STUDY OF RECIRCULATING FLOW AROUND COASTAL STRUCTURE BY USING LABSWE™

by

Ahmad El Afify Bin Mohd Safri

19091

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

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Universiti Teknologi PETRONAS

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Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL)

Approved by,

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(Dr Siti Habibah binti Shafiai)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

September 2017

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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AHMAD EL AFIFY BIN MOHD SAFRI

ABSTRACT

Breakwaters that are built at coastal area is a type of hard protection measure to protect the coastline, port, harbour or estuaries from the hydrodynamic effects due to severe waves condition. However, the presence of breakwaters will disrupt the natural condition of flow by dissipating, reflecting and refracting the incoming waves to produce calmer waves at the leeside of the structure. Thus, the flow separation occurs due to the blockade of breakwater which forming the recirculating flow inside the breakwater. This study is to simulate the recirculating flow around the breakwater at Chendering Fishery Port, Terengganu, Malaysia by using Lattice Boltzmann Method for shallow water equation with turbulence modelling (LABSWE^{TM}). The results of recirculating flow are analysed in the perspective of flow pattern and flow velocity. Three values of significant waves heights of 1.45m, 1.24m and 0.4m were tested for varying Lattice size of 180 × 130 and 90 × 64. The values were taken from Malaysia Meteorological Department (MMD) for year 2012 to 2016 and a literature which studied the significant waves heights at Terengganu coastline from 1998 to 2009. The results show the recirculating flow regions at the leeside of the breakwater which found to be one of the cause of sediment deposition. The high flow velocity is recorded at the breakwater head which is found to be because of the wall boundary implemented in the simulation and this situation is unlikely to happen at the real site condition. The sediments accumulated at the area behind of the breakwater is because of longshore sediment transport which is triggered by longshore current especially during Northeast Monsoon (NEM).

ACKNOWLEDGMENT

All praise is due to Allah The Almighty for His blessings and thanks for the strength which always makes me encourage to complete my Final Year Project (FYP) despite all the challenges.

My journey as a student is overwhelmed by wonderful people who always be there for me to complete this project in almost eight months. First of all, I would like to express my deepest gratitude and appreciation to my supervisor Dr Siti Habibah binti Shafiai for her continuous support and guidance from the beginning until the end of the project.

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Last but not least, I would like to thank Malaysia Meteorological Department (MMD) for giving me the required data for the use of the project and for those who contributed directly or indirectly towards accomplishing this project. Thank you.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Waves transmit energy which propagating from its formation location and has the potential to travel across the ocean. As the waves reach the shore, energy will be dissipated. The seemingly endless phenomenon will change the shape of the shore since erosion, transportation and deposition of sediments will take place as time goes by. The effects on the shore will become worst during high tide and storm. Recently, a few houses located near the shoreline at Tok Jembal Beach, Terengganu, Malaysia were destroyed by rough seas forcing the state government to approve funds in constructing the beach revetments which will preventing further erosion (Zakaria, 2016).

A preventative measure must be taken to preserve the coastline and estuary by constructing coastal structures such as breakwater. Breakwaters are usually built to provide protection for the beach, harbour or port by dissipating, reflecting and refracting the incoming waves which resulting in the formation of calm wave. The waves condition will be disturbed by constructing the breakwaters at coastal waters (Widagdo et al., 2015). However, according to Hsu, Hsieh, & Hwang (2004) who did the studied on vortex generation around impermeable submerged double breakwaters saying that a vortex flows that formed due to submerged obstacle may resulted in scouring effect on structures which can lead to structural failure in many cases.

Scouring process may occur along the length of trunk in front of the breakwater and around the head of breakwater (Gislason, Fredsøe, & Sumer, 2009). This is due to the flow depth is relatively shallow as compared with the size of obstruction which producing recirculating flow at the surface of water (Escarameia, 1999).

Therefore, this paper is intended to study the circulating flow around the coastal structure in order to prevent the scouring effects on the stability or structural integrity of the constructed structure. The study will be executed using lattice Boltzmann method for shallow water equation using turbulence modelling (LABSWE^{TM}) which is proposed by Zhou (2004).

Lattice Boltzmann method (LBM) is a recent numerical technique which turns out to be effective in solving shallow water equations due to its simplicity, efficiency and accuracy as compared with traditional computational fluid dynamics (CFD). Hence, numerical solution by using LBM is a superlative tool in studying numerous flow problems occurring in ocean, environmental and hydraulic engineering (Zhou, 2004). Previous study regarding recirculation flows in complicated channel geometries has been done by Shafiai (2011) using LABSWE^{TM}. The study is successfully validated by analysing five different types of shallow water flow problems which are turbulent flow within a channel with a circular cavity, flow within an open-channel with a spur-dike, turbulent flow within a single expansion open-channel, turbulent flow within a double expansion open-channel and turbulent jet-forced flow in symmetrical and asymmetrical circular basins. The advantage of LABSWE^{TM} to examine complicated flows is becoming the best method to carry out the study in demonstrating recirculation flow around the chosen coastal structure as a case study.

In conclusion, the study will be carried out based on the constructed breakwater which is located at Chendering Fishery Port, Terengganu, Malaysia. From an observation using Google Earth, the recirculating flow and scouring are predicted to be generated at the head of breakwater where the waves coming in. The hypothesis is made due to the real situation on site where the presence of sand sediments deposited inside the area of breakwater can be observed. This phenomenon need to be prevented in order to maintain the stability and maximise the functionality of the structure which is constructed to protect the harbour facilities including ships. Similar to bridges constructed using shallow foundations, they were found to fail due to scouring effects because of turbulence and vortex shedding generated when the river stream hit the piers (Zampieri, Zanini, Faleschini, Hofer, & Pellegrino, 2017). Thus, the study is undeniably essential to prevent the same failure from happening to the breakwater which also found to fail due to scouring in Oumeraci (1994), Lillycrop and Hughes (1993) and Sumer and Fredsøe (2002).

Figure 1: Breakwater at Chendering Fishery Port, Terengganu, Malaysia

1.2 Problem Statement

Waves that striking the breakwater will generate a recirculating flow where the change in direction and acceleration of the flow occur during the collision. The increasing flow velocity and turbulence will hasten the scouring process around the coastal structure since the soil can be loosened and suspended by this process (Hurricane Ike Recovery Advisory, 2009). The suspended soil will be deposited when the flow become calm. The endless phenomenon of scouring because of recirculating flow is expected to give impacts to the stability of structure which indeed need to be prevented.

1.3 Objectives

- To simulate the recirculating flow around coastal structure by using LABSWE^{TM}.
- To validate the result of simulation with previous research by Shafiai (2011) which studied about recirculating flow around spur-dike within an open channel using LABSWE^{TM}.
- To analyse the recirculating flow in the perspective of flow pattern and flow velocity that will be generated from the simulation.

1.4 Scopes of Study

The study of recirculating flow will be carried out around the breakwater which is located at Chendering Fishery Port, Terengganu, Malaysia with coordinate 5.0 – 5.4 North and 103.0 – 104.0 East. The waves height from year 2012 to 2016 are received from Malaysian Meteorological Department (MMD) based on ship observations to get the real waves condition at the study area. Besides, the waves conditions are also influenced by two seasonal monsoons which are Northeast Monsoon (NEM) and Southwest Monsoon (SWM). Therefore, the highest values of average monthly significant waves heights are taken into consideration during the two monsoons which are from November to March for NEM and from May to September for SWM. From the data, a regular wave will be simulated to represent the wave at the area of study. Meanwhile, the dimensions of breakwater and the area at the leeside are measured using the distance measurement tool in Google Map. The breakwater constructed at the area is from sloping-front type of breakwater which using concrete cube as the armour layer. The simulation will be done by scaling down the breakwater to simulate and run the analysis using LABSWE^{TM} on MATLAB software.

CHAPTER 2

LITERATURE REVIEW

2.1 Flow within An Open Channel with Spur-dike

Shafiai (2011) was applying LABSWE^{TM} in studying recirculation flow which related to problems that usually occurred in shallow water flow. Hence, the study of flow in an open channel with the presence of spur-dike will be used to validate this research on the recirculating flow around the coastal structure.

Spur-dike is defined as a river projected structure adjacent from the riverbank to the main flow that is usually used in changing the flow of water in a river (Molls and Chaudhry, 1995). But, the presence of the structure may result the flow to be separated and recirculated. The recirculating flow generated can cause the scouring process in the river (Yazdi et al., 2010). Same goes to the breakwater constructed at the coastal area which is expected to produce similar effect with the presence of spur-dike in the river.

The test is validated with the laboratory experiment conducted by Nwachukwu (1979) which investigated this problem using a rectangular channel flume with 37m long and 0.9m wide of dimension. A 0.003m thick and 0.152m long structure projected above the surface of the water is used to represent the spur-dike as illustrated below.

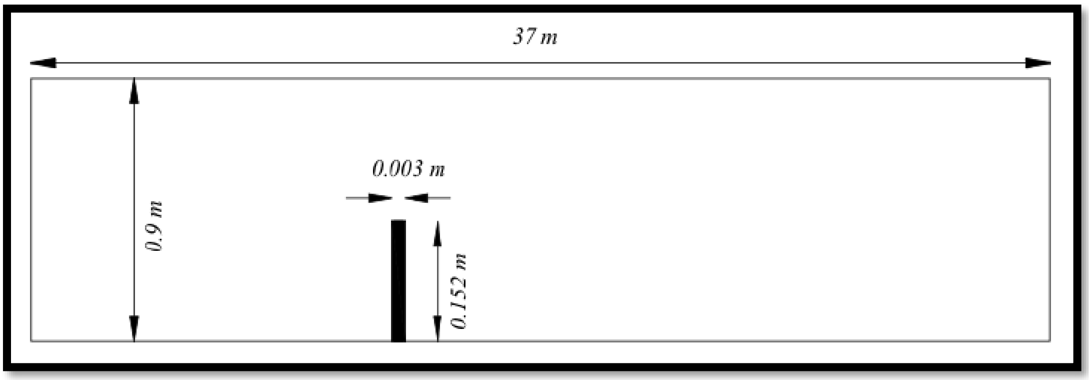

Figure 2: Illustration of channel flume with spur-dike (Shafiai, 2011)

A similar concept is modelled by Shafiai (2011) using 900 × 900 square Lattice with the input parameters $\Delta t = 0.005s$, $\Delta x = 0.01m$ and $\tau = 0.62$. The Smagorinsky constant $C_s = 0$ is applied to produce laminar flow condition. The velocity components at the upstream are set to $u = 0.253m/s$ and $v = 0m/s$. Meanwhile, the water depth is set to $h = 0.189m$ with extrapolated velocity components at the downstream.

After the 20000 iterations, the flow reached steady state with $E_R = 2.03 \times 10^{-9}$. E_R is defined as relative error in the velocities between two-time steps which is used in the computation. The velocity vector of the flow is shown below.

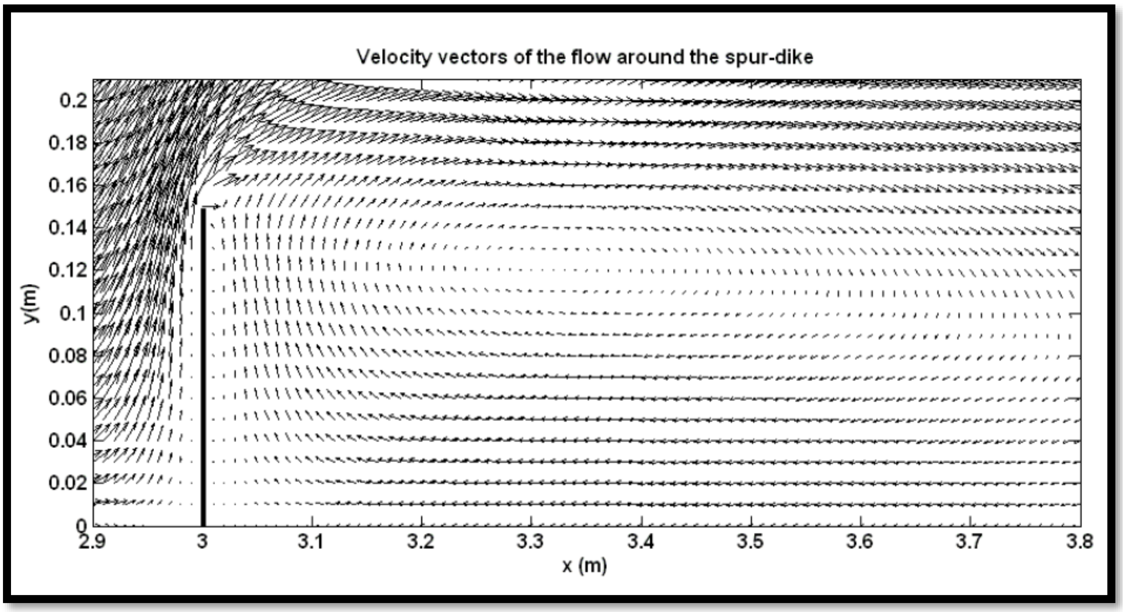

Figure 3: Velocity vectors of the flow around the spur-dike (Shafiai, 2011)

From the observation, as the flow passing through the spur-dike, the velocity vectors are the highest and the formation of recirculation eddy can be seen after the structure.

Then, Shafiai (2011) has compared the numerical results of water profiles with the experimental value which conducted by Nwachukwu (1979) at variable transversal locations for non-dimensional velocity along flow direction. As conclusion, the comparison was acceptable for all locations except for $\frac{y}{b} = 2$, where a huge variation from the experimental data can be seen at the downstream of the spur. After comparing from other numerical method done by Molls and Chaudhry (1995) and Tingsanchali and Maheswaran (1990), the data from experimental data may be inaccurate for that location only (Shafiai, 2011).

2.2 The Effect of Spur-dike on Sedimentation Pattern

A numerical study was carried out by Giglou, McCorquodale and Solari (2007) to analyze flow pattern including velocity distribution and water surface profile of flow around the spur-dike with variable angle and position which causing scouring. Thus, spur-dikes with angle 45, 75, 90, 105 and 120 degrees were simulated by using Flow-3D numerical model.

From the simulation, it is found that the flow velocity increases when the flow passing the head of the spur-dike and the velocity decreases at the downstream. Therefore, vortex is generated due to high flow impact and flow inversion to the spur-dike at the upstream which causing the scouring to happen. As the flow passed by the spur-dike, the flow separation causing the formation of big vortex with lower velocity which caused sedimentation.

Furthermore, the length and width of vortex generated is affected by the angle of the spur-dike relative to the flow direction. Consequently, the researchers have concluded that the length and width of sedimentation increase by 71 percent and 92 percent respectively when the angle of the spur-dikes increase from 45 to 120 degrees.

2.3 The Interaction Between Incident Waves and Vertical Breakwaters

A two-dimensional Reynolds Averaged Navier Stokes model was developed by Yeganeh-Bakhtiary, Hajivalie and Hashemi-Javan (2010) to simulate the hydrodynamic process during the interactions between incident waves and vertical breakwaters. From the study, it was found that the formation of turbulence fields of steady streaming in the partially standing waves is prevented when the wave overtopping the vertical breakwater. Meanwhile, the turbulence fields clearly can be seen in the fully standing waves formed in front of the breakwater. However, each type of waves is having a significant impact to the scouring or deposition pattern in front of the impermeable vertical breakwater.

The analysis has been done at the nodes and anti-nodes in the fully standing waves condition which yielded the higher results of wave height, and horizontal and vertical velocities individually as compared with partially standing waves condition. Yet, in both types of waves produced a significant increment of turbulence parameters at the overtopping region where the wave breaking occurs over the breakwater crown. Hence, the effect of turbulence in front of the breakwater is reduced which can be seen in the partially standing waves condition.

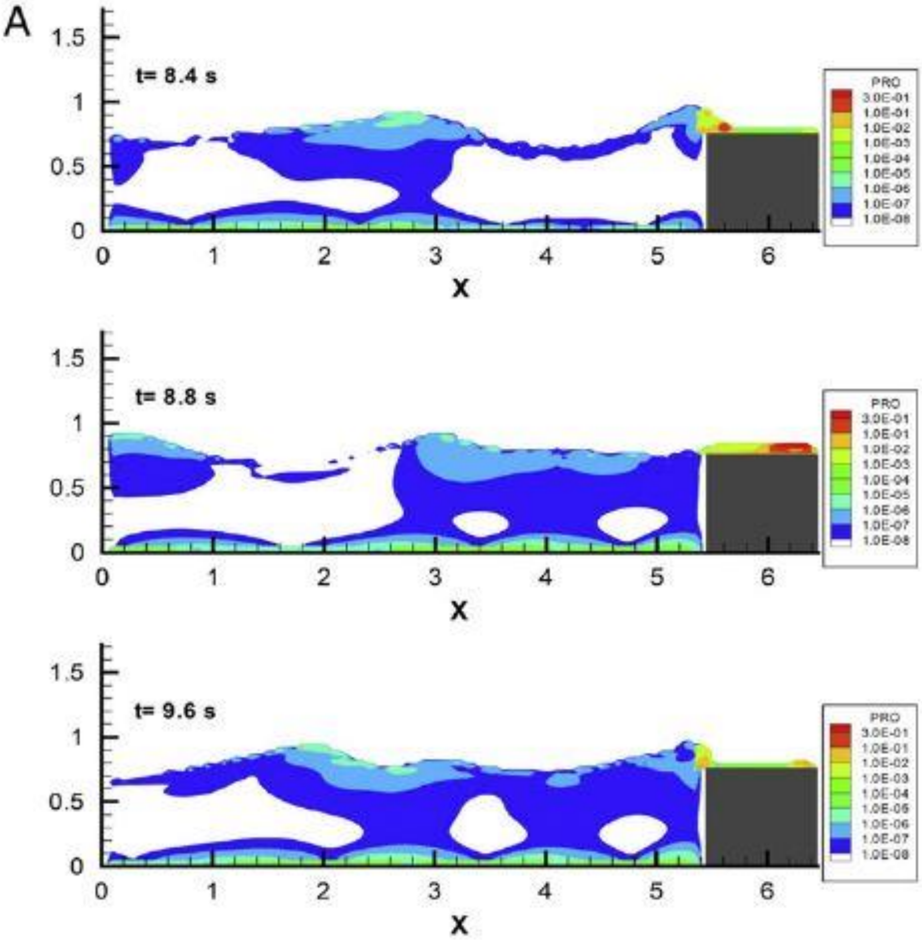

Figure 4: Turbulence formation due to overtopping during a wave period for partially standing waves (Yeganeh, et al., 2010)

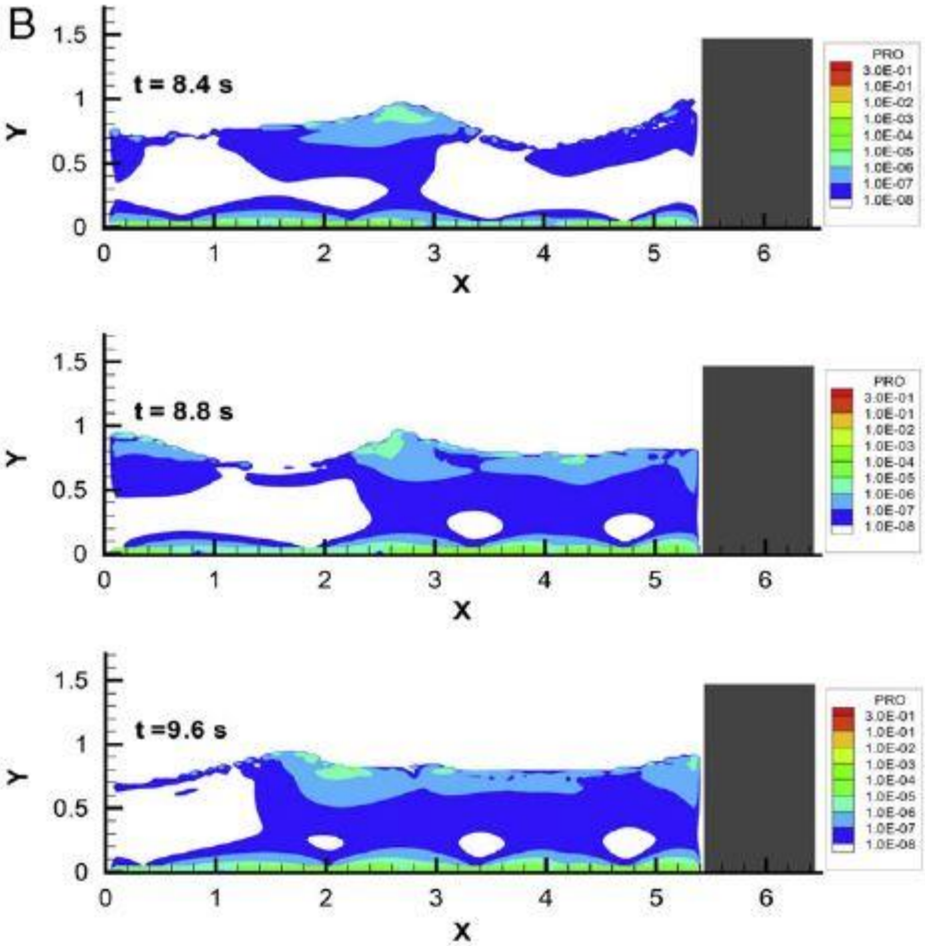

Figure 5: Turbulence formation during a wave period for fully standing waves (Yeganeh, et al., 2010)

In conclusion, the vertical wall of breakwater which is facing to the sea played an important role in the formation of turbulence for the case of fully standing waves. Whereas, for the case of partially standing waves, the wave that overtopping the breakwater crown will induced the effect of turbulence in front of the breakwater.

CHAPTER 3

METHODOLOGY

3.1 Lattice Boltzmann Method (LBM)

Numerical method is seen to be the most reliable and accurate to solve problems related to shallow water equation with requirement of complex conditions for variable topography (Shafiai, 2011). Thus, this study will be using a lattice Boltzmann model for shallow water flows which taking turbulence flow into consideration using LABSWE™ that has been proposed by Zhou (2002). As referred to lattice Boltzmann theory, LBM is made up of two main steps which are streaming and collision steps (Zhou, 2004). The streaming step is defined as the movement of particles towards neighbouring lattice points with respective directions of their velocities which is governed by

$$f_\alpha(x + e_\alpha \Delta t, t + \Delta t) = f'_\alpha(x,t) + \frac{\Delta t}{N_\alpha e^2} e_{\alpha i} F_i(x,t) \ , \qquad (3.1.1)$$

where $f_\propto$ is the particles distribution function; $f'_\propto$ is the value of $f_\propto$ before the streaming; $e = \Delta x / \Delta t$ where lattice size is denoted as Δx and time step is Δt; *Fi* is the force component in *i* direction; $e_\propto$ is the particle velocity vector in the $\propto$ link and *Na* is a constant, which is decided by the lattice pattern as

$$N_\alpha = \frac{1}{e^2} \sum_\alpha e_{\alpha x} e_{\alpha x} = \frac{1}{e^2} \sum_\alpha e_{\alpha y} e_{\alpha y} \ . \qquad (3.1.2)$$

Subsequently, as per scattering rules, the arriving particles at the points interact one another and change their velocity directions is defined as collision step which is stated as

$$f'_{\alpha}(x,t) = f_{\alpha}(x,t) + \Omega_{\alpha}[f(x,t)] \ , \qquad (3.1.3)$$

where the speed of change in $f_{\propto}$ during collision is controlled by the collision operator, Ω_{α}.

In general, Ω_{α} is a matrix gained by the microscopic dynamics. An idea to simplify the collision operator around its local equilibrium state was first presented by Higuera and Jimenez (1989). By using the fundamental on this idea, Noble, Chen, Georgiadis & Buckius (1995) have expanded Ω_{α} about its equilibrium value as follows

$$\Omega_{\alpha}(f) = \Omega_{\alpha}(f^{eq}) + \frac{\partial \Omega_{\alpha}(f^{eq})}{\partial f_{\beta}} \left(f_{\beta} - f_{\beta}^{eq}\right) + 0\left[\left(f_{\beta} - f_{\beta}^{eq}\right)^{2}\right] \ , \qquad (3.1.4)$$

where f^{eq} is denoted as the local equilibrium distribution function.

As the higher-order terms in equation (3.1.4) are neglected, a linearized collision operator is obtained below by implying $\Omega_{\alpha} \ (f^{eq}) \approx 0$.

$$\Omega_{\alpha}(f) \approx -\frac{\partial \Omega_{\alpha}(f^{eq})}{\partial f_{\beta}} \left(f_{\beta} - f_{\beta}^{eq}\right) \ . \qquad (3.1.5)$$

Assuming $f_{\beta} \rightarrow f_{\beta}^{eq}$, and the local particle distribution relaxes to an equilibrium state at a single rate τ (Fuhrman and Madsen, 2008; Titov and Synolakis, 1995) produces

$$\frac{\partial \Omega_{\alpha}(f^{eq})}{\partial f_{\beta}} = -\frac{1}{\tau}\delta_{\alpha\beta} \ , \qquad (3.1.6)$$

where $\delta_{\propto\beta}$is the Kronecker delta function:

$$\delta_{\propto\beta} = \begin{cases} 0 & \propto \neq \gamma, \\ 1 & \alpha = \beta. \end{cases} \qquad (3.1.7)$$

Hence, equation (3.1.5) can be revised as:

$$\Omega_{\alpha}(f) = -\tfrac{1}{\tau}\delta_{\alpha\beta}\left(f_{\alpha} - f_{\alpha}^{eq}\right) = -\tfrac{1}{\tau}\delta_{\alpha\beta}\left(f_{\beta} - f_{\beta}^{eq}\right) \ , \qquad (3.1.8)$$

resulting in the lattice Bhatnagar-Gross-Krook (BGK) model collision operator,

$$\Omega_{\alpha}(f) = -\tfrac{1}{\tau}\left(f_{\alpha} - f_{\alpha}^{eq}\right) \ , \qquad (3.1.9)$$

and τ is termed as the single relaxation time. The streaming and collision steps can be simplified efficiently by substituting equation (3.9) into lattice Boltzmann equation (3.3) which can be presented as follows

$$f_{\propto}(x + e_{\alpha}\Delta t, t + \Delta t) - f_{\alpha}(x,t) = -\frac{1}{\tau}(f_{\alpha} - f_{\alpha}^{eq}) + \frac{\Delta t}{N_{\alpha}e^{2}} e_{\alpha i}F_{i} \qquad (3.1.10)$$

3.2 Lattice Boltzmann Method with Turbulence Modelling

According to Zhou (2004), the momentum equation of shallow water between non-turbulent flow and turbulent flow can be differentiate with the presence of eddy viscosity v_e which is only used in computation of turbulent flow. The effects of the flow turbulence must be derived in the flow equations to consider the turbulence flow in shallow water flows by redefining the relaxation time, τ_t as follows

$$\tau_t = \tau + \tau_e \tag{3.2.1}$$

which gives a total viscosity, v_t,

$$v_t = v + v_e \tag{3.2.2}$$

thus, forming a new lattice Boltzmann equation,

$$f_\propto(x + e_\propto \Delta t, t + \Delta t) - f_\alpha(x,t) = -\frac{1}{\tau_t}\left(f_\alpha - f_\alpha^{eq}\right) + \frac{\Delta t}{6e^2} e_{\alpha i} F_i \tag{3.2.3}$$

3.3 Simulation Parameters

Table 1: Input parameters

LABSWE™ Parameters			
Domain Area (m^2)	900 × 640	Water Depth, h_0 (m)	2.218
Lattice Spacing, Δx (m)	5 & 10	Density, ρ (kg/m^3)	1027
Time Step, Δt (s)	0.01	Relaxation Time, τ	0.65

Data processing is done to obtain parameters needed in determining wave characteristics including water depth (h_0), significant waves heights (H_s). First of all, water depth (h_0) for the area is based on mean sea level (MSL) which is 2.218m. The value is obtained from DID Manual Book 2013 and derived from 28 years observation period that starting from 1985 to 2012. Meanwhile, significant wave height (H_s) is derived by using up crossing method and based on the 5 years ship observations data from 2012 to 2016 which yielded a value of 1.45m. The two values of the highest monthly average of significant waves heights during NEM and SWM periods are extracted from a research done by Muzathik, Wan Nik, Ibrahim, & Samo (2010). They studied on the waves data from January 1998 to August 2009 and come out with the variation of monthly average significant waves heights. Therefore, the highest value for NEM and SWM are taken as 1.24m and 0.4m respectively. Next, two lattice sizes will be used to test the variation of significant waves heights on the formation of recirculating flow which are 180 × 128 and 90 × 64 with fixed value of time step (Δt), density (ρ) and relaxation time (τ). The breakwater is assumed to be impermeable where the sediments are restricted to pass through along the trunk section that facing the open sea.

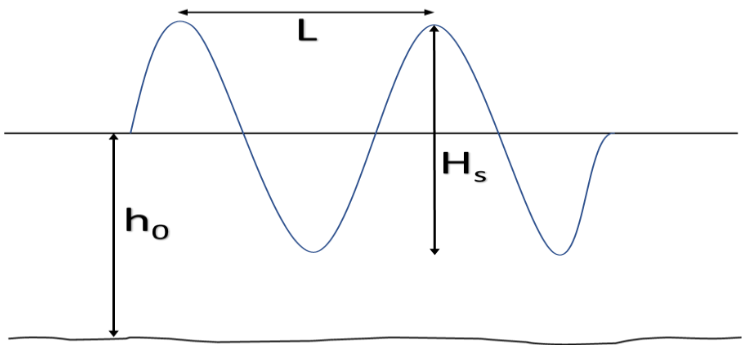

Figure 6: Typical wave cross section

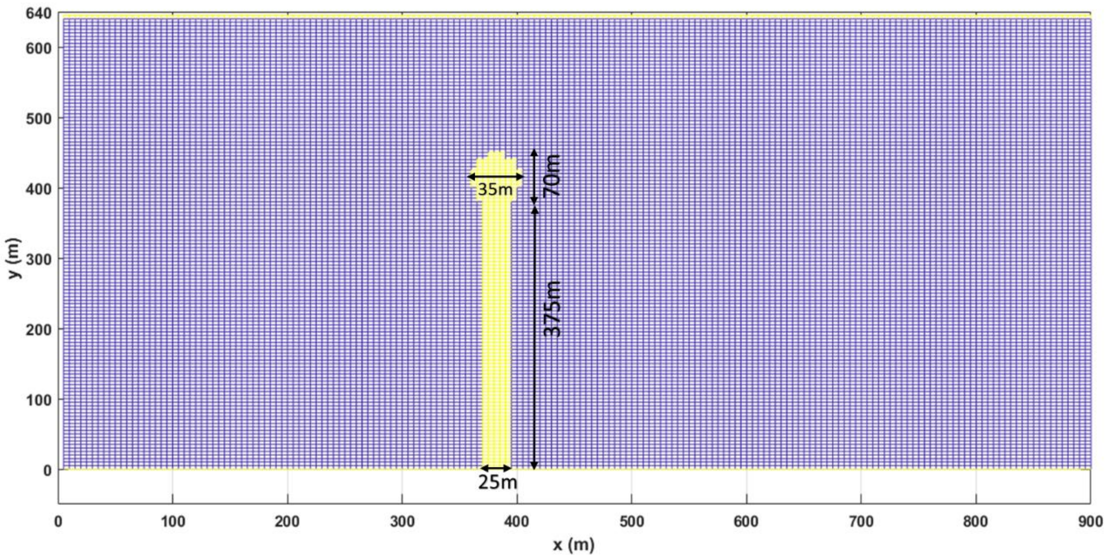

Figure 7: Dimension of the study area (plan view)

3.4 Tool Required

This project will be executed by using LABSWE™ on MATLAB software which stands for Matrix Laboratory according to Houcque (2005). It is a high-performance language for technical computing. The simulation is planned to be run using MATLAB due to its ability to handle numerical expressions and mathematical formulas. The lattice Boltzmann method for shallow water equations by using turbulence modelling will be converted into coding to demonstrate the recirculating flow around the breakwater.

3.5 Project Key Milestones

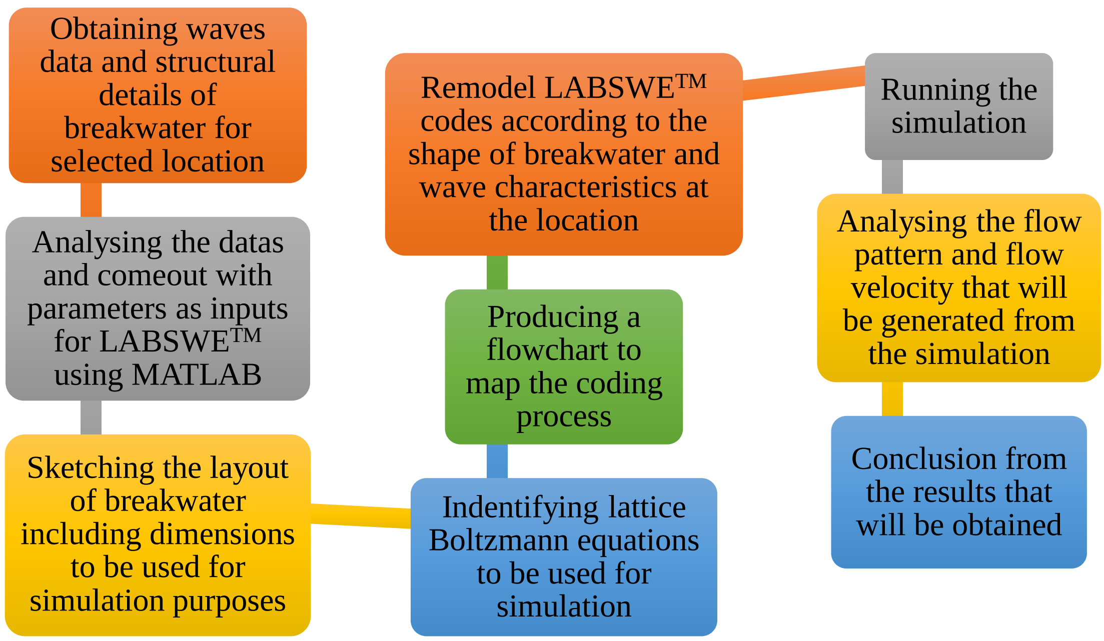

Figure 8: Key Milestones for Final Year Project

3.6 Gantt Chart

Table 2: Gantt chart for FYP I

Project Activities	Week													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Confirmation of the research topic with the supervisor	■													
Briefing by the supervisor regarding the research scope and area	■	■												
Introduction to LABSWE^{TM} coding and MATLAB software training			■											
Choosing the location of coastal structure to study the recirculating flow			■	■										
Gathering data required for the study				■	■	■								
Preparing the extended proposal				■	■	■								
Submission of the extended proposal						■								
Sketching the layout of breakwater including dimensions to be used for simulation purposes						■	■							
Producing a flowchart to map the coding process for the simulation						■	■							
Coding of LABSWE^{TM} using MATLAB							■	■	■					
Running the first trial of simulation								■	■	■				
Proposal defense								■	■					
Revising the data obtained from the first trial of simulation and identify the corrective measures (if any)									■	■	■	■		
Submission of interim report (draft)													■	
Submission of interim report (final)														■

Table 3: Gantt chart for FYP II

Project Activities	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sketching the layout of breakwater including dimensions	■													
Come out with test matrices and parameters	■													
Producing the model of breakwater in MatLab		■												
Running the simulation according to the test matrices and parameters		■	■											
Discussion and improvement on the simulation			■											
Running the final simulation (if any improvements needed)				■										
Analysing the results obtained and validation					■	■	■							
Submission of progress report							■							
Report writing		■	■	■	■	■	■	■	■	■	■			
Pre-SEDEX											■			
Submission of final report (draft)												■		
Submission of dissertation report (soft bound)												■		
Submission of technical paper												■		
Viva													■	
Submission of dissertation report (hard bound)														■

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Model Validation

Validation for recirculating flow model has been done by making comparison of the numerical result with previous researches by Shafiai (2011) and Nwachukwu (1979) using the case of flow around the spur-dike. The validation is important to further study about the flow around the breakwater at Chendering Fishery Port, Terengganu, Malaysia which has the same concept of boundary condition with the spur-dike.

Test parameters for the simulation was taken from Shafiai (2011) which used a 900 × 90 square Lattice with lattice spacing, $\Delta x = 0.01$. The initial velocity components are set as *u=0.253 m/s* and *v=0 m/s*. The experimental setup by Nwachukwu (1979) is used for the simulation where the structure of the spur-dike is 3mm width and 152mm long which is located at 3m from the upstream flow within the flume. Furthermore, the water height is set to *h=0.189 m* with the assume discharge of $Q=0.0175\ m^3/s$. The results are extracted after the flow reached the steady state for about 20000 iterations with time step, $\Delta t = 0.05s$. The following figure shows the steady state velocity vectors of the flow which is plotted using MatLab function, *quiver*.

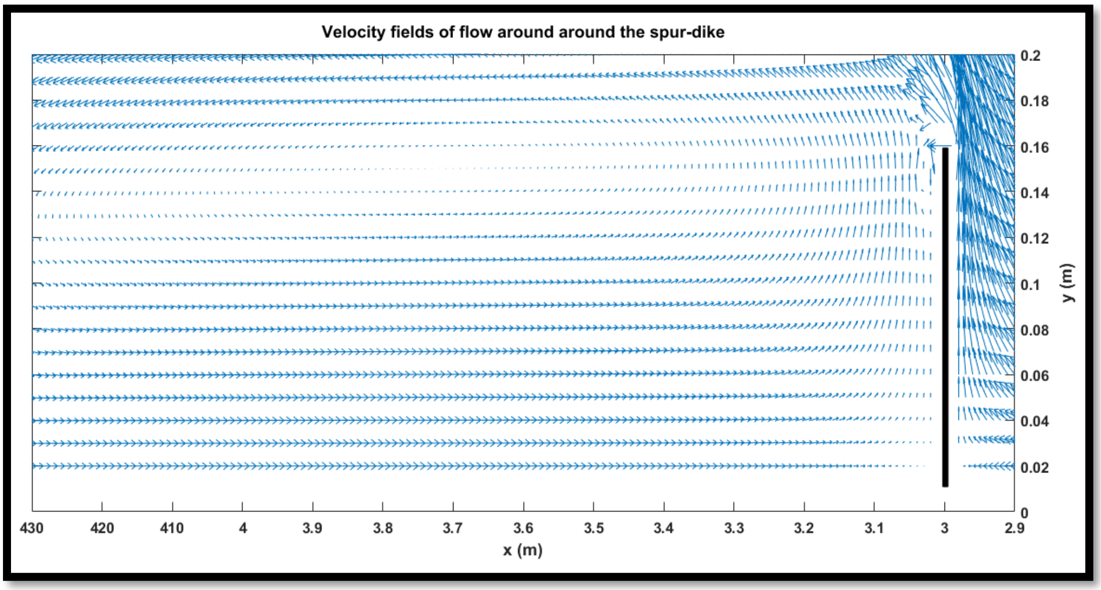

Figure 9: Velocity field of flow around the spur-dike

The velocity fields show a large eddy formation after the flow is diverted by the spur-dike structure. The flow direction of water is deflected to pass the spur-dike structure causing the recirculating flow occurred at the downstream. The following figure of *streamslice* gives a clear picture of the recirculation area right after the structure.

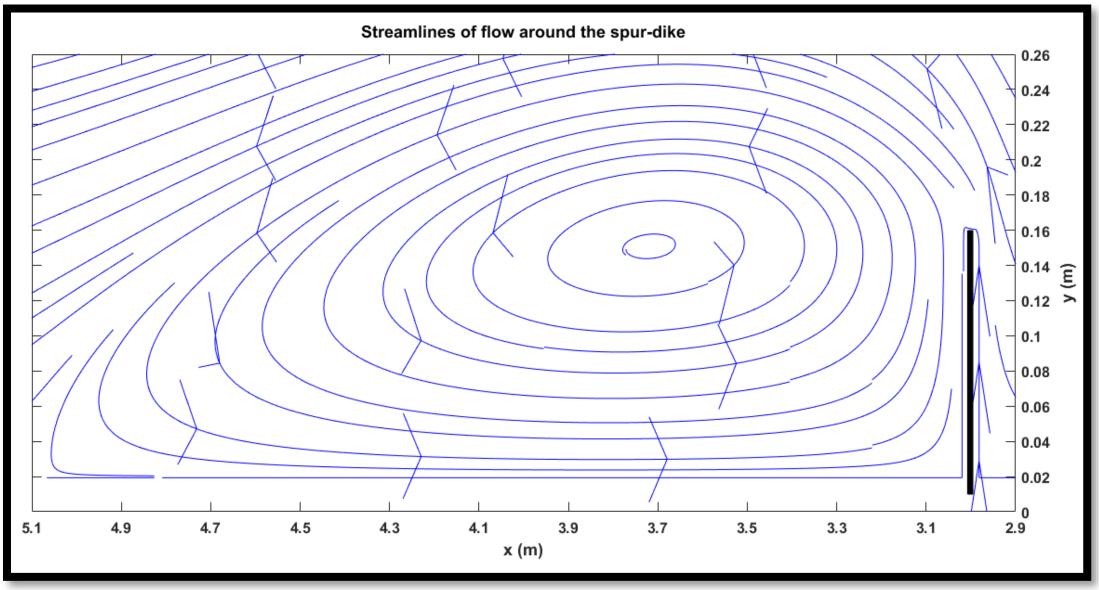

Figure 10: Streamline vectors of flow around the spur-dike

As results, the water profiles along the transversal locations are plotted and compared with the previous results by Shafiai (2011) and Nwachukwu (1979). The nondimensionalized velocity is obtained by dividing through with the inlet value of $u_0=0.253$ m/s while spur-dike length is denoted as b with the value of 0.152m.

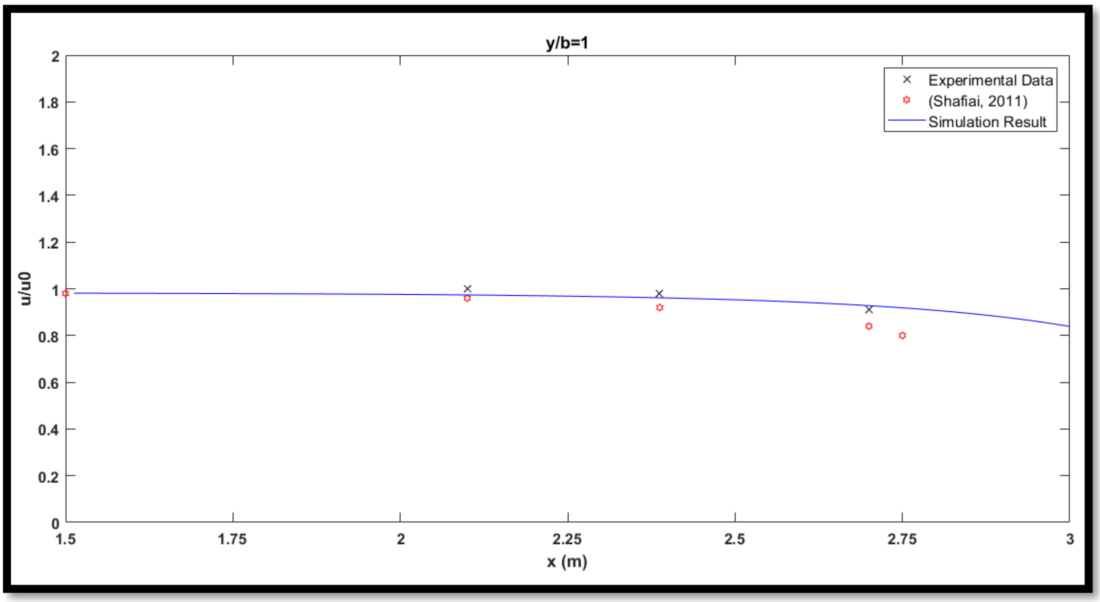

Figure 11: Water profiles along flow direction at transversal location of y/b=1

At y/b=1, the initial velocity of water is same with the previous numerical result and it is gradually decrease as the water reach the spur-dike structure at the distance of 3m. The pattern is more likely agreed with the experimental result.

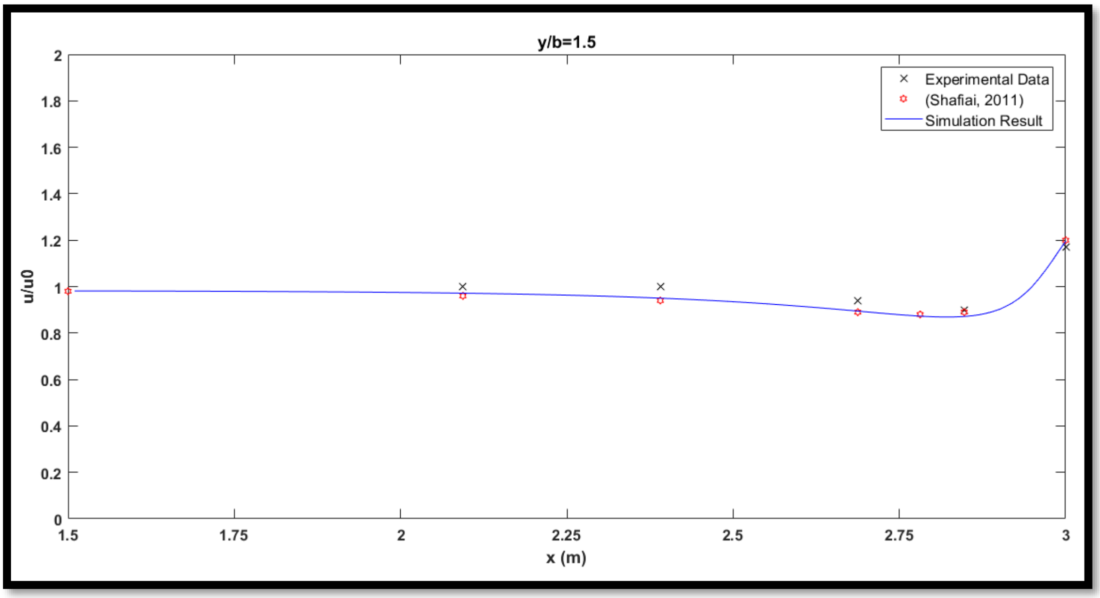

Figure 12: Water profiles along flow direction at transversal location of y/b=1.5

At y/b=1.5, the water profiles are same with the numerical simulation done by Shafiai (2011) and the decreasing trend in velocity can be seen at the upstream of the spur-dike until the distance about 2.8m. However, as the flow about to pass through the head of the spur-dike, the velocity is rapidly increasing.

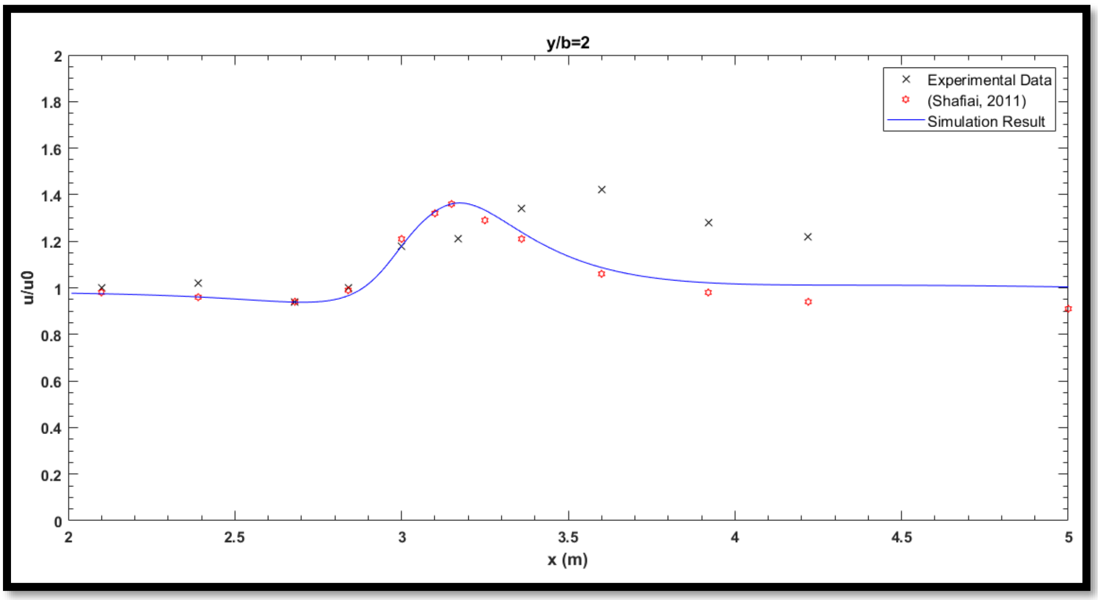

Figure 13: Water profiles along flow direction at transversal location of y/b=2

At y/b=2, the overall water profiles from 2m to 5m are seen to be agreed with the previous research by Shafiai (2011). The velocity trend is same as y/b=1.5 where the decreasing trend can be seen from upstream until the distance about 2.8m and the velocity continues to increase quickly as the flow passing through the head of the spur-dike with maximum velocity of 1.36 at the distance of 3.2m. Then, the velocity is decreasing gradually after it reached the maximum point.

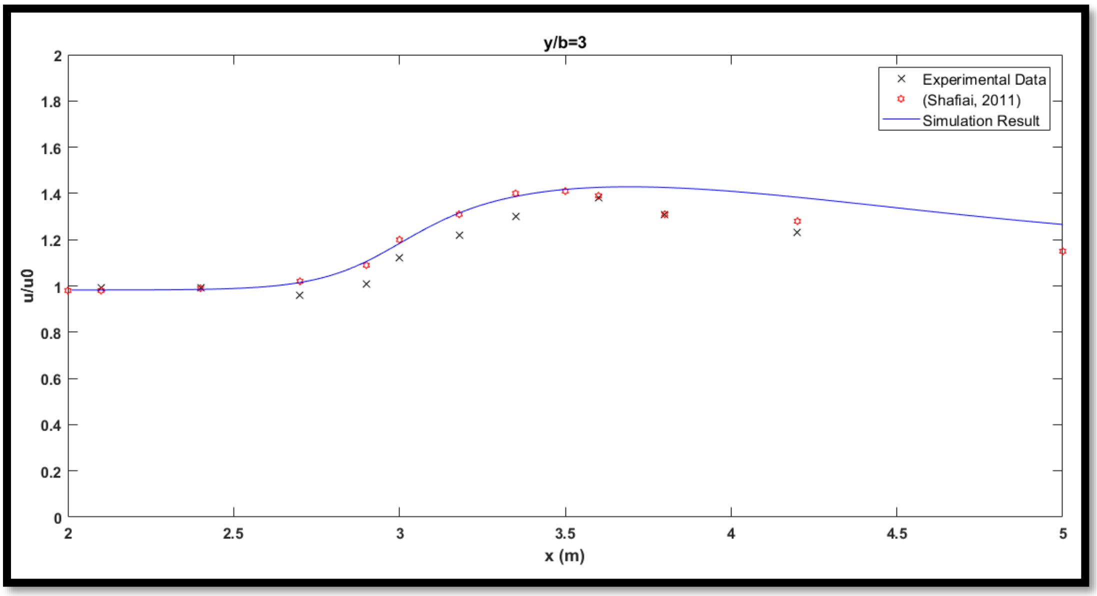

Figure 14: Water profiles along flow direction at transversal location of y/b=3

At y/b=3, the graph also shows the overall water profiles at transversal location of 0.45m above the head of the spur-dike. The maximum velocity recorded from the graph is 1.41 at the distance of 3.5m. The velocity is slowly decreasing at the downstream of the spur-dike but a significant difference between the numerical result by Shafiai (2011) and experimental data can be seen.

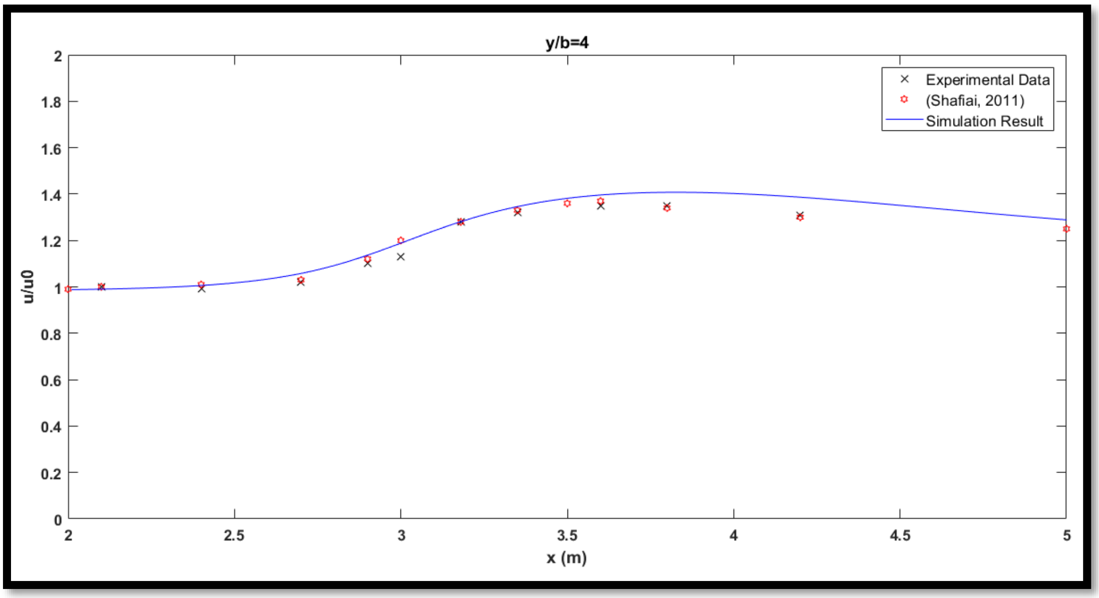

Figure 15: Water profiles along flow direction at transversal location of y/b=4

At y/b=4, the water profiles seem to be agreed with the previous research at the upstream until the distance 3.5m where the velocity trend is same as previous transversal locations. Therefore, it can be concluded that the flow velocity increases as the flow passing through the spur-dike which caused the formation of large recirculating flow at the downstream of the structure.

The present simulation results of water profiles at transversal locations have satisfactorily agreed with the previous simulation done by Shafiai (2011) and the experiment conducted by Nwachukwu (1979) in term of the water profiles pattern. However, there is some part of the results which not satisfy with the previous studies that might be because of the different value of discharge used for both studies. This will affect the result of velocity accordingly since the velocity is directly proportional to the discharge. Besides, the different implementation of boundary condition might be one of the cause which resulting in discrepancies with the previous numerical result. The present simulation used slip boundary condition whereas the previous study used no-slip boundary condition for the spur- dike and slip boundary condition is set for the channel walls.

4.2 Flow around The Breakwater

The model of breakwater is tested with varying the scale of the simulation and the significant waves heights. The results of flow pattern and flow velocity are extracted from the simulation for further analysis. The height of breakwater is 445m with 25m width of trunk and 35m radius of circular head.

4.2.1 Varying significant waves heights for lattice spacing, $\Delta x = 5$

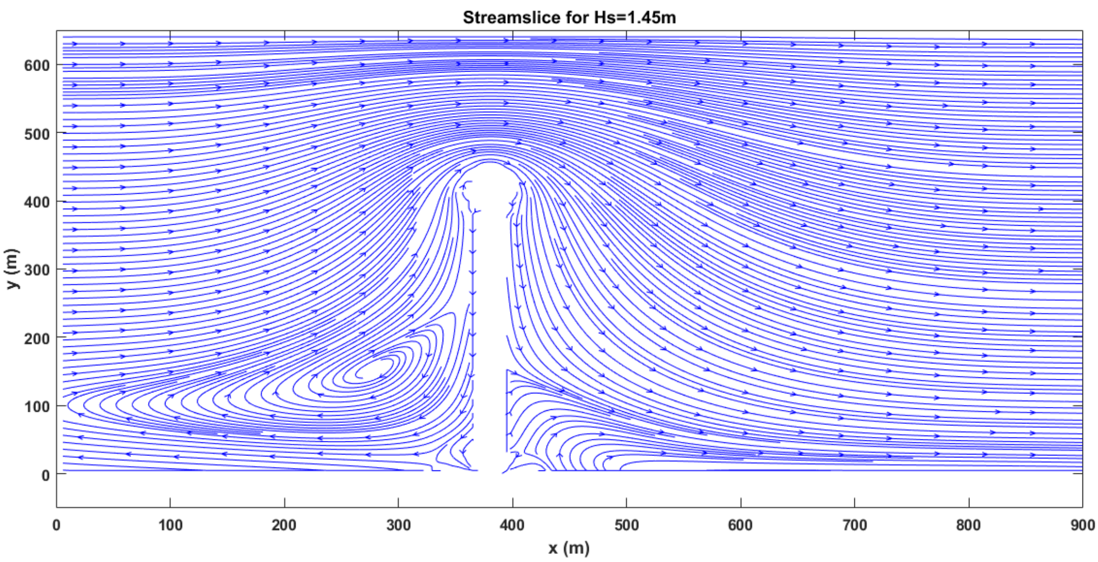

Figure 16: Flow streamlines around the breakwater for Hs=1.45m

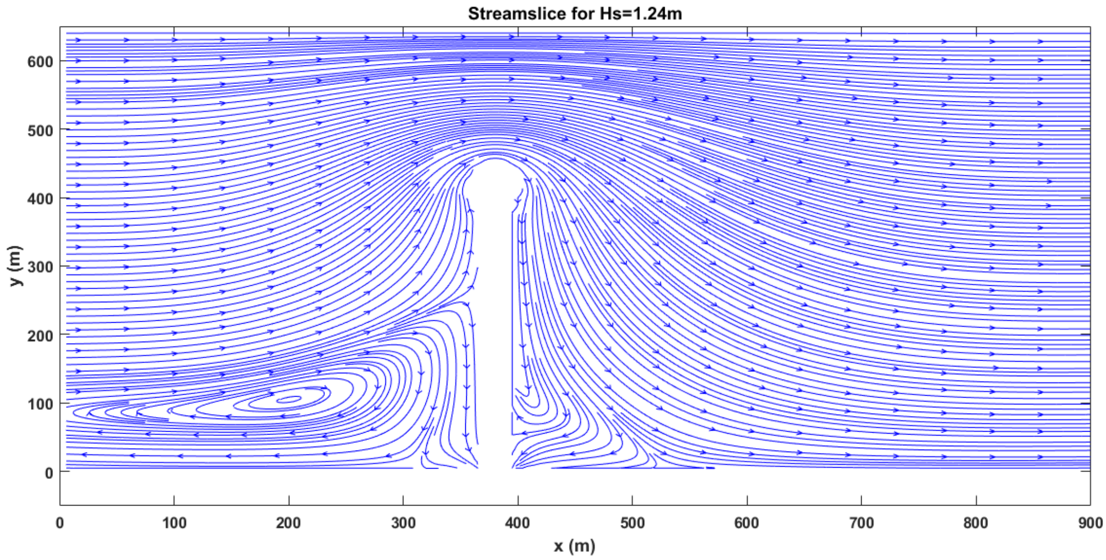

Figure 17: Flow streamlines around the breakwater for Hs=1.24m

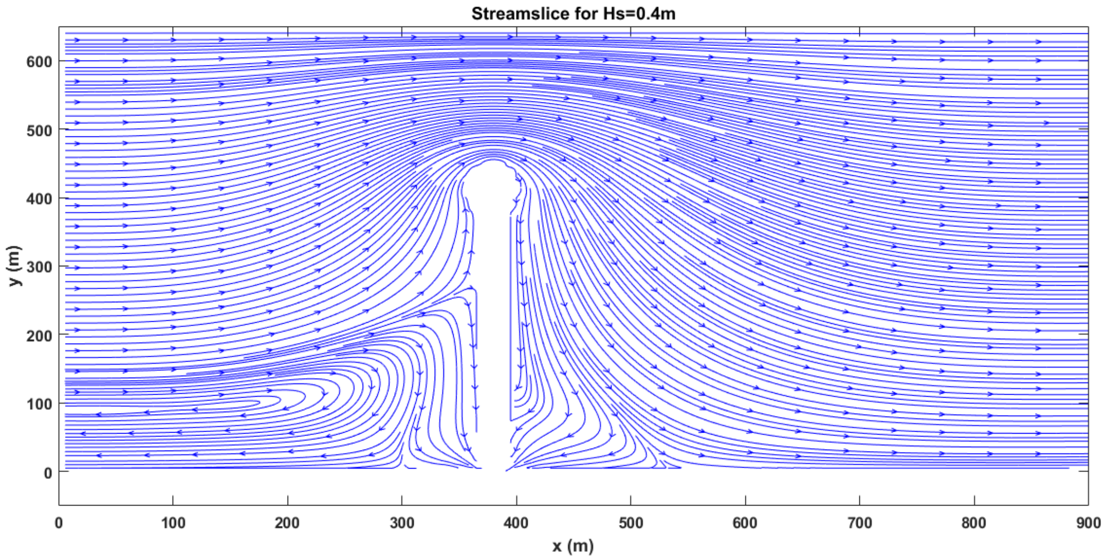

Figure 18: Flow streamlines around the breakwater for Hs=0.4m

After 100000 iterations, a large recirculating flow was formed before the breakwater while a formation of not fully developed recirculating flow can be seen after the breakwater.

Table 4: Particle velocity at certain location for Δx=5

$\Delta x = 5$				
Significant Waves Heights *(m)*	**Particle Velocity at Certain Location, *u (m/s)***			
	Before Breakwater	Breakwater Head	After Breakwater	
	(x=200m, y=320m)	**(x=380m, y=540m)**	**(x=450m, y=320m)**	**(x=500m, y=320m)**
1.45	0.0452	0.2716	0.0071	0.0266
1.24	0.0394	0.2321	0.0055	0.0215
0.4	0.0130	0.0750	0.0018	0.0068

As the significant waves heights increase, the flow velocity also increases. The flow velocity is maximum when it is flowing around the head of breakwater with the increasing trend can be seen before the breakwater towards the breakwater head. However, the flow is rapidly decreasing just at the leeside of the breakwater. Meanwhile, the flow is gradually decreasing along the jetty distance.

4.2.2 Varying significant waves heights for lattice spacing, $\Delta x = 10$

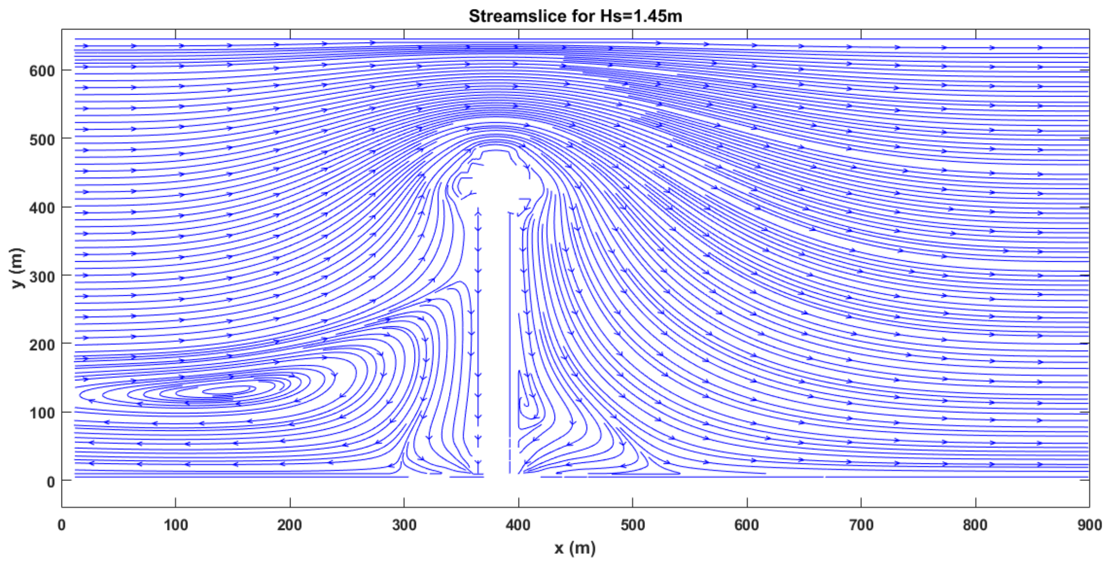

Figure 19: Flow streamlines around the breakwater for Hs=1.45m

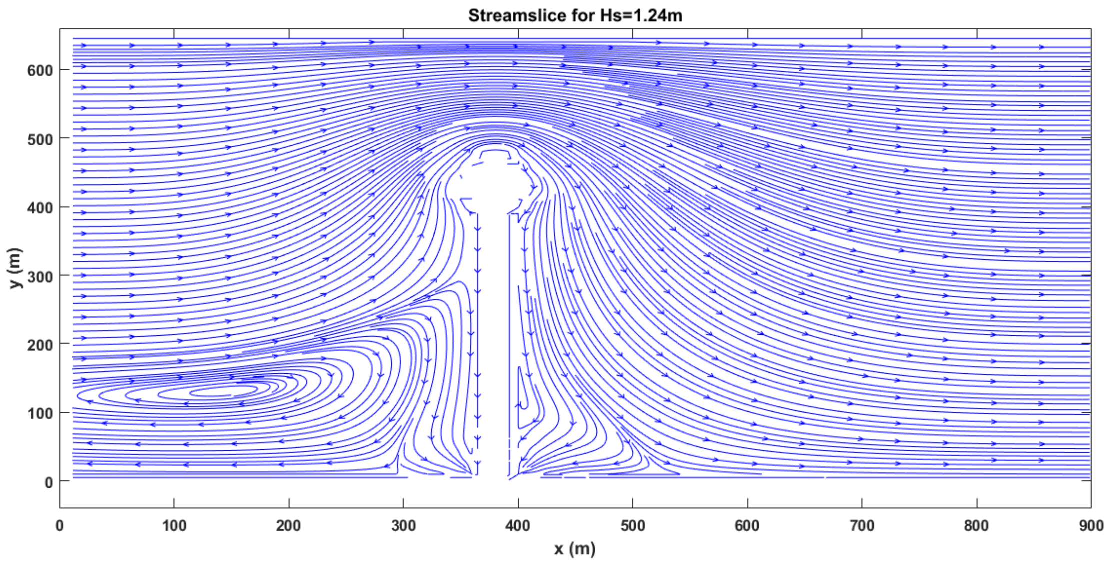

Figure 20:Flow streamlines around the breakwater for Hs=1.24m

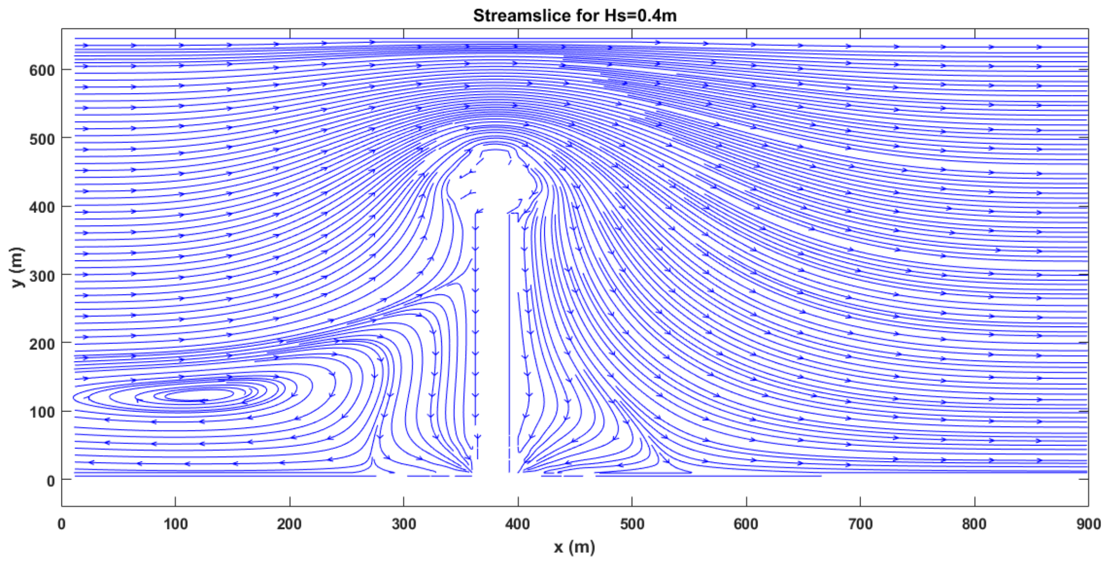

Figure 21: Flow streamlines around the breakwater for Hs=0.4m

After 98000 iterations, the flow reached steady state and a larger recirculating field can be seen before the breakwater as compared with the finer grid. Meanwhile, more detailed recirculating flow is shown at the leeside of the breakwater for significant waves heights of 1.45m and 1.25m. However, the recirculating flow is not fully developed inside the breakwater for significant waves height of 0.4m which might be due the slower velocity produced from the waves.

Table 5:Particle velocity at certain location for Δx=10

$\Delta x = 10$				
Significant Waves Heights *(m)*	**Particle Velocity at Certain Location, *u (m/s)***			
	Before Breakwater	Breakwater Head	After Breakwater	
	(x=200m, y=320m)	**(x=380m, y=540m)**	**(x=450m, y=320m)**	**(x=500m, y=320m)**
1.45	0.0121	0.1024	0.0012	0.0066
1.24	0.0104	0.0877	0.0010	0.0055
0.4	0.0035	0.0284	0.0000	0.0017

From the table, the same pattern can be observed where the flow velocity depends on the significant waves heights. The maximum value of velocity always recorded at the breakwater head and the flow gradually decreases along the jetty distance but rapidly decrease just at the leeside of the structure.

4.2.3 Overall Discussion

There are three significant waves heights tested with varying the scale of the simulation. Two of the values are taken from the highest monthly average of significant waves heights during NEM (1.24m) and SWM (0.4m) that was plotted by Muzathik et. al., (2010) while another one is calculated from ship observation waves data from MMD. The increase in hydrodynamics characteristics will affect the flow velocity at the area and the impact of waves on the breakwater during NEM where the highest significant waves heights are mostly recorded. The flow velocity which is rapidly decreasing just at the leeside of the breakwater causing accumulation of sediments which might continue to build up until reaching the jetty for the small vessels if it is not prevented. According to the position and location of the breakwater, the sediments are transported to the location by longshore drift which is due to rough waves condition NEM. The rough waves condition during the season causing erosion somewhere along the coastline at Terengganu and the sediments are travelled following the longshore current where the calm area because of the breakwater structure at Chendering, Kuala Terengganu is the perfect location for sediments deposition. This process will jeopardize the functionality of the jetty located at the leeside as the sediments will continue to build up. Moreover, the streamline figures shown that the flow recirculation is more detailed when using a larger grid or lattice spacing (Δx) as compared with finer grid. Yet, the finer grid yielded more accurate results of flow velocity as compared with the larger grid. The particles velocity presented in the tables are actually representing the fluid velocity at the area. The increase of flow velocity at the breakwater head is found to be because of wall boundary to contain the water within the lattice size area during the simulation. However, the condition is not the same as the real site condition since the area above the breakwater head is an open sea. This situation had caused the velocity of water flowing at the breakwater head to increase rapidly during the simulation since the area has been reduced. The best equation to explain the situation is $\left(Velocity = \frac{Discharge}{Area}\right)$ where the velocity inversely proportional to the area. Therefore, the problem of scouring at the breakwater head is unlikely to happen and the accumulation of sediments at the leeside of the breakwater is because of the longshore drift.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

There are a few studies had been carried out to study the eddy formation due to the bridges piers and spur-dike for river but none of them study the recirculating flow around the emerged coastal structure. Coastal structure such as breakwater is built up without any foundation and depends on the layers of rock stacks with different rock volumes for each layer. Therefore, any rapid changes on the seabed will trigger the structural integrity of the breakwater as the rock arrangement might be dislocated. However, this problem has been encountered at the design stage of the toe of breakwater.

This study had shown the significant increase of flow velocity at the breakwater head which is expected to cause scouring process at the seabed and may reduce the structural stability of the coastal structure. The high flow velocity at the breakwater head will cause the sediments around the armour layer for the toe to be remove continuously which later dislocate the original arrangement. However, this situation is unlikely to happen at the real site condition as discussed earlier. The sediments at the leeside of the breakwater is transported by longshore current which is expected at the highest during NEM where the rough waves condition always recoded. The recirculating flow at the leeside of the breakwater had caused the velocity to rapidly decrease which promoted the accretion of the sediments. The sediments accumulation at breakwater for Chendering Fishery Port, Terengganu, Malaysia can be clearly observed through satellite image.

Hence, a preventative measure must be taken in order to prevent the accumulation of sand inside the breakwater. However, in some cases the accumulated sand will be washed out due to different monsoon season and direction of longshore current but not in this case. This is might be because of the alignment of the breakwater which is not blocking the longshore sediment transport where the sediments can be drifted along the trunk section which is directly opposing the wave propagation. Thus, the calm water condition plus recirculating flow at the leeside had caused the flow to become sluggish which promoting the accumulation of sand.

There are several rooms for improvement in future study of this case where the variation of wavelength which governed by the time period of waves need to be tested and analyse to further study on the impact to the breakwater. Next, the real bathymetry condition at the study area can be included to further study the sediments transport pattern due to longshore current and the recirculating flow at the leeside of the breakwater. Lastly, a physical modelling need to be carried out so that the finding can be validated with the results obtained from the numerical study and the simulation must be designed to fully represent the real site condition.

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APPENDICES

JABATAN METEOROLOGI MALAYSIA
KEMENTERIAN SAINS, TEKNOLOGI DAN INOVASI

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Tarikh : 21 Jun 2017

Universiti Teknologi PETRONAS
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32610 Bandar Seri Iskandar
PERAK
(u.p.: Ahmad El Afify bin Mohd Safri)

Tuan,

PERMOHONAN DATA MARIN DAN OSEANOGRAFI UNTUK KAWASAN PERAIRAN CHENDERING, KUALA TERENGGANU BAGI TEMPOH 2012 HINGGA 2016

Perkara yang di atas dirujuk.

2. Bersama-sama ini disertakan data ketinggian ombak bagi kawasan dan tempoh seperti di atas. Data meteorologi marin ini merupakan hasil pencerapan meteorologi dari kapal-kapal VOS (*Voluntary Observation Ship*) serta bergantung kepada laluan kapal tersebut.

3. Dimaklumkan juga semua produk yang dikeluarkan oleh Jabatan Meteorologi Malaysia adalah hak milik Kerajaan Malaysia dan tidak boleh diguna semula oleh pihak ketiga. Tindakan undang-undang boleh diambil sekiranya berlaku sebarang perlanggaran.

4. Sebarang pertanyaan bolehlah dirujuk terus kepada pegawai bertugas di talian 03-7967 8113/8116.

Sekian, terima kasih.

'BERKHIDMAT UNTUK NEGARA'

Saya yang menurut perintah,

(ZAHARI BIN ABDULLAH)
Pengarah,
Pusat Operasi Cuaca dan Geofizik Nasional,
b/p Ketua Pengarah,
Jabatan Meteorologi Malaysia.

JABATAN METEOROLOGI MALAYSIA
Ship Observation

Period:	2012-01-01 00:00 - 2016-12-31 23:59					
Latitude	**From**	5.0		**Longitude**	**From**	103.0
	To	5.4			**To**	104.0

Date	Time (UTC)	Latitude (degree)	Longitude (degree)	Wave Height (m)
8 Jan 2012	00	5.4	103.8	2.0
13 Jan 2012	00	5.4	103.6	1.0
2 Feb 2012	06	5.3	103.7	2.0
3 Feb 2012	00	5.0	103.8	1.5
12 Mar 2012	00	5.1	103.9	1.5
20 Mar 2012	18	5.2	104.0	0.0
20 Apr 2012	18	5.2	103.9	0.5
16 Jun 2012	00	5.3	104.0	0.5
1 Oct 2012	06	5.2	103.9	1.0
9 Dec 2012	12	5.0	103.9	0.5
8 Jan 2013	06	5.3	103.9	2.0
9 Jan 2013	12	5.0	103.9	0.5
24 Feb 2013	18	5.4	103.8	0.5
13 Jun 2013	00	5.3	103.9	0.5
26 Aug 2013	12	5.2	103.9	1.0
20 Sep 2013	00	5.1	103.4	0.5
22 Nov 2013	06	5.4	103.9	0.5
26 Nov 2013	06	5.2	103.9	1.0
12 Dec 2013	06	5.1	103.9	0.5
13 Jan 2014	12	5.2	103.9	1.0
28 Feb 2014	06	5.3	103.7	1.0
17 Mar 2014	00	5.2	103.7	0.5
23 Mar 2014	12	5.0	103.9	0.5
9 Apr 2014	00	5.3	103.7	0.0
25 Apr 2014	12	5.1	103.9	0.5
9 May 2014	00	5.2	103.8	0.5
9 Oct 2014	00	5.2	103.9	0.5
30 Oct 2014	00	5.3	103.9	0.5
28 Dec 2014	12	5.0	103.9	1.0
31 Dec 2014	00	5.1	104.0	1.0
9 Jan 2015	00	5.2	103.8	1.5
14 Feb 2015	06	5.2	103.7	0.0
6 Mar 2015	06	5.3	103.8	0.5
12 May 2015	12	5.4	103.8	0.5
22 May 2015	06	5.2	103.8	0.5

26 May 2015	12	5.2	103.8	0.0
30 May 2015	12	5.0	103.9	0.5
3 Jun 2015	06	5.2	103.8	0.5
5 Jul 2015	06	5.0	103.9	1.0
7 Jul 2015	00	5.3	103.8	0.5
9 Jul 2015	00	5.1	103.9	0.0
5 Aug 2015	00	5.4	104.0	0.5
8 Sep 2015	12	5.4	103.8	1.0
26 Sep 2015	06	5.4	103.6	0.5
14 Oct 2015	12	5.3	103.8	0.0
29 Oct 2015	04	5.4	103.8	1.0
14 Nov 2015	00	5.1	103.9	0.5
17 Nov 2015	18	5.2	103.7	0.5
3 Dec 2015	18	5.3	103.7	1.0
7 Dec 2015	18	5.4	103.7	4.0
27 Dec 2015	06	5.0	103.9	1.5
16 Jan 2016	00	5.3	103.8	1.0
9 Feb 2016	12	5.1	104.0	1.0
13 Feb 2016	00	5.3	103.8	0.5
12 Mar 2016	12	5.0	103.7	1.0
13 Apr 2016	06	5.0	103.9	1.0
18 Oct 2016	18	5.2	103.9	0.5
20 Oct 2016	00	5.1	103.8	0.5
26 Nov 2016	06	5.2	103.9	1.0
2 Dec 2016	00	5.2	103.5	0.0