REVIEW OF WAVE ATTENUATION BY ARTIFICIAL OYSTER REEFS BASED ON EXPERIMENTAL ANALYSIS

Wei Xu, Hohai University, weixu123@hhu.edu.cn; Aifeng Tao, Hohai University, aftao@hhu.edu.cn; Jun Fan, Hohai University, fanjun@hhu.edu.cn; Chao Wu, Hohai University, 644647386@qq.com; Yanqun Li, Hohai University, liyanqunjy@163.com

INTRODUCTION

Oyster reefs-based soft coastal protection has emerged as a sustainable solution (Xu et al., 2023). However, it is difficult to quantify the wave attenuation of oyster reefs due to their different reef types, special spatial structures, rich voids and rough surfaces (Kitsikoudis et al., 2020). In addition, the wave attenuation mechanism is nonetheless doubtful due to the comprehensive outcomes of wave reflection, overtopping, breaking and frictional dissipation (Leone and Tahvildari, 2023). This paper focuses on the research progress and problems of wave attenuation by artificial oyster reefs, and presents the outlook.

OYSTER REEFS AS NATURAL BREAKWATERS

Common reefs for oyster larvae settlement and growth encompass Reef Balls, Oyster Shell Bags, Shell Gabions, Oyster Castles, Reef BLK, Wave Attenuation Devices (WAD), Oyster Breaks, ShoreJax, and Diagonal stone piles (Fig. 1). It is really worth noting that the reef shape itself already resembles a breakwater, and as the oysters grow, the reef surface roughness increases, which will enhance the attenuation of waves. At the same time, the original geometry will be changed in both horizontal and vertical directions. This results in a dynamic adjustment with sea level rise unlike traditional hard submerged dikes, effectively slowing coastal erosion.

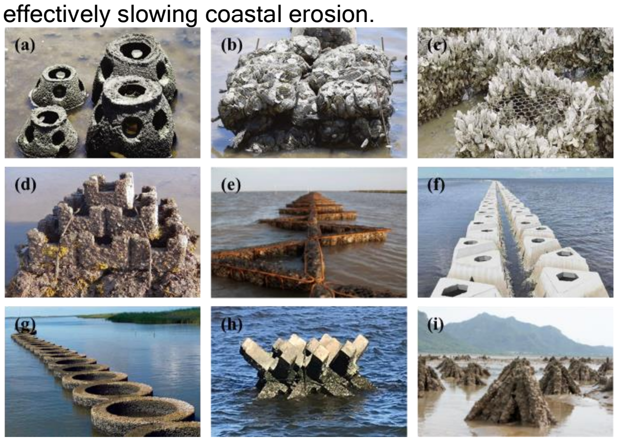

Fig. 1. Different artificial oyster reefs. (Photo credits: (a) Reef Balls; (b) Oyster Shell Bag; (c) Shell Gabions: Bersoza Hernández et al., 2018; (d) Oyster Castles: Stephanie Kiriakopolos; (e) Reef BLK: Beth Maynor Young; (f) WAD: Sea & Shoreline, LLC; (g) Oyster Breaks: Wayfarer Environmental Technologies; (h) ShoreJax: Shoretec; (i) Diagonal stone piles: Jun Cheng).

WAVE ATTENUATION BY ARTIFICIAL OYSTER REEFS

The dimensionless height h_s/d and dimensionless crest width B/H_i are viewed to be essential parameters affecting the wave attenuation (Dattatri et al., 1978). Relative water depth d/H_i and relative freeboard d_s/H_i (Bleck and Oumeraci, 2003) have additionally been proposed by using some researchers to make a contribution to wave transmission. In this section, the effects of oyster reef dimensionless height h_s/d, dimensionless crest width B/Hi and different reef types on wave attenuation are analyzed primarily based on preceding physical model experiments.

Influence of dimensionless height h_s/d

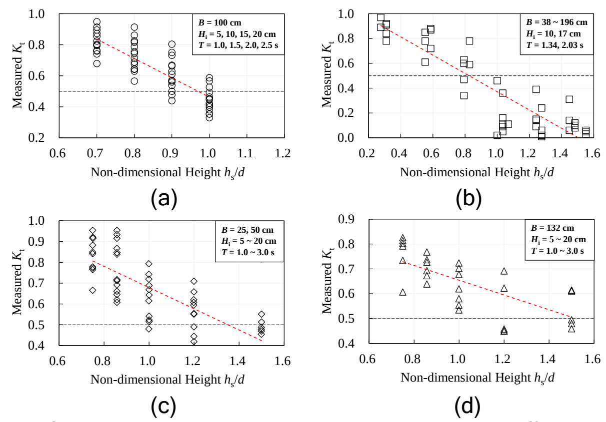

Fig. 2. Relationship between wave transmission coefficient K_t and dimensionless height h_s/d of typical oyster reefs ((a) Reef Balls (Armono and Hall, 2003); (b) Oyster Shell Bag (Allen and Webb, 2011); (c) WAD (Webb and Allen, 2015); (d) Reef BLK (Webb and Allen, 2015)).

Fig. 2 shows the relationship between the wave transmission coefficient K_t and the dimensionless height h_s/d of four typical artificial oyster reefs, such as Reef Balls, Oyster Shell Bag, WAD, and Reef BLK. Although the width, wave height and wave period of the four reefs tested are different, in general, the wave transmission coefficient decreases as the dimensionless height of the reef increases. When the dimensionless height is less than 0.8, the transmission coefficient is basically greater than 0.6, while the wave transmission coefficient less than 0.5 basically takes place when the dimensionless height is larger than or equal to 1.0, indicating that the wave attenuation effect of the reef below the water surface is relatively poor. The conclusion of Morris et al. (2021) additionally confirms this point.

Influence of dimensionless crest width B/H_i

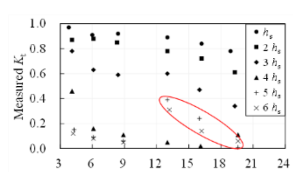

Fig. 3. Relationship between wave transmission coefficient K_t

and dimensionless crest width B/H_i of Oyster Shell Bag (Allen and Webb, 2011).

Fig. 3 shows the variation of the wave transmission coefficient K_t with the dimensionless crest width B/H_i of the Oyster Shell Bag. Overall, the wave transmission coefficient decreases with increasing reef dimensionless crest width. When the structure height is 4 h_s, which is close to the water surface, the wave attenuation effect is considerably greater than the working conditions with structure heights of h_s, 2 h_s and 3 h_s. It is noteworthy that when the structure height is 5 h_s and 6 h_s and the dimensionless width B/H_i is 13, the transmission coefficient shows an abrupt change (shown by way of the red circle in Fig. 3), which is significantly higher than that of the working condition with smaller dimensionless crest width. It is contradictory to the preceding conclusions obtained, and the cause may be an error in the experimental measurements, which has not been mentioned in Allen and Webb (2011).

Influence of reef types

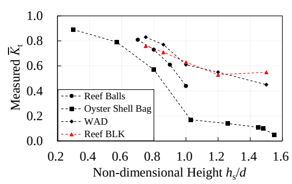

Fig. 4. Relationship between mean wave transmission coefficient and dimensionless height h_s/d of typical oyster reefs (Armono and Hall, 2003; Allen and Webb, 2011; Webb and Allen, 2015).

Fig. 4 shows the variation of the mean wave transmission coefficient with dimensionless height h_s/d for four different reefs. It can be seen that the wave attenuation effect varies broadly amongst reefs, with Oyster Shell Bag displaying a smaller wave transmission coefficient, which is associated to the tight shape and smaller porosity of Oyster Shell Bag. This is followed by Reef Balls, WAD and Reef BLK wave attenuation effects are relatively poor and the distinction between them is not significant. It is undeniable that the existing conclusion is based totally on the evaluation of the present physical model test results, and the control variables method should be used in the perfect experiment. The quite a number reef types differ greatly and the wave parameters are different in these tests. However, the results of the existing analysis are still of some reference value and need to be more fully validated in subsequent studies.

CONCLUSIONS AND PROSPECTS

This paper briefly reviews the development process of wave attenuation by artificial oyster reefs in experiment. The dimensionless height h_s/d and dimensionless crest width B/H_i are viewed to be essential parameters affecting the wave attenuation. The wave transmission coefficient decreases as the dimensionless height or crest width of the reef increases. The wave transmission coefficient less than 0.5 basically takes place when the dimensionless height is larger than or equal to 1.0, indicating that the wave attenuation effect of the reef below the water surface is relatively poor. The wave attenuation effect varies broadly amongst reefs, compared to Reef Balls, Wave Attenuation Devices, and Reef BLK, Oyster Shell Bag exhibits a smaller wave transmission coefficient.

It is recommended to conduct research in the following areas in the future. Firstly, it is suggested to increase the consideration of the effect of surface roughness, strengthen the research on the quantification and mechanism of wave attenuation of oyster reefs of different reef types. The influence of scale effect on physical model tests cannot be ignored. Secondly, the effect of enhancing wave attenuation can be considered by way of optimizing the layout type of oyster reefs. Once more, it is encouraged to establish a numerical model to link wave attenuation and coastal erosion, so as to supply extra direct assist for coastal protection. What's more, long-term monitoring of the constructed oyster reefs is encouraged to recognize the wave attenuation characteristics of oyster reefs in different growth periods. And it is advocated to consider the combination of oyster reefs and natural ecosystems such as mangroves to enhance the comprehensive disaster mitigation effect.

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