VERTICAL FLOATING BREAKWATER (VFB)

By

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DISSERTATION

To be submitted in partial fulfilment of
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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
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in partial fulfilment of the requirement for the
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Approved by,

____

(Assoc. Prof. Ahmad Mustafa bin Hashim)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
SEPTEMBER 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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NORAZY SHAKILA BINTI MD. SALLIH

ABSTRACT

The awareness to prevent the shorelines from erosion since many years ago has led to many efforts to protect the coastal areas. This paper focuses on the hard engineering way to protect the coast by the application of floating breakwater. The research is a laboratory-based project on the innovation of floating breakwater concept by introducing the vertical pipe as a part of floating structure that submerged into the water. The effect of variation of draft and the arrangement of the vertical pipes on the wave transmission were studied.

The design concept is aimed particularly for application in areas of weak soil profile especially for West Coast Peninsular Malaysia under the shallow water condition. In contrast to conventional fixed breakwater that poses direct loading to the seabed, the proposed floating breakwater has the potential to reduce wave transmission with promising application especially in the weaker muddy area. This objective has been demonstrated by experimental work using hydraulic 2D model test where small scale of 1:5 of designed models has been successfully tested with three designed models which are Designed Model A (4 rows of vertical pipes), Designed Model B (2 rows of vertical pipes) and Designed Model C (1 row of vertical pipes). Model parameters used: incident wave height of $0.02 \text{ m} < H_i < 0.06 \text{ m}$, relative draft of vertical pipe into the water of $0.2 < D_r/D < 0.6$, wavelength with range 0.25 m to 3 m, number of rows of vertical pipes (1, 2, and 4 rows) and wave period range of 0.5 sec – 2 sec.

Results of the investigation show that the greater the number of rows of vertical pipes attenuates the wave better. Using $D_r/D < 0.02$ becomes inefficient in reducing the wave of desired $K_t < 0.5$. Designed model C seems to be insignificant to be applied based on the performance shown by getting $K_t > 0.5$. For Designed Model A and B; they have capability to serve the purpose well as wave attenuator which applicable for moderate wave but with own limitation of wave height, wave period and wavelength.

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NORAZY SHAKILA, December 2012

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CHAPTER 1: INTRODUCTION

1.1 Background

The coastal zone or called shoreline is a dynamic region of natural and man-made changes. The coastal zone is about 15% of the of earth's land surface (200 km wide) but accommodate 50% of the world population. The beaches are the tourist attraction that contributes to the country's economy. The tourists love the nice scenery of the sea from the beaches and the place is favorable for relaxing. Therefore, the shoreline protection is a need from natural and manmade disasters (Vipulanandan, 2010). The natural disaster described such as changes in wave climate and rising sea level while the manmade disaster is done by the human activities such as removal of mangroves, construction of causeways that alter tidal circulation and wave processes around islands and change sediment transport patterns.

In Malaysia, a total of 1300 km of 4800 km of coastal areas (29%) are facing serious problems of erosion (Mohamed, 2010). According to Economic Planning Unit (1986), the coastal erosion in Malaysia can be classified into three based on the coastal condition affected: Category 1, 2 and 3 as shown in Table 1:

Table 1: Classification of Coastal Erosion **(Economic Planning Unit, 1986)**

Category	Description
Category 1	Shorelines currently in a state of erosion and where shore-based facilities or infrastructure are in immediate danger of collapse or damage.
Category 2	Shorelines eroding at a rate whereby public property and agriculture land of value will become threatened within 5 to 10 years unless remedial action is taken.
Category 3	Undeveloped shorelines experiencing erosion but no or minor consequent economic loss if left unchecked.

There are numerous devices have been introduced to stop the erosion processes shown in Figure 1 and Table 2.

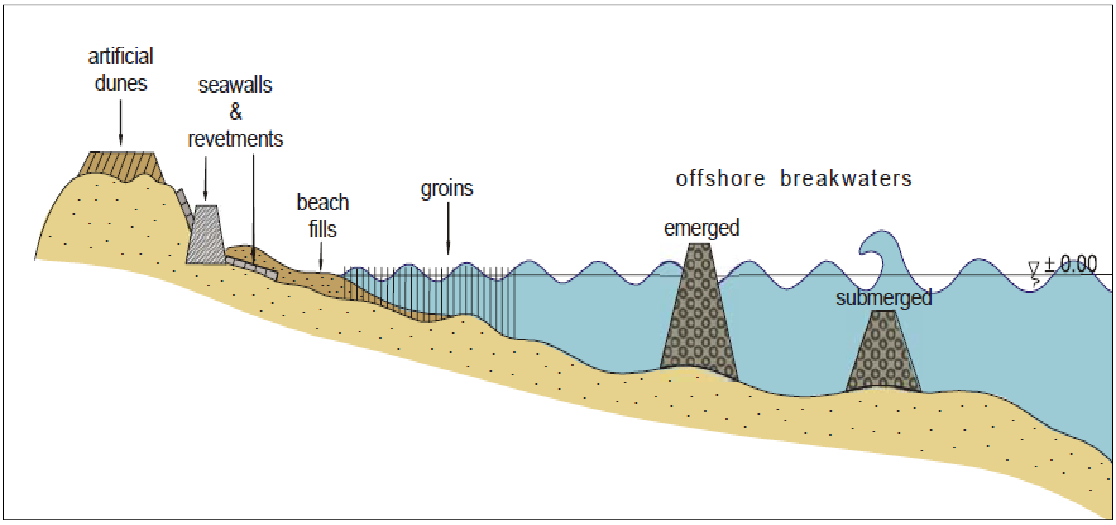


Figure 1: The Soft and Hard Shoreline Protection Measures

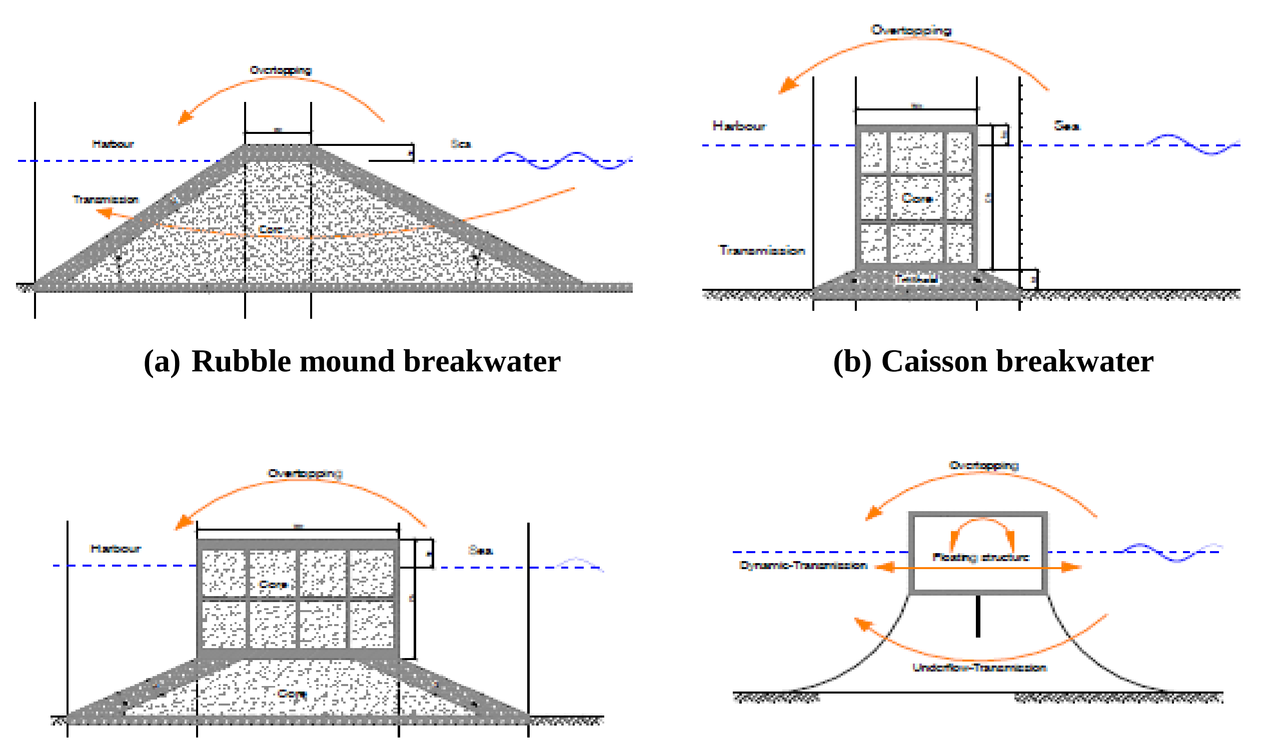
(Ostrowski and Szmytkiewiz, 2008)

Table 2: Alternative to Shore Protection **(US Army Corps of Engineers, 2002)**

TYPE	DESCRIPTION	METHOD
Armouring	Defending the shoreline at its current position	Revertments
Stabilisation	Reducing the erosion rate by slowing down the loss of sediments	Groynes, **Breakwater**
Beach Nourishment	Fill up the beach with similar material	Beach nourishment, New technologies
Adaption and retreat	Modify current usage and or relocation of existing population or activities	
Combination and new technologies	Combination of above methods or innovative methods	Nourishment and groynes, Geotextile bags, Eco-engineering techniques
Do nothing	Allow the beach to change without intervention (usually applied to areas with insinigficant or no economic importance)	Allow natural changes

The soft measures are those that are more natural such as beach nourishment. However, nourishment does not fix the cause of the erosion; it is the only method that involves adding sand to the coastal system. Mangrove is also one of the natural coastal protections and believed succeed to reduce the damage caused by the recent Tsunami in December 2004. Meanwhile, hard measures have been the traditional tool of the coastal engineers. The hard structure is more favourable as it helps to fix the cause of erosion. These include groins, jetties, sea walls, and also **breakwaters** (Yaakob, 2006).

Breakwaters are constructed to provide a calm basin for ships and to protect harbour facilities. They are also sometimes used to protect the port area from the intrusion of littoral drift. In fact, for ports open to rough seas, breakwaters play a key role in port operations (Horikawa, 1978). There are two types of breakwaters available: floating breakwater and fixed breakwater (emerged breakwater and submerged breakwater).



(a) Rubble mound breakwater **(b) Caisson breakwater**

(c) Composite breakwater **(d) Floating breakwater**

Figure 2: Several Breakwater Structures **(Fousert, 2006)**

Compared to fixed breakwater, the floating breakwater would minimize both reflection and transmissions by allowing some water to pass below the structure while the fixed breakwater restricting the water to pass through. The main function of a floating breakwater is to attenuate the wave action. Such a structure cannot stop all the wave action. The incident wave is partially transmitted, partially reflected, and partially dissipated. Energy is dissipated due to damping and friction and through the generation of eddies at the edges of the breakwater (Koutandos et. al., 2004).

The performance of the breakwater is normally presented by comparing the wave height after the structure (transmitted wave height) and the wave height measured before the structure (incident wave height) that gives the value of the wave transmission coefficient (K_t).The lower K_t represents a good structure that can dissipate more wave energy. The allowable maximum K_t for a structure is 0.5 (Briggs et. al., 2002).

1.2 Problem Statement

The construction of breakwater as wave attenuator requires a high cost due to the high usage of material. The idea of using the floating breakwater somehow becomes an option in reducing the material but it is still new and not widely used yet compared to the application of fixed breakwater (emerged and submerged breakwater) in Malaysia. There are still less researches being done about floating breakwater and innovation that can be made for floating breakwater. Modification of floating breakwater with introducing the vertical pipe arrangement is an interesting idea to explore for the effectiveness in wave transmission at the shallow water of coastal area in Malaysia.

1.3 Objective & Scope of Study

1.3.1 Objectives

This project aims to further research exploration on the floating breakwater by:

1. Designing a new floating breakwater concept with better performance of wave attenuation.
2. Determining the best configuration for wave attenuation by varying:

- Geometry	: Number of rows of vertical pipes
	: Draft of vertical pipes
- Wave condition	: Wavelength and wave height

1.3.2 Scope of Studies

The project is basically based on the laboratory experiment- based research project. There are three main elements in this scope of studies which are:

1. Proposing the model
2. Testing and varying the model arrangement
3. Analysing the model performance

To narrow down the project so that it is feasible and could be completed within the allocated time frame, the project is focusing on the effectiveness of variation of drafts, D_r (height of vertical pipes submerged into the water measured from the water surface) and number of rows of pipes positioned in parallel to act as a cluster on the different wave condition by disallowing the structure from experiencing the six degrees of freedom. The width of structure and the depth of water are also fixed for the experiment. According to Ozeren et al. (2011), when the breakwater models are fixed, the reflection is higher than in the partially restrained models, and the efficiency is strongly dependent on draft ratio (D_r = h, where D_r is the draft and h is the height of the structure).

CHAPTER 2: LITERATURE REVIEW

In this section, there will be a brief explanation about the coastal area in Malaysia, the wave transmission factor, and the floating breakwater.

2.1. Malaysia Coastline

Coastlines in Malaysia can be classified into two: **East Coast** and **West Coast.** East coast condition is generally known as hook-shaped sandy bays which the high sediment yield from the river discharges and harsher wave environment. For west coast area, the coastlines are more calmer affected from the mild wave climate of the Strait of Malacca make for wide mud shores and coastal forests rich in biodiversity. Coastlines at Sabah and Sarawak also have the similar forms characterised beaches like at the Peninsular Malaysia although certain sandy beaches are flat beaches (DID, 2012). The coastline distribution in Malaysia can be summarised as below:

(a) Coastlines of Malaysia

(b) Coastal Area (Peninsular Malaysia)

(c) Coastal Area (Sabah and Sarawak)

***Figure 3: Coastline Distribution of Malaysia* (DID, 2012)**

Coastal Engineering Division under Department of Irrigation and Drainage (DID) Malaysia has recorded the erosion happens according to each states of Malaysia based on the Natural Coastal Study 1986. The data recorded as in Table 3.

***Table 3: Coastal Erosion Areas in Malaysia* (DID: National Coastal Erosion Study 1986)**

State	Distance	Eroded Coastal (Categerised as follows)						Total Of Distance/Eroded Coastals		
		Category 1		Category 2		Category 3				
	(KM)	(KM)	Unit	(KM)	Unit	(KM)	Unit	(KM)	Unit	(%)
Perlis	20	4.4	3	3.7	1	6.4	4	14.5	8	72.5
Kedah	148	31.4	16	2.2	1	9.9	3	43.5	20	29.4
Pulau Pinang	152	42.4	9	19.7	5	1.1	1	63.2	15	41.6
Perak	230	28.3	4	18.8	2	93.1	4	140.2	10	61.0
Selangor	213	63.5	10	22.3	7	66.1	3	151.9	20	71.3
N. Sembilan	58	3.9	2	7.7	4	12.9	1	24.5	7	42.2
Melaka	73	15.6	5	15.1	2	6	2	36.7	9	50.3
Johor	492	28.9	9	50.3	9	155.6	11	234.8	29	47.7
Pahang	271	12.4	11	5.2	3	107.8	8	125.4	22	46.3
Terengganu	244	20	6	10	6	122.4	10	152.4	22	62.5
Kelantan	71	5	3	9.5	3	37.6	5	52.1	11	73.4
W.P Labuan	59	2.5	2	3	2	25.1	2	30.6	6	51.9
Sarawak	1035	17.3	8	22.3	10	9.6	7	49.2	25	4.8
Sabah	1743	12.8	5	3.5	2	279.2	12	295.5	19	17.0
Total	**4809**	**288**	**93**	**193**	**57**	**933**	**73**	**1414.5**	**223**	**29.41**

Focusing to west coast areas Malaysia, it can easily identified by the existence of mangrove trees which can grow at the muddy area. The wave approach at the west coast area is predominantly during South west monsoon period to the southern part of the area. The west coast is protected by the Sumatra Island from severe wave from the Indian Ocean thus limits the fetch length to 40 to 130 km in Melaka Straits. These are the parameters for the wave at this area:

Table 4: Wave Parameters at West Coast of Malaysia

Parameter	**Value**
Fetch length (km)	40 - 130
Normal wave height (m)	0.5 - 1.0
Maximum wave height (m)	2 - 3
Normal wave period (s)	3
Maximum wave period (s)	6 - 9

Teh and Lim (1993) record data about the mangrove area at Peninsular Malaysia that experiencing the erosion with Perak and Selangor are having severe erosion (Table 5).

Table 5: Condition of Mangrove Coastal in Peninsular Malaysia (**Teh and Lim, 1993)**

Size	Retreating (km)	Stable (km)	Advancing (km)	Total (km)
Perlis	5.6	0	3.4	9
Kedah	21.9	17.5	30.9	70.4
P.Pinang	21.2	10.7	21.4	59.3
Perak	**134.8**	**0**	**52.6**	**187.4**
Selangor	**148.7**	**5.1**	**47.3**	**201.1**
N.Sembilan	12.7	7.9	9.5	30.1
Melaka	5.1	0	18.2	23.3
Johor (West)	80.1	24.6	58.1	162.8
Johor (East)	32.0	18.0	0	50.0
Pahang	40.0	53.0	0	93.0
Terengganu	10.0	25.0	0	35.0
Kelantan	0	0	0	0
Total	518.1	161.9	241.4	921.4
%	56.23	17.57	26.20	100.00

The problems faced for the construction of coastal protection structure at the muddy soil area is due to soft soil with low shear strength and large compressibility as the result of high water content and low dry density. Therefore, the construction over this type of soil may experience bearing capacity failure and excessive settlement (Angraini, 2006). Realizing the condition happens at the West Coastline of Malaysia, the approach to solve the erosion problem by allocating the suitable structure at the muddy area.

2.2. Floating Breakwater

2.2.1 Types of Floating Breakwater

The types of floating breakwater available can be seen as combination of materials, breakwater shape, its mooring system (including configuration) and its function (Lee, 1999). McCartney (1985) divided the floating breakwaters into four types:

(1) Box

A box floating breakwater is the most commonly used floating breakwater as alternative to fixed breakwater that more economical, environmental and economic friendly (Kurum, 2010). It can be found constructed by 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. The usages of the structure are for recreational and temporary boat moorage. However, the main disadvantages for these structures are that they are considerably more expensive than mat types and require higher maintenance.

(2) Pontoon

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 (McCartney, 1985). Other usages of these types of structures are for floating walkways, storage, boat moorings, and fishing piers (Hales, 1981).

(3) Mat

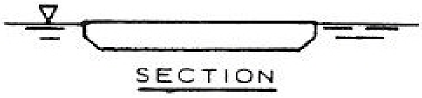
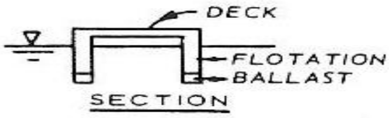
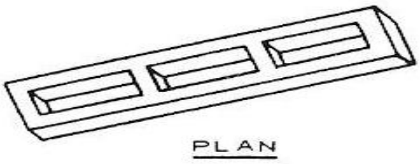
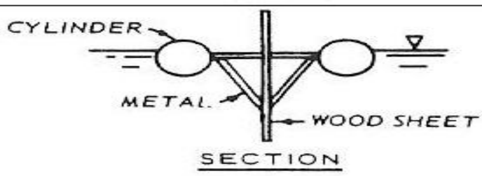
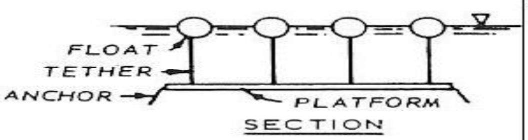
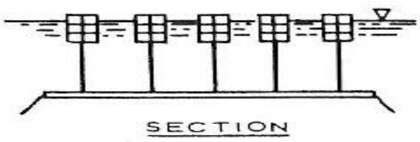
Tire mat breakwaters consist of three basic designs such as Wave Maze, Goodyear, and Wave-Guard (Hales, 1981). DeYoung (1978) and McCartney (1985) in their paper discussed about the advantages and disadvantages of these structure. Advantages of the tire mat breakwater are low cost, simple design and 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 wave lengths, they cannot be moored year round because of icing effects, and they can break apart if not constructed adequately and then they would create floating debris.

(4) Tethered float

Tethered floating breakwater is quite different from other types of floating breakwater. While the rest use their mass to attenuate waves, 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. Mays (1997, 1999) has performed work involving 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.

The examples of types of floating breakwater are listed in the table below:

Table 6: Types of Floating Breakwater **(McCartney, 1985)**

BOX Solid rectangle		Reinforced concrete units are the most common type. They may be empty or filled with light material
Barge		Derived from army
PONTOON Twin pontoon		Catamaran shape
Open compartment		Sometime called Alaska type
A frame		
Twin log		Deck is open wood frame
MAT Tire mat		Scrap tires strung on pole framework or bound together with chain or belting. Foam flotation is usually need
Log mat		Log raft chained or cabled together
TETHERED FLOAT Sphere		Float placed in rows
Tire		Arrangement similar to spheres. Steel drums with ballasts can be used instead of tires

2.2.2 Advantages and Disadvantages

Many researches have been done using different types of floating breakwater and the advantages of the floating breakwater through its effectiveness have been summarised as below:

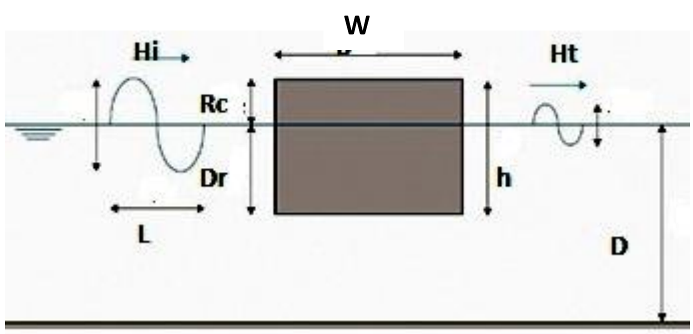
1. Floating breakwater is less expensive compared to fixed structure in deeper water which is greater than 3 m (Hales, 1981) (Grinyer, 1995).
2. Floating breakwater can effectively attenuate moderate wave heights which less than 1.98 m (Tsinker, 1995).
3. Poor soil condition may take floating breakwater more feasible to be used than heavy rubble fixed breakwaters. (McCartney, 1985) (Mani, 1991).
4. Floating breakwater affects minimal interference on water circulation, sediment transport, and fish migration (Kelly, 1990).
5. Floating breakwater can be moved and rearranged easily or transported to another site (Hales, 1981).
6. If the problem of ice formation occurs, the floating breakwater can be removed from the site (McCartney, 1985).
7. Floating breakwater is not as obtrusive as fixed breakwater and can be more aesthetically pleasing (McCartney, 1985).

However, the floating breakwater has some disadvantages too:

1. Inflating and towing would require higher labour cost than structure which is left in place.
2. The structure has the possibility to become punctured.

In summary, there are many advantages using the floating breakwater despite some minor disadvantages. Ability of the floating breakwater to survive at poor foundation make it has the major potential to be applied at the West Coast of Malaysia.

2.2.3 Parameters Effect Floating Breakwater Performance



The structural parameters used:
D = Water Depth
W = Width of the Breakwater
D_r = Draft of the Breakwater
RC = Freeboard of the Breakwater
h = Height of the Breakwater
(= RC + D_r)

The wave parameters used:
H_i = Incident Wave Height
L = Wavelength
H_t = Transmitted Wave Height

Figure 4: Definition of Parameter of Floating Breakwater **(Drieman, 2011)**

From the research done by Silander (1999), he proves that the wave transmission will mainly depend on **wavelength**, **space between the barriers** and **draft.** The statement is also supported by the research done by Koutandos et. al. (2004) that found that the ratios W/L and D_r/D are the most important parameters in the performance of the floating breakwater and operates more efficiently in intermediate waters under the action of shorter period waves. For the experiment, the effectiveness of floating breakwater can be determined by these parameters:

i. The relative structure draft = D_r/D
ii. The relative breakwater width = W/L

2.2.3.1 Wavelength

The efficiency of a floating breakwater depends primarily on the ratio of the width to the wavelength (W/L) of the oncoming waves. McCartney (1985) shows that as this value increases, the wave transmission coefficient decreases. The statement is also supported by the observation made by Rajappa et el. (2011) about the breakwater configuration using five layers of pipes as multi layered moored floating pipe breakwater found that K_t decreases with an increase in W/L values for the range of D_r/D from 0.06 to 0.40 and giving 78% is the maximum wave attenuation achieved with the present breakwater configuration. For design purposes, the wave transmission coefficient should be as low as possible for the given case. The waves with short wavelengths than the width of breakwater are more preferable to have the better wave transmission. Research by Sciortino (2010) found that given that ocean swell has a very long wavelength, floating breakwaters are not suitable for creating protected areas along an exposed coastline and should never be installed.

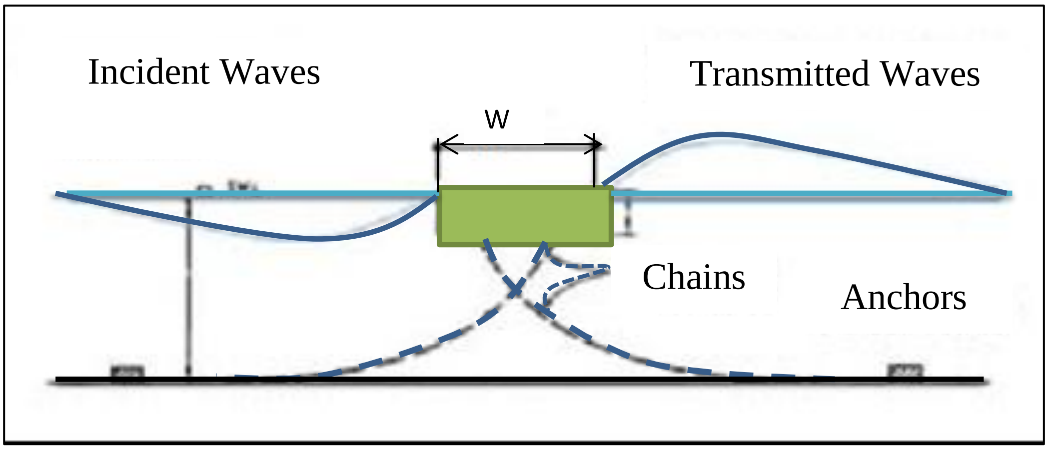


Figure 5: Relationship between Width (W) and Wavelength **(Sciortino, 2010)**

2.2.3.2 Draft

Wang and Sun (2010) tested a porous floating breakwater. In most cases, attenuation was concluded to be controlled primarily by the inertia and draft of the structure, and the breakwater is less efficient for longer waves. A 70% of wave transmission reduction can occur when the draft is large enough for the period up to 14 seconds (Fousert, 2006). An increase in the relative depth of submergence, D_r/D, from 0.025 to 0.15 leads to a reduction in K_t by about 30% (Sundar and Subbarao, 2003).

2.2.4 Potential of Vertical Structure

The vertical pipe as a part of structure has been used in the previous researches. Murali and Mani (1997) have proved that it is possible to gain a 15 - 20% reduction of the transmitted wave height when a screen of vertical pipes, separated by a gap, is installed. Mani et al. (1995) introduced a suspended pipe breakwater which uses the similar concept of using the vertical part as a part of the floating structure to be put at the small marinas. Wave interaction with vertical slotted walls as a permeable breakwater spaced far apart by fixing the gap to diameter ratio of 0.22 results a draft to water depth ratio (D_r/D) of 0.46 are recommended to achieve wave transmission coefficient less than 0.5.

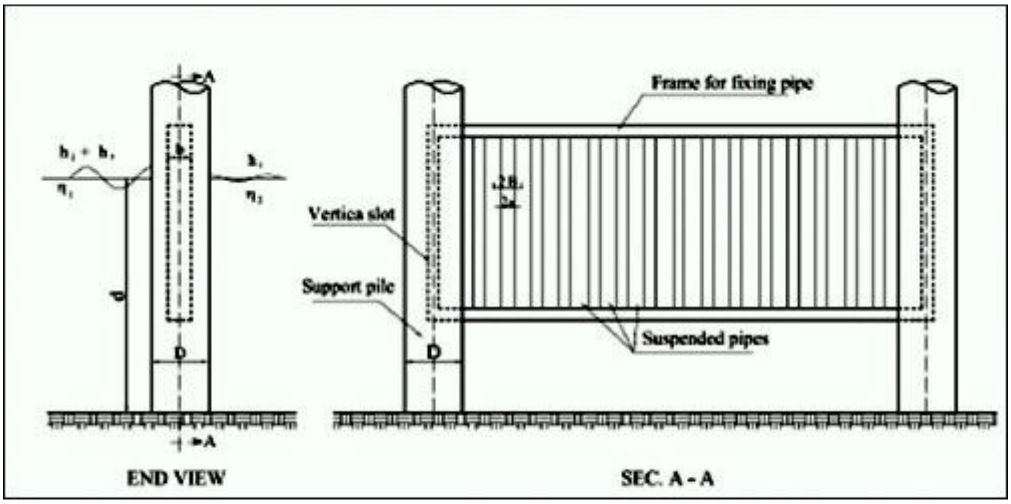


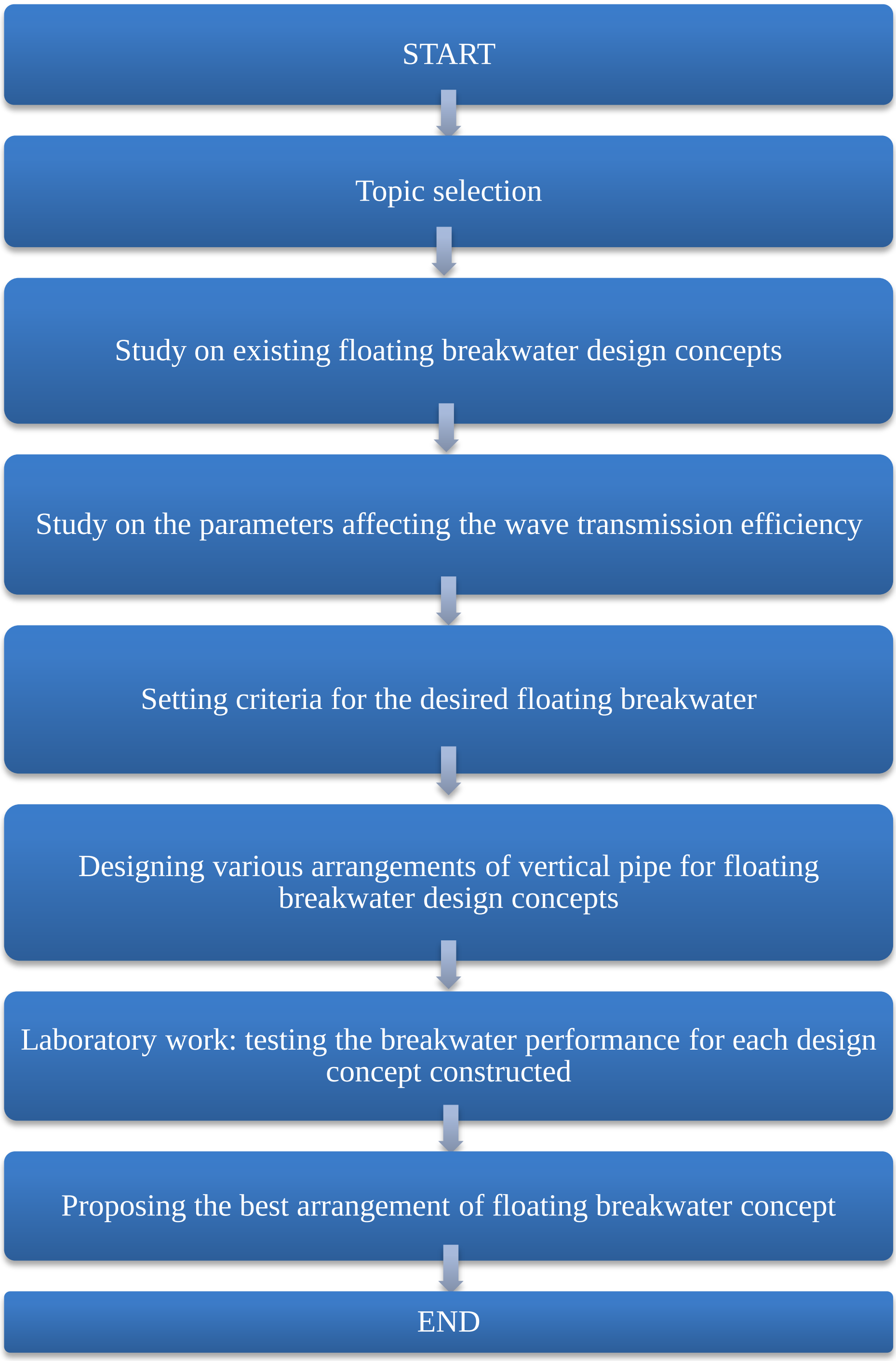
Figure 6: Suspended Pipe Breakwater **(Mani et al., 1998)**

The research on the effect of perforation of vertical pipe for the influence of water depth, wave steepness, spacing between piles and spacing of pile row reveals that more dissipation of wave energy can be obtained than using the non-perforated piles while the effect of staggered arrangement of pipes seem to give little effect on the wave transmission (Subba et al., 1999).

CHAPTER 3: METHODOLOGY

3.1 Research Methodology

In general, research methodology refers to a set of procedures used to conduct a research project.



3.2 Project Activities

3.2.1. Research and Floating Breakwater Design

This project starts with appropriate research to understand the project scope. For this phase it involves the review of related journals, books, and research papers and developers forum to increase the familiarity, better understanding and also to get a clear view about the research scope that will be carried out. The main information resources are from the Coastal Engineering Manual, e-journal, and e-thesis. This indirectly produces good analytical and critical literature review for the project.

3.2.2. Scaling of Breakwater Model

Purpose:

- To get the suitable scale of the unit for Hydraulic 2D model test in determining the desired K_t values.

Details:

- The scale used is 1:5. The model constructed is five times smaller than the prototype.
- Scaling is a need due to limitation of the dimension of the facilities provided.
- Scale models are copies of the prototype in a hydraulic laboratory where the model results are obtained by measurement.

3.2.3 Model Fabrication

After getting the details for designing, the project continues with fabricating the model. The shape of the breakwater model is made of two parts that were fabricated separately and will be combined to be a structure. The first is the rectangular shape with 2 m x 1 m dimensions using the hollow pipes of diameter 10 cm and four elbow pipes to join the two pipes of different direction. The second one is U-shape pipe with 45 cm x 10 cm dimensions using the elbow pipe to join the pipes. Finally, the U-Shaped pipes are hanged on the rectangular pipe with equal gap of 10 cm using the glue to prevent the pipe from moving.

Figure 7: Fabrication of Rectangular Pipe (Top part)

Figure 8: Hanging the U-Shaped Vertical Pipe onto the Rectangular Pipe

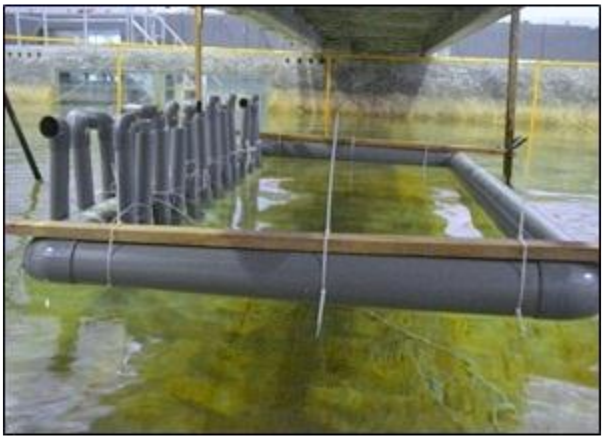


Figure 9: Placement of Model inside the Wave Tank

3.2.4. Hydraulic 2D Model Test

Purpose:

- To determine the K_t value by testing the model unit and get the best draft for wave transmission.

Details:

(a) **Tools/ Equipment:**

For this project, the tools needed are as follow:

i. Breakwater Model

ii. Wave Tank – wave paddle generates the wave

iii. Microsoft Excel - for data tabulation and graph plotting

iv. Probes – to record the wave height (H_i, H_t)

(b) **Wave tank details:**

The model tests were conducted in the wave tank of 22 m long, 10 m wide and 0.8 m water depth. The wave is produced by wave paddles that moved independently to each other by. Wave is generated by the backward and forward movement of the wave paddles.

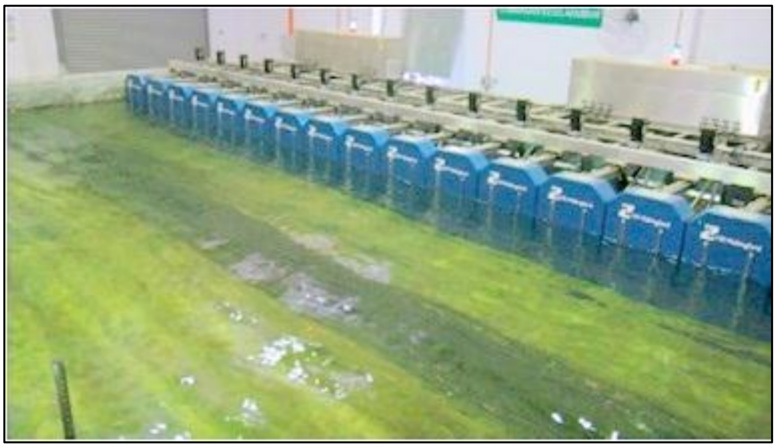


Figure 10: Wave tank Facility: Wave paddles

(c) **Parameters:**

The test is conducted by varying the number of rows of the vertical pipe hanging on the rectangular pipe. The measurement done for each test of incident wave height (H_i) = 0.02 m, 0.04 m and 0.06 m. Table 12 shows the number of tests done.

Table 7: Division of Laboratory Test

Dr/D	Model Test	Pipe Arrangement
0.6	A	4 rows (2 pair); 1 pair in front of incoming wave 1 pair at the back
	B	2 rows ;1 row in front of incoming wave 1 row at the back
	C	1 row; in front of incoming wave
0.4	A	4 rows (2 pair); 1 pair in front of incoming wave 1 pair at the back
	B	2 rows ;1 row in front of incoming wave 1 row at the back
	C	1 row; in front of incoming wave
0.2	A	4 rows (2 pair); 1 pair in front of incoming wave 1 pair at the back
	B	2 rows ;1 row in front of incoming wave 1 row at the back
	C	1 row; in front of incoming wave

- Depth of water is constant = 0.8 m

The parameters used for each arrangement are as shown in Table 7:

Table 8: Test Parameter

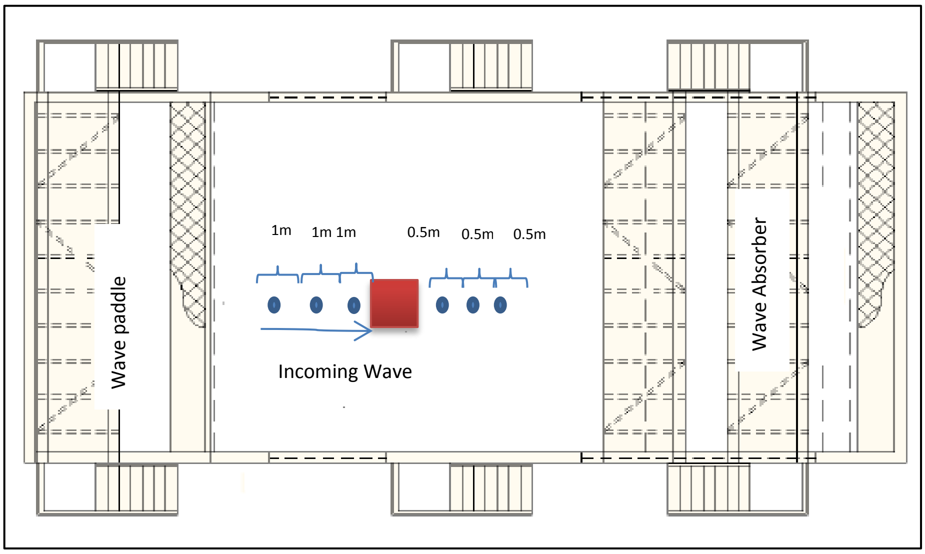
Parameter	Value
Water Depth, D (m)	0.80
Breakwater Width, W (m)	1.00
Incident Wave Height, Hi (m)	0.02 - 0.06
Breakwater Draft, Dr (m)	0.125, 0.35, 0.5
Relative Draft, Dr/D	0.20 - 0.60
Wave period, T (s)	0.5 – 2.0
Number of Rows, n	1 - 4
Wavelength, L (m)	0.25 – 3.00
Relative Width, W/L	0.3 – 4.00

(d) **Experimental Procedure**

The model tests were performed as described below:

i) Model set up:

- The fabricated breakwater is placed inside the wave tank.
- The model is fixed by clamping the top part of model to the vertical wood and then is clamped to the bridge at the top of model. The movement of breakwater is restrained throughout the tests. (Note: the experiment only analyzing the effect of geometries of structure).
- There are six probes used for the tests: three probes before the model and three probes after the model. The positions of probes are as Figure 8.
- The probes are then being calibrated before the test can be preceded.



-

- Breakwater Probes

Figure 11: Positions of Probes **(From Plan View)**

ii) Model test

- For the test series, 1 m width (W) of breakwater and the depth of water of 0.8 m are fixed for all tests.
- The draft is set at D_r = 0.5 m using 1 row of vertical pipes model configuration.
- The result of transmitted wave height (H_t) is recorded.
- The same variables used while varying the draft, D_r = 0.375 m and 0.125 m
- The test is repeated for each draft and model configuration.
- To start a new test with new model, the calibration should be done again before the test is continued. After all test being done, the data analysis is done followed by the discussion and recommendation of the good model.

iii) Result Analysis

- The calculation to gain the K_t is as below:

$$K_t = H_t / H_i$$

Where:

K_t = wave transmission

H_t = incident wave height

- The K_t gain is plotted into graph that presenting the model performances which having different pipes configurations, relative draft (D_r/D), relative width (W/L) and incident wave height (H_i).
- In summary, the test series are conducted according to the steps below:

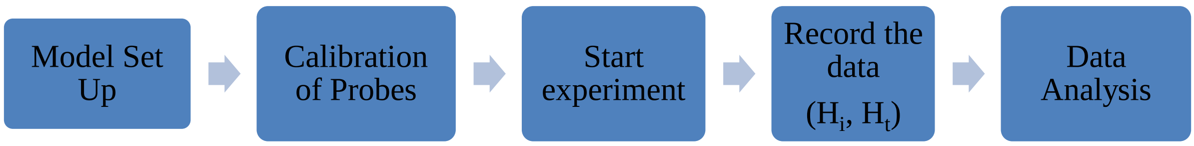


Figure 12: Summary of Test Procedure

3.3 Key Milestone

Below are the key milestones that need to be achieved to complete the project throughout the two semesters: Final Year Project 1 (FYP I) and Final Year Project 2 (FYP II).

3.3.1 Semester 1

Table 9: Key milestone for FYP I

Milestone	Week
Project Proposal	Week 3
Extended proposal (10%)	Week 6
Proposal Defence (40%)	Week 9
Interim Report (50%)	Week 14

3.3.2 Semester 2

Table 10: Key milestone for FYP II

Milestone	Week
Progress Report (10%)	Week 8
Pre-SEDEX (10%)	Week 11
Technical Report (10%)	Week 13
VIVA (30%)	Week 14
Dissertation (40%)	Week 15

3.4 Gantt Chart

Table 11: Gantt chart

Phase / Week	FYP 1														FYP 2														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Research on topic: Floating breakwater																													
Planning and sketching breakwater designs concept																													
Model Fabrication																													
Testing breakwater design (Laboratory work)																													
Analysis and Discussion of Result																													
Project Dissertation																													

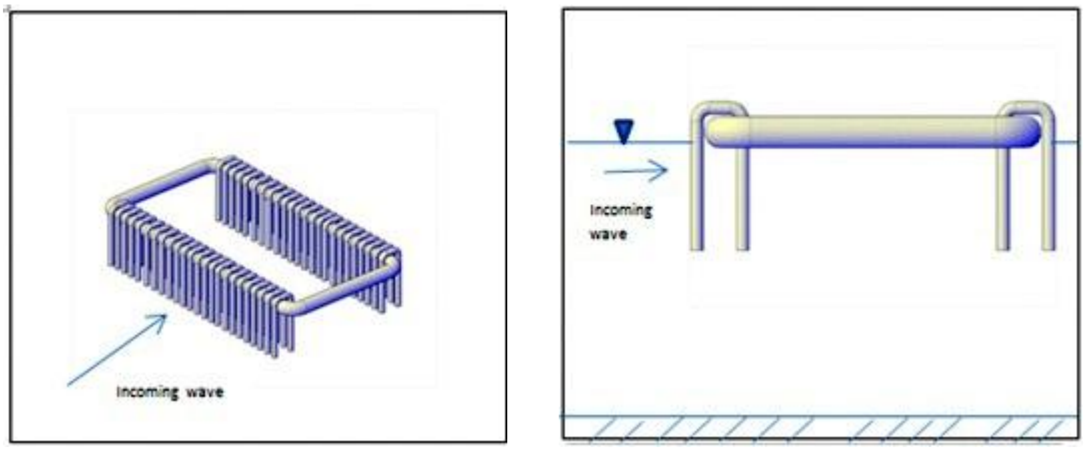
CHAPTER 4: RESULT AND DISCUSSION

4.1. Design Concept of Model

The designs of model are drawn using the AUTOCAD Software. There are 3 model designs selected:

a) Designed Model Test A :

4 rows of vertical pipes; 1 pair in front and 1 pair behind the structure

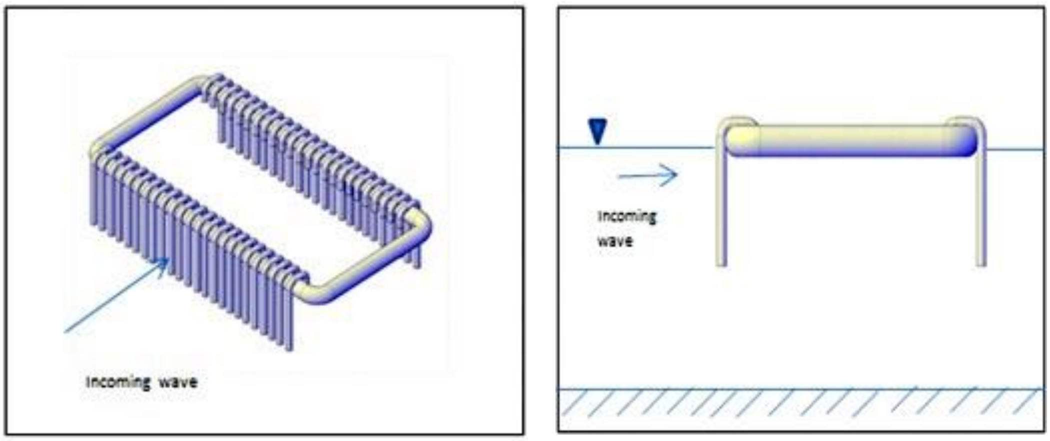


SE View of Model   Side view of model

Figure 13: Designed Model Test A

b) Designed Model B :

1 row of vertical pipes in front of structure

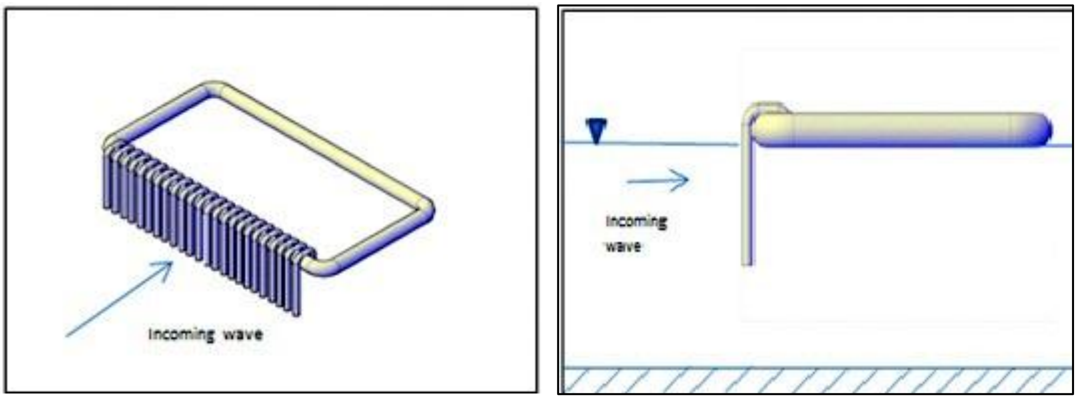


SE View of Model   Side view of model

Figure 14: Designed Model B

c) **Designed Model C:**

2 rows of vertical pipes; 1 row in front and 1 row behind the structure



SE View of Model Side view of model

Figure 15: Designed Model C

4.2. Results and Findings

The wave heights before and after the floating breakwater model for varying the vertical pipe arrangement (number and position of rows of vertical pipes), incident wave heights and wavelengths have been measured and plotted. The wave transmission (K_t) is calculated by using formula:

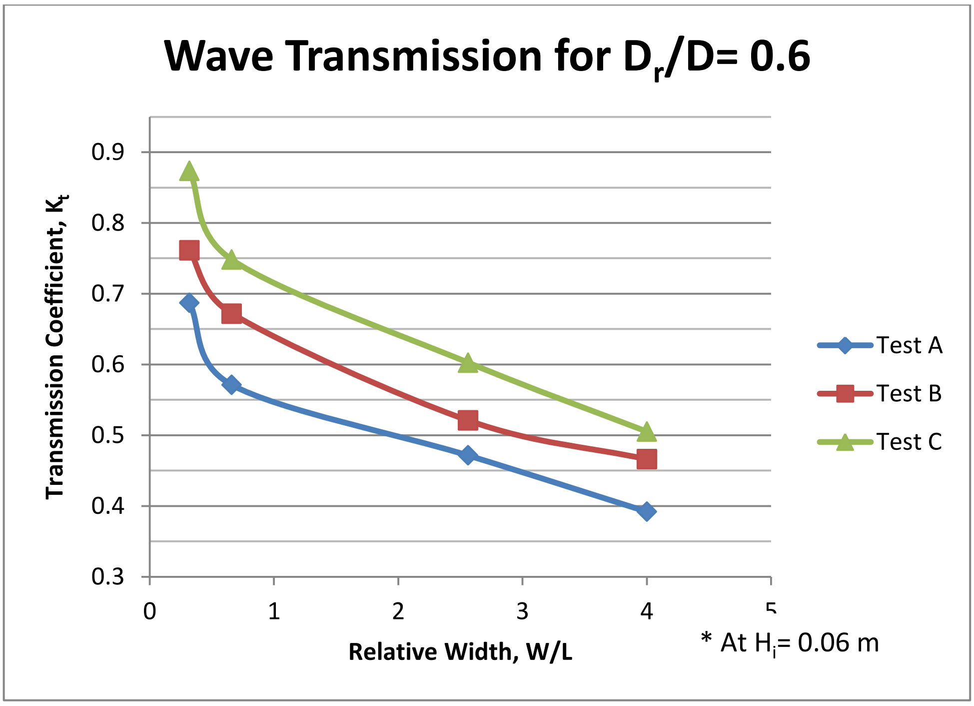
$$K_t = \frac{H_t}{H_i}$$

Where K_t = Wave Transmission Coefficient

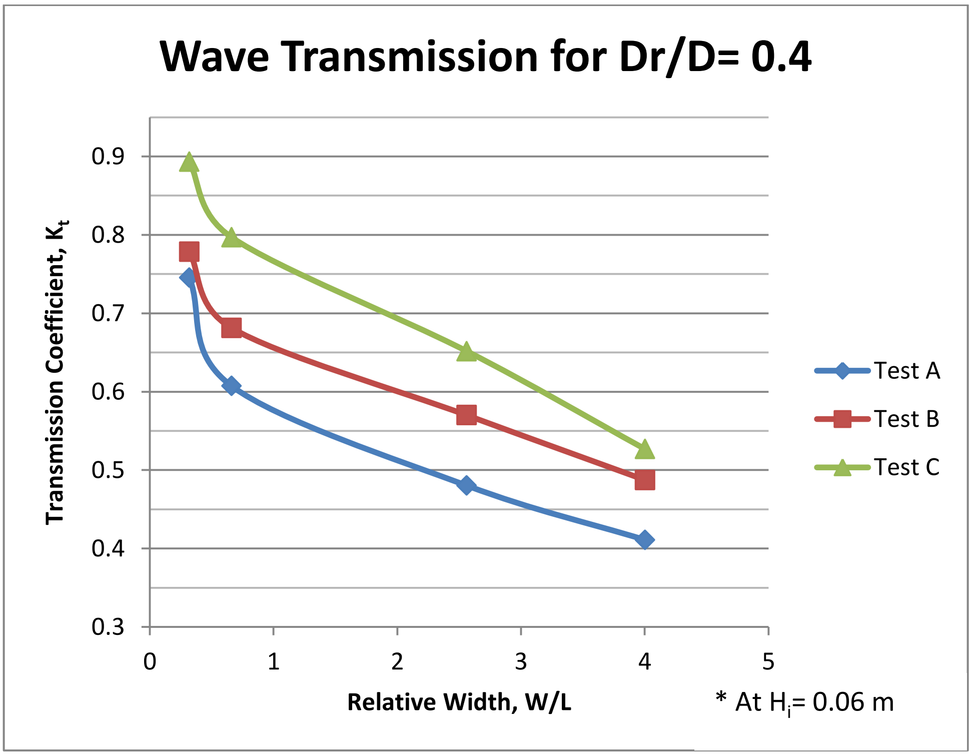
H_t = Transmitted Wave Height

H_i = Incident Wave Height

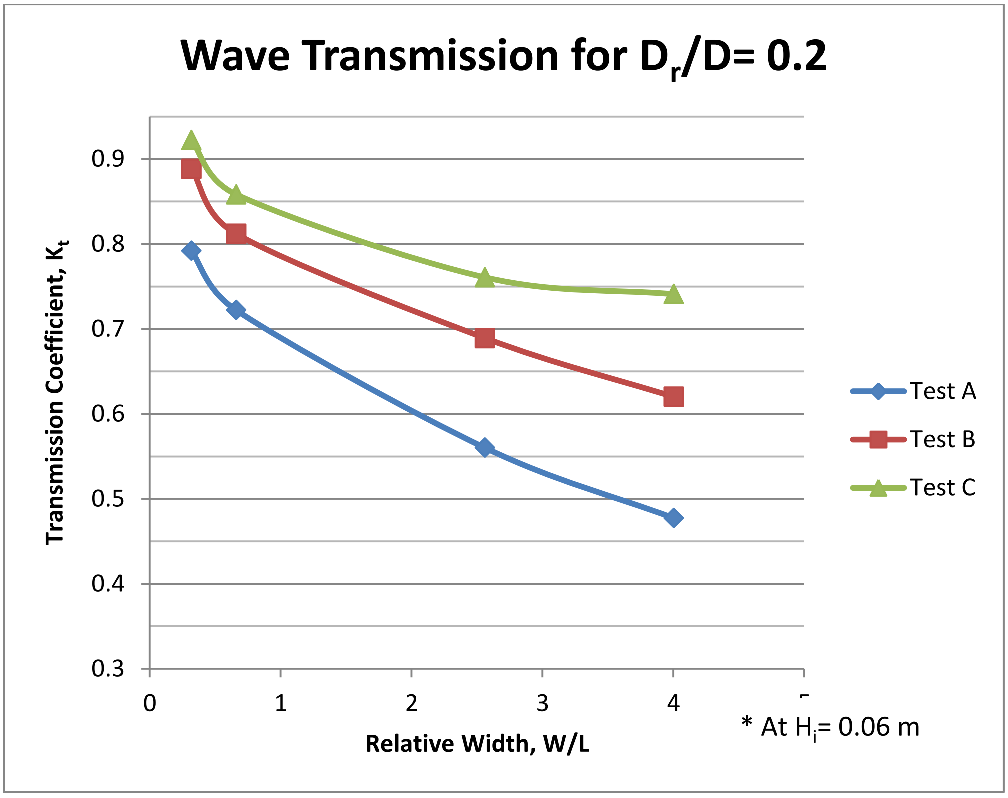
Figure 16 shows 3 graphs of different Dr/D for the same wave height of H_i= 0.06 m. For obtaining the minimum K_t of 0.5, using the relative draft, D_r/D = 0.6 gives the desired result; especially for Designed Model Test A and Test B. The model performance decreases as the D_r/D decreases. Figure 13 (c) describes clearly the performance efficiency of Designed Model B and C become insignificant to obtain the desired minimum K_t of 0.5. The W/L parameter can also be observed in these figures. For D_r/D = 0.6, Designed Model Test A requires W/L ≥ 1.8, Designed Model Test B requires W/L ≥ 3.0, and Designed Model Test C requires W/L ≥ 4.0. It can be observed that when the D_r/D decreases, the higher relative width, W/L required for each designed model to get the desired K_t.



(a)



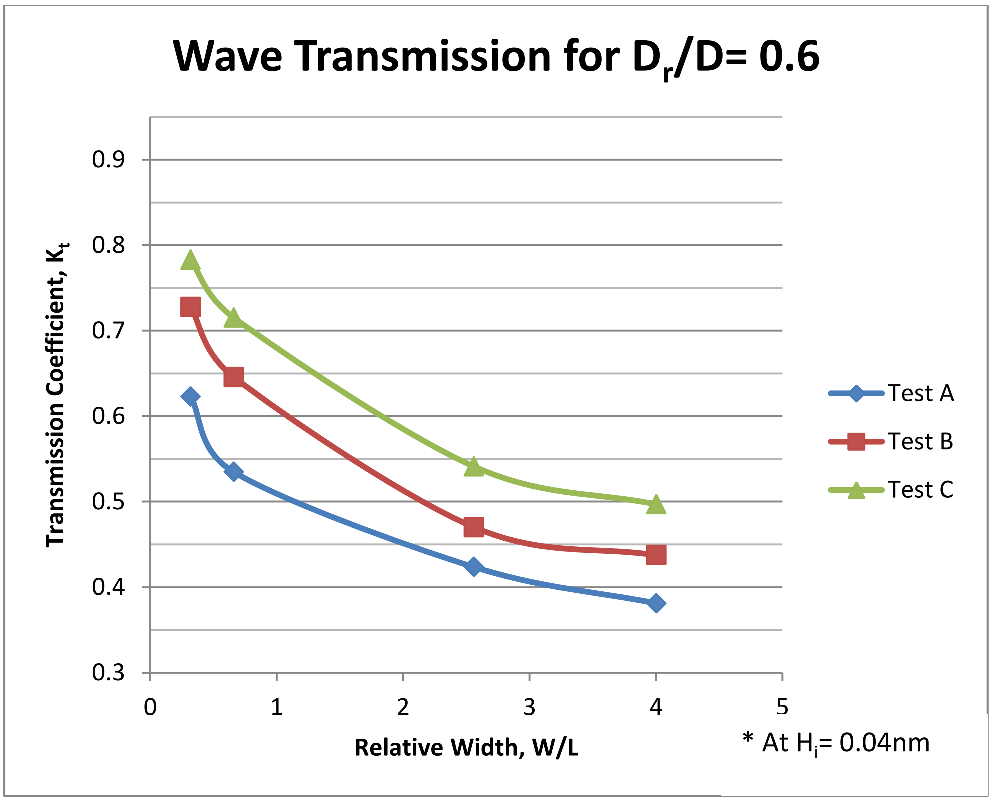
(b)



(c)

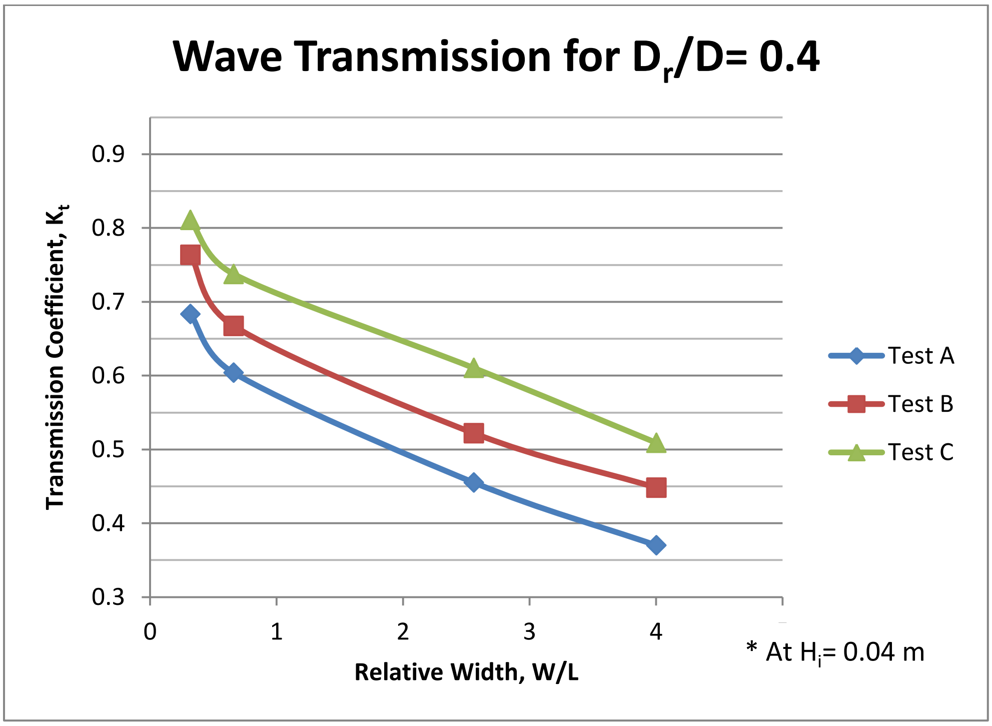
Figure 16 (a), (b), and (c): K_t for Different D_r/D at Incident Wave Height (H_i) = 0.06 m

An incident wave height, H_i = 0.04 m used for plotting the graphs shown in Figure 17 (a), (b) and (c). The graph patterns are same with the previous wave height used. The lower wave height results more wave energy can be attenuated by the models. Designed Model A is leading in performing the desired K_t for all the D_r/D used; however the performance level decreases with the decreasing of D_r/D. This performance level is applicable for Designed Model B and C too. From the observation made, the usage of fewer rows of vertical pipe reduces the performance is obtaining the $K_t \leq 0.5$. For example, Model Test B can achieve the desired wave transmission coefficient when the W/L > 2.5 for D_r/D = 0.4. Model Test C is more critical as it requires W/L > 4 at Dr/D < 0.4.



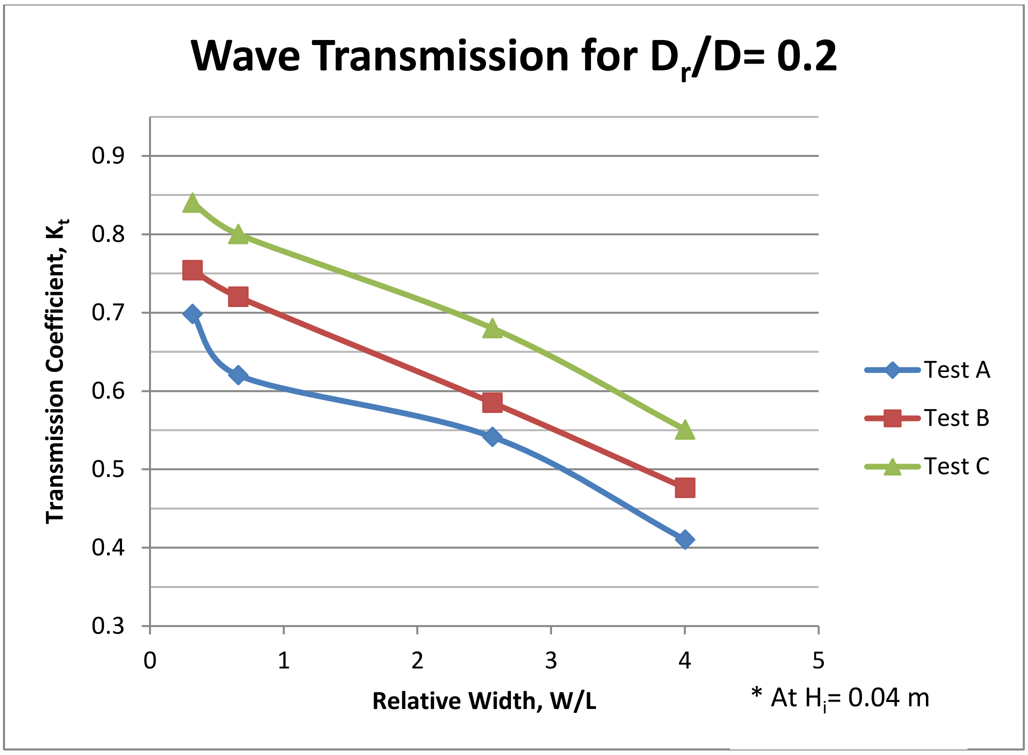
Wave Transmission for D_r/D= 0.6
Transmission Coefficient, K_t
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
1
2
3
4
5
Relative Width, W/L
Test A
Test B
Test C
* At H_i= 0.04nm

(a)



Wave Transmission for D_r/D= 0.4
Transmission Coefficient, K_t
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
1
2
3
4
Relative Width, W/L
Test A
Test B
Test C
* At H_i= 0.04 m

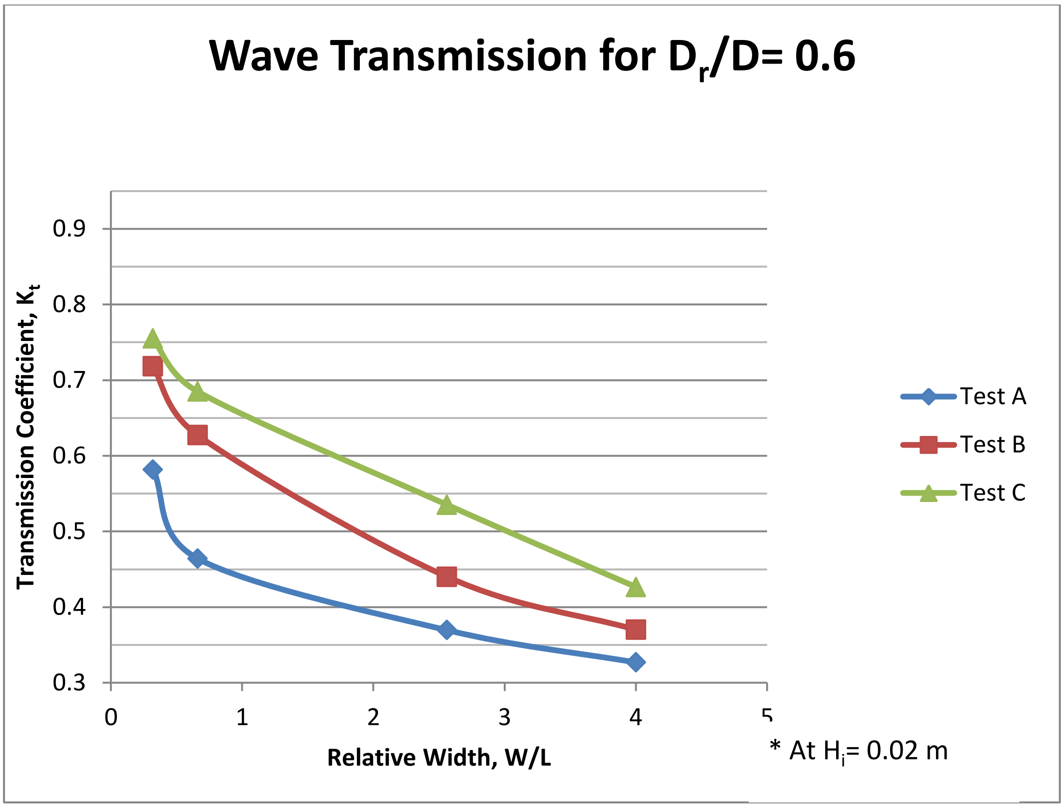
(b)



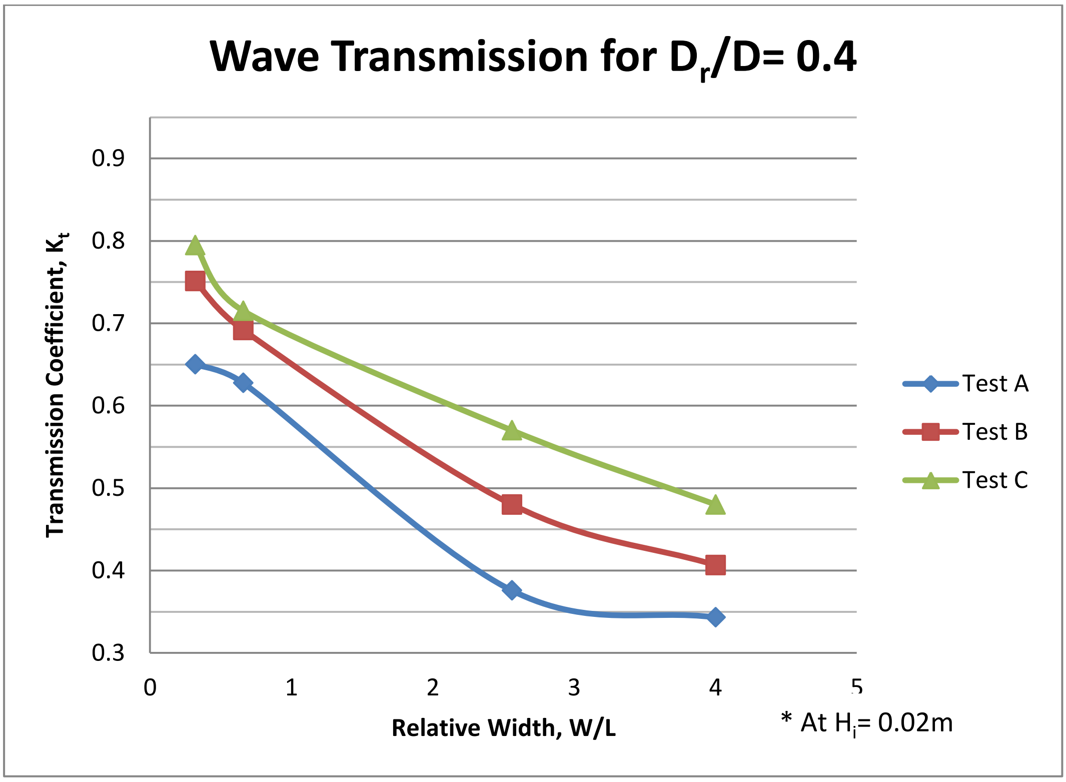
(a)

Figure 17 (a), (b), (c) K_t for Different D_r/D at Incident Wave height (H_i) = 0.04 m

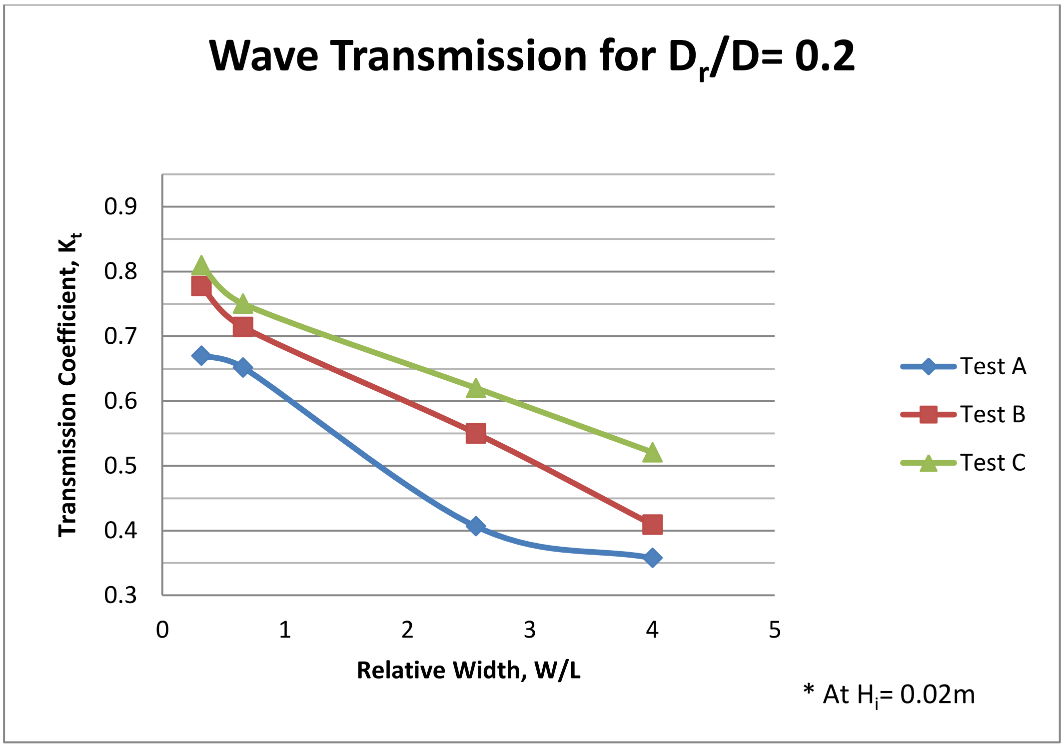
For Figure 18 (a), (b) and (c), when using lower incident wave height of $H_i = 0.02$ m, the efficiency attenuating the wave energy becomes significant. Model A capable for having $K_t \leq 0.5$ with W/L > 0.4 for $D_r/D = 0.6$ and B/L > 1.8 for $D_r/D = 0.2$. Model B is observed requiring W/L > 2.4 for $D_r/D = 0.06$ and W/L > 3.0 for $D_r/D = 0.02$. Model C seems to be insignificant in obtaining the desired $K_t \leq 0.5$ when the $D_r/D \leq 0.2$ due to smaller draft provided promoting the wavelength to escape the model without being dissipated.


Wave Transmission for D_r/D= 0.6
Transmission Coefficient, K_t
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
1
2
3
4
5
Relative Width, W/L
Test A
Test B
Test C
* At H_i= 0.02 m

(a)


Wave Transmission for D_r/D= 0.4
Transmission Coefficient, K_t
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
1
2
3
4
5
Relative Width, W/L
Test A
Test B
Test C
* At H_i= 0.02m

(b)



(c)

Figure 18 (a), (b), (c) K_t for Different D_r/D at Incident Wave height (H_i) = 0.02 m

4.3. Result Analysis

4.3.1 Effects of Relative Width (W/L) on the efficiency on VFB.

For all three different wave heights of regular wave, K_t can be found decreases with the increases of W/L. Throughout the test series, width (W) is constant at 1 m. Therefore, as the wavelength increases, the efficiency of VFB becomes insignificant due to the longer wavelength increases the probability of wave to be escaping the structure without being dissipated. This finding is also supported by the experiment and numerical research (Kountandos et al., 2005) which found that the performance of FBW is reducing when facing the long wave (low W/L).

4.3.2 Effects of Relative Draft (D_r/D) on efficiency of VFB

There are three D_r / D (0.6, 0.4, and 0.2) used for this experiment. The higher value of D_r/D represents the longer the length of vertical pipes being submerged into the water from the surface. The greater D_r/D gives the lower value of K_t. From the graphs, the performance curve for $D_r/D = 0.2$ for all wave height (0.06 m, 0.04 m and 0.02 m) invariably recommend a $D_r/D > 0.02$ for restricting the transmission coefficient below the desirable limit of 0.5.

4.3.3 Effects of model configuration on efficiency of VFB

For each D_r/D, the three Designed Models A, B, and C will be tested. Each model differs by the number and position of rows of vertical pipe attached to become a structure. Designed Model A (4 rows) is proven the best in reducing the incoming wave for all draft (D_r) and wave height (H_i) followed by Designed Model B (2 rows) and Designed Model C (1 row). However, Designed Model C is found is insignificant in getting the desired K_t which is less than 0.5.

It can be observed that Designed Model A and B have capability to attenuate the wave but have their own limitation. The selection of each model requires some limit for each parameter in order to obey the desired K_t of less than 0.5.

a. Designed model A can withstand the incident wave height up to 0.06 m. Although thus, when the D_r/D is low (0.2), the K_t gain is nearly 0.5; showing that this model not suitable to be used at 0.06 m for D_r / D < 0.2.
b. Designed model B can be used for the $H_i < 0.04$. Using the higher value of H_i will result the $K_t > 0.5$.

   Even though Designed Model A is the best model in attenuating wave, Designed Model B still can be used and be economical but just until the certain range. Table below is a summary of limitation ranges of the parameter for getting the desired $K_t < 0.5$ by using certain D_r/D to face certain wave height and wave length.

Table 12: Parameters Guideline for Model Selection

	Hi	Dr/D	Min Relative Width, W/L	Max. Wavelength, L (m)	Max. Steepness, S (m)	Max Period, T (s)
Model Test A	0.06	0.6	2	0.50	0.12	0.71
		0.4	2.2	0.45	0.13	0.67
		0.2	3.5	0.29	0.21	0.53
	0.04	0.6	1.2	0.83	0.05	0.91
		0.4	1.8	0.56	0.07	0.75
		0.2	3	0.33	0.12	0.58
	0.02	0.6	0.5	2.00	0.01	1.48
		0.4	1.5	0.67	0.03	0.82
		0.2	1.9	0.53	0.04	0.73
Model Test B	0.06	0.6	3	0.30	0.20	0.55
		0.4	3.7	0.27	0.22	0.52
	0.04	0.6	2.1	0.48	0.08	0.69
		0.4	2.8	0.36	0.11	0.60
	0.02	0.6	2	0.50	0.04	0.71
		0.4	2.5	0.40	0.05	0.63

CHAPTER 5: CONCLUSION

5.1. Conclusion

The Floating Vertical Floating Breakwater (VFB) configurations have been studied experimentally against the regular waves in the shallow water regions. Main conclusions are as the following:

(i) K_t decreases with increasing D_r/D and W/L and with decreasing H_i.

(ii) The floating breakwater with more rows of vertical pipes has a very efficient structure to reduce the wave transmission

The innovation of this floating breakwater by introducing the vertical pipe to be submerged inside the water from the water surface successfully create new favourable alternative to fit any coastal area with weak soil condition but with limitation the wave is not in swell condition. The number of rows of vertical pipe and the draft are proven to do play as important parameter for wave attenuation.

5.2. Relevancy to the Objectives

This project is relevant according to its objectives: (1) to design a new floating breakwater concept with better performance and wave attenuation and (2) to determine the best configuration for wave attenuation after varying the geometry and against the regular wave with different wave height and wave length. The research proves that this vertical floating breakwater concept can be applied for coastal protection in west coast Peninsular Malaysia with its lighter and less contact to the foundation to satisfy the weak soil profile. The experiment is done by using wave tank and other lab facilities in Coastal and Offshore Laboratory. The material and equipment needed to do the experimental works also can be prepared within the planned schedule.

In summary, the usage of floating breakwater as the wave attenuator at the shallow water over the emerged and submerged breakwater should be considered as it requires less material hence will reduce the cost of construction.

5.3. Recommendation

The author would like to give suggestions for the future work plan for further expansion of research for better continuation and improvement includes:

- To reduce the time consuming for conducting each test, the wave flume can be used over the wave basin which is bigger than the size of wave flume. The water need to be at calm before starting each test. The smaller size of wave flume enables the water to be at calm with minimum time.
- The current research just considering the effect of geometry of structure on wave transmission. The effect of motion of structure (Six degrees of motions: Heave, pitch, yaw, roll, sway, and surge) need to be included for getting the more significant result.
- The research can be continued by testing the performance of the floating breakwater against the random wave.
- In current research, it proves that floating breakwater that using less material can perform in attenuating wave. In further research, the comparison of material and cost reduction and the effectiveness should be shown in detail.

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APPENDICES

Wave Transmission Coefficient Calculation:

Using formula:

$$K_t = \frac{H_t}{H_i}$$

Where K_t = Wave Transmission Coefficient

H_t = Transmitted Wave Height

H_i = Incident Wave Height

Calculation is made based on the formula above to find the K_t using the Microsoft Excel for each Designed Model Test A, B and C.

Table A-1: K_t Results Tabulation for Designed Model Test A

Hi (m)	W/L	Dr/D = 0.6			Dr/D = 0.4			Dr/D = 0.2		
		Ht (mm)	Hi (mm)	Kt	Ht (mm)	Hi (mm)	Kt	Ht (mm)	Hi (mm)	Kt
0.020	0.320	10.228	17.581	0.582	13.325	20.500	0.650	16.365	24.433	0.670
	0.661	13.644	29.398	0.464	16.072	25.618	0.627	21.040	32.289	0.652
	2.562	11.877	32.145	0.369	12.122	32.271	0.376	9.886	24.327	0.406
	4.003	8.176	25.023	0.327	6.000	17.488	0.343	10.792	30.172	0.358
0.040	0.320	23.000	36.932	0.623	29.196	42.726	0.683	24.834	35.572	0.698
	0.661	29.398	54.986	0.535	32.585	53.969	0.604	23.988	38.690	0.620
	2.562	19.707	46.539	0.423	20.339	44.700	0.455	23.707	43.794	0.541
	4.003	15.733	41.294	0.381	15.670	42.350	0.370	19.081	46.539	0.410
0.060	0.320	39.511	57.515	0.687	43.161	57.902	0.745	47.500	60.000	0.792
	0.661	35.578	62.294	0.571	41.779	68.797	0.607	43.323	60.000	0.722
	2.562	29.127	61.787	0.471	28.816	60.000	0.480	33.512	59.843	0.560
	4.003	20.499	52.322	0.392	26.549	64.597	0.411	27.242	57.071	0.477

Table A-2: K_t Results Tabulation for Designed Model Test B

Hi (m)	W/L	Dr/D = 0.6			Dr/D = 0.4			Dr/D = 0.2		
		Ht (mm)	Hi (mm)	Kt	Ht (mm)	Hi (mm)	Kt	Ht (mm)	Hi (mm)	Kt
0.020	0.320	16.768	23.329	0.719	18.000	23.961	0.751	16.328	21.000	0.778
	0.661	20.000	31.889	0.627	21.797	31.511	0.692	22.245	31.148	0.714
	2.562	10.639	24.180	0.440	13.981	29.127	0.480	11.275	20.500	0.550
	4.003	8.562	23.140	0.370	9.907	24.369	0.407	9.141	22.342	0.409
0.040	0.320	35.619	48.943	0.728	31.015	40.617	0.764	30.974	41.084	0.754
	0.661	27.997	43.354	0.646	28.828	43.197	0.667	25.834	35.880	0.720
	2.562	22.076	46.970	0.470	26.093	50.000	0.522	27.894	47.686	0.585
	4.003	17.393	39.775	0.437	16.528	36.874	0.448	19.565	41.087	0.476
0.060	0.320	53.761	70.621	0.761	46.622	59.881	0.779	53.167	59.843	0.888
	0.661	43.764	65.136	0.672	46.154	67.750	0.681	60.000	73.900	0.812
	2.562	36.347	69.775	0.521	36.895	64.728	0.570	45.307	65.741	0.689
	4.003	25.234	54.156	0.466	26.809	55.014	0.487	38.353	61.860	0.620

Table A-3: K_t Results Tabulation for Designed Model Test C

Hi (m)	W/L	Dr/D = 0.6			Dr/D = 0.4			Dr/D = 0.2		
		Ht (mm)	Hi (mm)	Kt	Ht (mm)	Hi (mm)	Kt	Ht (mm)	Hi (mm)	Kt
0.020	0.320	18.000	23.844	0.755	19.000	23.911	0.795	19.399	23.961	0.810
	0.661	20.011	29.221	0.685	19.827	27.730	0.715	22.438	29.913	0.750
	2.562	16.648	31.105	0.535	14.236	24.976	0.570	20.863	33.650	0.620
	4.003	12.167	28.531	0.426	13.898	28.955	0.480	12.177	23.378	0.521
0.040	0.320	30.970	40.603	0.763	33.000	40.703	0.811	35.283	42.000	0.840
	0.661	33.339	46.616	0.715	39.413	53.431	0.738	35.368	44.210	0.800
	2.562	29.555	54.627	0.541	24.408	40.000	0.610	24.568	36.130	0.680
	4.003	20.108	40.471	0.497	21.258	41.766	0.509	22.028	40.000	0.551
0.060	0.320	54.915	62.859	0.874	53.272	59.640	0.893	65.000	70.474	0.922
	0.661	44.886	60.000	0.748	51.751	64.945	0.797	55.313	64.450	0.858
	2.562	44.000	73.011	0.603	48.090	73.799	0.652	45.637	60.000	0.761
	4.003	32.916	65.180	0.505	37.000	70.237	0.527	49.066	66.230	0.741

APPENDIX B

Laboratory Test Spread Sheet:

Table B-1: Laboratory Test Spread Sheet

Test No.	Hi	L (m)	Steepness, S	Period, T (sec)	Freq. (Hz)	Time, req (sec)	Tick (/) once done								
							Model Test A			Model Test B			Model Test C		
							$\frac{D_r}{D} = 0.6$	$\frac{D_r}{D} = 0.4$	$\frac{D_r}{D} = 0.2$	$\frac{D_r}{D} = 0.6$	$\frac{D_r}{D} = 0.4$	$\frac{D_r}{D} = 0.2$	$\frac{D_r}{D} = 0.6$	$\frac{D_r}{D} = 0.4$	$\frac{D_r}{D} = 0.2$
1	0.06	0.25	0.24	0.50	2.00	180.00									
2		0.39	0.15	0.62	1.60	180.00									
3		1.51	0.04	1.25	0.80	180.00									
4		3.13	0.02	2.02	0.49	180.00									
5	0.04	0.25	0.16	0.50	2.00	180.00									
6		0.39	0.10	0.62	1.60	180.00									
7		1.51	0.03	1.25	0.80	180.00									
8		3.13	0.01	2.02	0.49	180.00									
9	0.02	0.25	0.08	0.50	2.00	180.00									
10		0.39	0.05	0.62	1.60	180.00									
11		1.51	0.01	1.25	0.80	180.00									
12		3.13	0.01	2.02	0.49	180.00									

Note: A minimum 0f 10 minutes interval is required from one test to another test.