OPTIMUM CONFIGURATION OF MOORING LINES FOR SEMI-SUBMERSIBLE PLATFORMSUBJECTED TO REGULAR AND IRREGULAR WAVES

By

MOHD AMIR RASYID BIN MUSTAPHA

15176

Dissertation submitted in partial fulfillment of

The requirements for the

Bachelor of Engineering (Hons)

Civil Engineering

MAY 2014

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

OPTIMUM CONFIGURATION OF MOORING LINES FOR SEMI-SUBMERSIBLE PLATFORMS SUBJECTED TO REGULAR AND IRREGULAR WAVES

By

MOHD AMIR RASYID BIN MUSTAPHA

15176

A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi Petronas
In partial fulfillment of the requirement for the
Bachelor of Engineering (Hons)
Civil Engineering

Approved by,

____

(Dr Montasir Osman Ahmed Ali)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK DARUL RIDZUAN
MAY 2014

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 the original work contained herein have not been undertaken or done by unspecified sources or persons.

MOHD AMIR RASYID BIN MUSTAPHA

ABSTRACT

Floating offshore structure is widely used in deepwater and ultradeepwater fields all around the world. The configuration of mooring line for semi submersible platform subjected to regular and irregular waves has been studied experimentally. Initially, semi-submersible models were designed. The model was design base upon Froude Law to scale down the platfrom prototype and environmental surroundings. The model tests were performed in the wave tank located in the Offshore Laboratory of Universiti Teknologi PETRONAS. In the experiment the models were subjected to regular waves and irregular waves and limited to long crested waves. Comprehensive experimental studies were conducted to the semi submersible model. The model tests including quasi-static and free decay test were conducted to measure the stiffness of the system and natural frequencies. In addition, to measure the platform motions subjected to regular and random waves, a series of station keeping test were performed.

All three series of the experiment were conducted for the model with different parameter.The effect of pretension, and mooring line configuration among the parametric studies performed towards the experiment. Towards the end, the results of the experiment were analyzed to examine the effect of each parameter on the dynamic motion of the semi submersible platform model.

ACKNOWLEDGEMENT

The success and final outcome of this project would have not been possible without the support and guidance from many individuals.

First and foremost, I would like to express my profound gratitude to my supervisor, DrMontasir Osman Ahmed Ali whom gave his support to ensure the progression and smoothness of my final year project entitled **“Optimum configuration of mooring lines for semi-submersible platforms subjected to regular and random waves.”.**

I also am particularly grateful for the assistance given by Mr Anurag, a Master student of my supervisor. Assistance provided by him helped me in conducting the comprehensive experiment and analyses experimental data for the project.

Special thanks to Mr Meor Asniwan and Mr Zaid Zainuddin, technicians of UTP Offshore Laboratory for their cooperation during conducting the experiment of my project.

I hope that this project will be useful and contribute greatly to the industry in the future.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

G	Gravity
B	Buoyancy
Fr	Froude Law
UTP	Universiti Teknologi PETRONAS

CHAPTER 1

INTRODUCTION

1.1 Background of Study

To date, as demanding of hydrocarbon all around the world keep on increasing, there is need for Oil and Gas Industry to venture into deepwater and ultra deepwater region. This industry started to mark the history on offshore oil and gas production in October 1947,drilled in 14 ft of water in the open Gulf of Mexico’s Ship Shoal Area off southeastern Lousiana. This broad steps created a whole new phase of exploring and producing crude oil and natural gas.

Offshore structures can be classified into two main categories which is fixed or floating platforms Considering on capital expenditure of fabrication, technical and installation constraints of offshore drilling in deepwater,thus making the choices of floating structures are more practical.Fixed strictures became increasingly expensive and difficult to install as the exploration goes into deep water.More particularly,floating structures such as semi submersible drilling platform have been used. Semi-submersibles are multi-legged floating structures with a large deck. These legs are interconnected at the bottom underneath water with horizontal buoyant members called pontoons. Some of the earlier semi-submersibles resemble the ship form with twin pontoons having bow and a stern. This configuration was considered desirable for relocating the unit from drilling one well to another either under its own power or being towed by tugs. Early semi submersibles also included significant diagonal cross bracing to resist the prying and racking loads induced by waves.

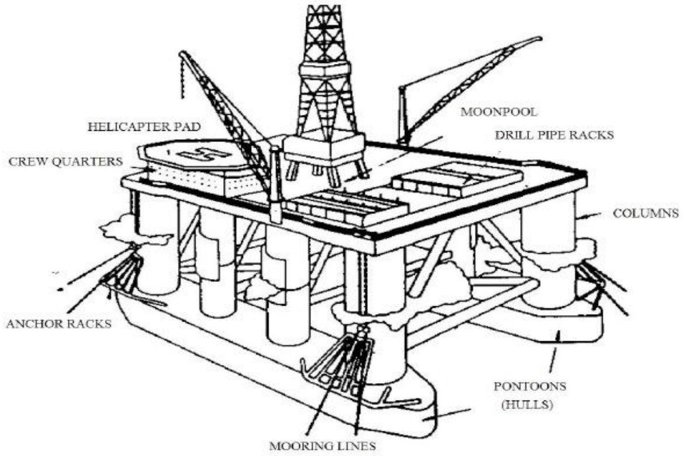


Figure 1: Typical type of semi-submersible

As for floating structures ,it could be be moored to the seabed, dynamically positioning by thrusters or may be allowed to drift freely.Moored floating structures are usually positioned at desired location at sea and their motion is externally constrained by moorings.Generally, floating structures have too much motion during extreme storm struck. Floating structure have multiple degree of compliancy..Typical buoyant structures, such as semi-submersible are dynamically unrestrained and allowed to have six degress of freedom which is heave,surge, sway, pitch, roll and yaw.

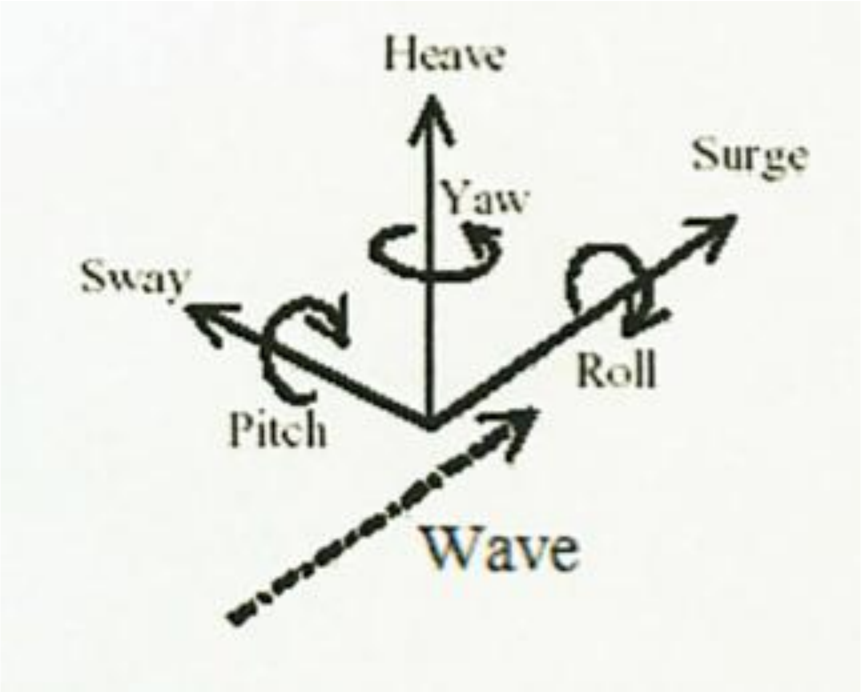


Figure 2: Motion Indicator for Semi Submersible Platform

This floating structure obtained their compliancy using mooring system.Mooring line and station-keeping are unique requirements of floating structures.Mooring is the means for providing a connection betweem the structure and the sea-floor for purposes of securing the structure against environmental loads.Station keeping is a term used to define a system for keeping the facility within a specified distance from desired location.

Mooring line might consists of chain,wire rope, synthetic rope, or combination of them. To achieve the given mooring perfomance requirements,there are many possible combinations of line type, size, location and size of the clump weight or buoys that can be used to. Out of all,the chain is most used as 85 % of all semi submersible using it for station keeping due to its durability and contribution to the anchor holding capacity. The wire is much lighter and provides a greater restoring force than chain and requires lower pretension. This becomes increasingly important as the water depth increases. The wire rope needs careful maintenance due to long-term abrasion where it is in contact with the seabed (Herbich,1999).

Mooring lines, which are essential components of semi submersible platform, are used to anchor the platform to the seabed. In common offshore engineering practice, mooring lines are modeled as linear or nonlinear springs to predict their contribution to the restoring force of the system. This is known as quasi-static analysis, which addresses the dynamics of the mooring lines in static manner, whereby a static equilibrium state is assumed at each time step of the simulation. This sort of analysis neglects the inertia of the mooring line as well as the additional drag forces that may increase the damping of the moored offshore structure. Therefore, a fully coupled dynamic analysis may be adopted to analyze the structure and mooring lines as a coupled system. However, such analysis may become quite expensive

There are two main approaches to evaluate the dynamic responses of any floating offshore structure. An approximate approach is to carry out the analysis in the frequency domain which results the steady state responses. Hence, this approach is adopted only in the preliminary design. An accurate approach is to analyze the structure in the time domain when the structure responses can be evaluated numerically at each time step.

Exciting wave forces can be predicted by the Morison equation, which assumes the force to be composed of inertia and drag forces linearly added together. These components involve inertia and drag coefficients, which can be determined experimentally. Morison equation is applicable when the structure is small in dimension compared to the wavelength $\left(\frac{\text{Structural Diameter}}{\text{Wave Length}} \leq 0.2\right)$. When the size of the structure is comparable to the wavelength, the presence of the structure is expected to change the wave field in the vicinity of the structure. In this case, diffraction of the waves from the surface of the structure should be taken into account in the evaluation of the wave forces. It is generally known as diffraction theory.

1.2 Problem Statement

During operation time in open sea, a semi-submersible platform is subjected to environmental loads dominantly waves.In design stage of the floating platforms,it is important to predits its dynamic responses. Thus,all the responses of the platform subjected to six degrees of Freedom (DOF) should be known. This prediction could be conducted through analytical solutions,numerical simulations (ANSYS,SACS,STAAD) and laboratory experiments.This project is concerned with a problem on how to find the optimum configuration of mooring line for semi-submersble plaform subjected to random and regular waves using experimental model.The design of moored semi submersible systems constitutes a challenging engineering problem, in which the platform offset, stability, payload and system optimized cost requirements are to be met simultaneously. This problem is complicated by the incomplete understanding of the configuration of mooring line associated with semi submersible platform. To date, there is no specific guideline for choosing optimum configuration of mooring line. In industries, the usage of trial and error method application for mooring line configuration is still being practiced until now.

1.3 Objectives

The objectives of this project are listed as follows:

- To predict optimum configuration of mooring system for semi submersible platform subject to random and regular waves using experimental studies based on Metocean data in Sabah Operation Field.

- To investigate the contributions of the various design parametes on responses of moored semi submersible such as pretension and mooring line configuration.

1.4 Scope of the Project

The scope of the research as per subject.

1. Only experimental studies will be used to achieve the objectives.

2. Only regular and irregular waves will use throughout the experiment and is limited to long crested waves.

3. Consider only two design parameter which is pretension and mooring line configuration.

4. Truncated mooring lines will be used in the experiment to represent the mooring line restoring forces.

CHAPTER 2

LITERATURE REVIEW

In this chapter, the related research on the aspects of the dynamic analysis of floating offshore structures particularly semi submersible platform, are discussed.

2.1 Hydrostatic Stability

A floating object is stable if it tends to restore itself to an equilibrium position after a small displacement. For example, floating object will generally have vertical stability, as if the object is pushed down slightly, this will create a greater buoyant force, which unbalanced against the weight force will push the object back up.

Metacentric height, MG, is given by

$MG = MB – GB$ or $MG = (I/Vs)- GB$ (Equation 1)

Where I is 2^{nd} moment of area of plan section of the body where it cuts the waterline. In other words, if you were to cut horizontally through the body of water surface and look at the area of the body exposed by the cut, I is the 2^{nd} moment of area of that body about the longest axis. Vs. is the submerged volume or volume of water displaced and GB is the distance between center of gravity and center of buoyancy.

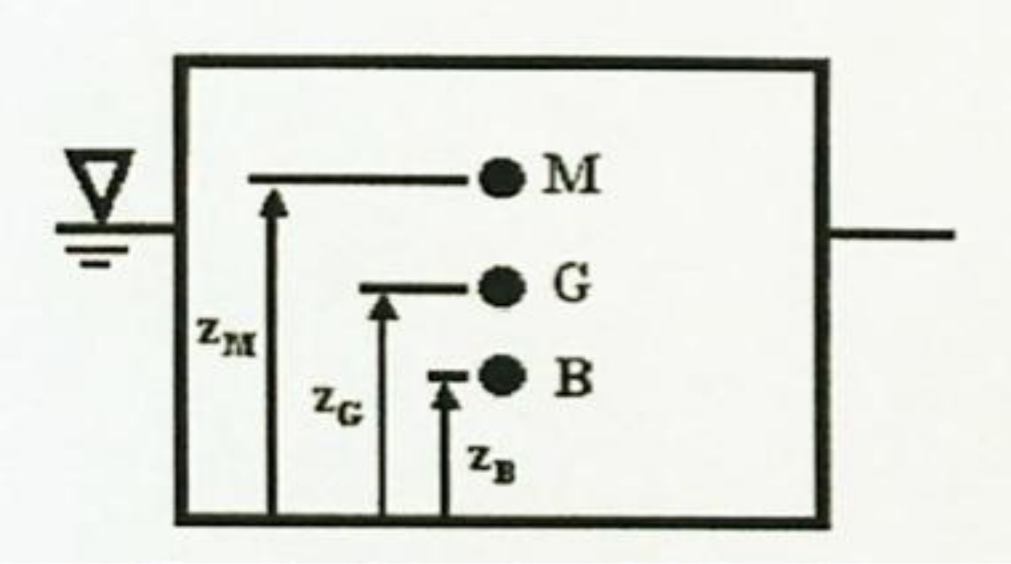


Figure 3:Orientation of M, G and B

2.2 Numerical Formulation

The earliest study of hydrodynamic analysis of conventional semi submersibles subjected to wave frequency forces was conducted by Hooft,1972. Wave frequency forces and motion responses of floating semi submersible were evaluated assuming that the submerged part of the platform could be sub-divided into typical slender elements. This, however, was valid only when the dimensions of the elemental part were smaller than one fifth of the wave length. The results obtained by this method were validated by comparing with model test results, and it was found that the numerical results differed within 5% from the experimental results (Hooft,1972).

Hooft hypotheses were followed by a number of researchers for the prediction of the floating platform motion and mooring tension responses like (Takagi and Arai, 1985.Tan,1992 & Wu,1997) An intensive comparison study on the methods for calculating the semi submersible wave motions was conducted by Takagi and Arai in 1985. The calculation results on the validity of 34 programs were examined by conducting comparisons with experimental results. These programs were classified into five groups based on the theoretical background of each program. Programs in the first class made use of the 3D potential theory with or without viscous damping correction. In the second class, Hooft method with Morison formula was adopted. In programs of the third class, use of the Hooft method with 2D potential theory was adopted. In the fourth and fifth classes, the programs adopted a mixture of the first and the third classes and the second and the third classes respectively. The results indicated that most of the programs provide virtually the same results for surge and sway, and these results were in a good agreement with the experimental results. For other motions, it was found that there was no good agreement between programs and it was concluded that by using appropriate force coefficients, the simple Morison method was able to obtain accurate results as good as those using the 3D potential theory.

2.3 Floating Structure Dynamics

The motions of a moored semi submersible in regular waves were studied both numerically and experimentally by Wu in 1997. Numerically, the semi submersible was modeled as an externally constrained floating platform, as composed of several rigidly connected parts. The idealized equations of motion of each part were obtained in a common reference system fixed on the platform. A consistent formulation of the wave-induced internal forces between two parts as well as the external constraining forces was evaluated. Experimentally, model tests were carried out using a 1:36 scale model of the semi submersible Glomar Arctic. Good agreement was achieved between the numerical results of platform motions and internal forces and those from model tests. Numerical results obtained with and without mooring lines indicated that the mooring effect on the platform motions and internal forces were insignificant in the wave frequency range.

Beside numerical simulations, model tests are the other important simulation method in the design of a floating system. The design of the mooring system in deepwater presents a challenge to the model tests in wave basins. Water depths around 1000 m can be modeled in the largest test basins in the world by typical scales ranging from 1:50 to 1:100 in the past (Stansberg, Yttervik, Oritsland & Kleiven, 2000). Due to the limitation of the depth of existing wave basins, either the model is made in very small scale, or the mooring system has to be distorted. It is truncated vertically and sometimes horizontally due to the limited horizontal dimensions of the basin (Buchner,Wichers &Wilder,1999). Truncated mooring line model tests showed that line dynamic tensions of a truncated mooring system are very different from those of a full-depth (undistorted) mooring system (Chen, Zhang, Johnson & Irani , 2000). Ormberg et al. (1999) has proposed a hybrid method to extrapolate a truncated mooring model test to the corresponding full depth mooring system with the aid of numerical simulations based on coupled dynamic analysis.

CHAPTER 3

METHODOLOGY

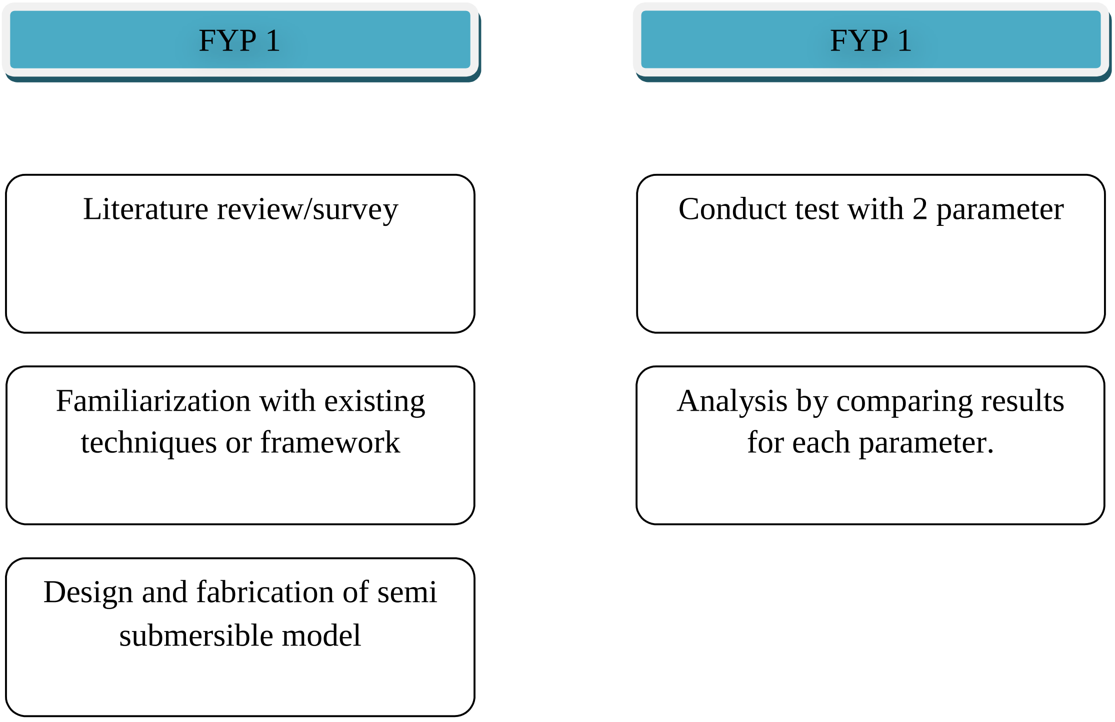


Figure 4: Project flow chart

3.1 Froude's Law

In case of water flow with a free surface, the gravitational effects predominate. The effect of other factors, such as viscosity, surface tension, roughness etc. is generally small and can be neglected. In this case, Froude's model law is most applicable. Eq 3.1 expressed the Froude Number,Fr, for the model and the prototype in waves. Where the subscripts *p*,*m* stand for prototype and model respectively. Assuming geometric similarity $D_p = \lambda D_m$, where λ is the scale factor for the model and *D* stands for any characteristic dimension of the object. Thus, the prototype velocity is given by $u_p = \lambda u_m$. In this study, a general assumption was made that the model follows the Froude's law of similitude; the common variables are listed in Table 3.

$$Fr = \frac{u^2{}_p}{gD_p} = \frac{u^2{}_m}{gD_m} \tag{3.1}$$

3.2 Scaling of a Froude Model

A general assumption is made that the model follows the Froude's law. The common variables found in the study of fluid mechanics are grouped under appropriate subheadings and are listed in Table 3. The units of these quantities are listed in the M-L-T (mass-length-time) system. If the variable is dimensionless, the 'units' column includes the entry 'NONE'. Using Froude's law and the scale as λ, the suitable multiplier to be used to obtain the prototype value from the model data is shown. Nevertheless, it should be clear that Froude models do not scale all of the parameters; they satisfy the most important and predominant factor in scaling a system in wave mechanics, namely inertia.

Variable	Unit	Scale Factor
Geometry		
Length	L	λ
Area	L^2	λ^2
Volume	L^3	λ^3
Angle	None	1
Radius of gyration	L	λ
Area moment of inertia	L^4	λ^4
Mass moment of inertia	ML^2	λ^5
CG	L	λ
Kinematics and Dynamics		
Time	T	$\lambda^{1/2}$
Acceleration	LT^{-2}	1
Velocity	LT^{-1}	$\lambda^{-1/2}$
Displacement	L	λ

Angular acceleration	T^{-2}	λ^{-1}
Angular velocity	T^{-1}	$\lambda^{1/2}$
Angular Displacement	None	1
Spring constant (Linear)	MT^{-2}	λ^{2}
Damping coefficient	MT^{-1}	$\lambda^{5/2}$
Damping factor	None	1
Natural period	T	$\lambda^{1/2}$
Wave mechanics		
Wave height	L	λ
Wave period	T	$\sqrt{\lambda}$
Wave length	L	λ
Celerity	LT^{-1}	$\sqrt{\lambda}$
Particle velocity	LT^{-1}	$\sqrt{\lambda}$
Particle acceleration	LT^{-2}	1
Water depth	L	λ
Water pressure	$ML^{-1}T^{-2}$	λ

Table 1: Model of prototype multipliers (*Source : Offshore Structure Modeling, Chakrabarti, 1994*)

3.3 Model Description

The subject of this project is twin-hulled semi submersible with six square columns and a displacement of 34,000 T in fresh water. Semi-submersible models were built to the scale factor 1:100, according to the dimension shown in Figure 3. The calculation and result will explain in the next chapter for further explanation. Froude scaling was applied for conversion between full scale and model scale units. Froude scaling laws assume the conservation of the ratio between inertial and gravitational forces by maintaining a constant Froude number. The weights were scaled down so that the model will have the same weight distribution as the prototype. A correct weight distribution will get the model to float at the correct draft as being planned. One way to get accurate weight distribution is by choosing the right thickness for each plate use to fabricate the model.

Fr = U/(g*L2)

g = Acceleration of gravity

U = Velocity

L = Length

If length scales by a factor, λ, Froude scaling implies the following relationships.

Length $U_m = L_f/\lambda^{.5}$ Time

$t_m = t_f$ / Acceleration $\lambda dU/dt_m =$

dU/d Force $F_m =$ t_f

$F_f/(\lambda^3 * \rho_f/\rho_m)$

Stiffness $K_m = K_f/(\lambda^2 * \rho_f/\rho_m)$

Pressure $P_m = P_f/\lambda$

Where, subscripts “m” and “f” are model and full (prototype) scale, respectively

<u>Prototype And Model Dimensions</u>

Descriptions	**Prototype**	**Model**
Pontoon Length	100m	1000mm
Pontoon Width	15.3m	153mm
Pontoon Height	7.6m	76mm
Column Length	15.3m	153mm
Column Width	15.3m	153mm
Column Height	30.5m	305mm

Topside Column Length	100m	1000mm
Topside Column Width	76m	760mm
Topside Column Height	1.5 m	1.5mm
Bracing Diameter	1m	10 mm

Table 2 : Dimension of Semi Submersible

The hydrostatic stability test was done to show the stability of the semi-submersible model in water. The stability of the structure can be proven by using the equation (1) shown in Literature Review before. With the changes in weight, the hydrostatic stability of the model needs to be calculated. This is to make sure the model will be able to float stable.

Below are the procedures to calculate the hydrostatic stability:

1. From geometry of body and density of fluid and body equate; Weight of displaced fluid = Total weight of body. This gives the depth of immersion of the body or the weight of the body, which ever is unknown.

2. To assess stability, first find the location of the center of gravity, G of the body.

3. Then, find the location of the center of buoyancy (centroid of displaced volume). For a regularly shaped body this will be at half the height of the immersed portion of the body (draft).

4. Calculate distance GB.

5. Calculate MB, using MB =I/ Vs. where 1 is the moment of inertia and Vs. is the volume of water displaced.

6. Calculate metacentric height, MG from MG = MB - GB. If MG >0 then body is stable. If MG <0 then body is unstable.

3.4 Experiment Studies

Three different types of test were conducted. The details are as follow:

Quasi-Static Test

Static offset tests were carried out to determine the mooring system stiffness. Load cells were attached to the up and down stream mooring lines. Static forces were applied and the load cell readings were recorded accordingly.

Free Decay Test

The purpose of these tests was to predict the natural frequencies of the system in different conditions.

Station Keeping Test: Waves

The general objectives of these tests were to measure the platform motions to regular and random waves. For evaluating the sea-keeping characteristics of the model, it was tested for regular and random waves. Soft linear springs were attached to steel wires to form the mooring line system of the model.

The twin-hulled semi submersible model was tested for one-model orientations (head seas) in wave basin of the UTP. The model motion and the restraining lines tension were measured by optical tracking system and load cell respectively. About 60 runs were carried out including free-decay, static offset and station keeping test.

Figure 5: Optical Tracking Setup during experiment

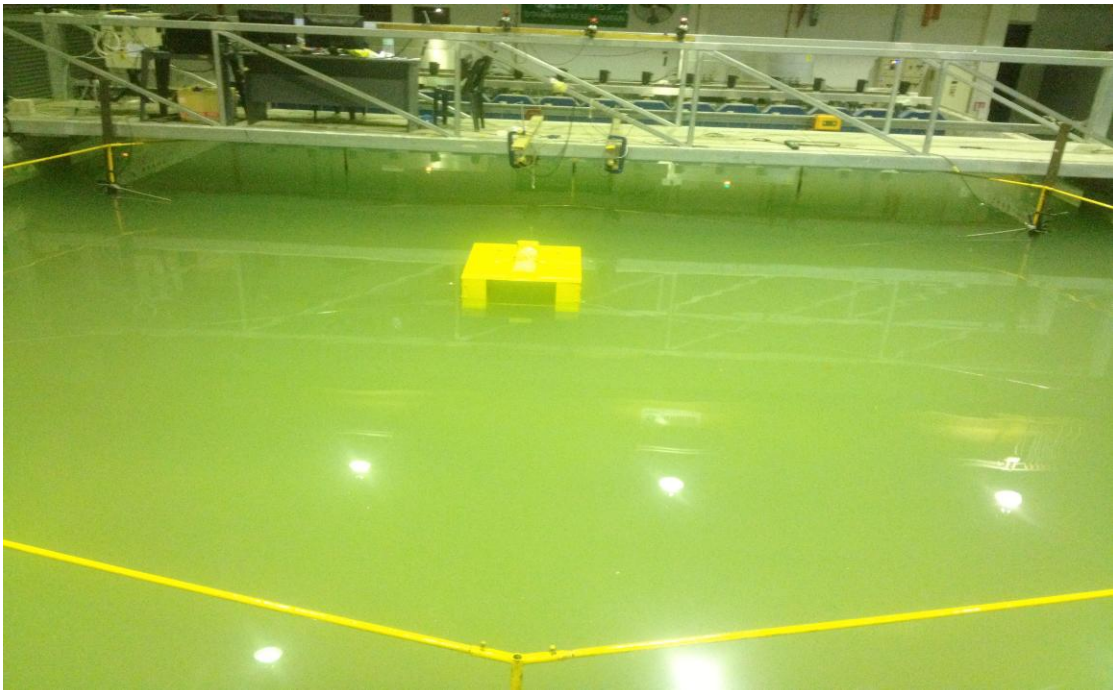


Figure 6: Model Setup in Wave basin

3.5 Test Facilities

The offshore lab wave basin measures approximately 22 m long, 10 m wide and 1.5 m deep. The wave maker system in this tank comprises of wave maker, remote control unit, signal generation computer and dynamic wave absorption beach. The wave-maker comprises of a number of modules, each having eight individual paddles, which can move independently of one another. These paddles move backward and forward horizontally to generate waves in the basin.

The wave maker is capable of generating up to 0.3 m wave height and period as short as 0.5 s (model scale). Major random sea spectra, such as JONSWAP, ISSC, PM, Bretschneider, and Ochi-Hubble, can be simulated. Also, custom spectra can be added to the software and calibrated. The progressive mesh beach systems minimize interference from reflected waves during tests. UTP basin also includes a current making system capable of providing a current speed of 0.2 m/s at a water depth of 1 m (the speed varies with water depth).

3.5 Wave Test

During this research, wave test is the dominant factor. Based on the result from this experiment, the actual movement of semi-submersible platforms subjected to wave loads during operation hour can be shown. Major design parameter were varied systematically to cover extensive range, which include as following

a) Wave Height, H

b) Wave Period, T

c) Wave Type (Regular or Irregular Wave)

d) Configuration of mooring line (Configuration and Pretension)

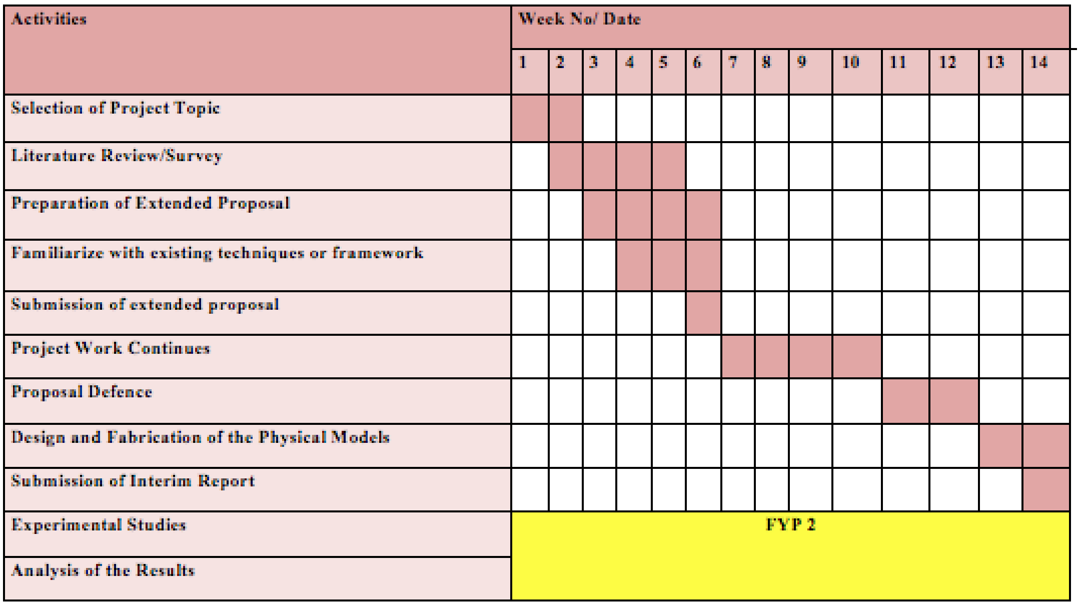
Estimated there will be around 50-wave test with variable parameters to be conducted throughout this experiment. Significance of each parameter can be seen through motion response of semi-submersible.

3.6 Project Milestone

- Selection of the Project
- Literature Review
- Extended Proposal
- Proposal Defense
- Design and Fabrication of the Physical Models
- Experimental Studies
- Analysis of the Results
- Final Report

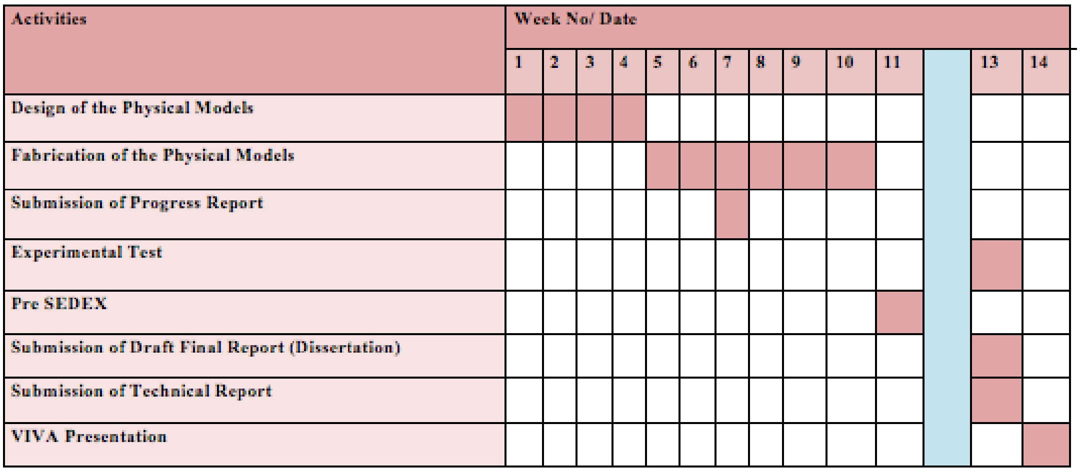
Gantt Chart

FYP 1



Activities	Week No/ Date													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Selection of Project Topic	🟥	🟥												
Literature Review/Survey		🟥	🟥	🟥	🟥									
Preparation of Extended Proposal			🟥	🟥	🟥	🟥								
Familiarize with existing techniques or framework				🟥	🟥	🟥								
Submission of extended proposal						🟥								
Project Work Continues							🟥	🟥	🟥	🟥				
Proposal Defence											🟥	🟥		
Design and Fabrication of the Physical Models													🟥	🟥
Submission of Interim Report														🟥
Experimental Studies	FYP 2													
Analysis of the Results														

FYP 2



Activities	Week No/ Date													
	1	2	3	4	5	6	7	8	9	10	11		13	14
Design of the Physical Models	🟥	🟥	🟥	🟥								▨		
Fabrication of the Physical Models					🟥	🟥	🟥	🟥	🟥	🟥		▨		
Submission of Progress Report							🟥					▨		
Experimental Test												▨	🟥	
Pre SEDEX											🟥	▨		
Submission of Draft Final Report (Dissertation)												▨	🟥	
Submission of Technical Report												▨	🟥	
VIVA Presentation												▨		🟥

CHAPTER 4

RESULT AND DISCUSSION

4.1 Wave Test

The semi –submersible model was tested with two types of wave; regular wave and irregular wave subjected to Head Seas heading.

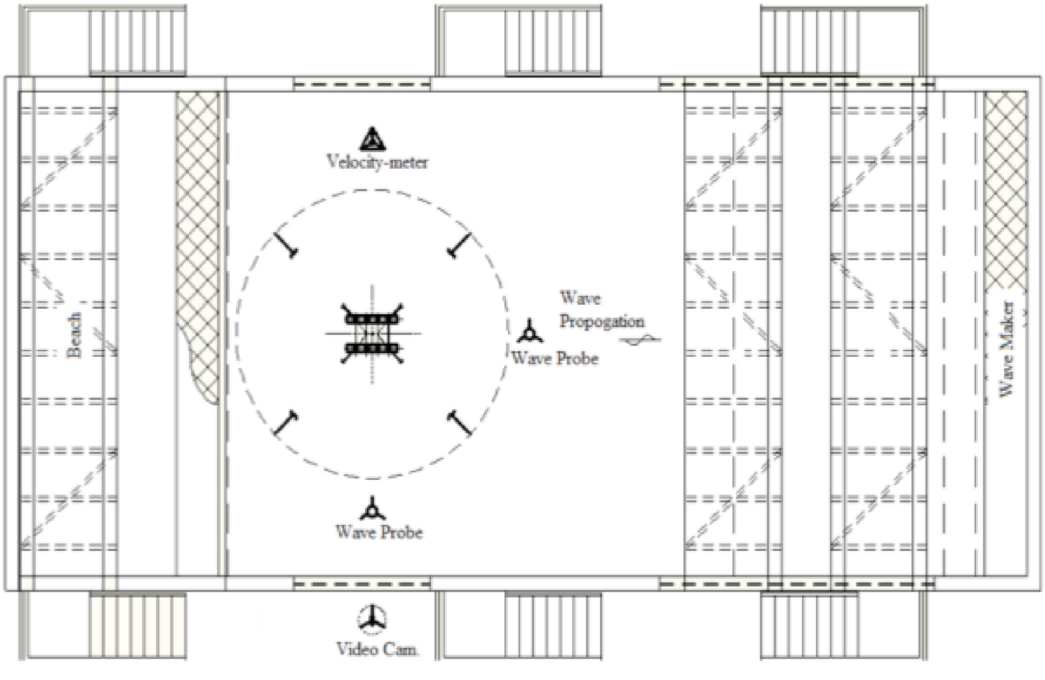


Figure 7: Test Setup for Head Seas Heading

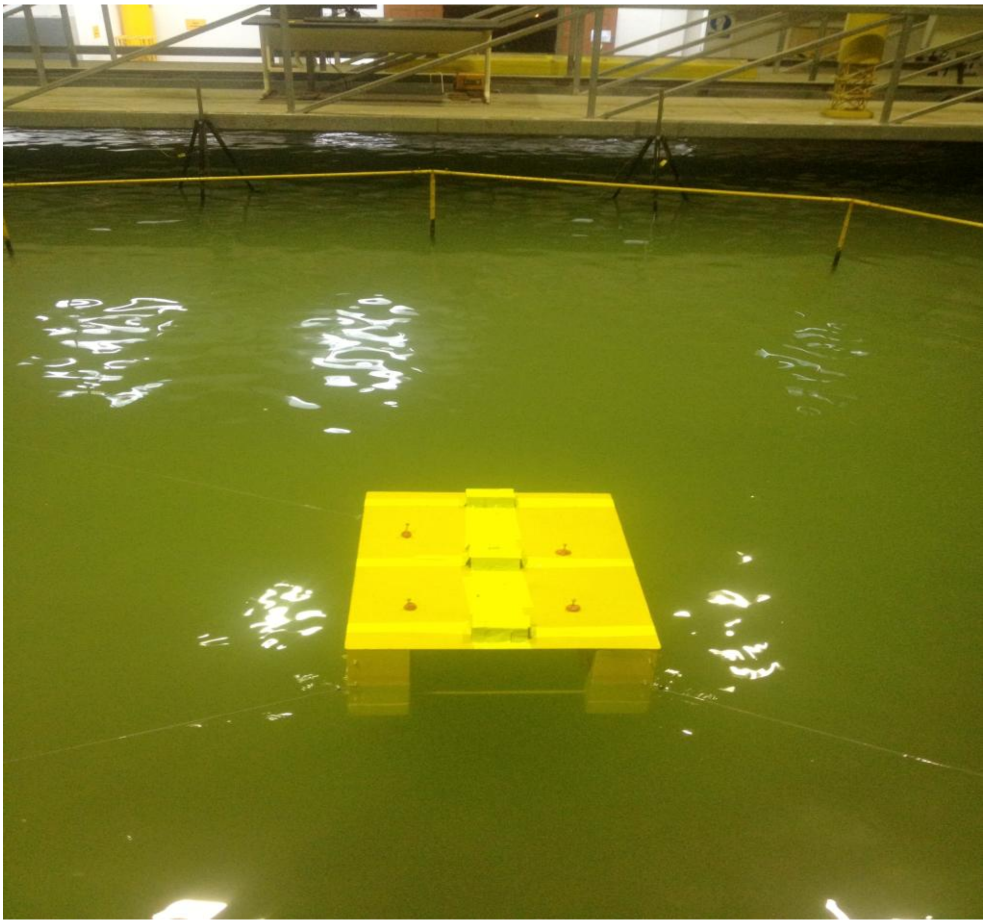


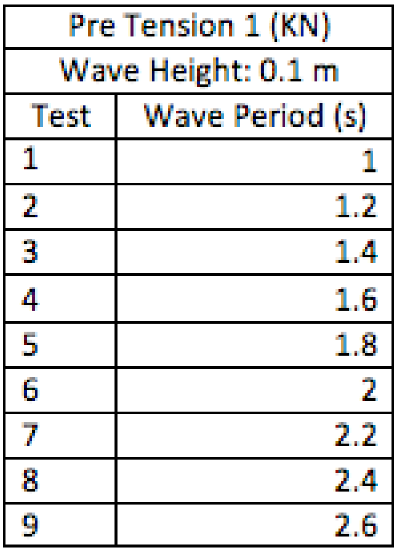
Figure 8: Experimental Setup

4.2 Experimental Setup

Througout this experiment, the models were subjected to both regular waves and irregular waves and limited to long crested waves based on Metocean data in Kikeh field tested in two parameter which pretension of the mooring line and configuration of the mooring line.The dynamic motions of the semi submersible platforms in six degree of freedom and the pretension in mooring line are measured. The mooring system is formed by 4 truncated mooring lines due to limitation of depth in the wave basin. Each tied to an anchor was fixed at the keel of the model to stabilize the spar from moving. The experiment was conducted in varies wave periods and wave heights according to the **Table 3** and **Table 4** below.

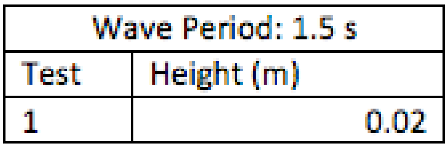
Parameter 1: Pretension of mooring line

1) Pretension 1: 10KN
2) Pretension 2: 20KN
3) Pretension 3: 30KN



Pre Tension 1 (KN)	
Wave Height: 0.1 m	
Test	Wave Period (s)
1	1
2	1.2
3	1.4
4	1.6
5	1.8
6	2
7	2.2
8	2.4
9	2.6

Regular Wave



Wave Period: 1.5 s	
Test	Height (m)
1	0.02

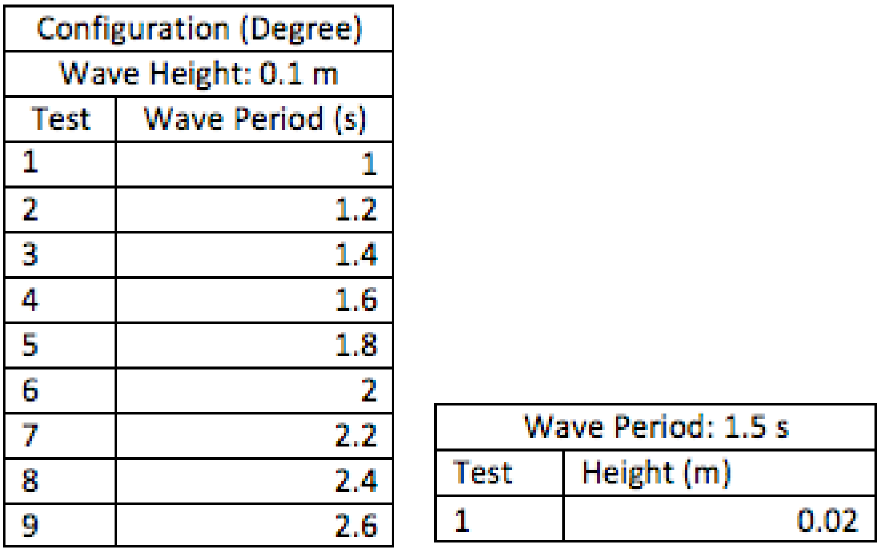
Irregular Wave

(Table 3: List of Wave Test for each pretension setup)

Parameter 2: Configuration of mooring line

1) Configuration 1: 30 degree

2) Configuration 2: 60 degree



Configuration (Degree)	
Wave Height: 0.1 m	
Test	Wave Period (s)
1	1
2	1.2
3	1.4
4	1.6
5	1.8
6	2
7	2.2
8	2.4
9	2.6

Wave Period: 1.5 s	
Test	Height (m)
1	0.02

Regular Wave

Irregular Wave

(Table 4: List of Wave Test for each configuration setup)

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The semi-submersible platform operated in Malaysia region is scaled down with scale factor of 1:100 and series of laboratory test with regular and irregular wave action was conducted.In conclusion, throughout this period, all the project flow from literature survey to planning of experimental setup is shown . All the calculation for design of fabrication of semi submersible models are shown in previous chapter. In case of water flow with a free surface, the gravitational effects predominate. The effect of other factors, such as viscosity, surface tension, roughness is generally small and can be neglected. In this case, Froude's model law is most applicable. A scale factor 1:100 is used to scale down the prototype to model scale. Experimental study will be continuosly run in the remaining of FYP II period. Thus,experimental setup is shown in this report.During the experiment, three tests will be conducted which are static offset, free decay and station keeping tests.Effect of 2 different design parameter which is pretension and mooring line configuration on responses of moored semi submersible will be investigate. To make it this experiment is really contibuted to our nation's oil and gas industry, the Metocean data from Kikeh project which is located at the Sabah offshore will be applied to this study.

RECOMMENDATION

As a recommendation, further research work focusing on other parameter may be done to know the effect of other variable towards achieving optimum configuration of mooring of semi-submersible platforms subjected to regular and irregular waves.In addition,due to time limitation,this experiment is conducted only in one heading which is head sea position.Therefore, future research work should also being carried in 2 other heading which is quartering sea and beam sea position to investigate the effect of semi subrmersible's position towards its motion.

This project shows a good progress and expected results are obtained from the runs of experiments conducted.

REFERENCES

1. J. Herbich,(1999) Developments in offshore engineering: wave phenomena and offshore topics: Gulf Professional Publishing

2. J. Hooft,(1972) "Hydrodynamic aspects of semi submersible platforms," PhD thesis, Netherlands Ship Model Basin

3. M. Takagi and S. Arai(1985), "A Comparison of methods for calculating the motion of a semi submersible," J. of Ocean Engineering, vol. 12, pp. 45-97, 1985.

4. S. Tan (1992), "Motion prediction of semi submersibles in early design stage," Maritime Resarch Institute Netherlands

5. D. Sunil and M. Mukhopadhyay(1995), "Free vibration of semi submersibles: A parametric study," J. of Ocean Engineering, vol. 22, pp. 489-502, 1995.

6. S. Wu, (1997) "The motions and internal forces of a moored semi submersible in regular waves," J. of Ocean Engineering, vol. 24, pp. 593-603, 1997.

7. C. T. Stansberg, R. Yttervik, O. Oritsland, and G. Kleiven,(2000) "Hydrodynamic model test verification of a floating platform system in 3000 m water depth," in Proceedings of the Offshore Mechanics and Arctic Engineering, New Orleans, pp. 325-333

8. B. Buchner, J. E. W. Wichers, and J. J. de Wilde (1999), "Features of the state-of-the- art deepwater offshore basin," in Proceedings of the Offshore Technology Conference, Houston, pp. 363-373

9. X. H. Chen, J. Zhang, P. Johnson, and M. Irani (2000), "Studies on the

dynamics of truncated mooring line," in Proceedings of the International Offshore and Polar Engineering Conference, Seattle, USA, pp. 94-101

10. H. Ormberg, C. T. Stansberg, and R. Yttervik (1999) "Integrated vessel motion and mooring analysis applied in hybrid model testing," in Proceedings of the Offshore and Polar Engineering Conference, Brest, France, pp. 339-346

APPENDIX

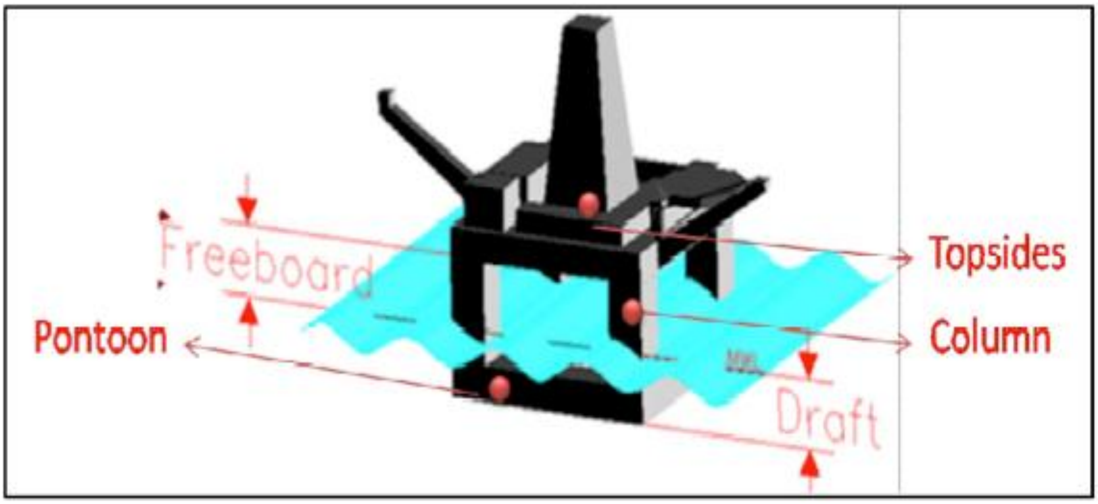


Figure 9 : Position of Semi Submersible in water

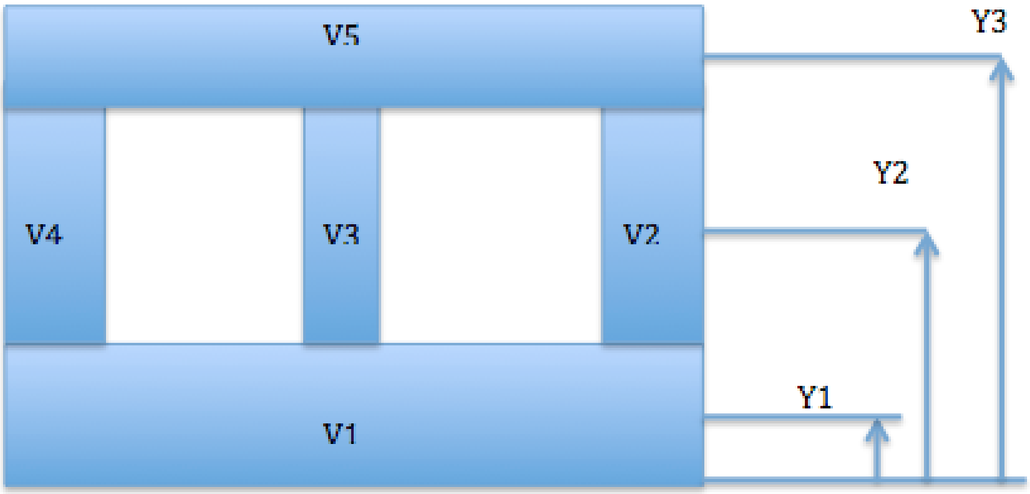


Figure 10 : Semi Submersible figure

Calculate weight respective to material density

Steel Plate Density : 7850 kg / m^3 ,this model was fabricated using steel plate of thickness 1.5mm

Hydrostatic Stability of Semi Submersible Model

Draft : 151mm

Model Weight

Pontoon : 11.33 Kg

Column : 13.19 Kg

Topside : 8.95 Kg

Braces : 0.43 Kg

Total : 33.89 Kg

Center Of Gravity (COG)

COG : $\sum WY / \sum W$

: 0.2033 m

:20.33 cm

Model Volume

Pontoon : 0.0233 m^3

Column : 0.0105 m^3

Topside : 0.00011 m^3

Center Of Buoyancy (COB)

COB : $\sum VY / \sum V$

: 0.0615 m

: 6.15 cm

GB : COG – COB

: 14.18 cm

MB : I / Vs

Where , I is the Moment of Inertia of the water plane area

Vs is the Volume of displaced water

I : Ixx + (A X D^2)

Area of the water plane only include of the column area

Hence area , A : 0.03389

D,distance between centre of column to center of hull

D : 0.3035 m

D^2 : 0.09211

Ixx : bd^2/12 where b : 0.153, d: 0.153

: 4.5665 E-05

Hence I : (Ixx + (A X D^2)) X 6

: 0.01322

Vs : 0.0444 m^3

MB : I / Vs

: 0.3913 m

: 39.13 cm

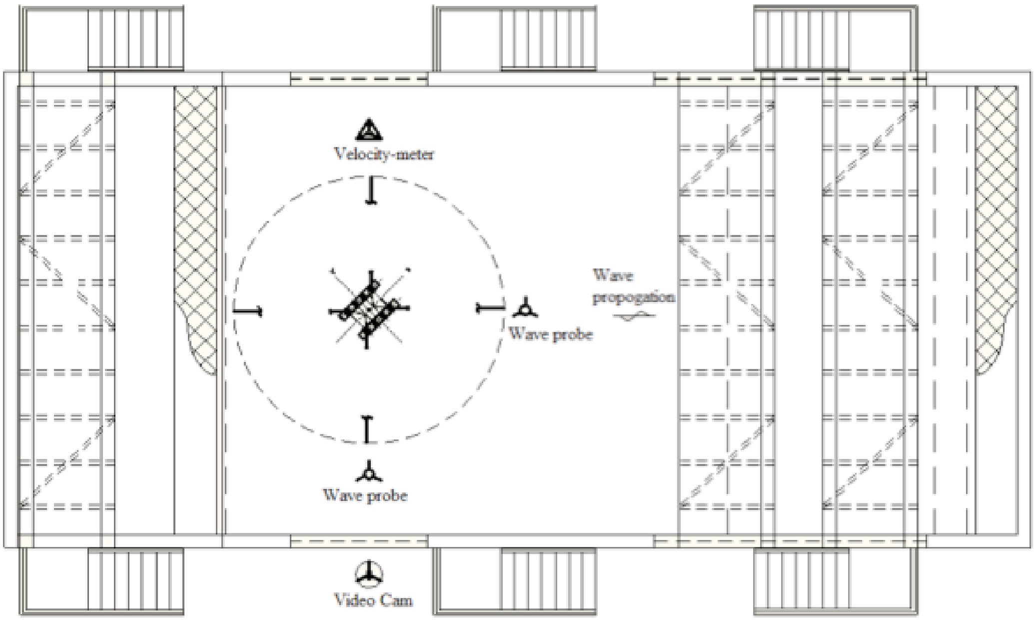
MG : MB-GB

: 39.13 cm – 14.21 cm

: 24.92 cm

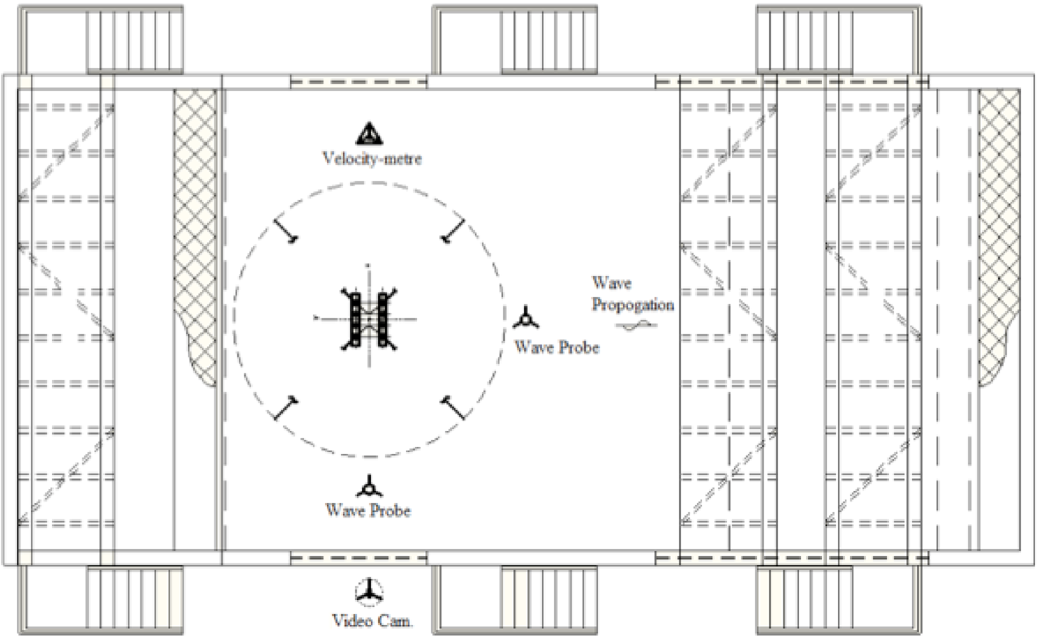
MG is >1, this mean the model can float stable on the water

.



.

. Figure 11 : Quartering Seas



.

Figure 12: Beam Seas

.