EXPERIMENTAL STUDY ON WAVE OVERTOPPING ON BREAKWATERS CO-LOCATED WITH SEAWEED AQUACULTURE SYSTEMS

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ABSTRACT
Coastal areas are expected to be subject to continuous and increasing pressure, both from world population growth and climate change. By nature, coastal areas are highly desirable and currently most densely populated and fastest growing urban areas are located near the coastline (McMichael et al., 2020). Furthermore, coastal communities and ecosystems are increasingly vulnerable to coastal hazards due to the sea-level-rise (Oppenheimer et al., 2019). Hard protection measures such as breakwaters, seawalls, and dikes, are widespread. However, soft protection measures have shown to offer a plethora of advantages, such as their flexibility and adaptability to varying maritime conditions.

Wave energy dissipation on vegetation fields has received extensive attention from the scientific community, and vegetation is known to play a vital role on coastal protection, representing the foundation for potential nature-based solutions (NBS). However, numerical and physical modelling studies on wave overtopping reduction due to the presence of vegetation fields is scarce, and the existing literature are mostly focused on bottom fixed vegetation (Zhao et al., 2022).Recently, the AquaBreak project proposed the Aquabreak offshore system (AOS), an offshore longline seaweed aquaculture system to serve both for harvesting and coastal protection. The objective of the current study is to evaluate the wave overtopping on rubble mound breakwaters co-located with the AOS under the Portuguese maritime conditions. Previous physical modelling studies on wave reduction on the AOS revealed that the AOS is capable of reducing the wave heights up to 45% (Miranda et al., 2024). The physical modelling campaign of the current study was performed in the wave-flume of the Hydraulics laboratory at the Faculty of Engineering of the University of Porto, on a 1:40 model scale. The wave-flume is 29 m long and 1m wide and is equipped with a wave generation system capable of reproducing regular and irregular wave fields. The AOS physical model consists of multiple horizontal 1 m long lines with 80 individual polyurethane stripes, representing the seaweed, fixed at 0.05 m (2 m in prototype) below the water surface (see Figure 1).

Figure 1 - Suspended offshore longline seaweed aquaculture system physical model.

The conditions tested were chosen based on historical wave data near the Portuguese coast, taking into consideration the constraints of the wave flume. The overtopping conditions were evaluated for an isolated breakwater and subsequently repeated the tests with the breakwater coupled with 3 different extents of the AOS. The tested conditions can be found in Table 1.

Table 1 – Wave conditions tested (model scale).

#	Significant wave height (m)	Peak period (s)	Nº of Waves
1	0.12	1.7	1000
2	0.13	1.7	
3	0.14	1.7	
4	0.13	2.2	
5	0.13	2.5	

A generic rubble mound breakwater model was built inside the flume with a height of 0.52 m. The wave overtopping was measured by channeling the overtopping events through a metal gutter to a calibrated reservoir (see Figure 2). A wave probe was placed inside the reservoir to quantify the variation of the water surface elevation. Additionally, a wave probe was placed above the breakwater to capture the number of overtopping occurrences.

Figure 2 - Overtopping measuring set-up.

The results of the current study showed that the presence of the AOS can significantly reduce the number and severity of the overtopping events under severe maritime conditions. Furthermore, it gave insights on the potential benefits of the coupling the AOS with existing breakwaters on the Portuguese coast. Overall, this study highlights the potential of sustainable NBS, such as suspended seaweed aquaculture systems, for coastal protection.

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