Effect of Hydrodynamic Force Coefficients on the Wave Forces on Jacket Platform

By

BONG SZE KIET

FINAL PROJECT REPORT

Submitted to the Civil Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Civil Engineering)

Universiti Teknologi Petronas
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CERTIFICATION OF APPROVAL

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Approved:

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(PROF. DR KURIAN V. JOHN)
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

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

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(BONG SZE KIET)

ABSTRACT

The evaluation of accurate hydrodynamic forces on a clean tubular member is the fundamental criteria in designing offshore structures. For the analysis and design of general jacket platforms, engineering consultants use Morison equation for wave forces are calculated based on the drag (C_D) and inertia (C_M) coefficients. The hydrodynamic coefficients used by consultants are constant or recommended values, even though the C_D and C_M are varying force coefficients that depend on Keulegan Carpenter number (KC) and Reynolds number (Re). This report provides a preliminary comparison of the maximum total force of jacket platforms on the various locations in Malaysian offshore regimes. The numerical analysis was done using Microsoft Excel by utilizing the existing wave parameters recorded in Petronas Technical Standard (PTS). The experimental data are derived from 1:70 scale model tests for the hydrodynamic total force acting on model tubes conducted in a wave tank. Structural Analysis Computer System (SACS) was used for verification and comparison of the numerical and experimental data to analyze the relevance of the data collected.

ACKNOWLEDGEMENTS

I would like to gratefully acknowledge my deepest gratitude to God Almighty that blessed me to persevere and have constant passion to complete the research work for this Final Year Project. I also wish to thank Universiti Teknologi PETRONAS for the support and encouragement especially Dr. Nurul Izma and Dr Raza Mustafa that constantly provide support and time to guide me throughout the entire process of the submission for this project.

It is my pleasure to acknowledge my supervisor, mentor, motivator and teacher Professor Doctor Kurian V. John for his continuous dedication, encouragement and guidance that lead me to complete this Dissertation Report. I would like to give him the full credit of the recent winning of a gold medal from Universiti Teknologi Petronas 33th Science and Engineering Design Exhibition emerged from this Final Year Project topic.

Special thanks to Mr Amal and Mr Jerin both Master students under Dr Kurian which assisted me in experimental data collection and processing. Good mentoring session from them on the application of Microsoft Excel and SACS software had effectively speeded up my progress for this Final Year Dissertation Report.

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LIST OF ABBREVIATION

C_D- Drag coefficient

C_M-Inertia coefficient

H-Wave Height

HFC -Hydrodynamic Force Coefficient

KC-Keulegen-Carpenter Number

PMO-Peninsular Malaysia Operation

Re-Reynolds number

SBO-Sabah Operation

SKO-Sarawak Operation

T-Wave Period

Chapter 1: Introduction

Structural analysis considerations needed for the design of offshore structures require tedious and complex formulation and calculations. Some parameters that govern the response include Reynolds number (Re) and Keulegan Carpenter number (KC). For the last decades, several successful experimental works pertaining to hydrodynamic forces acting on a single cylinder have been conducted by (Bryndum et al., 1983).

Jacket platform as the study for this project was the most common fixed platforms used in Malaysian offshore regimes. According to (Nizamani, 2011), jacket platform was a space framed structure with tubular members supported on pile foundation. Jacket type platform was commonly used in moderate water depths up to 400 m. 95% of the Malaysian offshore platform in service was of the jacket platform type.

(Morison et.al, 1950) suggested that the force exerted by unbroken surface wave on a vertical cylinder pile which extends from the bottom through the free surface was composed of drag and inertia forces which can be estimated using the Morison equation. In conjunction of that, the hydrodynamic force coefficients (HFC) are a function of wave height (H) and wave period (T) which is analyzed using experimental model testing.

The rise of the construction materials cost propelled researchers in identifying the most cost effective design, while keeping the safety and integrity of the structure to meet with today's competition. With this ideology, the foundation was laid for researchers to find out the most cost effective hydrodynamic force coefficients to be used in the design of jacket platform according to the location, climate and wave behavior of a given sea state.

Background

A good understanding and studies about wave parameters are crucial in the design of offshore structures such as jacket platforms. At coastal and offshore area, wave forces parameters are significantly important and must be put into careful considerations to prevent man-made tragedies. Wave action was present throughout the whole effective life of an offshore structure. Thus prediction of the wave behavior and its effect provides reliable understanding on the required maintenance while providing a time window for emergency response in an event of structural failures.

The knowledge of the hydrodynamic coefficient was fundamental for the design of marine structures as mentioned by (Haritos, 2007). It have been established by the work of (Chakrabarti, 1987) that the hydrodynamic force coefficients are the function of Keulegan-Carpenter (KC) number and Reynolds number. Since KC number and Re was a function of H, T and D, these parameters played an important role in the determination of HFC.

Petronas Technical Standard adopted the design standard from the technical data of North Sea and Gulf of Mexico which was relatively harsh than those in Malaysia offshore regimes. Due to different sea state, over-designing might occur as presented by (Kurian, Sebastian, Alyacouby, & Liew). The same authors also rebutted that hydrodynamic force coefficient used might be obsolete as no recent publications have highlighted the trend of C_D and C_M especially in Malaysia offshore regimes. This project was aimed to find the relevant trend of C_D and C_M changes according to the varied parameters of wave height, wave period and tubing diameter to suit the local offshore regimes in Malaysia.

Problem Statement

PTS 2010 recommended for unshielded tubular smooth members, typical design situations, the following values are used:

$$C_D=0.65 \quad C_M=1.6$$

(El-Reedy, 2012) adopt the same recommendation for the design of offshore structures. However, as the C_D and C_M are largely governed by several dynamic wave parameters such as wave height (H), wave period (T) and the diameter (D) of the legs of a jacket platform. Thus the relevance of applying fixed HFC value for jacket platform design for different locations remains doubtful.

On top of that, there was no literature addressing the issue of determination of accurate hydrodynamic coefficients for Malaysian offshore locations experimentally in the wave tank as discussed by (Kurian, Alyacouby, & Liew). Thus verifying the relationship between numerical and experimental data is crucial.

Objectives

Many ongoing researches suggest the varying nature of hydrodynamic force coefficients (HFC) are affected by H, T and D parameters. In this project, the varying nature of all these coefficients was accounted for, and the experimentally obtained HFC are to be used in the Morison equation. The wave force obtained by the use of the new coefficient was to be studied and any particular variation trend is to be recorded.

Therefore the main objectives include:

1) To determine the variation of wave forces on jacket members with respect to variation of hydrodynamic coefficients C_D and C_M.

2) To compare the theoretical forces with selected experimental model test values done in the offshore laboratory.

3) To use SACS software for the calculation of wave forces on jacket member and compares it with numerical and experimental value.

Scope of Study

This project covers the basic operating procedures and functionality of a wave tank. The main scope of interest for this experiment was to study the effect of the hydrodynamic force coefficients to the resulting maximum total wave force. Morison equation was used to assess the HFC obtained to generate the resultant wave forces. Linear wave theory was also used to explain the kinematics of the water particles movement.

The scope of the objective 1 of this project include the offshore location as recorded in PTS which include PMO, SKO and SBO locations in Malaysian offshore regimes. SKO was subdivided into Balingian and Baram Delta whereas SBO were Erb West and Samarang.

The PTS 2010 recommended C_D value was well defined by the numerical calculation range of 0.5 to 1.2 with increment of 0.1. C_M was varied from 1.0 to 2.0 with the increment of 0.2. The use of 75mm diameter of cylindrical tubing which had be done previously by (Li, Kang, & Fei, 1992) was selected to generate preliminary data for numerical calculations.

The experiments are conducted with the model wave height (H) of 0.075m, 0.10m, 0.15m, 0.020m and model wave period (T) of 1.5s, 2.0s, 2.5s, 3.0s in the factor of 55 which are varied in wave tank to simulate different wave behaviors. It is represented as below:

H=model value*55

T=model value*$\sqrt{55}$

Chapter 2: Literature Review

The initial study regarding the wave force estimation on small diameter cylinders dates back to the year 1950. Some of the very early works on determination of drag and inertia coefficients are conducted in the early 1980s.

There was no single parameter with which the drag and inertia coefficients may be correlated without the need for other parameters, thus showing the complexity of the determination of hydrodynamic force coefficients. Dean and Eagleson (1966) suggest that the hydrodynamic coefficients are functions of the Reynolds number, the Keulegan-carpenter number, as well as other parameters such as roughness and water depth effects. Both inertia coefficients and drag coefficients are affected by the magnitude and changes in wave height and wave period.

The hydrodynamic force coefficients were estimated using numerical computation by (Bryndum, Jacobsen, Inst, & Brand, 1983) which adopted the most suitable combination of drag coefficient, inertia coefficient and phase angle. This was such that the deviation of the numerically computed wave forces at all peaks and the zero-crossing points from the experimental forces were minimal simultaneously. With it the trends of C_D and C_M with respect to the maximum total force on a member can be observed.

Theory

Morison equation was developed by (Morison, O'Brien, Johnson, & Schaaf, 1950) to describe the horizontal wave forces acting on a vertical pile extending from the bottom to the free surface. Morison et al. suggested that the force exerted by unbroken surface waves on a vertical cylindrical pile was composed of two components which are inertia and drag which are linearly added together.

In general, Morison equation was denoted by

$$f = C_M A_1 \frac{\partial u}{\partial t} + C_D A_D |u|u$$

where f was the wave for per unit length of the member.

For this project, a modified Morison equation was further considered incorporating the entire member length as given below:

$$F_T = C_d \frac{1}{2} \rho D u |u| + C_m \rho \frac{\pi}{4} D^2 \hat{u}$$

where C_M was the inertia coefficient ; C_D was the drag coefficient; u was the water particle velocity; $\hat{u}$ was the water particle acceleration; F_T was the total wave force on the member

Based on the type and size of the members in an offshore structure, different formulations for wave forces are applicable. The formulations for water particle kinematics and free water surface elevation can be obtained from the linear wave theory as stated by (Haritos, 2007). The assumptions made by suitable wave theories are given into consideration.

A suitable wave theory was chosen by the analysis of the measured wave surface elevation and the predicted wave surface elevation by various theories. The choice of linear wave theory for the present study was substantiated help by the Morison equation. The wave forces on small diameter cylindrical structures can also be estimated by utilizing the work of (Bryndum et al., 1983) which support the Morison equation. Relevant modifications are made to the standard Morison equation to highlight the significance of the alteration of the parameters resulting to the difference in wave force.

Another expansion of Morison equation, total force is denoted by:

$$F = \rho g V \frac{H}{2d} tanhkd \ x \ [\ C_M sin\theta + C_D \frac{H}{4\pi D} \frac{2kd + sinh2kd}{sinh^2 kd} |cos\theta| cos\theta$$

where

$$sin\theta_0 = \pm \frac{\pi D C_M}{H C_D} \frac{2sinh^2 kd}{2kd + sinh2kd}$$

$$cos\theta_0 = \pm \sqrt{1 - sin^2\theta_0}$$

This formula provides the theoretical total force to be compared with the experimental values obtained from UTP offshore laboratory using selected diameter of single cylindrical tubular member which include 27mm, 34mm, 42mm and 48mm. The experiments are conducted with the factor of 55.

Chapter 3: Research Methodology and Project Activities

The theoretical data analysis was collected by using Microsoft Excel using the Morison equation.

$$F_T = C_D \frac{1}{2} \rho D u |u| + C_M \rho \frac{\pi}{4} D^2 \hat{u}$$

The graphs of maximum total force against the HFC for all 5 Malaysian locations are plotted and notable trends are discussed.

The experimental data analysis was conducted at offshore engineering laboratory of UTP. 1:70 scale model testing will be set-up and regular waves are generated to study the effect of wave parameters to the resulting maximum total force. The testing will be modeled according to the real-time meta-ocean criteria in a laboratory scale as practiced in PTS.

SACS software was used to calculate the actual maximum total force on a member of a jacket platform. 3 Dimensional representation of force distribution on the leg member of a jacket was generated. The actual maximum total force collected from SACS was used to compare and relate the data collected from both numerical and experimental data and to observe any possible link between the maximum total forces to the HFC. The percentage of error due to human and instrumentation error will be calculated to accommodate the difference in HFC values for different location in Malaysian offshore regimes.

Chapter 4: RESULTS

OBJECTIVE 1

Peninsular Malaysia Operation (PMO)

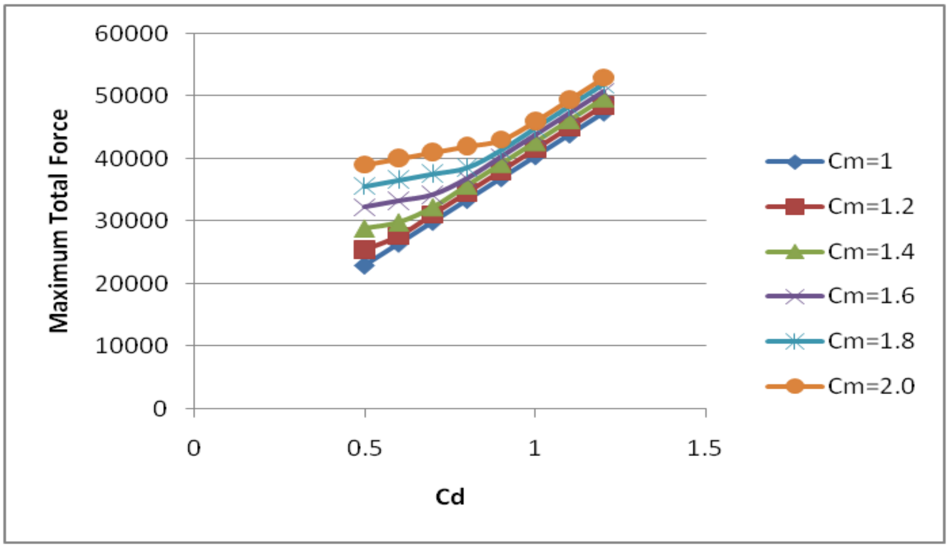

Figure 1: The plot of Maximum Total Force versus Cd value for PMO

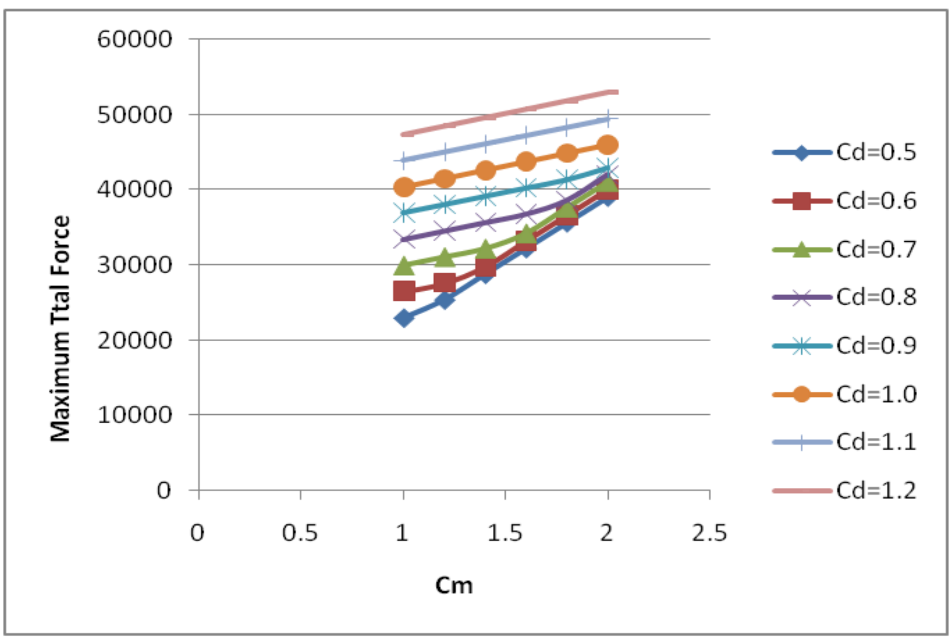

Figure 2: The plot of Maximum Total Force versus Cm value for PMO

Sarawak Operation (SKO I-Balingian)

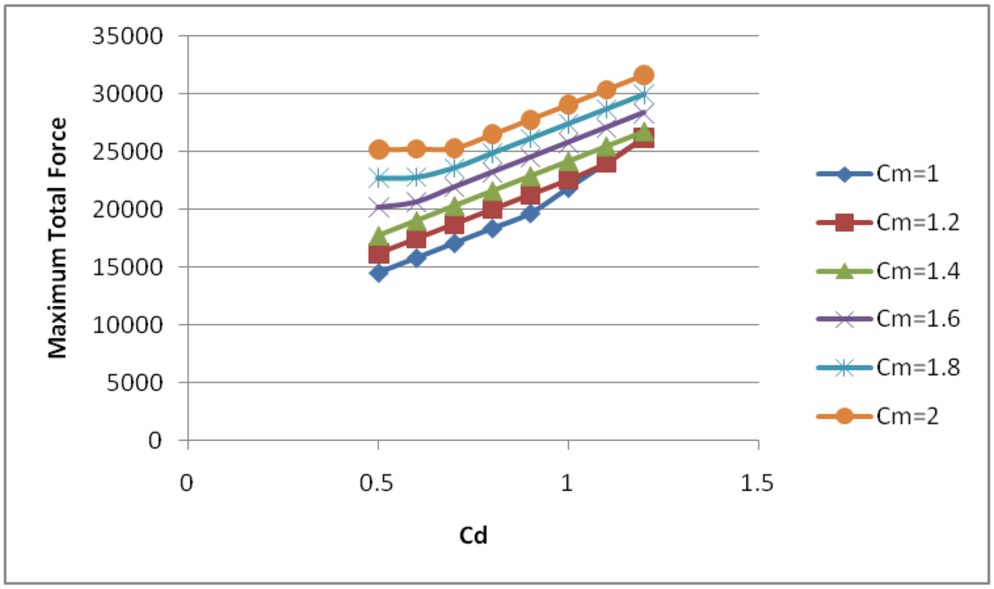

Figure 3: The plot of Maximum Total Force versus Cd value for Balingian

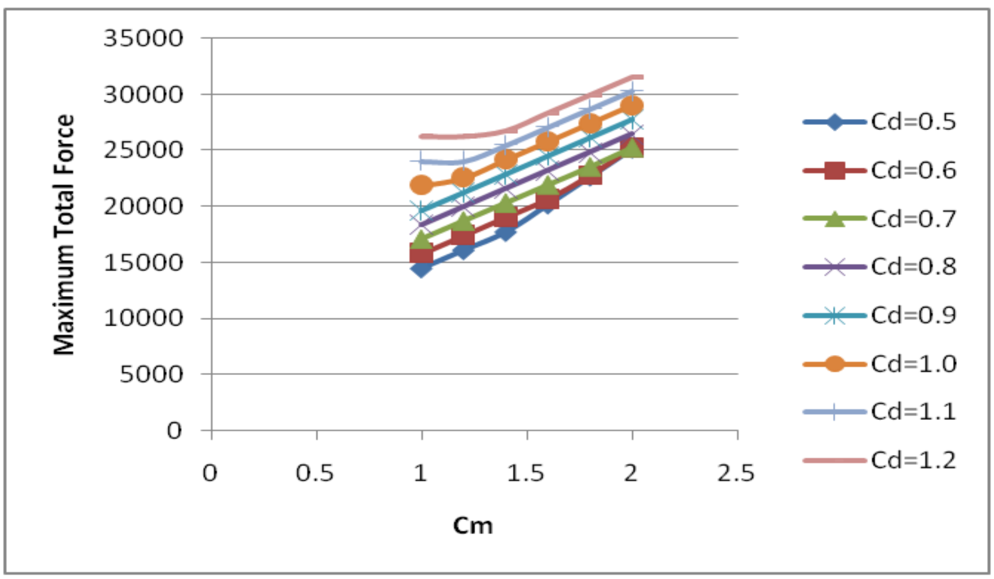

Figure 4: The plot of Maximum Total Force versus Cm value for Balingian

Sarawak Operation (SKO II-Baram Delta)

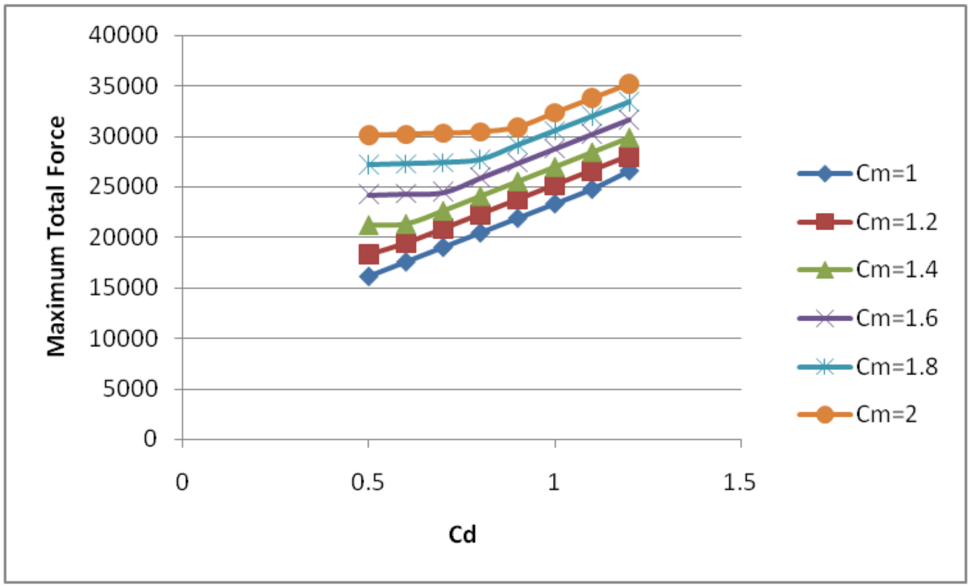

Figure 5: The plot of Maximum Total Force versus Cd value for Baram Delta

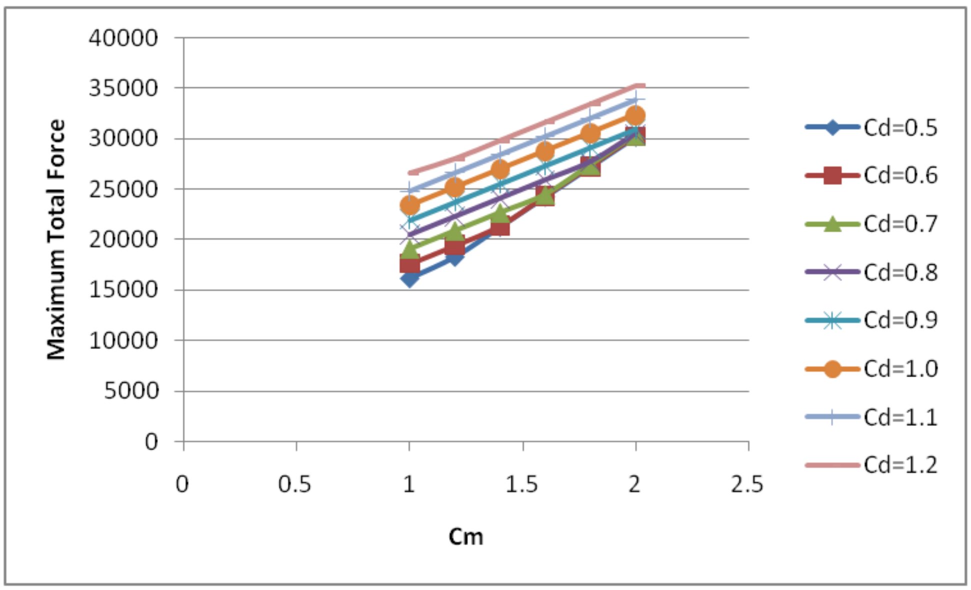

Figure 6: The plot of Maximum Total Force versus Cm value for Baram Delta

Sabah Operation (SBO I-Erb West)

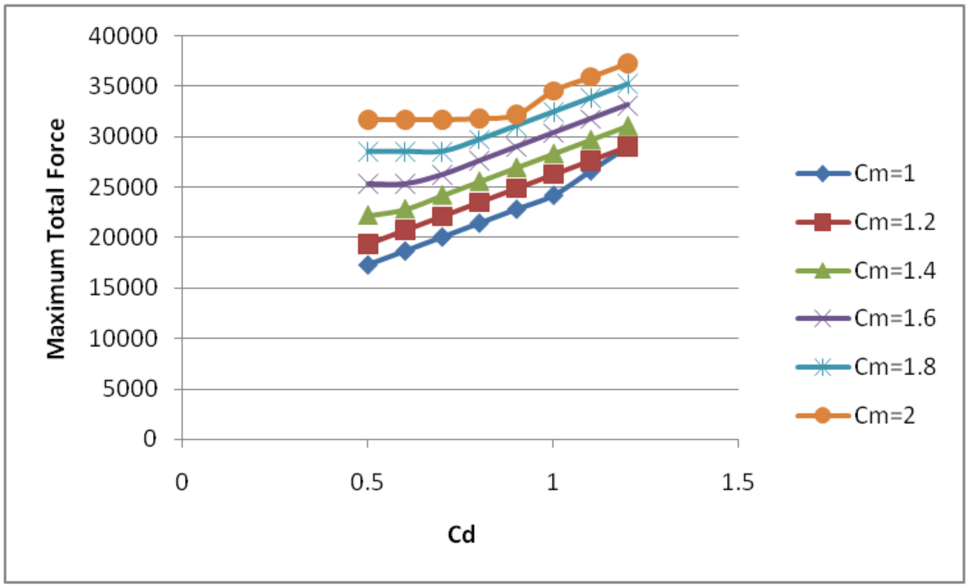

Figure 7: The plot of Maximum Total Force versus Cd value for Erb West

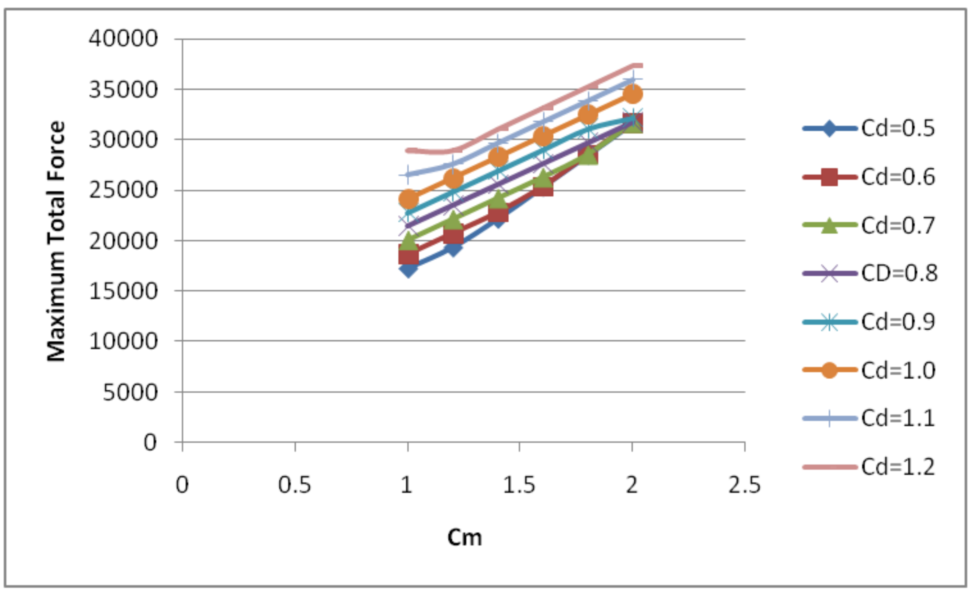

Figure 8: The plot of Maximum Total Force versus Cm value for Erb West

Sabah Operation (SBO II-Samarang)

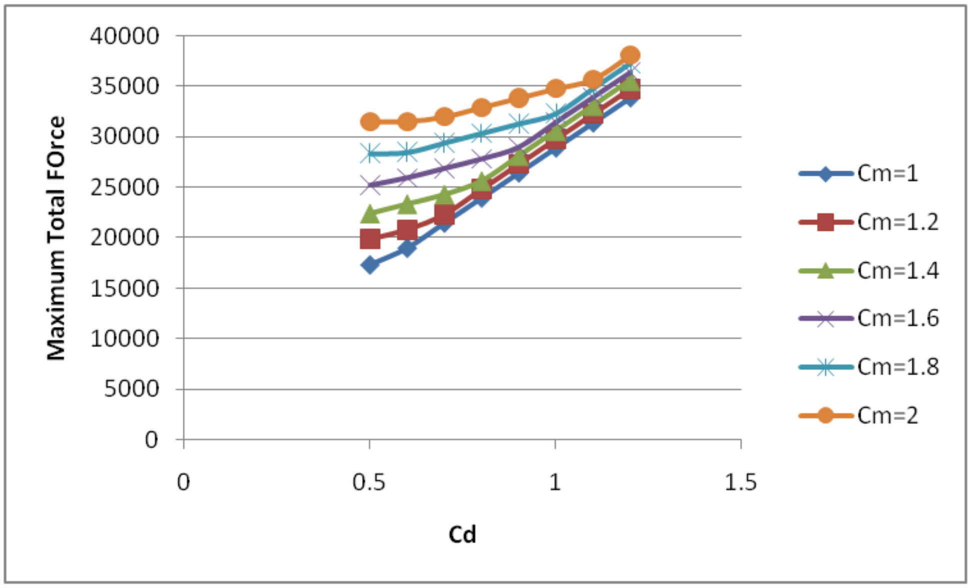

Figure 9:The plot of Maximum Total Force versus Cd value for Samarang

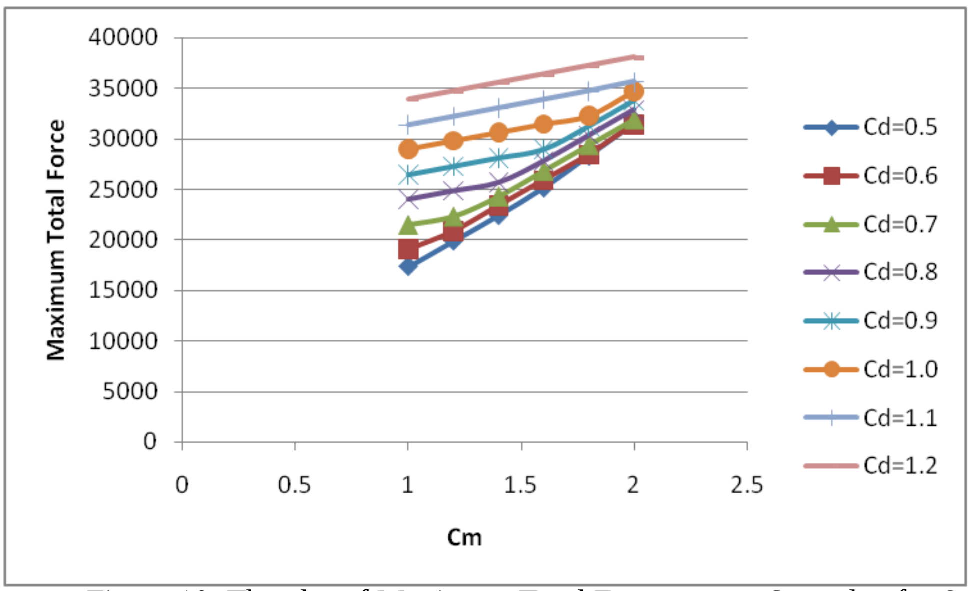

Figure 10: The plot of Maximum Total Force versus Cm value for Samarang

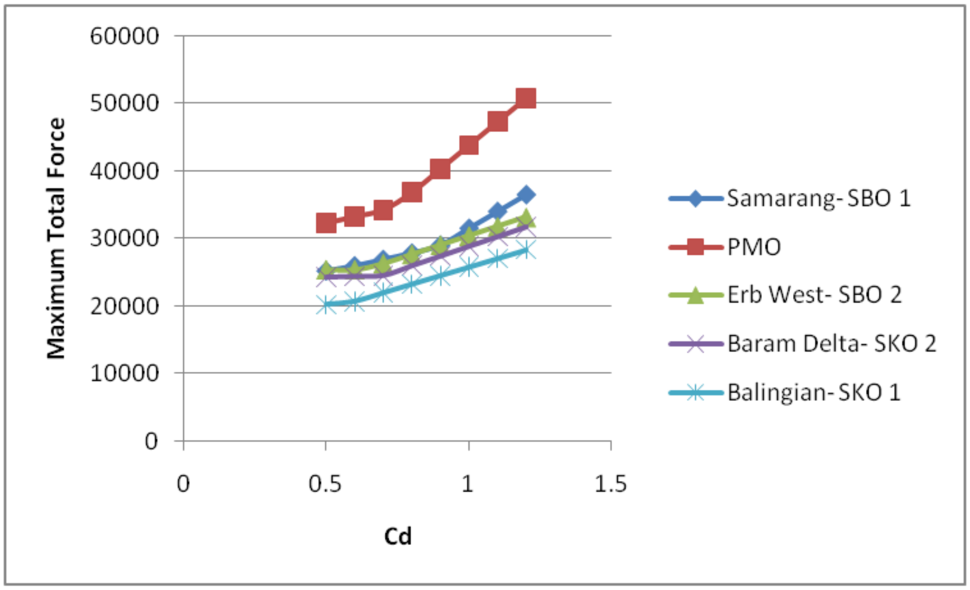

Figure 11: The plot of Maximum Total Force Vs Cd for all locations in Malaysia using Cm=1.6

By keeping C_M value fixed and varying the C_D value, the observed maximum total force for Peninsular Operation (PMO) shows the highest value. In fact a 15% difference between the subsequent Sabah Operation (SBO) with PMO which is then followed closely by Sarawak Operation (SKO).

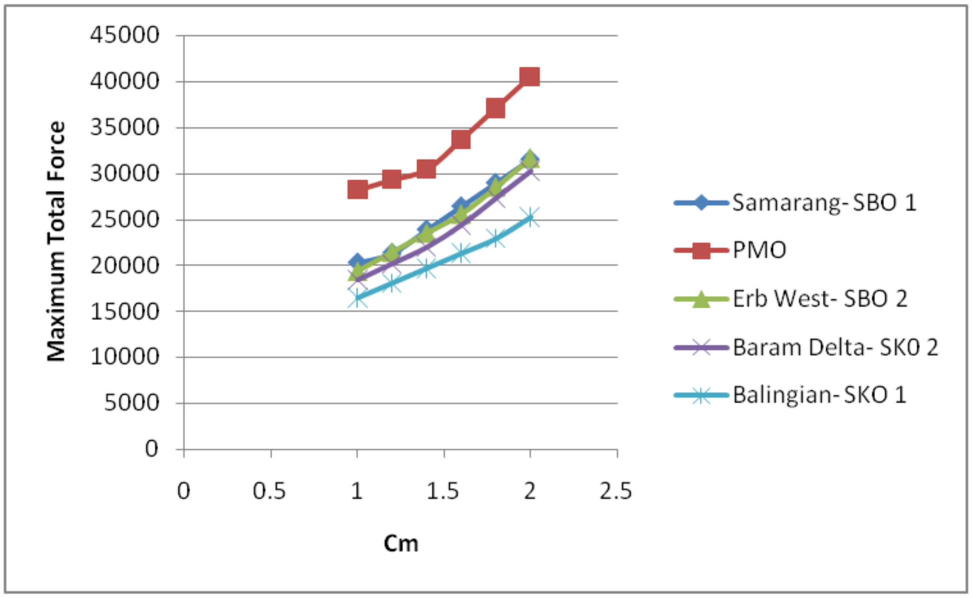

Figure 12: The plot of Maximum Total Force Vs Cm for all locations in Malaysia using Cd=0.65

Similar trend from Figure 11 is observed at Figure 12 where the maximum total force for PMO is peaking at around 20% difference as compared to SBO. SKO exhibits the similar properties as it was in Figure 11.

OBJECTIVE 2

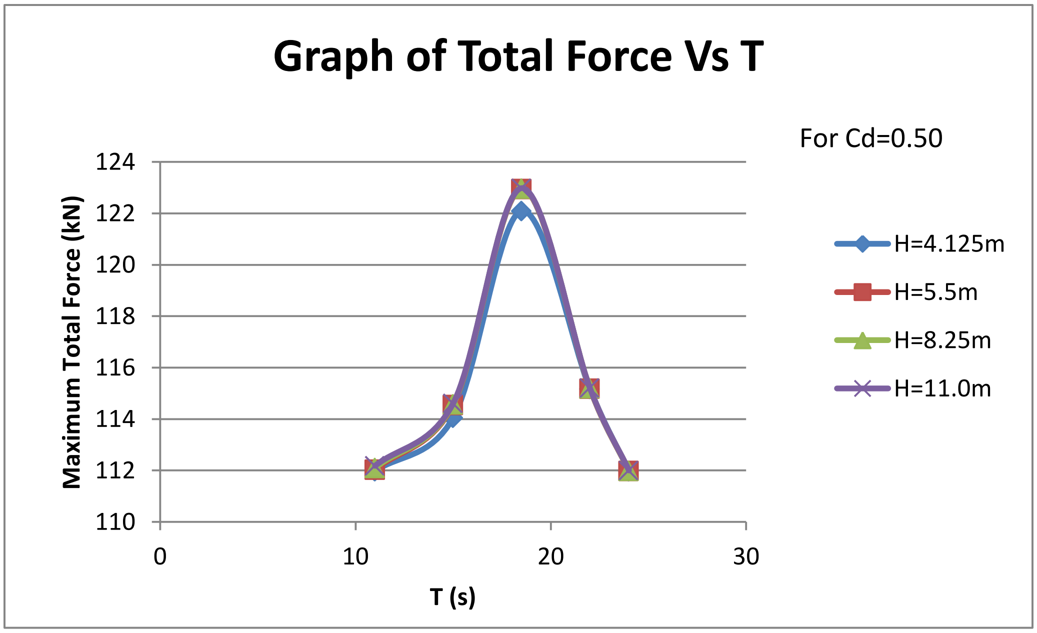

Figure 13: The plot of Maximum Total Force Vs T for different wave height, H using Cd=0.50

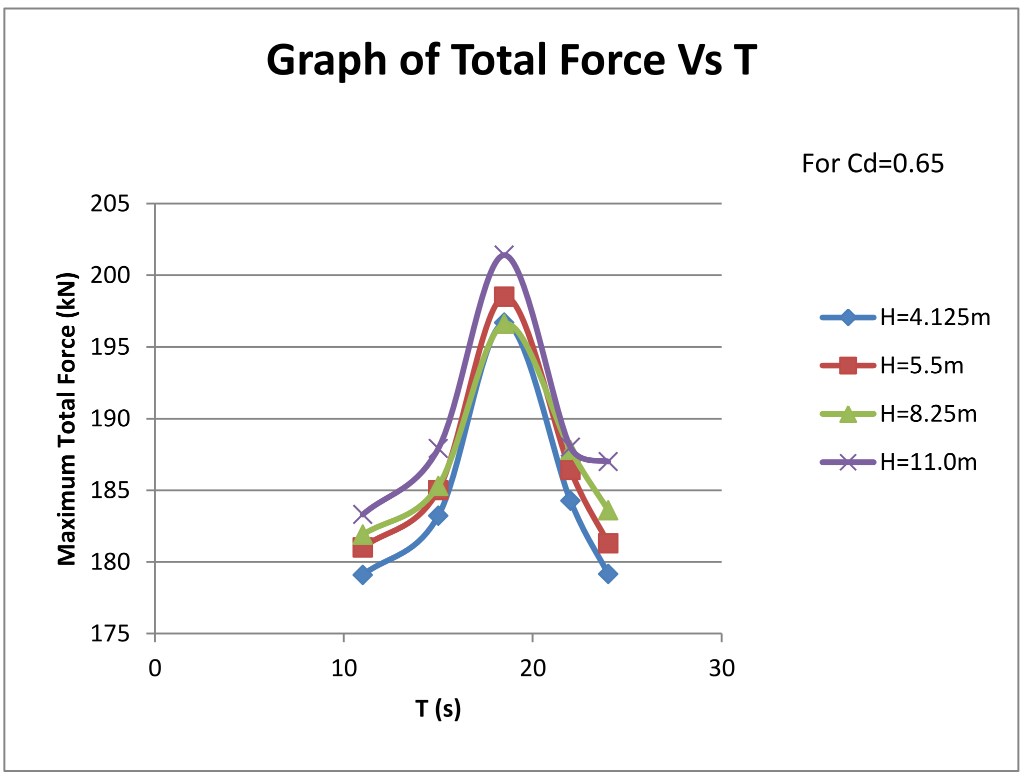

Figure 14: The plot of Maximum Total Force Vs T for different wave height, H using Cd=0.65

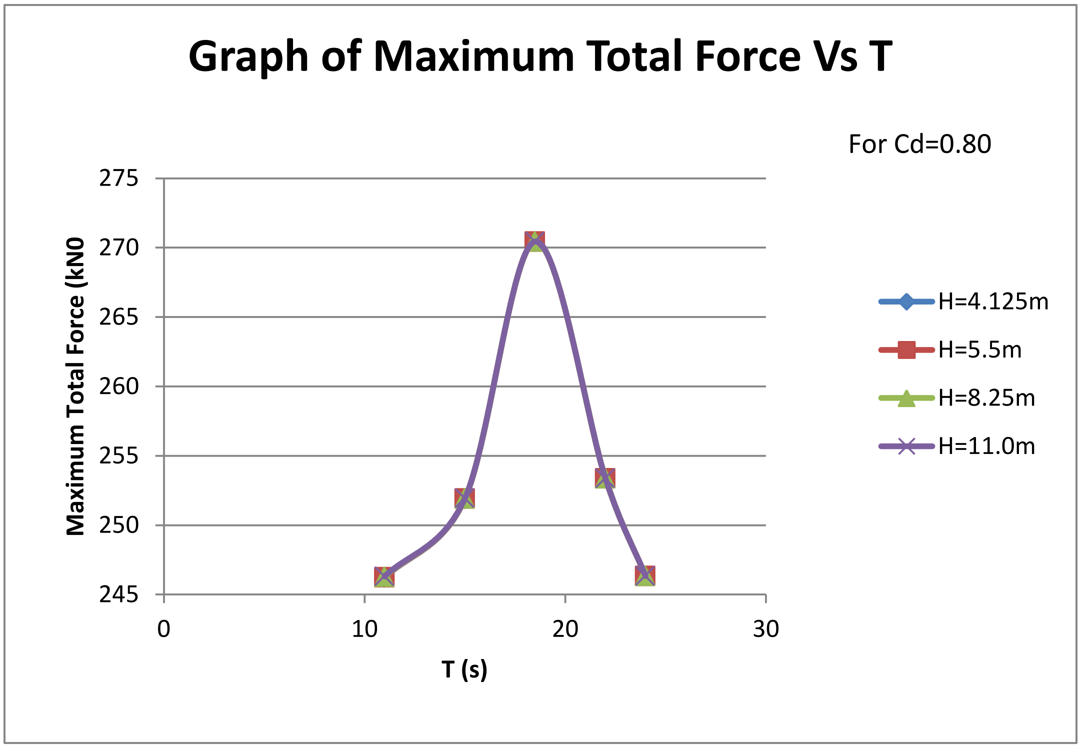

Figure 15: The plot of Maximum Total Force Vs T for different wave height, H using Cd=0.80

Experimental computation for maximum total force of a single member cylindrical member further proven that for different maximum wave height (due to difference offshore regimes), the resultant total force would varies also. C_D of 0.65 at Figure 14 is selected to be used in the experiment so that we can have a better idea of how relevant the test is with regard to PTS. Which in this case, the higher the wave height (H) the higher will be the total force. It comes with a good agreement with the Morison equation.

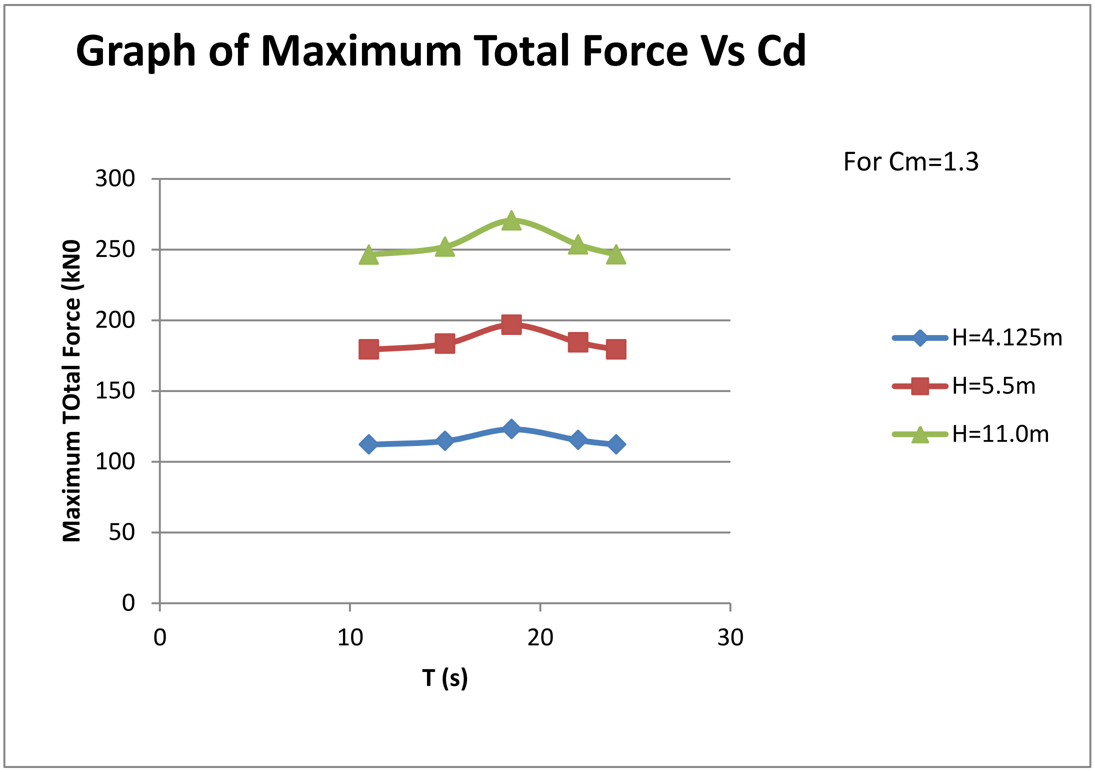

Figure 16: The plot of Maximum Total Force Vs T for different wave height, H using Cm=1.3

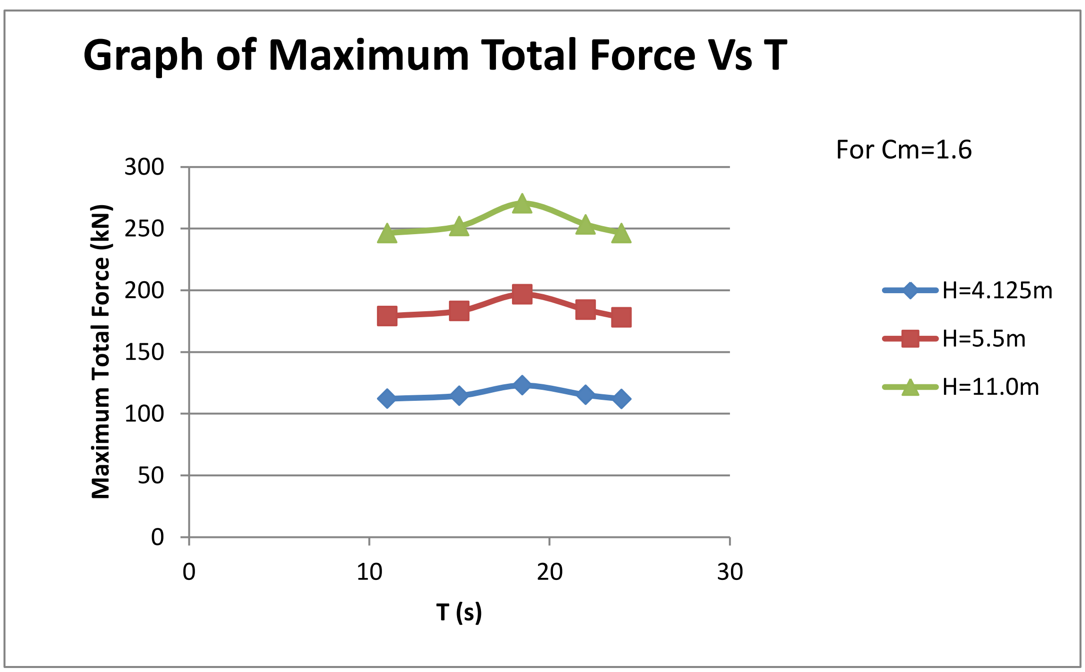

Figure 17: The plot of Maximum Total Force Vs T for different wave height, H using Cm=1.6

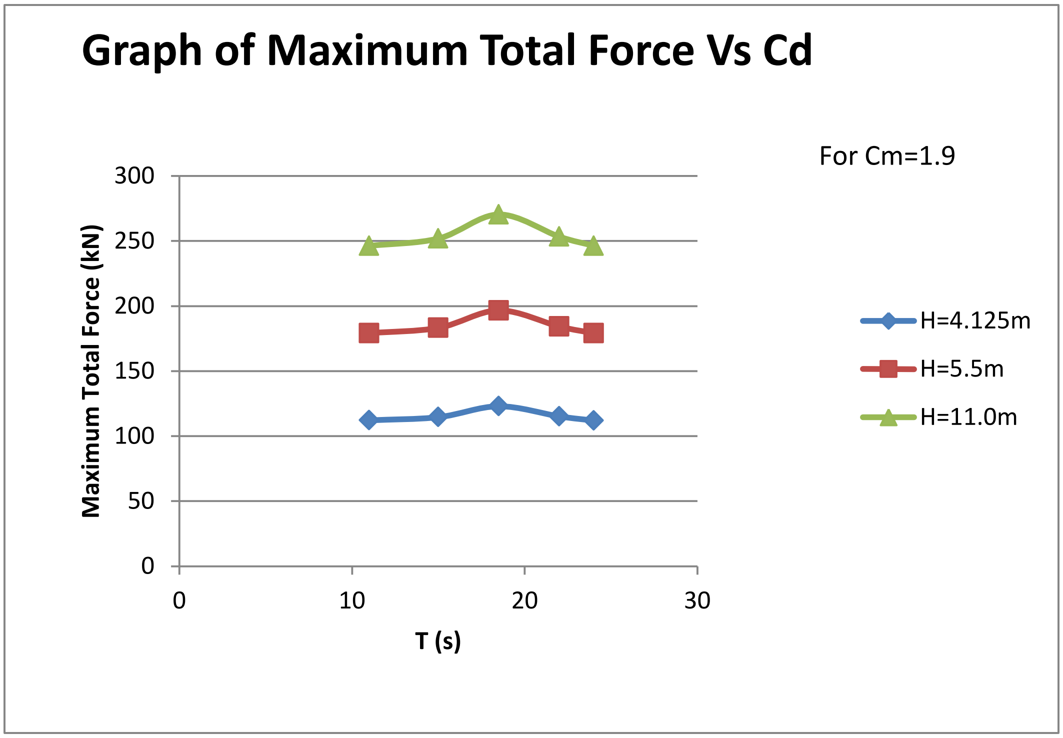

Figure 18: The plot of Maximum Total Force Vs T for different wave height, H using Cm=1.9:

Figure 13 to 18 show that the maximum wave force corresponding to all wave heights occur at a period of 18.4 seconds.

OBJECTIVE 3

Table 1: The wave force loadings for all Malaysian location for member 332- 373 modeled using platform X from PMO

Location	Horizontal Member	Axial (kN)	Shear in Y-Y (kN)	Shear in Z-Z (kN)	Torsion (kN.m)	Bending at Y-Y (kN.m)	Bending at Z-Z (kN.m)
PMO	332- 373	-47.492	1.266	-8.88E-02	-1.3814	1.1957	-8.7905
SKO- Balingian	332- 373	-31.118	1.4589	-1.088	-1.2034	2.1947	-8.0856
SKO- Baram Delta	332- 373	-35.671	1.3844	-0.77123	-1.2521	1.7969	-8.178
SBO- Samarang	332- 373	-39.352	1.6469	-0.58513	-1.2848	1.6198	-9.1434
SBO- Erb West	332- 373	-38.122	2.8769	0.64487	-0.0548	2.8498	-7.9134

Table 2: The wave force loadings for all Malaysian location for member 333- 373 modeled using platform X from PMO

Location	Horizontal Member	Axial (kN)	Shear in Y-Y (kN)	Shear in Z-Z (kN)	Torsion (kN.m)	Bending at Y-Y (kN.m)	Bending at Z-Z (kN.m)
PMO	333- 373	32.281	-0.87481	0.65776	-2.728	-1.391	-7.7317
SKO- Balingian	333- 373	14.932	-0.72543	1.4549	-1.7467	0.33484	-6.2136
SKO- Baram Delta	333- 373	19.863	-0.75949	1.1669	-1.9639	-0.30189	-6.5794
SBO- Samarang	333- 373	21.739	-0.77454	0.91947	-2.0801	-0.91141	-6.7723
SBO- Erb West	333- 373	21.739	-0.77454	0.91947	-2.0801	-0.91141	-6.7723

Table 3: The wave force loadings for all Malaysian location for member 289- 290 modeled using platform X from PMO

Location	Vertical Member	Axial (kN)	Shear in Y-Y (kN)	Shear in Z-Z (kN)	Torsion (kN.m)	Bending at Y-Y (kN.m)	Bending at Z-Z (kN.m)
PMO	289- 290	-116.72	-4.6791	-3.5404	-0.84292	27.98	36.122
SKO- Balingian	289- 290	-88.047	-3.202	-5.0848	0.2366	30.544	26.149
SKO- Baram Delta	289- 290	-94.089	-3.5224	-4.4211	-0.11647	28.633	28.17
SBO- Samarang	289- 290	-97.046	-3.7444	-3.7629	-0.38719	26.188	30.029
SBO- Erb West	289- 290	-97.046	-3.7444	-3.7629	-0.38719	26.188	30.029

Table 4: The wave force loadings for all Malaysian location for member 292- 290 modeled using platform X from PMO

Location	Vertical Member	Axial (kN)	Shear in Y-Y (kN)	Shear in Z-Z (kN)	Torsion (kN.m)	Bending at Y-Y (kN.m)	Bending at Z-Z (kN.m)
PMO	292- 290	-91.712	-1.6678	17.841	2.8675	-99.606	9.5208
SKO- Balingian	292- 290	-82.802	-1.3598	15.199	0.23471	-81.475	8.4683
SKO- Baram Delta	292- 290	-82.823	-1.4837	16.118	1.0085	-86.85	8.8275
SBO- Samarang	292- 290	-83.243	-1.7007	16.944	1.5534	-90.693	9.4613
SBO- Erb West	292- 290	-83.243	-1.7007	16.944	1.5534	-90.693	9.4613

Table 5: The wave force loadings for all Malaysian location for member 245- 283 modeled using platform X from PMO

Location	Diagonal Brace	Axial (kN)	Shear in Y-Y (kN)	Shear in Z-Z (kN)	Torsion (kN.m)	Bending at Y-Y (kN.m)	Bending at Z-Z (kN.m)
PMO	245- 283	5.3562	-6.44E-03	-0.32517	4.11E-16	-0.60415	-8.27E-02
SKO- Balingian	245- 283	5.361	7.29E-02	-0.39524	4.11E-16	-0.76098	0.12564
SKO- Baram Delta	245- 283	5.3597	5.31E-02	-0.37847	0	-0.72666	7.49E-02
SBO- Samarang	245- 283	5.3642	0.13786	-0.4641	4.11E-16	-0.93102	0.2846
SBO- Erb West	245- 283	5.3642	0.13786	-0.4641	4.11E-16	-0.93102	0.2846

Table 6: The wave force loadings for all Malaysian location for member 279- 283 modeled using platform X from PMO

Location	Diagonal Brace	Axial (kN)	Shear in Y-Y (kN)	Shear in Z-Z (kN)	Torsion (kN.m)	Bending at Y-Y (kN.m)	Bending at Z-Z (kN.m)
PMO	279- 283	-1.7053	-7.02E-03	0.31933	0	-0.13833	5.45E-03
SKO- Balingian	279- 283	-1.83	0.14861	0.30803	0	-0.13346	-0.12475
SKO- Baram Delta	279- 283	-1.8008	0.11011	0.31185	0	-0.1351	-9.28E-02
SBO- Samarang	279- 283	-1.9702	0.28323	0.3161	0	-0.13695	-0.24128
SBO- Erb West	279- 283	-1.9702	0.28323	0.3161	0	-0.13695	-0.24128

Chapter 5: DISCUSSION

Generally the maximum total force was proportional to the hydrodynamic force coefficients. Larger HFC resulted in a higher peak value of the maximum total force which was in good agreement with Morison equation. On top of that, this phenomenon was valid for all 5 locations in Malaysia offshore regimes which are: PMO, SKO and SBO.

For Objective 1, the recommended value of C_D and C_M by PTS was utilized to plot the Figure 11 and 12. The graphs clearly show the difference in the maximum total force for different locations given that one of the HFC is fixed. Overall, PMO have the highest maximum total force, followed by SBO and SKO. The relationship between the maximum total force and HFCs were theoretically proven that the difference in location significantly affects the maximum total force on a member of jacket platform. Maximum total force vs C_D graphs are observed to be in proportional whereas Maximum total force vs C_M graphs peaked at about 1.6 which is of good agreement with the recommended value by PTS.

Experimental data obtained from Objective 2 shown that for region with greater wave height, the greater will be the maximum total force acted on the structure. As different offshore location have different maximum wave height, H_{max} and associate wave period, T_{ass}, the experimental results further reinforced the findings obtained in Objective 1.

Objective 3 further shown that PMO that are having generally high wave force loadings will require more reinforcements and considerations for jacket platform design. Therefore by using fixed HFC for less wave force loadings location especially SKO will results in over-design and cost ineffective.

CONCLUSION

This report mainly investigates the effect of location-specific hydrodynamic force coefficients to the maximum total force using the Morison equation. The maximum total wave force for all Malaysian offshore location indeed differs according to the difference in wave parameters and terrain. Thus a more site specific hydrodynamic force should be formulated to optimize the design of jacket platform in Malaysian offshore environment. From the numerical, theoretical and model test point of view, the following conclusion can be drawn:

i) Generally, the effect of HFC to the total maximum force was in good agreement with Morison equations as higher HFC values and wave force loadings produced comparatively higher total maximum force.

ii) Because the wave height for PMO are more than that of SKO and SBO, the software analysis show the same trend with regard to the member force on leg, horizontal member and diagonal brace.

RECOMMENDATION

Collaboration studies should be established with Malaysian neighboring countries in knowledge sharing as several ASEAN countries shared the common sea state and offshore environment.

Scaled-down jacket platform prototypes should be produced to study the overall effect of HFC to the maximum total force as a whole structure of a jacket platform rather than on a member to obtain a better estimation.

KEY PROJECT MILESTONES

FYP I

Key Milestone	Date
Completion of background studies	31 January 2014
Completion of the selection for wave parameters and tubing size to be used in the experimental analysis	10 February 2014
Submission of Extended Proposal Report	24 February 2014
Completion of calculation of theoretical maximum total force	12 March 2014
Tabulation of maximum total force against wave coefficient graph	15 March 2014
Discussion on the results	20 March 2014
Proposal Defense Presentation	26 March 2014
Completion of results with verification of experimental laboratory model testing	9 April 2014
Submission of Interim Report	16 April 2014

FYP II

Key Milestone	Date
Set up of the experimental equipments	I June 2014
Produce draft for Progress Report	15 June 2014
Finalizing Progress Report	30 June 2014
Submission of Progress Report	7 July 2014
Modeling of Results using SACS software	21 July 2014
Pre-SEDEX	28 July 2014
Submission of Draft Report	7 August 2014
Submission of Final Report	14 August 2014
Viva	21 August 2014

PROJECT TIMELINE: GANTT CHART

Progress \ Week number	FYP I													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Topic Selection	■	■												
Briefing Session	■													
Background Study / Lit. Review	■	■	■	■	■	■								
IRC Training					■									
Preliminary Research Work	■	■	■	■	■	■								
Research on PTS manual	■	■	■	■	■	■								
Submission of Extended Proposal						■								
Amendment on Extended Proposal						■	■	■	■					
Numerical modelling of the Maximum Total Force						■	■	■	■					
Graphical representation of findings						■	■	■	■					
Compiling results									■					
Proposal Defence										■	■	■		
Submission of Interim Draft Report													■	
Submission of Interim Report														■

Progress \ Week number	FYP II													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Booking of laboratory slot and setting up the equipments	■	■												
Data Collection in offshore laboratory		■	■	■										
Data analysis				■										
Graph Plotting				■										
Drafting of Progress Report					■	■								
Submission of Progress Report							■							
Amendment on Progress Report							■							
Modelling of the Maximum Total Force using SACS software								■	■					
Graphical representation of findings										■				
Finalizing Findings										■	■			
Pre-SEDEX												■		
Submission of Final Report													■	
Submission of Tecnical Report / Viva														■

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