Experimental testing of wave transmission coefficients for oyster shell-filled bag berms

Amanj Rahman, Nation Research Council Canada, Amanj.Rahman@nrc-cnrc.gc.ca
Mitch Provan, Nation Research Council Canada, Mitch.Provan@nrc-cnrc.gc.ca
Enda Murphy, Nation Research Council Canada, Enda.Murphy@nrc-cnrc.gc.ca

INTRODUCTION

Climate change and rising sea levels pose a significant risk of extreme flooding and erosion in coastal zones, requiring adaptation to make the shorelines more resilient. Berms composed of oyster shell filled-bags have been implemented at shorelines in western Canada (Provan et al., 2023) and in the United States (Milligan et al., 2018; Spiering et al., 2021; Wellman et al., 2021, among others) to provide a nature-based solution to reduce shoreline erosion or help stabilize restored salt marshes. However, there is limited available information on the performance and ability of these oyster shell berms in terms of wave attenuation. Previous experimental studies have been conducted to address this lack of information (Allen and Web, 2011; Coghlan et al., 2017); however, the studies were limited in tested wave conditions and sizes of the tested oyster shell filled-bags. To address this, a series of full-scale (1:1) physical model experiments were carried out to investigate the wave attenuation ability of oyster shell bags for different bag sizes and configurations.

EXPERIMENTAL SETUP

Experimental tests were conducted in the Large Wave-Current Flume (LWCF) at the National Research Council of Canada's Ocean, Coastal, and River Engineering Research Center. Approximately 500 kg of empty oyster shells were collected from a local restaurant and prepared for testing. The empty shells were weighed to the appropriate target (10, 15, or 20 kg) and were placed into a biodegradable mesh biopolymer bag. The filled bags had a consistent length of 0.5 m, a height of approximately 0.2 m. Since the length and height of the filled bags were fixed, the width of the filled bags (approximately 0.15 m, 0.22 m, and 0.3 m) varied based on the target mass of the bag. Filled bags of the same mass were arranged in either a 3-bag or 5-bag berm (see Figure 1) and were placed in the testing section of the flume. A non-erodible concrete bathymetry with a mild 1:100 slope was constructed offshore of the testing section. The berms were tested at three different water depths at the toe of the berm (0.2 m, 0.4 m, 0.6 m). At each water depth, the berm was exposed to significant wave heights (H_s) ranging from 0.05 m to 0.35 m (depending on the water depth), and peak wave periods (T_p) of 1.5 s, 2.5 s, and 3.5 s. Capacitance style wave probes were used to measure the wave conditions both up-wave and down-wave of the oyster shell filled-bag berms to document the wave attenuation ability of each berm design.

Figure 1 – Test setup of the 20 kg bags in a 5-bag berm orientation; top – view through the flume windows, bottom – view from above.

RESULTS

A wave transmission coefficient, K_T, was calculated based on the measured wave conditions for each test. Figure 2 provides calculated K_T values for a significant wave height of 0.2 m with varying wave periods at a water depth of 0.4 m and 0.6 m. From Figure 2 it can be seen that all of the tested berm setups were more effective at attenuating wave energy at the 1.5 s peak wave period compared to the 3.5 s period tests and the wider 5 bag berms were more effective at attenuating wave energy compared to the narrower 3 bag berms. This is similar pattern to that observed for low crested breakwaters (Van de Meer et al., 2005). The minimum K_T value, and therefore highest amount of wave attenuation, from the H_s = 0.2 m tests was

K_T = 0.48 for the 5-bag berm composed of 20 kg bags at the 0.4 m water depth. Also similar to that of low crested breakwaters, increasing the water depth or submergence of the berm reduced the ability of the berm to attenuate wave energy. The largest value of K_T from the H_s = 0.2 m tests was K_T = 0.99 and was observed from the 3-bag berm composed of 10 kg bags at the 0.6 m water depth.

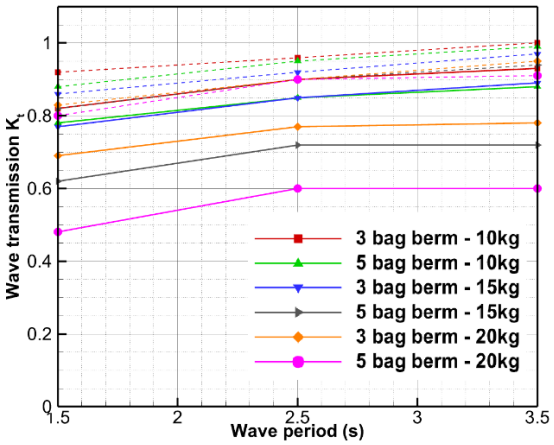

Figure 2 – Measured wave transmission coefficients (K_t) for a significant wave height of 0.2 m with varying wave periods. Solid lines represent results from a 0.4 m water depth at the berm toe and dashed lines represent results from a 0.6 m water depth.

This study will provide guidance on the wave attenuation performance of each configuration under the various tested water depths and wave conditions and provide comparisons to field and other experimental data where applicable. This will provide valuable insight to practitioners when designing oyster shell filled-bag berms for shoreline protection.

REFERENCES

Allen and Webb (2011). Determination of Wave Transmission Coefficients for Oyster Shell Bag Breakwaters, Proceedings Coastal Engineer Practice 2011.

Coghlan, Glamore, Howe and Felder (2017). Innovative Ecological Engineering: Two-Dimensional Physical Modelling of Oyster Shell Filled Bags for Coastal Protection, Proceedings Coasts & Ports 2017 Conference.

Milligan, Hardaway, and Wilcox (2018). Oyster Bag Sill Construction and Monitoring at Two Sites in Chesapeake Bay, Gloucester Point, VA: Virginia Institute of Marine Science.

Provan, Murphy, Rahman, Morris, and Matfin (2023): Experimental Study of Wave and Sediment Interactions with Edge Treatment Features on a Living Dyke, Proceedings of Coastal Sediments 23, New Orleans, USA.

Spiering, Kibler, Kitsikoudis, Donnelly, and Walters (2021). Detecting hydrodynamic changes after living shoreline restoration and through an extreme event using a Beofre-After-Control-Impact experiment. Ecological Engineering (169), 106306.

Van der Meer, Briganti, Zanuttigh and Wang (2005). Wave Transmission and Reflection at Low-Crested Structures: Design Formulae, Oblique Wave Attack, and Spectral Change. Coastal Engineering, 52, 915-929.

Wellman, Baillie, Puckett, Donaher, Trackenberg, and Gittman (2021). Reef design and site hydrodynamics mediate oyster restoration and marsh stabilization outcomes. Ecological Applications (32), e2506.