WAVE TRANSMISSION OVER A WIDE NEARSHORE REEF

Saeed Valikchali, Baird, svalikchali@baird.com
Patrick Joynt, Baird, pjoynt@baird.com
Mohammad Dibajnia, Baird, mdibajnia@baird.com
Jarrod Dent, Baird, jdent@baird.com

INTRODUCTION

The coastal engineering community is experiencing increasing willingness from stakeholders to consider the broader benefits of green solutions over historic grey solutions, which were often associated with lower construction cost, for mitigating shoreline erosion. This has allowed for the opportunity to investigate the effectiveness of nearshore reefs on mitigating shoreline erosion.

As a shoreline erosion mitigation measure, nearshore reefs have attracted increasing attention. Nearshore reefs are wide submerged porous structures with mild natural slopes constructed in shallow nearshore waters. These reefs mitigate shoreline erosion by managing wave energy through a variety of wave transformation processes (e.g., refraction and energy dissipation through breaking and internal turbulence and friction). Wave attenuation over solid impermeable structures have been widely studied (e.g., Gurley 1994; Chella et al., 2015; Lowe et al., 2022). On the other hand, details of wave transformation over wide porous reef structures and the corresponding rate of wave energy dissipation are yet to be understood. The goal of this study is to develop a better understanding of how waves interact with porous nearshore reefs using Computational Fluid Dynamics (CFD).

NUMERICAL MODEL

A solid model of the porous reef was generated using Blender, an open-source visualization software, as shown in Figure 1. Approximately 20,000 stones from 14 unique shapes were stacked randomly to generate the reef with a 5H:1V outer slope followed by a long flat crest.

The CFD model was developed using OpenFOAM, an open-source CFD package produced by OpenCFD Ltd. As shown in Figure 2, the model consists of the solid reef represented as an STL surface, an impermeable beach at the end of the domain for natural wave absorption, and an offshore area to propagate incoming waves from the offshore boundary to the toe of the structure. In the present work, 18 scenarios of monochromatic waves were studied. Modelled cases included combinations of two wave heights, two wave periods, four water levels, and three reef thicknesses. The offshore section of the model as well as the flat part of the reef were designed to a length to account for at least one wavelength for each wave period investigated.

RESULTS

The model has been calibrated and validated against a laboratory study of an impermeable reef (Gurley, 1994). As shown in Figure 3, the numerical result shows good agreement to the experimental data.

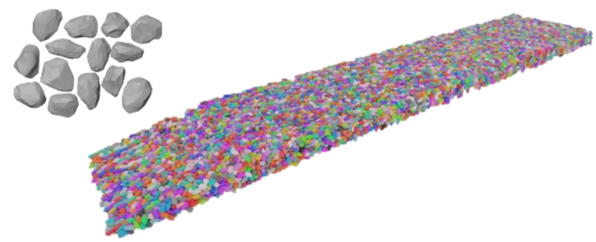

Figure 1 - Solid model of generated porous reef

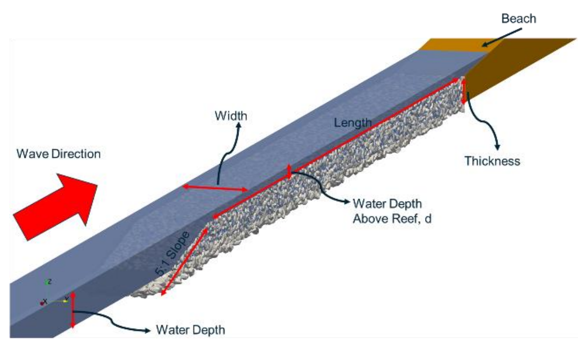

Figure 2 - Schematic of the CFD numerical flume

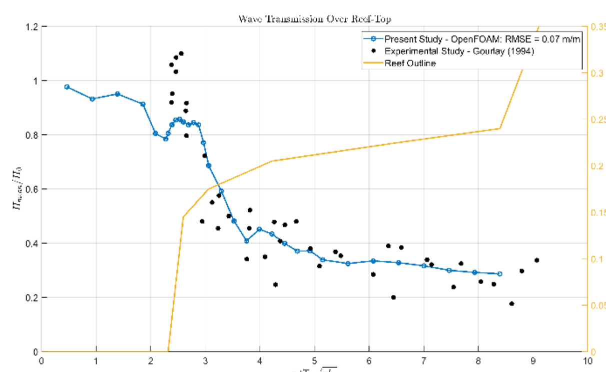

Figure 3 - Comparison of the CFD result to experimental data of Gourlay (1994)

As an example of the results, wave transformation over the reef represented by normalized significant wave height is presented in Figure 4 for the two studied wave periods of 4.5 sec and 9 sec. As seen, wave breaking occurs just after the crest of the reef and a recovery wave starts to form after the turbulent energy caused by wave breaking reduces. The 4.5 sec wave requires about 45 m (i.e., approximately 1.5 deep-water wavelengths) to reach 65% wave height attenuation, while the 9 sec wave reaches the same amount of attenuation in 100 m (i.e., after less than one deep-water wavelength). This indicates that under practical wave conditions, a distance of 0.5 to 1.5 wavelengths (depending on wave period) is required to achieve wave recovery (i.e., zero dissipation) over the porous reef.

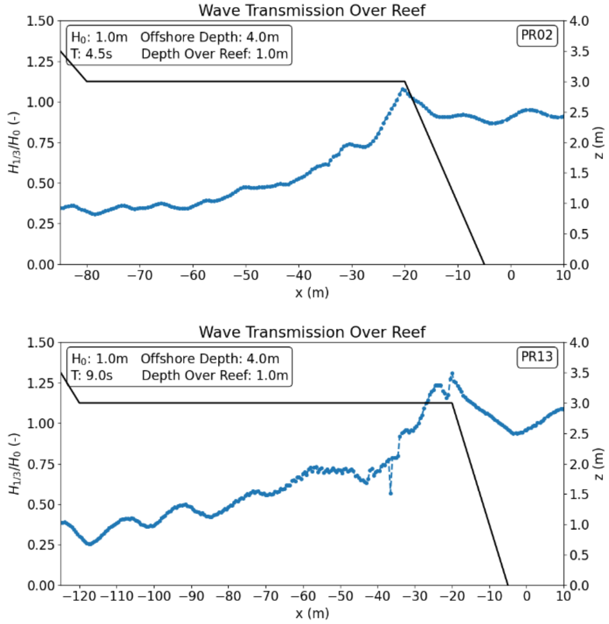

Figure 4 - Wave transmission over the reef for wave period of 4.5 s (top), and 9 s (bottom).

The ratio of wave height to water depth above the reef (H_0/d) was found to be an important parameter explaining wave energy dissipation on the reef. Figure 5 shows predicted wave heights at the shore-end of the reef normalized and plotted against the H_0/d ratio. Assuming a breaking index of 0.8 for monochromatic waves, the dashed line in this figure separates wave conditions that are expected to break over the reef from non-breaking conditions ($H_0/d < 0.8$).

Figure 5 indicates that wave attenuation varies from 40% to 80% depending on reef configuration and wave conditions. A 40% to 60% attenuation is predicted for non-breaking waves. This is attributed to resistance against the wave-induced flow through the porous reef structure. This finding is important as reef structures are often considered not suitable for coastal environments with variable water levels (as waves can transmit over the reef without breaking when the water level is high). The above results indicate that significant wave attenuation can be achieved over a wide reef even when water levels are high.

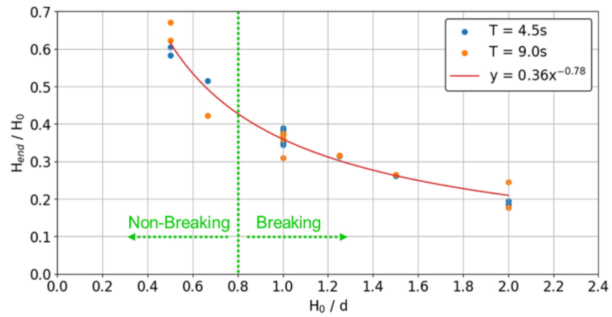

Figure 5 - Predicted wave heights at the shore-end of the reef.

REFERENCES

Gourlay (1994): Wave transformation on a coral reef. Coastal engineering, 23(1-2), pp. 17-42.

-

Chella, Bihs, Myrhaug (2015): Characteristics and profile asymmetry properties of waves breaking over an impermeable submerged reef. Coastal Engineering, 100, pp. 26-36.

Lowe, Altomare, Buckley, da Silva, Hansen, Rijnsdorp, Domínguez, Crespo (2022): Smoothed Particle Hydrodynamics simulations of reef surf zone processes driven by plunging irregular waves. Ocean Modelling, 171, p. 101945.