E-ISSN : 2963-4946
Vol. 2 No. January 04, 2024

Asian Journal of
Social and Humanities
https://ajosh.org/

Development of Experimental Models on Floating Breakwaters

Hotma Harapan Saragih, Roesdiman Soegiarso, Indra Noer Hamdhan
Universitas Tarumanagara, Indonesia
E-mail: saragih.hotma@gmail.com, roesdiman@gmail.com, indrahamdhan@gmail.com

*Correspondence: saragih.hotma@gmail.com

KEYWORDS
breakwaters; archipelagic; coastal abrasion

ABSTRACT

Indonesia is the largest archipelagic country in the world with a potential area consisting of 17,480 islands with a sea stretch of 5.8 million km2 and has the fourth longest coastline in the world at 95,181 km, has a very high level of risk of abrasion hazards, especially considering that more than 60% of Indonesians live in coastal areas. The main purpose of a floating breakwater is to protect an area against unwanted wave heights. One of the most important boundary requirements in port design is allowable downtime. This is a period of time when the port cannot fulfill its function so as to prevent the occurrence of unwanted things from the movement of ships. Downtime occurs when a certain wave height is exceeded, causing unwanted ship movements. This implies that the wave transmitted by the floating breakwater to the port determines the downtime. Of the 7 (seven) types that exist, the box type is taken for research because the box type is more effective and efficient in dampening waves. Then the type of box that is used as a test model is carried out with 2 (two) conditions. The test model to be studied is a floating pontoon with a mooring line and a floating pontoon tethered to a pile.

Introduction

Indonesia is the largest archipelagic country in the world with a potential area consisting of 17,480 islands with a sea stretch of 5.8 million km2 and has the fourth longest coastline in the world at 95,181 km, has a very high level of risk of abrasion hazards, especially considering that more than 60% of Indonesians live in coastal areas.

The main problem in coastal areas is coastal abrasion. This abrasion is caused by sea wave activity that erodes coastal areas. One method of overcoming coastal abrasion is the use of breakwaters where the structure functions as a damper of wave energy in certain areas. Large waves can be suppressed by reducing the energy of the incident wave, so that the waves heading to the beach have little energy. For this reason, it is necessary to construct a breakwater that serves to break, reflect and transmit wave energy.

A breakwater is a structure located in water and is used to protect an area from waves, for example a harbor. There are various types of breakwaters that have been known, namely rubble mound breakwater, caisson breakwater, composite breakwater and floating breakwater (Fousert, 2006). Floating breakwaters are classified as a special type of breakwater and are applied in locations where conventional breakwaters are not suitable to be applied (d'Angremond, 2018).

Floating breakwater or known as floating breakwater has advantages compared to other types of buildings, namely the structure can be used in soft bottom soil conditions (McCartney, 2015) and sea depths of more than 10 feet (Hales, 1981), Floating breakwaters produce minimal interference to water circulation, sediment transport and fish migration, effectively dampen waves less than 2 meters, These structures can also be moved and rearranged easily with different layouts to other locations (Murali & Mani, 2017), do not cause scouring (McCartney, 2015). From an economic point of view, it is often cheaper to implement floating breakwaters in deep water than conventional breakwaters. However, floating breakwaters also have disadvantages, including less effective at reducing waves for short waves. Practically the upper limit of the wave period is 6 seconds with a frequency of 1.6 radians/second; if mooring structure fails, it will cause disaster; and these structures require high maintenance costs compared to conventional breakwaters (Tsinker, 2015).

The application of floating breakwaters for ports is less frequent. This is because ports are often located near seas or oceans where higher and longer waves occur than in (deep) lakes. Floating breakwaters have historically been ineffective in harsher marine environments (Briggs et al., 2022). The main reason is that the wavelength relative to the width of the floating breakwater is large, causing the floating breakwater to move up and down above the wave without weakening the wave energy. To achieve better wave attenuation, the floating breakwater must have a large width compared to the wavelength, thus producing very large waves and an uneconomical design.

The main purpose of a floating breakwater is to protect an area against unwanted wave heights. One of the most important boundary requirements in port design is allowable downtime. This is a period of time when the port cannot fulfill its function so as to prevent the occurrence of unwanted things from the movement of ships. Downtime occurs when a certain wave height is exceeded, causing unwanted ship movements. This implies that the wave transmitted by the floating breakwater to the port determines the downtime. Therefore, the wave transmission coefficient of the floating breakwater is the most important parameter determining its effectiveness. The wave transmission coefficient, Ct, is defined as the ratio of the height of the transmitted wave (Ht) to the height of the incident wave (Hi). Low wave transmission coefficient implies effective wave attenuation. Since the wave transmission coefficient is an important parameter for determining effectiveness, it is necessary determine this parameter as accurately as possible during the design stage.

Over the past two decades, floating breakwaters have been more frequently applied in ports, particularly in areas with large water depths. The effectiveness of floating breakwaters depends largely on the period of the incident wave and the dimensions of the structure forming a complex problem. From earlier floating breakwaters, it turns out that the effectiveness of floating breakwaters is often overestimated during the design stage.

Research on floating breakwaters usually focuses on their performance, namely the ability of structures to dampen waves (transmission coefficient), stability of structures and mooring systems in various wave conditions, structural configuration and depth of location.

Some of the selected research results as a basis for supporting references in this study, are shown in the following table 1:

Table 1 Relevant Research Results

No.	Title, Name &; Year of Research	Research Results and Criticism
1	Floating Breakwater Design (McCartney, 2015)	Floating breakwaters can provide appropriate protective measures for ports in multiple locations. This paper presents an inventory of floating breakwater types, their limitations, and some design considerations. Floating breakwaters are inventoried into 4 general categories namely boxes, pontoons, mats, and tethered floats. Tethered floats are identified as a special category but these models are rarely used for more detailed analysis.
2	Dynamic Analysis of Floating Breakwater Mooring Systems (Headland et al., 1990)	This study presents a numerical model for the calculation of the mooring force of a floating breakwater. The box-shaped model is based on mooring analysis by simulation: (1) the load characteristics of the nonlinear mooring rope and (2) the load of the mooring rope is related to the deviation force of the second-order wave. The results of numerical studies were compared with physical tests (Torum, 1989) and measurements (Nelson and Broderick, 1986). This comparison shows that numerical models give a good estimate on the strength of the breakwater mooring rope. Therefore, it was concluded that numerical models are useful for the analysis and design of floating breakwater mooring systems.
3	Perfomance of Cage Floating Breakwater (Murali & Mani, 2017)	Experiments were conducted to study the performance of cage floating breakwater under wave environments and wave currents. The results of the study, transmission and reflection coefficients are elaborated and compared with those reported in the literature. Also discussed are the variations in oscillations and velocities of the water surface in the cage, the influence of the stiffness of the mooring rope, and the initial stress on transmission characteristics.
4	Design Optimization of Floating Breakwaters with an Interdisciplinary Fluid – Solid Structural Problem (Elchahal et al., 2009)	Optimization of floating breakwater design has implications for solving interdisciplinary problems consisting of: three models. The first arises from the interaction of linear waves with floating breakwaters tethered with downwind boundary directions consisting of vertical sidewalls representing dock walls in the harbor. The second includes the dynamic behavior of oscillating structures caused by incoming waves. Both assemble the hydrodynamic performance of floating breakwaters; While the third concerns its structural mechanics which are influenced by

No.	Title, Name &; Year of Research	Research Results and Criticism
		hydrostatic and hydrodynamic forces. The goal of the optimization problem is to design a floating breakwater that can optimally dampen waves to a minimum and meet the requirements of stability, and structural resistance. Functions and constraints are expressed in mathematical geometry parameters of the breakwater that are assembled in an optimization algorithm based on the sequential quadratic programming method (SQP).
5	Hydrodynamic Characteristics of a Free-Surface Semicircular Breakwater Exposed to Irregular Waves (Teh et al., 2012)\	Free-surface semicircular breakwaters have been developed to protect coastal and marine infrastructure from ocean waves. The hydrodynamic characteristics of breakwaters were investigated in irregular seas through experimental programs. The results showed that the waterproof semicircular model is an effective wave reflector, and the permeable semicircular model is a good energy reliever.
6	Limits of the New Transmission Formula for π type Floating Breakwaters (Ruol et al., 2012)	This study was to assess the results of available experiments and numerical simulations, the possibility of which occurred an expansion of the range of application of the formula proposed by Ruol et al. (J. Wat. Port, Coast. Ocean Eng., 1, 2013), provides wave transmission for π type floating breakwaters tethered with chains. Ruol et al. (2012) proposed a formula that is a modification of Macagno's analytical relationships. The formula here is applied to other types of floating breakwaters. The error between the predicted value and the measured value is explained and discussed with reference to geometric variables. It seems that the formula works well for floating breakwaters.
7	Experimental Study on a New Type Floating Breakwater (Cheng et al., 2013)	A new type of floating breakwater is proposed in this paper. Its hydrodynamic performance has been tested. The new breakwater structure named the cylindrical floating breakwater consists of two parts: a rigid cylindrical main body, and a flexible mesh cage containing a number of spherical suspensions intended to absorb wave energy into its mechanical energy. A series of experiments were conducted on this floating breakwater and traditional double pontoon and box buoyancy breakwater to compare their performance. The results showed that the new floating breakwater has better performance than traditional double pontoons and box floating breakwaters: wave transmission is significantly reduced by cage nets with balls, especially for long waves.

No.	Title, Name &; Year of Research	Research Results and Criticism
8	Review of Recent Research and Developments on Floating Breakwaters (Dai et al., 2018)	This study presents a literature review and development of floating breakwater. Floating breakwaters can be categorized into seven main types, namely boxes, pontoons, frames, mats, tethered floats, horizontal plates and other types. Research and development and its performance, various types of floating breakwaters and wave absorbing devices are reviewed and discussed. The results present that box-type and pontoon-type floating breakwaters are the most common designs, and are effective in protecting coastlines primarily by reflecting incoming waves. Their regular configuration allows economical and efficient construction and installation. Compared to box-type breakwaters, pontoon designs have greater inertia in rolls without much material upgrade. Extensive studies of the performance of various designs have been conducted, and many innovative configurations, such as porous plates and pneumatic chambers, have also been introduced to reduce wave transmission.
9	Study of Wave Characteristics in Floating Breakwater Anchored and Mooring types (Sujantoko et al., 2021)	This research is about attenuation and wave reflection from various configurations of floating breakwater types of piles and moorings, by testing physical models of floating breakwater in the laboratory, at a water depth of 80 cm, wave height of 3.5 - 5.5 cm, wave period of 0.5 - 2 seconds, and mooring rope angle (45º, 60º, 90º). This floating breakwater is arranged variously in the direction of longitudinal and transverse towards the beach. The results present the influence of configuration and width on the floating breakwater structure on transmission and wave reflection influenced by mooring angle. Configuration 3 with the largest width is able to give the best value transmission coefficient Kt = 0.797 at mooring angle 45o and reflection coefficient Kr = 0.572 at mooring angle 90º. In the embedded type, configuration 3 gives the largest value Kt = 0.431 – 0.623 and Kr = 0.053 – 0.997 compared to other configurations. In configurations 1 and 2 at the back of the structure is not supported by piles so that a swing that generates waves occurs. While the influence of wave slope, Kt will increase as the wave slope decreases.
10	Comparison of Hydrodynamic Performances Between Single Pontoon and Double Pontoon Floating Breakwaters Through the SPH Method	A numerical study adopting the 2D model of δ-SPH was conducted to compare the hydrodynamic characteristics of a single-pontoon floating breakwater and a double-pontoon floating breakwater. Numerical

No.	Title, Name &; Year of Research	Research Results and Criticism
	(Chen et al., 2022)	simulations were performed using the δ-SPH model and experimental tests were conducted to validate the numerical model. The numerical results of both the height of the free surface and the motion of the floating breakwater correspond to the experimental results. The study's conclusion showed that when the draft pontoon is larger, the double-pontoon floating breakwater will perform better in wave attenuation compared to the single-pontoon floating breakwater, and for all drafts, the amplitude of movement including wobble, heave and roll of the double-pontoon floating breakwater is always smaller. In addition, increasing the distance between the two pontoons can further reduce the amplitude of pontoon movement and improve the damping ability of the double-pontoon floating breakwater wavelength.
11	A Machine Learning Method for the Evaluation of Hydrodynamic Performance of Floating Breakwaters in Wave (Saghi et al., 2022)	This paper presents a two-dimensional simulation model for the idealization of rectangular moorings and trapezoidal floating breakwater motion on regular waves and irregular waves. The Quick-Fictitious Domain and the Fluid Volume Method are combined to track the effect of free surfaces and predict floating breakwater motion. Research presents that a suitable combination of the aspect ratio of floating breakwater and its sidewall mooring angle can help dampen incoming waves to minimum height. The study concluded that tethered trapezoidal floating breakwater is more efficient than traditional rectangular designs.

Research gaps from some of the studies above that have been reviewed are related to floating breakwaters and breakwater models. Most previous studies focused on the process of floating breakwaters attenuating so that research was not carried out on mooring and anchors to resist the movement of floating breakwaters

This research is using one type of pontoon structure model with two types of treatment, namely floating breakwater tethered with piles (one degree of freedom) and floating breakwater tethered with chains (six degrees of freedom). So that the latest of this research is:

1. A more profitable floating breakwater model was obtained.
2. Acquired the ideal distance between the floating wavebreaker and the port

The benefits to be achieved or obtained from this research include the following:

1. Theoretical benefits, this study can provide information on the study of optimal models in protecting ports

2. Practical benefits, this research is expected to contribute to sustainable infrastructure development, as well as become an illustration of the breakwater model in protecting ports in Indonesia

Research Methods

Research methods on energy attenuation research on poles are carried out by physical modeling. Physical modeling is carried out with a 2D model. in the implementation of this physical model utilizing the 3D wave pool owned by the laboratory, by insulating the existing wave pool. So it only uses a few segments of the wave generating machine. In this study, the width of the pool used was 3 m wide and 40 m long. After the preparation for the pool is complete, preparations are then made for the wave measurement device.

The location to be studied in this study is a port directly facing the ocean (not protected by surrounding islands).

Physical modeling is carried out to determine changes in the characteristics of wave height transformations against various piling structures. To determine the change in wave height against the pole, several model scenarios were compiled. Schematize the model by changing the shape of the pile arrangement in rows and columns with respect to the water level. The modifier to be observed is the height of the incident wave Hi, the wave after the structure Ht to the shape of the pile shape. Model scenario preparation by varying the arrangement of pile shapes, water table height, wave period and height.

The test method in this laboratory is the same as that introduced by (Owen & Allsop, 2014), in the physical model of breakwater testing it is also observed how the structure influences the variation of wave height. In this study, significant variations in wave height at the peak of the storm were carried out and their correspondence to the period of waves raised in the wave channel at 60%, 80%, 100%, and 120%. The wave period is obtained based on the assumption of constant wave steepness (Chawla et al., 2020).

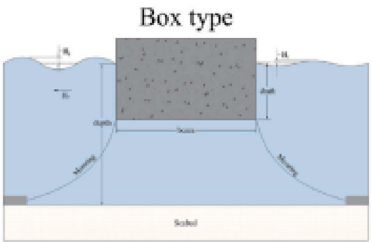
In the test method, storm events are often simulated as a number of tests that take place with fixed water table elevation, increased wave height, and increased wave periods in discrete steps until damage occurs or wave height reaches 120% of the design wave height. The duration of each step should be between 3 and 10 hours; (Jensen et al., 2017) prototypes suggest durations between 100 and 500 waves. The method is referred to as the classical testing method so that the physical model testing conducted by the coastal Research and Development Center observed about 100 waves that occurred first.

Data collection techniques or methods are a way done by researchers to get the data needed in a study. Data is a collection of facts obtained from a measurement. A good decision making is the result of drawing conclusions based on accurate data or facts. In general, the data in this study is divided into two data sources, namely primary data sources and secondary data.

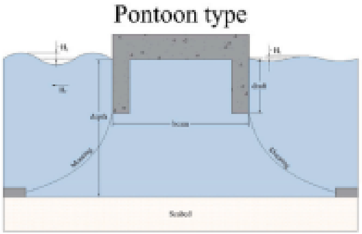
Results and Discussions

Based on previous research, there are 7 (seven) types of test models, namely: :

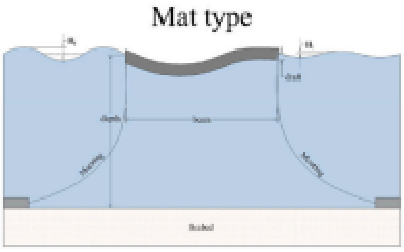
1. Tipe Box



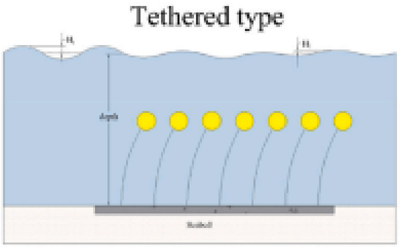
2. Tipe Ponton



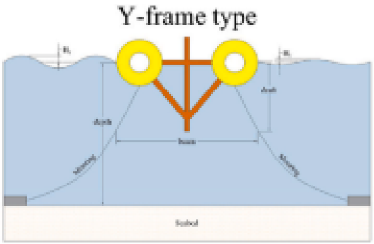
3. Tipe Mat



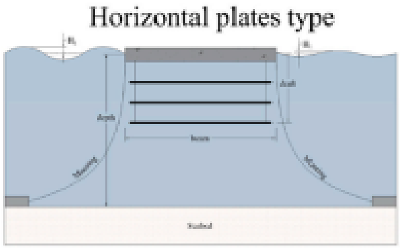
4. Tipe Tethered



5. Tipe Y Frame



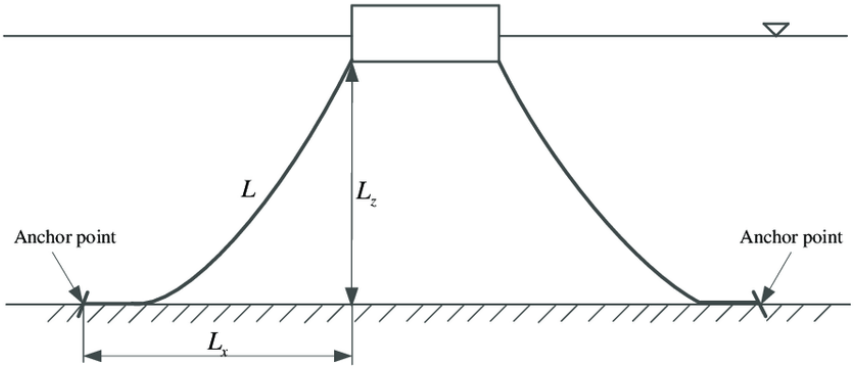
6. Tipe Horizontal Plate



1. Other Types

Of the 7 (seven) types that exist, the box type is taken for research because the box type is more effective and efficient in dampening waves. Then the type of box that is used as a test model is carried out with 2 (two) conditions, namely:

1. Use Mooring Line



2. Use Pile

The 2 (two) conditions above were conducted research on wave damping. Which one is more effective and efficient.

Conclusion

The test model to be studied is a floating pontoon with a mooring line and a floating pontoon tethered to a pile. These two test models will be carried out further research in the laboratory to obtain the results of which test models are more effective and efficient in reducing waves.

References

Briggs, M., Ye, W., Demirbilek, Z., & Zhang, J. (2022). Field and numerical comparisons of the RIBS floating breakwater Comparaisonsderésultatsd'unecampagnedemesuresetdecalculsnumériquessur le brise-lame RIBS. *Journal of Hydraulic Research*, *40*(3), 1.

Chawla, R., Madhu, S. V, Makkar, B. M., Ghosh, S., Saboo, B., Kalra, S., & Group, R.-E. C. (2020). RSSDI-ESI clinical practice recommendations for the management of type 2 diabetes mellitus 2020. *Indian journal of endocrinology and metabolism*, *24*(1), 1.

Chen, Y., Liu, Y., & Meringolo, D. D. (2022). Comparison of Hydrodynamic Performances Between Single Pontoon and Double Pontoon Floating Breakwaters Through the SPH Method. *China Ocean Engineering*, *36*(6), 894–910.

Cheng, L. H., Fen, C. Y., Li, Y. H., & Jiang, W. Y. (2013). Experimental study on a new type floating breakwater. *Proceedings of the 7th International Conference on Asian and Pacific Coasts (APAC 2013) Bali, Indonesia*.

d'Angremond, K. (2018). *Breakwaters and closure dams*. CRC Press.

Dai, J., Wang, C. M., Utsunomiya, T., & Duan, W. (2018). Review of recent research and developments on floating breakwaters. *Ocean Engineering*, *158*, 132–151.

Elchahal, G., Lafon, P., & Younes, R. (2009). Design optimization of floating breakwaters with an interdisciplinary fluid–solid structural problem. *Canadian journal of civil engineering*, *36*(11), 1732–1743.

Fousert, M. W. (2006). *Floating Breakwater*. Msc thesis, Delft University of Technology.

Hales, L. Z. (1981). *Floating breakwaters: State-of-the-art literature review*. US Army Coastal Engineering Research Center CE, Fort Belvior, Virginia.

Headland, T. N., Pike, K. L., & Harris, M. E. (1990). Emics and etics: The insider/outsider debate. *This book had its genesis at a symposium of the 87th Annual Meeting of the American Anthropological Association in Phoenix, Arizona, on Nov 19, 1988.*

Jensen, T., Andersen, H., Grønbech, J., Mansard, E. P. D., & Davies, M. H. (2017). Breakwater stability under regular and irregular wave attack. In *Coastal Engineering 1996* (bll 1679–1692).

McCartney, B. L. (2015). Floating breakwater design. *Journal of Waterway, Port, Coastal, and Ocean Engineering*, *111*(2), 304–318.

Murali, K., & Mani, J. S. (2017). Performance of cage floating breakwater. *Journal of Waterway, Port, Coastal, and Ocean Engineering*, *123*(4), 172–179.

Owen, M. W., & Allsop, N. W. H. (2014). 6 Hydraulic modelling of rubble mound breakwaters. In *Breakwaters Design & Construction* (bll 71–78). Thomas Telford Publishing.

Ruol, P., Martinelli, L., & Pezzutto, P. (2012). Limits of the new transmission formula for pi-type floating breakwaters. *International Conference on Coastal Engineering*.

Saghi, H., Mikkola, T., & Hirdaris, S. (2022). A machine learning method for the evaluation of hydrodynamic performance of floating breakwaters in waves. *Ships and Offshore Structures*, *17*(7), 1447–1461.

Sujantoko, S., Wardhana, W., Djatmiko, E. B., Armono, H. D., & Putro, W. S. (2021). STUDI KARAKTERISKTIK GELOMBANG PADA FLOATING BREAKWATER TIPE TERPANCANG DAN TAMBAT. *Jurnal Teknik Hidraulik*, *12*(1), 39–52.

Teh, H. M., Venugopal, V., & Bruce, T. (2012). Hydrodynamic characteristics of a free-surface semicircular breakwater exposed to irregular waves. *Journal of waterway,* *port, coastal, and ocean engineering*, *138*(2), 149–163.

Tsinker, G. P. (2015). Marinas. In *Marine Structures Engineering: Specialized Applications* (bll 412–503). Springer.