DYNAMIC RESPONSE OF FLOATOVER BARGE SUBJECTED TO RANDOM WAVES DURING STANBY MODE

By

Halimahton Binti Yusup

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Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

FLOATOVER BARGE RESPONSES FOR RANDOM WAVES

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Approved by,

____

(Professor Dr. Kurian V. John)
Project Supervisor

Universiti Teknologi PETRONAS
Tronoh, Perak

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CERTIFICATION OF ORIGINALITY

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

HALIMAHTON BINTI YUSUP

I. ABSTRACT

The float-over method was initially developed by Brown & Root Energy Services in the year 1970's. Nevertheless during this past 20 years float-over installation has become a common method for the topside installation on the offshore platforms. The method involved barges to transport the topside to the site precisely positioned next to or in between of the substructure legs. The ballasting and de-ballasting happen to transfer the load from the barge to the legs. Previously, the conventional method has been used by using the heavy lifting crane vessel. The problem with this method is that very difficult to mobilize in remote area and also need multiple lifting if the topside has massive weight. This new method of float-over installation has overcome the problem of the conventional method. This method as well result in reduction of time. In Malaysia, this concept has been used for the Kikeh Spar platform and it was successful.

During the installation process, the barges will be subjected to the environmental loads such as waves, wind and current with most dominant by the wave's loads. In this study, the dynamic responses of the barges are measured using numerical simulation method and also the model tests. After obtaining both of the data, the results will be compared. The model tests study is very important but unfortunately, the study on model tests for barge responses still limited.

This research contains the calculations of the dynamic motion responses of the barge by using numerical simulation and model tests. The numerical simulations uses frequency domain analysis, the wave forces are calculated using the Froude-Krylov equations. Also, the linear wave theory or also known as the Airy's theory will be used to calculate the wave particle kinematics and dynamics. The results are finalized by using Response Amplitude Operators (RAO) for the six degrees of freedom. But for this study only focus on three degree of freedom; surge, heave and pitch.

The numerical simulation for 0^0 and 180^o degree direction has been calculated and the graphs are plotted. Thus, the comparison can be made based on the graphs. Different location will have different value for the heave, surge and pitch force. This is to have more results to analyse the behaviour of the force at three different locations.

For this study three locations of the platforms were chosen which are Peninsular Malaysia Operation (PMO), Balingian and Samarang which have different conditions of the depth, wave, wind and current. The numerical simulation will be conducted separately for each of the location.

The results obtained will be compared between each of the location. Next, the result from one of the research that has been successfully conducted in Caspian Sea will be put onto account. The Balingian, PMO, and Samarang results will be compared as well with Caspian Sea results. Analysis and finding based on the comparison will highlight the similarities and differences between the locations.

The numerical simulation method is conducted to determine the important parameters in the prediction of the float-over barge responses. The findings from the present study is believed can contribute to the development of the float-over installation technology for Malaysia.

II. ACKNOWLEDGEMENTS

Highest gratitude and appreciation goes to my supervisor Professor Dr. Kurian V John for his supervision, guidance and advices. He has guide with the input and time for me to have better understanding on my topic.

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CHAPTER 1
INTRODUCTION:

1.1 Introduction

Oil and gas is now the top leading industry that control the economy of the world. The demand in oil and gas has caused the rapid increase in technology for the construction of the platform. A lot of research is currently being undertake to find the best method and solution to overcome the challenges in developing this field. The objective is mainly focus on the cost and time effective and the ease of installation. Attentive study in this area has enhance the innovation and new technology. One of the technology is called float-over installation method.

1.2 Background

The rapid development in oil and gas industry both in shallow and deep water has induced bigger and heavy deck to meet the production requirement. The conventional method is by transporting the topside on a barges and then by using the heavy crane vessel, the topside is lifted up onto the leg structure. This type of method has weight limitation. More than one crane vessel will be needed if the weight is exceeding the crane limit. But, this will cause additional cost for the whole operation. Beside that as the industry becoming more important the remote area exploration is now the target. With this current method the installation will be difficult to be accomplished. Thus, the float-over installation method becoming more reliable for both of these situations. Basically, for this method the barges are not only used for deck transportation but also as lifting mechanism. This method is becoming more popular because of the advantage of the reduction in time and cost as it allow testing and commissioning of topside onshore with minimization of the duration of offshore hock-up.

There are a lot types of platform in offshore structure such as jacket, spar, tension leg platform and semi-submersible platform. Attentively, for this research is focus on the fixed jacket platform only. The topside will be transported on the barge to the site and accurately positioned in the between of the jacket legs. Then, ballasting and de-ballasting operation take place to transfer the topside onto the jacket. Once the topside is resting accurately at the position, matting and barge withdrawal will happen next.

This method has been developed since 1970s by Brown & Root Energy Services but only started to becoming more common in this past 20 years after the installation successfully executed in Africa, Asia, Australia and Middle East. This method is suitable under normal and harsh condition. Up until now, there is only one successful float-over installation in Malaysia for Kikeh spar platform at water depth of 1320m in year 2006 with deck weight 3200 tons. It is located at the Sabah and the company involved is Technip.

1.3 Problem Statement

The important factors for float-over design are size and the weight of the integrated decks, selection of float-over barges and the environmental conditions. Among these factors, barge motion responses during standby phase of the operation is the main focus for this study. To study the barge motion is very important as these motions need to be limited during the installation to avoid excessive interaction between barge, deck and the jacket legs. The necessary data that should be obtained are the wave environment for the operations and the assessment of barge responses at preparation mode. The determination of the dynamic responses of the barge subjected to random wave is the main purpose of this study. Additional parameter such as the barge draft or ballast conditions and wave headings are crucial for the motion and stability.

In this study, the investigation of the dynamic responses is done by using numerical method. The numerical method is much simpler and easy to use. But yet it need other method of analysis to improve the reliability of the data obtained.

1.4 Objective of Study

The present study has objectives that plan to be achieved:

- To determine the dynamic motion responses of a float-over barge in the preparation mode by using numerical simulation.
- To compare the barge motion responses at the three offshore location of Malaysia.
- To verify the motion responses of float-over barge by comparing with the numerical simulation data from Caspian Sea.

1.5 Scope of Study

The scope of the location of study are at Peninsular Malaysia Operation (PMO), Balingian and also Samarang. These three locations are located at different part of Malaysia. Balingian is at Sarawak whilst Samarang is at Sabah. All have different water depth, wind, wave and current characteristic. Thus, in this study there will be comparison between these three locations. The study for the dynamic response of float-over barge are conducted by using numerical simulation method. For the first method, frequency domain dynamic analysis will be used. The linear motion is determine by using the Airy wave theory. Whilst the wave force is calculated by using the Froude-Krylov force theory. The regular and random wave graph of energy against frequency can be plotted by using JONSWAP spectrum. From the six degree of freedom motion only surge, heave and pitch are the main interest in this research. This research will cover these three motions for 0^0 and 180^0 degree. The result will then be compared to the research conducted by one of the master student for the Caspian Sea location.

a) Fixed parameters:
   i. Unidirectional waves at 0^o and 180^o heading.
   ii. 3 degrees of freedom are studied; surge heave and pitch
   iii. Same frequency from 0.035-0.395 Hz

b) Varying parameters:
   i. Locations of studies; Balingian, PMO, Samarang and Caspian Sea
   ii. Different wave parameters

The parameters will be used to obtain the following outputs:

- Wave energy spectrum (JONSWAP)
- Time series of wave profile
- Motion RAO
- Response spectrum

1.6 Relevancy of Project

This research is more focus on the understanding of environmental condition from the metocean data obtained for the dynamic response of the floating structures. From this research there is clear correlation between the knowledge gained from offshore structure course with actual analysis that has been done. The basic knowledge that already in hand help to ease work throughout the duration of 8 months. Float-over barge installation is a new technology in Malaysia that from this research has proven that more installation using this method can be executed at Malaysia's water (South China Sea).

1.7 Feasibility Study

The availability of resources have given a positive outcome for this entire project. The data, facilities and resources are provided either by UTP and parties interested.

a) Metocean Data- Provided by PETRONAS (PETRONAS Technical Standards) and Technip (M) Sdn. Bhd as needed for the barge analysis.
b) Facilities- 1.5m depth wave tank in offshore laboratory for the actual observation of the responses of the barge.
c) Support and Technical Expertise- From supervisor which have many years of experience in offshore structure.
d) Referencing material- The availability of resources from Information Resource Centre (IRC) for books, journal and research paper.

CHAPTER 2
LITERATURE REVIEW:

2.1 Introduction

The float-over barge installation has many advantages as well as some challenges. Thus, the design of the barge is very important. The dynamic responses acting on the barges should be studied to get the stability and motion requirement to ensure the successful completion of the operations. Throughout this second chapter will be discussing on the barge motion and the float-over installation method.

2.2 Wave Induced Loads and Motions on Floating Platforms

The barge is subjected to environmental forces such as wind, wave and current [3]. The barge has a ship shaped structure with a flat surface at the bottom. The basic knowledge in understanding the wave induced loads and motions are very crucial both for the design as well as the operational studies. Barge function is not only for the topside transporter but also assist in the installation of offshore deck and equipment.

According to Chakrabarti [4] there are two basic approaches that are considered in the floating structure dynamic problem-frequency domain or time domain analysis. Frequency domain analysis is performed for the simplified solution obtained from simple iterative technique. This analysis is very convenient for long term prediction for the problem related to floating structure dynamic. The technique as well is very helpful in measuring the responses due to random wave input through spectral formulations.

There will be a series of motion that act on the floating body. The floating barge is subjected to a three-dimensional plane of hydrodynamic motion that resulted in a 6 degree of freedom. These 6 types of motions are acting at the centre of the body. The motion can be divided into two parts; translational and rotational. The translational motion consist of surge, sway and heave that acting along the x, y and z axis whilst the rotational motion consist of roll, pitch and yaw [4]

The figure 1 below will give the bigger picture in which direction these motions are acting:

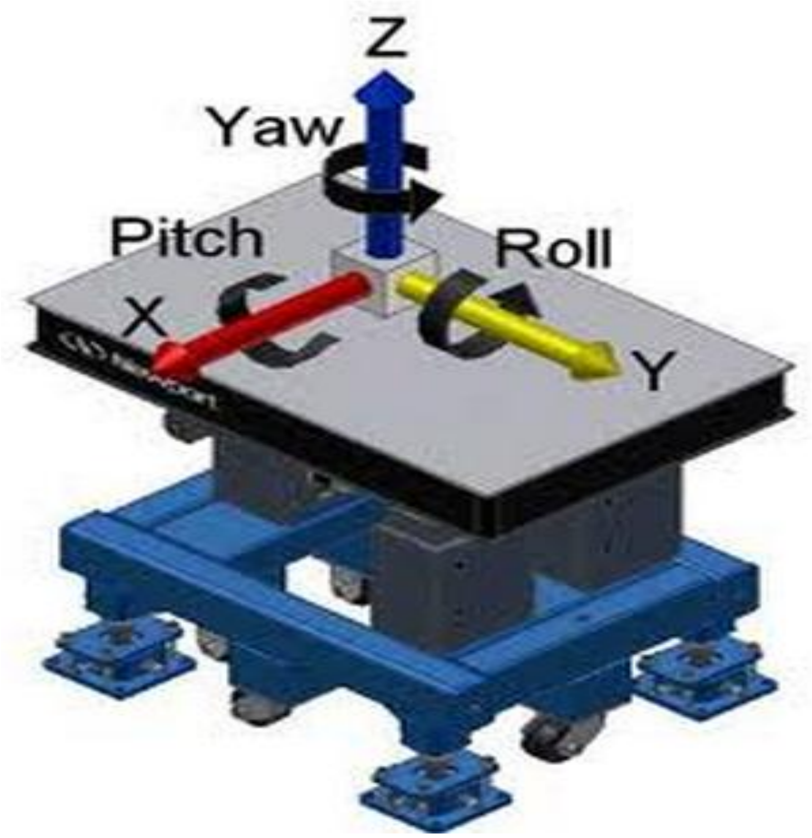


Figure 1: Definition of Six Degree of Motion of a Floating Barge

2.3 Wave Theory

Wave theories are very important in this study. The development of these theories are on the specific basis of the environmental parameter such as the characteristics of the waves. The study of characteristic of waves can include the wave height, wave period and water depth. In this current study, the main focus is linear wave theory.

2.3.1 Linear Wave Theory

Chakrabarti [4] stated that linear wave theory or small amplitude wave theory or also known as the Airy theory is the most common used for the wave theory. It is the simplest and most useful of all wave theories. In this theory, the assumption that is used is the height is smaller compared to the wave length or the water depth. Thus, this will permit the assumption of the free surface boundary conditions. Also, ensure the free surface conditions to be fulfil at mean sea water level (SWL), but not at the oscillating free surface. The equation for surface wave profile can be presented by equation 2.1 below:

$$\eta = \alpha \cos(kx\text{-}\omega t) = \frac{H}{2} \cos (kx\text{-}\omega t) \qquad (2.1)$$

Where η is the water surface elevation relative to SWL, α is the wave amplitude equal to one half of the height H/2, k is the wave number and ω is the wave frequency in rad/sec. The wave kinematics and dynamics formula are listed in table 2.1:

Table 2. 1: Equation for kinematics and dynamics

Type	Formulae
Horizontal force	$u = \frac{\pi H}{T}\frac{\cosh ks}{\sinh kd}\cos\theta$
Vertical Force	$v = \frac{\pi H}{T}\frac{\sinh ks}{\sinh kd}\sin\theta$
Horizontal acceleration	$\dot{u} = \frac{2\pi^2 H}{T^2}\frac{\cosh ks}{\sinh kd}\sin\theta$
Vertical acceleration	$\dot{v} = -\frac{2\pi^2 H}{T^2}\frac{\sinh ks}{\sinh kd}\cos\theta$
Horizontal particle displacement	$\xi = -\frac{H}{2}\frac{\cosh ks}{\sinh kd}\sin\theta$
Vertical particle displacement	$\eta = \frac{H}{2}\frac{\sinh ks}{\sinh kd}\cos\theta$
Dynamic pressure	$\rho = \rho g\frac{H}{2}\frac{\cosh ks}{\cosh kd}\cos\theta$

2.3.2 Wave Spectrum

The selection of the wave design environment for the offshore platforms can be performed by using two methods; single wave method that represented by wave period and wave height and the second method is wave spectrum in which the energy spectrum is given in term of power of the wave frequency.

JONSWAP equation as Equation 2.2

$$S\ (f) = \alpha^* H_s^2\ \frac{f^{-5}}{f^{-4}} \exp[-1.25(\frac{f}{f_0})^{-4}]\gamma^{\exp[-\frac{(f-f_O)^2}{(2\tau^2 f_O)}]} \qquad (2.2)$$

Where γ is the peakedness parameter (taken as 3.3) and τ is the shape parameter (taken as 0.07 if $\omega_0 \geq \omega$ or 0.09 if $\omega_0 < \omega$

Where $\alpha^* = \frac{0.0624}{0.230+0.0336\gamma-0.185(1.9+\gamma)^{-1}}$

And

$H(f)=2\sqrt{2S(f)\Delta f}$

2.4 Review of Literature

Seij et al. [10] studied the strengths, weaknesses, opportunities and threats of float-over installation. The strengths are the reduction in schedule interface, higher weight capacity, reduced offshore hook-up and commissioning, cost savings and increase the safety aspect. Whilst the weaknesses are restricted to weather condition, different jacket slot requirement and early commitment from contractor.

Hamilton et al [6] in the study stated that dynamic system and environmental condition information is very important to allow consistent design load to be measured. Mention also on the need to reduce risk and increasing installation sea states must be known. The paper explain how the jacket-barge model simulation give an impact on the stiffness, mass and gap size.

Sun et al [8] studied the interaction effects due to diffraction by the large volume substructure and an installation barge, during the operation of setting the deck onto the substructure. It is stated in the paper that the attachments to the fixed substructure will constrained the barge motions. The effect of this is model by a two stage hydrodynamic/dynamic analysis. This research use the linear theory application.

Jung et al [7] the paper studied on how to evaluate the impact load during the float-over topside installation to design the contact substructures such as leg mating unit (LMU), deck support undocking stages. Impressively, the development of this analysis has been applied to the real offshore project.

Shashikala et al [12] have written a paper on the dynamics of moored barge under regular and random waves. An attentive study on the three dimensional problem of the wave interactions with a barge moored to a single point is resolve based on the finite element method. Also, included the investigation of the effect of flexibility of the mooring line and the point of mooring on the response of the barge and the mooring line tension. This paper use the comparison between the numerical results with the model tests of barge moored to a fixed support under regular and random waves. There is discussion on the effect of the stiffness of the mooring line on the barge response for different mooring points and also the viscous damping. In this study, it shown that analytic results are in good agreement with the experimental results in both regular and random waves.

Muga [2] has conducted an experiment at reduced scale in the laboratory using the linear theory of rigid ship's motion to study the experimental and theoretical motion of moored barge. In his study the prototype and model tests were analysed using time-series techniques to provide amplitude-response operators for all the ship's motions and mooring forces and is calculated from a linear theory based on slender body approximation. For the second calculation, the author has used the in-line couple equations of motion for the 6 degrees of freedom and solved literally and numerically. The author has obtained results in the form of complex-response operators and are comparing with the results obtained from the prototype and models analysis.

Wilson [14] stated in his book the linear waves or also known as Airy's theory is the most important of the classical theories because it is both easy use and it forms the basis for the spectral description of waves. Also include in the book the summary assumptions, the governing equations and the solutions for the wave velocity and pressure profiles useful for predicting wave-induced forces on offshore structures.

CHAPTER 3
METHODOLOGY

3.1 Chapter Overview

The method used for this project is numerical simulations using the frequency domain dynamic analysis by converting wave spectrum to wave time series and converting the responses time series to response spectra. The barge is design with fork shape structure and already being fabricated and available to use. The dimension of the barge is measured to calculate the centroid (CG). For the calculation for the numerical analysis the ratio used is 1:50 to apply the fundamental of Froude-Krylov equation. The barge that UTP has is 50 times smaller than the actual barge used at Caspian Sea.

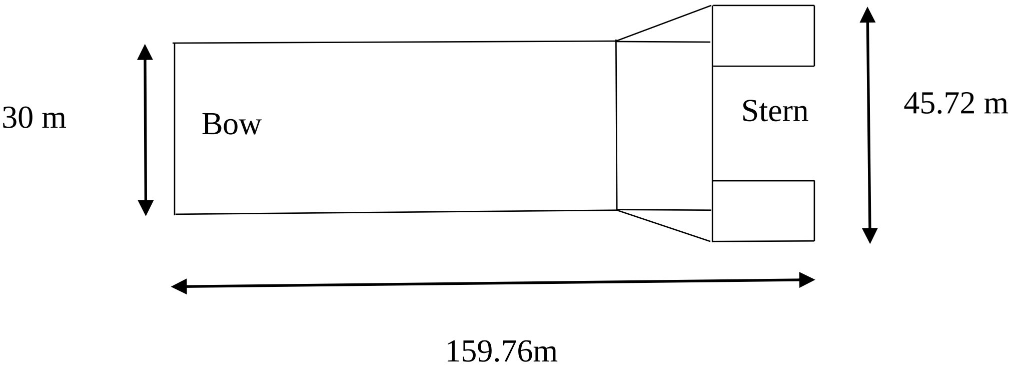


Figure 3. 1: Barge Dimension

Table 3. 1: Barge description

Description	Value
Length	156.76 m
Width at bow	30 m

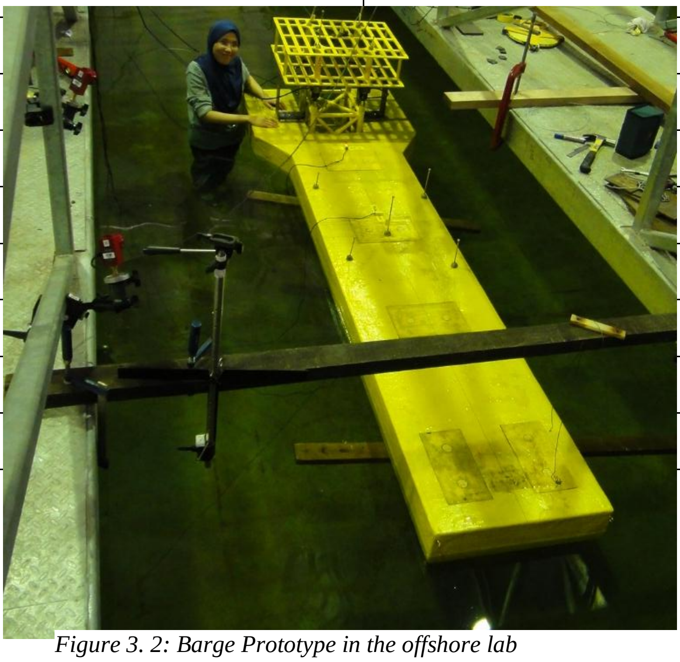


Figure 3. 2: Barge Prototype in the offshore lab

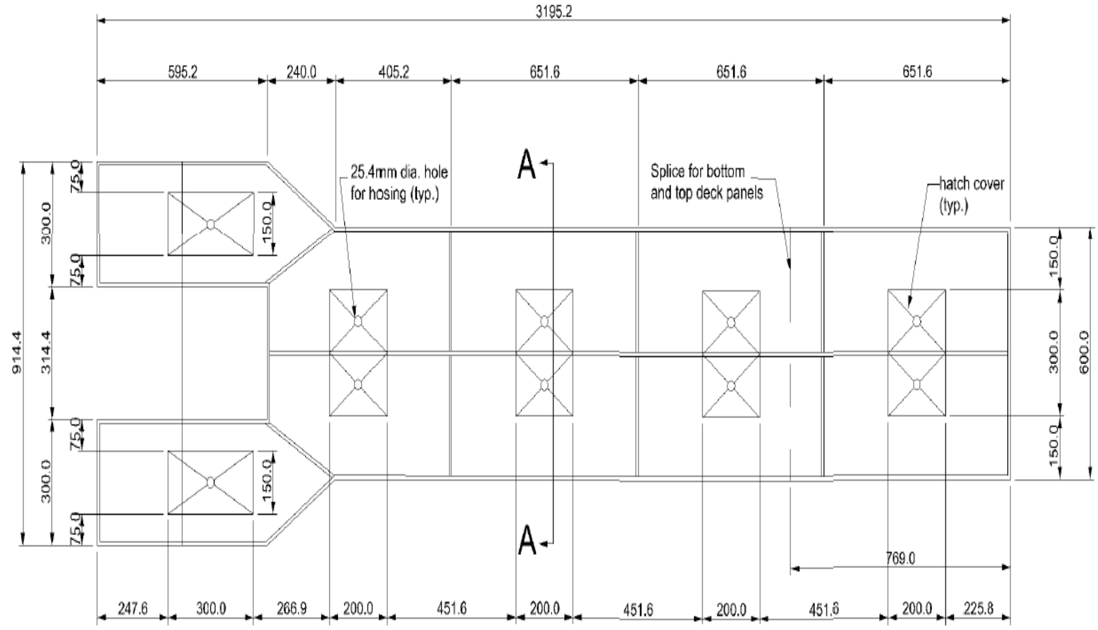


Figure 3. 3: Barge layout

3.2 Theoretical Analysis

Attentive study of the waves are very crucial for the dynamic analysis of the offshore platform. As mention before the offshore platforms are subjected to the environmental effects of waves, wind and current that have the impact on the installation of the topside by using the barge. In this study, we will assume the barge to have the rectangular shape. Thus, the Froude-Krylov method can be used to calculate the wave forces acting on the barges. According to Chakrabarti (2001) the rectangular block is assumed to have the dimensions $l_{1,}$ l_2 and l_3 where l_3 is the height and l_2 is perpendicular to the wave direction. The elevation of the rectangular block is given as s_0 being the distance from the ocean bottom to the centre axis of the block. The theory forces on the structure are calculated by a pressure-area method in which the expression of the pressure due to the incident waves is used on the surface of the structure.

The linear or Airy's theory will be applied as well. According to Wilson (2002) this theory forms the basis for the probabilistic spectra description of waves. Some of the assumption stated by him are; the amplitude of the surface disturbance is very small relative to the wave length and water depth, velocity depth is small compared with the hydrostatic pressure head, water depth is uniform, the water is homogeneous and the sea level atmospheric pressure is uniform.

Froude-Krylov for rectangular block equation:

Horizontal wave force

$$F_x = C_H \rho V \frac{\sinh(\frac{kl3}{2})}{(\frac{kl3}{2})} \frac{\sinh(\frac{kl1}{2})}{(\frac{kl1}{2})} \dot{u} \tag{3.1}$$

Vertical wave force

$$F_Y = C_V \rho V \frac{\sinh(\frac{kl3}{2})}{(\frac{kl3}{2})} \frac{\sinh(\frac{kl1}{2})}{(\frac{kl1}{2})} \dot{v} \tag{3.2}$$

Whereas:

$$\dot{u} = \frac{2\pi^2 H}{T^2} \frac{\cosh ks}{\sinh kd} \sin\theta \tag{3.3}$$

$$\dot{v} = \frac{2\pi^2 H}{T^2} \frac{\sin ks}{\sinh kd} \cos\theta \tag{3.4}$$

3.2.1 Numerical simulation using frequency domain analysis

There are two basic approaches used in this study for the investigation of the dynamic responses of the floating structure. The first one is the time domain and the second one is the frequency domain analysis. The dynamic response of the barge is determine in terms of Response Amplitude Operators (RAO). The RAO at frequency

0.1 Hz to 0.4 Hz is determine for only surge, heave and pitch direction. The below equations are the RAO equation for each component:

$$\text{Surge RAO} = \frac{(F_x)\,/(H/2)}{[(K_1 - m\omega^2)^2 - (C\omega)^2]^{1/2}} \tag{3.5}$$

$$\text{Heave RAO} = \frac{(F_y)\,/(H/2)}{[(K_{hyd} - m\omega^2)^2 - (C\omega)^2]^{1/2}} \tag{3.6}$$

$$\text{Pitch RAO} = \frac{M\,/(H/2)}{[(K_{ang} - I\omega^2)^2 - (C\omega)^2]^{1/2}} \tag{3.7}$$

Whereas;

F_x = total horizontal force on the barge

F_y= total vertical force on the barge

M= summation of moment in horizontal and vertical direction

$K_1 = (\frac{2\pi}{T_n})^2 m$ (3.8)

$K_{hyd} = \rho g A_{wp}$ (3.9)

$Kang = I\omega_n^2$ (3.10)

Damping ratio for surge and heave = C = $2\sqrt{Km}\ X\ \zeta$ (3.11)

$C=2I\omega_n\zeta$ (3.12)

ζ for surge is 3.18%, heave 1%, pitch 2.3%

From RAO, the S_R (f) can be calculated by using the below equation:

$$RAO = \sqrt{\frac{S_R(f)}{S(f)}} \tag{3.13}$$

3.2.2 Wave parameter

Table 3. 2: Wave parameter

	Balingian	PMO	Samarang	Caspian Sea
Hs (m)	3.1	4.38	3.7	0.5
Tp (s)	9.8	9.74	10.1	7

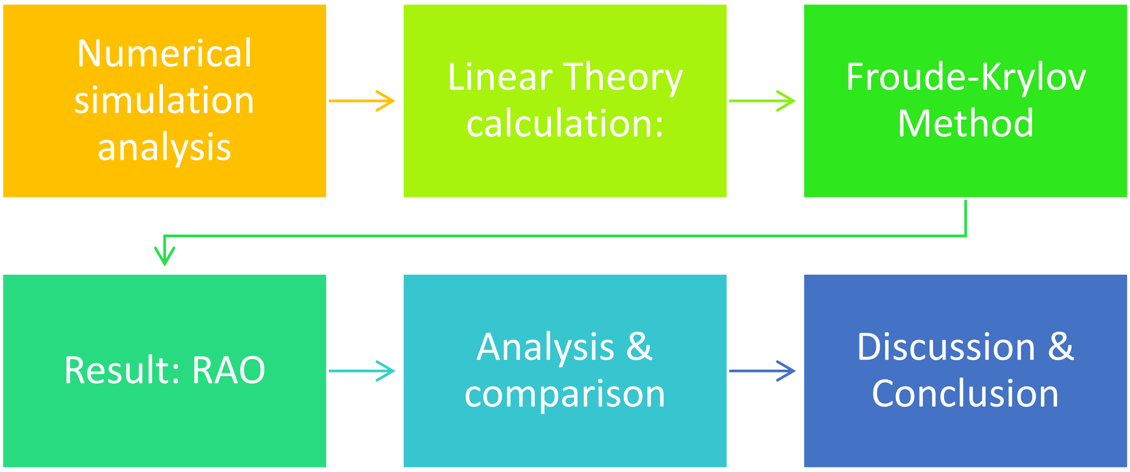
Water depth (m)	30.0	70.0	50.0	61.7

3.3 Numerical simulation flow

Figure 3. 4: Numerical simulation

The S (f) can be obtained from the linear theory calculation. After obtaining RAO and S_R (f), three types of graphs are plotted:

- JONSWAP spectrum



- Heave, surge and pitch response spectrum
- Heave, surge and pitch RAO
- Wave profile

All the three locations; PMO, Balingian and Samarang will have these type of graphs. The graphs will be compared between each locations. The Numerical simulation has been determined for 180^0 and 0^0 direction. Then the graph also being compared with the Caspian Sea.

3.4 Project Timeline

Table 3. 3: FYP Timeline

No	Detail/week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1	Numerical Simulation- 180 degree water draft 2m	🟥	🟥						mid-semester break								
2	Numerical Simulation- 0 degree water draft 2m			🟥	🟥												
3	Compilation and analysis of result					🟥	🟥										
4	Progress Report draft and Submission							🟥		🟥							
5	Numerical Simulation- 180 degree water draft 4m									🟥	🟥						
6	Numerical Simulation- 0 degree water draft 4m										🟥	🟥					
7	Pre-Sedex Poster presentation												🟥				
8	Submission of disertation (soft bound)													🟥	🟥		
9	Submission of technical paper														🟥		
10	Viva presentation															🟥	
11	Submission of disertation (hard bound)																🟥

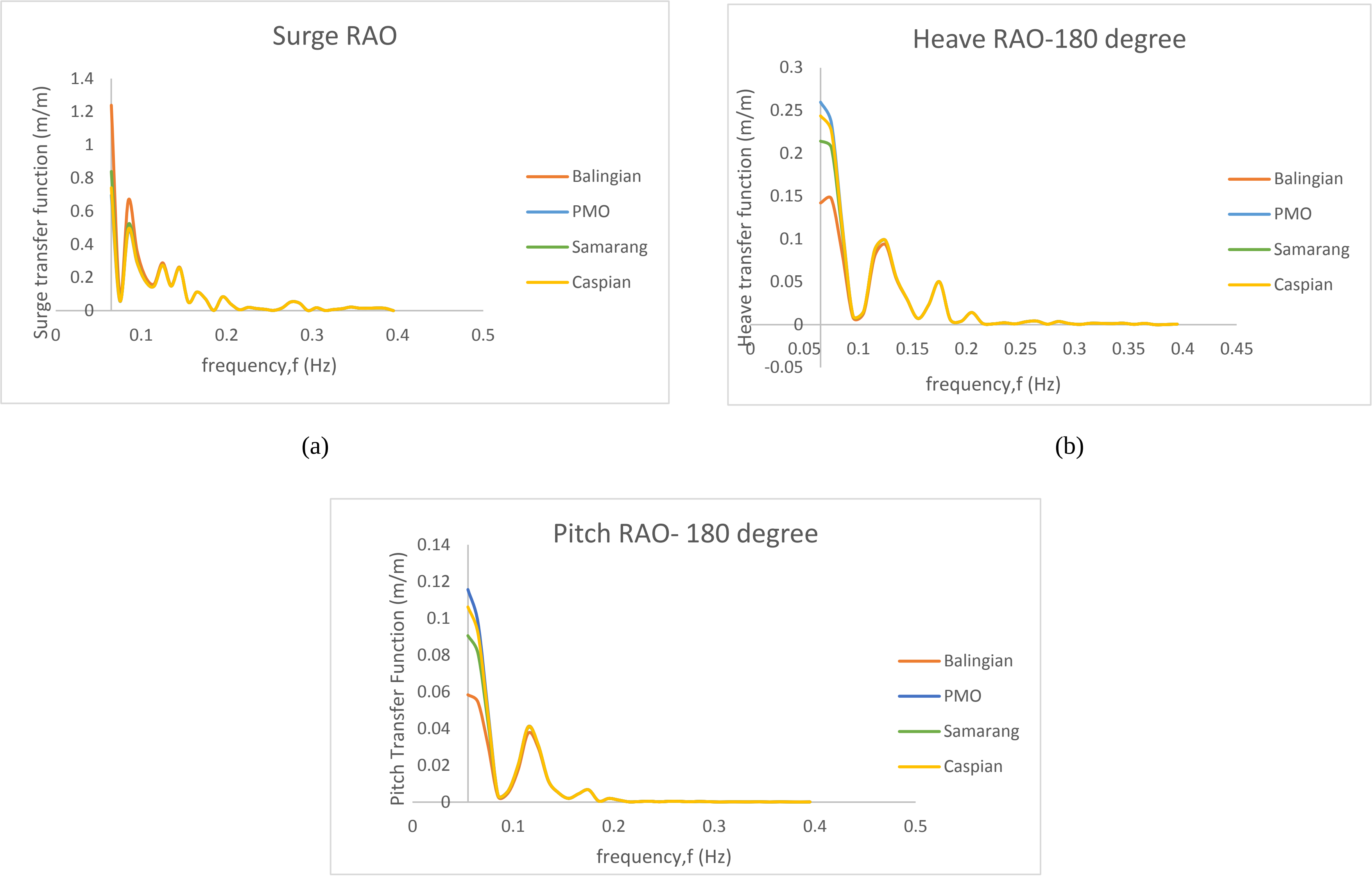
CHAPTER 4

RESULTS AND DISCUSSION:

4.1 180^0 Degree direction

For

Surge, Heave and Pitch 2m Water Draft

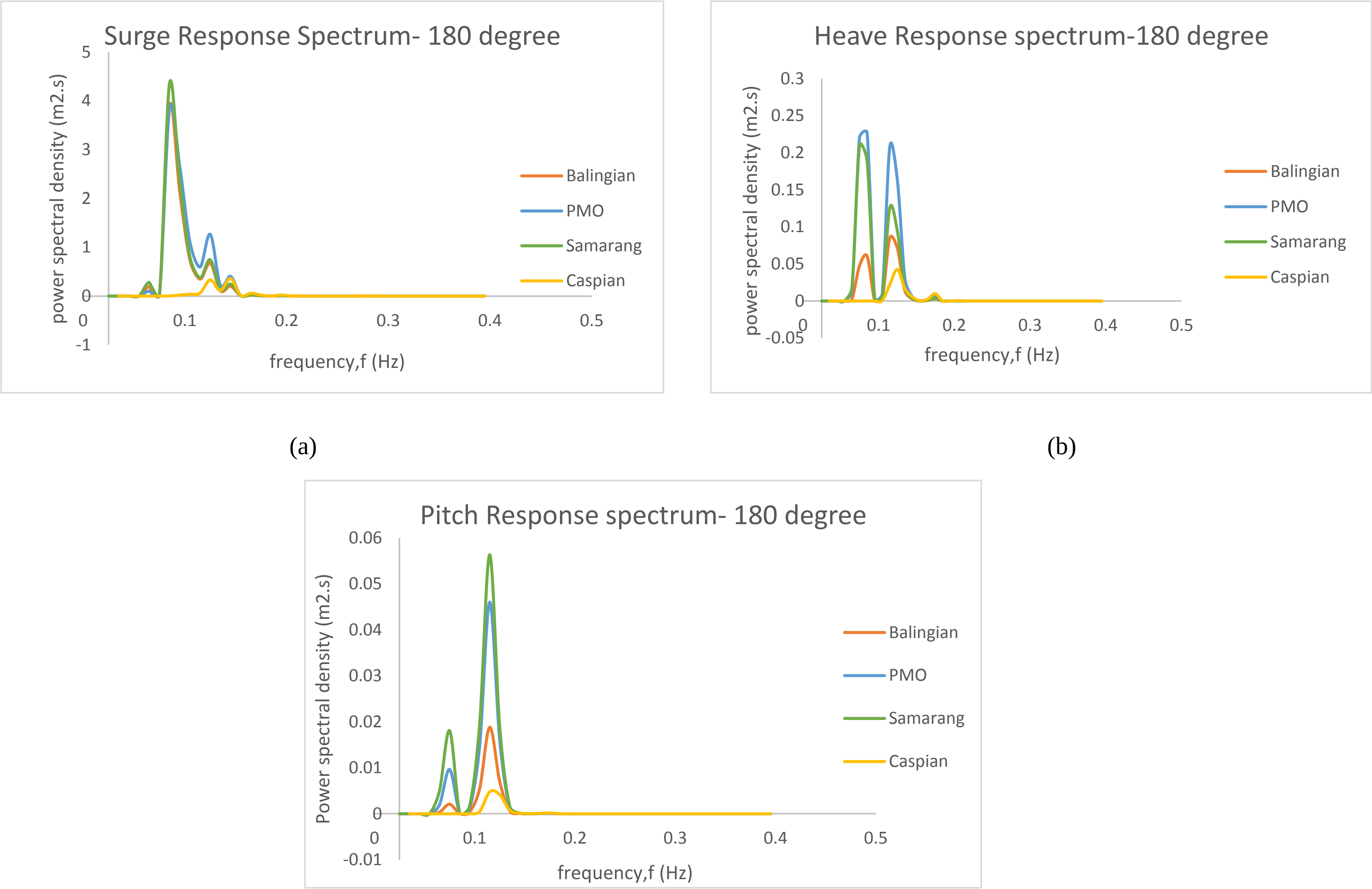


(a)

(b)

(c)

Figure 4. 1: RAO for 180 degree for surge, heave and pitch



(a)

(b)

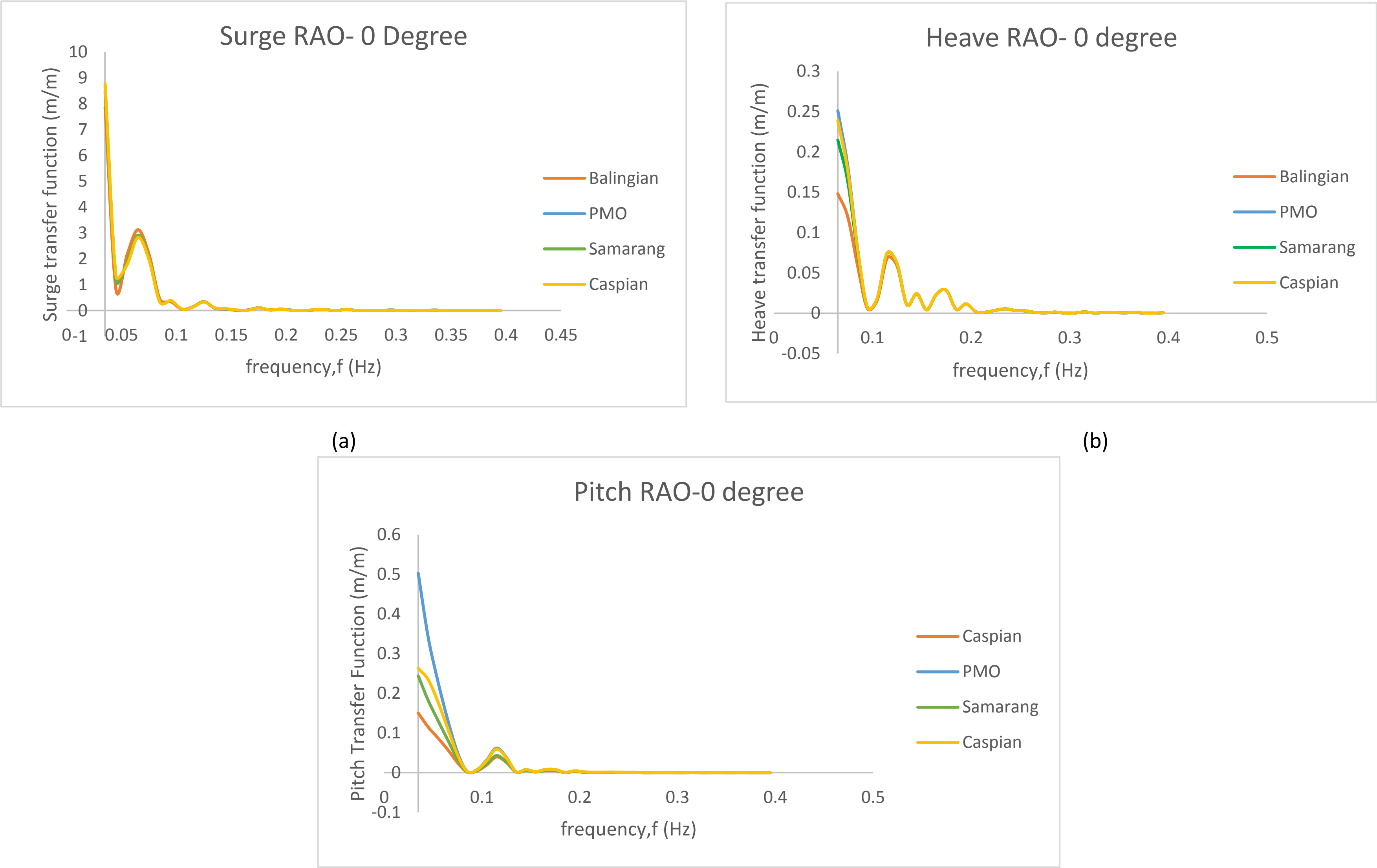
(c)

Figure 4. 2: Response spectrum for 180 degree

4.2 0^0 Degree direction

For

Surge, Heave and Pitch 2m Water draft

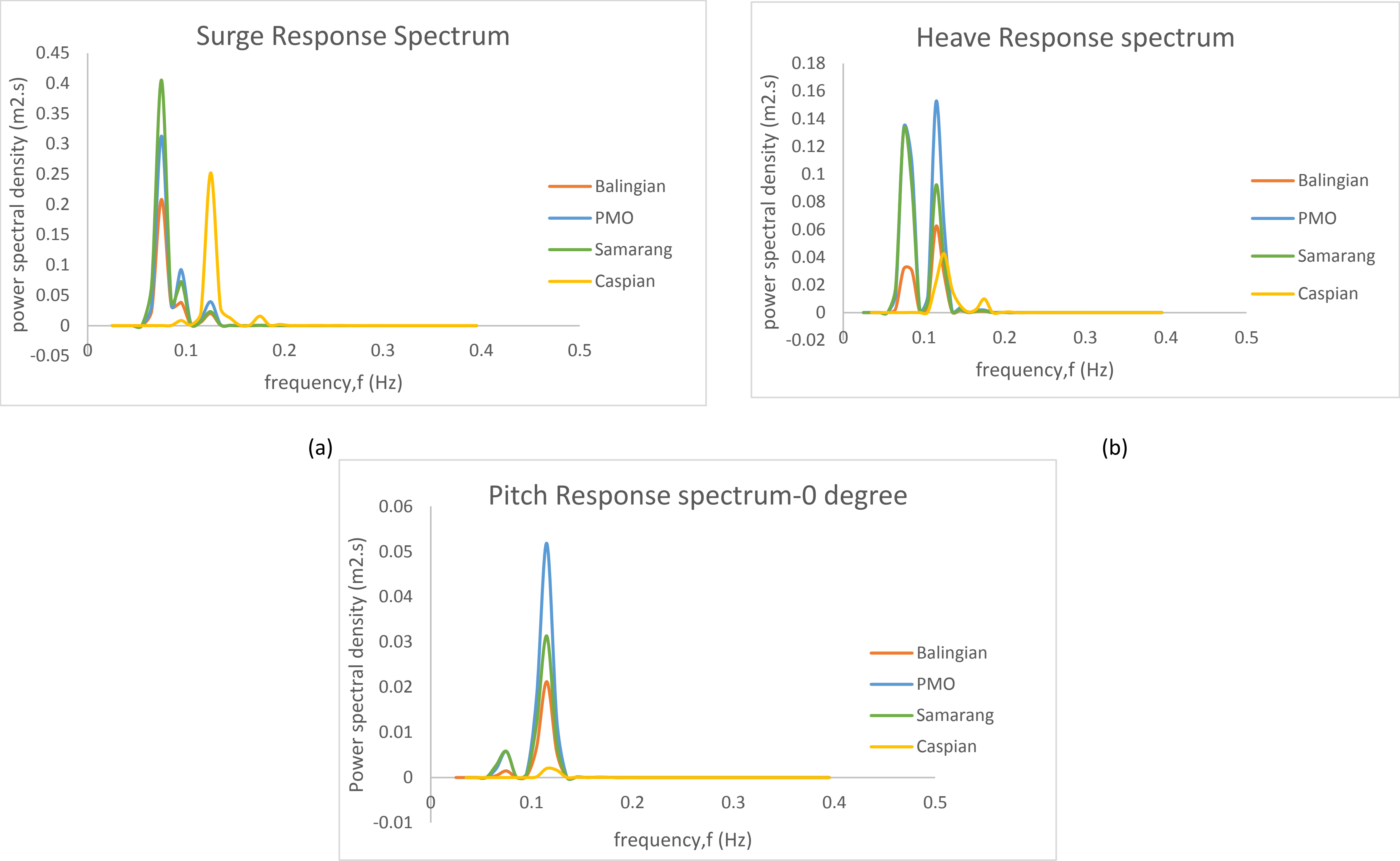


(a)

(b)

(c)

Figure 4. 3: RAO 0 degree for surge, heave and pitch



(a)

(b)

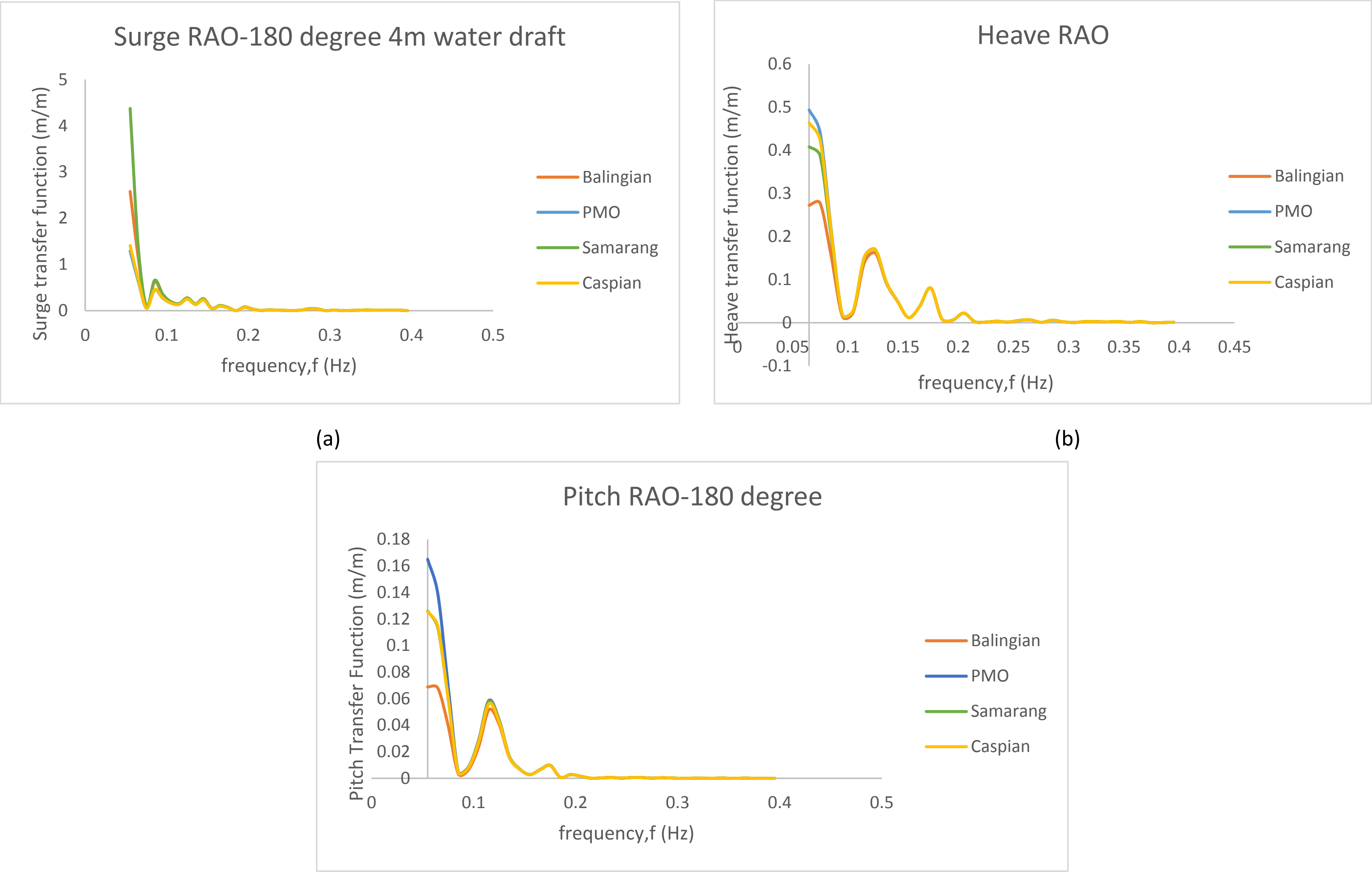
(c)

Figure 4. 4: Response spectrum for 0 degree

4.3 180^0 Degree direction

For

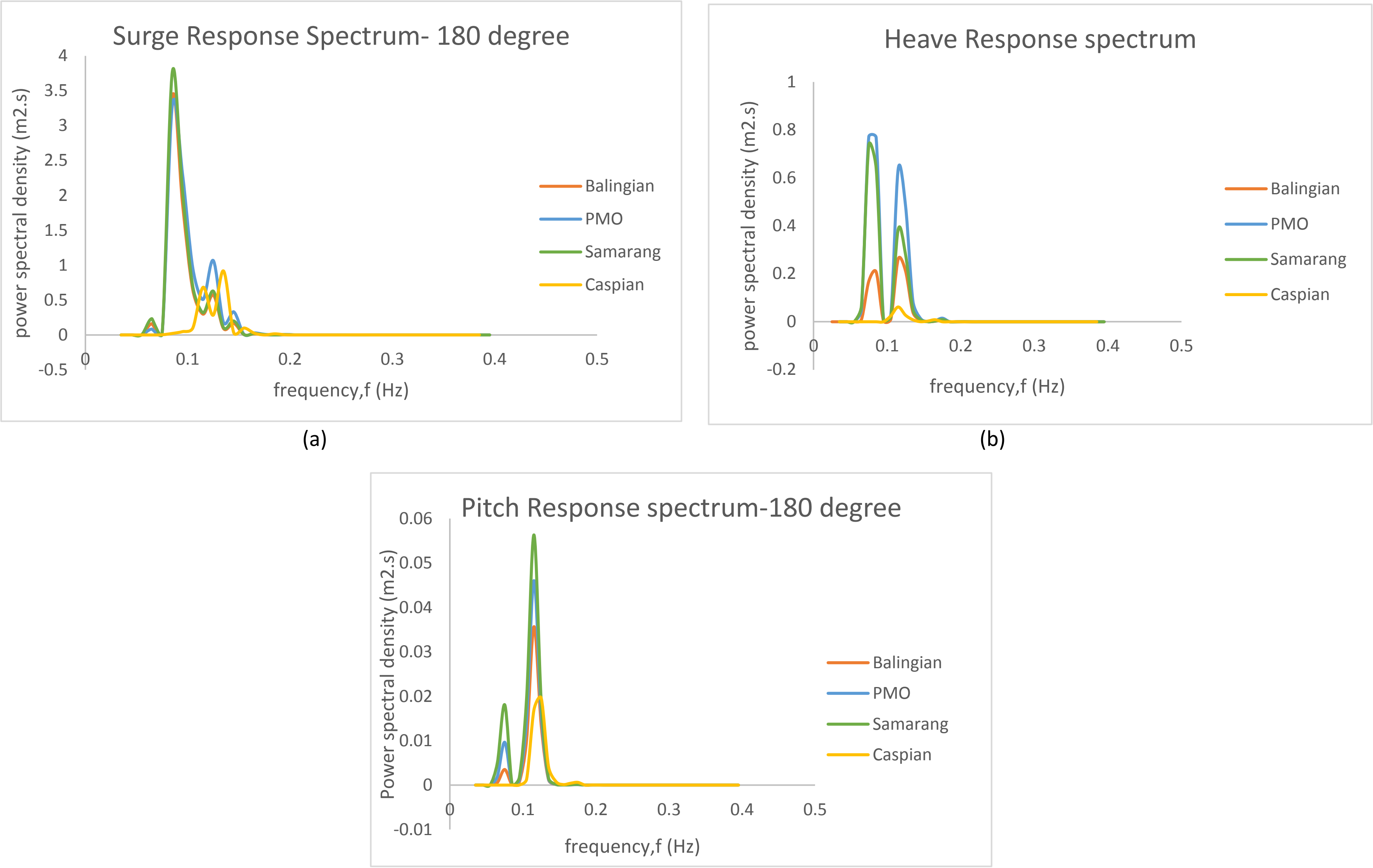
Surge, Heave and Pitch 4m Barge Draft



(a) (b)

(c)

Figure 4. 5: 180 degree barge RAO response for surge, heave and pitch



(a)

(b)

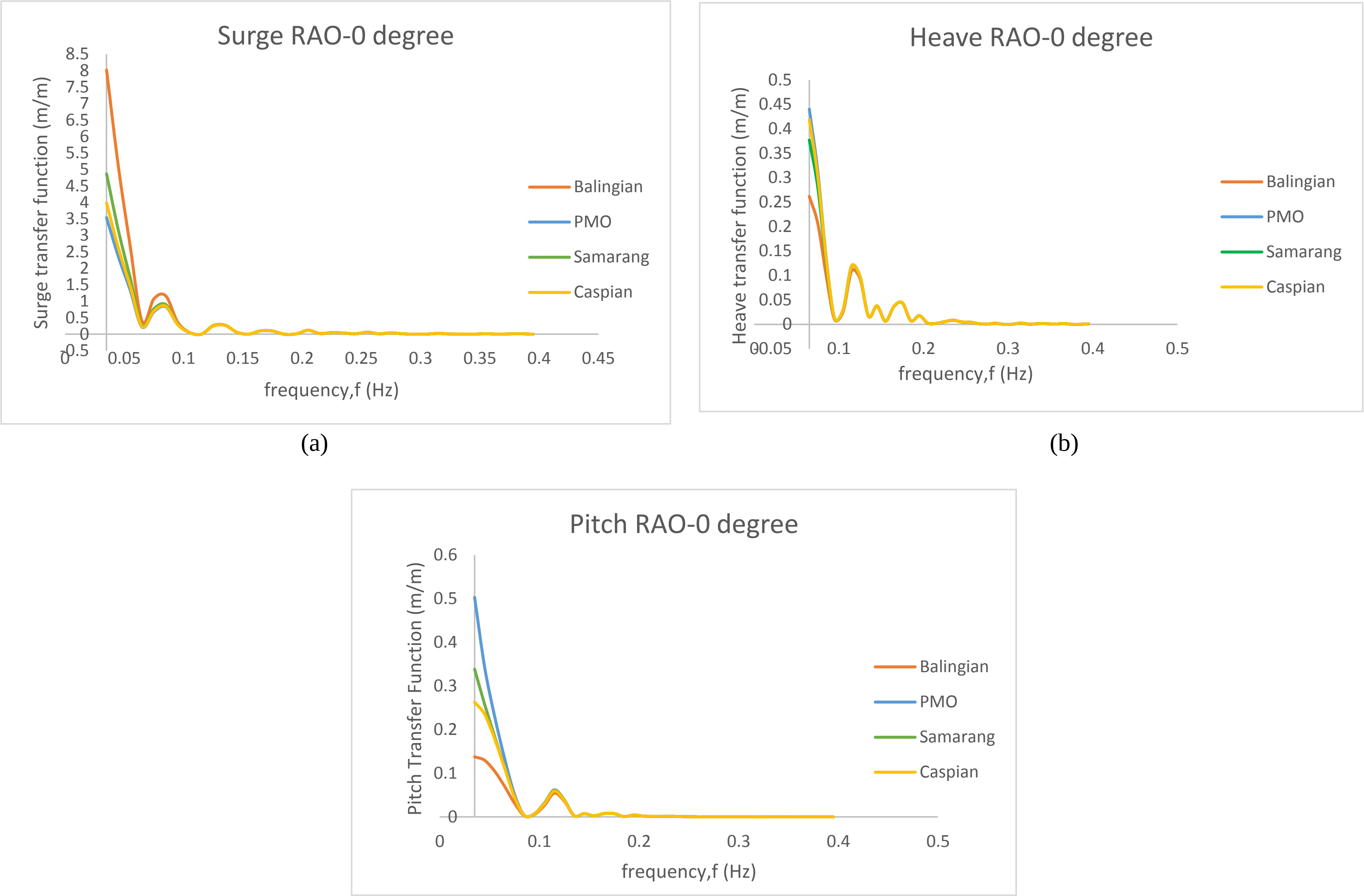
(c)

Figure 4. 6: Response spectrum at 180 degree for surge, heave and pitch

4.4 0^0 Degree direction

For

Surge, Heave and Pitch 4m Water Draft

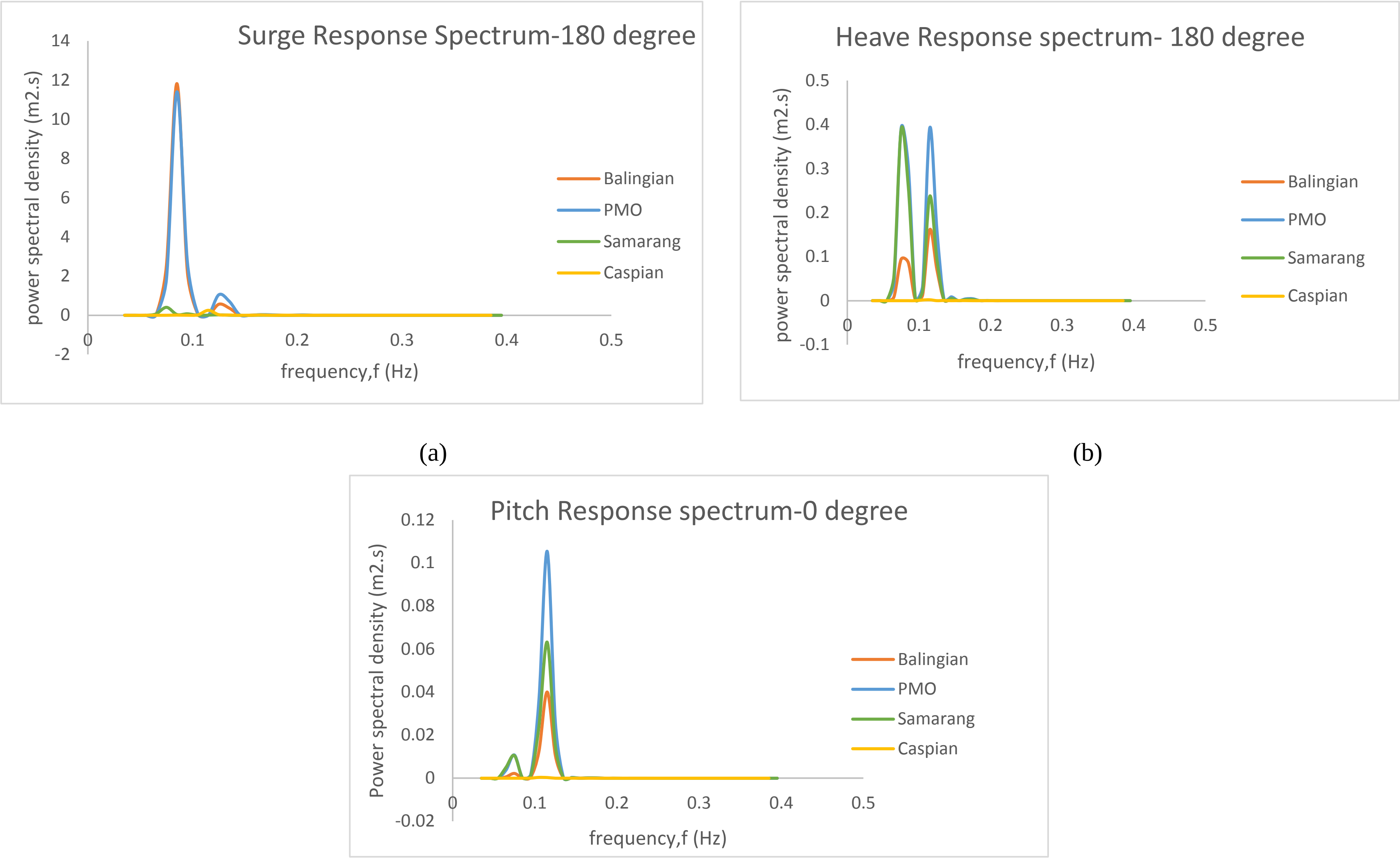


(a)

(b)

(c)

Figure 4. 7: RAO for surge, heave and pitch for 0 degree direction



(a)

(b)

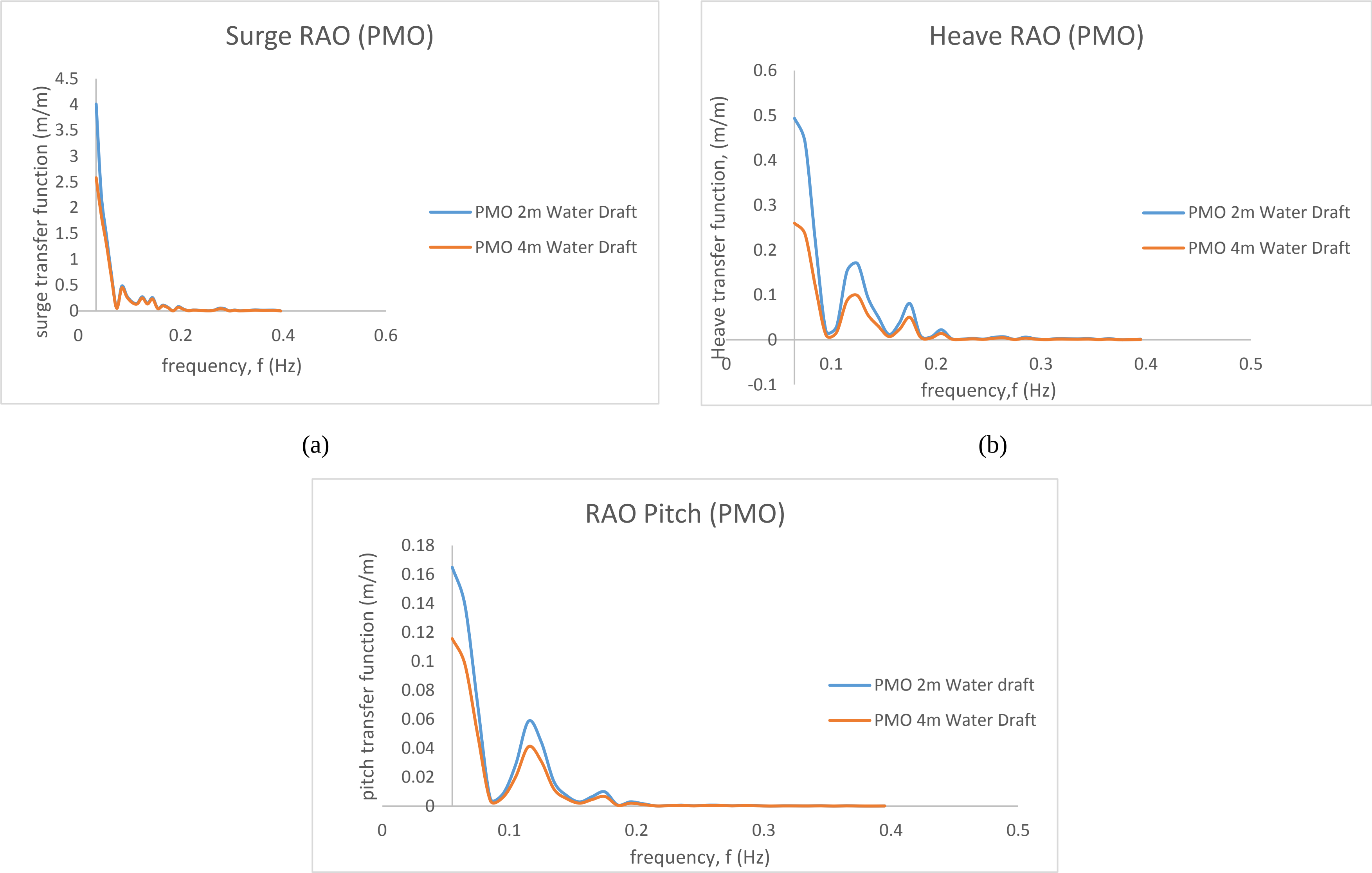
(c)

Figure 4. 8: Response spectrum for surge,heave and pitch for 0 degree

4.5 180^o Degree Direction

For

Comparing the result from different barge draft



(a)

(b)

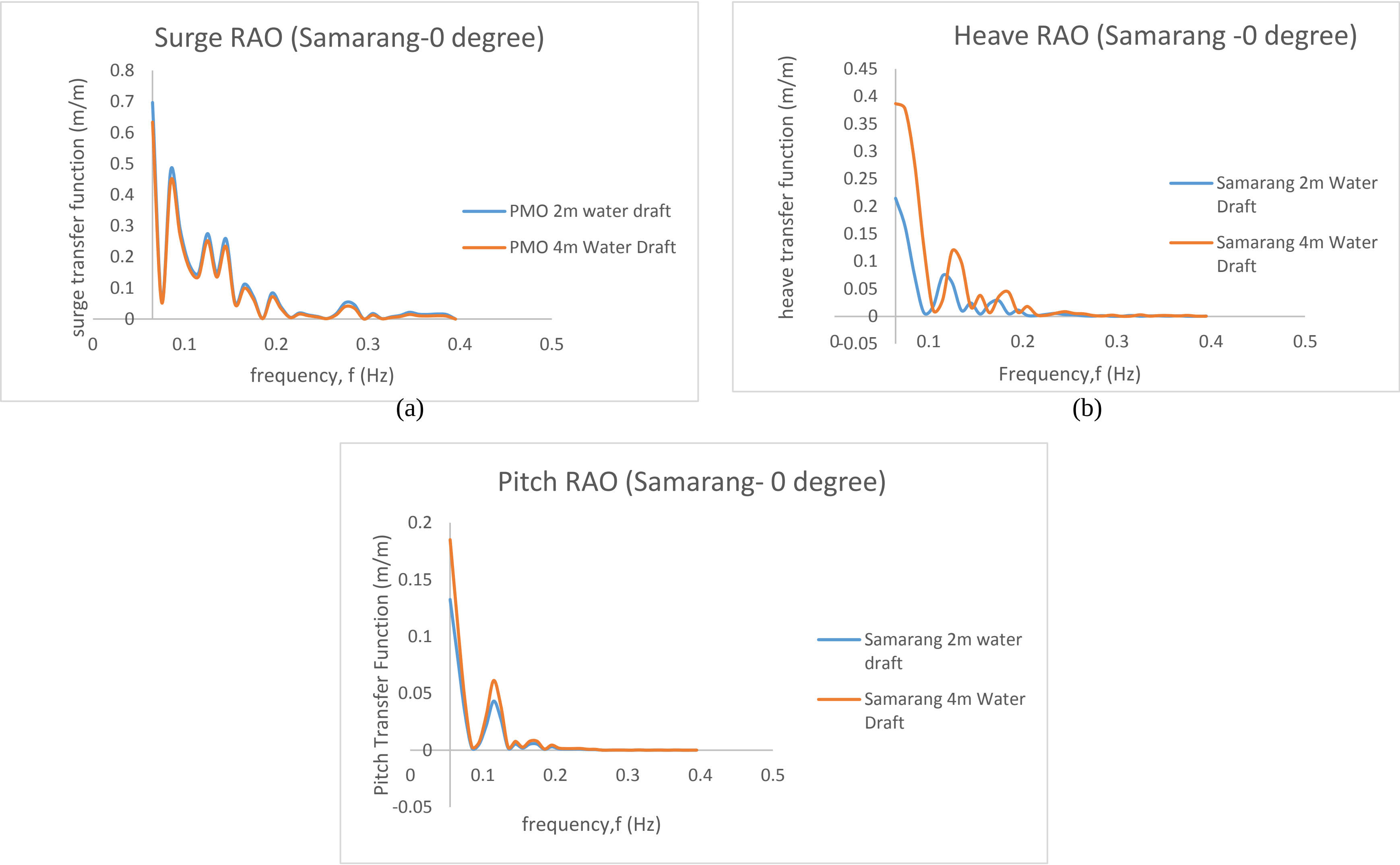
(c)

Figure 4. 9: Barge draft 2m and 4m RAO comparison for 180 degree direction

4.6 0^o Degree Direction

For

Comparing the result from different water draft



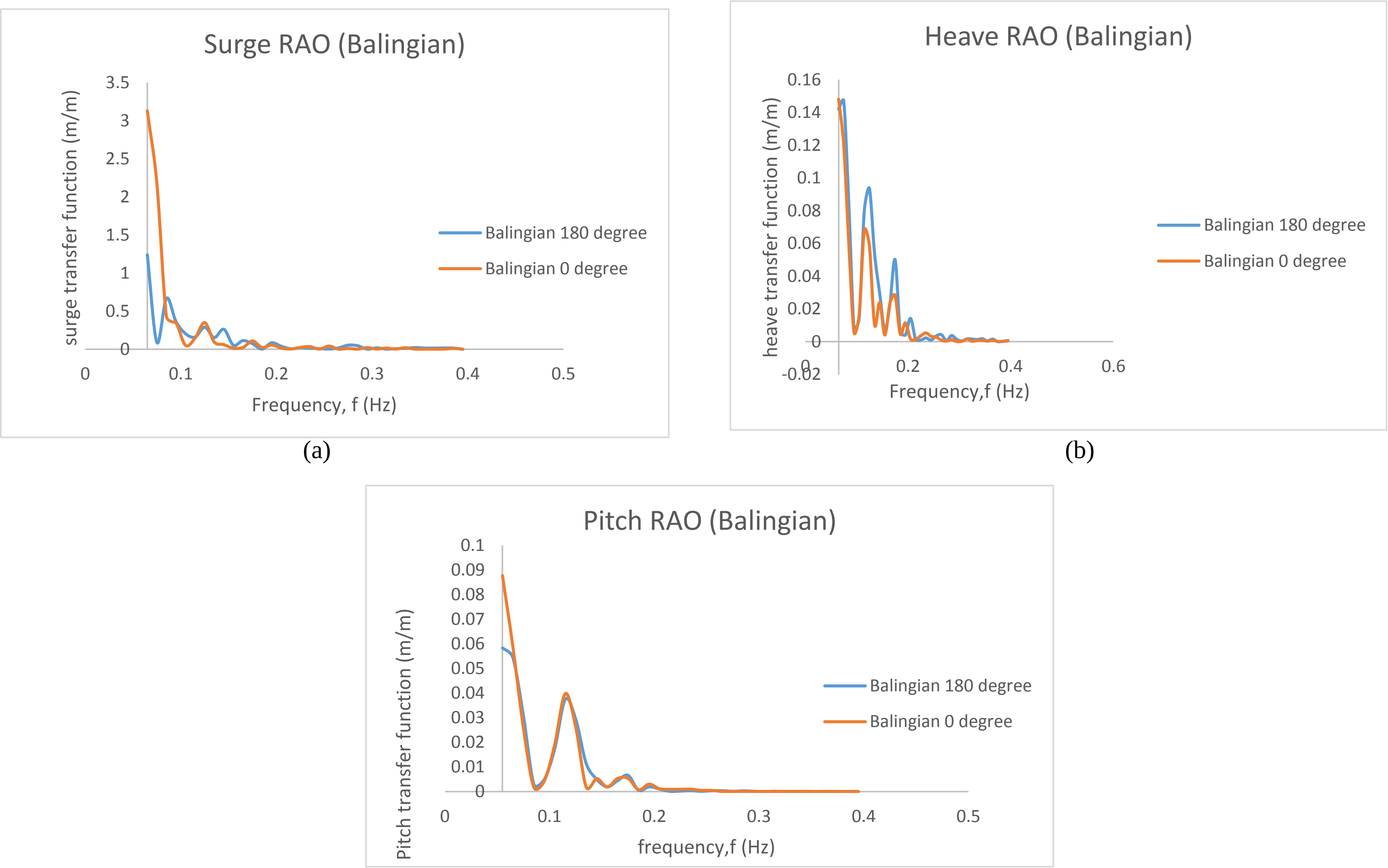
(a) (b)

(c)

Figure 4. 10: Barge draft 2m and 4m RAO comparison for 0 degree

4.7 Result for direction comparison

Comparing the result from different direction



(a)

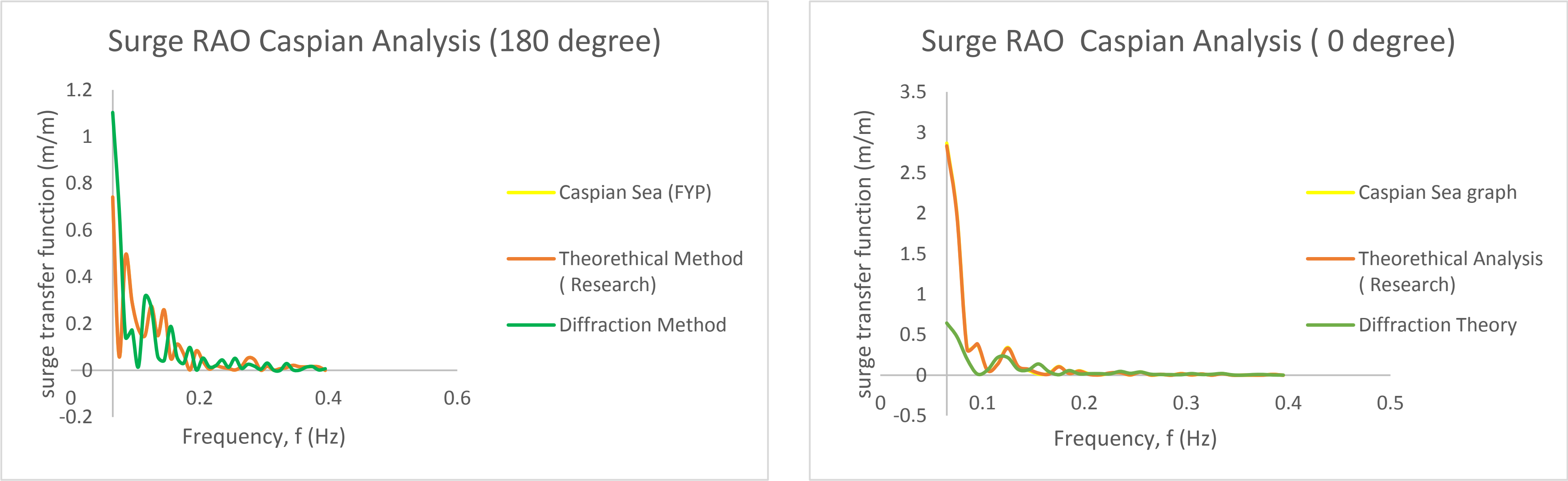
(b)

(c)

Figure 4. 11: 180 and 0 degree comparison

4.8 Comparison of results with research

For Caspian Sea



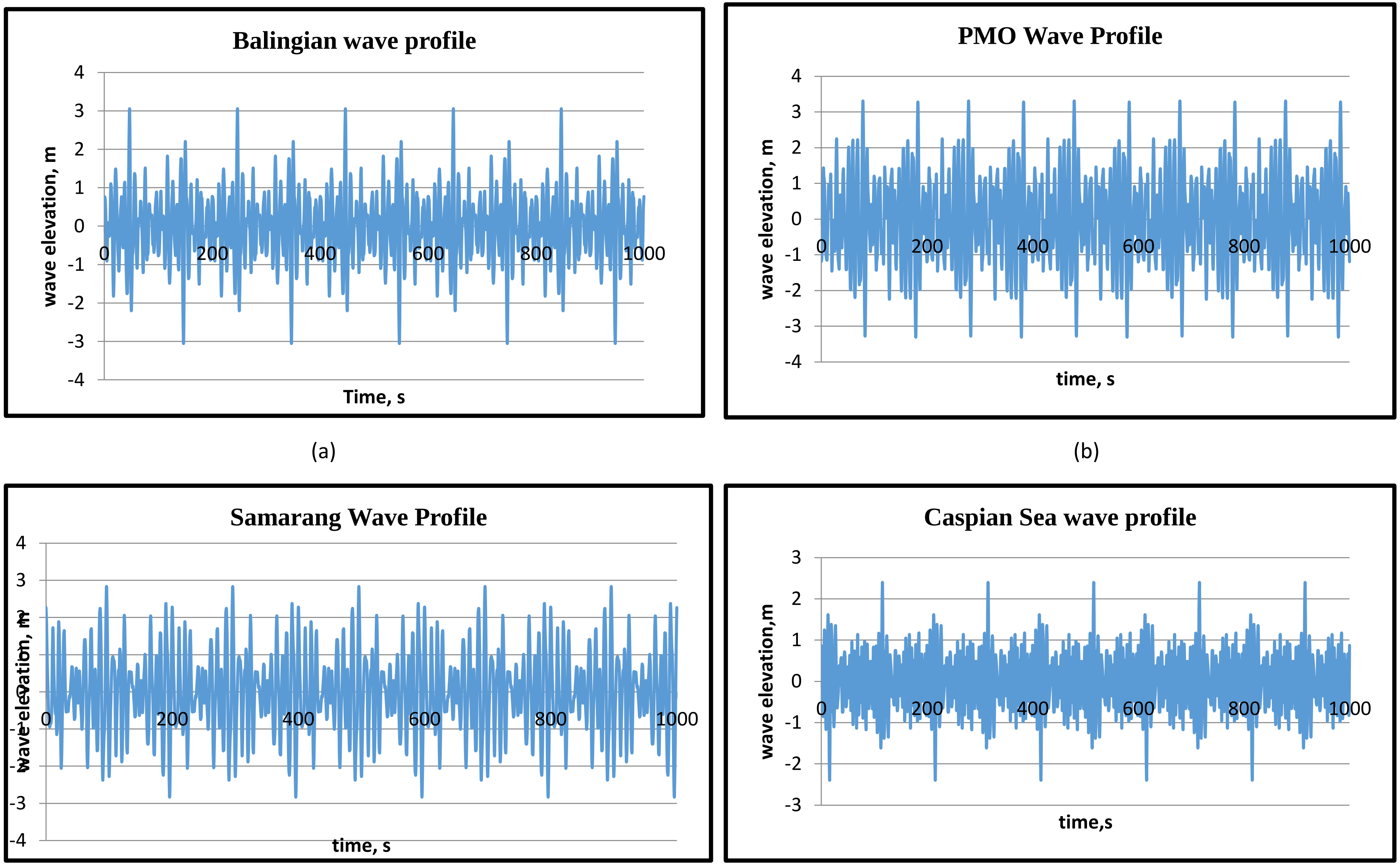
(a) (b)

Figure 4. 12: Surge RAO comparison for Caspian Sea

4.9 Wave Profile

For

Balingian, PMO, Samarang and Caspian Sea



(a)

(b)

(c)

(d)

Figure 4. 13: Wave profile

DISCUSSION:

1. Surge

180^0 degree direction:

For the RAO for surge the graph variation is nearly the same for the four of locations. The distinctive measure is in term of the RAO level. As in Figure 4.1 (a), Balingian have the highest surge RAO value followed by Samarang, PMO and Caspian Sea. The surge of RAO is more significant for Balingian condition. . For the surge response spectrum the graph for Malaysia's locations are the same. The maximum amplitude is at 0.085 Hz for these three. Samarang having the highest value of 4.2 m^2.s. Again the amplitude for Caspian Sea is very small for surge response spectrum.

0^0 degree direction:

The surge trend for this bow direction is very close to each other. The graphs are having a peak at 0.65 Hz. Approximately the value is 3 m/m. For response spectrum the Caspian Sea is having the highest amplitude of 0.5 m^2.s at 0.12 Hz. While the same trend occurred at the Malaysia's location with the different amplitude value.

2. Heave

180^0 degree direction:

For the Balingian, Samarang and PMO the trend of RAO agree from frequency 0.85 Hz until 0.495 Hz. The only different is in term of the amplitude. While the Caspian Sea trend is relatively very small as compare to the result from the three locations. Heave response from Figure 4.1 (b) showing PMO having the highest amplitude following by Samarang and Balingian. All three locations having the same shape of graph with two higher peaks. The Caspian Sea amplitude is very small. The highest value is only 0.04 m^2.s.

0^0 degree direction:

Only Caspian Sea is having different trend. The rest of the locations are having the same design of graph. The Caspian Sea amplitude is nearly at zero for the first time is at amplitude 0.95 Hz while the rest is at 0.65 Hz. That is explain the graph trend is shifted more toward the right side. Response spectrum for heave is different between the locations. The similarities lies at the shape of the graph which having two peak. For Malaysia's location the first peak is at 0.85 Hz and the second one is at 0.115 Hz. Another peak for Caspian Sea is at 0.175 Hz.

3. *Pitch*

180^0 degree direction:

The same trend occur for pitch for all locations. It shows that the amplitude is nearly the same for the four locations. As the Figure 4.1 (c) the line of the graph as observe is clearly seen in one colour (yellow) due to all the amplitude are approximately the same value along the increasing frequency. For the pitch response spectrum, the highest peak for the graphs are at the 0.115 Hz. At the 0.075 Hz also showing another smaller peak. Caspian Sea highest amplitude is only 0.05 m^2.s at 0.115 Hz.

0^0 degree direction:

Closely follow the same trend. PMO and Caspian Sea having small peak at 0.115 Hz while the other two at 0.12 Hz. After that the amplitude is approaching to zero. At the pitch response spectrum, clearly from Figure 4.4 (c) the trend is the same. Having highest peak at 0.115 Hz.

4. *Different direction of wave headings*

Different wave headings might give a different results in term of the trend and amplitude. As in Figure 4.7 a-c shows that there is not much different between 0 degree and 180 degree. For Surge 0 degree has greater amplitude compare to 180 degree but at frequency 0.195Hz 0 degree is nearly has the same trend as 180 degree. Different with heave response. 180 degree has greater value compare with 0 degree. For pitch both graph looks similar in trend. The reason due to this differences is might due from the shape of the barge. 0 degree wave heading is coming toward the fork shaped while 180 degree affected the rectangular part of the barge.

5. *Different in barge drafts*

The different in barge draft as well influence the dynamic response of the barge. Observation from Figure 4.5 a-c shows that 2m barge draft for all the responses with 180^o wave heading have the highest amplitude compare with 4m barge draft although they have similar in trend. This might due to the buoyancy force acting on the barge. As the Archimedes principle of buoyancy force $=\rho gV$ explain that the volume of the object submerged in water the stable it become. This is proven by 4m barge draft is more stable than 2m barge draft thus will give lesser responses.

Ironically the same approach for 0^o degree wave heading cannot be apply. Only surge 2m barge draft has higher response (only slightly higher). For heave and pitch 4m barge draft are higher than 2m barge draft. This might again due to the fork shaped of the barge that influence this scenario.

6. *Surge RAO Comparison for Caspian Sea.*

The reason why this analysis is done to see the reliability of method used for this project. Attentively it is done through comparison between the researches that is successfully conducted by one of the master student. Supposedly from Figure 4.8 (a) and (b) there are graphs in one set. But as observed apparently we can only see two graphs. This is because the graph obtained from this project showing the same result for the theoretical method done by the previous researcher. She is also doing the numerical simulation. The diffraction method used from WAMIT software give the response of the barge. For 180^o and 0^o degree both shows that the result is not extremely showing much different. There are a lot of interception between the graphs.

7. *Wave Profile*

Only PMO having wave elevation more than 3m. This might due to the highest water depth of 75m when compare to the rest of the location. Balingian maximum wave elevation is at 3m and Samarang is nearly to have wave elevation of 3m as well. The lowest wave elevation is at the Caspian Sea which is at 2.4 m height.

CHAPTER 5

CONCLUSION

5.0 Conclusion:

The theoretical results are the output based on Airy's linear wave theory and Froude-Krylov theory that is then converted in term of RAO. The objectives of finding the response of the barge for surge, heave and pitch have successfully completed. The reliability of the data has been induced from the comparison of analysis of Caspian Sea with the published research.

The results obtained from the numerical simulation shows that although these three locations are at Malaysia's water of South China Sea, they have different environmental condition. The different of metocean data do not gave very large differences between these locations as the most important aspect is the barge itself.

The optimization of the barge draft is very important as barge draft play important role for the installation. Thus during the mating process, the barge draft should be controlled by ballasting and de-ballasting to ensure the leg of topside will not collide with the structure's legs.

The Peak RAO that are usually ranging from 0.1-0.2 Hz (period 5- 10 s) should be put as important data as during installation the wave induce such frequencies should be avoided. This is because at these range of frequencies the barge motions are at the highest. The knowledge of RAO's will aid in forecasting the suitable weather condition for the installation of the topside.

CHAPTER 6

RECOMMENDATION

6.0 Recommendation

The parameters used for this project do not cover the overall aspect of the dynamic response of the float-over barge. Due to limited time and availability of facilities for this research, the parameters and method of analysis are constraint.

There are some recommendation highlighted to further enhance the research on the response of the float-over barge:

a) Conducting experiment for more comparison of data.
b) Varying the wave headings- 22.5°, 45°,90°,135° and 157.5°
c) Varying the barge draft of 3m, 5m and 6.75m
d) To improve the reliability of the data, results can also be compare with software such as SACS and WAMIT.

CHAPTER 7

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