTRODUCTION

Hybrid artificial reef structures can be designed to promote the development of a self-sustaining habitat for reef organisms while simultaneously enhancing the extent to which they provide coastal protection. Such hybrid structures offer many additional ecosystem benefits over conventional engineering structures that are used to provide coastal protection. Here, we investigate the wave attenuation capacity of engineered oyster reef modules that have been designed through the DARPA initiative Reefense: A Mosaic Oyster Habitat for Coastal Defense. The modules are designed with significant porosity (through misaligned holes), shelves to facilitate oyster recruitment, and an interlocking mechanism to maximise reef stability.

2 REEF MODULES

Reefs were constructed from concrete modules designed by Reef Design Lab (Figure 1). On the prototype scale, they are 60 cm high, with a 60 cm basal diameter and 6-15 cm holes in all sides. The misaligned holes prevent straight line water paths through the module to enhance drag dissipation. In addition to the default reef module design, two shorter module designs (45 cm and 30 cm in height on the prototype scale) were employed to create height variations in the reef arrays tested.

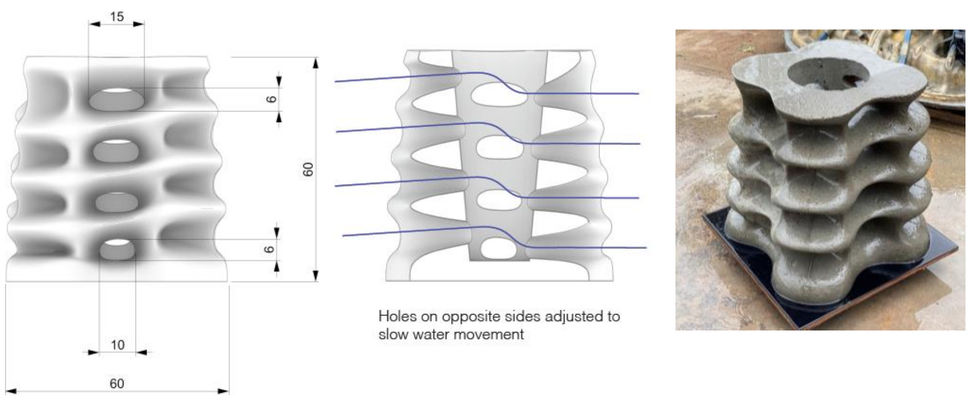

Figure 1. Left: Side view of the reef modules with prototype dimensions (in centimeters); Middle: The misalignment of holes in the modules to enhance drag dissipation; Right: A concrete reef module at prototype scale.

3 EXPERIMENTAL TESTING

Reduced scale (1:2) physical model testing of numerous modular reef layouts was conducted in the 54-m-long wave flume at the University of Western Australia's Coastal and Offshore Research Laboratory (Figure 2). A piston-type wave maker with active absorption was used to generate both regular and irregular wave conditions, with test conditions spanning a range of wave heights, periods and water depths. The number and spacing of module rows as well as the height and porosity of modules varied across each layout tested to investigate how module arrangement can influence attenuation. Wave heights, velocities and force time series were measured across each reef to quantify the attenuation of wave energy by dissipation due to both wave breaking and drag forces.

Figure 2. Left: Top view of a reef consisting of interlocking, porous modules; Middle: A reef consisting of full height scaled modules in the wave flume; Right: A modified layout with varying module heights.

4 RESULTS

The transmission (K_t), reflection (K_r) and attenuation (K_a) coefficients were calculated for each reef using the decomposed transmitted (H_t), offshore incident (H_i) and reflected wave heights (H_r):

$$K_t = H_t / H_i \quad (1)$$

$$K_r = H_r / H_i \quad (2)$$

$$K_a = \sqrt{1 - K_t^2 - K_r^2} \quad (3)$$

Wave transmission across the reef was strongly governed by the dimensionless relative freeboard, the mean water depth above the top of the reef (R_C) normalised by the offshore incident wave height (Figure 3). The attenuation of wave height along the reef was dominated by dissipative processes, due to both drag forces associated with the porous modules and wave breaking, with wave reflection making only a minor contribution. Over a broad structural and hydrodynamic parameter space, predictive tools have been developed to quantify wave attenuation over the modular reefs. Such tools will enable the development of design guidelines for modular porous hybrid reef structures as nature-based solutions for coastal protection.

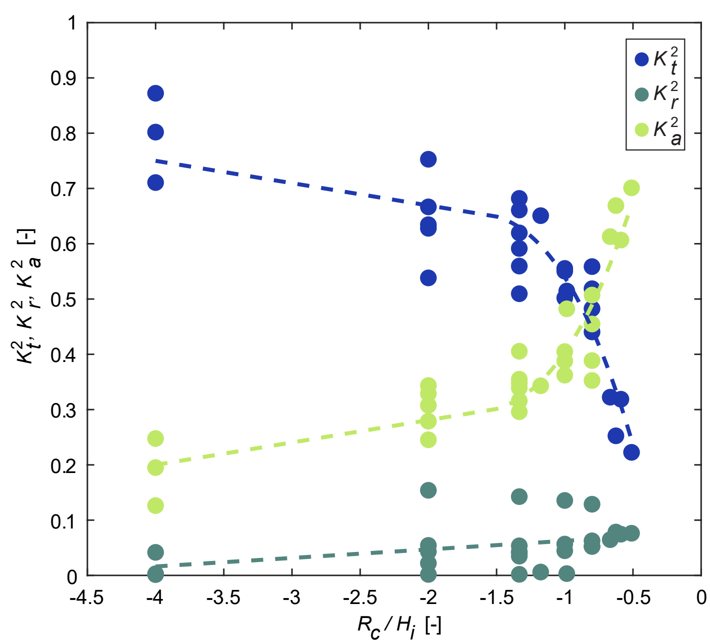

Figure 3. The impact of relative freeboard on the fraction of wave energy transmitted over 5-row model reefs.