Study of Wave Deformation Around Floating Breakwater

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Abstract. Breakwater is a structure to protect waters from wave interference. The structure separates the port basin from the open sea, so that sea waves will not enter the basin. In applying for deep water conditions, floating breakwater is more efficient than conventional types, because it requires less material. Floating breakwater is suitable for soft soils where the strength of the soil is low; and is also good for the environment. The development of floating breakwater has increased significantly in the past decade. This study focuses on the magnitude of the wave transmission coefficient. Two types of floating breakwater were tested, namely FBW Type-1 and FBW Type-2, using physical modeling as well as numerical model (FLOW3D software). The experimental model was carried out in 50 m long of wave flume equipped with a regular wave generator. The study results transmission coefficient ranged from 0.53 to 0.91. Based on the results, therefore more study is needed to get better coefficient.

Keywords: floating breakwater, physical model, numerical simulation, transmission coefficient

1. Introduction
Breakwater is installed at nearshore area in order to reduce wave amplitude propagates to protected area used for specific purposes. Rubble mounts type and caisson, as well as the hybrid are commonly applied as breakwater. This conventional breakwaters are usually need a lot of material and time-consuming for construction, and therefore are expensive. As a massive structure, it may change the original near shore current system and destroy littoral sand balance and ecological system.

As an alternative, a floating breakwater might be adopted for particular condition. Studies on floating breakwater have been conducted [1-3]. In general, floating breakwater has low sheltering efficiency and high maintenance difficulties. Hence the floating breakwater has been rarely built.

The types of floating breakwater available depend on the combination of materials, breakwater shape, its mooring system (including configuration) and its function [4]. There are four general types of floating breakwaters [5]:

- **Box type floating breakwaters**
  It is the most frequently used as alternative to the fixed breakwaters due to the more economical, environmental and economic friendy [6]. This is usually made up of reinforced concrete, rectangular-shaped modules that may be flexibly or rigidly connected to other modules to make a larger breakwater and also of steel or even barges. This type of breakwaters is numerous and include a fifty-year design life, proven performance, simple construction and effectiveness under...
moderate wave condition. However, the major disadvantages are its relatively high cost and require higher maintenance.

- **Pontoon type floating breakwaters**
  The ladder type, catamaran type, sloping-float (inclined pontoon), and a frame type are the examples of pontoon types floating breakwater. Pontoon types have similar advantages and disadvantages to the box type but less expensive than box. Important parameter to be given attention is to the L/B parameter as it was in the box type [5]. Other usages of these types of structures are for floating walkways, storage, boat moorings, and fishing piers.

- **Tethered float**
  Tethered floating breakwater type is seldom used and quite different from other types of floating breakwater. Rather than attenuate waves by using their mass, the tethered floating breakwater uses its mooring system to dissipate wave energy. Waves move the breakwater around until the mooring system restricts its motion, then wave energy is transferred to the anchors and ultimately the sea floor, dissipating the wave height. This type of breakwater; although thus, this type of breakwater is still under investigation and there is not a significant amount of information on these moored breakwaters to make any conclusive remarks [7].

- **Mat**
  Tire mat breakwaters consist of three basic designs such as Wave Maze, Goodyear, and Wave-Guard [5]. Advantages of the tire mat breakwater are low cost, simple design and construction, portability, low anchor loads, and greater effectiveness than box and pontoon types while the disadvantages include lack of buoyancy, 15-20 year design life, they do not effectively damp long wavelengths, they can’t be moored year round because of icing effects.

### 2. Physical modeling
Physical modeling is carried out to obtain the magnitude of the transmission wave due to the installment of the floating breakwater.

#### 2.1. Wave Flume and measuring equipments
The facilities and equipment used for experiment of wave transmission on the floating breakwater are :

- Wave flume is 45 m length, 2 m width and 1.6 m height. The wave flume is equipped with a wave generator on one side and a wave absorber on the other side.
- Wave probe
- Data acquisition and computer

![Figure 1. The wave flume.](image)

#### 2.2. Model Scale
The model scale in this research is 1:20, and the various variables in the model are as follows :
Table 1. Floating Breakwater Model Scale.

| No | Variable          | Prototype | Model |
|----|-------------------|-----------|-------|
| 1  | Wave Height (m)   | 0.5       | 0.025 |
| 2  | Period (det)      | 6.0       | 1.34  |
| 3  | Water Depth (m)   | 10.0      | 0.50  |
| 4  | FBW Length (m)    | 30.0      | 1.50  |
| 5  | FBW Width (m)     | 10.0      | 0.50  |
| 6  | FBW Height (m)    | 3.0       | 0.15  |
| 7  | FBW Draft (m)     | 1.6       | 0.08  |
| 8  | FBW Free Board (m)| 1.4       | 0.07  |
| 9  | Mooring (m)       | 1.92      | 0.096 |
| 10 | Mooring Force (kN)| 2454.27   | 0.307 |

2.3. Floating Breakwater (FBW) Model

The floating breakwater models tested were 2 models, first is FBW Type-1 and the second is FBW Type-2.

- **FBW Type-1**
  FBW Type-1 is a model with a three foot shape with dimensions (1.5 x 0.5 x 0.15) m and a thickness of 1.8 mm. The body made from iron plates as illustrated in figure 2. Based on measurements in water, draft in a free state (without chains and load cells) is 8 cm. When testing using chains, the draft floating breakwater is 8.5 cm.

![Figure 2. FBW Type-1.](image)

- **FBW Type-2**
  FBW Type-2 model is a three foot model with dimensions (1.5 x 0.5 x 0.15) m and 1.8 mm thickness made of iron plates as illustrated in Figure 3. Based on measurements in water, the draft on free state (without chains and load cells) is 8 cm. When testing using chains, the draft floating breakwater is 8.5 cm.
2.4. Wave Probe Layout
Wave probes are installed in the middle and parallel to the canal direction, with a particular configuration as shown in the following figure.

![Wave Probe Layout](image)

**Figure 3.** FBW Type-2.

2.5. Modeling Scenario
The test aims to analyze wave transmission that going through the floating breakwater. Summary of the test series are presented in the table below.

| No. | Model        | d (cm) | T (det) | H (cm)  | Type of test         |
|-----|--------------|--------|---------|---------|----------------------|
| 1   | FBW Type-1   | 50     | 1.34    | 2.5     | wave transmission    |
| 2   | FBW Type-1   | 50     | 1.34    | 6.25    | wave transmission    |
| 3   | FBW Type-1   | 50     | 1.34    | 10      | wave transmission    |
| 4   | FBW Type-2   | 50     | 1.34    | 2.5     | wave transmission    |
| 5   | FBW Type-2   | 50     | 1.34    | 6.25    | wave transmission    |
| 6   | FBW Type-2   | 50     | 1.34    | 10      | wave transmission    |
2.6. Test Result

Examples data taken from the wave probe 5 (blue) and 8 (red) are presented in figure 5.

![Figure 5. Examples data from wave probe 5 (Blue) and 8 (Red).](image)

2.7. Data Analysis

The transmission coefficient for experiments on the fix floating breakwater is presented in figure 6 and 7.

![Figure 6. Kt as function of Hi/L for FBW Type-1, fix condition.](image)
And the transmission coefficient for experiments on the floating breakwater with mooring is presented in Figure 8 and 9.

3. Numerical Modeling

3.1. Computational Fluid Dynamics

As in the physical modeling, the numerical modeling is implemented for FBW Type-1 and FBW Type-2 on fix conditions. The numerical modeling was conducted using Flow3D software.
3.2. Numerical Modeling Scenario
The scenario adapts to the physical model test scenario. In order to get more detail and accurate results, the numerical model was running using the prototype scale, as shown in table below.

**Table 3. Numerical modeling scenario.**

| No. | Water depth (m) | Wave Height (m) | Period (s) |
|-----|----------------|----------------|------------|
| 1   | 10             | 0.5            | 6          |
| 2   | 10             | 1.25           | 6          |
| 3   | 10             | 2              | 6          |

3.3. Numerical Modeling Results
Results of simulation in form of time series of water surface elevation are shown in the figure below.

**FBW Type-1**

![Wave Height = 0.5 m](image1)

![Wave Height = 1.25 m](image2)

**Figure 10.** Time series of water surface elevation at sensor 5 and 8 on the modeling of FBW Type-1.

**FBW Type-2**

![Wave Height = 0.5 m](image3)

![Wave Height = 1.25 m](image4)

**Figure 11.** Time series of water surface elevation at sensor 5 and 8 on the modeling of FBW Type-2.

Image below, in a 2-dimension view, indicates wave height in front of and in behind of the FBW Type-1 and FBW Type-2.
3.4. Data Analysis
Results of the Flow3D simulation are then analyzed using MIKE's software. The wave data on the front side of the floating breakwater is split into incident wave (Hi) and reflection wave (Hr). Transmission coefficient (Ct) and reflection coefficient (Cr) are then determined.

4. Comparison of Results between Numerical Modeling and Physical Modeling
Comparisons of results between them are prepared in figure 15 and figure 16. The coefficient of transmission is depicted as function of the wave height. A good agreement is found for the FBW Type-2, where the results of numerical modeling similar to those of the results of the physical modeling. A different pattern is found for the FBW Type-1, a bigger gap occur between them.
Figure 14. Transmission coefficient (Ct) as function of wave height (H) for FBW Type-1.

Figure 15. Transmission coefficient (Ct) as function of wave height (H) for FBW Type-2.

5. Conclusion
Based on experiments using both numerical simulation and physical modeling, it is possible to make the following conclusions:

a) Phenomena of wave deformation around floating breakwater can be imitated quite well using physical modeling as well as numerical simulation.

b) Fix type of floating breakwater give a better result in reducing incoming wave to the protected area.

c) Most of floating breakwater is mooring type therefore the moored floating breakwater type (type-2) should be reassessed and modified in order to get better reduction.

d) Numerical simulation has fairly results that similar to the physical model and produce smaller transmission coefficient.

e) Although the numerical simulation has a good performance for the simulation, it still has potential of misuse an un-proper parameter in the simulation, and necessity to check all variables adopted in the case.
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7. Reference

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