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The Effect of Structural Configuration on the Effectiveness of Double Pontoon Floating Breakwater: A Review

Muhammad Salman[1], Sujantoko[2,*], Haryo Dwito Armono[3]

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Abstract**—** Coastal protection against increasingly extreme wave conditions due to climate change requires more flexible and environmentally friendly solutions. The Double Pontoon Floating Breakwater (DPFB) offers a more efficient alternative compared to traditional breakwaters. This study aims to explore the influence of four key design parameters: pontoon geometry, pontoon porosity, pontoon configuration, and gap spacing between pontoons on wave attenuation effectiveness, with a focus on reducing the transmission coefficient (K_T). The method used in this study is a literature review that collects and analyses previous research findings on the design and performance of DPFB. The results show that pontoon geometry, particularly larger pontoon dimensions, and optimal gap spacing between pontoons improve wave attenuation by lowering K_T, although this results in an increase in K_R. Pontoons with higher porosity are more effective in wave attenuation without significantly increasing reflection. The study also reveals that connected pontoons provide more stable wave attenuation, while unconnected pontoons are more flexible in responding to varying wave conditions. These findings reinforce understanding of how interrelated design parameters directly impact wave attenuation, highlighting the importance of optimizing designs to improve coastal protection effectiveness.

Keywords— double pontoon floating breakwater, gap distance, transmission coefficient, reflection coefficient.

[*]*Corresponding Author: sujantoko@its.ac.id.*

I. INTRODUCTION

Coastal infrastructure protection against the destructive impact of ocean waves is a critical issue, particularly given the increasing frequency and intensity of waves driven by global climate change [1]. Traditionally, fixed breakwater structures have been the dominant solution for coastal protection globally. However, these permanent structures often cause significant environmental problems, such as disrupting water circulation, leading to sedimentation and erosion elsewhere, and they also entail extremely high construction costs, making them difficult to install in very deep waters [2][3]. Therefore, there is a strong global trend towards transitioning to more flexible, modular, and environmentally friendly solutions, one of which is the innovation in the design of Floating Breakwaters (FB), seen as a promising alternative [4] and [5].

This issue is highly relevant in Indonesia, an archipelagic nation with the second-longest coastline in the world, where maritime activities, fisheries, and port infrastructure depend heavily on calm water conditions. One of the primary issues is coastal abrasion and damage to mooring facilities caused by waves, particularly in locations with soft seabed geology, where constructing fixed breakwaters becomes impractical or costly [6][7]. Pontoon-type FBs, characterized by their simple geometry and inherent stability, have been identified as a potential technological solution to address these challenges [8][9]. Floating breakwaters attenuate wave energy through reflection, diffraction, and the motion of the structure itself, resulting in low wave transmission coefficients (K_T) in sheltered waters [10][11][12].

While single pontoon FBs have been extensively tested, their effectiveness is often limited in mitigating long-period waves that dominate certain locations [13][14]. Therefore, technological development has shifted towards multi-row configurations, particularly Double Pontoon Floating Breakwaters (DPFB), which have been shown to enhance damping performance significantly [15][16]. The success of DPFB depends on its structural configuration, which includes crucial parameters such as the distance between pontoons (spacing), the relative structural width (B/L), and the mooring system used [17][18][19]. Variations in these configuration parameters directly affect the wave-structure interaction mechanisms, ultimately determining the value of K_T.

However, previous studies on DPFB show significant limitations. Many studies still focus on simple comparisons between single and double configurations or are limited to specific wave conditions and geometries [10][20]. Existing numerical and physical models often fail to systematically vary all configuration parameters, such as geometric shape, pontoon gap, connector usage, and pontoon porosity, simultaneously, making it difficult to identify an optimal configuration that can effectively work across various wave spectra. The lack of a comprehensive synthesis of data regarding the performance sensitivity to changes in structural configuration remains an obstacle in formulating universal and efficient design guidelines.

Muhammad Salman, Departement of Ocean Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, 60111, Indonesia.

Sujantoko, Departement of Ocean Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, 60111, Indonesia, E-mail: sujantoko@its.ac.id.

Haryo Dwito Armono, Department of Ocean Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, 60111, Indonesia.

Given the complexity of the wave interaction dynamics with DPFB and the urgent need for adaptive coastal protection solutions in Indonesia and globally, the need for further research in the form of a systematic literature review is paramount. This literature review aims to synthesize key findings from various studies, identify patterns of relationships between structural configurations, such as geometric shape, pontoon spacing, porosity, and connector usage, and their effectiveness in damping (Kt), and highlight the research gaps that still exist. The results of this review will provide a strong theoretical foundation and more optimal design guidelines for coastal engineers, accelerating the adoption of more efficient and sustainable DPFB solutions.

II. METHOD

The interaction between waves and floating structures is described by linear wave theory, which assumes an inviscid fluid, small-amplitude waves, and irrotational flow. When waves encounter a floating breakwater, wave energy is divided into reflected, transmitted, and dissipated energy due to viscous effects and structural motion. To evaluate breakwater performance, the transmission coefficient (K_T), reflection coefficient (K_R),
and dissipation coefficient (K_d) are commonly used. Mathematically, these parameters are expressed as:

1. Transmission Coefficient (K_T): Measures the effectiveness of wave attenuation.

$$K_T = \frac{H_t}{H_i} \tag{1}$$

2. Reflection Coefficient (K_R): Measures the proportion of wave energy reflected toward the open sea (an important factor for navigation safety in front of the structure).

$$K_R = \frac{H_r}{H_i} \tag{2}$$

3. Dissipation Coefficient (K_d): Evaluates the efficiency of floating breakwaters and other coastal structures in dissipating wave energy.

$$K_d = 1 - K_R^2 - K_T^2 \tag{3}$$

Where: H_i = Incident wave height, H_t = Transmitted wave height, and H_r = Reflected wave height

A low K_T value indicates good wave attenuation capability, whereas K_R represents the level of reflected energy that must be controlled to prevent excessive turbulence or standing waves in front of the structure. According to [21], floating breakwaters primarily function by reducing wave transmission through the combined effects of structural mass and dynamic response to incoming waves.

In a double-pontoon system, wave energy attenuation occurs through three main mechanisms: reflection at the front face, friction beneath the pontoons, and the trapping effect within the gap between the two pontoons.

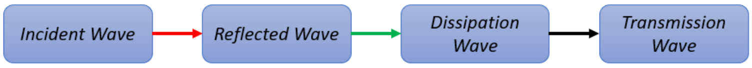


Figure 1. Working mechanism of floating double pontoon breakwater

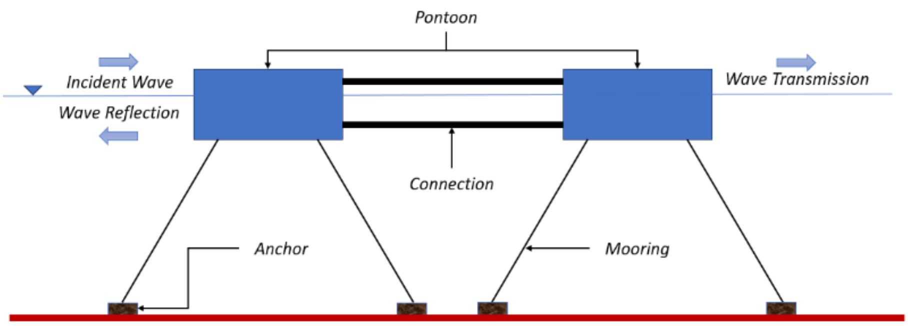


Figure 2. Floating breakwater double pontoon

III. RESULTS AND DISCUSSION

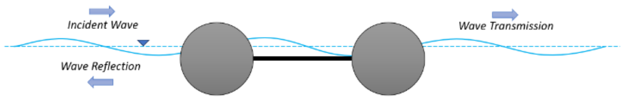
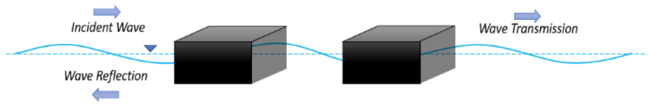
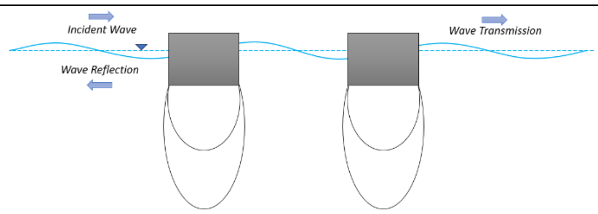
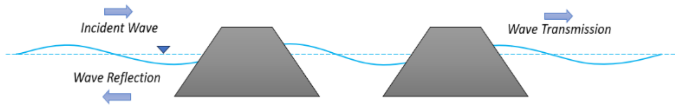
3.1 *Influence of Pontoon Geometry*

Pontoon geometry is a key factor in determining the wave attenuation effectiveness of double pontoon floating breakwater systems. Primary dimensions such as length, width, and draft influence the interaction between the pontoon and the wave pressure profile. Reference [21] explains that the ratio of pontoon length to wavelength has a direct relationship with the reduction of the transmission coefficient, where longer pontoons provide greater wave attenuation. Draft also plays an important role, as it determines how deeply the structure can resist subsurface wave pressure, while pontoon width affects response stability and wave reflection level. The findings of [22][23] indicate that variations in pontoon shape and basic dimensions can result in significant changes in wave transmission patterns.

In double pontoon configurations, geometric effects become more complex due to wave interactions within the space between the pontoons. Research by [24] demonstrates that double pontoon systems not only increase the overall mass of the structure but also modify wave interference patterns, where pontoon spacing and size govern the formation of destructive interference that can significantly reduce K_T values. Further notes that geometric modifications, such as the addition of porous vertical plates, influence pressure distribution and enhance turbulent energy dissipation [25]. The effects of pontoon width and cross-sectional shape variations are also associated with improved attenuation capacity, as shown in a study by [26] that analyzed the performance of various pontoon cross-sectional forms.

Pontoon geometry is also closely related to the structure's natural frequency and dynamic response under wave action. Studies [27][28][29] found that pontoons with large length-to-width ratios exhibit higher pitch responses to long-period waves, indicating that geometric design must be tailored to local wave-spectrum conditions to avoid resonance. The classical study by [30] demonstrated that variations in pontoon end shapes, such as chamfered edges, can reduce vortex shedding and smooth wave transmission patterns. This is further supported by studies [31][32] showing that geometric optimization, whether in draft, length, or cross-sectional shape, can significantly enhance dynamic stability and reduce transmission coefficients across a wide range of wave conditions. Several double pontoon floating breakwater models reflecting these geometric variations are presented accordingly.

TABLE 1.
TYPES OF FB DOUBLE PONTOON MODELS

Type	Models DPFBs
Model FB Cylinder [33]	
Model FB Box [34]	
Model FB Membrane [35]	
Model FB Trapezoid [36]	

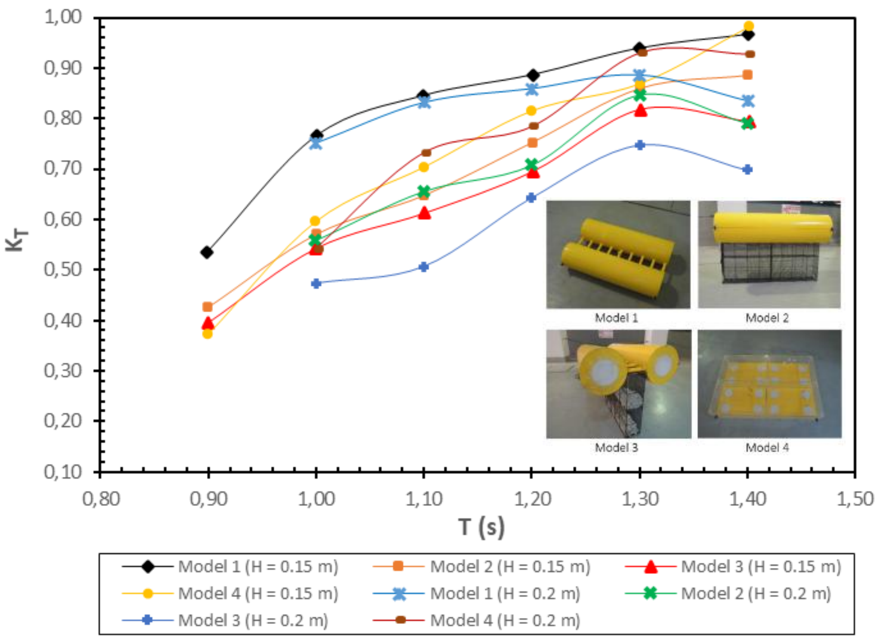


Figure 3: Transmission coefficient as a function of wave period (T) for four models at wave heights of H = 0.15 m and H = 0.20 m [37].

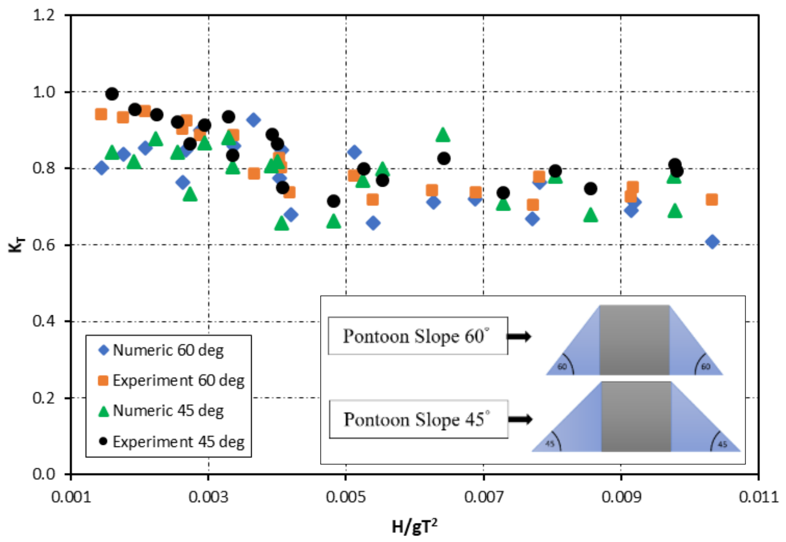


Figure 4: Effect of the transmission coefficient for models with slopes of 60° and 45° [20].

In Figure 3, K_T is analyzed as a function of wave period (T) for four wave-attenuation models under two wave-height conditions (H = 0.15 m and H = 0.20 m), as summarised in Figure 4. The general trend shows that K_T increases with T from 0.90 s to 1.30 s, indicating a reduction in attenuation effectiveness with increasing wavelength. The best performance is consistently observed for Model 3 (two cylinders with netting filled with balls), particularly at the wave height of H = 0.20 m, where K_T attains the lowest values, starting at approximately 0.38 and remaining below 0.70 for most wave periods. In contrast, Models 4 (porous box) and 1 (plain cylinder) exhibit the highest K_T values, approaching 1.0 at the longest wave periods, indicating that these two designs are the least effective at attenuating waves under the given conditions. The pronounced differences in K_T among the models highlight the significant influence of structural geometry on wave transmission mechanisms.

Figure 4 illustrates the relationship between the reduced wave parameter and K_T for two pontoon slope configurations, namely 60° and 45°, based on both numerical and experimental results. In general, the data are distributed within a K_T range of approximately 0.70–0.95 and do not exhibit a sharp trend with respect to wave parameter. However, pontoons with a 60° slope tend to produce slightly higher K_T values than those with a 45° slope in both numerical and experimental results, indicating that steeper slopes transmit a greater portion of wave energy. The agreement between numerical and experimental results is reasonably good, although some scatter among the data points is observed. Overall, the figure suggests that the pontoon slope has a more significant influence on wave transmission than variations in wave parameters.

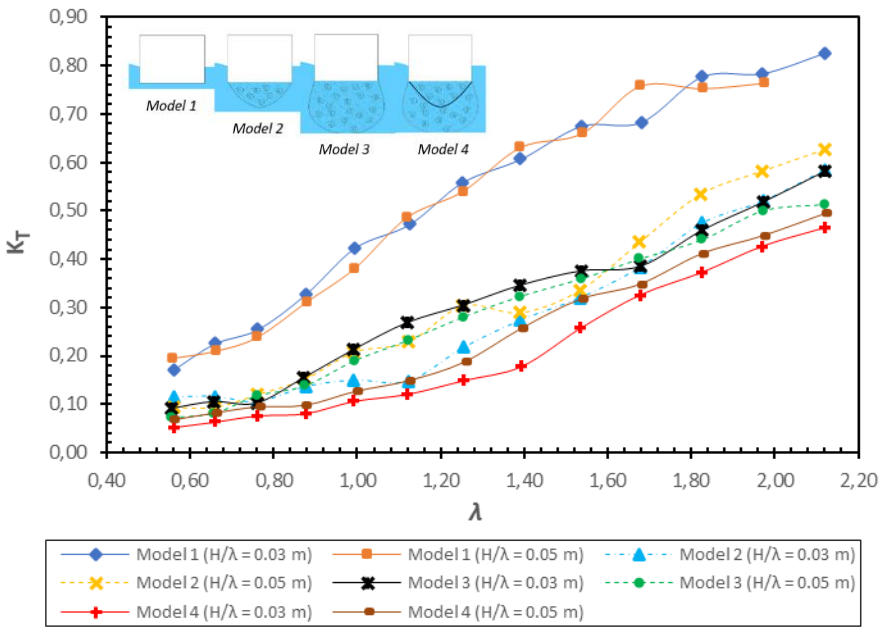


Figure 5: Comparison of the transmission coefficient with the wavelength ratio H/λ for four models at d = 0.06 m [38]

Figure 5 illustrates the influence of wavelength (λ) on K_T for four basic geometric models, each tested at two relative roughness ratios (H/λ = 0.03 and 0.05). In general, all curves exhibit an increasing trend, where Kt rises with increasing λ. At small λ values, all models show low Kt, indicating that short waves are more easily attenuated. Differences among the models become apparent at intermediate λ values (1.0–1.5), where Model 1 produces the highest K_T, indicating the lowest attenuation capability, while Model 4 consistently exhibits the lowest K_T, making it the most effective in wave attenuation. The effect of relative roughness (H/λ) is also evident: configurations with a larger H/λ ratio (0.05) tend to yield higher K_T values, indicating increased wave transmission. At large λ values, all models show progressively higher K_T, confirming that longer waves are more difficult to attenuate, regardless of shape or base roughness.

3.2 Role of Structural Porosity

Porosity in floating breakwater structural elements, such as vertical plates, bottom plates, or internal void spaces between pontoons, plays a significant role in enhancing wave energy dissipation. Porous structures allow a portion of the fluid flow to enter internal spaces, thereby reducing dynamic pressure and lowering the amplitude of transmitted waves. According to [39], flow through porous media results in energy losses due to internal turbulence and friction, thereby directly reducing K_T. This is further supported by [40], which demonstrates that increasing porosity in vertical plates reduces hydrodynamic pressure on pontoon surfaces, thereby decreasing the oscillatory forces transmitted behind the structure.

In double pontoon systems, porosity provides additional effects through vortex shedding mechanisms and enhanced energy dissipation within the inter-pontoon region. Studies [39][41][42] found that porous plates placed between two pontoons significantly improve wave attenuation, particularly for short-to-intermediate waves, with K_T reductions exceeding 20% compared to solid plates. Furthermore, [25] shows that porous systems produce smaller pressure gradients, leading to more stable and consistent destructive wave interference within the inter-pontoon gap across various wave conditions. Optimal porosity also helps prevent the formation of standing waves in the inter-pontoon region, which could otherwise degrade structural performance.

However, excessively high porosity levels may increase wave transmission due to reduced hydrodynamic resistance. Therefore, porosity design must balance turbulence dissipation with pressure resistance. Recent research by [39] confirms that effective porosity levels for floating breakwaters typically range between 20–40%, depending on wave frequency and plate geometry. The study also emphasizes that combining porosity with geometric modifications, such as inclined or stepped plates, yields greater performance improvements than porosity adjustments alone. Accordingly, porosity is a critical design variable in enhancing the effectiveness of double pontoon floating breakwater systems.

Figure 6 illustrates the relationship between wave period (T) and K_T for a porous floating breakwater under different incident wave heights. The results show that K_T increases with wave period, indicating reduced wave attenuation effectiveness for longer-period waves. At shorter wave periods, stronger wave structure interactions enhance energy dissipation through the porous elements, resulting in lower K_T values. In contrast, longer-period waves have relatively large wavelengths compared to the structure's characteristic dimensions, allowing a greater portion of wave energy to be transmitted. The relatively small variation in Kt among different wave heights suggests that wave period is a more dominant parameter influencing the performance of the porous floating breakwater.

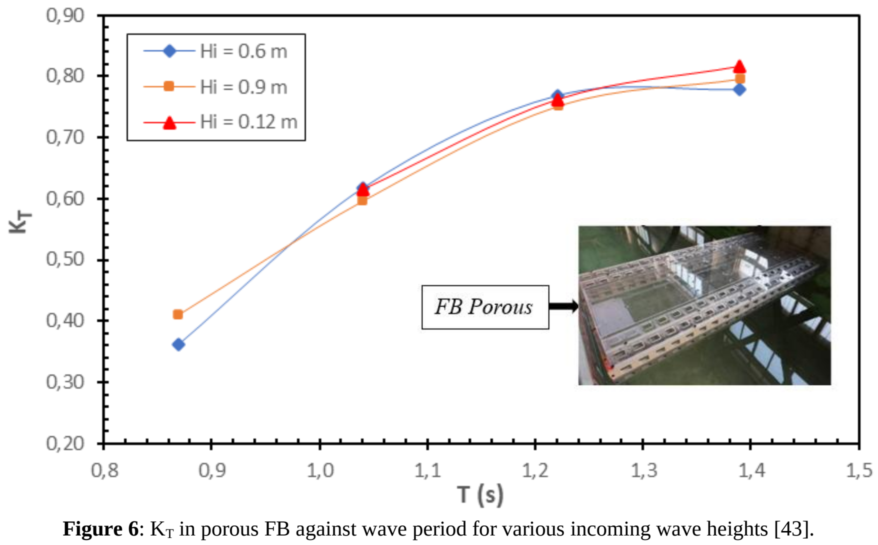


Figure 6: K_T in porous FB against wave period for various incoming wave heights [43].

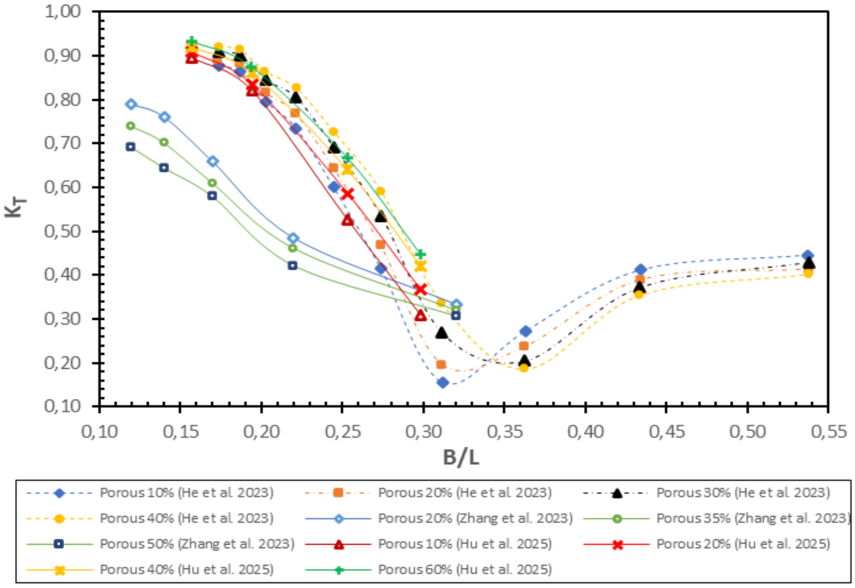


Figure 7: K_T versus the ratio of structural width to wavelength (B/L) for various porosities of porous FB [44][45][42].

Figure 7 compares K_T as a function of the structural width-to-wavelength ratio (B/L) from various literature studies on porous wave-attenuating structures. The general trend across all curves is a significant reduction in K_T as the B/L ratio increases, reaching a minimum K_T (optimal wave attenuation) at approximately 0.30–0.35. Specifically, the study by [45] with a porosity of 30% achieved the lowest K_T of about 0.15 at B/L = 0.32. Beyond this minimum point, K_T increases again, indicating a deterioration in attenuation effectiveness when the B/L ratio exceeds the optimal range. Notable differences are observed in the minimum K_T values reported across studies; for instance, some investigations, such as [44], reported K_T values below 0.20, whereas others, such as [42], maintained K_T values above 0.30 at the same optimal point. This highlights that variations in porosity levels and specific structural design characteristics are key factors governing wave attenuation performance.

3.3 Influence of the Connector System

The configuration of the connection between the two pontoons in a double-pontoon floating breakwater significantly affects the structural dynamic response and wave-attenuation effectiveness. Although studies directly comparing the performance of connected and unconnected pontoons remain limited, several investigations of multi-pontoon systems provide insight into how these conditions influence wave energy dissipation capacity. In configurations with pontoons connected, the two modules tend to move more synchronously, resulting in a more stable, coordinated structural response. This condition is believed to reduce the likelihood of waves penetrating the inter-pontoon space and to enhance a more organized wave-scattering pattern.

In contrast, in unconnected pontoon configurations, each pontoon moves independently in response to incoming waves. Study [10] shows that phase differences in motion between modules in systems without structural connections can increase the transmission coefficient (K_T), as waves can more easily pass through the energy gap between pontoons. Although this study did not specifically focus on double pontoon systems, the findings suggest that unconnected pontoons tend to produce lower energy dissipation. Furthermore, studies [13][46] analyzing unconnected modular structures reported higher relative deformations, leading to non-uniform wave-scattering patterns that allow greater energy transmission.

Additional studies by [18][47] reveal that pontoon systems with better-integrated motion, as represented here by wider pontoons exhibiting smaller vertical responses, have the potential to reduce K_T values. Based on these findings, the authors suggest that connected pontoons are more likely to achieve better wave attenuation performance than unconnected pontoons. Nevertheless, as no studies have yet directly tested this comparison for double-pontoon configurations, the present analysis remains interpretative, grounded in theoretical considerations and supported by evidence from similar pontoon systems.

This limitation in the existing literature highlights a significant research opportunity. Studies that explicitly examine both connected and unconnected pontoons are essential to better understand how differences in relative motion responses influence K_T and K_R values. Accordingly, this subtopic represents one of the most promising avenues for advancing the design of more effective, quantifiable double-pontoon floating breakwater systems. An illustrative figure depicting floating breakwaters with and without connectors is provided for clarity.

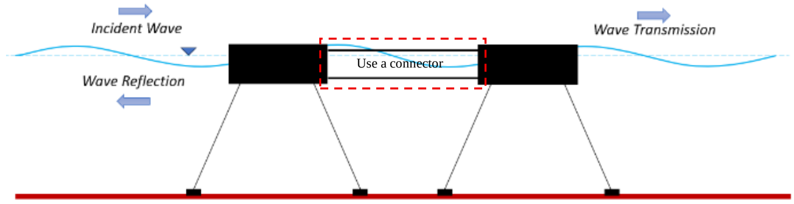


Figure 8: FB using a connector

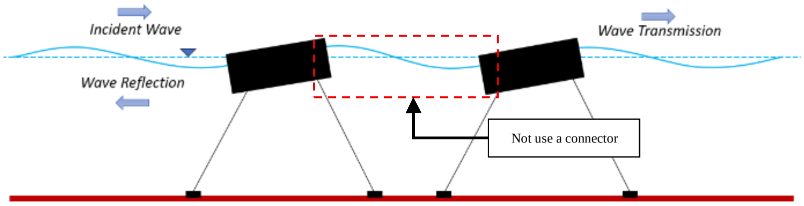


Figure 9: FB does not use a connector

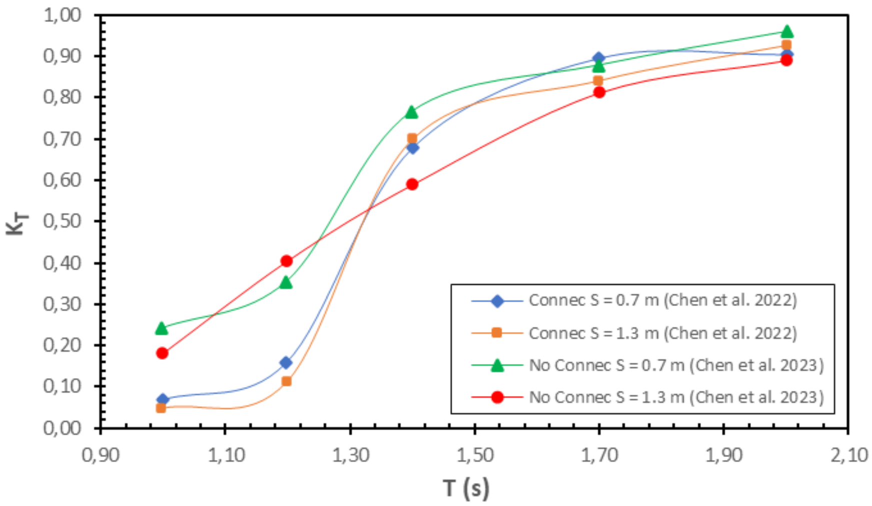


Figure 10: Comparison of K_T for connected and non-connected pontoon designs [47] [48].

Figure 10 illustrates the relationship between wave period (T) and K_T for four different conditions: structures with and without connectors, and two gap spacings (S=0.7m, S=1.3m). In general, all curves exhibit an increasing trend, with K_T values rising as the wave period increases. At short time scales (T=1.0–1.2s), all configurations exhibit very low K_T values, indicating that the structures are highly effective at attenuating high-frequency waves. However, differences become apparent at intermediate times (T=1.3s). Unconnected structures exhibit higher K_T values, particularly at a gap spacing of S=1.3m, indicating that waves can more easily transmit through the system when the elements are not connected. In contrast, connected configurations, especially with a smaller gap spacing of S=0.7m, maintain lower K_T values, demonstrating better wave attenuation performance under intermediate resonance conditions. At longer periods ($T \geq 1.7$s), all configurations tend toward high K_T values (0.80–0.90), reflecting the dominance of long waves, which are inherently difficult to attenuate using floating structures regardless of connection conditions. Overall, the results indicate that inter-pontoon connections and smaller gap spacings play a crucial role in reducing wave transmission, particularly in the intermediate period range, which is most critical for structural performance.

3.4 Optimization of Gap Spacing

The inter-pontoon spacing (G) is a unique parameter in double pontoon systems. Optimizing the gap spacing between two pontoons significantly influences wave interference patterns and the ability of double-pontoon floating breakwater systems to attenuate wave energy. Reference [49] shows that gap spacing determines whether wave energy undergoes destructive interference or instead finds a direct transmission pathway. When the gap is too small, the system behaves like a single large pontoon, limiting wave-scattering mechanisms. Conversely, [21] reports that excessively wide gaps lead to the formation of high-transmission channels, where waves can pass through the gap with minimal energy loss. Therefore, gap spacing must be carefully selected based on the characteristics of the dominant wave conditions.

Studies by [50][51] confirm that well-controlled gap spacing promotes turbulence generation and multiple wave scattering between pontoons, thereby enhancing energy dissipation. References [52][27][53] further note that the ideal gap spacing depends strongly on the ratio of the gap width to the incident wavelength; an appropriate ratio enhances destructive interference. Research by [54] also supports this conclusion, stating that multi-body floating systems exhibit significant reductions in Kt when the gap spacing corresponds to specific resonance conditions relative to the wavelength. These findings indicate that gap spacing optimization cannot be decoupled from wave parameters such as wavelength, period, and amplitude.

Moreover, studies [55][56][57] emphasize that gap spacing should be regarded as a primary hydrodynamic parameter rather than merely an additional geometric feature. They highlight that destructive interference is most effective when the gap forms an energy-reducing zone that is phase-aligned with the incoming waves. By synthesizing these findings, it can be concluded that gap-spacing optimization plays a critical role in enhancing wave-attenuation efficiency in double-pontoon floating breakwater systems. This parameter directly governs energy interactions between pontoons and is a key variable to prioritize in the design of double-pontoon-based floating breakwaters.

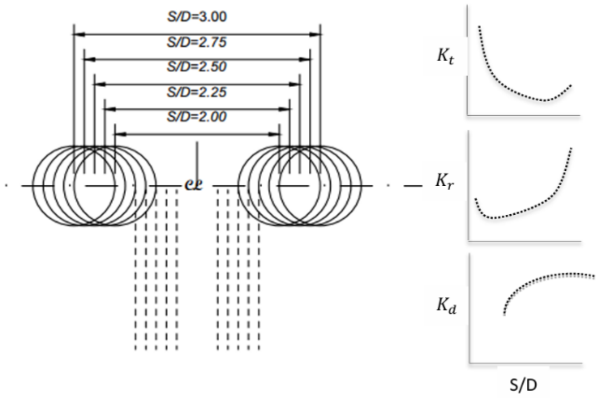


Figure 11: Effect of the S/D ratio of a twin-pontoon net FB on K_T, K_R, and K_d [58].

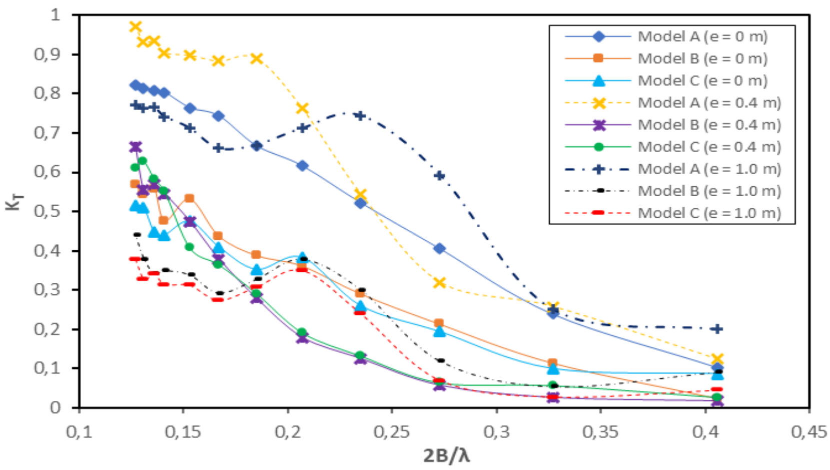


Figure 12: Comparison of K_T for three models and different gap spacings [47][48][59].

Figure 11 illustrates the impact of the distance between pontoons (S/D) on the wave attenuation coefficients in a Double Pontoon Floating Breakwater (DPFB) system. The graph on the right shows the relationships among S/D, the transmission coefficient (KT), the reflection coefficient (KR), and the dissipation coefficient (K_d). The results indicate that as the S/D ratio decreases, wave attenuation becomes more effective, as shown by the decrease in K_T. Conversely, K_R increases as S/D decreases, indicating that more waves are reflected. Additionally, Kd increases as S/D decreases, indicating greater energy dissipation due to turbulence. Overall, this figure demonstrates that optimizing the gap between pontoons can improve wave-attenuation efficiency in the DPFB system.

Figure 12 illustrates the relationship between the ratio 2B/λ and K_T for three geometric models (Models A, B, and C) with three gap variations between pontoons (e = 0 m, 0.4 m, and 1.0 m). In general, all curves exhibit a decreasing trend, with K_T decreasing as 2B/λ increases, indicating improved wave attenuation as the incident wavelength becomes relatively shorter than the structure width. At low values of 2B/λ, differences among the models are clearly observed: Model A, particularly with larger gaps, shows the highest K_T, indicating that more wave energy is transmitted. In contrast, Model C consistently exhibits the lowest K_T, making it the most effective in attenuating waves. Gap variation also plays a role: larger gaps tend to reduce K_T in Models B and C, whereas in Model A, the reduction is less pronounced. At high 2B/λ ratios, all models approach very low K_T values, demonstrating that the structures can effectively attenuate waves under these conditions, regardless of geometric form or gap variation.

3.5. Synthesis and Future Research Directions

This study reveals several important findings regarding the effectiveness of the Double Pontoon Floating Breakwater (DPFB) in wave attenuation, driven by complex interactions among design parameters, including pontoon geometry, porosity, gap spacing, and configuration. One of the main findings is that pontoon geometry, including width, effective height, and base shape, plays a significant role in reducing the transmission coefficient (K_T). This finding aligns with previous research by [63], which demonstrated that variations in base shape and pontoon width directly impact K_T. Increasing the interaction area between the waves and pontoons helps dissipate more wave energy, which results in a lower K_T.

Pontoon porosity was also found to be a key factor in energy dissipation. Research by [61] shows that higher porosity reduces KT through internal turbulence, without significantly increasing it. This finding confirms that pontoons with higher porosity are more effective in reducing K_T, offering a more environmentally friendly design without worsening reflection effects. This is consistent with findings by [48], [66], and [67], which emphasise the potential of porosity in modular floating structures to enhance wave attenuation.

The pontoon configuration, whether connected or unconnected, was found to influence the system's dynamic response and K_T. Using connectors between pontoons results in more uniform movement, reducing fluctuations in pontoon motion that increase K_T. In contrast, pontoons without connectors are more flexible and respond more dynamically to varying wave conditions, making K_T more sensitive to these changes. This suggests that a design with unconnected pontoons offers advantages in terms of adaptability to different water conditions. Similar results were observed in studies by [56] and [33], which showed that multi-body interactions in floating structures can affect wave attenuation patterns, though they did not focus specifically on connected versus unconnected configurations. Furthermore, gap spacing between pontoons plays a crucial role in wave interference and resonance phenomena. This study reinforces that optimal gap spacing can improve wave damping and significantly reduce K_T, while improper gap spacing can lead to an increase in K_T, reducing the effectiveness of wave attenuation. These findings align with previous research by [49] [64] and [65], which showed correlations between the gap-to-wavelength ratio, but this study extends the understanding by focusing on modern double pontoon configurations.

Although these findings offer deeper insights into the influence of design parameters on K_T, there remain gaps in the literature that require further research. One major gap is the lack of studies comparing connected versus unconnected pontoon systems in the context of DPFBs. No research has specifically examined how these configuration differences affect K_T and the overall efficiency of wave attenuation. Given that relative motion between pontoons can affect wave interference patterns, gap resonance, and energy dissipation, this comparison becomes a crucial area for further exploration. The findings of [56], [68], and [33] highlight the importance of understanding the effects of these configurations on performance, but further research is needed to directly compare these scenarios in the context of DPFBs. Additionally, while this study identified the importance of gap spacing between pontoons, further research is needed to determine the optimal gap spacing for DPFB designs, particularly given the more complex variations in water conditions and pontoon geometry. Studies by [49] [64] and [65] provide initial insights into gap spacing effects, but a more comprehensive approach is needed.

Future research should focus on developing a more comprehensive hydrodynamic model that integrates the complex interactions among design parameters, including pontoon geometry, porosity, gap spacing, and pontoon configuration. Research into the combined effects of these parameters will provide deeper insights and lead to more efficient, adaptable DPFB designs. Studies such as those by [21] and [51] provide a strong theoretical basis, but more advanced models are needed for real-world applications. In addition, larger-scale physical experiments and numerical simulations are required to validate the findings under real-world conditions, enabling DPFB designs to be optimized for various wave conditions in coastal waters. These experimental studies should focus on validating the model's performance across a range of wave frequencies and environmental conditions. Overall, these findings pave the way for the development of more environmentally friendly, efficient, and adaptable DPFB designs that can be tailored to various coastal wave conditions.

IV. CONCLUSION

Based on the discussion and literature review, it can be concluded that the effectiveness of the Double Pontoon Floating Breakwater (DPFB) is determined by four key interrelated parameters that influence the structure's performance in wave attenuation, particularly in reducing the transmission coefficient (K_T). First, the pontoon geometry, which includes the width, effective height, and base shape, plays a crucial role in lowering K_T. The geometry affects the inertia mass and the area of interaction with the waves. The larger the interaction area, the greater the structure's ability to reflect waves and reduce incoming wave energy, resulting in a lower K_T. Second, pontoon porosity serves as an internal energy dissipation mechanism that creates turbulence losses. This dissipation effectively reduces K_T without significantly increasing the reflection coefficient (K_R), meaning it reduces the impact of waves without causing stronger waves to be reflected back into the sheltered area. Third, the pontoon configuration, whether connected or not, influences the system's dynamic response, directly affecting K_T. Using connectors between pontoons results in more uniform movement across the structure, generally increasing reflection and reducing K_T in a more stable manner, while pontoons without connectors respond more flexibly, making K_T more sensitive to wave conditions. Fourth, the gap spacing between pontoons plays a significant role in wave interference and resonance phenomena, which directly affects K_T. An optimal gap spacing can lead to phase cancellation, improving wave damping and thereby reducing K_T. In contrast, improper gap spacing can lead to an increase in K_T, reducing the effectiveness of wave attenuation.

Furthermore, the literature synthesis shows that studies on the simultaneous interaction of these parameters are still limited, particularly regarding the comparison of pontoon performance with and without connectors, as well as the combination of geometry, porosity, and gap spacing. Therefore, future research should focus on the development of more comprehensive hydrodynamic models, integrated multi-parameter studies, and verification through large-scale experimental testing. This approach is expected to provide a deeper understanding of nonlinear mechanisms and pontoon coupling dynamics, leading to the development of more optimized DPFB configurations with low K_T and controlled K_R across various water conditions.

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