CERTIFICATION OF APPROVAL

Wave Transmission and Reflection of the Alternatively Submerged Geotube Breakwater

by

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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.

MUHAMMAD SYUKRI BIN SAADON

ABSTRACT

This paper conducted the experiment on investigating the effect of wave on transmission and reflection of the alternatively submerged geotextile tubes breakwater when subjected to regular waves. Hydraulic characteristics of modular of alternatively submerged geotube such as wave steepness Hi/L, relative wave height Hi/d, and relative submergence, d'/Hi are being determined in order to achieve the aim at the end of the process. From the research gap of other research, the project study about designing and the application of geotextile tube structure in providing a natural barrier at coastal areas. However, this study purposely done to provides an option in tuning the wave properties to meet the requirement of various coastal and marine applications. At the end of the result, this research will provide a solution to the FRIM researchers in tuning the waves at the sheltered site with the presence of the geotube breakwater. By conducting this research, the outcome of rehabilitation process conducted by FRIM will be more effective and efficient together with their innovative mangrove planting techniques which are Comp-Mat, Comp-Pillow and Bamboo Encasement Method (BEM). As recommendation for future research, coastal processes at coastline areas is different when it comes other places. Therefore, the study of wave properties must always be up to date from time to time in order to come out with a better solution especially in designing a coastal engineering structure such as geotextile tube breakwater.

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To all my family members, thank you for your full support and encouragement since the first day I stated involving myself in this Final Year Project I (FYP I).

Last but not least, my appreciation also goes a friend of mine who is Shadana Gupta d/o Baldev Raj for all her kindness and guidance during the process of finishing the project. Your contribution is highly appreciated.

Sincerely,

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CHAPTER 1

INTRODUCTION

1.1 Chapter Overview

Throughout this chapter, the important of using submerged geotextile tubes as a breakwater for mangrove protection is discussed. Based on the previous existing researches, there are many challenges and outcomes have been studied. The background of study related to Sungai Haji Dorani site and the application of geotextile tube breakwater is well elaborated. Moreover, the objective of the present study are stated and the scope of the study is prepared. At the end of this chapter, the significance of the project is covered.

1.2 Background of Study

World climatic changes that happened from year to year have resulted in significantly increase the incidence of shoreline erosion to occur due to high impact of produced energy wave. According to Economic Planning Unit (1985), over 30% of Malaysian shoreline suffers from this high energy of wave impact which largely eroded the shoreline of Peninsular Malaysia. Over the last 12 years, the number of erosion problem that occurred at coastal lands in Malaysia is keep increasing due to changes in littoral dynamic and human activities. The consequences of coastal erosion are severe in Malaysia as much as economic and social life of Malaysia depends on activities in its coastal area (Lee et al., 2014). In order to solve this coastal problem, the Ministry of Natural Resources and Environmental of Malaysia has decided to intensively plant mangroves such as Avicenna sp. and Rhizophora sp. along the several affected areas including Sungai Haji Dorani in Selangor, Tanjung Piai, Johor and also Kuala Teriang in Langkawi.

Mangroves plantation play an important role in maintain the integrity of the shoreline area thus give protection towards it (Russell & Michaels, 2012). Mangroves are complex ecosystems that act as a coastal bio-shield in order to protect the coastal habitats and society from natural disasters such as Tsunami and etc. The planted mangroves along the shoreline area will dissipates the wave energy and become a natural defense against the wave. Based on research done, mangrove population in Malaysia was reported to be third largest country in Asia Pacific after Indonesia and Australia which represent 1.7% of total land area (Sulaiman, 2004). In December 2004, mangroves and coastal forests was reported one of the most effective way in mitigate the tsunami waves through hydraulic resistance. In order to ensure the rehabilitation of mangroves, Forest Research Institute of Malaysia (FRIM) was instructed by Ministry of Natural Resources and Environment (NRE) to formulate an economical and viable solution. Therefore, providing an anchorage to planted mangrove seedlings at sites is one of the solution given by FRIM and they managed to develop three innovative planting techniques, which are Comp-Mat, Comp-Pillow and also Bamboo Encasement Method (BEM). All these three innovative planting techniques were successfully done in Sungai Haji Dorani, Selangor.

Figure 1.1: Mangrove plantation at Sungai Haji Dorani, Selangor

Based on the previous researched that have been done by Seng (2010), mangrove grow in the region between Mean Low Water (MLW) and Mean High Water (MHW) which is subjected to wave energy. The minimum distance required by the mangroves in order to sustain its survivability is 200 meters from any development area. As mentioned by Brown (2012), there are a few reasons towards mangrove plantation failures such as poor selection of mangrove species, poor quality of its seedlings and the most important part is lack of protection of the seedlings from wave forces. Thus, in order to moderate the incident waves and mitigate the coastal erosion at mangrove areas, man-made soft engineering structure known as geotextile tubes were conceptualized.

There are many type and design of geotextile tubes breakwater while in this case of study, semicircular shape was chosen throughout the research. According to Zhang (2005), the first world concept of solid semicircular breakwater was developed in Japan in the year of 1992. In comparison vertical breakwater, this semicircular design have shown a better characteristics and result. On top of that, semicircular design of geotextile tubes breakwater perform better in reducing wave energy impact compared to rectangular shape which good in dissipating the wave energy (Lokesha et al., 2015). However, the implementation of using geotubes as a breakwater has widely been used in Malaysia to provide protection towards mangrove plantation especially in Sungai Haji Dorani, Selangor as shown in figure below.

Figure 1.2: Semicircular design of geotube breakwater

1.3 Problem Statement:

According to Tamin (2011), mangroves are complex ecosystems that provide coastal bio-shield to safe guard coastal habitats and societies from natural disasters which give protection against strong wave surge and tsunamis. Nowadays, mangroves plantation in Malaysia are facing a serious issue regarding the decreasing in number of its population at coastal areas. Thus, rehabilitation of these mangroves is needed in order to maintain the shoreline integrity and protection towards the coastal areas. The eroded coastline at Sungai Haji Dorani, Selangor is the main focus towards this research since the presence of large grain size shell hash along the coast which indicates that the shoreline is still experiencing high wave and current action. In facts, this high wave action will definitely affect the survivability of the mangrove plantation at that area which proposed by Forest Research Institute Malaysia (FRIM).

The 26-km shoreline of Sungai Haji Dorani has been gusseted as FRIM research site for mangrove plantation. The primary source of sediment is supplied by Bernam River and Perak River (Stanley & Lewis, 2011). Nevertheless, the beaches fail to trap the sediment permanently due to unavailability of the coastal forest. Mangrove can be planted along sheltered coastlines using conventional planting technique. However, in exposed coastal areas the technique has proven to be unsuccessful due to the impact of strong wave actions (Barizan, et al., 2008). Based on Stanley and Lewis (2011), mangroves are unable to survive at sites that are subjected to limited water depths (i.e. water depths below the mean sea level) and also loose sediment substratum (i.e. high silt bound sediment and excessive silt dominance). Hence, there is a need to further enhance the understanding on how the environmental forces such as wave and current affect the mangrove ecosystem and their growth.

Alvares et al. (2007) had previously studied the factor that effect the wave attenuation performance towards this geotextile tube structure such as wave parameter, relative submergence and also shape of the breakwater. In this research, mangrove plantation techniques conducted by FRIM were tested at Sungai Haji Dorani with an external wave protection of an array of geotube breakwater. By observation, the results showed that the presence of the geotube breakwater significantly helped in promoting the growth of mangroves at the lee side. Nonetheless, the underlying physics that explain effectiveness of the breakwater in tuning the waves at the sheltered site remain unknown to the FRIM researchers. In year 2015, FRIM have made a collaboration with UTP thus engaged by them to look into this problem. The aim of this research project is set to investigate the effect of wave transmission of a geotube breakwater subjected to irregular waves by using physical modelling. Other than that, extensive experiments are to be undertaken to assess the wave transmission contour behind the breakwater since this will help to provide a beneficial information and guidelines to the FRIM researchers thus help to tune the wave properties to meet the requirement of various coastal and marine applications.

1.4 Objectives:

The research aims at investigating the effect of wave transmission and reflection of alternatively submerged geotextile tubes breakwater when subjected to regular waves. To achieve the goal, the following objectives are skeletoned:

1. To determine the hydraulic characteristics of modular of alternatively submerged geotube with respect to:

    a) wave steepness Hi/L,

    b) relative wave height Hi/d,

    c) relative submergence, d'/Hi,

1.5 Scope of Study

The scopes of the present study is listed below:

1. The research study is designed to particular address the real application of geotextile tubes breakwater installed at Sungai Haji Dorani, Selangor, Malaysia.
2. Throughout the research, there are several parameters was considered which are wave steepness (Hi/L), relative wave height (Hi/d) and also relative submergence (d'/Hi).
3. The effect of physical properties of the geotextile tubes such as UV radiation, tensile strength, current and sediment transport are neglected since it is beyond the scope of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 General

The sequence of this literature review section will start with the introduction on the important role of mangroves plantation towards coastal areas. This discussion will focus on the study area of this research which is at Sungai Haji Dorani, Selangor, Malaysia. Afterward, the usage of partially submerged Geotube as a breakwater will be presented including the factors influencing its stability and also durability. Besides, the design criteria of the Geotube is one of the important things throughout this research which also be deliberated in this section. Last but not least, the wave transmission by using this soft man-made engineering structure as the breakwater will be evaluate at the end of the section.

2.2 Mangroves Plantation

The incident of Tsunami that occurred in December 2004 which hit many countries in Asia including the west coast of Peninsular Malaysia had sparked the Malaysian Government on the important of coastal rehabilitation especially related to mangroves plantation. The ministry of Natural Resources and Environment of Malaysia has embarked on intensive coastal mangrove plantation along the country coastline including Sungai Haji Dorani of Selangor. This programme aimed towards creating a first line of defense that might protect or reduce the impact of any natural disaster which act as a buffer zone at coastline area.

Referred to Seng (2007), mangrove forests are home of many marine species and also tidal inlets that form a highly productive ecosystem at coastal areas. These mangroves live in the upper tidal zone which is above Mean Sea Level to High Water at moderate wave climate. This plantation could give protection against erosion of the high wave water impact and as a buffer zone by dissipating the wave energy through its availability of unique root system. Besides, this mangroves also act as the primary backup from flooding to occur. The reduction of wave energy impact totally depends on the several parameters such as water depth, wave period, wave height, mangrove species, density of the mangroves forest and last but not least the individual diameter of the mangrove trunks and roots (Kathiresan & Rajendran, 2005).

2.3 Study Area

Forest Research Institute of Malaysia (FRIM) had chosen Sungai Haji Dorani which has 26-km shoreline as their research site towards this mangrove plantation. The shoreline that is in proximity of Kuala Bernam Forest Reserve is dominated by mud flats of 1:100 foreshore slope and currently populated by two mangrove species which are *Avicennia* and *Brugeira* (Hashim et al., 2010). Because of the unavailability of coastal forest, Sungai Haji Dorani fail to trap the sediment permanently that driven from the primary source which are Bernam River and Perak River (Stanley & Lewis, 2011). Based on latest research done by Hashim et al. (2010), this study area was covered by mud deposit with mixture of 22% of clay, 56% of silt, 17% of fine sand and also 5% of organic matters. Stanley (2009) classified that there are tentatively three parts of zone that must be considered for mangroves plantation which are high tidal zone, mid tidal zone and low tidal zone. Based on the previous research, mid tidal zone is the most potential zone for mangrove rehabilitation.

In order to protect the eroded coastline of Sungai Haji Dorani, both hard and soft engineering structures were designed and applied. In year 2006, FRIM had conducted a research by using geotextile tubes which act as a breakwater structure there to protect the shoreline of Sungai Haji Dorani thus aim to give protection towards the saplings of the mangroves. Then, University of Malaya (UM) continued solving the problem there by installing L-Block breakwater which known as hard engineering structure (Roslan, 2006). However, Lee et al. (2014) reported that the mangrove belt dominated by Avicenna sp. protected by the geotubes expanded in size over the years as compared to the areas covered by L-Block breakwater. In addition, there is also a coastal protection measure called SAUH revetment being constructed by Department of Irrigation and Drainage (DID) in order to support the eroded coastline of Sungai Haji Dorani.

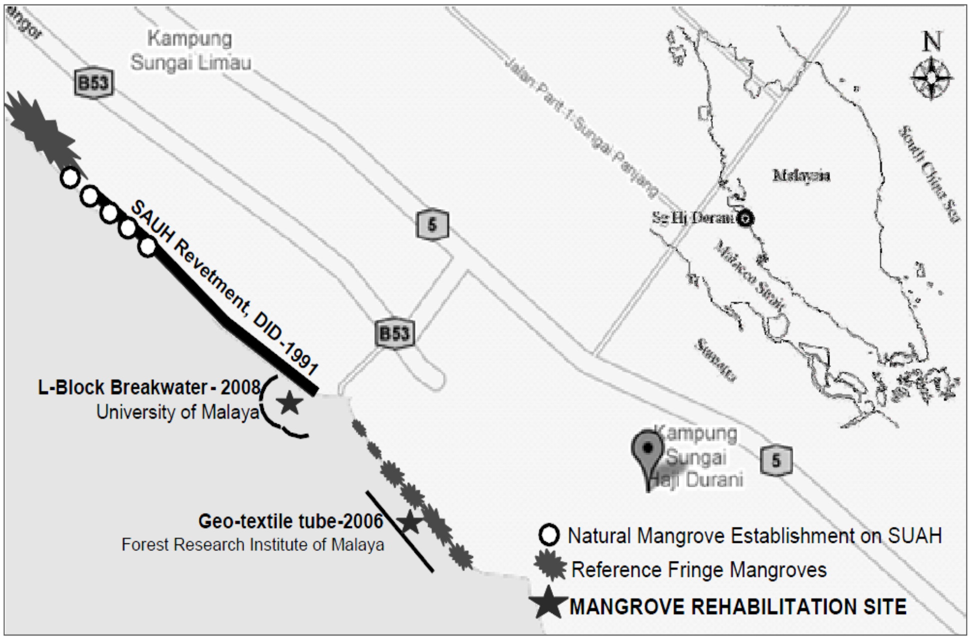


Figure 2.1: Mangrove rehabilitation sites at Sg. Hj. Dorani

2.4 Geotube Breakwater

This geotextile tube technology is mainly used for flood and water control which preventing the beach erosion thus give shore protection and environment application (Koerner, 2006; Muthukumaran & Ilamparuthi, 2006). Besides, geotube acts as a breakwater that slowing down the wave speed and its impact towards the shorelines. Geotubes are made of geotextile bags that are filled with natural sedimentary materials such as rocks and sand that are readily available near the construction sites. This structure exist in various size and configuration arranged in an array to serve as an alternatively submerged breakwater. Besides controlling the wave action, this soft engineering structure promotes sedimentation and soil enrichment needed for the growth of coastal vegetations (Rasidah et al, 2010). During extreme tidal events, the wave energy will be much reduced and hence will slow down littoral transport leading to sedimentation within an area enclosed by the geotubes structure. Nowadays, due to its low construction cost geotube breakwater are commonly used to protect the coastal mangrove from intrusion of destructive waves and boat wakes (Stanley & Lewis, 2009).

Figure 2.2: Example of geotube used in Sungai Haji Dorani, Selangor, Malaysia

Figure 2.3: Example of geotube condition in Sungai Haji Dorani now in 2016

Figure 2.4: Example of geotube condition in closer view

2.5 Breakwater Condition

There are two principle catogories of breakwater which are emerged and submerged. According to David (2008), emerged breakwater are designed to provide protection on their seaward face by inducing breaking, runup and also partial reflection of incident wave. Similarly, submerged breakwater are designed to offer protection by inducing breaking and partial reflection-transmission of large waves (Grilli et al., 1994). The focus of this paper is both emerged and submerged condition since the geotube breakwater is alternatively submerged during high tide and emerged during low tide.

Based on Hur (2003), the submerged breakwater has become increasingly popular due its multiple function thus, it usually dissipates less wave energy than an emerged breakwater. Submerged breakwaters, however, are often times more aestatically pleasing than emerged breakwaters, which is critical to tourism market of most coastal areas (Johnson 2005). Another advantages of submerged breakwater is that it maintain the landward flow of water, which may be important for water quality considerations (Kobayashi et al., 2007). However, different breakwater condition either emerged or submerged have their own pros and cons depending on the situation.

2.6 Stability and Durability of Geotube

Referring to Shin and Oh (2007), the main problem in geotextile tube technology is lack of proper design criteria such as hydraulic stability, structural functionality and behavior of the geotube during and after construction. By using two-dimensional (2-D) limit equilibrium theory, this hyraulic stability analysis can be perform. Hydraulic stability failure of the geotube can be expressed in several term which are sliding failure, overturning failure, bearing capacity failure and also rotating failure. Current wave forces must be carefully study first in order to assess the stability of the filled geotextile tube structure. Based on the field expererience that have been done, it is possible that to fill in the geotube to 70% or 80% of the theoritical circular diameter to achive its stability agaisnt strong wave current (Shin & Oh, 2007).

By following rule of thumb, the hydraulic stability of the design criteria for the geotextile tube is highly depends on the size of the structure per single unit. The bigger the unit, the more stable the structure against the wave current (Seng & Hisham, 2007). Besides, the stability of any structure is also depends on the shape and size of its foundation or base. Therefore, the application of flat geotubes are widely adopted in this coastal engineering studies. However, until now there is no specific theory or formulae available for those flat geotube structures (Gang et al., 2011). In addition, horizontal and vertical forces are also one of the factors influencing the stability of the geotube structure.

Based on Nishold et al. (2014), there are two major reasons for the failure of the geotube structure which are hydrodynamic failure mechanism and also geotechnical failure mechanism. The example of both failure mechanism are explained by (Steeg & Breteler, 2008) such as the occurence of hydrodynamic failure is because of sand loss and sand migration due to strong wave current that imposed to the geotube structure.

2.7 2-D Hydraulic Stability Analysis

Failure of geotextile tube structure might cause by its hydraulic structure failure such as sliding, overtuning, bearing capasity failure and rotating which forcing associated with waves that propagate over the tube. To assess the stability of the geotextile tube structure, current wave forces have to be estimated. However, the theoritical stability analysis is not being studied in this paper. For future research, this geotextile tube structure can be analyse based on linear wave theory and geotechnical stability analysis method.

2.8 Wave Transmittance Properties

According to Pilarczyk (2003), the transmission coefficient can be defined as the ratio of the height directly shoreward of the breakwater to the height directly seaward of the breakwater, has the range $0<K<1$, for which a value of 0 implies no transmission (high, impermeable), and a value of 1 implies complete transmission (no breakwater). Factors that control wave transmission include crest height and width, structure slope, core and armour material (permeability and roughness), tidal and design level, wave height and period. As wave transmission increases, diffraction effects decrease, thus decreasing the size of a salient through direct attack by the transmitted waves and weakening the diffraction-current moving sediment into the shadow zone (Hanson and Kraus, 1991).

In order to evaluate the wave transmittance properties of a geotextile tube, the transmitted wave height was being measured and the transmitted wave spectrum was analysed. Due to the interference of the geotube structure, there are a few parameters have been effected. For an example, the wave transmitted ratio and transmitted wave height will significantly decrease when wave height is increase (Shin & Oh, 2007).

2.9 Wave Energy Dissipation

The wave energy dissipation is mainly caused by either wave breaking or flow percolation. The concept of energy dissipation related with the flow percolation occurs because of decay of incoming waves while percolating through the porous structure. If the spilling type of wave breaking undergoes on submerged structures, then most of the wave energy will be dissipated without considerable amount of wave attenuation due to type of breaking. Therefore, if the incoming wave height undergoes plunging type of break at the structure, it would not be possible to distinguish the reason of energy dissipation on the basis of flow percolation and spilling type of break. The requirements for greater wave height for plunging type of breaks implies that there must be a lower limit for the incoming wave height to observe wave energy dissipation due to wave break.

2.10 Concluding Remark

Geotextile tubes breakwater is an alternative solution that widely used as a long term green protective barrier towards coastline erosion problem especially in maintaining the mangrove plantation by dissipating the wave thus reducing the wave energy impact. By conducting this study, the significant of installing geotube breakwater towards mangrove rehabilitation near Sungai Haji Dorani can be determine. Based on the previous research done by Rasidah et al. (2010), they managed to carry out a study on evaluation of soil profile after geotube installation and the effect of it towards the survival of mangrove plantation. Similarly, the latest research conducted by Tamin et al. (2011) also study about the change in soil composition after the construction of hard breakwater at mangrove area. However, the effect of wave transmission and reflection of an alternatively submerged geotextile breakwater towards mangrove rehalibitation area especially near Sungai Haji Dorani have not much been explore and further study yet.

CHAPTER 3

METHODOLOGY

3.1 General

There are three major steps to be carried out in this section which are physical simulation experimental setup for three series, development of empirical model and development of analytical model. In physical modeling, discussion of the experimental setup will be done focusing on the test program that been planned and tabulated. Further data analysis will be done respected to wave that been transmitted due to the present of geotube followed by development of empirical model and development of analytical model.

3.2 Site Investigation

Site investigation was done on 23th of July 2016 together with supervisor and also one of the representative from FRIM department, Dr. Raja Barizan. For extra information, Dr. Raja Barizan is one of the team who conducted the rehabilitation of mangrove project at Sg. Haji Dorani. During the site investigation process was done, we had a great opportunity by having a short discussion with Dr. Raja Barizan there related to this project especially on the behavior of the mangrove saplings when expose to wave actions with the protection given by Geotextile tube breakwater. Throughout the discussion, she also included the planting technique that have been used by her team during the earlier rehabilitation process. Even though the process was successfully done, but the outcome still need a lot more improvement based on her opinion. Dr. Raja Barizan said that in order to make sure the saplings of the mangroves grows well, the protection from soft engineering structure such as geotube need to be design and applied.

On the day of site visit, we were given an opportunity by Dr. Raja Barizan to visit the geotube structure in order to allow us to take some measurement and samples for further studies to be done. As observed, it is clearly seen that the geotube condition had degraded over the years. Since this is a temporary based structure that can only be serve estimate around 5 years, geotube structure has shown its maximum durability level. The geotube became flat and some parts especially at the edges was torn apart which resulting in loss of the sand material inside it. A few pictures was taken there during the visit in order to have some discussions and review. Dr. Raja Barizan once again highlighted the need of goetube structure in protecting the mangrove rehabilitation process which shows the need of collaboration. This collaboration with UTP is aim to produce a suitable design and dimension of the geotube that can be used as a guidelines for their next mangrove rehabilitation project.

Figure 3.1: Mangrove forest in Sg. Haji Dorani, Selangor

As mentioned before, geotextile tube breakwater is only a temporary structure that can serve and give protection towards the mangrove forest at the lee side of it for 5 years or less. Based on Dr. Raja Barizan, a continuous soft engineering protection measure such as this geotube structure with a good design must be there in order to make sure the aim of this rehabilitation process is achieve. However, during the site investigation we found that there are SAUH protection being constructed on top of the geotube strcture due to failure of the geotube after few years.

Figure 3.2: SAUH revetment was constructed on top of the Geotube breakwater

3.2 Test Model

For hydrodynamic performance comparison purpose, geometrical details of the geotube breakwater model is determined based on those of the semicircular breakwater model developed by (Zhang et al. 2005). Froude scaling of 1:20 is used as a scaling ratio for this study. The geotube breakwater model is composed of 4 modular units, each with a base width of 500mm, and a length of 500mm as shown in Figure 3.1. The geotubes are made of geotextile bags that filled with the same amount of sand of the similar mean diameter which will be medium dense sand approximately 0.2 – 0.6 mm (slightly silty and fine to coarse grained, containing gravel size shell debris and fragment of carbonate sandstone). This is to ensure physical properties of the filled geotubes are identical throughout the experiment. The geotubes are aligned in series to form a continuous breakwater.

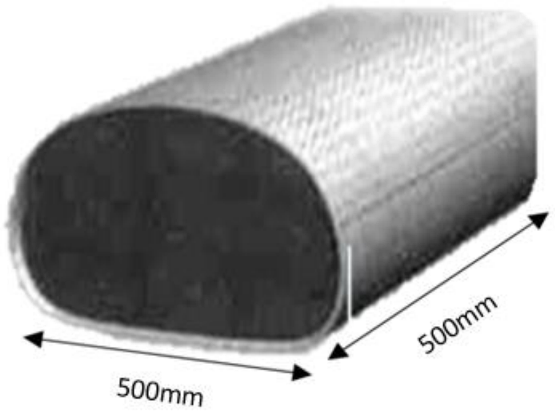


Figure 3.3: Schematic diagram of the geotube model

Figure 3.4: Plan view of the real geotube model

Figure 3.5: Side view of the real geotube model

3.3 Laboratory Equipment and Instrumentations

3.3.1 Wave Basin

A 20 m long, 10 m width and 3 m high wave basin, as shown in the Figure 3.6 is used to conduct experiments. The walls of the wave flume are made of reinforced concrete, with several transparent flexi glasses located at both side of the wave basin. These glasses provide full visibility to the test structure and close monitoring of the experiments.

Figure 3.6: UTP Wave Basin

3.3.2 Wave Paddle

Wave paddle is used to generate waves of varying physical characteristics. The wave paddle is installed at one end of the wave basin, as shown in Figure 3.7. It is able to generate both regular and random waves of different periods and heights. The wave paddle was fabricated by the Edinburgh Design Ltd., United Kingdom.

Figure 3.7: Wave Paddles

3.3.3 Wave Absorber

At the other end of the wave basin, a wave absorber is placed to absorb the remaining wave energy from the incident waves generated in the basin. This is to avoid the reflected waves that interfere with the ongoing experiments. As a requirement, the wave absorber must be made up of a material that can absorb up to 90% energy from the incident waves (Edinburgh Design Ltd.).

3.3.4 Wave Probes

Wave probes are used to measure water level fluctuation in a test facility. In this study, 3 wave probes with different intervals are respectively place at the back of the test model while 1 probe was place in front of it for the measurement of the change of water level. Decomposition of the wave signals using the three-point method (Mansard & Funke, 1980) is to be performed to desire the reflected waves. Prior to the test, the wave probes will need to be carefully calibrated in still water. Figure 3.8 shows the placement of the wave probes inside the wave flume.

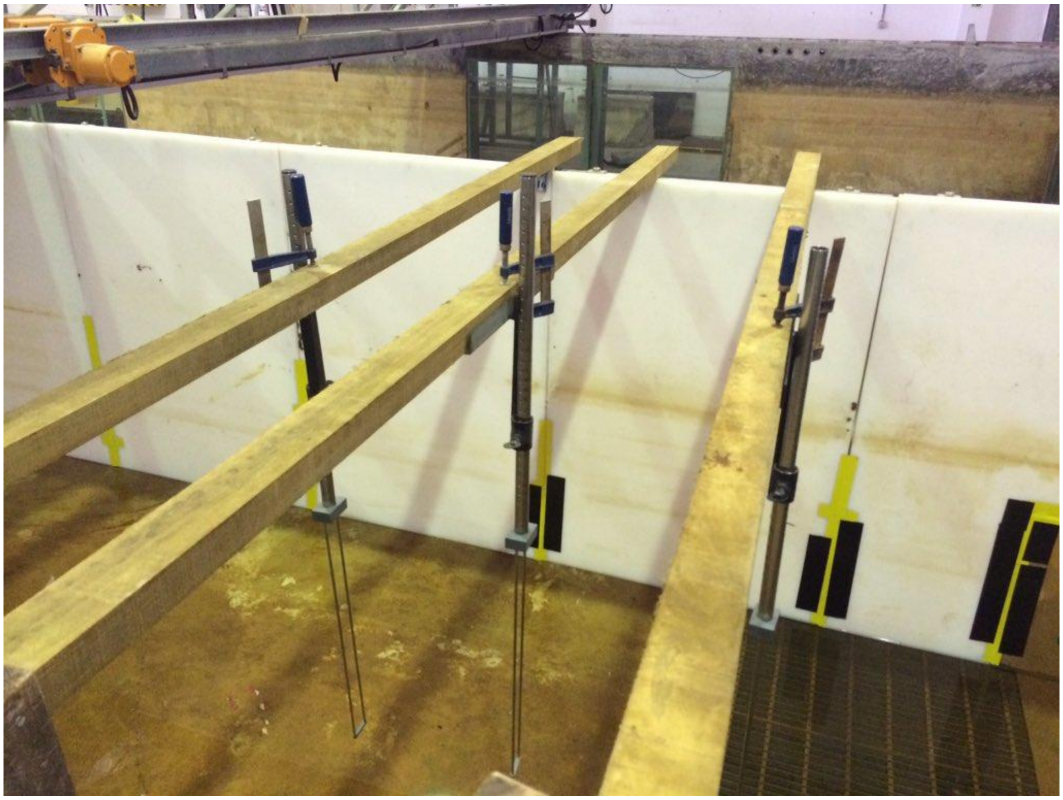


Figure 3.8: Three probes method being used to measure the reflected wave

3.4 Test Conditions

Hydrodynamic characteristics of the geotubes breakwater model is investigated in unidirectional waves of different steepness. The irregularity of the waves produced by the wave generating facility is defined by the JONSWAP spectrum with a peak enhancement factor of 3.3. The main factors affecting the wave transmission of a geotube breakwaters are wave steepness H_i/L, relative wave height H_i/d, and relative submergence, d'/H_i, where H_i is the incident wave height, L is the wavelength, d' is the freeboard (the still water level to the crest of the breakwater) and d is the still water depth in front of the breakwater as presented in Figure 3.9

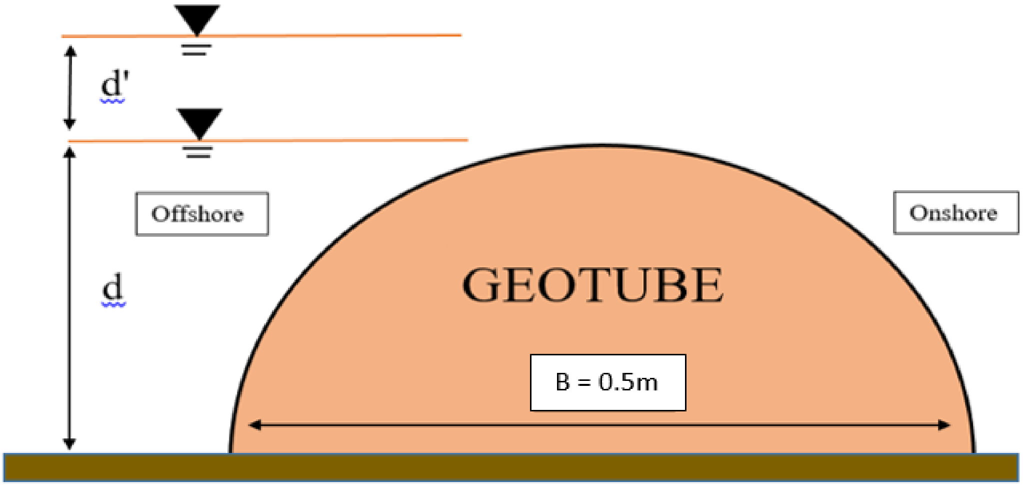


Figure 3.9: Cross section of the test model

Three series of experiment are proposed for this study to evaluate the variation transmission with respect to the following dimensionless parameters which are:

a. Series I: Effect of wave steepness, H_i/L
b. Series 2: Effect of relative wave height, H_i/d
c. Series 3: Effect of relative submergence, d'/H_i

3.5 Model Setup

A series of experiment are conducted in a 20m long, 10m wide and 1m deep wave basin at the Offshore Engineering Laboratory, Universiti Teknologi PETRONAS. Due to un-preferable condition, the wave basin was being modified into wave flume condition by using partitions. An active type wave maker composed of 4 independent paddles is installed at one side of the basin. The wave maker is capable of generating regular, random, oblique and multidirectional waves depending on the research being conducted. The geotube breakwater model consists of four parts. The total length of the breakwater is 2m. The model is arranged at the right angle with the wave maker. A total of 4 wave probes are been used throughout the whole experiment. The schematic diagram of the wave basin set-up is as below:

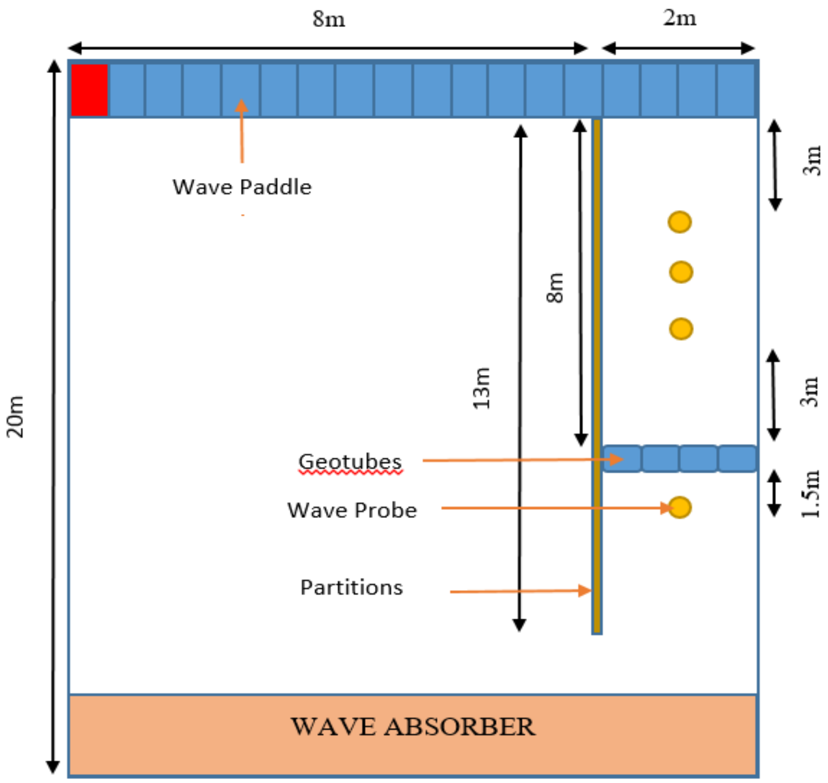


Figure 3.10: Schematic diagram of UTP wave basin

Figure 3.11: Setting up of the empty tank test

Figure 3.12: Front view of the modified wave basin

3.6 Test Procedure

All wave probes are carefully calibrated prior to experiment on daily basis as the conductivity of the probes is greatly influenced by the temperature and property of the water. In order to do calibration of the wave probes, significance change of water level must be prohibited because it will definitely give impact to its reading. Therefore, the water level must always being check and do the calibration before and after each test. On top of that, the water must be completely calm throughout the process.

Throughout the experiment, there are three water depths was used which are 0.3m 0.4m. In each water depth, there are 12 wave periods ranging from 0.8s up to 1.9s was used. These wave period was repeated for three wave steepness which are 0.02, 0.04 and 0.06. Since the test parameters in the wave basin was scale down, there will be a small percentage of error produced by the wave generator. Therefore, comparison graph between the set and gain values in the system must be determine in order to counter the error. This set and gain value factor can be achieve by running the test according to the produced test matrix without any structure inside the modified wave flume. During the test, a set of camera was being installed at the side of the wall of the basin in order to record the generated waves. This procedure was done to make sure the wave height generated by the wave maker is accurate.

Figure 3.13: Manual recording using Go-Pro

3.7 Test Matrix

Table 3 1: Test series I with wave steepness of 0.02 (Emerged)

TEST	Wave Height (Hi)	T(s)	Frequency	L(m)	Hi/d
1	0.01921	0.8	1.250	0.96032	0.06402
2	0.02336	0.9	1.111	1.16791	0.07786
3	0.02746	1.0	1.000	1.37301	0.09153
4	0.03147	1.1	0.909	1.57332	0.10489
5	0.03540	1.2	0.833	1.77008	0.11801
6	0.03927	1.3	0.769	1.96356	0.13090
7	0.04308	1.4	0.714	2.15420	0.14361
8	0.04698	1.5	0.667	2.34925	0.15662
9	0.05056	1.6	0.625	2.52798	0.16853
10	0.05424	1.7	0.588	2.71223	0.18082
11	0.05790	1.8	0.556	2.89519	0.19301
12	0.06153	1.9	0.526	3.07670	0.20511

Table 3 2: Test series I with wave steepness of 0.04 (Emerged)

TEST	Wave Height (Hi)	T(s)	Frequency	L(m)	Hi/L	Hi/d
1	0.03841	0.8	1.250	0.96032	0.04	0.12804
2	0.04672	0.9	1.111	1.16791	0.04	0.15572
3	0.05492	1.0	1.000	1.37301	0.04	0.18307
4	0.06293	1.1	0.909	1.57332	0.04	0.20978
5	0.07080	1.2	0.833	1.77008	0.04	0.23601
6	0.07854	1.3	0.769	1.96356	0.04	0.26181
7	0.08617	1.4	0.714	2.15420	0.04	0.28723
8	0.09397	1.5	0.667	2.34925	0.04	0.31323
9	0.10112	1.6	0.625	2.52798	0.04	0.33706
10	0.10849	1.7	0.588	2.71223	0.04	0.36163
11	0.11581	1.8	0.556	2.89519	0.04	0.38603
12	0.12307	1.9	0.526	3.07670	0.04	0.41023

Table 3.3: Test series I with wave steepness of 0.06 (Emerged)

TEST	Wave Height (Hi)	T(s)	Frequency	L(m)	Hi/L	Hi/d
1	0.05762	0.8	1.250	0.96032	0.06	0.19206
2	0.07007	0.9	1.111	1.16791	0.06	0.23358
3	0.08238	1.0	1.000	1.37301	0.06	0.27460
4	0.09440	1.1	0.909	1.57332	0.06	0.31466
5	0.10620	1.2	0.833	1.77008	0.06	0.35402
6	0.11781	1.3	0.769	1.96356	0.06	0.39271
7	0.12925	1.4	0.714	2.15420	0.06	0.43084
8	0.14095	1.5	0.667	2.34925	0.06	0.46985
9	0.15168	1.6	0.625	2.52798	0.06	0.50560
10	0.16273	1.7	0.588	2.71223	0.06	0.54245
11	0.17371	1.8	0.556	2.89519	0.06	0.57904
12	0.18460	1.9	0.526	3.07670	0.06	0.61534

Table 3 4: Test series II with wave steepness of 0.02 (Submerged)

TEST	Wave Height (Hi)	T(s)	Frequency	L(m)	Hi/L	Hi/d	d'/H
1	0.01797	0.8	1.250	0.89865	0.02	0.04493	-2.7820
2	0.02447	0.9	1.111	1.22340	0.02	0.06117	-2.0435
3	0.02927	1.0	1.000	1.46330	0.02	0.07317	-1.7085
4	0.03402	1.1	0.909	1.70124	0.02	0.08506	-1.4695
5	0.03872	1.2	0.833	1.93611	0.02	0.09681	-1.2913
6	0.04332	1.3	0.769	2.16589	0.02	0.10829	-1.1543
7	0.04785	1.4	0.714	2.39262	0.02	0.11963	-1.0449
8	0.05231	1.5	0.667	2.61570	0.02	0.13079	-0.9558
9	0.05670	1.6	0.625	2.83488	0.02	0.14174	-0.8819
10	0.06106	1.7	0.588	3.05318	0.02	0.15266	-0.8188
11	0.06541	1.8	0.556	3.27064	0.02	0.16353	-0.7644
12	0.06963	1.9	0.526	3.48129	0.02	0.17406	-0.7181

Table 3 5: Test series II with wave steepness of 0.04 (Submerged)

TEST	Wave Height (Hi)	T(s)	Frequency	L(m)	Hi/d	d'/H
1	0.03595	0.8	1.250	0.89865	0.08986	-1.3910
2	0.04894	0.9	1.111	1.22340	0.12234	-1.0217
3	0.05853	1.0	1.000	1.46330	0.14633	-0.8542
4	0.06805	1.1	0.909	1.70124	0.17012	-0.7348
5	0.07744	1.2	0.833	1.93611	0.19361	-0.6456
6	0.08664	1.3	0.769	2.16589	0.21659	-0.5771
7	0.09570	1.4	0.714	2.39262	0.23926	-0.5224
8	0.10463	1.5	0.667	2.61570	0.26157	-0.4779
9	0.11340	1.6	0.625	2.83488	0.28349	-0.4409
10	0.12213	1.7	0.588	3.05318	0.30532	-0.4094
11	0.13083	1.8	0.556	3.27064	0.32706	-0.3822
12	0.13925	1.9	0.526	3.48129	0.34813	-0.3591

Table 3 6: Test series II with wave steepness of 0.06 (Submerged)

TEST	Wave Height (Hi)	T (s)	Frequency	L(m)	Hi/L	Hi/d	d'/H
1	0.05392	0.8	1.250	0.89865	0.06	0.13480	-0.9273
2	0.07340	0.9	1.111	1.22340	0.06	0.18351	-0.6812
3	0.08780	1.0	1.000	1.46330	0.06	0.21950	-0.5695
4	0.10207	1.1	0.909	1.70124	0.06	0.25519	-0.4898
5	0.11617	1.2	0.833	1.93611	0.06	0.29042	-0.4304
6	0.12995	1.3	0.769	2.16589	0.06	0.32488	-0.3848
7	0.14356	1.4	0.714	2.39262	0.06	0.35889	-0.3483
8	0.15694	1.5	0.667	2.61570	0.06	0.39236	-0.3186
9	0.17009	1.6	0.625	2.83488	0.06	0.42523	-0.2940
10	0.18319	1.7	0.588	3.05318	0.06	0.45798	-0.2729
11	0.19624	1.8	0.556	3.27064	0.06	0.49060	-0.2548
12	0.20888	1.9	0.526	3.48129	0.06	0.52219	-0.2394

3.8 Study Plan

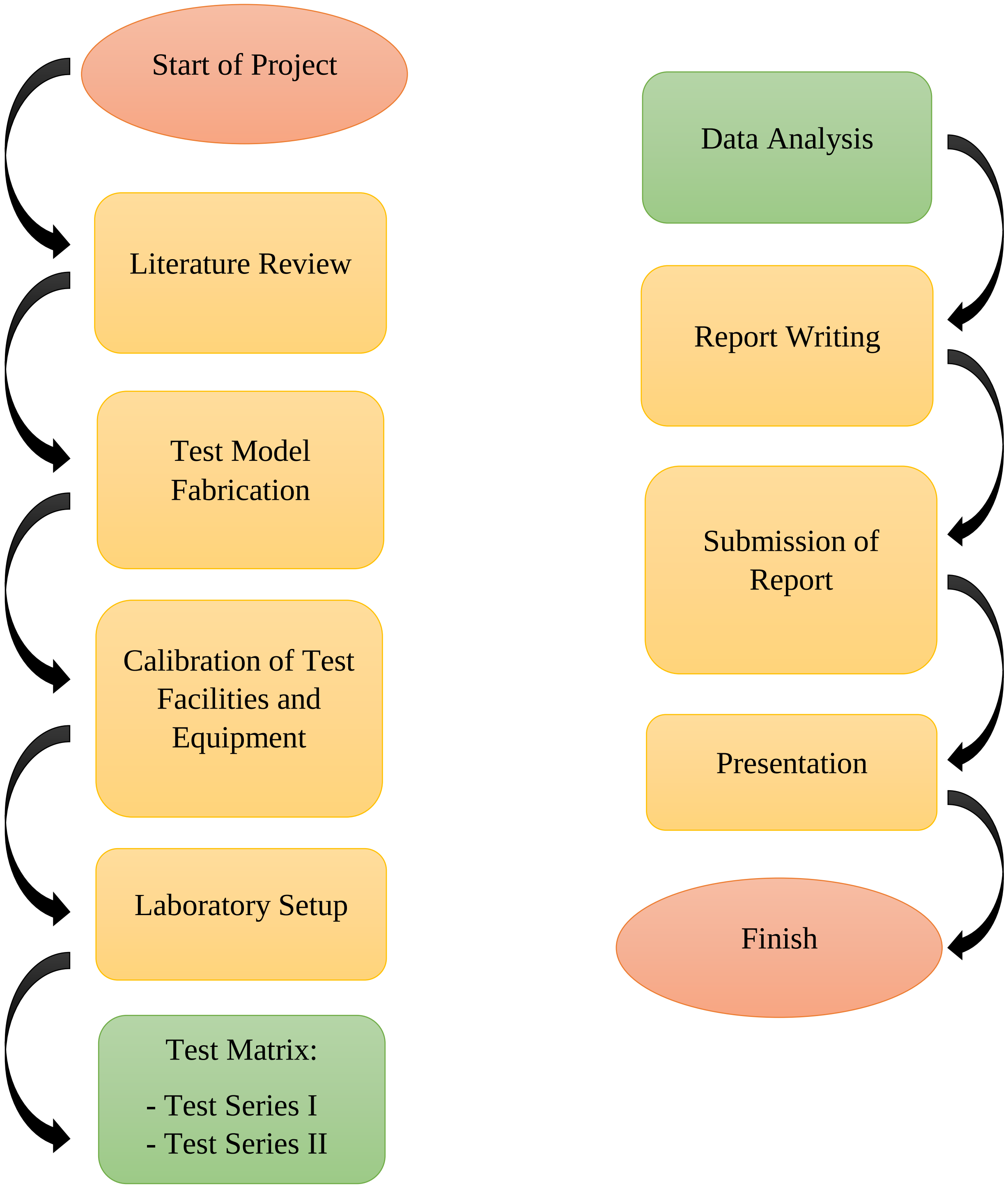
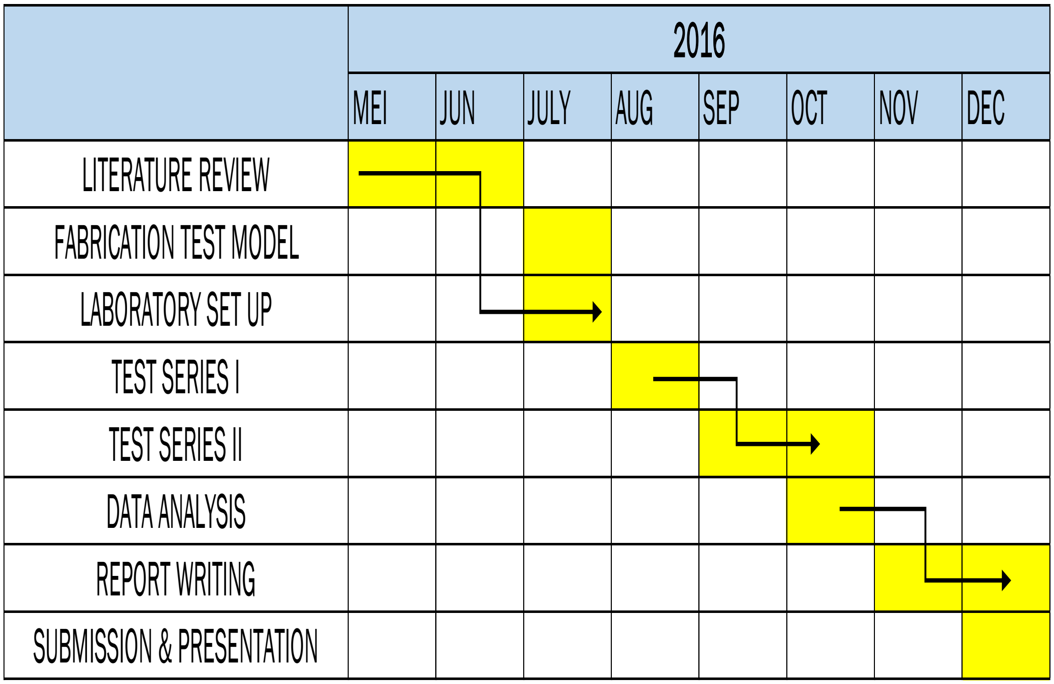


Figure 3.14: Flow Chart

3.9 Gantt Chart



	2016							
	MEI	JUN	JULY	AUG	SEP	OCT	NOV	DEC
LITERATURE REVIEW	■	■						
FABRICATION TEST MODEL			■					
LABORATORY SET UP			■					
TEST SERIES I				■				
TEST SERIES II					■	■		
DATA ANALYSIS						■		
REPORT WRITING							■	■
SUBMISSION & PRESENTATION								■

Figure 3.15: Gantt chart including milestone of the project

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter presents the results obtained from the experiments of test series I and II. These series are represent 2 different water depth being conducted which are 0.30m and 0.40m respectively. The experiment are conducted according to the prepared test matrix and the results are presented by following its wave steepness, H_i/L 0.02, 0.04 and 0.06. Then, performance of the models in emerged and submerged cases are discussed also in this chapter.

4.2 Wave Kinematics

4.2.1 Wavelength

In this experiment the water depth, *d* was varies at 0.30m and 0.40m while the wave period, *T* was in the range of 0.8s to 1.9s. To calculate the local wavelength, *L* it is first required to determine the deepwater wavelength, L_o by using equation below.

$$L_0 = \frac{gT^2}{2\pi}$$

where g = gravitational acceleration (m/s^2).

By referring to the wave table from Shore Protection Manual, *d/L* can be obtained by interpolation. Therefore, wave length, *L* can be easily calculated. Wave classification is also done whereby the wave type used in this experiment is transitional water. Wave classification is made according to the magnitude of *d/L*, where it satisfies the properties $1/25 < d/L < ½$.

4.3 Calibration Factor Graphs

Based on these graphs, the factor of error produced by the wave maker can be obtained thus, an approximately desired wave height can be achieve throughout the experiment. There are 12 trend lines represent each wave period starting from 0.8s to 1.9s in individual graph. By using this trend line, a linear graph between set and gain value can be produced.

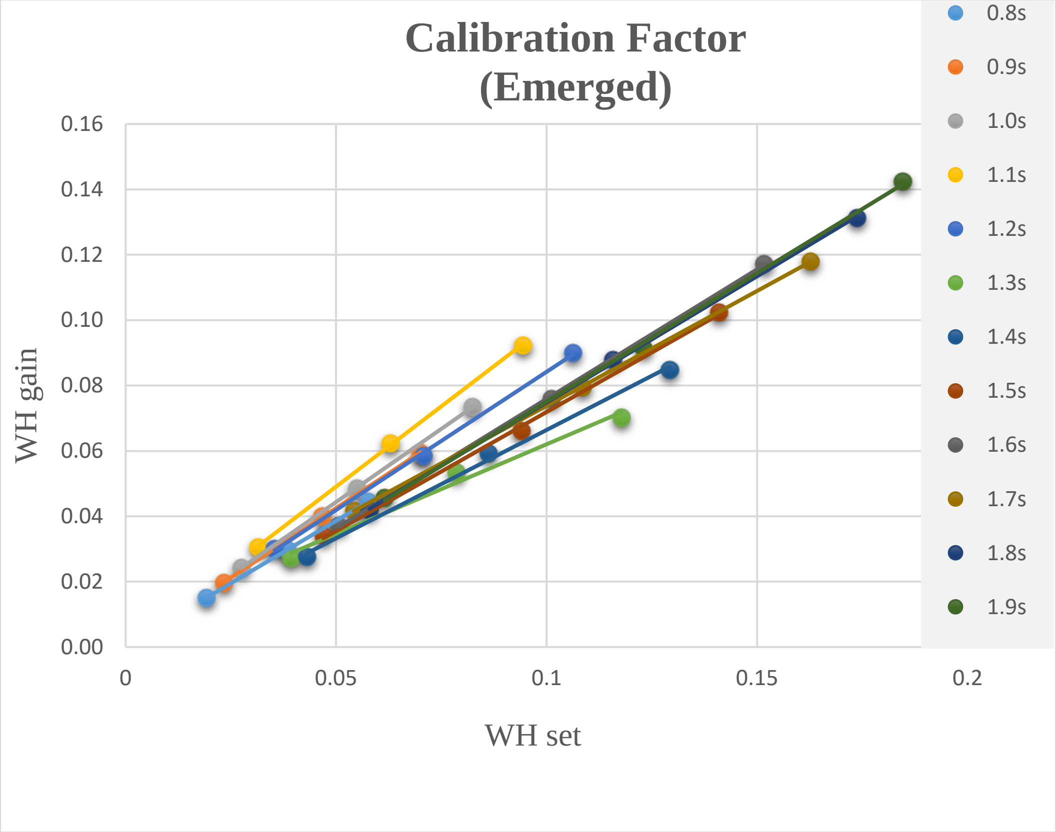


Figure 4.1: Graph of wave height gain versus wave height set for wave period (T) 0.8s – 1.9s in 0.30m water depth.

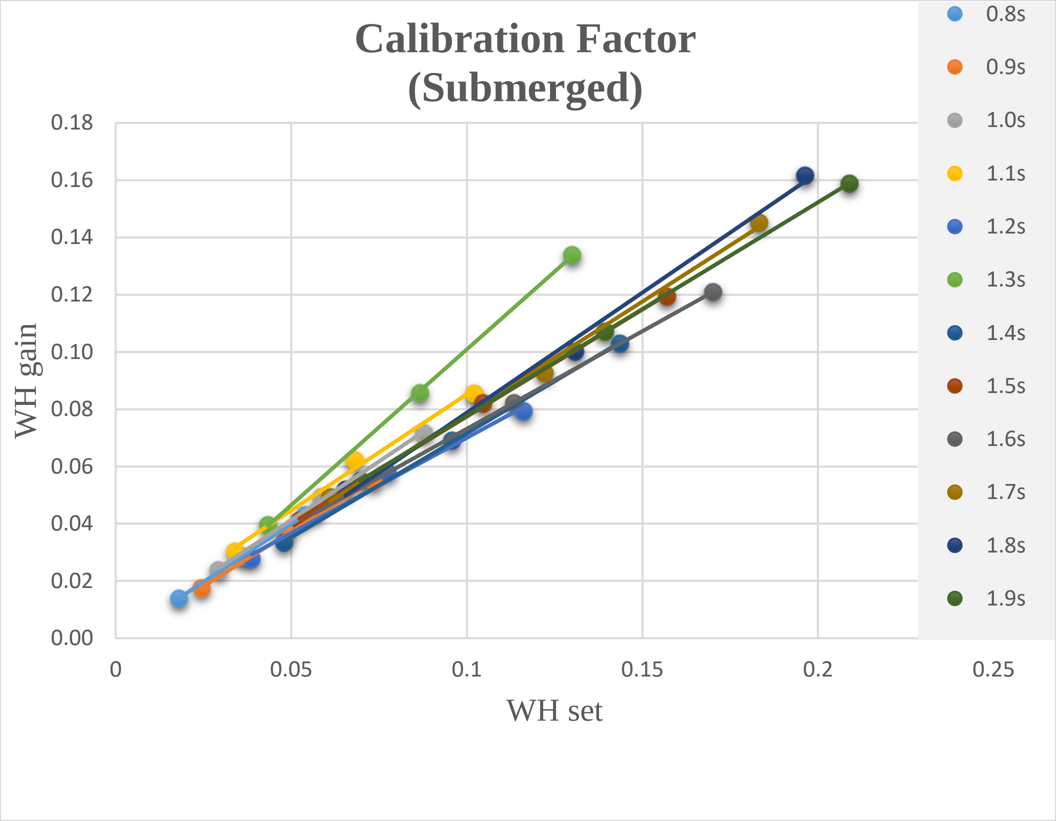


Figure 4.2: Graph of wave height gain versus wave height set for wave period (T) 0.8s – 1.9s in 0.40m water depth.

4.3.1 Comparison table for the R^2 values (0.3m depth)

Y = mHi + C		
Period (T)	Hi Set	R^2 value
0.8s	0.02460	1.0000
	0.04971	
	0.07484	
0.9s	0.02745	0.9997
	0.05494	
	0.08243	
1.0s	0.03113	0.9999
	0.06180	
	0.09248	
1.1s	0.03208	0.9996
	0.06410	
	0.09613	
1.2s	0.04223	0.9991
	0.08410	
	0.12598	
1.3s	0.05846	0.9842
	0.13004	
	0.20162	
1.4s	0.06473	0.9963
	0.12707	
	0.19482	
1.5s	0.06578	0.9988
	0.13033	
	0.19488	
1.6s	0.06798	0.9996
	0.13179	
	0.19561	
1.7s	0.07210	1.0000
	0.14933	
	0.22655	
1.8s	0.07808	0.9997
	0.15306	
	0.22803	
1.9s	0.08276	0.9991
	0.16107	
	0.23937	

Y = mHi		
Period (T)	Hi Set	R^2 value
0.8s	0.02483	0.9998
	0.04965	
	0.07448	
0.9s	0.02747	0.9997
	0.05495	
	0.08241	
1.0s	0.03089	0.9999
	0.06178	
	0.09267	
1.1s	0.03205	0.9996
	0.06410	
	0.09615	
1.2s	0.04208	0.9991
	0.08417	
	0.12625	
1.3s	0.06264	0.9609
	0.12528	
	0.18792	
1.4s	0.64880	0.9963
	0.12977	
	0.19465	
1.5s	0.06527	0.9986
	0.13055	
	0.19582	
1.6s	0.06617	0.9981
	0.13234	
	0.19851	
1.7s	0.07176	0.9981
	0.14851	
	0.22277	
1.8s	0.07676	0.9991
	0.15353	
	0.23029	
1.9s	0.08082	0.9979
	0.16166	
	0.24248	

4.3.2 Comparison table for the R^2 values (0.4m depth)

Y = mHi + C		
Period (T)	Hi	R^2value
0.8s	0.02292	1.0000
	0.04511	
	0.06728	
0.9s	0.03318	0.9994
	0.06532	
	0.09744	
1.0s	0.03521	0.9985
	0.07101	
	0.10683	
1.1s	0.03691	0.9921
	0.07888	
	0.12085	
1.2s	0.05295	0.9905
	0.11117	
	0.1694	
1.3s	0.05987	0.9905
	0.12500	
	0.19012	
1.4s	0.06733	0.9998
	0.13315	
	0.19898	
1.5s	0.06636	0.9993
	0.13632	
	0.20629	
1.6s	0.07585	1.0000
	0.15904	
	0.24221	
1.7s	0.07803	0.9969
	0.15581	
	0.23359	
1.8s	0.08398	0.9951
	0.16201	
	0.24003	
1.9s	0.08923	1.0000
	0.18260	
	0.27599	

Y = mHi		
Period (T)	Hi	R^2 value
0.8s	0.02257	0.9996
	0.04516	
	0.06773	
0.9s	0.03274	0.9990
	0.06549	
	0.09822	
1.0s	0.03553	0.9985
	0.07104	
	0.10657	
1.1s	0.03943	0.9874
	0.07887	
	0.11830	
1.2s	0.05502	0.9865
	0.11003	
	0.16506	
1.3s	0.06155	0.9865
	0.12310	
	0.18464	
1.4s	0.06674	0.9996
	0.13347	
	0.20022	
1.5s	0.06798	0.9983
	0.13597	
	0.20395	
1.6s	0.07882	0.9964
	0.15763	
	0.23643	
1.7s	0.07788	0.9969
	0.15578	
	0.23366	
1.8s	0.08122	0.9933
	0.16246	
	0.24369	
1.9s	0.09103	0.9992
	0.18205	
	0.27308	

4.4 Hydraulics Performance of the Geotube

As mentioned earlier the main objective of this alternatively submerged geotube breakwaters is to give sort of protection towards coastal forest from impact of sea waves. Reduction in height of waves transmitted to the protected area compared to the incident wave heights can quantify performance of the breakwater. Comparison of the incident and transmitted wave heights is expressed as the wave transmission coefficient C_T.

$$C_T = \frac{Ht}{Hi} \qquad (4.1)$$

As wave attenuation by the structure is due to reflection or dissipation so reflection coefficient C_R and energy loss coefficients C_L^2 are also used to analyze performance of the geotube breakwater along with the transmission coefficient C_T. Relation between C_T, C_R and C_L can be expressed as:

$$C_T^2 + C_R^2 + C_L^2 = 1 \qquad (4.2)$$

Formula for C_R is:

$$C_R = \frac{Hr}{Hi} \qquad (4.3)$$

Value for C_L^2 can be obtained by:

$$C_L^2 = 1 - C_T^2 - C_R^2 \qquad (4.4)$$

Energy dissipation coefficient can also be represented in form of energy:

$$C_L^2 = \frac{El}{Ei} \qquad (4.5)$$

Where Ei is the total incident energy and E_l is energy dissipated.

Steepness Hi/L	Test Name	Hi	Hr	Ht	C_T Value	C_R Value	C_L^2 Value	B/L
0.02	real-ts3-0.8sv1	0.01929	0.00135	0.00310	0.16	0.07	0.97	0.52
	real-ts3-0.9sv1	0.02195	0.00291	0.00390	0.18	0.13	0.95	0.43
	real-ts3-1.0sv1	0.02604	0.00463	0.00402	0.15	0.18	0.94	0.36
	real-ts3-1.1sv1	0.02711	0.00932	0.00991	0.37	0.34	0.75	0.32
	real-ts3-1.2sv1	0.02916	0.00963	0.00536	0.18	0.33	0.86	0.28
	real-ts3-1.3sv1	0.03486	0.01689	0.00769	0.22	0.48	0.72	0.25
	real-ts3-1.4sv1	0.04480	0.02658	0.01079	0.24	0.59	0.59	0.23
	real-ts3-1.5sv1	0.04402	0.02645	0.01110	0.25	0.60	0.58	0.21
	real-ts3-1.6sv1	0.06102	0.03818	0.01881	0.31	0.63	0.51	0.20
	real-ts3-1.7sv1	0.04801	0.03092	0.01578	0.33	0.64	0.48	0.18
	real-ts3-1.8sv1	0.07151	0.03448	0.03031	0.42	0.48	0.59	0.17
	real-ts3-1.9sv1	0.06725	0.03588	0.02651	0.39	0.53	0.56	0.16
0.04	real-ts3-0.8sv2	0.04109	0.00278	0.00358	0.09	0.07	0.99	0.52
	real-ts3-0.9sv2	0.04448	0.00702	0.01010	0.23	0.16	0.92	0.43
	real-ts3-1.0sv2	0.05008	0.01184	0.01124	0.22	0.24	0.89	0.36
	real-ts3-1.1sv2	0.05612	0.01906	0.01501	0.27	0.34	0.81	0.32
	real-ts3-1.2sv2	0.05759	0.01848	0.01725	0.30	0.32	0.81	0.28
	real-ts3-1.3sv2	0.08132	0.03144	0.02866	0.35	0.39	0.73	0.25
	real-ts3-1.4sv2	0.08915	0.04076	0.02582	0.29	0.46	0.71	0.23
	real-ts3-1.5sv2	0.08222	0.04416	0.03556	0.43	0.54	0.52	0.21
	real-ts3-1.6sv2	0.11110	0.06962	0.05517	0.50	0.63	0.36	0.20
	real-ts3-1.7sv2	0.09777	0.05698	0.04750	0.49	0.58	0.42	0.18
	real-ts3-1.8sv2	0.11880	0.04515	0.06850	0.58	0.38	0.52	0.17
	real-ts3-1.9sv2	0.12050	0.05158	0.06503	0.54	0.43	0.53	0.16

0.06	real-ts3-0.8sv3	0.05976	0.00421	0.00837	0.14	0.07	0.98	0.52
	real-ts3-0.9sv3	0.06598	0.01116	0.02163	0.33	0.17	0.86	0.43
	real-ts3-1.0sv3	0.07472	0.01665	0.02332	0.31	0.22	0.85	0.36
	real-ts3-1.1sv3	0.08387	0.02591	0.02768	0.33	0.31	0.80	0.32
	real-ts3-1.2sv3	0.08854	0.02403	0.03011	0.34	0.27	0.81	0.28
	real-ts3-1.3sv3	0.10740	0.04871	0.04239	0.39	0.45	0.64	0.25
	real-ts3-1.4sv3	0.12840	0.04199	0.05635	0.44	0.33	0.70	0.23
	real-ts3-1.5sv3	0.12070	0.06283	0.05434	0.45	0.52	0.53	0.21
	real-ts3-1.6sv3	0.14580	0.08192	0.05922	0.41	0.56	0.52	0.20
	real-ts3-1.7sv3	0.13620	0.05079	0.04847	0.36	0.37	0.73	0.18
	real-ts3-1.8sv3	0.15610	0.03176	0.06345	0.41	0.20	0.79	0.17
	real-ts3-1.9sv3	0.15820	0.05785	0.06356	0.40	0.37	0.70	0.16

Table 4.1: Hydraulic performances based on each wave steepness, Hi/L (Emerged case)

Wave steepness H_i/L	H_i	H_r	H_t	C_T Value	C_R Value	C_L^2 Value	B/L
0.02	0.01588	0.00955	0.01565	0.99	0.60	-0.33	0.56
	0.02578	0.00565	0.03188	1.24	0.22	-0.58	0.41
	0.02980	0.00442	0.03346	1.12	0.15	-0.28	0.34
	0.03047	0.00410	0.03996	1.31	0.13	-0.74	0.29
	0.03463	0.00291	0.03517	1.02	0.08	-0.04	0.26
	0.04347	0.00272	0.04470	1.03	0.06	-0.06	0.23
	0.05033	0.00784	0.03767	0.75	0.16	0.42	0.21
	0.05379	0.01336	0.04522	0.84	0.25	0.23	0.19
	0.05638	0.01498	0.05247	0.93	0.27	0.06	0.18
	0.07032	0.01995	0.06045	0.86	0.28	0.18	0.16
	0.06027	0.02311	0.04946	0.82	0.38	0.18	0.15
	0.07577	0.02911	0.05952	0.79	0.38	0.24	0.14
0.04	0.03326	0.01971	0.03571	1.07	0.59	-0.50	0.56
	0.05053	0.01045	0.04713	0.93	0.21	0.09	0.41
	0.05877	0.00961	0.04759	0.81	0.16	0.32	0.34
	0.06820	0.00724	0.05153	0.76	0.11	0.42	0.29
	0.07832	0.00478	0.05471	0.70	0.06	0.51	0.26
	0.08966	0.00612	0.08222	0.92	0.07	0.15	0.23
	0.10090	0.01453	0.06302	0.62	0.14	0.59	0.21
	0.10580	0.02952	0.08348	0.79	0.28	0.30	0.19
	0.11700	0.02895	0.07386	0.63	0.25	0.54	0.18
	0.13600	0.03092	0.08783	0.65	0.23	0.53	0.16
	0.11780	0.04290	0.08085	0.69	0.36	0.40	0.15
	0.14600	0.05583	0.09414	0.64	0.38	0.44	0.14

0.06	0.05008	0.02715	0.03571	0.71	0.54	0.20	0.56
	0.07285	0.01302	0.05972	0.82	0.18	0.30	0.41
	0.08655	0.01278	0.05877	0.68	0.15	0.52	0.34
	0.09950	0.01038	0.06145	0.62	0.10	0.61	0.29
	0.11360	0.01387	0.05770	0.51	0.12	0.73	0.26
	0.12920	0.01452	0.07337	0.57	0.11	0.66	0.23
	0.12890	0.02401	0.08185	0.63	0.19	0.56	0.21
	0.15500	0.04574	0.09765	0.63	0.30	0.52	0.19
	0.16510	0.04573	0.09769	0.59	0.28	0.57	0.18
	0.08929	0.00409	0.05113	0.57	0.05	0.67	0.16
	0.17370	0.05903	0.10730	0.62	0.34	0.50	0.15
	0.19740	0.06411	0.09841	0.50	0.32	0.65	0.14

Table 4.2: Hydraulic performances based on each wave steepness, Hi/L (Submerged case)

4.5 Wave Transmission

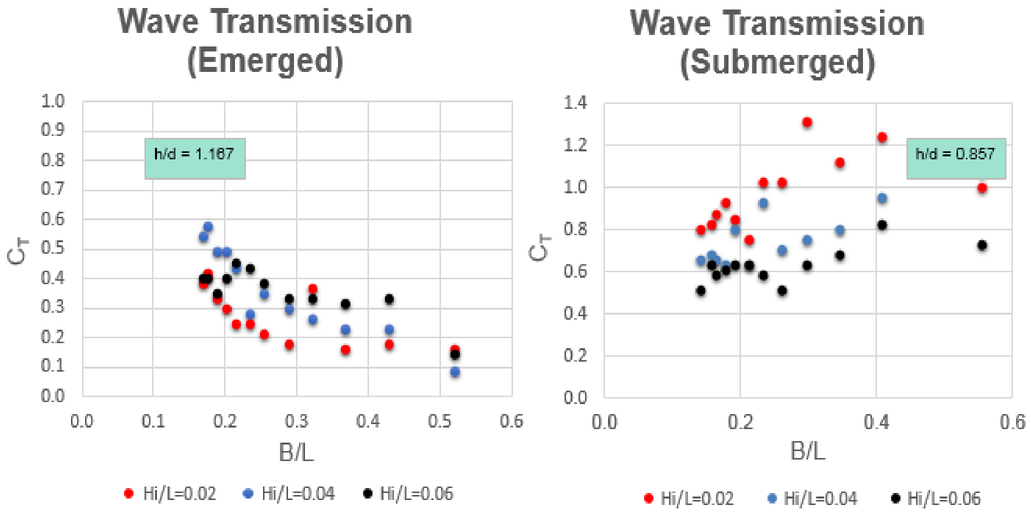


Figure 4.3: Wave transmission coefficient (a) h/d = 1.167; (b) h/d = 0.857

Figure 4.3 shows wave transmission coefficients of the geotube breakwater in both emerged (h/d = 1.167) and submerged (h/d = 0.857) cases. The breakwater was exposed to a range of wave period, giving relative wavelength, *B/L* from 0.15 to 0.52, and waves of steepness *Hi/L* = 0.02, 0.04 and 0.06. For emerged case (***Figure 4.3a***), it is apparent that C_T of *Hi/L* = 0.02, 0.04 and 0.06 reduce with the increase of *B/L*. It seems that the breakwater attenuates more wave energy when exposed to low steepness waves. At larger range of *B/L*, the geotube breakwater is capable of reducing the incident wave height up to 90% (i.e. *B/L* = 0.52, C_T = 0.1). Wave transmission of the emerged geotube breakwater is mainly due to wave overtopping over the crest. The transmitted water reaching the lee side of the breakwater will produce a new series waves with reduced wave height.

When the breakwater is submerged (during the occurrence of high tides), the wave dampening ability deteriorates significantly. ***Figure 4.3b*** demonstrates the increased C_T with B/L, signifying increased wave transmission over the breakwater when subjected to shorter period waves. The higher the wave steepness, the better will be the wave attenuator. This phenomenon is contrary to that of the emerged case. Selection of B/L and Hi/L in the design of submerged geotube breakwaters must be carefully conducted as the 'wrong combinations' may lead to amplification of the transmitted wave height. For instance, when the submerged breakwater of $h/d = 0.857$ designed at $B/L > 0.3$ is exposed to mild steepness waves ($Hi/L = 0.02$), the resulting C_T is more than unity ($C_T > 1$). This is due to the occurrence of wave shoaling at the slope of the breakwater and the energy of the steepened waves has not been dissipated in time during the propagation across the breakwater.

4.6 Wave Reflection

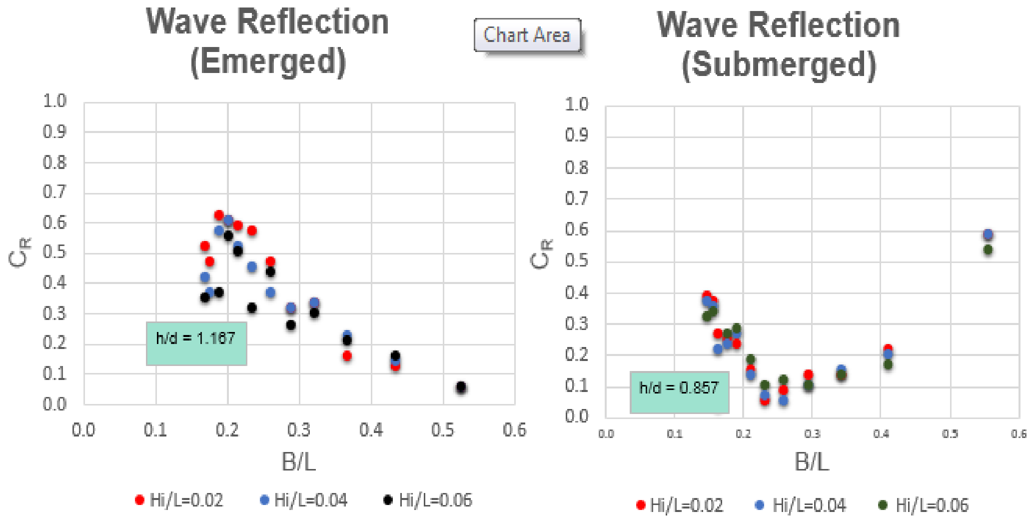


Figure 4.4: Wave reflection coefficient (a) h/d = 1.167; (b) h/d = 0.857

Figure 4.4 demonstrate wave reflection ability of both emerged and submerged geotube breakwater in correspondence with *B/L* and Hi/L. In ***Figure 4.4a***, the C_R of the emerged breakwater reduces with an increase in *B/L* regardless of Hi/L. This indicates that the geotube breakwater serves as a good wave reflector when exposed to long waves. The effect of wave steepness on C_R is not appreciable when the breakwater is emerged at h/d = 1.167.

At h/d = 0.857, the submerged geotube breakwater displays a bragging effect in ***Figure 4.4b***, at which the minimum C_R is found at B/L = 0.25. Similarly, the C_R is less dependent upon wave steepness. The maximum C_R recorded is approximately 0.6 at B/L = 0.55. If the submerged breakwater is designed to be a good wave reflector, it is recommended to be designed at B/L = 0.55. On another hand, the submerged breakwater is good to be design at B/L = 0.25 if it is desired to serve as an effective anti-reflection structure.

4.7 Energy Dissipation

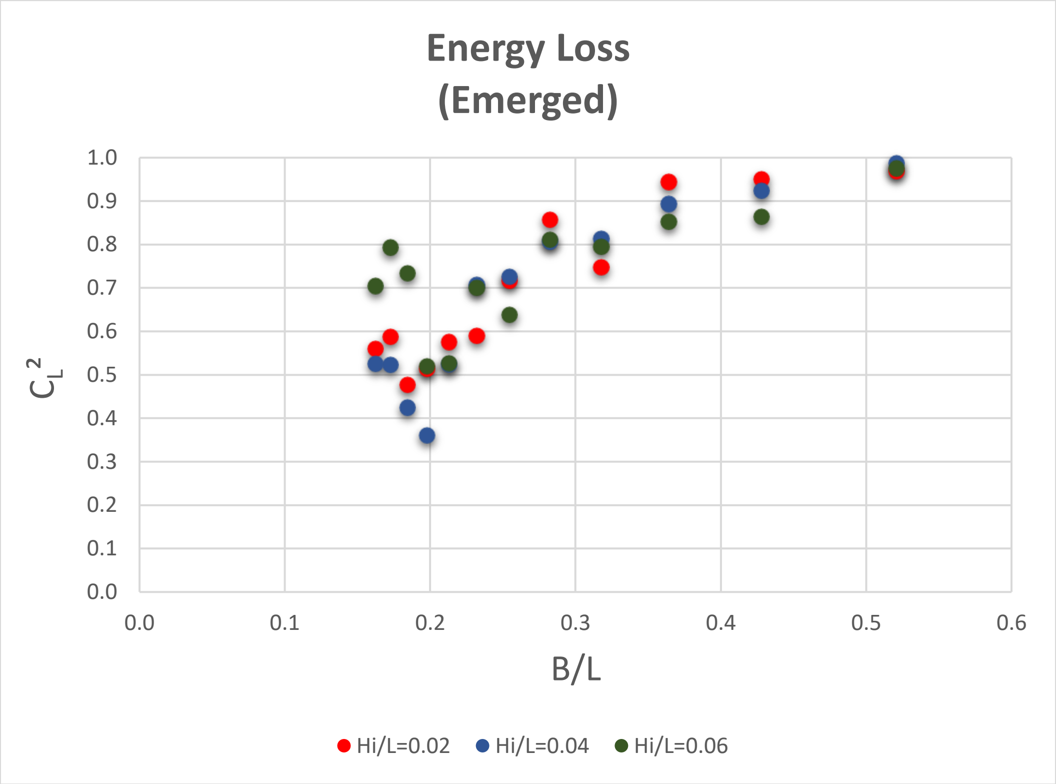


Figure 4.5: Energy dissipation coefficient of h/d = 1.167

Figure 4.5 displays energy loss coefficient, C_L^2 of the geotube breakwater of h/d = 1.167 and h/d = 0.857. For the case of emerged breakwater (h/d = 1.167), C_L^2 increase drastically with an increase of *B/L*, giving the maximum C_L^2 value of 0.98 at *B/L* = 0.52. This indicates that the emerged geotube breakwater acts as an efficient energy dissipation when subjected to smaller wave period. The short waves interact with the breakwater and the majority of the energy is dissipated at the breakwater. It is also found the C_L^2 of the breakwater is less dependent upon wave steepness.

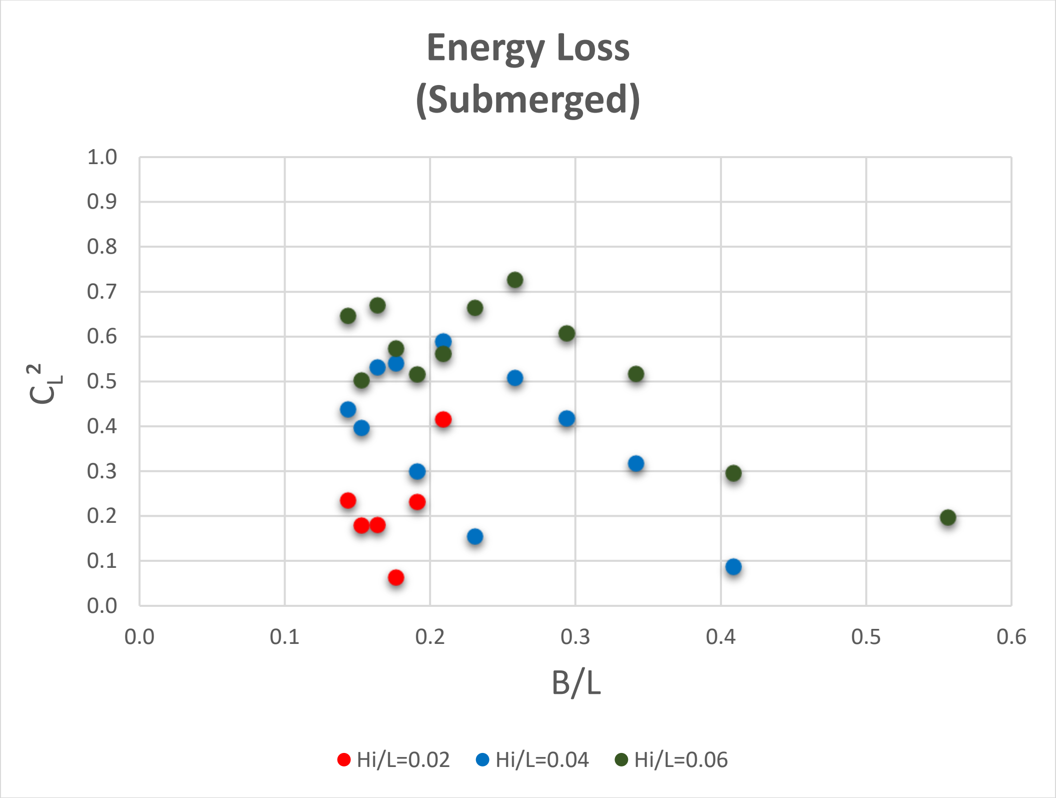


Figure 4.6: Energy dissipation coefficient of h/d = 0.857

For the case of submerged breakwater (h/d = 0.857), the data points are rather scattered as shown in the ***Figure 4.6***. Nevertheless, the data points still show a general trend, for which C_L^2 decrease with increasing *B/L*. The observed C_L^2 trend is somewhat opposed to ***Figure 4.5***. It is important to note that the hydraulic characteristic (including energy loss) are strong dependent upon relative immersion of the breakwater. The breakwater behave very differently with the state of immersion.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Geotubes exist in various configurations and sizes which serve as an alternatively submerged breakwater. Besides controlling the wave action, the geotube installation promotes sedimentation (soil acrretion) and soil enrichment needed for the growth of coastal vegetations. This research provides an option to 'tune' the wave properties to meet the requirement of various coastal and marine applications. The sectors that are directly benefited by this research project are local authorities at coastal towns, recreational water parks, beach resorts and etc. In facts, by conducting this research will definitely give some ideas to FRIM in designing a better dimension of geotube structure at a particular area.

The model that were tested in this experiment able to reduce the incident wave height thus reducing the wave energy especially in emerged condition ($h/d = 1.167$) of geotube breakwater. The model also serves as a good wave reflector when exposed to long wave in emerged condition as compared to submerged which displays a bragging effect in the result. However, to designed a good wave reflector in submerged condition, it is recommended to design the geotube breakwater at $B/L = 0.55$ due to high value of coefficient reflection. On another hand, the submerged breakwater is good to be design at $B/L = 0.25$ if it is desired to serve as an effective anti-reflection structure.

For overall performance of tested models for both conditions, it shows that the geotube breakwater performed better during emerged because it attained the optimum hydraulic characteristic. In facts, this geotube act as a good wave attenuation ($C_T < 0.6$), high wave reflection ($C_R < 0.7$) and good energy dissipaters which able to dissipate more energy as compared to submerged condition. Based on the result gained, it is also can conclude that the reflectivity of the test model is not dependent upon wave steepness in both condition.

This research project is particularly relevant to FRIM in the effort of creating conducive and sheltered sites for mangrove plantation close to the waterline. As mentioned, the involvement of UTP in this research with FRIM will definitely manage to develop a mechanism in enhancing the surviving rate of mangrove seedling at the plantation sites using geotextile tube structure. The research develops an economical option using the naturally available resources (sand) to reduce the marine environmental forces in a more sustainable manner. The success of the project will not just benefit our nation, but also the countries surrounded by water body.

For future research, it is important that to make some improvement and also to conduct the 2-dimensional test of the geotube breakwater. By conducting such test, it will help to determine the wave transmission at the lee side of the geotube breakwater even better. Besides that, it also will help the researchers to study the best location in plating the mangrove behind the geotube structure. On top of that, breakwaters are exposed to extreme waves thus it is important that to conduct a stability test in order to ensure the stability of the structure against the wave force. Last but not least, effect of physical properties of the geotextile tubes such as UV radiation, tensile strength, current and sediment transport are also need to be further study since it is beyond the scope of this project.

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APPENDICES

Figure a: Testing of the geotube breakwater at 0.30m water depth

Figure b: The setting up for the geotube breakwater and the wave probe

Figure c: The setting up of the 3 probes method in order to measure the reflected wave from the geotube breakwater

Figure d: The condition of the geotube breakwater in 0.40m water depth

Figure e: The current site condition at Sg. Haji Dorani, Selangor

Figure f: The current condition of geotube breakwater at Sg. Haji Dorani, Selangor

Figure g: The condition of the geotube breakwater after experiment being done

Figure h: From left, Dr Teh Hee Min (supervisor), Dr. Raja Barizan binti Raja Sulaiman (FRIM), Shadana Gupta and Syukri Saadon. (Collaboration with Forest Research Institute Malaysia, FRIM and Universiti Teknologi PETRONAS, UTP)