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Study on the Suitability Analysis of the Use of Floating Breakwaters in Palipi Fishing Port

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Abstract

Palipi Fishing Port functions as a fish landing site with a pier facing directly into the open sea, lacking the protection of a harbor pond. This discourages fishermen from anchoring, especially during the west wind season. In addition, the low carrying capacity of the seabed due to thick sediment deposits makes it difficult to use pile-type breakwaters. To improve functionality, Palipi Fishing Port needed a geographically appropriate breakwater solution to protect it from wave battering. Floating breakwaters offer a suitable approach, providing effective wave attenuation through a floating structure and requiring no subgrade support. This study evaluates the feasibility of using floating breakwaters at Palipi Fishing Port to ensure the jetty area is well protected. The analysis was conducted by assessing the suitability between wave conditions and the performance of the floating breakwater, as well as considering the practicality of construction. Based on the findings of this study, it was found that there is an unsuitable use of floating breakwater in the study area, so further studies are needed to support optimal port functions and encourage economic growth in the region.

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1. Introduction

Palipi Fishing Port is a fishing boat berth port with an area of about 8.8 Ha and began operating in 2012 [1]. However, Palipi Port has not been optimally utilized in the loading and unloading process and as an anchorage for fishing boats. This is because the port dock is directly facing the open sea without any protection in the form of wave breakers. This causes the waves that occur around the dock and harbour pool to be relatively high, preventing fishing boats from [1], [2]. The purpose of a breakwater is to protect a harbour, beach, or coastal facility from strong waves and storms, as it helps create calm within the harbour so as to achieve vessel safety and ease of operation [3]–[5]. Therefore, a breakwater is needed so that loading and unloading activities and ship mooring can take place safely and effectively [6], [7].

Breakwater buildings have various forms and types [2], [5], [8] which are adjusted to the geographical conditions of a port, such as bathymetry conditions, oceanographic conditions that occur, and soil layer structures [6], [7], [9]. Based on research conducted in 2019 by the Maritime and Fisheries Service of West Sulawesi Province, it is known that the basic condition of the Palipi Fishing Port soil consists of sediment deposits that are thick enough to cause very low soil bearing capacity. Therefore, it is necessary to design a breakwater building that is effective in reducing waves without considering the basic conditions of the land topography [10].

Floating breakwaters offer advantages in deep water harbours, aquaculture, and offshore construction [3]. Floating breakwaters are more flexible in their design and installation compared to fixed breakwaters [9]. Various studies have explored various aspects of floating breakwaters, including their effectiveness in wave attenuation, structural performance, and coastal protection capabilities. Experimental studies have investigated the impact of geometric and hydrodynamic parameters on the performance of floating breakwaters [11], [12], such as shape, width, and draft depth [9] [3], [8], [13]. In addition, floating breakwaters also have the advantage that floating breakwaters are more feasible to use in poor ground conditions than heavy fixed breakwaters because the underground pressure is almost non-existent, but floating breakwaters must be moored to the seabed [14]. The typology and layout of mooring lines significantly affect the structural behaviour of floating breakwaters [6]. However, the limited range of effective wave heights and periods for floating breakwaters remains a challenge, especially in deeper waters where shore response may be limited [14].

Floating breakwater structures have several classifications of floating breakwater structures [5], where box-type and pontoon-type breakwaters are the most common and effective designs in protecting the coast by reflecting incoming waves [15]. The floating structure used must, of course, pay attention to materials with the criteria of increasing the aesthetic capacity of the building, reducing locally available construction costs, increasing building life, improving building quality, and making the building safe to function [16],[2], [4], [8]. The use of materials that are environmentally friendly and have good durability is essential to ensure the structure can withstand the frequently changing sea conditions [13], thereby increasing the life of the building. In addition, the use of cheaper and locally available materials can reduce construction costs. In addition, good design and proper material selection can improve the building quality and aesthetics, which is very important in the context of floating structures. By paying attention to all these aspects, the building will not only be safe to function, but will also provide added value in terms of aesthetics and cost efficiency. The construction cost factor is important because it must be balanced with the ability of a sustainable approach to ensure that the environmental, economic, and social needs of present and future generations can be met in the urban domain [17].

In this study, we will describe the research methods, which include bathymetry survey, wave data analysis, and modelling of floating breakwater structures. The results of this study are expected to provide clear recommendations regarding the suitability of using breakwater structures in Palipi Fishing Port to protect the port from high wave impact and improve the operational performance and safety of the port.

2. Methods

The research was conducted by collecting primary data by conducting bathymetry surveys [18] and secondary data, namely indexed journal reviews relevant to the research and from the ECMWF (European Center for Medium Range Weather Forecasts) website [19] which was used to retrieve wave event data at the research location with a data collection distance of every three hours for the last 10 years (2012-2022).

Based on the data obtained, an analysis was then carried out using the graph of the analysis results from [20], which states that floating breakwater structures will generally function effectively in waters with wave heights below 5 ft or approximately 1.5 m in Figure 1.

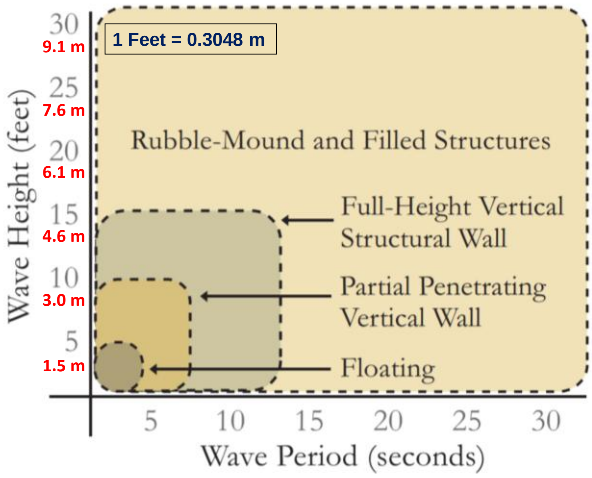


Figure 1. Floating breakwater effectiveness based on wave height

Based on the analysis of the correspondence between wave height and wave period in Figure 1, the planning of floating breakwater buildings needs to take into account the dimensions of the breakwater building with wave-damping capability. This will reduce the construction cost of the rectangular cross-sectional area required to produce the same wave attenuation [3]. In its determination, Tolba, 1998 describes it as in Figure 2 below.

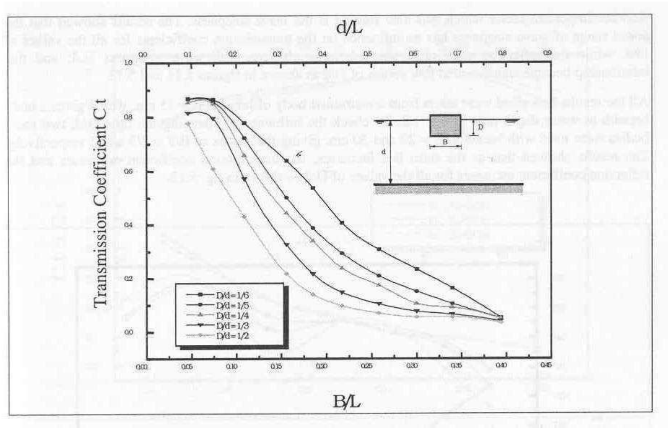


Figure 2. Graph of Building Dimensioning against Transmission Coefficient

The determination of building dimensions can be made if the transmission coefficient is known. The wave transmission coefficient is the wave energy remaining after passing through the wave retaining structure; in other words, the wave transmission coefficient is the ratio of the wave height at the pier to the wave height in front of the floating breakwater.

Furthermore, modelling is carried out to compare the wave-damping ability with the dimensions of the floating breakwater structure. So that the suitability between the planning dimensions of the floating breakwater structure and the level of efficiency of its use in the Palipi Fishing Port can be obtained.

In this study, it is planned that the installation of the floating breakwater will be carried out as shown in Figure 3 below.

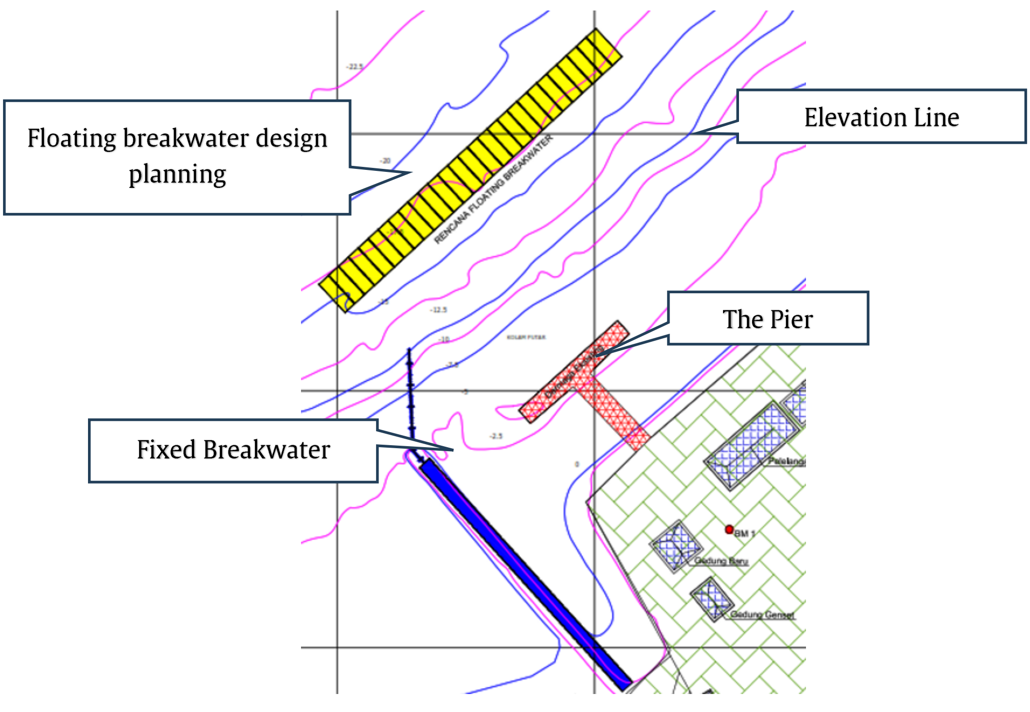
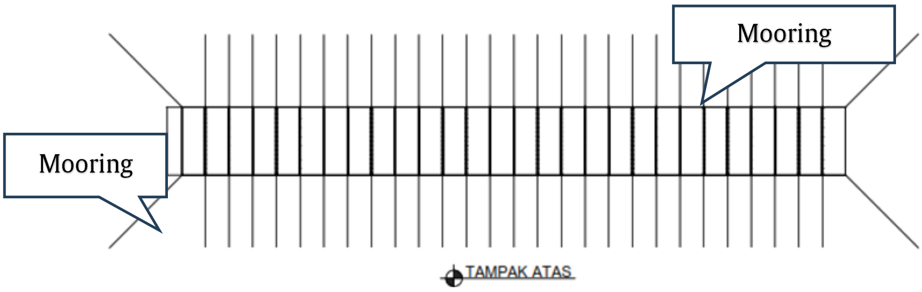
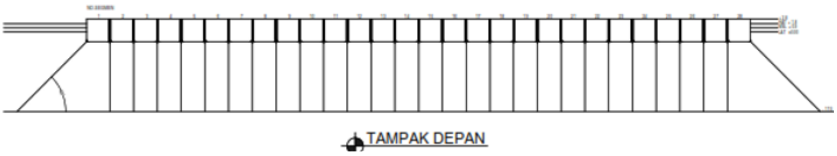


Figure 3. Layout plan of floating breakwater research

Based on this figure, it is known that Floating will be installed a few metres in front of the pier using the anchor (mooring) method. The details of the floating breakwater design are depicted in Figure 4.



Top view of floating breakwater



Front view of floating breakwater

Figure 4. Top vie er planning design

3. Results and Discussion

This section contains the results of the analysis of bathymetry data in the harbour, wave data, and the results of the analysis of the suitability of using floating and estimating the dimensions of the floating breakwater building.

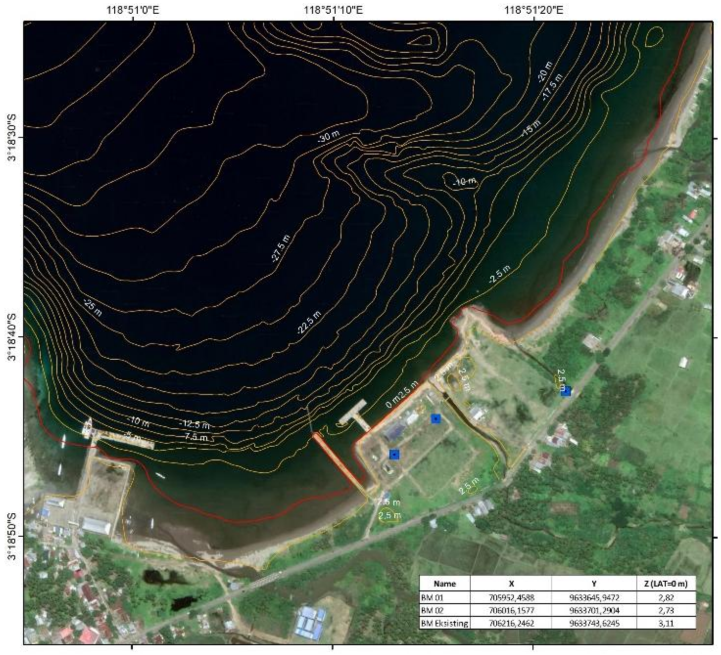
3.1. Bathymetry Condition of Palipi Fishing Harbour

Bathymetry and topographic data analysis were each analysed separately before being combined into a common tie point of LAT=0m. Analysis of bathymetry data was first carried out by extracting raw data into measurement data, which included date and time of measurement, measured depth, and easting and northing coordinates. After the measurement results table is prepared, the water level fluctuation correction is carried out based on the results of the 10-minute interval tide recording. This is then continued with the correction of the transducer depth of the water surface. The bathymetry data correction process can be seen as follows in Table 1.

Table 1. Bathymetry Data Analysis of Palipi Harbour Site

Date	Time	X	Y	Z	Transducers (Correction Factor I)	Fluctuations (Correction Factor II)	Z Corrected	LAT=0
19/08/2003	20:18:42	705919	9633811	18.4	0.31	0	18.71	17.64
19/08/2003	20:18:45	705922	9633809	16.4	0.31	0.00018255	16.71	15.64
19/08/2003	20:18:47	705924	9633809	16.8	0.31	0.000365099	17.11	16.04
19/08/2003	20:18:49	705926	9633808	16.9	0.31	0.000547649	17.21	16.14
19/08/2003	20:18:51	705928	9633807	16.2	0.31	0.000730198	16.51	15.44
19/08/2003	20:18:53	705929	9633806	16.0	0.31	0.000912748	16.31	15.24
19/08/2003	20:18:55	705931	9633805	15.2	0.31	0.001095297	15.51	14.44
19/08/2003	20:18:57	705932	9633804	14.8	0.31	0.001277847	15.11	14.04
19/08/2003	20:18:59	705934	9633803	15.1	0.31	0.001460396	15.41	14.34
19/08/2003	20:19:01	705935	9633802	13.5	0.31	0.001642946	13,81	12.74
19/08/2003	20:19:03	705937	9633801	12.8	0.31	0.001825495	13.11	12.04
19/08/2003	20:19:05	705938	9633800	12.6	0.31	0.002008045	12.91	11.84
19/08/2003	20:19:07	705940	9633800	12.1	0.31	0.002190594	12.41	11.34
19/08/2003	20:19:09	705941	9633800	11.0	0.31	0.002373144	11.31	10.24
19/08/2003	20:19:11	705943	9633799	10.4	0.31	0.002555693	10.71	9.64
19/08/2003	20:19:13	705944	9633799	10.6	0.31	0.002738243	10.91	9.84
19/08/2003	20:19:15	705945	9633798	10.1	0.31	0.002920792	10.41	9.34
19/08/2003	20:19:17	705947	9633798	8.6	0.31	0.003103342	8.91	7.84
19/08/2003	20:19:19	705948	9633797	9.0	0.31	0.003285891	9.31	8.24

After correction for fluctuation and transducer depth, the bathymetry data was then tied to the tidal measurements using LAT=0. The bathymetry and topography maps of the study location can be seen as follows in Figure 5.



Name	X	Y	Z (LAT=0 m)
BM 01	705952,4588	9633645,9472	2,82
BM 02	706016,1577	9633701,2904	2,73
BM Eksisting	706216,2462	9633743,6245	3,11

Figure 5. Bathymetry Map of Palipi Fishing Harbour

Based on the results of data analysis, the dock area of Palipi Fishing Port has a water depth of -2.5 m to -4 m below the tidal LAT. Depths of -5 m can be approximately 18 metres from the dock. While the water depth at a distance of 100 m from the pier reaches -20 m LAT.

3.2. Palipi Fishing Harbour Wave Conditions

Wave conditions in the Palipi Fishing Harbour area based on return time and water depth using dominant waves from the Southwest, West, and Northwest directions are shown in Figure 6 below.

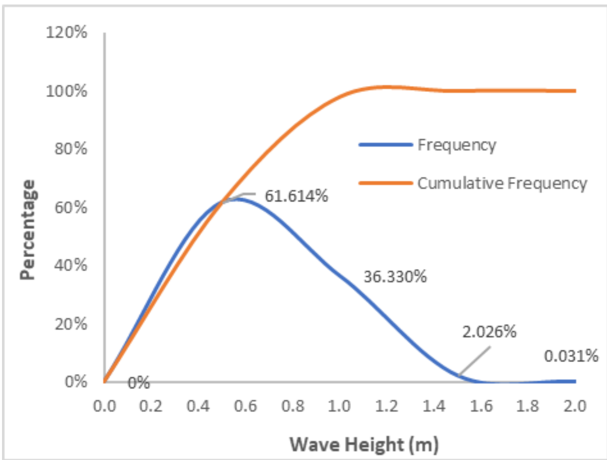


Figure 6. Function graph of percentage of wave occurrence against wave height

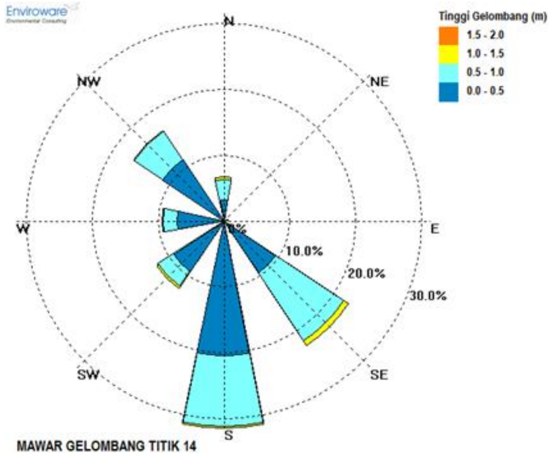


Figure 7. Dominant direction wave rose graph

The wave rose diagram above (Figures 6 and 7) shows the distribution of wave direction and height around Palipi Fishing Port. From this diagram, it can be seen that the most dominant waves come from the Southeast (SE) and South (S) directions. Waves with these dominant directions have different height variations, as indicated by the colours in the diagram. The Southeast direction dominates with wave heights of 1 m to 1.5 m, while the south direction has longer waves reaching about 30% with heights of 0.5 m to 1 m. Wave height varies between 0.0 - 2.0 m, with darker colours indicating lower waves. This information is important in determining the optimal design and orientation of the breakwater to protect the jetty area from these dominant waves.

Based on the wave direction graph, an analysis is then carried out to measure the dimensions of the planned floating breakwater using the Height of incident wave or initial wave height (Hi) data, which means the height of the incident wave or the initial height of the wave before it changes due to interaction with the beach or other objects. In addition to Hi, breaking wave height (Hb) data is used, which is the height of the wave when it starts to break in shallow water, usually near the shoreline. It is the maximum height a wave reaches before it loses stability and breaks. The waves that influence Palippi Fishing Port are waves from the northwest, west, and southwest directions. (Figure 8 to Figure 13) present the breaking wave graphs from these directions for wave return periods of 5 and 10 years.

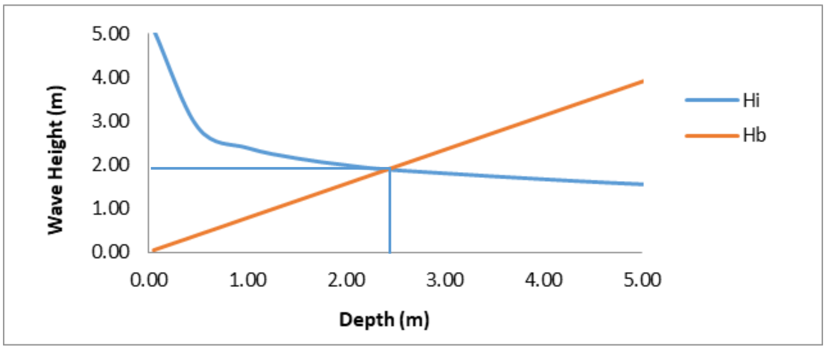


Figure 8. Northwest Direction Breaking Wave 5-Year Return Period

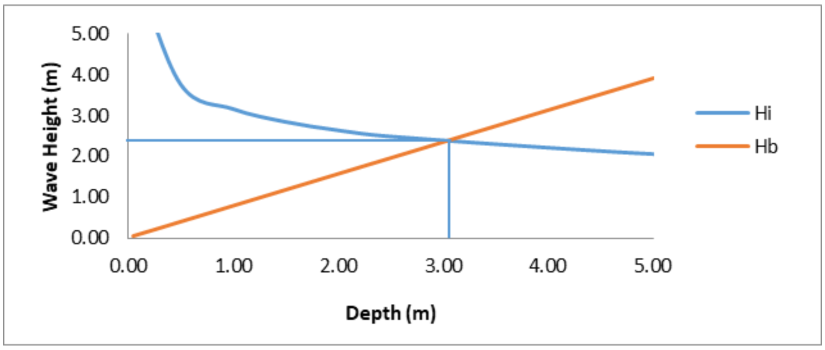


Figure 9. West Direction Breaking Wave 5-Year Period

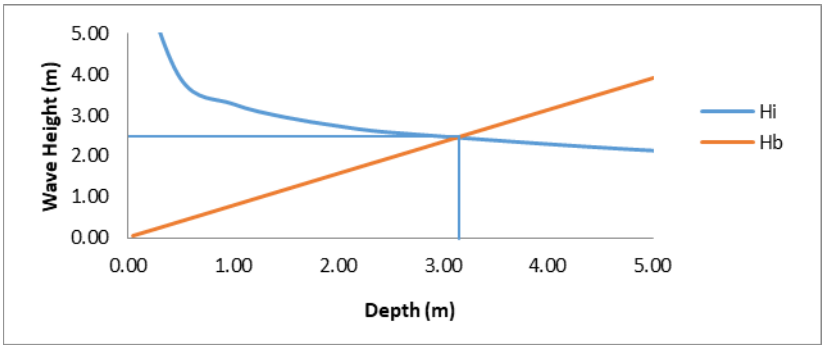


Figure 10. Southwest Direction Breaking Wave 5-Year Return Period

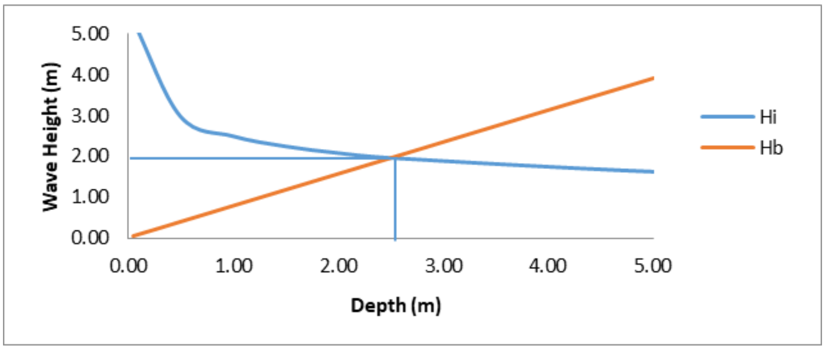


Figure 11. Northwest Direction Breaking Wave 10-Year Return Period

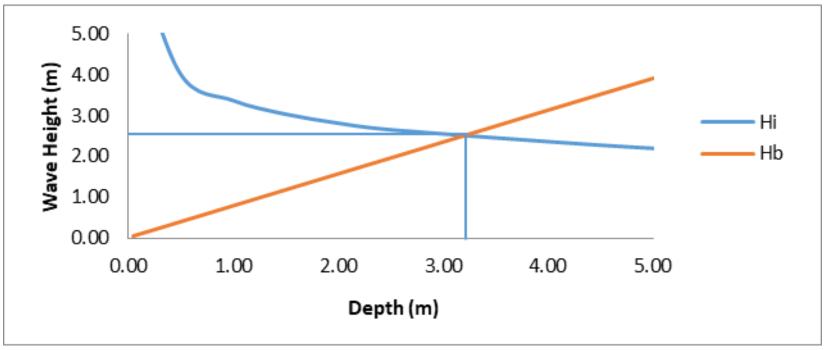


Figure 12. West Direction Breaking Wave 10-Year Period

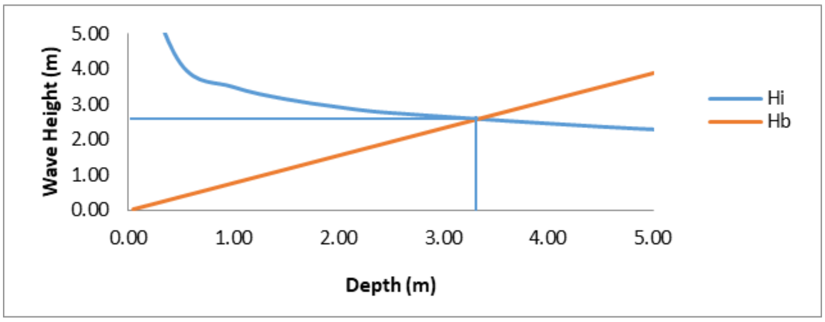


Figure 13. Southwest Direction Breaking Wave 10-Year Period

Based on the Figure 6 to Figure 11, it is known that the breaking wave from the Northwest direction occurs at a depth of 2.5 m - 2.9 m. The breaking waves that occur from the West are at a depth of 3 m - 3.5 m and the breaking waves from the Southwest occur at a depth of 3 m - 3.8 m.

Based on the results of wave data analysis using the floating breakwater suitability graph in Figure 1, it is known that the floating breakwater cannot reduce the overall wave event at Palipi Fishing Harbour, as shown in Figure 14.

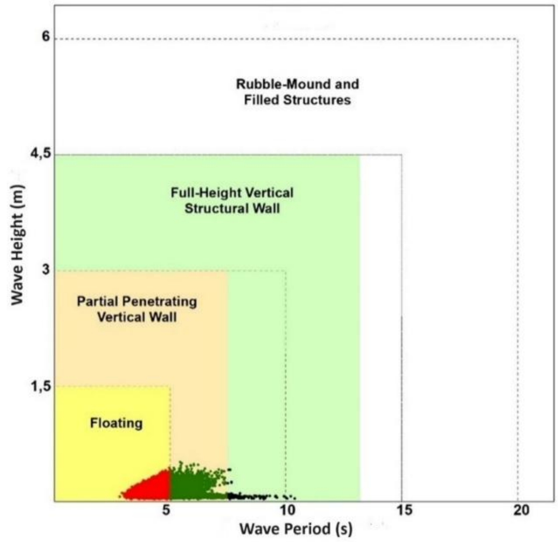


Figure 14. Analysis results of wave factor compliance with floating breakwater damping criteria

Based on Figure 14, it is known that the use of a floating breakwater is not fully able to reduce the waves that come to the Palipi Fishing Harbour pool area. Where some wave events can only be reduced by using partial penetrating vertical walls and full-height vertical structural walls, which are a type of fixed breakwater.

3.3. Floating Breakwater Feasibility Analysis Based on Estimated Floating Breakwater Dimensions

Modelling the estimated dimensions of the floating breakwater structure as an effort to reduce the entire wave event by the floating breakwater obtained the following results in Figure 15.

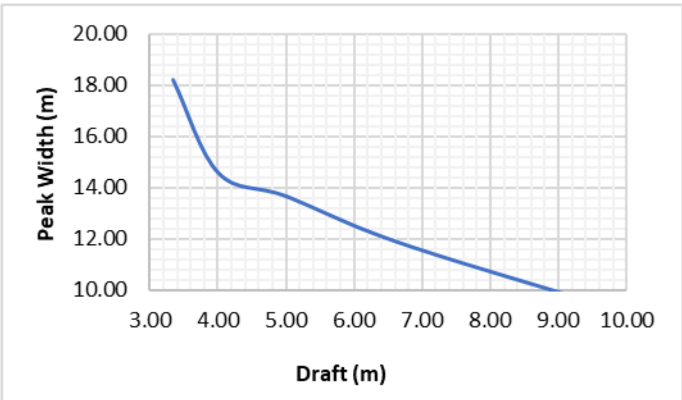


Figure 15. Estimated Dimensions of Floating Breakwater Structure

Based on Figure 15, with the assumption that the building is in the form of a beam, it is known that to reduce wave events in Palipi Fishing Port, the building is required to be 9 metres in height and 18 metres in width. In order to support the damping strength of the floating breakwater building, modelling is then carried out by varying the ratio of the building's height and peak width. Wave transmission phenomenon behind the floating breakwater, along with the Determination of Points and Rows Under Review (Left Part Picture). Values of Wave Transmission Coefficient against Distance from floating breakwater based on Row Review (Right Figure) are as follows.

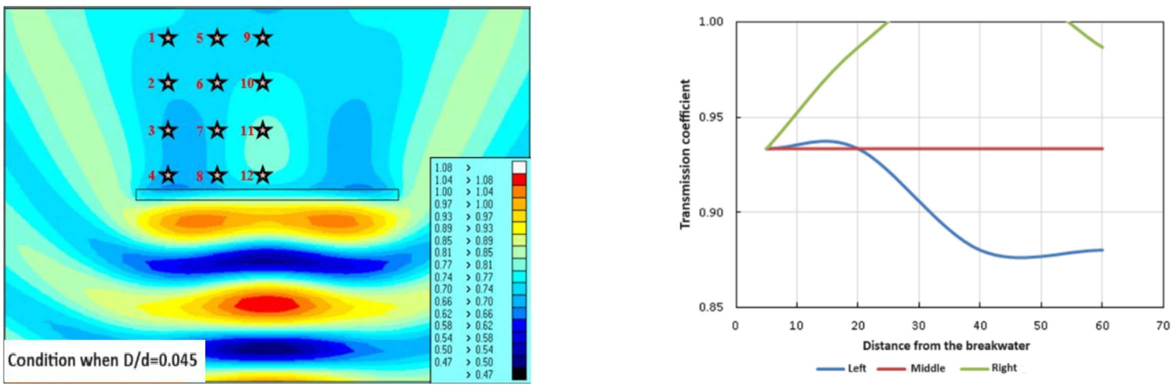


Figure 16. Wave Transmission under the conditions of D/d= 0.045

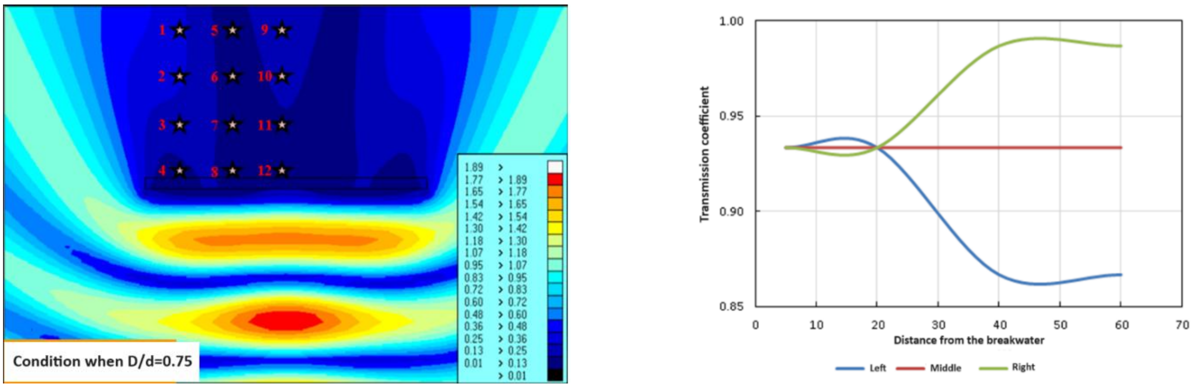


Figure 17. Wave Transmission under the conditions of D/d= 0.075

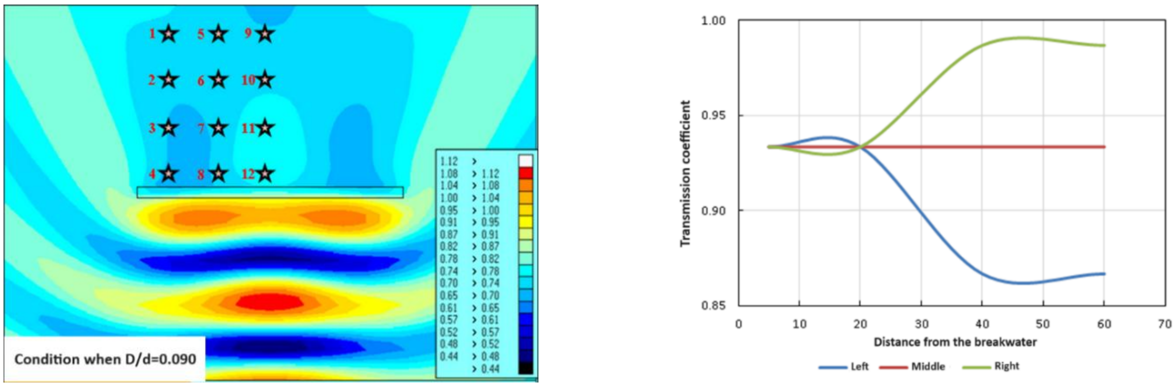


Figure 18. Wave Transmission under the conditions of D/d= 0.090

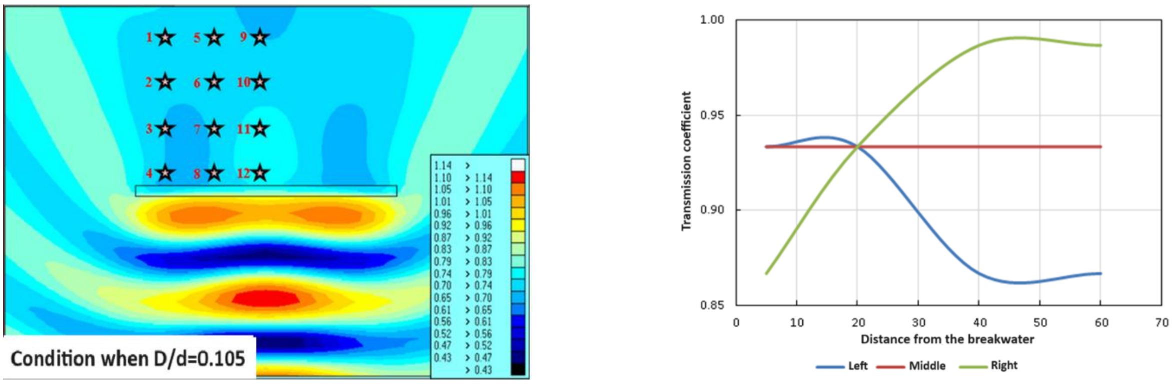


Figure 19. Wave Transmission under the conditions of D/d= 0.105

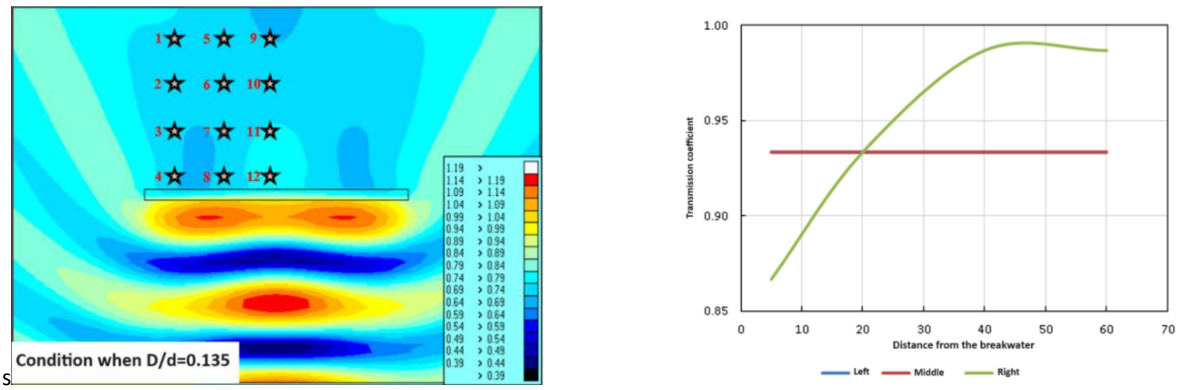


Figure 20. Wave Transmission under the conditions of D/d= 0.135

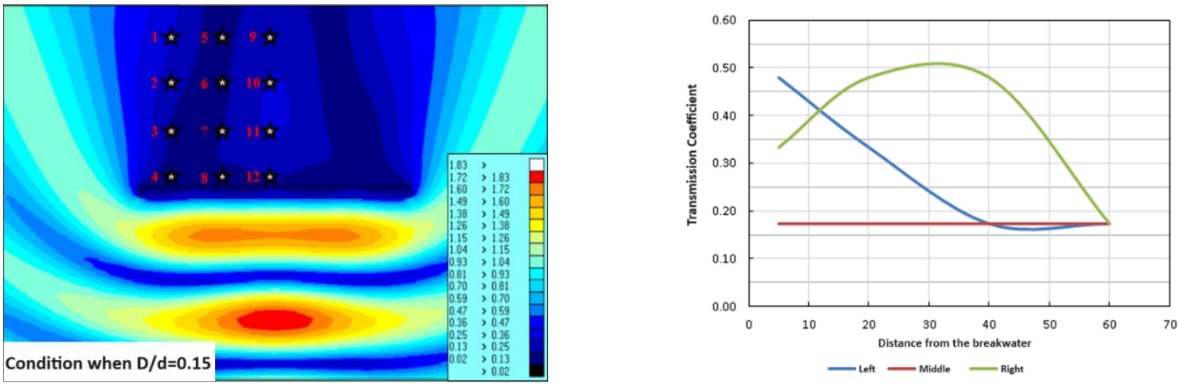


Figure 21. Wave Transmission under the conditions of D/d= 0.15

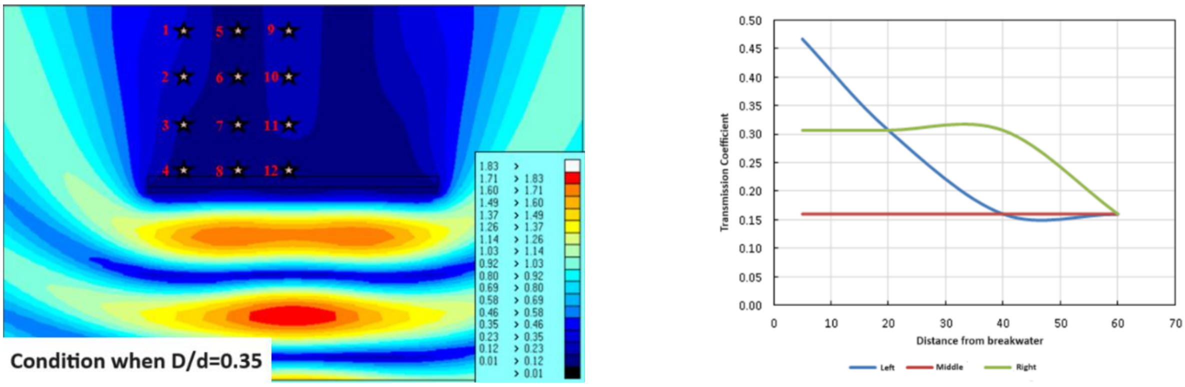


Figure 22. Wave Transmission under the conditions of D/d= 0.35

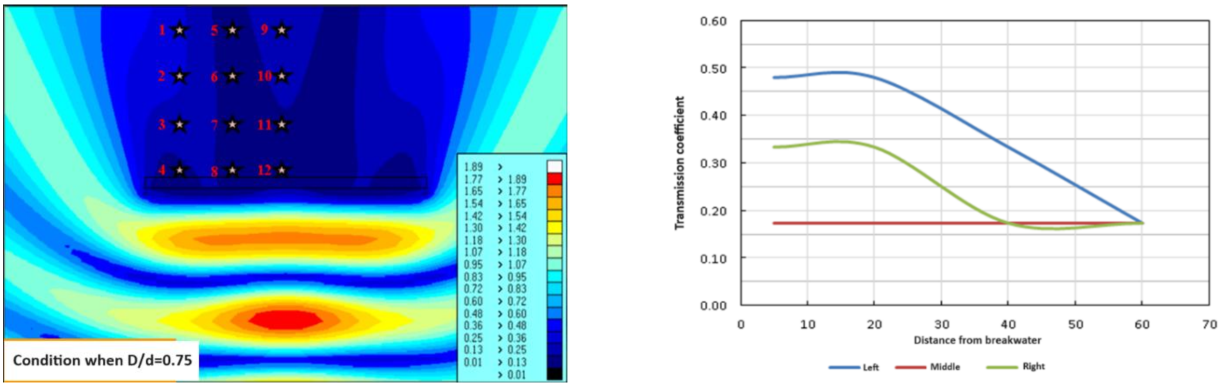


Figure 23. Wave Transmission under the conditions of D/d= 0.75

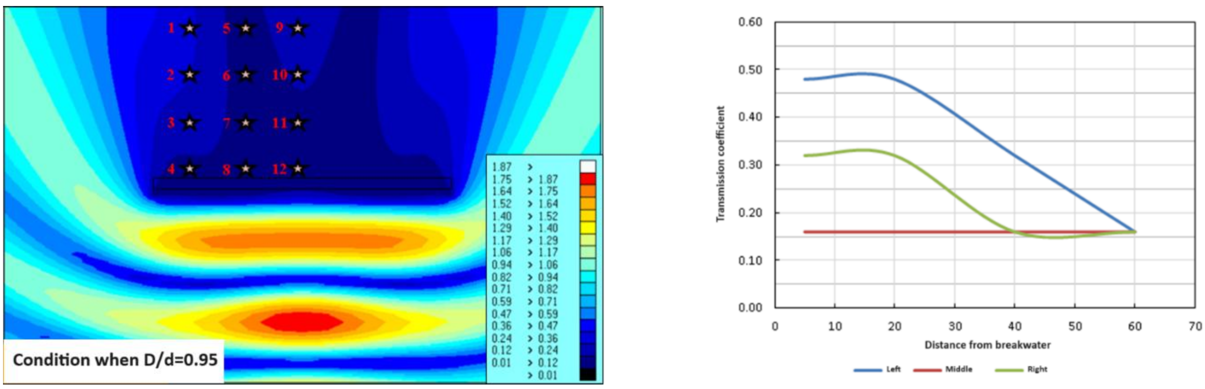


Figure 24. Wave Transmission under the conditions of D/d= 0.95

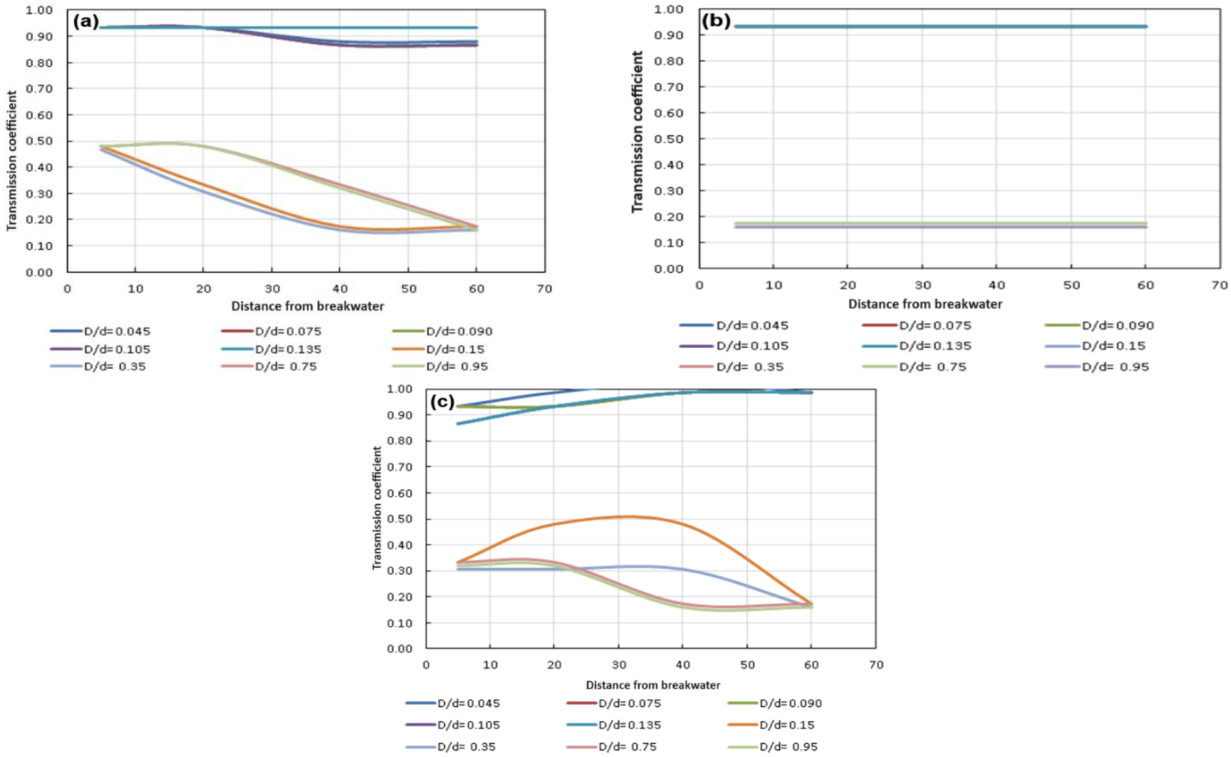


Figure 25. Effect of D/d on wave transmission coefficient by line of sight; (a) Left Section, (b) Centre Section, and (c) Right Section

Next is the analysis of the wave transmission phenomenon behind the floating breakwater along with Wave transmission phenomenon behind the floating breakwater along with Point Determination and Row Review (Left Figure). The value of Wave Transmission Coefficient against Distance from the floating breakwater based on Row Review (Right Figure) as follows.

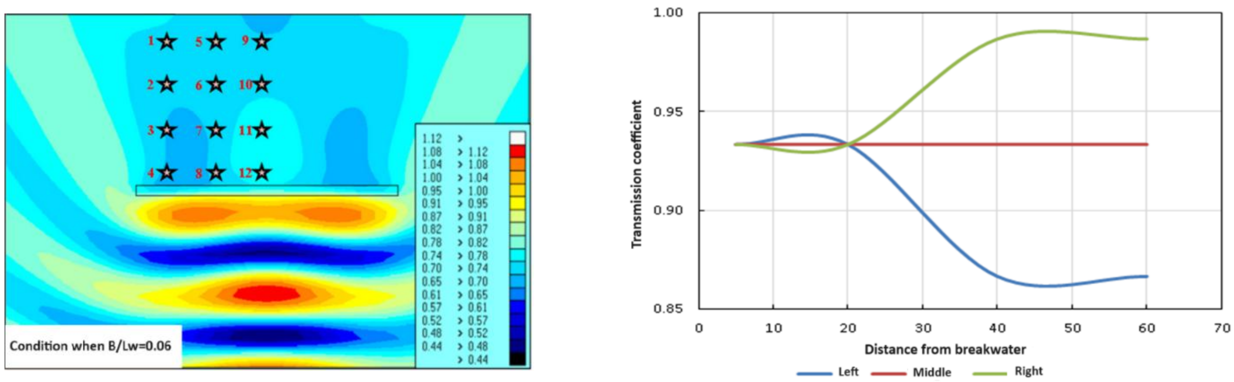


Figure 26. Wave Transmission under the conditions of B/Lw= 0.06

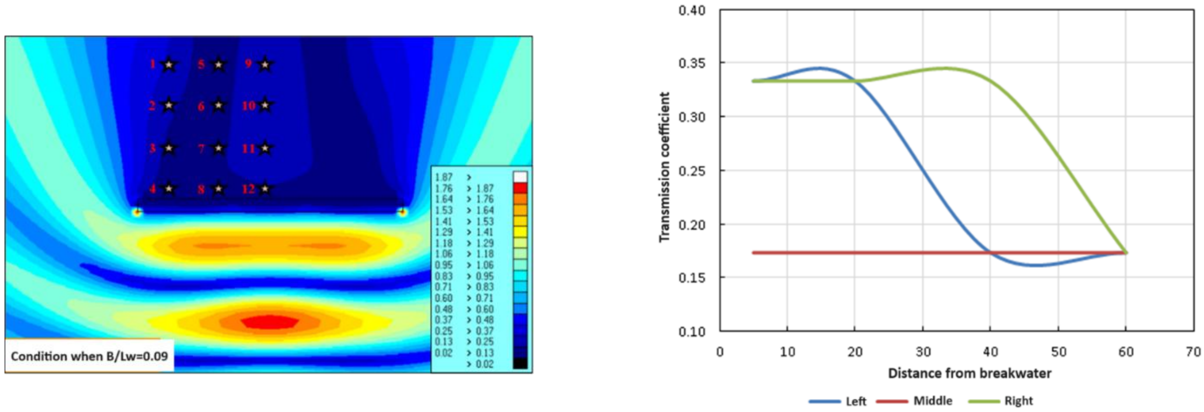


Figure 27. Wave Transmission under the conditions of B/Lw= 0.09

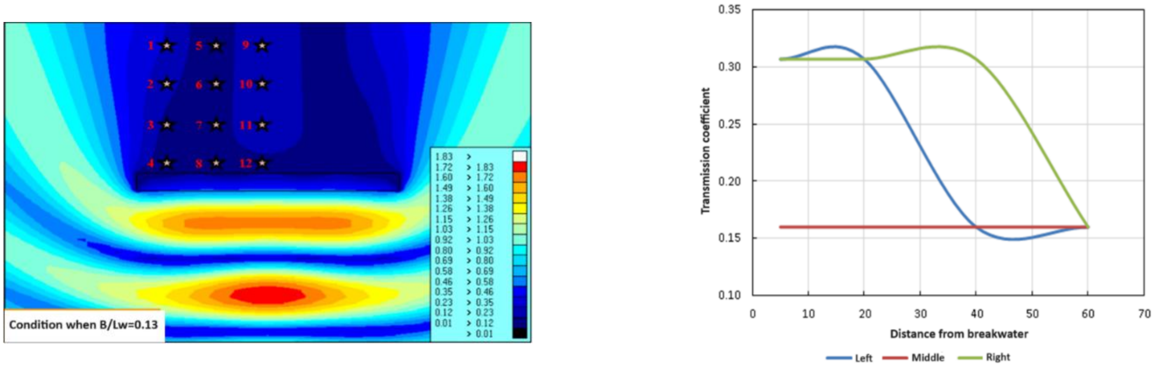


Figure 28. Wave Transmission under the conditions of B/Lw= 0.13

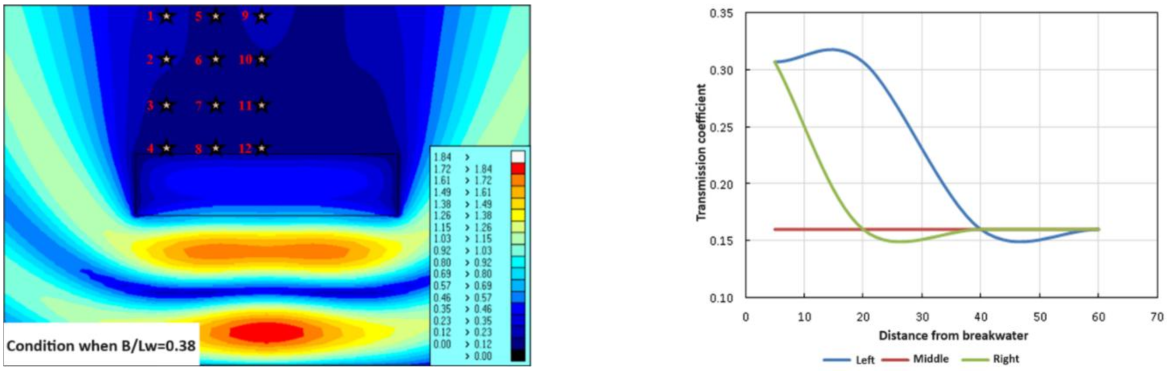


Figure 29. Wave Transmission under the conditions of B/Lw= 0.38

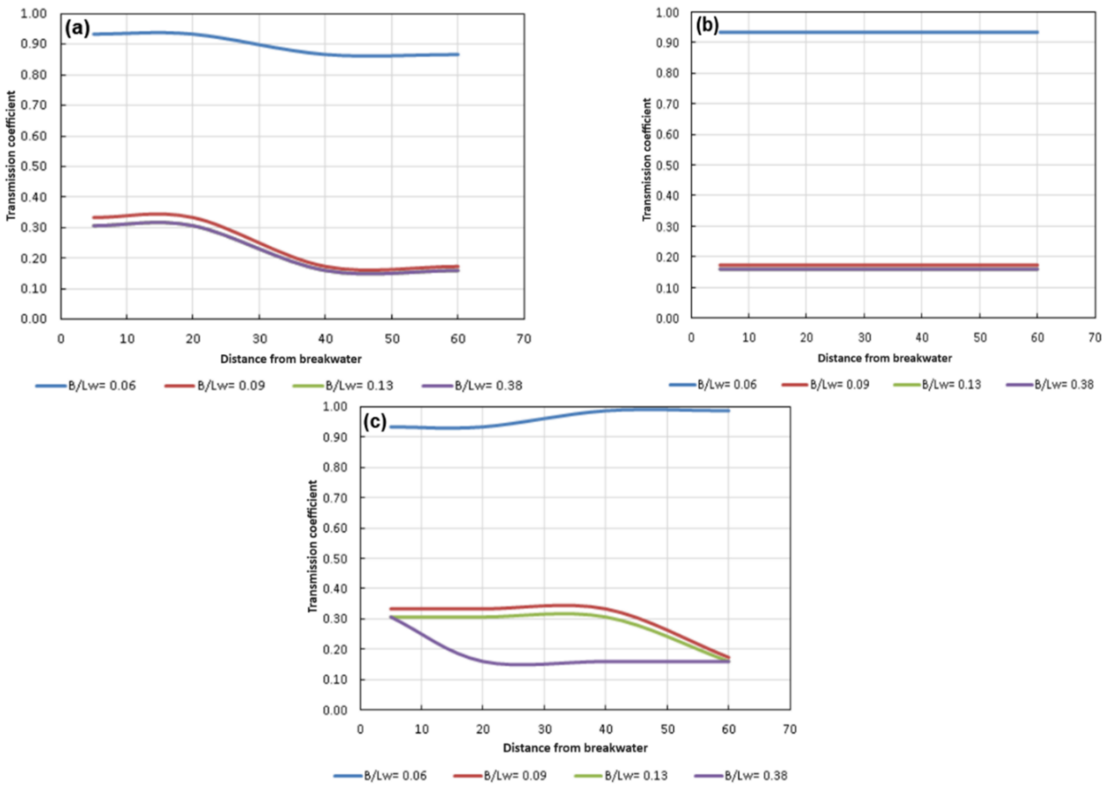


Figure 30. Effect of B/Lw on wave transmission coefficient based on line of sight; (a) Left Section, (b) Centre Section, and (c) Right Section

The hydrodynamic behaviour of a floating breakwater is determined by the dimensional parameters of the structure such as the water level ratio (D/d; where D = water level/draft, and d = water depth), and the width ratio (B/Lw; where B = breakwater width, and Lw = incident wavelength in metres). This ratio is an important parameter to control wave transmission. The term in reviewing wave transmission can be called the transmission coefficient (Kt). The wave transmission coefficient is the ratio between the wave height behind the floating breakwater (Ht) and the wave height in front of the floating breakwater (Hi). The smaller the Kt value, the better the floating breakwater performance in reducing wave height. To investigate the transmission coefficient, hydrodynamics-based numerical modelling was conducted. This modelling uses the Boundary Element Method (BEM) as the fundamental equation to simulate the dynamic effects of motion and pressure of the floating breakwater and its surroundings. This method implies that viscous forces are not taken into account, the fluid is incompressible and irrotational, which is solved in the frequency domain or time domain.

Figure 16 to Figure 25 show the correlation between the lineup behind the floating breakwater and the value of the transmission coefficient (Kt). In order to simplify the interpretation of the results obtained, the reviewed row refers to a collection of several points where the transmission wave amplitude data (0.5Ht) was collected from a total of 12 points. Points 1 to 4 are defined as the Left Row, points 5 to 8 as the Centre Row, and points 9 to 12 as the Right Row. When D/d = 0.045, the transmission coefficient produces a value of more than one in the Right Row. This indicates that the transmission wave height is greater than the incident wave height. More precisely, the value of the transmission coefficient in the Centre Row tends to be constant in every D/d condition. This is because the transmission wave height does not experience energy loss. In addition, when D/d = 0.075, 0.090, and 0.105, the trend of the transmission coefficient curve is identical across the rows under review, except for the Right Row D/d = 0.105, where there is an increase in the coefficient value. The similarity of the transmission coefficient values in the Right and Left Rows occurs only when D/d = 0.135. With this occurrence, the energy reduction phenomenon in the row can be said to be identical as well. Similarly, D/d = 0.15 and 0.35 cause a different curve trend compared to the smaller D/d value than before. The comparison of the two ratio values has a difference only when the value of the transmission coefficient in the right row decreases. The values of D/d = 0.75 and 0.95 produce a similar pattern of transmission values. To find out the effect of the transmission coefficient on the variation of the D/d value on the Left, Centre, and Right Rows, reviewed in detail, is presented in Figure 26. The results show that all rows are able to reduce the wave height with a transmission coefficient value of about 0.16 starting from a distance of 40 to 60 metres from the floating breakwater location. This occurs in the conditions of D/d = 0.15, 0.35, 0.75, and 0.95 only, despite the high transmission coefficient value before a distance of 40 metres from the floating breakwater. This indicates that the greater the value of the ratio, the trend of the curve and the value of the D/d ratio tend to be the same in the rate of decrease.

In addition, Figure 26 to Figure 30 display the effect of the reviewed row behind the floating breakwater on the value of the transmission coefficient (Kt) in the variations of B/Lw = 0.06, 0.09, 0.13, and 0.38. Broadly speaking, the similarity of the curve trend occurs only in the Left and Centre Rows. In addition, the Right Row changes significantly with each increase in the value of B/Lw. When B/Lw = 0.06, the transmission coefficient produces a value close to one in the Right Row. This indicates that the transmission wave height tends to be the same compared to the incident wave height. More precisely, the value of the transmission coefficient in the Centre Row tends to be constant at every distance. This is because the transmission wave height does not experience energy loss. In addition, when B/Lw = 0.09, 0.13, and 0.38, the trend of the transmission coefficient curve is identical in all the rows under review, except for the Right Row at the condition of B/Lw = 0.38 where there is a significant decrease in the coefficient value. With this occurrence, the energy reduction phenomenon in the row can be said to be identical as well. To find out the effect of the transmission coefficient on the variation of the B/L value w on the Left, Centre, and Right Rows reviewed in detail is presented in Figure 28. The results show that all rows are able to reduce the wave height with a transmission coefficient value of around 0.16 starting from a distance of 30 to 60 metres from the floating breakwater location. This occurs under the conditions of B/Lw = 0.09, 0.19, 0.13, and 0.38 only despite the high transmission coefficient value before a distance of 30 metres from the floating breakwater. Therefore, the greater the value of the B/L ratio w, the trend of the curve and the value of the ratio tend to be the same in the rate of decrease.

Based on the correlation of the determination of the D/d ratio and B/L ratio w to the transmission coefficient value, the floating breakwater model that is expected to reduce the incident wave height is easily known. According to the recapitulation results, the range of D/d ratio = 0.045 to 0.135 does not meet the wave transmission coefficient value or in other words is not able to reduce the incident wave significantly. Meanwhile, the ratio of D/d = 0.150 to 0.950 is able to obtain a low wave transmission coefficient. So that the effect of draft on floating breakwater design is influential if the value of water level starts from 3 metres. Furthermore, the recapitulation results of the B/L ratio w = 0.06 produce a large wave transmission coefficient. On the other hand, the B/L ratio w = 0.09 to 0.38 is able to obtain a low wave transmission coefficient. This indicates that the effect of floating breakwater width is significant. The effect of width occurs when the value of B = 7 metres. It should also be noted in depth, the effect of width is closely related to the location of the damped wave energy where the transmission coefficient in Figure 26 is smaller than the transmission coefficient in Figure 28 for the review location near the floating breakwater. In the end, the recommended dimensions of the floating breakwater are capable of producing small wave transmission coefficient values with the main variables D = 3 metres, and B = 7 metres.

4. Conclusion

Based on the study of the potential use of floating breakwaters in Palipi Fishing Harbour, it has been determined that the implementation of floating breakwaters in this location is not suitable. The analysis of wave parameters indicated that the floating breakwater cannot sufficiently reduce the waves entering the harbour dock area. To achieve the necessary wave attenuation for the safety of vessels at the dock, the required dimensions of the floating breakwater would be impractically large. Consequently, from both constructional and economic perspectives, the deployment of floating breakwaters at Palipi Fishing Harbour is deemed ineffective and inefficient.

Based on the findings of the unsuitability of using a floating breakwater at the Fish Landing Port in Palipi, it is necessary to analyse through a breakwater approach with another design. the use of piles can be an alternative to breakwater construction by taking into account the condition of the soil bearing capacity.

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