

MEASUREMENT AND CFD MODELLING OF A FLOATING PARABOLIC BEACH SHAPED BREAKWATER

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INTRODUCTION

Offshore aquaculture systems require protection from extreme seas and swell waves. Floating wave breakwaters are generally ineffective for long waves and transmission coefficients increase rapidly as wave steepness decreases (Dai et al., 2018, Zheng et al., 2018). This paper outlines the development of a novel floating breakwater, which self-adjusts to form a parabolic beach shape, inducing energy loss through wave breaking. The beach shape can be easily altered through ballast. A small-scale physical model is developed, and measurements of transmission coefficients are compared to a CFD (Flow3D) model of the breakwater. Different breakwater lengths, and mooring depth are examined. Transmission coefficients are plotted versus Iribarren number and compared well between laboratory and CFD model. The full presentation will present full details of the models and discuss scaling the model results to natural full-scale conditions.

METHODOLOGY - PHYSICAL MODELLING

Offshore floating breakwaters must not only reduce wave transmission but must be very robust. The breakwater concept therefore utilises the same materials presently in use, with the aim of recycling the HDPE circular section pipes discarded by the Aquaculture industry, which are typically 0.5-0.8m in diameter with a wall thickness of 0.01m. This contrasts with conventional designs which use steel pontoons, nets or bespoke plastic shapes. Existing designs generally have the form of a Box, Pontoon, Mats, Tethered array of floats, or a Spar buoy. Here, a scaled conceptual design for a Floating Wave Breakwater Model was developed and a 1:20 to 1:50 scaled physical model ($N_L=20, 50$) was constructed using off-the-shelf agricultural polyethylene irrigation piping tubes, Figure 1.

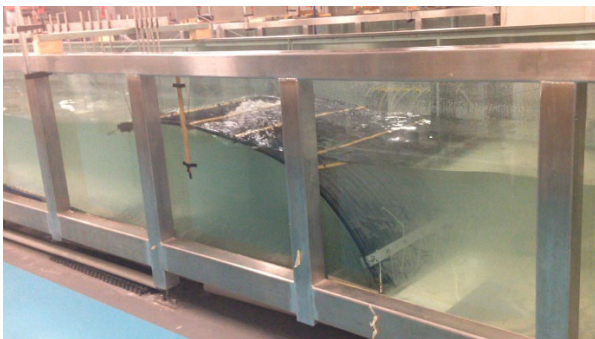


Figure 1 - Elevation view of the physical model of the bottom-mounted floating breakwater in the 1m wide UQ wave flume. The toe of the beach is hinged at the flume floor. The tubes are fully filled with air in this example but can be ballasted with sand or water to alter the buoyancy.

In the model the circular tubes had an external diameter of 0.023m and wall thickness 0.002m, material density 950kg/m³, flexural stiffness $EI = 0.0073 \text{ kN.m}^2$, with $E = 1.10^6 \text{ kN/m}^2$ (HDPE), $I = 7.34 \times 10^{-9} \text{ m}^4$. This corresponds to

The physical model was tested in two 20m long wave flumes (1m width and 2m width) with dissipative sand beaches at the down wave end. Different mooring configurations, different lengths of beach and different degrees of ballast were investigated, focusing on transmission coefficients. The different lengths included extension to the flume bed, representing shallow-water conditions, and deep-water conditions, with the beach extending two to three wave heights below the water surface. The flume arrangement and instrumentation are illustrated in Figure 2.

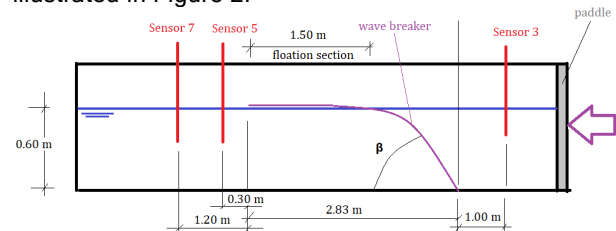


Figure 2 - Elevation view of the wave flume and general arrangement of wave gauges.

Wave conditions comprised monochromatic and random waves with active wave absorption, with wave heights ranging from 0.05m-0.15m, and wave periods from 0.6s-2s. The stiffness of the pipes in the physical model is compared to those at prototype scale through Euler beam theory and Cauchy scaling, where $EI \frac{d^4y}{dx^4} = w(x)$ where y is the displacement, x the horizontal coordinate and $w(x)$ is the net buoyancy force per unit length. Correct scaling of the stiffness requires $N_{EI} = \frac{[EI]_p}{[EI]_m} = N_L^3$. $N_L^2 = N_L^5$. With $E_p = E_m$ (same material) the flexural stiffness of the model corresponds to that of the commercial HDPE pipes of 0.6-1m diameter and wall thickness 20-40mm.

METHODOLOGY - CFD MODELLING

A 2-D model of the floating breakwater was modelled in FLOW3D, using a rigid model with solid HDPE tubes and with a density corrected to match the hollow tubes in the laboratory. The model shape was set to match that naturally adopted by the laboratory model in still water. Rotation about the bed or mooring system was enabled to match that in the laboratory model. The CFD model details were as follows: Up to 600s simulation time, monochromatic and random waves, 1:10 sloping beach,

moving Floating Breakwater 6-deg of freedom, lateral boundaries set to Wall, Paddle boundary set to Wave (regular waves) or Moving Object (random waves), 0.01 and 0.02m cell size, with the timestep configured within the model. An example screenshot of a random wave model run is given in Figure 2.

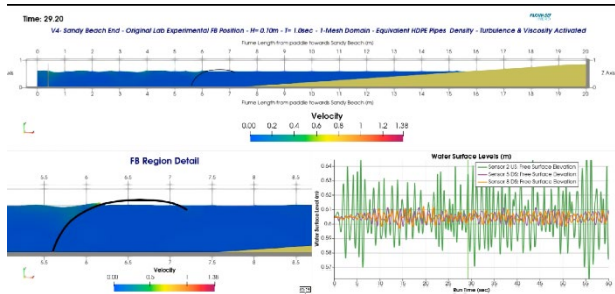


Figure 2 - Snapshot of CFD simulation for random waves and bottom mounted breakwater.

RESULTS

Figure 3 compares the measured and modelled transmission coefficient for different Iribarren numbers. The Iribarren number is determined from the slope of the beach at the wave breakpoint, taken as $d=0.8H$. The parabolic beach floating breakwater has much lower transmission coefficients than those found for conventional floating breakwaters (Dai et al., 2018, Zheng et al. 2018), as previously presented by Fernandez et al. (2020). This is particularly true for long-period waves, provided they break. The key difference between this breakwater and conventional floating breakwaters is the forcing of breaking, runup and overwash by the parabolic beach shape, which is the most effective shape for the dissipation of wave energy through breaking (Power et al. 2013).

The trends in k_t predicted by the FLOW3D simulation match well with the laboratory results but are slightly smaller than the laboratory results for this set of tests. Taking a range of simulations together, the model results compare well with the laboratory data overall, figure 4, with little bias.

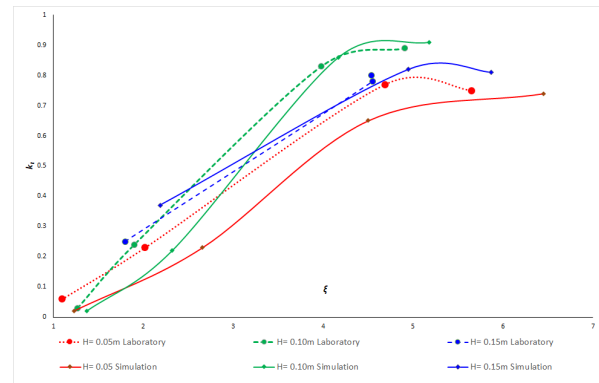


Figure 3 - Measured versus modelled transmission coefficients for different Iribarren numbers.

The rigid CFD model performs well despite being a simplification of the flexible laboratory model, and correlates well with the measurements. This is because the breakwater is hinged at the bottom, and the shape is not significantly distorted by the wave-breaking process, particularly for a mid-depth mooring. This is checked through comparing the angle of the breakwater at the breakpoint in the physical model and CFD model (not shown). The efficacy of making a flexible pipe model in FLOW3D is being investigated. The full paper will provide further details and the results of alternate configurations including a half-depth breakwater with taught mooring lines applicable in deeper water.

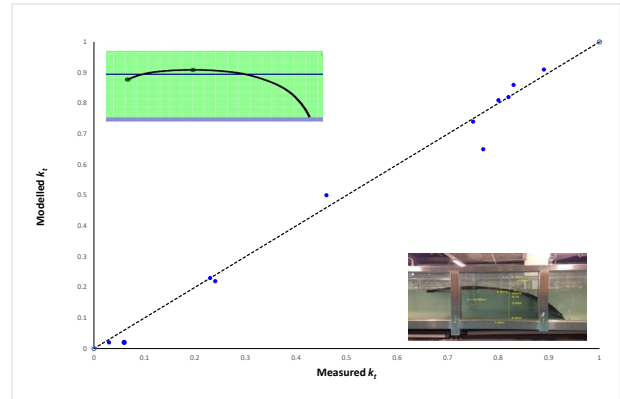


Figure 4 - Measured versus modelled transmission coefficients.

CONCLUSIONS

A physical model of a novel floating breakwater and a CFD model of the breakwater have been compared. The breakwater naturally adopts a parabolic shape, which is the most efficient shape for dissipation by wave breaking. FLOW3D provides a practical basis to model the system, with a close correlation between transmission coefficients from the physical model and numerical simulation. Design options and details of scaling up to prototype scale will be discussed in the full paper.

REFERENCES

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