Coir Rolls as Temporary Measure For Wave Attenuation

by

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CERTIFICATION OF APPROVAL

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Approved by,

....
(AP Ahmad Mustafa bin Hashim)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

JANUARY 2016

CERTIFICATION OF ORIGINALITY

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

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VEERINDER KAUR A/P GURBACHAN SINGH

ABSTRACT

Coir rolls is a categorized as one of the bioengineering solution to coastal erosion. Objective of this project is to investigate the wave attenuation on the coir rolls with respective to depth of water, d and wave steepness. The testing of the coir rolls with a diameter of 11.5 cm and a length of 30 cm was done in the wave flume of the Hydraulics Lab with respect to different depths of 20 cm, 15 cm, 12 cm and 11.5 cm as well as different wave period and wave steepness as well. Two different configurations of coir rolls were tested. The incident wave heights and transmitted wave heights were recorded and the results were interpreted in the results and discussion chapter of this report. The coir rolls were found to have attenuated the waves effectively at the depth of 11.5 cm as the range of Ct values at this depth are the lowest compared to the ranges of other depths. Due to the wave being obstructed more by the coir rolls, the transmitted wave height was lower causing the Ct coefficient to be lower.

ACKNOWLEDGEMENT

I would like to express my gratitude to those who have helped me in contributing towards this process of study. I would firstly like to thank my advisor, AP Ahmad Mustafa for the guidance and advice given during this project period which was for both the final year semesters. Not forgetting my fellow coursemates, Lachmi, Gan and Thinagran who helped me in conducting the experiments in the laboratory for this project.

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CHAPTER 1

INTRODUCTION

1.1 Background

We cannot deny the increasing number of development by the coastal area for tourism, housing estates as well as resorts are taking place rapidly. Take a country where coastal development is taking place tremendously like Australia for an example; 81% of its population lives within the range of 50 kilometer - 60 kilometer from the coastline [6]. This demand for development by the coastline has driven analysts to study wave condition to enable engineers to come up with techniques like the well known hard structures as a measure for coastal erosion problems. The increase in sea level globally has also contributed to coastal erosion today. The Global Mean Sea level has risen by 4 to 8 inches. Studies from National Geographic have also forecasted that there will be further rise of sea level reported to be between 2.5 feet to 6.5 feet [8]. These hard structures have proved to be strong and powerful in withstanding the waves of high energy rushing to the shoreline with the aid of the wind speed. It also protected the coastline from severe erosion that was observed before the hard structures were taken as a measure to prevent it. However, the effects of these hard structures are widely visible these days. The side effects are somehow detrimental to the natural process of the longshore sediment transport, to the environment and marine life at that particular coastline. Natural habitats of the marine life are destroyed as the hard structure is constructed. Fishes and other marine lives will either die or move away from the location which affects the economic prospects and income source of fishermen if the hard structures were placed by villages along the coastline. The costs of hard structures comprising of the transportation, construction procedures and materials are expensive. Most hard structures are usually constructed when the erosion problem at that particular site is a critical stage. Instead of solving the problem at an earlier stage, the measures are only taken at the end to protect the severely eroded beach.

Bioengineering techniques are a more environmental friendly and affordable way to solve coastal erosion. Rather than solving the problem once the coastal area is severely eroded, an initial prevention measure using the affordable and environmental friendly bioengineering technique should be used to combat erosion. It does not harm the environment as it is biodegradable and encourages the growth of vegetation. Maintenance wise, bioengineering techniques are cheap and easy to maintain as well. The plants used in the bioengineering methods functions well in combating coastal erosion by preventing soil detachment, the binding of the root systems with the soil to prevent the sediments from escaping, increasing the beach surface runoff and stabilizing the beach area [12]. Coir rolls are also affordable, lightweight and easily transported to sites [21]. Some examples of bioengineering methods include branchpacking, live fascines, coir rolls, live staking and brushlayers.

1.2 Problem Statement

Commonly, most problems are only rectified when its impact starts deteriorating. This same concept applies in the coastal erosion prevention measure. Only when the erosion reaches the critical stage, hard structures are built to protect the coastline from erosion. Most hard structures constructed these days for coastal erosion are expensive, brings a huge amount of negative impact on to the surrounding coastline and are expensive for installation and maintenance. Though it is a permanent structure, maintenance is still important to be done. The concept of prevention is better than cure should be grasp by the coastal development agencies or people residing by the coastal area. The problem of coastal erosion can be delayed if there is a temporary measure taken first. Temporary coastal protection works under the *Coastal Protection Act 1979* states that the purpose of a temporary measure is to reduce the impact of wave on the shoreline [12].

Environmental Planning and Assessment Act 1879 states that placement of rocks, concrete, construction waste or other debris for temporary works are not allowed as they can erode adjacent beach lands. Bioengineering techniques using coir rolls made from coconut husks is the potential solution for coastal erosion as it acts as a temporary measure, affordable in cost, easy to install, maintenance is easy as well as it has very less impact on its surrounding environment. The coir rolls can be used during the times of when the beach is experiencing a significant erosion stage as the coir rolls could function as a sediment trap and reduce the harsh impacts of the waves onto the beach. In other words, the coir rolls serves to stabilize the beach rather than exposing it to further erosion.

1.3 Objectives

The objective of this project is to investigate the wave attenuation on the coir rolls with respective to depth of water and wave steepness.

1.4 Scope of Study

Scope of study for this project should be planned in line with achieving the objective of this project. There are several stages to the scope of work required for this project. The first stage is the basic study. In coastal engineering, there are certain laws and regulations to adhere to during the consideration of protection measures for erosion of the coastline. The very famous *Coastal Protection Act 1979* serves as an important guideline in suggesting coastal erosion measures [12]. It is very important to study the method of erosion measure thoroughly by reading up on previous research papers and journals for the expansion of knowledge on the subject matter. Moreover, existing coastal measures are to be read up on as well for the comparison purposes. In the case of this project, coir rolls is a soft engineering solution that is to be compared with the current hard structures used as a control erosion prevention measure. The second stage would be the designing of the coir rolls as a coastal prevention measure technique. In this project, several designs were suggested to be implemented for the coir rolls arrangement. This is to test out on the effectiveness of the coir rolls in dissipating wave energy based on its arrangement.

Once the designing stage it completed, the implementation stage begins. The materials are purchased and the prototype is built for testing. The prototype for this project will be tested out in the wave flume in the offshore lab. The fourth stage would involve the analyzing of the results obtained and lastly recommendations and improvement based on technical guidelines will be done.

CHAPTER 2

LITERATURE REVIEW

2.1 Causes of Coastal Erosion

Rise of sea level is one of the main causes that lead to coastal erosion [8]. In the New England and Mid-Atlantic states, around 68% of the beaches are facing erosion [13]. U.S. Environmental Protection Agency has estimated an approximate of 80%-90% of erosion along the American coastline is occurring due to the rise in sea level [14]. Rise in sea level causes the coastal storms to bring about greater waves that sweep of the sediments from the beach area [14]. In the year 1962, Bruun introduced a concept based on his work done at the beaches that when responding to the rise in sea level, the coastal area changes its landforms to maintain the relative position [15].

Hard structures such as breakwater, groins, seawalls and revetment are used to protect the coastal areas from erosion. However, the hard structures have also backfired and brought along detrimental consequences to the coastline. Construction of hard structures for the purpose of preventing coastal erosion has been built worldwide at most coastlines and contributes to the worsening of coastline erosion at adjacent beaches and the reflected waves resulting from the existence of this hard structure causes scouring at the adjacent beaches as well [1]. The effects of this hard structure can be observed within a range 10 meter to 1,000 meter of its surrounding [2]. Examples of hard structures are like groins, seawalls, revetment and breakwater. Professor Paul Komar, at the College of Oceanographic and Atmospheric Sciences at Oregan State University stated that hard structures have contributed to the worsening of erosion where the updrift coastal defense caused downdrift erosion by 30% [4].

In the year 2007, North Carolina's group of 40 coastal geologists insisted that the ban of hard structures remains as the engineers predicted that the hard structures, if built, would cause the other parts of the coast to be eroded terribly [8]. An alternative to constructing hard structures is turning to soft engineering solution such as beach nourishment to control coastal erosion. However, the consequence of beach nourishment is that it destroys the marine life due to the very thick layer of sand used for beach nourishment [9]. During construction period for beach nourishment, the sounds from the machinery and transportation vehicle (bulldozer) scares the marine life away from the shore area [3]. Not only is the natural process of longshore sediment transport affected, the surrounding environment of the coastal areas are affected by hard structures too. Coral reefs damaged due to excessive deposition of sediment resulted in the death of marine life around that protected coastline [5].

2.2 Bioengineering Solution for Coastal Erosion

As observed, there are two options to curb coastal erosion which is to permanently maintain the coastline by using hard structures at a fixed position and the other option is to use soft engineering techniques such as beach nourishment, dune stabilization, bioengineering and other non-structural management [16]. For economic reasons, the soft engineering solutions are usually preferred as it is considered a cheaper option compared to hard engineering methods [16]. Results showed that soft engineering methods reduce coastal erosion without causing harm to the beaches and properties along the coastline [16]. However, soft engineering applications are only temporary solutions which require frequent maintenance to be done [16]. Termed as "soil bioengineering", it involves vegetation to act as structural resistors towards coastal erosion that contribute to a friendly shoreline for marine life [10]. Certain consideration that can be taken into account for bioengineering is the soil class or type being sand, silt, clay and loam [19]. Soil bioengineering poses as a cost effective and amazing approach to stabilize slopes against erosions [22]. A trend in coastal engineering has been identified lately where there is a large focus on vegetation as shore protection measure, as it provides a natural habitat for many different species as well [23].

Vegetation dampens the incoming waves as well as dissipates wave energy and deposits sediment in vegetated areas too [23]. Wave dissipation by vegetation depends on a number of vegetation characteristics such as geometry, stiffness, buoyancy, density, and spatial coverage as well as hydrodynamic wave conditions such as wave direction, height and period [24]. The linear wave theory was applied in the shallow condition of water to show a wave setup, a storm surge component resulting from the transfer of wave breaking momentum to water column, is reduced by 2/3 in the presence of the vegetation relative to conditions without vegetation [24]. Examples of very well known vegetation that dissipates wave energy well are aquatic halophytic vegetation such as salt marshes and mangroves [25]. For an example, in Vietnam, the thick mangrove leaves were studied and found to be capable of attenuating huge quantities of wave energy, especially during typhoons and storms [25].

2.3 About Coir Rolls

One of the bioengineering techniques is fiber coir rolls that helps in soil stabilization and encourages vegetation growth to prevent instability of the shoreline [7]. Coir rolls are made up of coconut fiber which is extracted from the husk part of the coconut. It is a geosynthetic material. Coir rolls are able to withstand waves less than 20 inches (0.5 meter) and are able to break waves at the coastline [7]. There are many benefits to using coir rolls (bioengineering technique) as a coastal erosion prevention measure such as it is environmental friendly, does not contribute to severe erosion to the downdrift coastal area, and it is cheap in constructing and maintaining [11]. Coir rolls are usually not recommended for areas with severe erosion, however, if necessary, the coir rolls will be combined with cutting of hazel, chestnut or willow bundles that will provide reinforcement in strength for the coir rolls [27]. As the plants grow in the coir rolls, they become a living revetment, protecting the shoreline from erosion [27].

Bioengineering solution should be made a temporary measure to combat coastal erosion. The word temporary may scare others because of the materials lifespan to protect the coastline, however, if the material serves its purpose, there should be no worries about its lifespan. It is just a matter of maintaining it by replacing the previous material with a new one. A coir roll has a lifespan of 5 years to 7 years based on its biodegradable property [7]. The coir fiber properties are presented in the table below:

Table 2.1: Properties of Coir Fiber (Anderson, 2011)

Property	Type A1	Type A2
Breaking load, N	487.3	217.8
Tenacity (cN/tex)	12.4	11.5
Modulus (Initial) (cN/tex)	113.7	85.9
Modulus offset) (cN/tex)	13.8	9.5
Breaking extension,%	44.8	41.7
Energy to break (Joules)	0.0158	0.0062
Thickness in 1/100th mm	20.42	13.57
Linear density (tex)	39.4	18.9

For marine construction, the specific gravity of a material is usually taken into account to prevent it from moving or being affected by the wave current action [21]. A heavier specific gravity means a more stable material. As stated in the U.S. Army Corps of Engineers, any materials, following the British Standard, with specific gravity less than 1.5 are of least use for coastal protection works [21]. Taking a clay-coir mixture as an example, its specific gravity is within a range of 2.16-2.68 [21]. Coir fiber enhances other available construction materials strengths' and the strength of the coir fiber soaked in water were found to have higher strength rather than being dry, where the tensile strength was within a range of 73-118 MPa [21].

Here is an example of bioengineering solutions to coastal or bank erosion. The first one is the live bank protection which is made up of wattle fences along the bank of the stream [17]. The protection against river bank erosion is done by these wattle fences which have twigs and trimming from the cuttings that fills the gaps in between the wattle fences [17].

The wattle fences encourage the growth of vegetation that would later on stabilize the soil along the river bank [17].

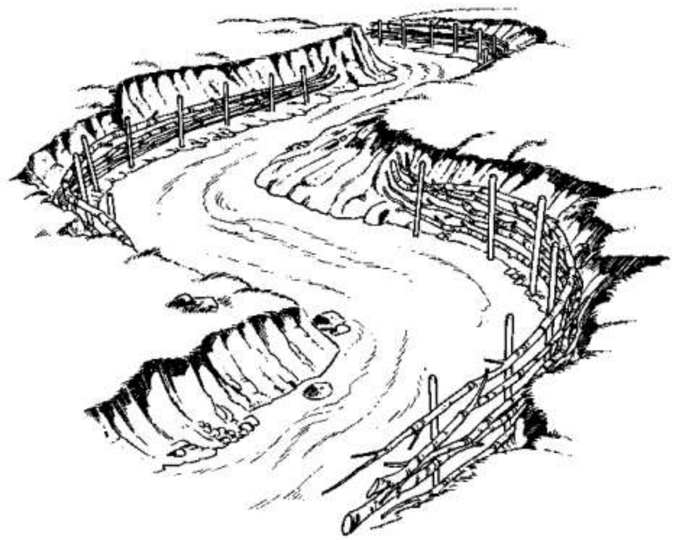

Figure 2.1: Wattle fencing along the river stream

A trench is dug at the toe of the slope where the coconut fiber rolls will be placed. There are conditions where vegetation is planted in to the rolls itself as coconut coir rolls provide a suitable medium and protection for this vegetation to grow [26]. The construction and material costs for the installation of coconut coir rolls are approximately $68 per linear feet, where the materials cost are usually $11 per linear feet [26]. Sold on the amazon for the price of $48.49 USD for 8 feet long and 39 feet width, it proves that the coir roll is indeed an affordable measure for coastal erosion measure. In the cases of areas in Malaysia, the abundance of coconut coir rolls supply is usually around at villages by the coastal areas. This will be an advantage for the villagers' to construct their own coir rolls to be used as the temporary coastal protection measure. Coir rolls are aesthetically pleasing compared to other types of hard engineering protection approaches as it is a natural form of coastal protection and it allows easy access to the shoreline area too.

CHAPTER 3

METHODOLOGY

3.1 Experimental Model

The model for this experiment was to be coir rolls. The coir rolls can be easily made up of the following materials below:

Table 3.1: Materials needed in making coir roll model

MATERIALS	
Coir Rolls	
Netting (to wrap coir rolls)	
Cable tie	

Figure 3.1: Coir rolls of dimension 11.5 cm diameter and 30 cm long

Figure 3.2: Coconut husks wrapped in netting to form coir roll

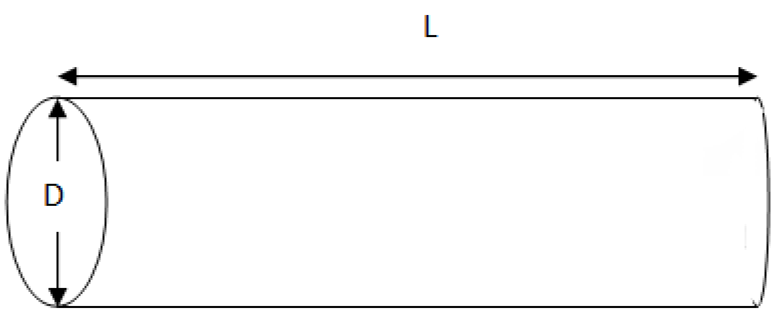

Figure 3.3: Cross Section of Coir Roll

The coir roll model has a dimension of 11.5 cm of diameter and 30 cm of length during the experimental conduct in the hydraulics lab.

3.2 Equipment Set Up

The experiment was conducted using the wave flume in the hydraulics lab at Universiti Teknollogi PETRONAS. The wave flume has a dimension of 10 m length, 32 cm width and 48 cm height.

Figure 3.4: Wave Flume

Figure 3.5: Self-made wave absorber at the end of the wave flume

The wave absorber made out of sponge was attached to an inclined metal surface. Its function is to minimize the reflection of waves that reaches the other end of the wave flume tank as it absorbs the wave energy.

Figure 3.6: Closer View of Wave flume tank

Figure 3.7: Controllers for frequency, wave generation and pump.

3.3 Experiment Set Up

The experiment of wave attenuation testing on the coir rolls took place in the wave flume at the Hydraulic Lab of Universiti Teknologi PETRONAS. The experiment set up was as below:

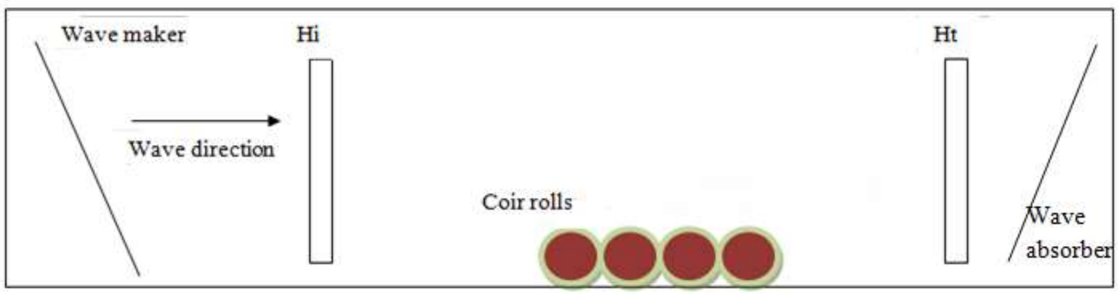

Figure 3.8: Experimental setup of coir rolls in wave flume

Two configurations were tested out in this experiment to investigate which arrangement attenuated wave the best. The configurations were as below:

Configuration 1:

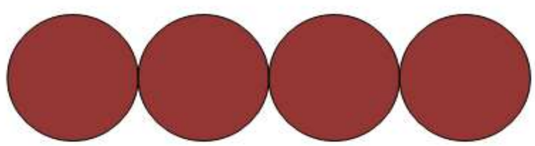

Figure 3.9: Configuration 1 where coir rolls are arranged next to each other in a row

Configuration 2:

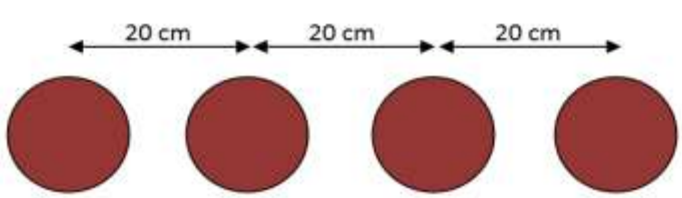

Figure 3.10: Configuration 2 where coir rolls are arranged with a gap of 20 cm from one another

3.4 Experiment Parameter

The coir rolls model will be tested in the wave flume of the Hydraulic Lab by testing against 3 variables being water depth, d, wave steepness, Hi/L and wave period (T). The wave type tested is regular wave. The table below shows the fixed variables and manipulated variables for this experiment:

Table 3.2: Fixed variables and manipulated variables for experimentation conduct

Fixed Variables	Manipulated Variables
Slope Regular waves	Water Depth Wave Period Wave Steepness

Table 3.3: Experiment parameters

Configuration	**Wave Period, T (s)**	**Water Depth (cm)**	**No. of Tests**
1	0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0	11.5, 12, 15, 20	84
2	0.8, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0	11.5, 12, 15, 20	84
		Total Tests =	168

3.5 Experiment Methodology

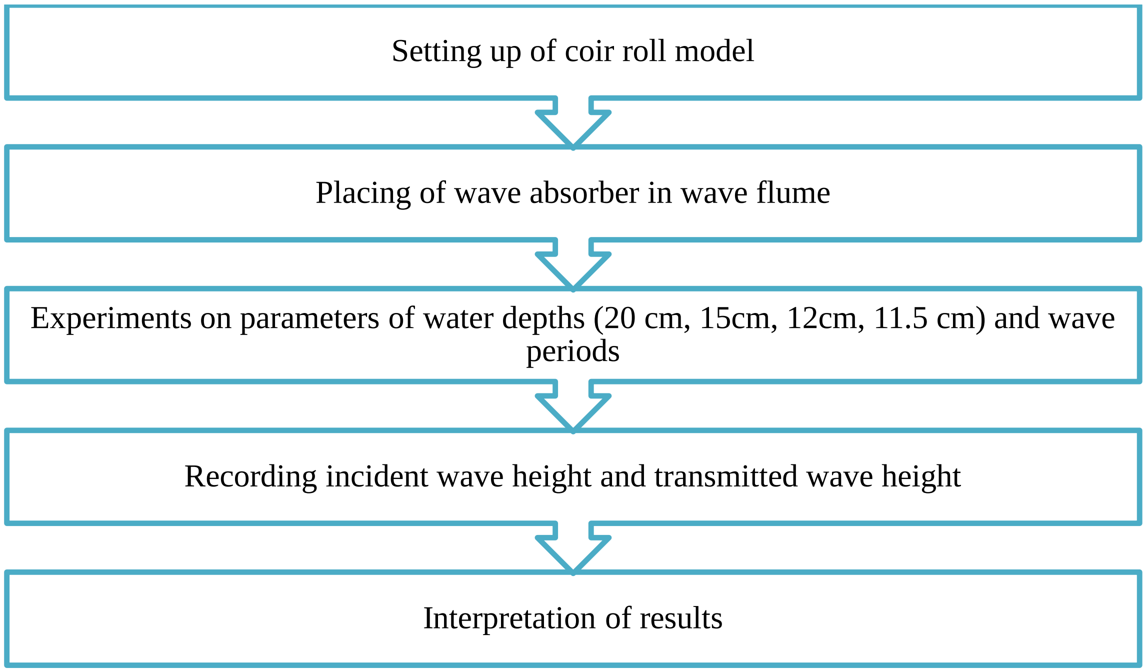

Figure 3.11: Methodology of Experiment

CHAPTER 4

RESULTS AND DISCUSSION

The coir rolls was studied thoroughly to investigate wave attenuation capacity of this bioengineering product through physical modeling. Once the experimentation was done, the values of Hi and Ht were keyed into the Microsoft Excel spreadsheet. The value of Hi (incident wave) and Ht (wave transmitted) were recorded during the experiment for all the different parameters involved as shown in the methodology section. Ct can be represented as the ratio of transmitted wave height to the incident wave height. The value of Ct was calculated by the formula below:

$$Ct = Ht/Hi \qquad (1)$$

Ct coefficients range from 0 to 1, for which a value of 0 implies no transmission on the lee side of the coir rolls placed (normally when the structure is high or impermeable), and a value of 1 implies complete transmission (normally when there is no structure present to attenuate waves).

The 2 configurations used for the results below were of 4 coir rolls, each 11.5 cm in diameter that were placed side by side with no gap between them. Graphs comparing Ct values of different depths for all stroke was done and compared to each other to find out the efficient wave attenuation done by the coir rolls prototype that was used in the experiment. Graphs of Ct against Hi/L (Hi/L representing wave steepness) were plotted as well as graphs of Ct against B/L; B being the coir rolls width (30 cm).

The different strokes in this experiment (200, 160, and 120) were varied to change the incident wave height and wavelength as well. This is to test out the capability of the coir rolls to attenuate waves of different conditions.

The lower the Ct curves that are found to be plotted onto the graph, the better the wave attenuation performance is. This is due to the fact that a lower Ct means smaller wave transmitted.

4.1 Interpretation of Results for Configuration 1

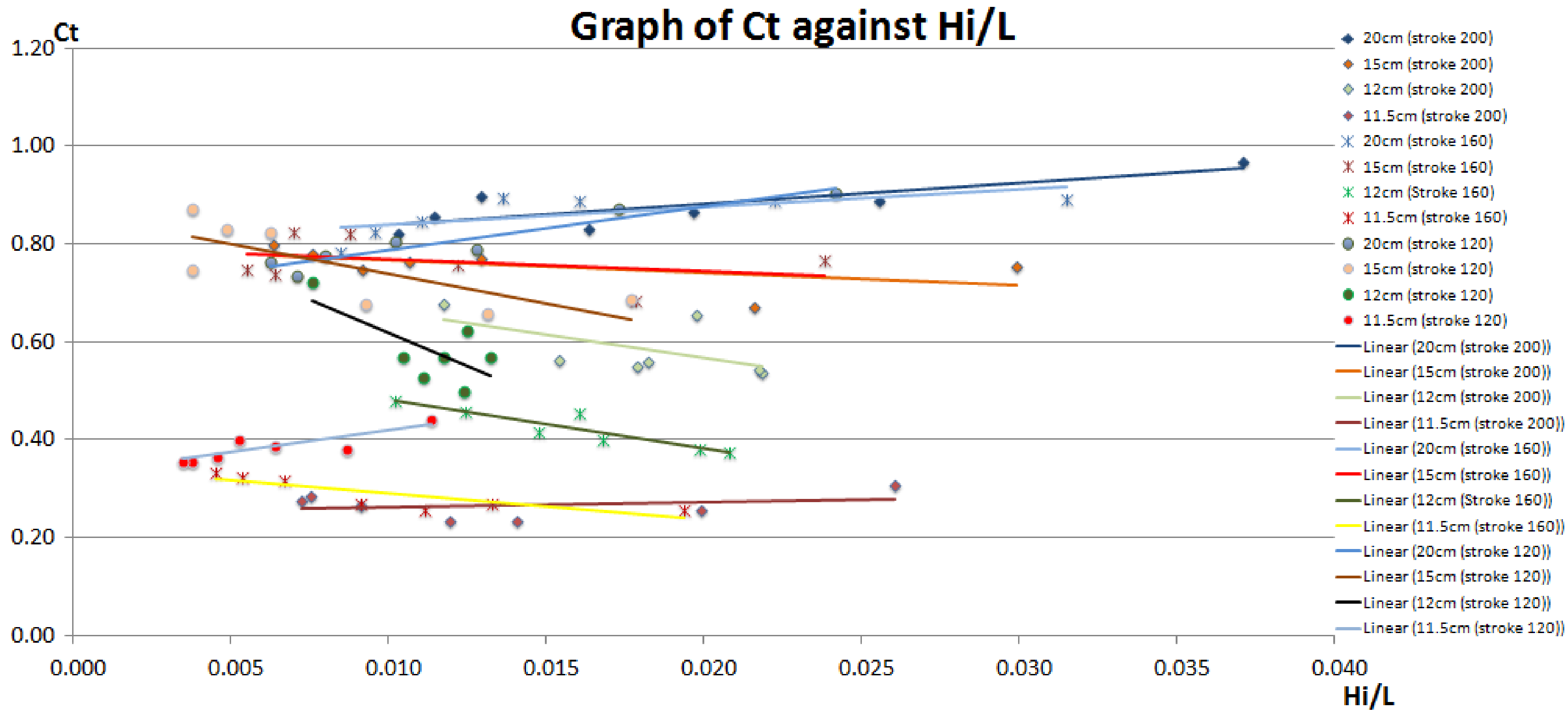

Figure 4.1: Graph of wave transmitted coefficient, Ct against wave steepness, Hi/L for all strokes and water depths for configuration 1

Configuration 1:

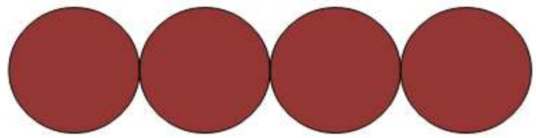

Figure 4.2: Configuration 1 of coir rolls

The wave transmitted coefficient, Ct are plotted against the wave steepness, Hi/L where Hi is the incident wave height and L is the wavelength. From the graph, it can be observed that at different strokes and water depths, the Ct values are not significant as the difference among another point is not much. However, the effect of water depth on the wave attenuation performance can be clearly seen. As the water depth decreases, the Ct values decreases as well. It can be observed that at all depths, the wave generated experiences attenuation but at different rates.

For the depth of 20 cm, it can be noticed that the trendlines of all three strokes 200, 160 and 120 shows an increasing pattern. This can be interpreted that as the wave steepness increases, the Ct value increases. Wave attenuation by the coir rolls is not effective at this depth. The wave attenuation at stroke 160 was the most effective one compared to stroke 200 and 120 as the Ct values at this stroke is the lowest. The performance of the coir rolls in attenuating waves at this depth was between 4% to 11% based on the Ct coefficient.

For the depth of 15 cm, the trendlines of all three strokes 200, 160 and 120 shows a decreasing pattern. It can be interpreted that the higher the wave steepness, the lower the Ct value. Wave attenuation at this depth was effective as at all strokes, the transmitted wave height was lower after passing the coir rolls. The wave attenuation at stroke 120 was the most effective compares to stroke 200 and 160 as the Ct values at this stroke is the lowest based on the rapid decrease in pattern observed from the trendline. The performance of the coir rolls in attenuating waves at this depth was between 10% to 24% based on the Ct coefficient.

For the depth of 12 cm, the trendlines of all three strokes 200, 160 and 120 shows a decreasing pattern. It can be interpreted that the higher the wave steepness, the lower the Ct value. Wave attenuation at this depth was effective as at all strokes, the transmitted wave height was lower after passing the coir rolls. The wave attenuation at stroke 120 was the most effective compares to stroke 200 and 160 as the Ct values at this stroke is the lowest based on the rapid decrease in pattern observed from the trendline. The performance of the coir rolls in attenuating waves at this depth was between 27% to 52% based on the Ct coefficient.

For the depth of 11.5 cm, the trendline of stroke 200 shows a slight increase which indicates that the higher the wave steepness, the higher the Ct value. Wave attenuation by the coir rolls at this depth is not effective. However, the trendline at stroke 160 shows a decrease which indicates that the higher the wave steepness, the lower the Ct value. The wave attenuation by the coir rolls is effective. The trendline of 120 shows an increase which can be interpreted that the higher the wave steepnesss, the higher the Ct value. The wave attenuation at this stroke is not effective. The performance of the coir rolls in attenuating waves at this depth was between 56% to 74% based on the Ct coefficient.

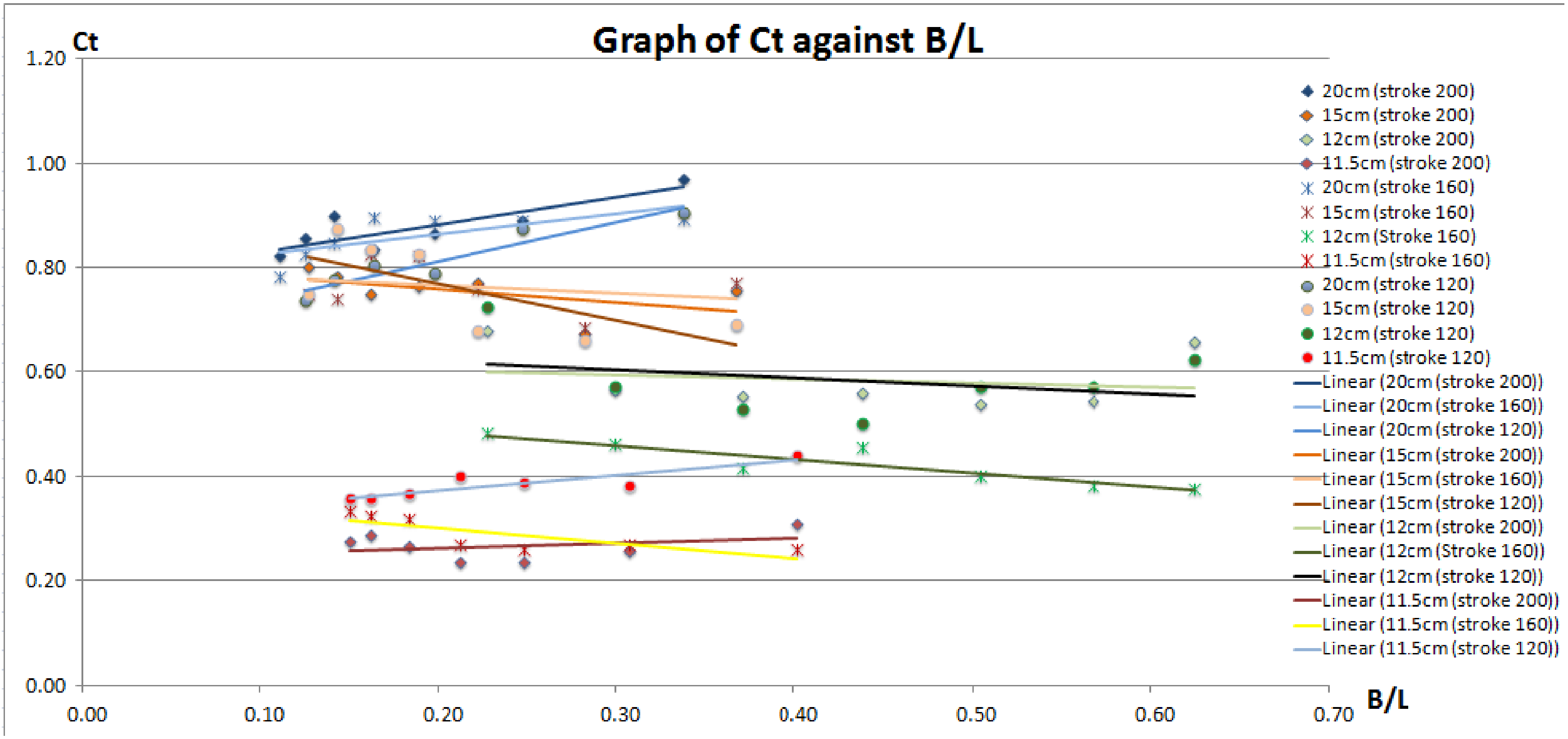

Figure 4.3: Graph of wave transmitted coefficient, Ct against coir rolls width, B/L for all strokes and water depths for configuration 1

The wave transmitted coefficient, Ct is plotted against the relative coir rolls width (B/L) where B is the coir roll width and L is the wavelength. As B/L increases, the Ct values changes for all water depths. Effect of water depths on the wave attenuation is not significant. The coir rolls are observed to be functioning better in shallow water depth as compared to the highest depth, 20 cm. It can be deduced that the deeper the water depth, most waves simply propogate over the coir rolls without much disturbance, causing the transmitted wave height to be higher. However, when the water level is the same as the coir rolls, the waves will be easily disturbed by the structure; hence the wave energy will be dissipated and the transmitted wave height will be significantly reduced.

For the depth of 20 cm, it can be noticed that the trendlines of all three strokes 200, 160 and 120 shows an increasing pattern. This can be interpreted that as the coir rolls width increases, the Ct value increases. Wave attenuation by the coir rolls is not effective at this depth. This is due to the coir rolls not causing much disturbance to the incident wave height due to the high depth tested which leads to the transmitted wave height to be higher. The wave attenuation at stroke 120 was the most effective one compared to stroke 200 and 160 as the Ct values at this stroke is the lowest. The performance of the coir rolls in attenuating waves at this depth was between 3% to 11% based on the Ct coefficient.

For the depth of 15 cm, it can be noticed that the trendlines of all three strokes 200, 160 and 120 shows a decreasing pattern. This can be interpreted that as the coir rolls width increases, the Ct value decreases. Wave attenuation by the coir rolls is effective at this depth. This is due to the coir rolls causing disturbance to the incident wave height due to the depth tested being nearer to the coir rolls which leads to the transmitted wave height to be lower. The wave attenuation at stroke 120 was the most effective one compared to stroke 200 and 160 as the Ct values at this stroke is the lowest. The trendline of stroke 120 shows a rapid decreases showing that the wave was attenuated as a fast rate at this stroke. The performance of the coir rolls in attenuating waves at this depth was between 23% to 31% based on the Ct coefficient.

For the depth of 12 cm, it can be noticed that the trendlines of all three strokes 200, 160 and 120 shows a decreasing pattern. This can be interpreted that as the coir rolls width increases, the Ct value decreases. Wave attenuation by the coir rolls is effective at this depth. This is due to the coir rolls causing disturbance to the incident wave height due to the depth tested being nearer to the coir rolls which leads to the transmitted wave height to be lower. The wave attenuation at stroke 160 was the most effective one compared to stroke 200 and 120 as the Ct values at this stroke is the lowest. The performance of the coir rolls in attenuating waves at this depth was between 27% to 52% based on the Ct coefficient.

For the depth of 11.5 cm, it can be noticed that the trendlines of all strokes 200 and 120 shows an increasing pattern whereas the trendline of stroke 160 shows a decrease. For the stroke fo 160, it can be interpreted that as the coir rolls width increases, the Ct value decreases. For strokes 200 and 120, it can be interpreted that as the coir rolls width increases, the Ct value increases. Wave attenuation by the coir rolls is effective at stroke 160. This is due to the coir rolls causing disturbance to the incident wave height due to the depth tested being nearer to the coir rolls which leads to the transmitted wave height to be lower. The wave attenuation at stroke 160 was the most effective one compared to stroke 200 and 120 as the Ct values at this stroke is the lowest. The performance of the coir rolls in attenuating waves at this depth was between 56% to 74% based on the Ct coefficient.

Range of Ct coefficients (minimum and maximum value) based on all the depths is showed in the table below:

Table 4.1: Ranges of Ct values for coir rolls for configuration 1

Depth (cm)	h/d ratio	Min Ct value	Max Ct value	Range of Ct value
20	0.57	0.74	0.97	0.74-0.97
15	0.77	0.66	0.88	0.66-0.88
12	0.96	0.38	0.73	0.38-0.73

11.5	1.00	0.24	0.44	0.24-0.44

From the table above, it can be interpreted that the coir rolls attenuated the waves effectively at the depth of 11.5 cm as the range of Ct values at this depth are the lowest compared to the ranges of other depths. Due to the wave being obstructed more by the coir rolls, the transmitted wave height was lower causing the Ct coefficient to be lower.

4.2 Interpretation of Results of Configuration 2

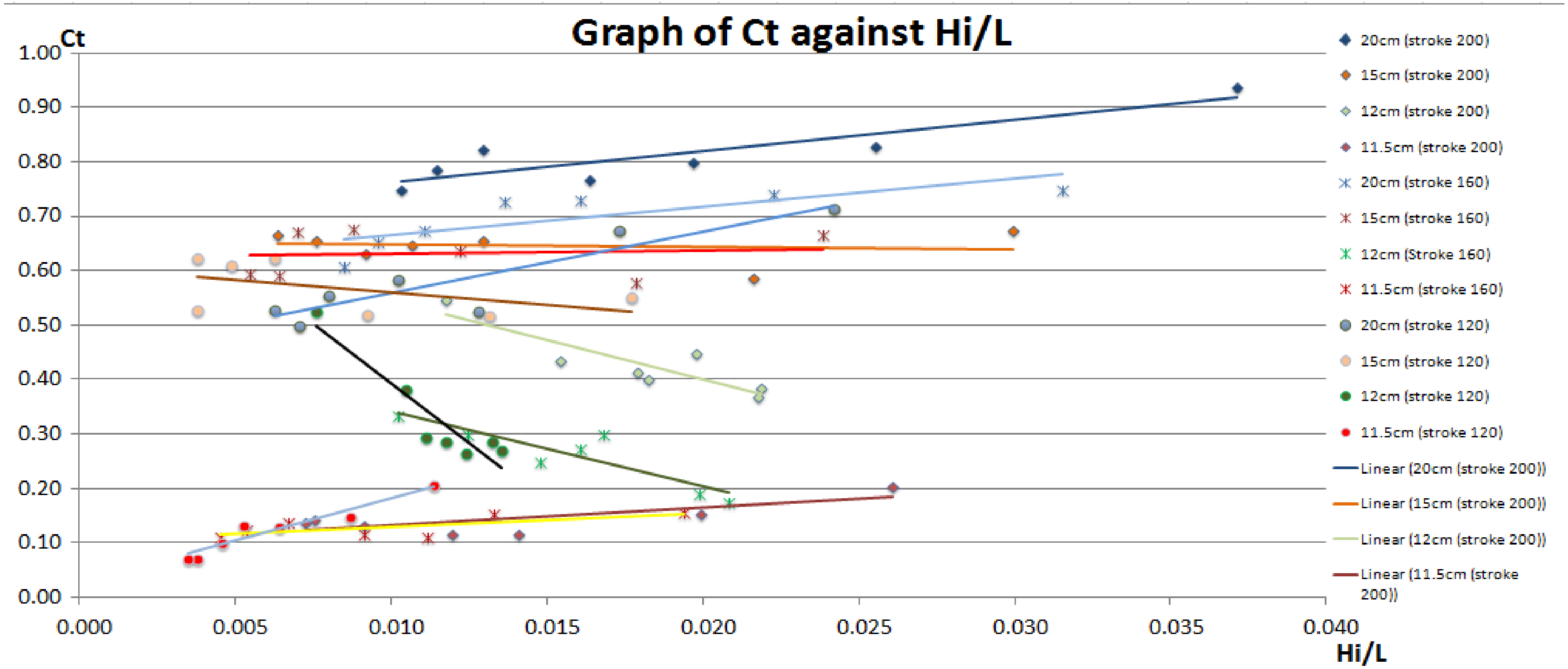

Figure 4.4: Graph of wave transmitted coefficient, Ct against wave steepness, Hi/L for all strokes and water depths for configuration 2

Configuration 2:

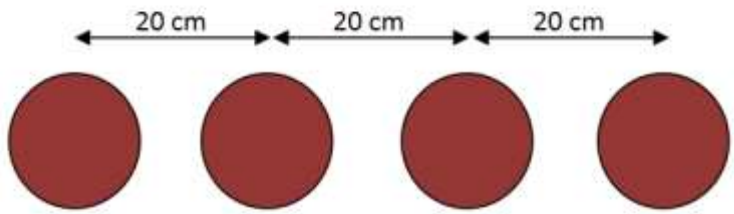

Figure 4.5: Configuration 2 of coir rolls

The wave transmitted coefficient, Ct are plotted against the wave steepness, Hi/L where Hi is the incident wave height and L is the wavelength. From the graph, it can be observed that at different strokes and water depths, the Ct values are not significant as the difference among another point is not much. However, the effect of water depth on the wave attenuation performance can be clearly seen. As the water depth decreases, the Ct values decreases as well. It can be observed that at all depths, the wave generated experiences attenuation but at different rates.

For the depth of 20 cm, it can be noticed that the trendlines of all three strokes 200, 160 and 120 shows an increasing pattern. This can be interpreted that as the wave steepness increases, the Ct value increases. Wave attenuation by the coir rolls is not effective at this depth. The wave attenuation at stroke 120 was the most effective one compared to stroke 200 and 160 as the Ct values at this stroke is the lowest. The performance of the coir rolls in attenuating waves at this depth was between 7% to 50% based on the Ct coefficient.

For the depth of 15 cm, the trendlines of all three strokes 200, 160 and 120 shows a decreasing pattern. It can be interpreted that the higher the wave steepness, the lower the Ct value. Wave attenuation at this depth was effective as at all strokes, the transmitted wave height was lower after passing the coir rolls. The wave attenuation at stroke 120 was the most effective compares to stroke 200 and 160 as the Ct values at this stroke is the lowest based on the rapid decrease in pattern observed from the trendline. The performance of the coir rolls in attenuating waves at this depth was between 33% to 49% based on the Ct coefficient.

For the depth of 12 cm, the trendlines of all three strokes 200, 160 and 120 shows a decreasing pattern. It can be interpreted that the higher the wave steepness, the lower the Ct value. Wave attenuation at this depth was effective as at all strokes, the transmitted wave height was lower after passing the coir rolls. The wave attenuation at stroke 160 was the most effective compares to stroke 200 and 120 as the Ct values at this stroke is the lowest based on the rapid decrease in pattern observed from the trendline. The performance of the coir rolls in attenuating waves at this depth was between 45% to 82% based on the Ct coefficient.

For the depth of 11.5 cm, the trendline of stroke 200 shows a slight increase which indicates that the higher the wave steepness, the higher the Ct value. Wave attenuation by the coir rolls at this depth is not effective. However, the trendline at stroke 160 shows a decrease which indicates that the higher the wave steepness, the lower the Ct value. The wave attenuation by the coir rolls is effective. The trendline of 120 shows an increase which can be interpreted that the higher the wave steepnesss, the higher the Ct value. The wave attenuation at this stroke is not effective. The performance of the coir rolls in attenuating waves at this depth was between 79% to 93% based on the Ct coefficient.

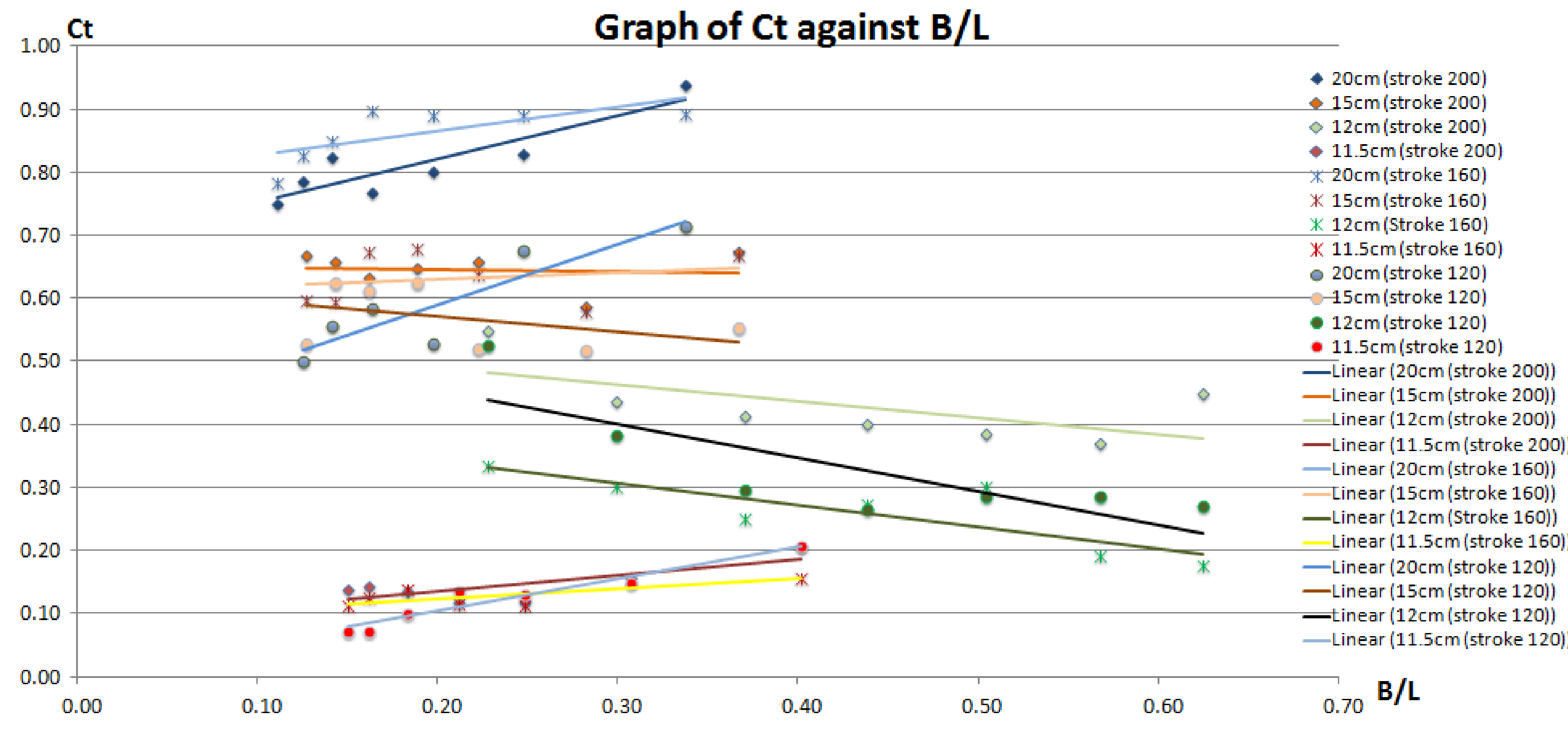

Figure 4.6: Graph of wave transmitted coefficient, Ct against coir rolls width, B/L for all strokes and water depths for configuration 2

The wave transmitted coefficient, Ct is plotted against the relative coir rolls width (B/L) where B is the coir roll width and L is the wavelength. As B/L increases, the Ct values changes for all water depths. Effect of water depths on the wave attenuation is not significant. The coir rolls are observed to be functioning better in shallow water depth as compared to the highest depth, 20 cm. It can be deduced that the deeper the water depth, most waves simply propogate over the coir rolls without much disturbance, causing the transmitted wave height to be higher. However, when the water level is the same as the coir rolls, the waves will be easily disturbed by the structure; hence the wave energy will be dissipated and the transmitted wave height will be significantly reduced.

For the depth of 20 cm, it can be noticed that the trendlines of all three strokes 200, 160 and 120 shows an increasing pattern. This can be interpreted that as the coir rolls width increases, the Ct value increases. Wave attenuation by the coir rolls is not effective at this depth. This is due to the coir rolls not causing much disturbance to the incident wave height due to the high depth tested which leads to the transmitted wave height to be higher. The wave attenuation at stroke 120 was the most effective one compared to stroke 200 and 160 as the Ct values at this stroke is the lowest. The performance of the coir rolls in attenuating waves at this depth was between 7% to 50% based on the Ct coefficient.

For the depth of 15 cm, it can be noticed that the trendlines of all three strokes 200, 160 and 120 shows a decreasing pattern. This can be interpreted that as the coir rolls width increases, the Ct value decreases. Wave attenuation by the coir rolls is effective at this depth. This is due to the coir rolls causing disturbance to the incident wave height due to the depth tested being nearer to the coir rolls which leads to the transmitted wave height to be lower. The wave attenuation at stroke 120 was the most effective one compared to stroke 200 and 160 as the Ct values at this stroke is the lowest. The trendline of stroke 120 shows a rapid decreases showing that the wave was attenuated as a fast rate at this stroke. The performance of the coir rolls in attenuating waves at this depth was between 33% to 49% based on the Ct coefficient.

For the depth of 12 cm, it can be noticed that the trendlines of all three strokes 200, 160 and 120 shows a decreasing pattern. This can be interpreted that as the coir rolls width increases, the Ct value decreases. Wave attenuation by the coir rolls is effective at this depth. This is due to the coir rolls causing disturbance to the incident wave height due to the depth tested being nearer to the coir rolls which leads to the transmitted wave height to be lower. The wave attenuation at stroke 160 was the most effective one compared to stroke 200 and 120 as the Ct values at this stroke is the lowest. The performance of the coir rolls in attenuating waves at this depth was between 45% to 82% based on the Ct coefficient.

For the depth of 11.5 cm, it can be noticed that the trendlines of all strokes 200 and 120 shows an increasing pattern whereas the trendline of stroke 160 shows a decrease. For the stroke fo 160, it can be interpreted that as the coir rolls width increases, the Ct value decreases. For strokes 200 and 120, it can be interpreted that as the coir rolls width increases, the Ct value increases. Wave attenuation by the coir rolls is effective at stroke 160. This is due to the coir rolls causing disturbance to the incident wave height due to the depth tested being nearer to the coir rolls which leads to the transmitted wave height to be lower. The wave attenuation at stroke 160 was the most effective one compared to stroke 200 and 120 as the Ct values at this stroke is the lowest. The performance of the coir rolls in attenuating waves at this depth was between 79% to 93% based on the Ct coefficient.

Range of Ct coefficients (minimum and maximum value) based on all the depths is showed in the table below:

Table 4.2: Ranges of Ct values for coir rolls of configuration 2

Depth (cm)	h/d ratio	Min Ct value	Max Ct value	Range of Ct value
20	0.57	0.50	0.94	0.50-0.94
15	0.77	0.52	0.68	0.52-0.68
12	0.96	0.18	0.55	0.18-0.55
11.5	1.00	0.07	0.21	0.07-0.21

From the table above, it can be interpreted that the coir rolls attenuated the waves effectively at the depth of 11.5 cm as the range of Ct values at this depth are the lowest compared to the ranges of other depths. Due to the wave being obstructed more by the coir rolls, the transmitted wave height was lower causing the Ct coefficient to be lower.

4.3 Comparison of Configurations of Coir Rolls

Comparing the ratios of the Ct values obtained for configuration 1 and configuration 2 of the coir rolls, it can be said that configuration 2 was more effective as the Ct values are much lower compared to configuration 1. This could be due to the fact that when waves travel over a distance of obstruction by the coir rolls, it attenuates the waves more rather than coir rolls arranged right next to each other. Configuration 1 covers a distance of 46 cm in the wave flume whereas configuration 2 covers a distance of 106 cm in the wave flume. This shows that configuration 2, which has gaps of 20 cm between coir rolls, attenuates wave more effectively because as the wave travels over a distance, the wave experiences frictional force for a longer period of time when it passes the coir rolls. Based on the ranges of Ct values for both configurations, it can be observed that configuration 2 attenuated waves better than configuration 1 by 21% at the depth of 11.5 cm. The depth of 11.5 cm was chosen for comparison as it is at this depth that both configurations of coir rolls attenuated the waves most effectively.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The wave attenuation on the coir rolls was successfully investigated for two different configurations of coir rolls tested with respective depths of 20 cm, 15 cm, 12 cm and 11.5 cm. For configuration 1, the ranges of Ct coefficients showed that the most effective wave attenuation by the coir rolls was at depth 11.5 cm, exactly the height of the coir rolls. The performance of the coir rolls in attenuating waves at the depth of 11.5 cm was between 56% to 74% based on the Ct coefficient. For configuration2, the ranges of Ct coefficient showed that the waves were attenuated the best at the depth of 11.5 cm. The performance of the coir rolls in attenuating waves at this depth was between 79% to 93% based on the Ct coefficient. Comparing both configurations, configuration 2 proved to attenuate wave better than configuration 1.

5.2 Recommendation

Based on the experiment conducted, there are some recommendations to be made:

1. Human error may exist due to the incident wave height and transmitted wave height being recorded without a wave probe. It is recommended to get a wave probe in recording data for the experiment mentioned above to obtain results as accurate as possible.

2. More configurations should be tested out for this wave attenuation by coir rolls experiment to obtain the best configuration for wave attenuation purposes.

REFERENCES

[1] L. Janke, *"Erosion Control Methods and the Effect on Beach Succession," senior thesis, Department of Biology, Environmental Science, Geography, 2006.*

[2] L. Airoldi, M. Abbiati, M. W. Beck, S.J. Hawkins, P. R. Jonsson, D. Martin, P. S. Moschella, A. Sundelof, R.C. Thompson, and P. Aberg, "An ecological perspective on the deployment and design of low crested and other hard coastal defense structures," *Low Crested Structures and the Environment,* vol. 52, (10-11), pp. 1-73-1087, 2005.

[3] M. R. Phillips and A. L. Jones, "Erosion and tourism infrastructure in the coastal zone: Problems, consequences and management," *Tourism Management*, vol. 27, (3), pp. 517-524, June 2006.

[4] Santa Aguila Foundation. (2015, February): The Negative Impacts of Groins [Online]. Available: http://coastalcare.org/2009/02/the-negative-impacts-of-groins/

[5] Bas W. Borsje, Bregje K. van Wesenbeeck, F. Dekker, P. Paalvast, T. J. Bouma, M. M. v. Katwijk and M. B. d. Vries, "How ecological engineering can serve in coastal protection," *Ecological Engineering*, vol. 37, 20, pp. 113-122, February 2011.

[6] Australian Government, Department of the Environment. (2011)" 11 Coasts | 2 Major issues for coastal environments | 2.7 Population Growth and urban development [Online]. Available: https://www.environment.gov.au/science/soe/2011-report/11-coasts/2-major-issues/2-7-population

[7] L. H. Knapp, (1997). Use of Manufactured Materials in Shoreline Restoration Projects. *Restoration and Reclamation Review.* [Online]. 1 (2). Available: http://conservancy.umn.edu/bitstream/handle/11299/58744/1/2.2.Knapp.pdf

[8] Emily Jack. (2007). Coastal erosion and the ban on hard structures. [Online]. Available: http://www.learnnc.org/lp/editions/nchist-recent/6374

[9] Beachpedia. (n.a.). Shoreline Structures. [Online]. Available: http://www.beachapedia.org/Shoreline_Structures

[10] Duke Energy. (n.a.). Stabilization Techniques. [Online]. Available: https://www.duke-energy.com/shoreline-stabilization/stabilization-techniques.asp

[11] Technical Supplement 14I. (2007, August). Streambank Soil Bioengineering. [Online]. Available: https://www.nh.gov/dot/org/projectdevelopment/highwaydesign/documents/StreamlineSoilBioEng.pdf

[12] G. H. Donald and S. B. Robbin, “Biotechnical and Soil Bioengineering: Slope Stabilization”. 1996. Available: https://books.google.com.my/books?hl=en&lr=&id=kCbp6IvFHrAC&oi=fnd&pg=PA1&dq=examples+of+bioengineering+measures+for+coastal+protection&ots=JRcdJ_Stah&sig=SfGWWS6P-lSwOx84wHERCb1ilU8&redir_esc=y#v=onepage&q&f=true

[13] SCIENTIFIC AMERICAN. (2008, December). What Causes Beach Erosion? [Online]. Available: http://www.scientificamerican.com/article/what-causes-beach-erosion/

[14] Climate Central. (2012, May). Climate Change, Sea Level Rise Spurring Beach Erosion. Available: http://www.climatecentral.org/news/its-beach-season-enjoy-it-while-you-can

[15] P. John. (January, 2001). Coastal Management and Sea Level Rise. *CATENA.* [Online]. *Volume 42 (Issues 2-4),* pp. 307-322. Available: http://www.sciencedirect.com/science/article/pii/S0341816200001430

[16] S. Vera and N. Alice. (December, 2015). Overview of erosion and beach quality issues in three Southern European countries: Portugal, Spain and Italy. *Ocean & Coastal Management.* [Online]. *Volume 118, Part A,* pp 12-21. Available: http://www.sciencedirect.com/science/article/pii/S0964569115300120

[17] P. F. David. “Soil Bioengineering For Site Restoration” M. Sc, Boreal Research Institute, 2013.

[18] C. W. Wei and T. C. Daniel. (October, 2015). Effects of wave steepness and relative water depth on wave attenuation by emergent vegetation. *Estuarine, Coastal and Shelf Science.* [Online]. *Volume 164,* pp 443-450. Available: http://www.sciencedirect.com/science/article/pii/S0272771415300664

[19] RVCA (March, 2011). Solutions for Shoreline Erosion; A Basic Guide to Bioengineering. [Online]. Available: http://www.rvca.ca/PDF/SolutionsforShorelineErosion_PDF_EN1.pdf

[20] K. S. Beena (April, 2013). Case Studies on Application of Coir Geotextiles for Soil Stabilization. Presented on Seventh International Conference on Case Histories in Geotechnical Engineering. [Online]. Available: http://scholarsmine.mst.edu/cgi/viewcontent.cgi?article=3360&context=icchge

[21] M. Nadira (2012). Sustainable Coastal Engineering in the Caribbean: A Coir Fiber Approach. Presented on ICE Young Professionals and Students Paper Competition 2012. [Online]. Available:

http://iceusa.org/GS2%20N%20Mathura_Sustainable%20coastal%20engineering%20in%20the%20carribean.pdf

[22] D. H. Gray and R. B. Sotir, "Introduction to Biotechnical Stabilization" in *Biotechnical and Soil Bioengineering Slope Stabilization,* A Wiley-Interscience Publication, 1996, pp. Chapter 1. Available: https://books.google.com.my/books?hl=en&lr=&id=kCbp6IvFHrAC&oi=fnd&pg=PA1&dq=coastal+erosion+prevention+using+bioengineering+solution&ots=JRckIVYl2k&sig=TVvMMfoi40b_BVrl9bFrknyexX4&redir_esc=y#v=onepage&q=coastal%20erosion%20prevention%20using%20bioengineering%20solution&f=false

[23] L. N. Augustin, J. L. Irish and P. Lynett, "Laboratory and numerical studies of wave damping by emergent and near-emergent wetland vegetation," *Science Direct*, vol. 56 (3), pp. 332-340, 2009. Available: http://www.sciencedirect.com/science/article/pii/S037838390800152X

[24] M. E. Anderson, J. M. Smith and S. K. Mckay, "Wave dissipation by Vegetation," *US Army Corps of Engineers,* 2011. Available: file:///C:/Users/Acer/Downloads/Wave_dissipation_by_vegetation_US_4073.pdf

[25] T. Suzuki, M. Sijlema, B. Burger, M. C. Meijer and S. Narayan, "Wave dissipation by vegetation with layer schematization in SWAN," *Science Direct,* vol. 59 (1), pp. 64-71, 2012. Available: http://www.sciencedirect.com/science/article/pii/S0378383911001347

[26] A. J. Rella and J. K. Miller, "Engineering Approaches for Limiting Erosion along Sheltered Shorelines: A Review of Existing Methods," *Hudson River National Estuarine Research Reserve,* 2012. Available: http://www.dec.ny.gov/docs/remediation_hudson_pdf/limiteros.pdf

[27] L. Allen and M. Smout, "The Retreating Village". Available: http://discovery.ucl.ac.uk/9740/1/9740.pdf