HYBRID MODELLING OF SUBMERGED RUBBLE-MOUND BREAKWATERS AS PASSIVE HARMONIC FILTER FOR SELECTIVE WAVE TRANSMISSION

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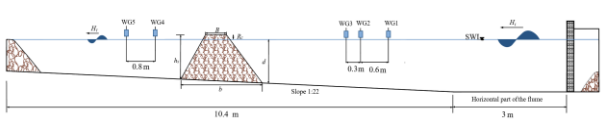
ABSTRACT

Coastal regions have always been alluring places for settlements due to their proximity to the ocean, abundant natural resources, and the high quality of life they provide. Nevertheless, these areas face various vulnerabilities, including the effects of climate change like rising sea levels, storm surges, and more frequent extreme weather events. Rubble-mound breakwaters are commonly used as protective structures along the coast, but recent years have brought significant challenges due to climate change and growing environmental concerns. Coastal communities and managers are now seeking solutions that are more sustainable and have fewer impacts on the landscape and ecology. These demands are reshaping the conventional approach to designing these structures. To address these challenges, it is necessary to adapt breakwaters to meet present, future, social, and environmental expectations.

Several studies indicate that the large change in the hydro-morphodynamic beach response is a result of the nearshore combination within the wave groups specifically the effective maximum wave height and the presence of free and forced long waves induced by the groupiness, rather than just the energy content (Baldock et al. [2011]; Vicinanza et al. [2009]).

Tuning the filtering capacity of submerged breakwaters opens interesting scenarios for traditional coastal engineering. Emerged breakwaters, or traditionally conceived semi-emerged rubble-mound breakwaters, are considered unsustainable in the future since they are non-permeable, causing water stagnation and anoxia, biodiversity reduction, and disruption of natural nearshore littoral transport. In addition, they are found to be unadaptable, necessitating continuous maintenance or rebuilding over time (Bridges et al. [2013]; Narayan et al. [2016]; McLachlan and Brown. [2006]).

This study aims to propose alternative solutions, building on the concept that it is possible to "tune" the wave transmission to get the desired beach response. To achieve this objective, a combination of physical and numerical investigations was conducted. Physical experiments were carried out in a wave flume that has dimensions of 13.4 meters in length, 0.8 meters in width, and 0.6 meters in depth. Different designs of breakwaters were constructed using crushed stones. Figure 1 shows the plan and cross-section of the wave flume that was utilized.



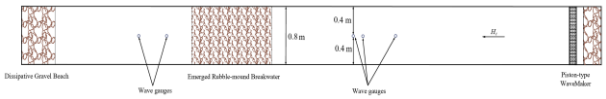


Figure 1. Plan and cross-section of the wave flume and experimental set-up

Different wave climates were employed for the tests, and the harmonic filter hydraulic performance of these breakwater configurations was assessed by analyzing wave transmission (K_t), wave reflection (K_r), and wave energy dissipation (K_d) coefficients against various geometric parameters for different wave conditions.

Figure 2 shows the results from the analysis of the average wave transmission coefficient underscoring the significance of considering diverse wave climates when assessing breakwater performance. The findings highlight the potential of a selective passive filter that can effectively suppress specific harmonic frequencies. When appropriately calibrated, this filter can significantly attenuate storm waves, while allowing poor/mild wave conditions to pass the barrier, thus preventing water stagnation.

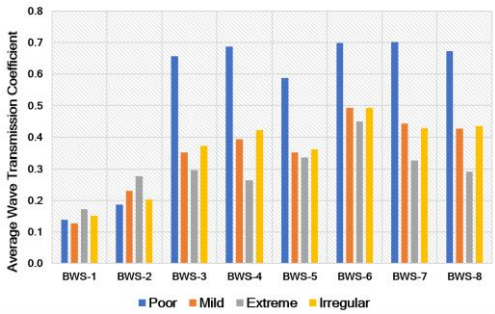


Figure 2. Effect of different wave climates on the average transmission coefficient for breakwater structures

The study relies on a two-dimensional numerical investigation performed using the IH2VOF method. This investigation aims to gain a better understanding of each configuration's behavior regarding wave-structure interaction.

In summary, this comprehensive analysis seeks to provide valuable insights for coastal engineers and researchers interested in optimizing this passive harmonic filter to meet more sustainable and effective coastal protection structures. Additionally, the findings of this research will give engineers a deeper understanding of how breakwaters function and operate in a changing climate.

REFERENCES

Baldock, T. E., Alsina, J. A., Caceres, I., Vicinanza, D., Contestabile, P., Power, H., & Sanchez-Arcilla, A. (2011): Large-scale experiments on beach profile evolution and surf and swash zone sediment transport induced by long waves, wave groups and random waves. Coastal Engineering, 58(2), 214-227.

Bridges, T., Henn, R., Komlos, S., Scerno, D., Wamsley, T., and White, K. (2013): Coastal risk reduction and resilience: using the full array of measures. Washington, DC.

McLachlan A, Brown A. (2006): Human impacts. The ecology of sandy shores, 273-301.

Narayan, S., Beck, M. W., Reguero, B. G., Losada, I. J., Van Wesenbeeck, B., Pontee, N., and Burks-Copes, K. A. (2016): The effectiveness, costs and coastal protection benefits of natural and nature-based defences. PloS one, 11(5), e0154735.

Vicinanza, D., Cáceres, I., Buccino, M., Gironella, X. and Calabrese, M., (2009): Wave disturbance behind low-crested structures: Diffraction and overtopping effects. Coastal Engineering, 56(11-12): 1173-1185.