WAVE TRANSMISSION, REFLECTION AND ENERGY LOSS OF AN ALTERNATIVELY SUBMERGED GEOTUBE BREAKWATER SUBJECTED TO REGULAR WAVES

by

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Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

(Civil)

SEPTEMBER 2017

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DECLARATION OF DISSERTATION

Title of thesis	Wave Transmission, Reflection and Energy Loss Of An Alternatively Submerged Geotube Breakwater Subjected To Regular Waves

I SATESH VENGADARAMAN ____

hereby declare that the dissertation is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTP or other institutions.

Witnessed by

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ABSTRACT

Over the years, there are quite a number of research and studies has been done towards the cause and effect of shoreline erosion. Some researchers used hard engineering method (conventional) and others followed the soft engineering method (geosynthetic). However not every research that has been conducted leads to success as there are still a lot of gaps that needs to be filled in their research. This study will be conducted to test the effect of wave transmission, reflection and energy loss of an alternatively submerged geotextile tube (geotube) that act as semicircular breakwater when subjected to regular waves. The water when subjected to regular waves, has few hydraulic characteristics such as wave steepness H_i/L, relative wave height H_i/d, and relative submergence, d'/H_i that will be determined in order to achieve the aim at the end of the experiment. This study focus mainly on testing the physical model of geotube against the wave parameters that was mentioned above. Overall performance of all model, it shows that breakwater performed the best during emerged case in terms of wave transmission because it attenuates energy efficiently with $C_T<0.01$. Wave transmission of a model should be optimum to allow some wave energy to pass through the geotube for mangrove survivability. As for reflection, it should be optimum to avoid wave amplification at the seaward. Hence in terms of wave reflection, the submerged case $h/d=0.778$, gives the best value of $C_R<0.40$. The best model for energy dissipation can be developed from crest case $h/d=1.00$ with *the* highest C_L^2 value recorded is 0.9 at $B/L= 0.52$. Upon the result gained, it can be concluded that the reflectivity of the test model is dependent on wave steepness in all condition.

ACKNOWLEDGEMENT

The author would like to express his greatest thankfulness to the supervisor Dr. Teh Hee Min for his support, enthusiasm and constant dedication in guiding the author throughout this research and also to complete his work within the provided time period. He has been constantly aiding the author to handle the project in the most effective way while correcting all the errors and mistake that was done by the author. Every effort from him is very much appreciated.

Secondly, the success of this project would not been possible without their full and endless support. This gratitude extends to all Universiti Teknologi PETRONAS staffs especially the Civil Engineering Department.

A special gratitude also is expressed to the author family members and friends for their moral support. Author is very grateful to have very supportive parents, Vengadaraman and Malliga who have always believed and support the whole journey of FYP 1 and FYP 2.

Last but not least, my indebtedness also will be extended to the friends of mine, Shadana Gupta, Bhinitha and Rathnarupini for all their kindness and guidance during the process of finishing the project. Your contribution is highly appreciate

Thank you.

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NOMENCLATURE

C_R = Wave Reflection Coefficient

C_T = Wave Transmission Coefficient

C_{L^2}= Energy Loss Coefficient

H_i= Incident wave height

H_r= Reflected wave height

H_t= Transmitted wave height

L= Wave Length

d= Still water depth in front of the breakwater

d'= Free Board (the still water level to the crest of the breakwater)

T=Wave Period

L_O=Deepwater Wavelength

E_i= Total incident energy

E_l= Energy dissipated.

CHAPTER 1
INTRODUCTION

1.1 Background of Study

As humans are advancing towards a better future, the one thing that could not be controlled by men is the world climate changes. This vigorous change in climate directly affects all the natural occurrences, mainly on sea waves. How does this climate changes affect the ocean? It's by the constant increase in wave energy which tips to shoreline erosion (Lee et al., 2014). The Economic Planning Unit (1985) once stated that more than 30% of shoreline in Peninsular Malaysia is experiencing critical erosion of shoreline due to monstrous wave energy which results in increasing the impact on shoreline. This issue is being repeating over a decade in a severe manner. Often this issue is proven to be the effect of littoral dynamic and reckless human activities. The loss that human deals from this agenda is divided into two, which is economy and social life because this is correlated with shoreline erosion (Lee et al., 2014). As a remedy to this illness, Ministry of Natural Resources and Environment of Malaysia came up with an indication of planting mangroves in various areas that were affected by this issue such as Sungai Haji Dorani, Selangor.

Studies proves that mangrove swamps do bring out the best solution in reducing coastal erosion and minimizes natural disaster to an acceptable level, but due to men's irresponsible behavior and attitude, this mangrove species is facing its age of extinction. This is where an external aid is needed to promote the growth of mangrove seedlings. Ever since, a lot of creation was done by coastal engineers to overcome this situation (Russell & Michaels, 2012). According to Sulaiman (2004), with presence of mangrove, the wave energy that reaches the shoreline passing through mangrove swamp general low compared to the shoreline which is absence from mangrove swamp. To add to that, these waves also permitting residue estimated materials to stay near shoreline.

For ages, mangrove swamp is known as the natural vegetation against shoreline erosion and also provides strength to soil through its unique root system which promotes dissipation of wave energy, not forgetting its highly productive ecosystem that provides habitable zone to ample of species. Mangrove survivability very much depends in upper tidal zone which is roughly above mean sea level to high water and also the mild sloping coasts which has moderate wave climate (Seng, 2010). He also added that mangrove is the best natural way to aid in flood protection.

The safety measure that was taken by the Ministry of Natural Resources and Environment (NRE) by ordering Forest Research Institute of Malaysia (FRIM) to increase the rehabilitation of mangrove swamp in a very economical and reasonable solution. One of the step took by FRIM was accommodating the planted mangrove seedlings with the aid of wharf. FRIM also evolve three effective and efficient planting methods such as Comp-Pillow, Comp-Mat and Bamboo Encasement Method (BEM). These planting methods was all executed successfully in Sungai Haji Dorani, Selangor. Figure belows is the illustration of mangrove plantation in Sungai Haji Dorani, Selangor.

Figure 1.1: Mangrove plantation at Sungai Haji Dorani, Selangor

As mentioned by Sanford (2009), 97% of direct-use values of mangrove ecosystem is refined. The acceptable distance needed by a mangrove seedling is about 200 meters from any development space to ensure its survivability. On a general view, the sole reason of mangrove plantation failure is due to scanty selection of mangrove species, low quality of seedlings and not forgetting the lack of protection towards monstrous wave action. As a solution to balance the incident waves and ease the coastal erosion at places where mangrove seedlings are present, Geotextile tube is installed to diminish the effect of wave action on these mangrove seedlings. These actions will increase lifespan and survivability of mangrove seedlings till the mangrove is matured enough to survive on own without any external protection. The geotextile tube is simply a tubular shaped tube filled with sand which will be hydraulically pumped in through the filling port. For this research, the semicircular geotextile tube is used mainly. The first world idea of the solid semi-circular breakwater was developed in Japan within the year of 1992 (Zhang, 2005). In spite of the way that geotextile tubes are more affordable and have less environmental effect on the coastal system than traditional types, in the event that they are designed appropriately; it was discovered that now and again shore protection and shoreline stabilization was accomplished with the geotextile tube structure however in different spots the outcomes have been a long way from the normal (Gonzalez et al, 2011).

Compared to other breakwater, semi-circular breakwater provides better version of result. To top it all semi-circular designed breakwater acts better in reducing wave energy impact compared to rectangular shaped breakwater, which is the best when comes to dissipating the wave energy (Lokesha et al., 2015). Since this project is related to an actual site, figure below show the existing geotube structure that was installed in proposed site, without taking any parameters into consideration

Figure 1.2: Semicircular design of geotube breakwater in Sungai Haji Dorani

1.2 Problem Statement

According to Tamin, (2011), with the current depletion of mangrove swamps, due to human factors, the shoreline is being eroded compulsively. This erosion is effecting the environment ecologically in various ways. To overcome this problem, Geosynthetic approach has become one of the most desirable methods used nowadays. The material that is used is called geotube which comes in various size and shape but most commonly tubular. The increase in use of geosynthetic in coastal engineering is developing due to the advancement in their engineering properties and fabrication technique (Oyegbile et al., 2017). The main aim of the research is correlated with the eroded coastline at Sungai Haji Dorani, Selangor, since the presence of bigger diameter of grain size shell hash along the coast which proves that the shoreline is still exposed to high wave and current action. Addition to that, this high wave action will certainly affect the survivability of mangrove plantation in the area that was proposed by Forest Research Institute Malaysia (FRIM).

Sungai Haji Dorani, Selangor was choosen by the FRIM to be their research site for mangrove plantation. Bernam River and Perak River supplies the primary source of sediment (Stanley & Lewis, 2011). Nonetheless, due to unavailability of the coastal forest, the beaches fail to trap the sediment permanently. Under normal condition, the conventional planting technique will be used to plant the mangrove along the sheltered coastlines. Nevertheless, the impact of strong wave actions exposed towards coastal areas causes the technique to be a failure (Barizan, et al., 2008). Generally, if the sites 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), the mangroves will most likely unable to survive (Stanley and Lewis, 2011). Therefore, it is crucial to understand how these environmental factors such as wave and current impacts the mangrove ecosystem and their growth rate.

In the past, Alvares et al. (2007) studied the wave parameter, relative submergence and also shape of the breakwater as the factor that effect the wave attenuation performance towards his geotextile tube. In this research, the effect of wave transmission, reflection and energy loss of a geotube breakwater subjected to regular waves was investigated by using physical modelling. By far there is no research done on the effect of wave transmission, reflection and energy loss of a geotube breakwater.

1.3 Objective

The study purpose is to explore the effects of wave transmission, reflection and energy loss of an alternatively submerged geotextile tube when subjected to regular waves. To accomplish the aim, to determine the hydraulic characteristics of modular of alternatively submerged geotube with respect to:

a) Wave steepness H_i/L,
b) Relative wave height H_i/d,
c) Relative submergence, d'/H_i

1.4 Scope of Study

The scopes of the current study is listed below:

a) The research study is connected to a certain address, there is real application of geotextile tube as breakwater at Sungai Haji Dorani, Selangor, Malaysia.
b) Throughout the study, there were some parameters considered such as wave steepness H_i/L, relative wave height (H_i/d,) and also relative submergence (d'/H_i,).
c) There are few effect of physical properties of the geotextile tube, such as UV radiation, current, tensile strength and sediment transport been neglected because is it beyond the scope of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discuss about the concept of semicircular breakwaters, and their principle and application in protecting shoreline against wave transition and erosion. A semicircular model, known as geotextile tube is the emphasis of this study and the design parameters will be discussed thoroughly throughout this paper.

2.2 Mangroves Plantation

The emphasis from all countries on the coastal restoration, especially related to mangrove plantation has been a key highlight due to the occurrence of natural disaster; tsunami. One of the example can be observed from the actions of the Malaysian Government initiating on a thorough coastal mangrove plantation as seen in Sungai Haji Dorani, Selangor. The purpose of this act is to establish an effective and efficient defense to minimize the effects of any natural disaster related to coastal (Alongi, 2008). The protective functions of mangrove ecosystem is widely recognized worldwide. (Alongi, 2008; Danielsen et al., 2005; Kathiresan et al., 2005; Othman, 1994; Sanford, 2009; Tanaka, 2009). It is the home for plants that grow in coastal regions forming the boundary between the land and the sea (Akbar, Sartohadi, Djohan, & Ritohardoyo, 2017).One of the many techniques available in preventing mangrove loss and soil erosion is through mangrove plantation (Van Cuong, Brown, To, & Hockings, 2015).Over the years, the success rate of mangrove plantation decreases due to the lack of protection from the wave action and seasonal sediment movement (Van Cuong et al., 2015).

Adaptive capacity to protect coastal areas against erosion and flooding due to sea condition (sea level rise, wave action or storm surge) is obtain by strong, stable and healthy mangrove ecosystem. As a matter of fact it also enhances the climate change mitigation through the acting of carbon sink (Duarte et al., 2013; Raghavendra, 2009). Mangroves does not always provide a stand-alone solution; they may need to be combined with other risk reduction measures to achieve a desired level of protection. If they are integrated appropriately, mangroves can contribute to risk reduction in almost every coastal setting, ranging from rural to urban and from natural to heavily degraded landscapes (Narayan. s et al, 2016). The content within the many articles and journals published in regards towards mangrove plantation can be correlated towards the project that the author worked on. However, a plus point with this particular project is that the application utilizes a real study area in Sungai Haji Dorani, Selangor .This site, consist of application of geotube and through the conduction of this experiment, it will enable the author to provide a more efficient and improved model. The types of mangrove related to this site are Avicennia Alba, Rhizophora mucronata, and Rhizophora apiculate (Zhila et al, 2014). In short mangroves can indeed reduce the risk of a large number of hazards and act a natural wave dissipater once it is fully grown.

2.3 Geosynthetic

Geosynthetic products are tested in many sort of maritime structures. The usage of geosynthetic product could lead to minimum construction costs. The cost benefit of a structure increases with an increase in the isolation of the construction site. Local material and low-skilled labor can be used, rather than transporting all the required construction materials and labor to the construction site. Compared to traditional construction methods, the application of geotextile sand filled ingredient may add considerable operational advantages to the execution of marine studies and may provide attractive financial chances. The main advantages of geotextile systems when compared with traditional methods is decrease in work, use of local material, equipment and low-skilled labor, and unrequired heavy construction machinery (Ergin et al. 2003). Using geotextile tubes in conjunction with dredging operations has the advantage of reduced environmental shock in the aquatic habitat surrounding the site. Disposing of dredged material by hydraulically filling geotextile electron tube greatly reduces the turbines, siltation and migration of fines to the surrounding surface area and impacts on the environment (Fowler et al. 2002).

Rock and concrete are well known for their use as coastal defense structure (dikes and seawalls).Although the rate of success of this structure is satisfactory, the recent experience has shown a sharp decline in the availability of high quality materials leading to increasing cost of construction. In today's world, researchers from all around the world has moved their interest to geosynthetic when comes to stabilization of soil and protection of coastal areas due to the success rate of geosynthetic in its application. There are various types of construction material that can be used for coastal protection structure ranging from conventional (natural rocks and concrete blocks) until the leading edge of innovation outcomes such as geotextile and gabion. Among the describe materials, geotextile has been the most popular material protection structure (Sulaiman, Bachtiar, Taufiq, & Hermanto, 2015). Oyegbile et al., (2017) also mentioned that geotextile is now a substitute material for natural rocks, and carries a high standard in protecting coastal from shore erosion.

2.4 Geotextile Tube (Geotube)

Geotube is basically a tube filled with natural sedimentary materials such as rocks and sand that act as a breakwater to protect the shoreline (Lin et al., 2011). Stability Hydration and cementation of the volume after the filling helps these tubes gain stability and resists external loads as a retaining structure in and out of water body (Stanley & Lewis, 2009). As mentioned by (Sulaiman et al., 2015) , Geotextile tube leads to several advantages such as:

a) The availability of geotextile material such as geotubes or geotextile sand container (GSC) that comes in various configurations and size in the market.
b) Its light weighted nature increases the mobilization of the structure.
c) Provides flexible response to wave action.
d) Uses sand (natural sediment) as a filler material
e) No expertise is needed when installation needs to be done but local power.

In the growth of coastal vegetation, this structure not does only help in sedimentation and soil enrichment but also controlling the wave action. Within an enclosed area by the geotubes, littoral transport leading to sedimentation will slow down due to reduce in the wave energy, this occurs due to intense tidal events (Pilarczyk, 2006).The model that has been developed for this study is made out of geotextile (geotube) material and it is designed in tubular form.

2.5 Semicircular Breakwater

Breakwater is known as a barrier built out into a body of water to reduce the intensity of wave action hence protect coast from major erosion (Jiang, Zou, & Zhang, 2017). Erosion can be overcome effectively in the presence of breakwater due to rapid sedimentation on shoreline and other contribution of breakwater such as widening the shore seaward with the formation of salient and tombolo (Sulaiman et al., 2015). Breakwater minimizes wave speed and its impact towards the shoreline (Pilarczyk, 2006).There are various types of breakwater such as cassion, semicircular, detached, attached, head land, near shore, low and high crested and rubble mound breakwaters that has been studied and tested over the years for various purposes with different parameters by (Akbar et al., 2017; Alvarez, Rubio, & Ricalde, 2007; Ji, Dong, Luo, & Guedes Soares, 2017; Jiang et al., 2017; Koley & Sahoo, 2017). In this particular study, an alternatively submerged, semicircular breakwater will be studied against few wave parameters that will be discussed throughout this paper. There are many advantages to this semicircular breakwater. Some of it includes:

a) There is no overturning moment induced by the wave pressure because the wave pressure on the semicircular surface passes through the center of the circle.
b) The stability of a semicircular breakwater is higher because the lateral wave acting on it is smaller than on a vertical breakwater with the similar height. This way the construction cost can be reduced.
c) The hollow structure and vertical force acting on the foundation soil of a semicircular breakwater is small and distributed uniformly thus serve as an advantage to the soft soil foundation.
d) It has an easy installation and setup as it has to be placed on a rubble foundation for the structure to work. This type of structure is very much suitable for the rough sea.(Yuan & Tao, 2003) also commented that it has an appealing structure.

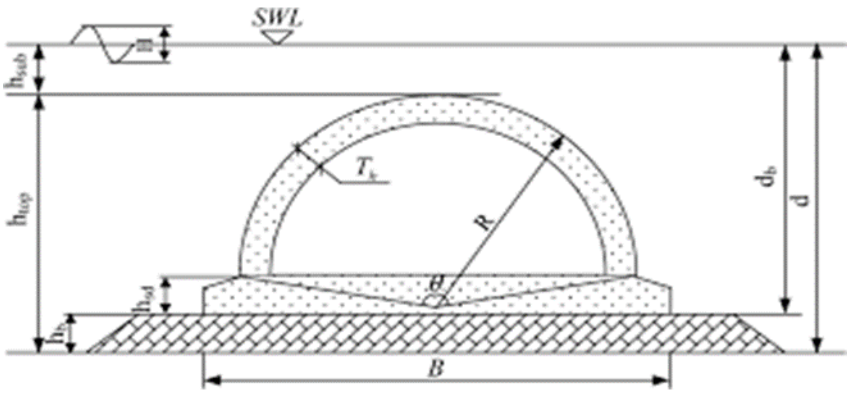

Figure 2.1: Semicircular Breakwater

2.6 Breakwater at Different Submergence

(Yuan & Tao, 2003), explained that there is three conditions of hydrodynamic state for semicircular structure breakwater which includes submerged, alternatively submerged and emerged .The are three hydrodynamic states for the semicircular breakwater that is shown in figure below

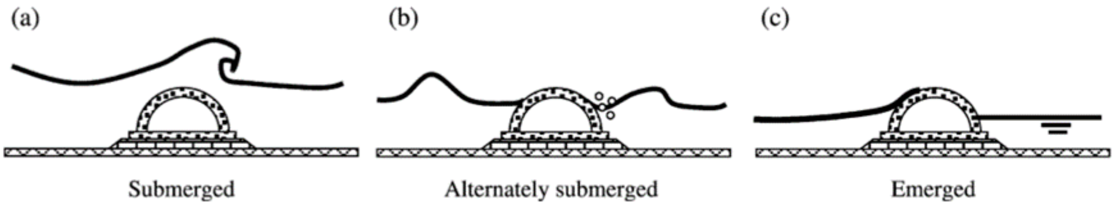

Figure 2.2: Typical hydrodynamic statuses for semicircular breakwaters

In relating to the figure above, when a structure is submerged, the waves becomes propagated very close to the structure and in some irregular incidents, there is possibilities of wave breaking near the structure. As for alternatively submerged (crest) or emerged cases, the waves are also studied very near to the structure. When the top of the structure is completely emerged as in figure (c), the surface of structure needs to be examined as the wave will run up and down along the surface. In relation according to Alvarez et al., (2007), the dynamic level on the shoreline can be controlled to an optimized level by controlling the wave-breaking process which correlates to reducing the incident value. This reduction of incident value can be done using a submerged geotube.

2.7 Mechanical Properties Relative to Hydraulic and Structural Stability

Alvarez et al., (2007) mentioned that environmental aspects needs to be taken seriously for any type of beach restoration. The project introduced especially for beaches needs to be environmentally friendly and needs to consider all the negative impacts that can be implicated on the beach quoted by Milanian et al., (2017).The stability, efficiency and economic are vital considerations that Milanian et al., (2017).needs to be focused on to provide an accurate and reliable design. According to Milanian et al., (2017), sometimes these consideration are overlooked due to high cost of design and construction for the protective structure. One of the ways to overcome this is by introducing geotextile tubes. Geotextile tube is made into consideration because there are cost effective and have less environment effect on the coastal system compared to the conventional methods use nowadays. According to Oyegbile et al., (2017), there was stabilization achieved with the use of geotextile tube but not in every research.

There were some research that did not obtain wanted results with the use of geotextile tubes. Milanian et al., (2017) mentioned that if the irregularity in arrangement of armor pieces is increased, the wave-run up reduces significantly. According to (Mustapa et al., 2017), the hydraulic stability of a flat geotube structure has no specific derivations of formulae and theory which is why there is no certain references to prove the reason on why the geotubes are not stable. Not only that, it is discovered that the horizontal and vertical forces may also contribute to the stability of the structure. Oyegbile et al., (2017), stated that there are models made from geosynthetic material and have made it to successful application stages and proved to be very efficient while other structures still lack in design formulas and specifications. This is why a continual effort in experimental procedures is needed to understand this process better in order to prefer the optimization parameters such as the hydraulic performances, stability and modes of failure of these structures. There are several causes for the structural failure of geotextile tube structures.

The key failure mechanisms are:

a) sliding
b) overturning
c) overall stability (slip circle)
d) bearing capacity failure in the subsoil
e) movement of the elements
f) internal migration of sand in the tube, resulting in large deformations
g) scour in front of the structure
h) geotextile skin rupture

Aspects that influence the stability of the structure are:

a) size of the element
b) location of the element in the structure
c) friction between the elements
d) layout of the structure
e) slopes of the structure
f) overall stability of the structure
g) scour in front of the structure

The stability characteristics depend on:

a) wave-induced forces on the tubes, which are determined by:
   - wave height and currents
   - angle under which the waves and current reach the tubes

b) wave induced pressure differences in the tube, which are influenced by:
   - internal movement of sand in the tubes
   - filling percentage
   - sand characteristics
   - tube dimensions

c) other processes leading to the deformations and displacement of the tubes are influenced by:
   - fixation between the tubes
   - friction coefficient between the tubes

Among the many varying aspects of stability, the instability of the geotextile tube during filling is one that is often overlooked. This aspect is supposedly be taken into account for due to its significances. The geotextile tube should be fixed horizontally up until the filling is complete because it does not have any torsion stiffness therefore unable to provide any resistance to currents or wave action (CUR, 2004).

2.8 Wave Transmittance Properties

As mentioned by Pilarczyk, (2003), ratio of the height directly shoreward of the breakwater to the height directly seaward of the breakwater is knowns as the transmission coefficient. Transmission coefficient has range $0<K<1$, where value of zero indicates no transmission (high impermeable), and the value of 1 indicates complete transmission (no breakwater). Factors that control wave transmission are as such:

a) crest height and width
b) structure slope
c) core and armour material (permeability and roughness)
d) tidal and design level
e) wave height and period

The higher the wave transmission increase, the greater the diffraction effect decrease, thus the size of salient is decrease through direct attack by the transmitted waves and weakening the diffraction-current moving sediment into shadow zone (Hanson et al., 1991). The transmitted wave height along the transmitted wave spectrum was analyzed in order to examine the wave transmittance properties of a geotextile tube. There are some parameters affected considering the interference of the geotube structure. For an instance, the wave transmitted ratio and transmitted wave height will significantly decrease as wave height increases (Shin et al, 2007).

2.9 Wave Energy Dissipation

Wave energy dissipation is one of the main aims of geotube. This can occur due to wave breaking or flow percolation. Since there is three types of condition that the geotube can go through, each types of breaking explains differently about the wave breaking. The degree of submergence is the ratio of the water depth to the height of the structure. The primary function of a breakwater is to minimize the wave energy in its lee side. According to the (U.S. Army Corps of Engineers, 1984), the wave energy that travel past a breakwater, either by passing through and/or by overtopping the structure is defined as “wave transmission”. There are two means in which the wave energy is attenuated in the lee of the breakwater. One is by the structure such as by friction, wave breaking and armour unit movement and another is reflected back in the form reflected wave energy. The measurement of the amount of wave energy that is transmitted past the structure is defined as the effectiveness of a breakwater in attenuating wave energy. Therefore, the greater the wave transmission coefficient, the lesser the wave attenuation.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Overall there are few important steps that will be discussed throughout chapter 3, which starts with experimental setup for three series, as for 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.

3.2 Test Model

According to the semicircular breakwater model produced by Zhang et al. (2005), the geometrical details of the geotube breakwater were determined for the sole purpose of hydrodynamic performance. The geotube breakwater model has a width, length and height of 0.5m, 1.8m, and 0.35m that weighs approximately 900kg as illustrated in the figures below. For this research the scaling ratio utilize is the Froude scaling of 1:20 respectively The geotubes are filled similar volume of sand with similar mean diameter that is of 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).

Figure 3.1: Front view of the geotube

Figure 3.2: side view of the geotube

3.3 Laboratory Equipment and Instruments

3.3.1 Wave Basin

The wave basin with a length, width and height of 20m, 1.7m and 3m high has walls made out of reinforced concrete. Addition to that, there are several flexi glass fixed in between these concrete walls shown in the figures below. The function of this flexi glass is to deliver full visibility of the test structure and close monitoring of the experiments.

Figure 3.3: Wave Basin

3.3.2 Wave Paddle

Random or regular wave can be produced from the wave paddle equipment by generation of waves of distinct physical characteristic. In relation to that, this wave paddle is connected to a computer system that controls the manual wave height and speed of water which is installed at one end of the wave basin. A total of three paddles, fabricated by the Edinburgh Design Ltd., United Kingdom have been used throughout conducting this experiment. Figure below portrays the image of the wave paddle.

Figure 3.4: Wave Paddle

3.3.3 Wave Absorber

Wave absorber is located at the opposite end of the wave paddle and it serves the purpose of absorbing remaining wave energy from the incident waves generated in the basin. This is to avoid the reflected wave from interfering with the ongoing experiment. Besides that, the wave absorber has a standard requirement of absorbing up to 90% energy from the incident waves. The figure below an actual wave absorber.

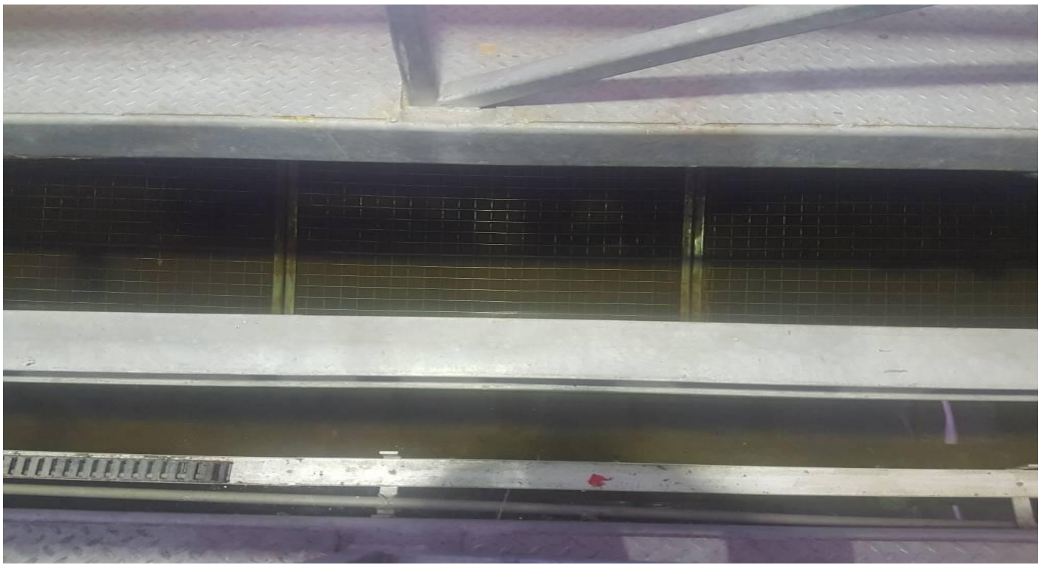

Figure 3.5: Wave Absorber

3.3.4 Wave Probes

Wave probes is the suitable equipment required to measure water level fluctuation in a test facility. For this experiment, there were six wave probes used with different intervals. Three wave probes are placed before the wave paddle that serves the purpose of measuring the wave reflection and the remaining wave probes are placed before the wave absorber to measure the wave transmission. Energy loss can then be calculated by analyzing the result of all six wave probes. In order to design the best reflector, the three point method (Mansard & Funke, 1980) should be utilize to decompose the wave signals. Before conducting the experiment, all the probes need to be sensitively calibrated in still water to obtain the best data.

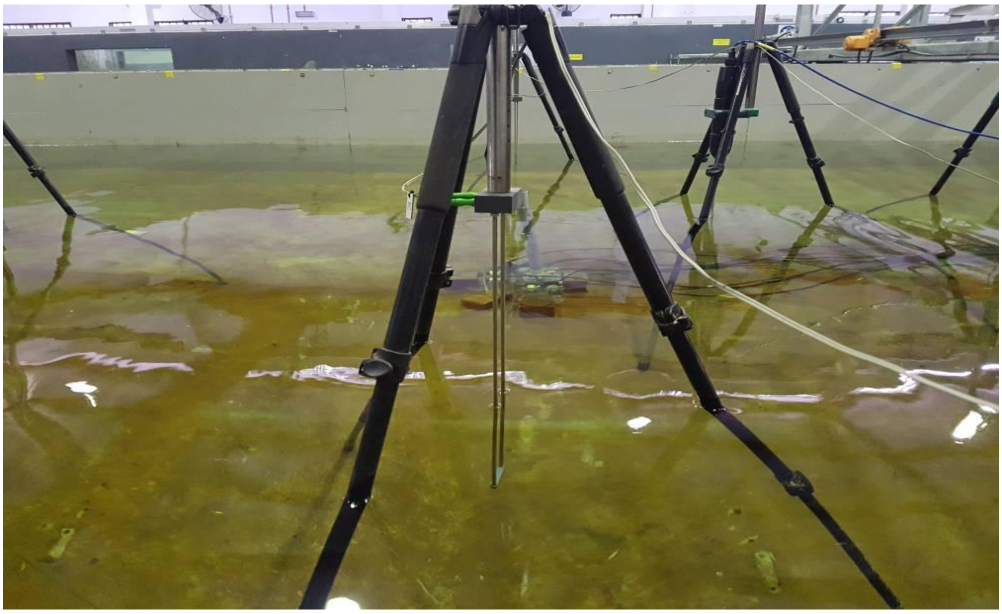

Figure 3.6: Wave Probes

3.4 Test Condition

In order to investigate the hydrodynamic characteristics of the geotube breakwater model, a unidirectional wave of different steepness is adopted. The JONSWAP spectrum with a peak enhancement factor of 3.3 defines the inconsistency of the wave produces by the wave generating facility. Below are the list of factors affecting the wave transmission of a breakwater:

a) wave steepness *Hi/L*,

b) relative wave height *Hi/d*,

c) relative submergence, *d'/Hi*,

Figure below indicates the test condition for this experiment.

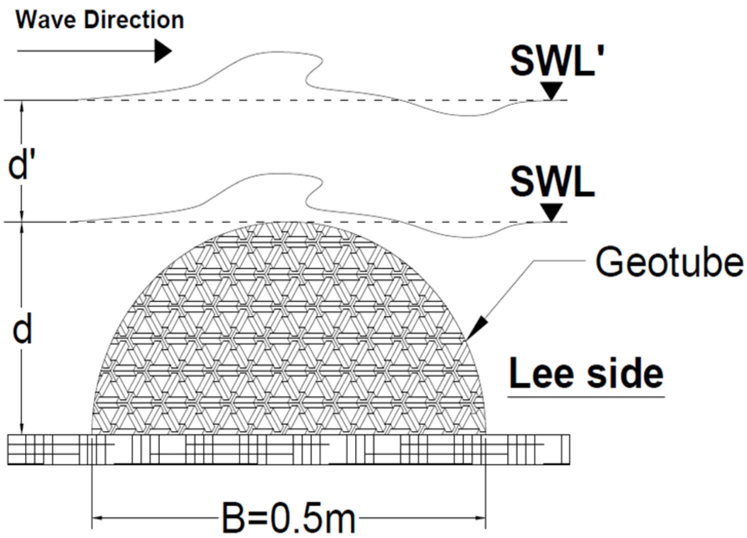

Figure 3.7: Cross section of test model

3.5 Experiment Setup

A 20m long, 10m wide and a 1m deep wave basin is used in this experiment which is based at the Offshore Engineering Laboratory, Universiti Teknologi PETRONAS. Next partitions are used to modify the wave basin into wave flume condition. Located at one side of the basin, three independent wave paddles is composed by an active type wave maker that generates regular, random, oblique and multidirectional waves according to the type of research that is going on.

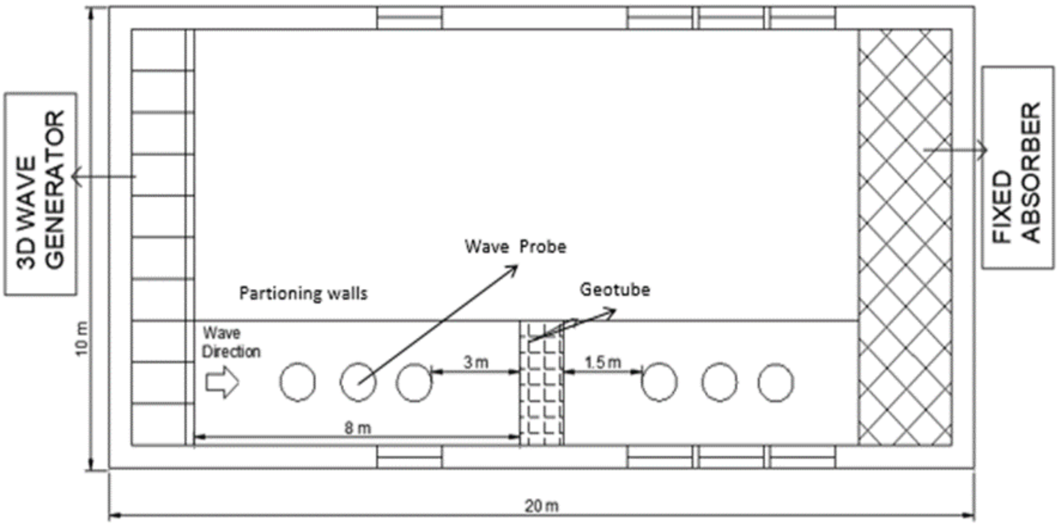

Figure 3.8: Schematic diagram of UTP wave basin

3.6 Experimental Procedures and Setup

First and foremost, calibration needs to be done as it is the most crucial part of the experiment and calibration has to be done on a daily basis as the conductivity of the probes is highly influenced by the property of water and the surrounding temperature. Since the wave probes are very sensitive to surrounding temperature, proper calibration is sometimes very hard and needs a lot of time to be done alone, as one must be able to get in and out of the water tank several times before the calibration is completely done. Significant change in water level must be restricted as it will surely give an unwanted impact to the reading. Hence, water level must be checked and calibration is suggested to be done before and after each test is complete. The most crucial part that one needs to pay attention is that after each test, there should be interval of 5 to 10 minutes to allow the water to calm down. By doing this, the data that one receive will be more accurate and less error. The water depth that are tested throughout this experiments are 0.25m, 0.35m and 0.45m respectively. For each water depths, there are total of 13 wave periods ranging from 0.8s up to 2.0s was used. The wave period mentioned had been repeated for three different wave steepness which are 0.02, 0.04 and 0.06. Due to the scaling down of test parameters in the water basin, small percentage of error will be affecting the result. So, comparison between the set and gain values in the system should be determined in order to overcome the error later on. This set and gain value test can be obtained by running 'Empty tank test' using the produced test matrix. Empty tank test is basically running the test without any geotextile model in the tank and the result will be recorded to calculate the percentage of error from the graph that will be produced with the results. A set of 'Go Pro' camera is installed at the side of the transparent glass in order to measure the wave height generated by the wave maker and to ensure it is accurate and according to the produced test matrix.

Figure 3.9: Manual recording using Go-Pro

3.7 Test Matrix

Tables below shows the simplified and the original test matrix. The details that the table carry is the depth of water that the geotube will be tested, the wave steepness, wave periods, and also the models dimension.

Table 3.1: Simplified Test Matrix

Condition		Model
Water depths (m)		0.25 0.35 0.45
Wave Steepness		0.02 0.04 0.06
Wave periods (s)		0.8-2.0
Model Dimensions (mm)	Width	500
	Length	1800
	Height	350

Table 3.2: Test Series I with (d=0.25)

Test	D(m)	Ths(s)	Frequency	L(m)	Hi/L
1	0.25	0.8	1.250	0.93242	
2	0.25	0.9	1.111	1.12008	
3	0.25	1	1.000	1.30316	
4	0.25	1.1	0.909	1.48333	0.02
5	0.25	1.2	0.833	1.65907	0.04
6	0.25	1.3	0.769	1.83283	0.06
7	0.25	1.4	0.714	2.00284	
8	0.25	1.5	0.667	2.17258	
9	0.25	1.6	0.625	2.33931	
10	0.25	1.7	0.588	2.50691	
11	0.25	1.8	0.556	2.67182	
12	0.25	1.9	0.526	2.83628	
13	0.25	2	0.500	2.99976	

Table 3.3: Test Series II with (d=0.35)

Test	D(m)	Ths(s)	Frequency	L(m)	Hi/L
1	0.35	0.8	1.250	0.97795	
2	0.35	0.9	1.111	1.20084	
3	0.35	1	1.000	1.42451	
4	0.35	1.1	0.909	1.64477	0.02
5	0.35	1.2	0.833	1.86089	0.04
6	0.35	1.3	0.769	2.07320	0.06
7	0.35	1.4	0.714	2.28205	
8	0.35	1.5	0.667	2.48758	
9	0.35	1.6	0.625	2.69154	
10	0.35	1.7	0.588	2.89173	
11	0.35	1.8	0.556	3.09734	
12	0.35	1.9	0.526	3.28891	
13	0.35	2	0.500	3.48745	

Table 3.4: Test Series III with (d=0.45)

Test	D(m)	Ths(s)	Frequency	L(m)	Hi/L
1	0.45	0.8	1.250	0.89865	
2	0.45	0.9	1.111	1.22340	
3	0.45	1	1.000	1.46330	
4	0.45	1.1	0.909	1.70124	0.02
5	0.45	1.2	0.833	1.93611	0.04
6	0.45	1.3	0.769	2.16589	0.06
7	0.45	1.4	0.714	2.39262	
8	0.45	1.5	0.667	2.61570	
9	0.45	1.6	0.625	2.83488	
10	0.45	1.7	0.588	3.05318	
11	0.45	1.8	0.556	3.27064	
12	0.45	1.9	0.526	3.48129	
13	0.45	2	0.500	3.88333	

3.8 Study plan

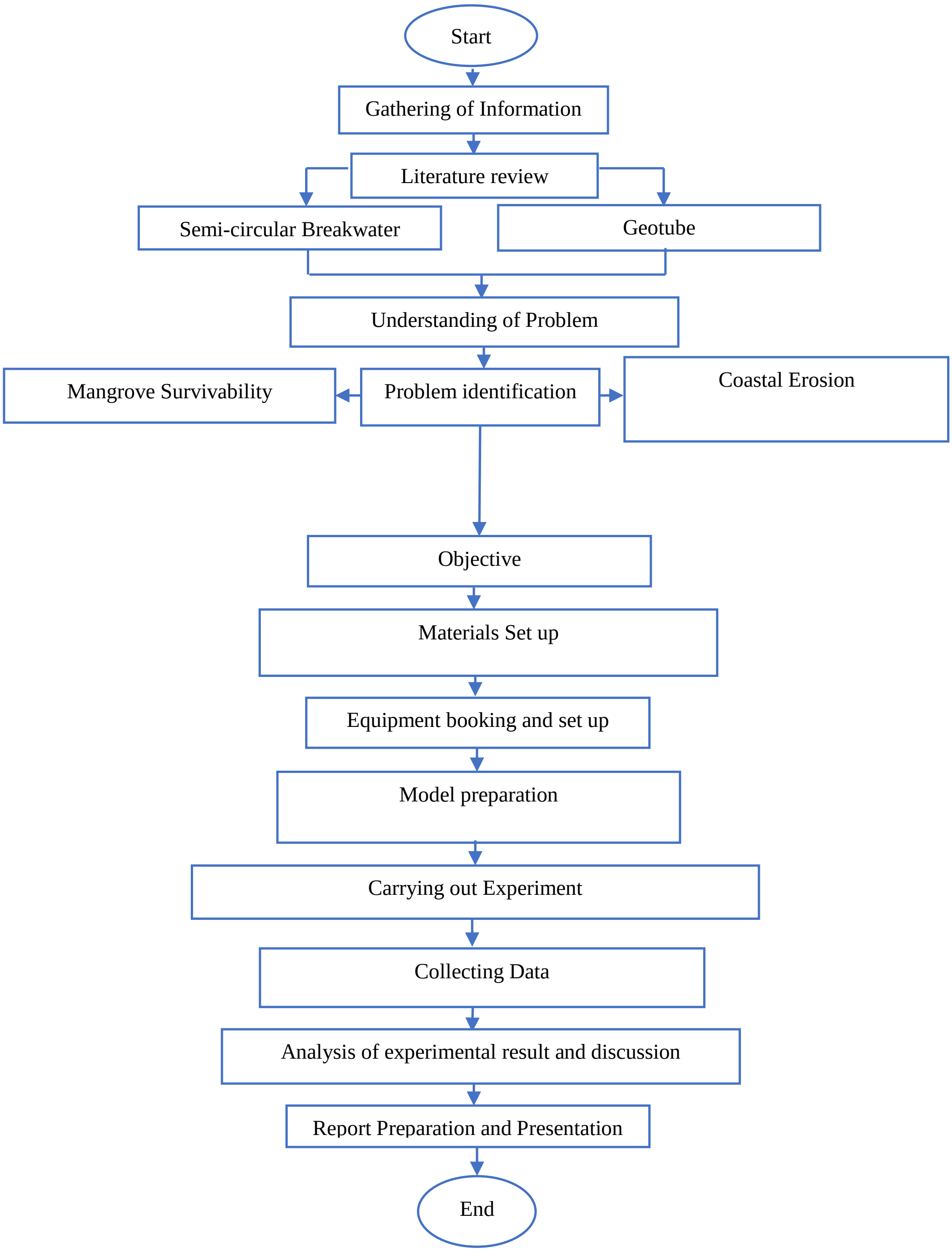

Figure 3.10: Process Flow chart of the Project

3.9 Project Timeline and Key milestone

Table 3.5: FYP II project Key milestone

No	Project Work	Week													
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	Preliminary Research Work														
2	Extended Proposal Submission														
3	Proposal Defense														
4	Project Work Continuation														
5	Final Report Submission														

Table 3.6: FYP II project Key Timeline

No	Activity	Complete in
1	Literature review on the preliminary research work	Week 2
2	Literature review on semicircular breakwater and impact of wave to shoreline	Week 3 – Week 5
3	Preparation of Extended Proposal	Week 6
4	External Proposal Submission	Week 7
5	Apparatus and Equipment Preparation	Week 9
6	Practice of Experimental Set Up	Week 10
7	Project Work Continuation	Week 10 - 12
8	Drafting of final report	Week 13
9	Submission of completed final report	Week 14

CHAPTER 4

RESULTS & DISCUSSION

4.1 Introduction

This chapter discuss about the results that was obtained from the proposed experiment. All the graph that will be shown in this chapter were discussed accordingly. The difference between all the test conditions is the water depth (*d=0.25m, 0.35m, 0.45m*) which varies for each condition (*emerged, crest and submerged*). The experiment was carried out according to the prepared test matrix and the results are presented according to wave steepness, (*Hi/L)* of 0.02, 0.04 and 0.06.

4.2 Wave Kinematics

4.2.1 Wavelength

The water depth,d that is being tested on the geotube varies from 0.25, 0.35 and 0.45 and the wave period, were in the range of 0.8s to 2.0s.To determine the wavelength,L it is crucial to calculate the deep-water wavelength, L_o by the aid of the equation below

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

Where;

g = gravitational acceleration (m/s2).

Firstly, after L_o is calculated, d/L_o was referred through the wave table from shore protection manual and d/L_o can be obtained through interpolation. Determining the wave classification is also a plays a role in the experiment, hence the wave type used is transitional wave as it is made according to the magnitude of *d/L* where it satisfies the properties $1/25<d/L<1/2$.

4.3 Calibration Factor Graph

Calibration is done prior to the experiment to obtain the factor of error that will be produced by the wave maker, this leads to achieving a much reliable wave height throughout the experiment. All together 13 trend lines is been shown in the graph below as example and each line represents each wave period starting from 0.8s to 2.0s. This trend aids in producing a linear graph between set and gain value which will be used to calculate the error later on, if need be.

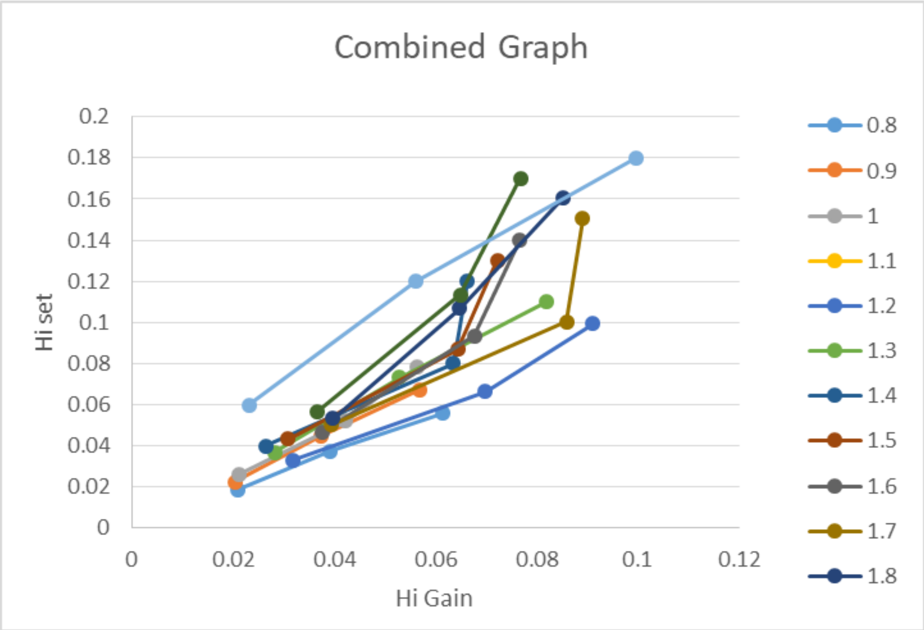

Figure 4.1: Graph of Hi set vs Hi gain in 0.25m water depth for 13 wave period

4.4 Hydraulics Performance of Geotube

As discussed before the primary purpose of a breakwater is to reduce the wave energy in its lee. The term “wave transmission” is used in reference to the wave energy that does travel past a breakwater, either by passing through and/or by overtopping the structure (U.S. Army Corps of Engineers, 1984). The wave energy that is attenuated in the lee of the breakwater is either dissipated by the structure (such as by friction, wave breaking, or reflected back as reflected wave energy.

The effectiveness of a breakwater in attenuating wave energy can be measured by the amount of wave energy that is transmitted past the structure. The greater the wave transmission coefficient, the less the wave attenuation. Wave transmission is quantified by the use of the wave transmission coefficient.

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

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^2 can be expressed as:

$$C_T^2 + C_R^2 + C_L^2 = 1$$

Formula for C_R is:

$$C_R = \frac{H_r}{H_i}$$

Value for C_L^2 can be obtained by:

$$C_L^2 = 1 - C_T^2 - C_R^2 = 1$$

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

$$C_L{}^2 = \frac{EL}{Ei}$$

Where ***Ei*** is the total incident energy and ***El*** is energy dissipated.

4.5 Wave Transmission

There are three different cases that will be discussed based on the graph which includes the geotube being emerged, submerged and at the crest cases. A range of wave period is exposed towards the breakwater, giving relative wavelength, *B/L* from 0.17 to 0.54 and wave steepness *Hi/L*= 0.02, 0.04 and 0.06. Generally, if the depth of water, *d* is greater than half of the wavelength, *L*, it causes the production of short wave whereas if the depth of water, *d* is lesser than half of the wavelength, *L*, it produces long waves. Long waves overtop the geotube easily compared to short waves. The higher the wave steepness, the better the wave attenuation. Overtopped waves causes wave transmission.

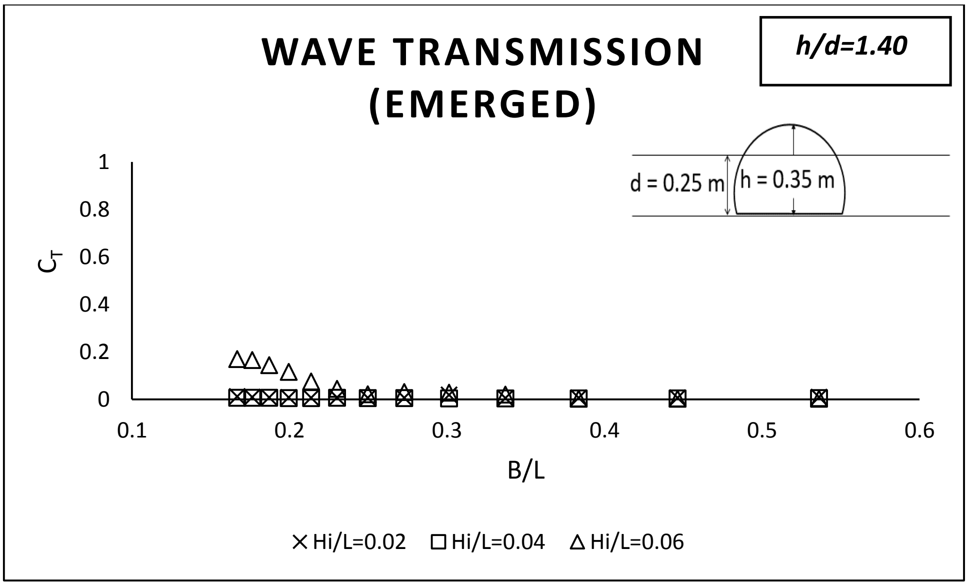

Figure 4.2: Wave transmission coefficient, h/d=1.40

Figure 4.2 shows wave transmission coefficients of the geotube breakwater in emerged *(h/d = 1.40)* case. It is obvious that *CT* of *Hi/L*= 0.02, 0.04 and 0.06 decreases with increasing *B/L* .Apparently the breakwater attenuates more wave energy when exposed to low wave steepness. The relative wavelength was achieved when the geotube was exposed to a range of wave period. The geotube breakwater is capable of reducing the incident wave, when exposed to larger range of *B/L.* A new series of reduced wave height produced from the transmitted waves reaching the lee side of the breakwater. The model performs the best in shorter wave condition. It can be seen that H_i/L=0.04 produces the lowest C_T value *(CT<0.01)* compared to other wave steepness.

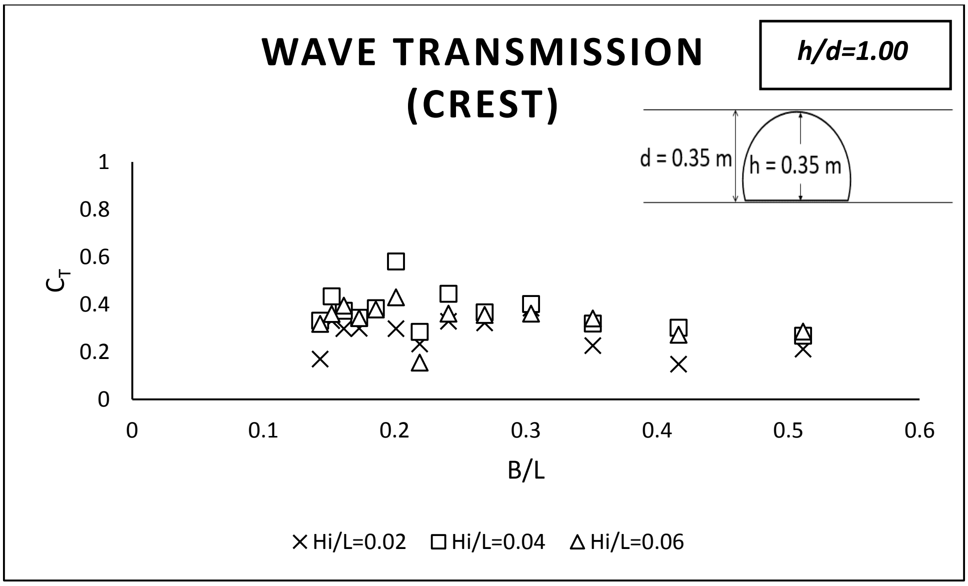

Figure 4.3: Wave transmission coefficient, h/d=1.00

Figure 4.3 shows wave transmission coefficients of the geotube breakwater in crest *(h/d = 1.00)* case. Upon observing the graph portrayed, partial effect of bragging is visible. Compared to all three-wave steepness, $H_i/L=0.02$ produces the lowest wave transmission resulting in the best performance of the hydraulic system with *(h/d = 1.00)* case.

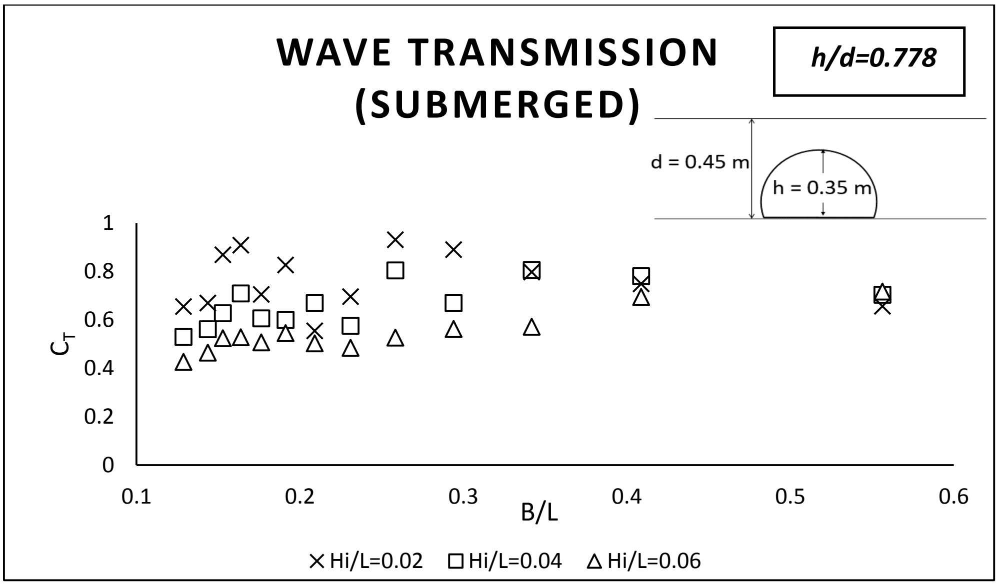

Figure 4.4: Wave transmission coefficient h/d=0.778

Figure 4.4 shows wave transmission coefficients of the geotube breakwater in crest *(h/d = 0.778)* case. Upon observing the graph portrayed, partial effect of bragging is visible. Compared to all three-wave steepness, $H_i/L=0.06$ produces the lowest wave transmission throughout the 13 wave periods resulting in the best hydraulic performance for this *(h/d = 0.778)* case.

To conclude on wave transmission, when comparing the three conditions (emerged, crest, and submerged), the outcome illustrates that the best model for wave attenuation was recorded in the emerged condition. To add to that, this model can best be designed from *(B/L>0.2).*

4.6 Wave Reflection

There are three different cases that will be discussed based on the graph of emerged, submerged and at the crest case of the geotube. A range of wave period was exposed towards the breakwater, giving relative wavelength, *B/L* from *0.17* to *0.54* and wave steepness *Hi/L= 0.02, 0.04 and 0.06*. Generally, high wave steepness produces shorter waves that will result in two outcomes which are higher wave reflection and a higher wave height. On the other hand, low wave steepness produces longer waves. Hence making the waves to overtop easily when it hits the geotube as compared to short waves. This condition causes lower wave reflection. To summarize, the best model that can be produced is the shorter wave reflection condition because high wave reflection will cause wave amplification at the seaward.

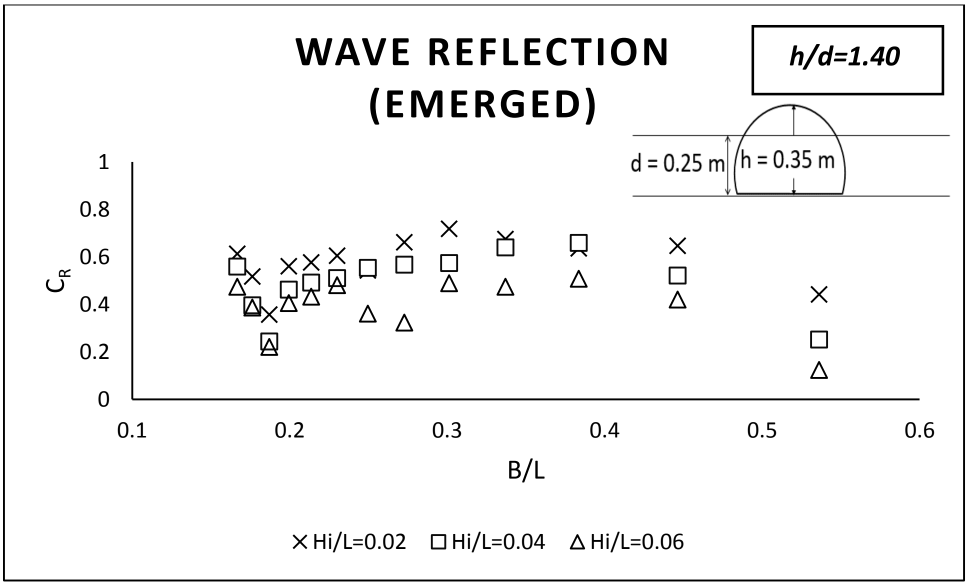

Figure 4.5: Wave reflection coefficient h/d=1.40

In *h/d=1.40*, lower C_R value is recorded in $H_i/L=0.06$. This happens due to the production of long waves, which will result in the waves to overtop frequently. Henceforth causing it to reflect lesser wave energy as compared to other steepness in this condition; minimum C_R is found at *B/L = 0.19*. Based on the outcome of this experiment, we can observe that the C_R is dependent upon wave steepness. The maximum C_R recorded is approximately at *B/L = 0.55*. In this case the best wave reflector can be produced based on $H_i/L=0.02$, because it has the highest C_R value, which is 0.75 when *B/L=0.3*.

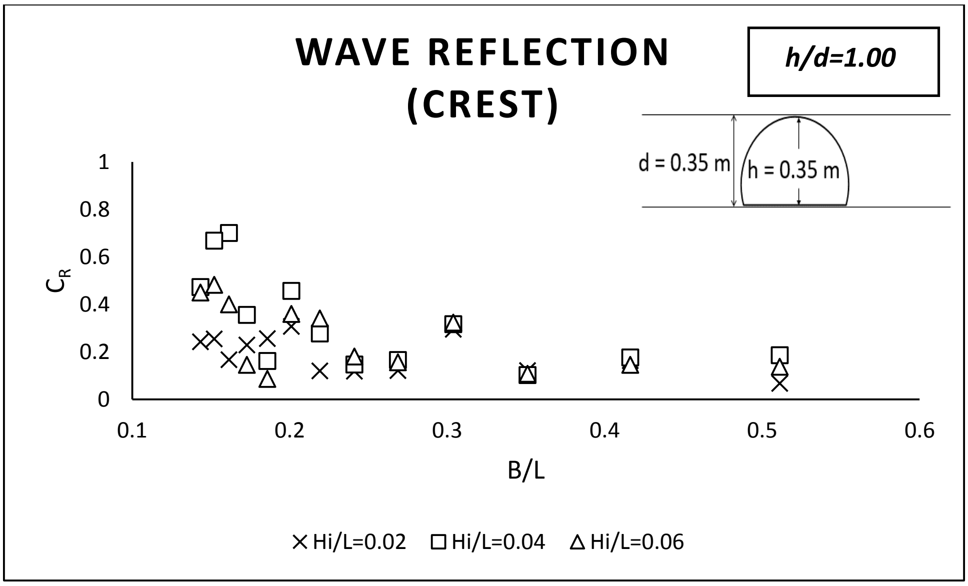

Figure 4.6: Wave reflection coefficient h/d=1.00

In *h/d=1.00* case, a lower series of C_R value is recorded in $H_i/L=0.02$. As can be seen from the graph above, bragging effect is noticeable throughout the series. This happens due to the production of long waves that enables the wave to overtop easily. Henceforth causing it to reflect lesser wave energy as compared to other steepness.

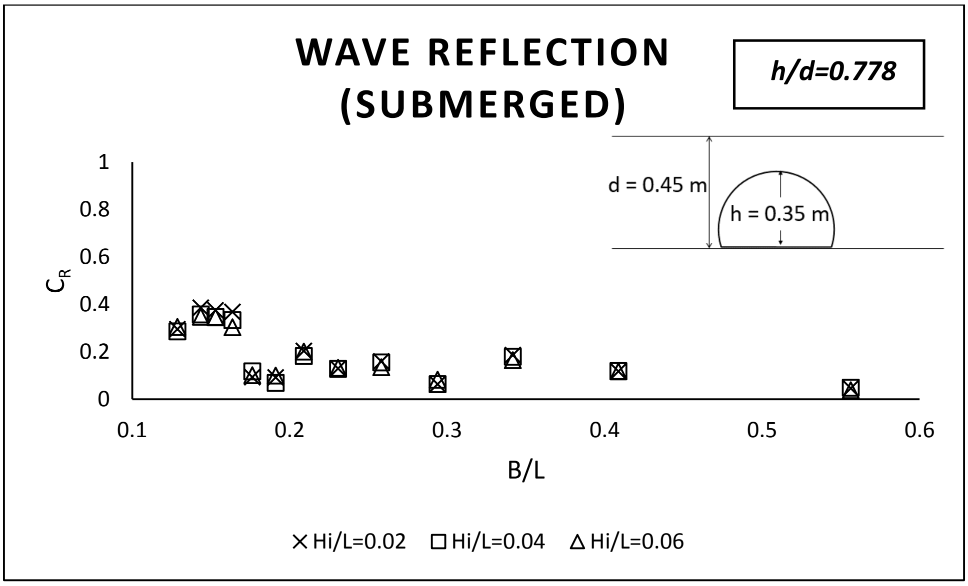

Figure 4.7: Wave reflection coefficient h/d=0.778

The effect of wave steepness on C_R is not permissible when the breakwater is emerged at *h/d=0.778.* There are no obvious changes between the steepness as shown in the figure above. All the points of different wave steepness overlap with each other but overall it produces a trend of partial bragging effect with increasing *B/L.* In this case, C_R of the breakwater is less dependent upon wave steepness.

To conclude on wave reflection, when comparing the three conditions (emerged, crest, and submerged), the outcome portrays that the best model for wave reflection was recorded in the submerged condition. Geotube can be designed using h/d=0.778 (submerged) when exposed to shorter waves at (B/L=0.15) to obtain minimum wave reflection (C_R<0.40). On another hand, the crest condition breakwater is good to be design at B/L = 0.15 if it is desired to serve as an effective anti-reflection structure.

4.7 Energy Dissipation

Figures below displays energy loss coefficient. The graph portrays a trend for C_L^2 of the geotube breakwater of *h/d = 1.40, h/d = 1.00* and *h/d = 0.778.* In general, the preferred model is the best energy dissipater. This can be achieved with optimum wave transmission and low wave reflection, as C_L^2 is correlated with C_R and $C_{T.}$

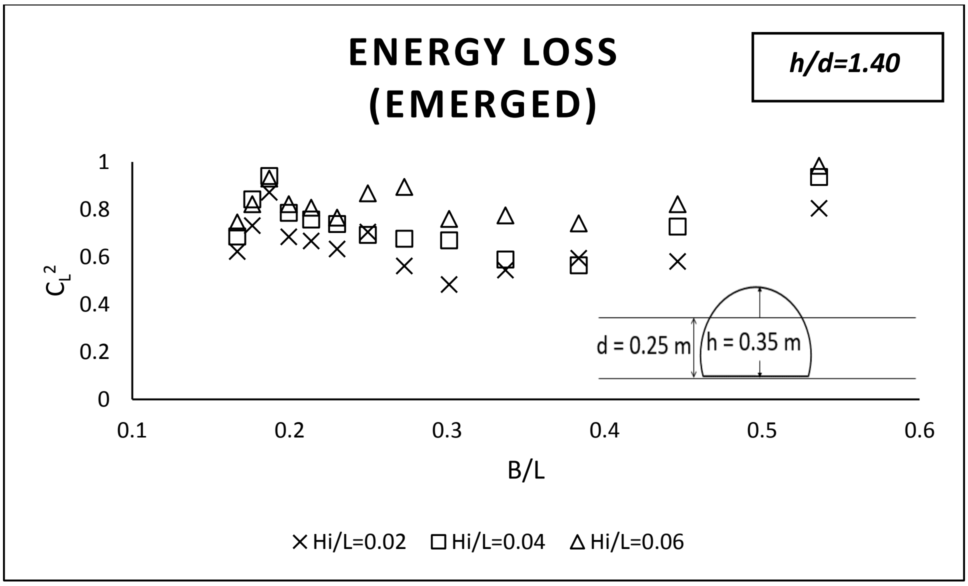

Figure 4.8: Energy dissipation coefficient of h/d = 1.40

All H_i/L in *h/d=1.40* case, displays an obvious bragging affect. When compared to all three steepness, *Hi/L=0.06* has the highest C_L^2 value because it dissipates more energy under this submergence. The reason is because it has a higher energy loss. Most of the points can be seen below $C_L^2 < 0.8$, this proves that the model is not dissipating energy as efficient as predicted. The highest C_L^2value recorded is 0.98 at *B/L= 0.53.*

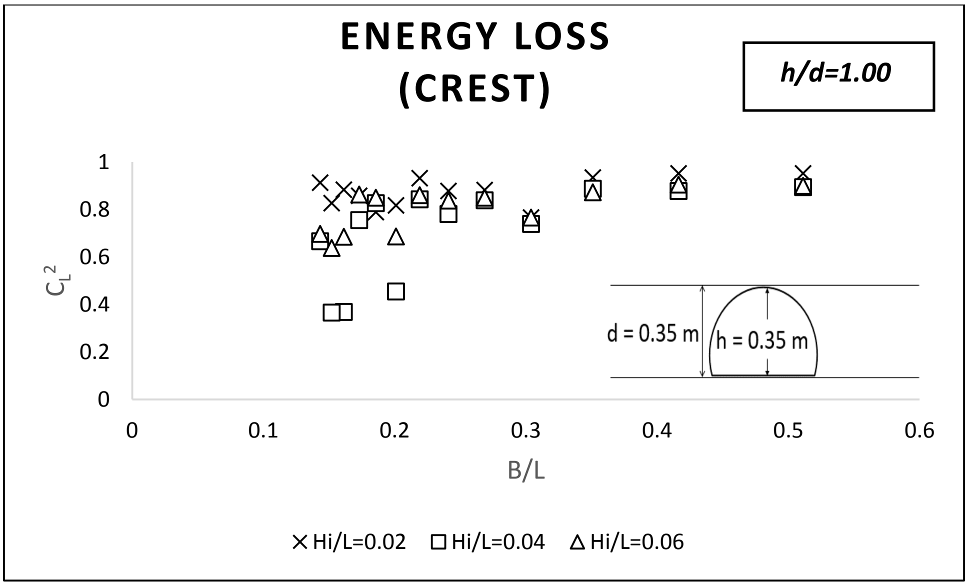

Figure 4.9: Energy dissipation coefficient of h/d = 1.00

Generally, the breakwater behaves in a distinct manner with the states of immersion. For energy loss, the crest case condition dissipates the most energy for *Hi/L=0.02* as compared to the other wave steepness. A valid explanation to the statement mentioned above is because geotube breakwater acts as an efficient energy dissipation when subjected to larger wave period and most of the point is recorded above $C_L^2 > 0.8$. As illustrated in the graph above, the highest C_L^2 value recorded is 0.9 at *B/L= 0.52*.

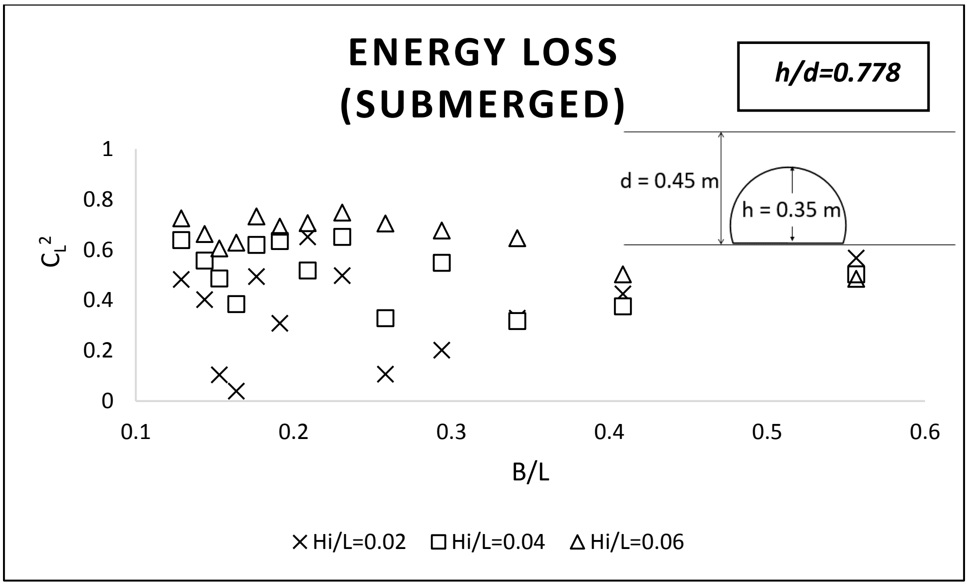

Figure 4.10: Energy dissipation coefficient of h/d = 0.778

According to the graph, the data points observed are scattered within different wave steepness for the *h/d*=0.778. Other information that can be extracted from this graph also mentions *Hi/L=0.06* having the highest C_L^2 value recorded at 0.7 at *B/L= 0.12, 0.19* and *0.24*. To summarize, important points to take into account from this result is, that the relative immersion of the breakwater is strongly dependent upon the hydraulic characteristics and generally the breakwater behaves in a distinct manner with the states of immersion.

To summarize on energy dissipation, the water level at crest *h/d=1.0*, gave the highest rate of energy loss $C_L^2=0.98$. Thereafter producing the best energy dissipater model at *B/L=0.25*.

CHAPTER 5

CONCLUSION & RECOMMENDATION

5.1 Conclusion

Geotubes are manmade from soft engineering that comes in various sizes and configuration which act as alternatively submerged breakwater in many sea shores. Besides acting as shore line protection and controlling the wave action, installing geotubes enhance sedimentation also known as soil accretion. Soil improvement is crucial for the growth of coastal floral. This research study is done to meet the requirement of multiple marine and coastal applications by accommodating an alternate to control the wave properties. The local authorities in recreational parks, beach resorts, and coastal towns are the sectors that are precisely favored by this research project. As a matter of fact, this research broadens the ideas of designing a more appropriate and workable aspects of geotube to the FRIM, considering a particular area. In the effort of generating conducive and protected sites for mangrove plantation close to the shoreline, this project is specifically relevant to the FRIM. Collaboration between UTP and FRIM will surely bring an expected end result by developing a mechanism in promoting the survivability rate of mangrove seedlings at the shoreline using geotextile tube structure.

In a nutshell, when compare the overall performance of all model, it shows that breakwater performed the best during emerged case in terms of wave transmission because it attenuates energy efficiently with ($C_T<0.01$). Wave transmission of a model should be optimum to allow some wave energy to pass through the geotube for mangrove survivability. As for reflection, it should be optimum to avoid wave amplification at the seaward. Hence in terms of wave reflection, the submerged *h/d=0.778*, gives the best value of ($C_R<0.40$). The best model for energy dissipation can be developed from crest case *h/d=1.00*, with the highest energy dissipation compared to other case ($C_L^2<0.98$). Upon the result gained, it can be concluded that the reflectivity of the test model is dependent on wave steepness in all condition. Due to the utilization of natural available resource (sand), as the material to be filled in the geotextile tube, this research is considered economical and sustainable. An added advantage will be available for countries surrounded by water body from the success of this project.

5.2 Recommendation

There is a necessity to do some improvement for any future research done on this project and also to understand and conduct a 2-D test on the geotube breakwater. Test like this would contribute to understand and determine the lee side of the geotube breakwater. It will also a stepping stone for the mangrove seed planters to decide on the best location to plant the seeds. The hydraulic performance of geotextile tube that will be studied in this paper will be a handy tool for designing stage for coastal engineering. However, improvement can be done in the part of UV radiation, tensile strength, and current and sediment transport of the geotube. In addition to that, future research can include the study of determining the acceptable level of wave attenuation for each species of mangrove to aid the upcoming plantation to be successful.

REFERENCES

Akbar, A. A., Sartohadi, J., Djohan, T. S., & Ritohardoyo, S. (2017). The role of breakwaters on the rehabilitation of coastal and mangrove forests in West Kalimantan, Indonesia. Ocean & Coastal Management, 138, 50-59. doi:http://dx.doi.org/10.1016/j.ocecoaman.2017.01.004

Alvarez, I. E., Rubio, R., & Ricalde, H. (2007). Beach restoration with geotextile tubes as submerged breakwaters in Yucatan, Mexico. Geotextiles and Geomembranes, 25(4), 233-241. doi:http://dx.doi.org/10.1016/j.geotexmem.2007.02.005

Ji, Q., Dong, S., Luo, X., & Guedes Soares, C. (2017). Wave transformation over submerged breakwaters by the constrained interpolation profile method. Ocean Engineering, 136, 294-303. doi:http://dx.doi.org/10.1016/j.oceaneng.2017.03.037

Jiang, X.-L., Zou, Q.-P., & Zhang, N. (2017). Wave load on submerged quarter-circular and semicircular breakwaters under irregular waves. Coastal Engineering, 121, 265-277. doi:https://doi.org/10.1016/j.coastaleng.2016.11.006

Koley, S., & Sahoo, T. (2017). Wave interaction with a submerged semicircular porous breakwater placed on a porous seabed. Engineering Analysis with Boundary Elements, 80, 18-37. doi:http://dx.doi.org/10.1016/j.enganabound.2017.02.019

Lin, G., Shu, Y.-m., Lu, X., Dai, L.-j., Yu, X.-z., Zhang, X.-l., & Yi, J.-r. (2011). Laboratory studies on wave force of coastal structures made of flat geotubes. Journal of Hydrodynamics, Ser. B, 23(6), 820-825. doi:http://dx.doi.org/10.1016/S1001-6058(10)60181-3

Mustapa, M. A., Yaakob, O. B., Ahmed, Y. M., Rheem, C.-K., Koh, K. K., & Adnan, F. A. (2017). Wave energy device and breakwater integration: A review. Renewable and Sustainable Energy Reviews, 77, 43-58. doi:http://dx.doi.org/10.1016/j.rser.2017.03.110

Stanley, O. D., & Lewis, R. R. (2009). STRATEGIES FOR MANGROVE REHABILITATION IN AN

ERODED COASTLINE OF SELANGOR, PENINSULAR MALAYSIA. Journal of Coastal Development, 12(3), 144-156.

Sulaiman, D. M., Bachtiar, H., Taufiq, A., & Hermanto. (2015). Beach Profile Changes Due to Low Crested Breakwaters at Sigandu Beach, Central Java. Procedia Engineering, 116, 510-519. doi:http://dx.doi.org/10.1016/j.proeng.2015.08.320

Van Cuong, C., Brown, S., To, H. H., & Hockings, M. (2015). Using Melaleuca fences as soft coastal engineering for mangrove restoration in Kien Giang, Vietnam. Ecological Engineering, 81, 256-265. doi:http://dx.doi.org/10.1016/j.ecoleng.2015.04.031

Yuan, D., & Tao, J. (2003). Wave forces on submerged, alternately submerged, and emerged semicircular breakwaters. Coastal Engineering, 48(2), 75-93. doi:http://dx.doi.org/10.1016/S0378-3839(02)00169-2

Alongi, D. M. (2008). "Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change." Estuarine Coastal and Shelf Science 76(1): 1-13.

Ji, C.-Y., et al. (2015). "Experimental study of a new type of floating breakwater." Ocean Engineering 105: 295-303.

Milanian, F., et al. (2017). "Effect of hydraulic and structural parameters on the wave run-up over the berm breakwaters." International Journal of Naval Architecture and Ocean Engineering 9(3): 282-291.

Oyegbile, B. O. and B. A. Oyegbile (2017). "Applications of geosynthetic membranes in soil stabilization and coastal defence structures." International Journal of Sustainable Built Environment.

Shen, J., et al. (2017). "Subsidence estimation of breakwater built on loosely deposited sandy seabed foundation: Elastic model or elasto-plastic model." International Journal of Naval Architecture and Ocean Engineering 9(4): 418-428.

Stanley, O. D. and R. R. Lewis (2009). "STRATEGIES FOR MANGROVE REHABILITATION IN AN ERODED COASTLINE OF SELANGOR, PENINSULAR MALAYSIA." Journal of Coastal Development 12(3): 144-156. Continuous mangrove ecosystem degradation and coastal erosion is observed along the coastline of Sungai

Zou, Q. and Z. Peng (2011). "Evolution of wave shape over a low-crested structure." Coastal Engineering 58(6): 478-488.

APPENDIX A

GHANTT CHART

No	Project Work	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Preliminary Research Work														
2	Extended Proposal Submission														
3	Proposal Defense														
4	Project Work Continuation														
5	Final Report Submission														

No	Activity	Complete in
1	Literature review on the preliminary research work	Week 2
2	Literature review on semicircular breakwater and impact of wave to shoreline	Week 3 – Week 5
3	Preparation of Extended Proposal	Week 6
4	External Proposal Submission	Week 7
5	Apparatus and Equipment Preparation	Week 9
6	Practice of Experimental Set Up	Week 10
7	Project Work Continuation	Week 10 - 12
8	Drafting of final report	Week 13
9	Submission of completed final report	Week 14