PARAMETRIC STUDY ON ENVIRONMENTAL EFFECTS OM JACKET STRUCTURE

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Parametric Study on Environmental Effects on Jacket Structure

by

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the requirement for the
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CERTIFICATION OF APPROVAL

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TRONOH, PERAK
January 2009

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.

Nur Khalidah Binti Abdullah Yusuff

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This experiences that the author had endured during her Final Year Project, has definitely polished her communication skills, knowledge level and will definitely be put to great use in her future undertakings.

ABSTRACT

Jacket typed structures are most commonly used as supporting structure for deck facilities which are stabilized by leg piles driven through the seabed constructed mainly in shallow water regions. Their sizes ranges from three to eight legged depending on the facilities to be installed on topsides. In jacket design phase, both operational and environmental loads are very important and must be investigated intensively to ensure that the structures are able to withstand the transmitted forces during its design life. This report focused on studying the parameters of the environmental loads and its effects on jackets during In-place. Results are presented in a graphical form of parametric study in which a typical jacket type platform was subjected to waves of varying height and period, increments of currents and wind loads. Relationship between critical joint depth with water depth and total weight of platforms are also studied. Result shows that all the parameters involved have significant effects on the jacket structure. Software called SACS Executive 5.2 will be used to conduct the analysis throughout the project. All design and analysis of the jackets will be based on design recommendations in *Petronas Technical Specification PTS 20.073 "Design of Fixed Offshore Structures" and API Recommended Practice 2A-WSD (RP 2A-WSD)* Twenty-first edition, December 2000.

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CHAPTER 1

INTRODUCTION

1.1 Background Study

Offshore structures are used worldwide for exploration of Oil & Gas from under seabed and for processing. Platform size basically depends on the facilities to be installed on topside. For jacket structures, it can vary in size and height from three (3) to eight (8) legged depending on the size of the topside. All offshore structures are typically built out of steel, concrete or a combination of steel and concrete. There are basically two (2) functions of jackets which are to provide the substructure for the production facility (topside), keeping it stable above the waves and also to support laterally and protect the well conductors and pipeline riser.

In offshore structures, circular hollow sections or tubular members are used almost exclusively as it can reduce the drag coefficient to a relatively low and smaller hydrodynamic loads. These tubular members will then be welded to form welded tubular joints that display the geometrical discontinuity. Under harsh environmental loadings, these members and joints need to be checked to ensure that it can withstand the forces transmitted within the system. This analysis can be performed by using software called SACS in which enables the engineers to design offshore structures under both operating and extreme storm conditions during transportation, installation and in-place. Figure 1.1 shows a typical structure of an offshore platform.

Figure 1.1 Offshore Structures

1.2 Problem Statement

On 27th March, BBC News reports that "At least 120 oil rig workers are feared dead after a North Sea accommodation platform, Alexander Kielland collapsed during gales. Reports say a massive wave hit one of the legs of the platform, causing it to break and send the 208 people on board into the sea at around 1830 GMT. A previously undetected crack in one leg of the platform is thought to be the reason the structure gave way."(BBC News, 27 March).This incident are one examples of many catastrophic event ever occurred in history related to the failure of jackets under harsh environmental conditions. This shows how devastating environmental loads can affect the durability of a particular jacket platform mostly due to joint failures. Thus, a thorough research on the response of the critical joints and the members under different environmental loading conditions needs to be performed as to ensure that a basic understanding on the trends of the joints failures and stress distributions under the influents of harsh environmental loadings can be studied.

1.3 Objective of Research

The main objective(s) of this research are:

I. To study the response of the jacket under different environmental loading conditions.
II. To study the effects of total weight and water depth of jackets on the depth of critical joints.

1.4 Scope of Research

To ensure that the objectives of the project are achieved, a structured well organized plan has been produced. The plan consists of:-

1. **Self Revisions**

   a. To provide a better understanding on the Oil & Gas Industry and other information related to the topic, a continuous research on journals and other reading materials has been carried out. This is to ensure that the progress of the project can updated regularly on weekly basis and reports can be prepared efficiently.

2. **Software Analysis**

   a. SACS Executive 5.2 or also known as Structural Analysis Computer System will be used to conduct all the analysis involved for the jackets. SACS is basically software which is developed for both Offshore Structure and Civil Engineering applications.

3. **Design Analysis**

   a. To confirm the stability of a particular jacket structure, several analysis including In-place, fatigue, dynamic, load-out, transportation, lifting and launching are performed. For this project, only In-place will be taken into consideration. Thus, a study on the load condition, parameters, load combinations and results analysis needs to be executed.

CHAPTER 2

LITERATURE REVIEW

2.1 Offshore Structure

Basically, there are two types of offshore structure, named fixed and compliant. For this project, focus is put onto the fixed typed offshore structure which basically consists of two parts, superstructure and the substructure. Superstructure mainly consists of topsides while substructure is the submerged jackets. Varies in sizes and height, these platforms are built on concrete and/or steel legs anchored directly onto the seabed, supporting a deck with space for drilling rigs, production facilities and crew quarters. Steel jackets are vertical sections made of tubular steel members, and are usually piled into the seabed. Due to its steel properties, it has a high tendency of corroding. This is when cathodic protection using sacrificial anodes are welded on the jackets at different location for corrosion protection. These sacrificial anodes each consists of zinc or aluminum bar cast which typically covers approximately 5% of the jacket weight. Tubular sections are used in constructions of a particular jacket structure as it is known for reducing forces acting on the legs. Up until now, fixed platforms are economically feasible for installation in water depths up to about 1,700 feet (520 m). Deeper than that, the consultant companies need to come up with other floating typed platforms available in the industry. It is known that "Fixed structures experience greater forces than compliant structure" "(Chakrabrati, S.K., 1987).Figure 2.1 shows several types of offshore structures available in the industry.

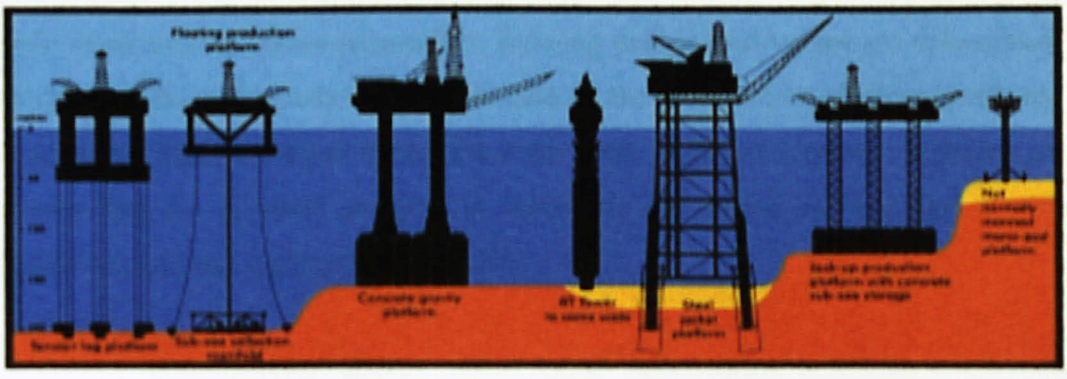

Figure 2.1 Types of Offshore Structure

2.2 Parametric Study

Basically, parametric study is done to determine and to have a better understanding on the influence of a particular characteristic on the response of the system. According to Dustin M Brandt "These studies can involve hundreds to thousands of individual cases which can determine the effect of the variance of a parameter on the system."(Dustin M.Brant, 2008)

2.3 Environmental Loads

The loading of an offshore structure consists of two components: vertical structural loads and lateral wave loads. Basically loads that have been considered acting on the structure may be classified into the following categories. These loads will be individually inserted onto the model depending on the location of the acting loads on the structure. Based on a journal written by D.Zhang, it is said that, "As the water depth gets deeper, the hydrostatic pressure increases, hence, the design characteristics of each member will also behavior differently."(D.Zhang, 2006)

- Dead Loads
- Live Loads
- Environmental Loads

According to PTS 20.073 "Environmental loads are loads arise from the action of waves, currents and winds on the structure"(PTS, 2005). In other words, environmental loads are those caused by environmental phenomena such as wind, waves, current, tides, earthquakes, temperature, ice, sea bed movement, and marine growth. Their characteristics parameters, defining design load values are determined in special studies on the basis of available data. In the design of an offshore structure, environmental loads are acted on the structure under different loading conditions as to ensure that the structure are able to withstand the maximum load that it will definitely experiences during its design life.

Among those environmental loads that are taken into considerations are:

- Wind

For in-place analysis, the one-minute mean wind speed is used for calculating wind loads on the topsides corresponding with maximum wave forces on the substructure. For operating condition and storm condition, the 1-year and the 100-year return period is used respectively. The values given are referenced to 10 m elevation above MSL. Wind is assumed to be Omni-directional and acting concurrently with wave in the same direction.

- Waves

Wave loading is the most important environmental loadings which majorly contribute to the total force experienced by structure and for which the structure must be designed. Caused by the motion of water generated by the action of the wind on the surface of the sea, wave loads acted as forces on the structure. Omni-directional wave parameters are applied for operating, storm and mooring conditions. For mooring operating case, annual 90% non-exceedance wave are used.

It has been proven that "The wave load due to storms acting on the structure during its design life is divided into a set of stationary sea states each being described by wave spectra. The probability of occurrence of each sea state is available from sea scatter diagram and is used to account for the long term distribution (Vughts and Kinra, 1976; Chakrabarti, 1987)" and that, according to research, "The periods of most ocean waves are in the range 2 to 20 s (SNAME, 1993). However, at the lower end of this range only very small wave heights are stable" (Martin S William, 1997).

- Currents

The following omni-directional current profiles are used in the design. The current is assumed to be acting concurrently with wave in the same direction. A 1/7 power current profile is used in the analysis. The 1-year return period is used for operating and operating with soft-mooring conditions. The 100-year return period is used for extreme storm condition.

- Marine Growth

The following marine growth profile is used for the analysis. Linear interpolation is used between the stated points. Dry unit weight of marine growth is taken as 1025 kg/m^3. Based on a study, "Marine growth influenced the magnitude of loading on structures which will then significantly affects it performances. 50-mm thickness of marine growth can increase the overall loading by 5.64%. " (Iberahin Jusoh, 1997). It consists of large variety of organisms and may be expected at any site within 2 years of installation and cleaning starts after about 4 years.

2.4 Types of Joints

There are several types of tubular joints available which can be categorized which depend on the configurations of the welded tubular members. Each comprises of one or more members being welded together into a bigger diameter referred to as chords. A thorough research has been done to study hysteretic behavior of tubular N-Joints which can be found in (Y.Yin, 2007). Following are the types of joints available:

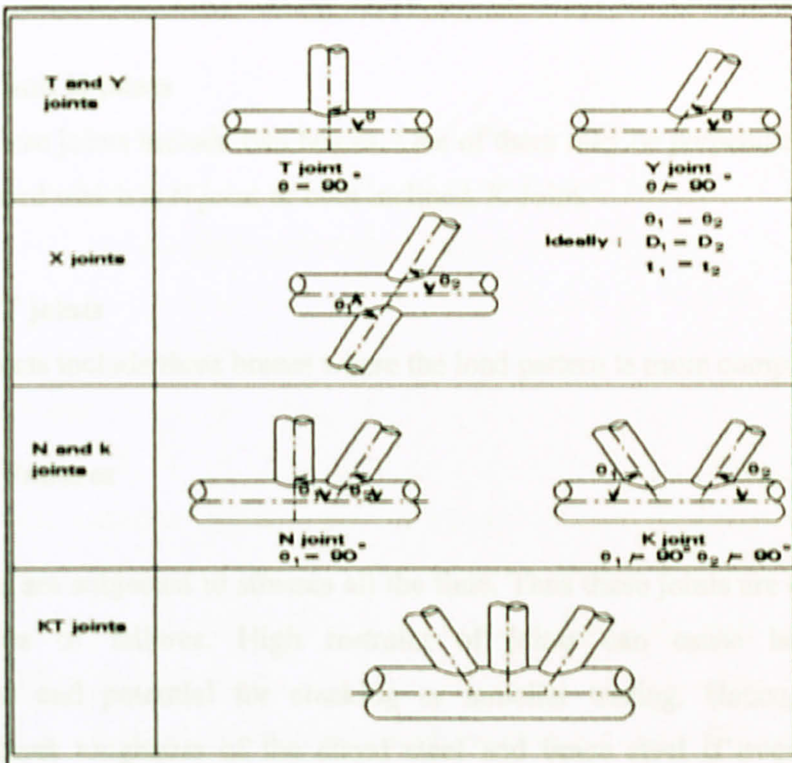

Figure 2 Joint classification

Figure 2.2 Types of tubular joints

Source of Design of Offshore Structure Lecture Notes

- **T-joint and Y-joint**

  T joints are made up of a single brace, perpendicular to the chord where the axial force acting in the brace is reacted by bending in the chord while Y joints are made inclined to chord where the axial force is reacted by bending and axial force on the chord.

- **X joints**

  Includes two coaxial braces on either side of the chord. Axial forces are balanced in the braces, which in an ideal X joint have the same diameter and thickness. In fact, other considerations such as brace length, which can be different on each side of the chord, may lead to two slightly different braces. Angles may be slightly different as well.

- **N and K joints**

  These joints include two braces. One of them may be perpendicular to the chord which is N joint or both inclined, K Joint.

- **KT joints**

  Joints include three braces where the load pattern is more complex.

2.5 Types of Failures

Tubular joints are subjected to stresses all the time. Thus these joints are exposed to different types of failures. High restraint of joints can cause large strain concentrations and potential for cracking or lamellar tearing. Hence, adequate through-thickness toughness of the chord steel and brace steel if overlapping is present should be considered as an explicit requirement. One type of joint failures is due to fatigue failure. Due to the subjected stresses which varies in time, offshore structures can experience millions of variable amplitude load cycles during their service life. Such fatigue loading represents a main cause of degradation in these structures. As a result, fatigue is an important consideration in their design. Many research has been done which focused on the wave-induced vibration such as fatigue of stiffened steel tubular joints, such as corrosion fatigue and fatigue behavior.(Gandhi et. Al (2000a,b) and Vugts (2005) also had discussed on fatigue damage assessment and the influents of wave directionality. (Gang Li, 2007)

Apart from that, there are, punching shear which occurs to tubular joint connection exists primarily in the jackets structure or between members that will be submerged by the design wave. Under the design wave and wave loadings, the forces in each cross sectioned members are transmitting directly to the wall of the leg. Due to the high risk of failures, checks will be made for all tubular joint connections to analyze the strength of tubular joints against punching shear. Overstressed joint cans can be remedied by the addition of doubler plate at joints between two members or by increasing the wall thickness of the chord or main members.

2.6 Load Combinations

Load combinations are used in analysis to produce the worst possible conditions during the offshore structure's design life and during installation phase. The loading conditions should include environmental conditions with appropriate deal and live loads.

2.7 Analysis Phase

The model will undergo various analyses according to its respective condition. Basically, there are two (2) types of analysis, In-Service and Pre-Service Analysis. Basically, the analyses are analyzed due to its Interaction Ratio (IR) as known as Unity Check (UC). IR or UC is the ratio of actual stress to the allowable stress. There are three types of stress to be considered; axial, bending and shear. The combinations of the ratios to determine the UC is depending on the characteristic of the member. Figure below shows a basic design stages for any offshore structures.

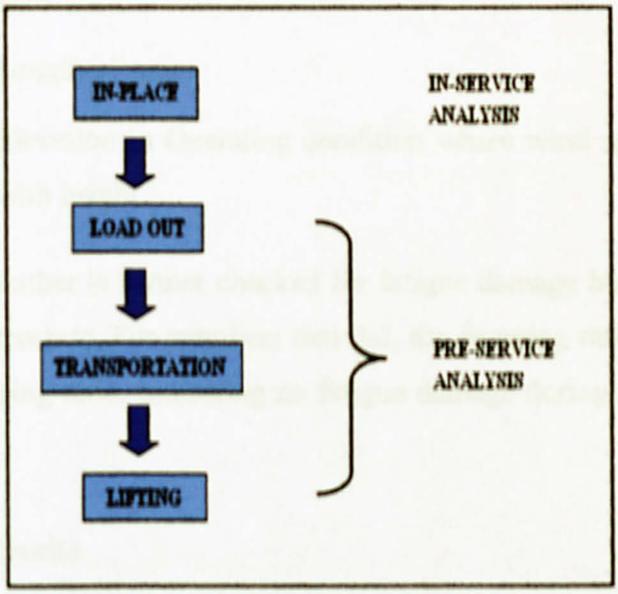

Figure 2.3 Design Stages

2.7.1 In place Analysis and Design

The objective of in-place analysis is to ensure that the structure is capable of supporting the installed facilities in normal operating and extreme storm conditions throughout the design life of the platform. The basic loads are factored in accordingly to generate the worst possible loading conditions that the structure may experience during its design life. Two of the most important global responses will be analysed which are Maximum Overturning Moment and Maximum Base Shear. According to a study, "Jacket legs are battered to provide larger base for the structure at the mud line and thus assist in resisting higher environmentally induced overturning moment" (Iberahin Jusoh, 1997)

2.7.2 Vortex-Induced Vibration Analysis Results

Representative members are checked for occurrence of vortex-induced vibrations (VIV). Screening is based on:

(1) Size

(2) Length of span

(3) Elevation in Operating condition where wind speed increases with height

If VIV is observed, member is further checked for fatigue damage based on critical damping ratio of the structure. For members that did, the damping ratio is above the minimum critical damping ratio, indicating no fatigue damage during the design life of the structure.

2.8 Design Analysis Results

For connection tubular to tubular members, checks will be made to analyze the strength of tubular joints against punching shear instead of check for stresses alone. The punching shear analysis in the SACS software is referred to as Joint Can Analysis. Example of the Environmental Loads Output List and Joint Can Summary can be referred to in Appendix III and Appendix IV. The UCs must not exceed 1.0.

If joint can UCs exceed 1.0, these can be remedied by the addition of doubler plates at joint between two pipe members. The doubler plate provides a virtual increase in the chord pipe's wall thickness preventing the brace pipe from puncturing through the chord pipe member. Joint can overstress problems can also be fixed by increasing wall thickness of the chord member involved, or increase the outside diameter of the brace. Lower UCs also needs to be taken into consideration as it would be uneconomical if the values are too small. Thus this particular member needs to be upsize to an optimum level.

2.9 Load formulation

Load formulation is important for loading in the analyses. All calculations are referring to AISC and API. Like design loads explained before, the loads are to be applied either as pressure, point load or ultimate design load depending on the how the loads acting on the structure.

2.9 Standards for design guidelines

- **American Petroleum Institute (API)**
  "Recommended Practice for Planinng, Designing and Constructing Fixed Offshore Platforms – Working Stress Design", API RP2A – WSD 21st Edition, December 2000

- **American Institute of Steel and Construction (AISC)**
  AISC Manual of Steel Construction – Allowable Stress Design – AISC-ASD 9th Edition 1989

- **PETRONAS Technical Standard**
  'Design of Fixed Offshore Structures', PTS 20.073, December 1983 and 'Supplementary to PTS 20.073' Rev 4, August 2005

CHAPTER 3

METHODOLOGY

This section basically gives an idea on the basic methods used by the author throughout the completion of this software based project. Figure 3.1 below shows the flow chart of the methodology used.

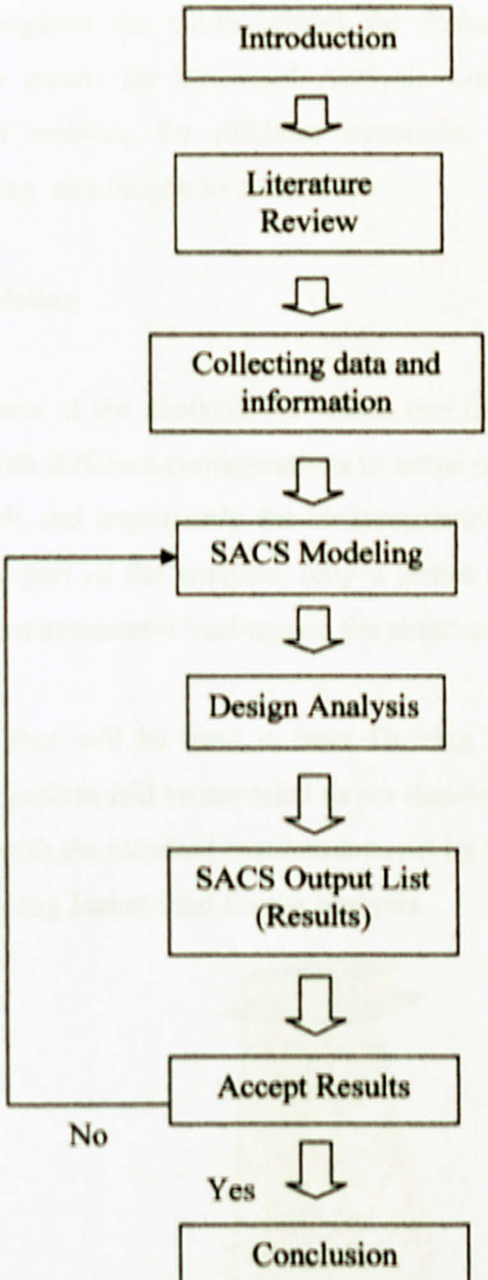

Figure 3.1 Flow Chart of Research Methodology

3.1 Project Planning

3.1.1 Literature Reviews

During the earlier phase of the project, more effort are put into research on journals and other reading materials closely related to the topic. This is to enhance understanding regarding the subject matter. Skills using SACS Executive 5.2 also needs to be practice and acquired on a regular basis as this software is chosen and will be used throughout the entire project for design analysis purposes. SACS Software basically stands for Structural Analysis Computer System used to run different types of analysis for offshore structures, namely in-place, load-out, transportation, lifting, and fatigue to name a few.

3.1.2 SACS Modeling

There will be 2 parts of the analysis, for which one of them requires the aid for 4 jacket platforms with different configurations in terms of the locations, water depths, appurtenances loads and importantly the environmental loads to build relationships .As for the second part of the analysis, only a jacket is analysed to determine the effects of several environmental loadings on the structure during in-place.

The major jacket that will be used is from Duyung Project. Basically, in SACS Modeling process, jackets will be modeled as per drawings and all parameters will be added complying with the standard requirements set by the PTS. Figure below shows a model of the Duyung Jacket used for the analysis.

Figure 3.2 SACS Model 3D View of DDP-A Platform

3.1.3 Design Analysis

For this particular project, only In-place analysis will be investigate against the impacts of environmental loads on the jacket structure. Under In-place analysis, various load combinations will be analyzed to come up with the worse possible condition during both operational and extreme storm conditions.

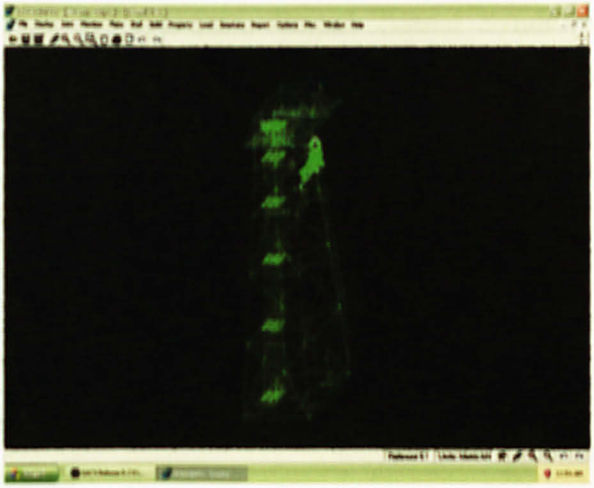

Figure 3.3 Example of platform model using SACS Software

3.1.4 SACS Output List (Results)

The results of the analysis basically consist of three (3) major outputs named SACS output list which contain all results of the analysis, Joint Can Summary which summarized the joint UCs and also Postvue, an interactive graphic post processor. Focused will be put on the joint can summary to determine the critical joints under different environmental conditions and also two of the most important global responses which are Maximum Overturning Moment and Maximum Base Shear.

3.1.5 HSE Requirements

Health Safety and Environmental (HSE) requirements are not only being applied to hazardous workplaces such as laboratories and factories but also needs to be implemented in normal workplaces particularly in computer workstations. For this project, computer ergonomic values will be applied as most of the time is spent on performing analysis using computer. Among the common medical problems related to computer workplace are eyestrain, Carpal Tunnel Syndrome, Neck and Back Strain. Following are the procedures recommended by the OSHA to improve ergonomics of the workstation. (Osha)

➢ **Good Working Posture**

- Top off monitor at or just below eye level.
- Head and neck balanced and in-line with torso.
- Shoulder Relaxed
- Elbows close to body and supported
- Wrists and hand in-line with forearms
- Adequate room for keyboard and mouse
- Feet flat on the floor.

3.1.5.1 Workstation Environment

Appropriately placing lighting and selecting the right level of illumination can enhance your ability to see monitor images. Eyestrain or headaches may be developed, and may have to work in awkward postures to view the screen id the lighting is excessive or causes glare on the monitor screen. Ventilation and humidity levels in office work environments may affect user comfort and productivity.

3.2 Gant Chart

Please refer to Appendix I for the Gantt chart and Appendix II for the overall project planning.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results

Based on a thorough research of the project for the past few months of last semester for FYP1, more focus are concentrated on finding and understanding concepts for all subjects related to the topic particularly on environmental loadings. Thus, most of the concepts have surely been mastered during the intended duration by now. These loads are crucial as to determine the trends of critical joints under different environmental conditions based on the standard requirements. It must be verified based on the actual data at the site. As for this case, the jacket model that is used is based on the 'Metaocean Design Data'. Details are given in Appendix V.

For the second part of the semester, more work is put into conducting design analysis phases for the jackets during in place under different environmental loading conditions. It is that from the results of this analysis that we can start to undergo research to determine the trends of the critical joints, and also the forces and moments under different loading conditions. Before variations of environment loads are put into consideration, the jacket structures will be first be subjected to its original location environmental forces. This is due to the fact that, environmental loads cannot be simply adjusted but it must be based on the actual environment data at that location given by a third party. If not, the conditions will not be the same as the original location ones. Thus, inaccurate data are received. This is because during the design phases, the jackets have already been designed in a way that it can withstand the maximum environmental loads at that particular location. If it can withstand the capacity beyond the original environmental loads at that location, then it will not be economical. Table 4.1 shows the data of the platforms being analyzed subjected to its original location during in-place:-

1. Existing Environmental Loads

Table 4.1 Result summary of in-place analysis of jackets in existing environmental conditions

No.	Platform	Total Weight (kN)	Water Depth (m)	Depth of Critical Joint (m)	Joint Type
1	LHDP-A	23268.7	71.00	0.702	X
2	MLDP-A	25074.9	79.86	76.60	X
3	DPP-A	12986.7	75.90	11.50	T
4	MDA	10179.1	61.30	21.00	K

Figure 1-4 below shows the corresponding model of the jackets above:

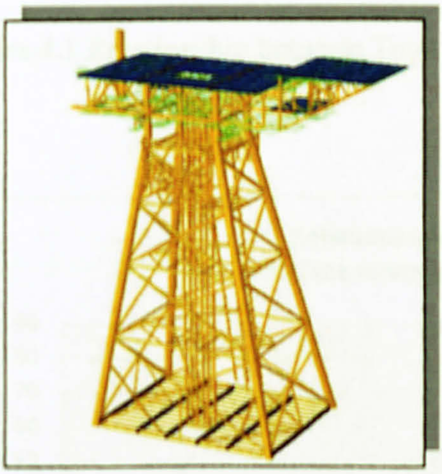

Figure 1

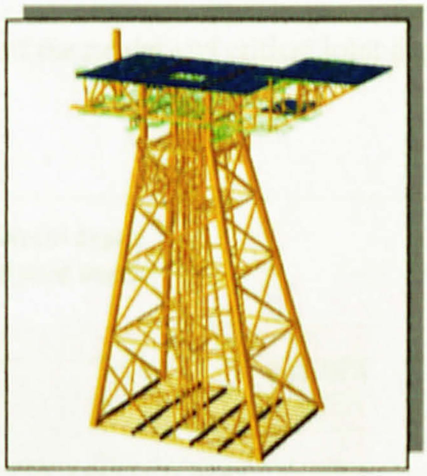

Figure 2

Figure 3

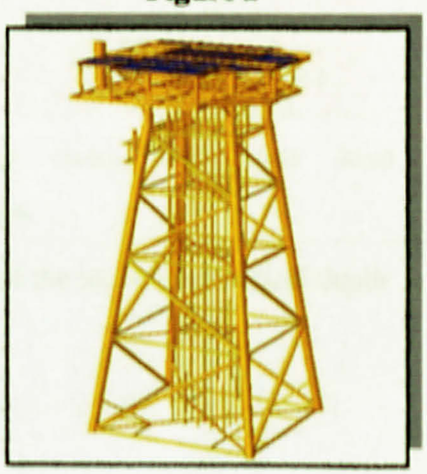

Figure 4

Figure 4.1 and 4.2 below show the first analysis conducted which was among four jacket platforms using their existing environmental loads. The relationship between the total weight and water depth of the jackets are being analysed and the effects on the critical joints depth are observed.

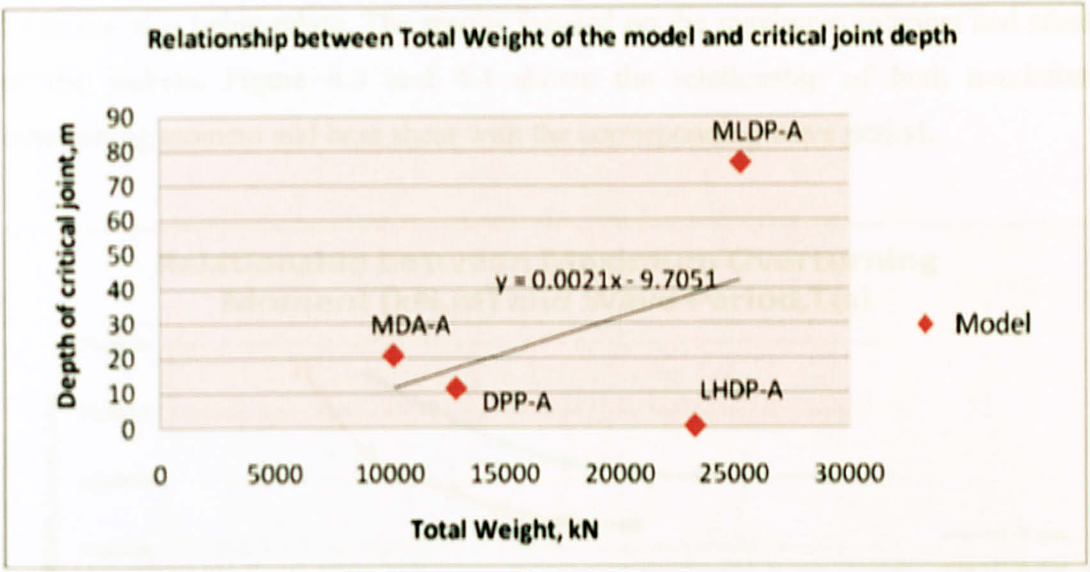

Figure 4.1 Relationship between Total Weight of the model and critical joint depth

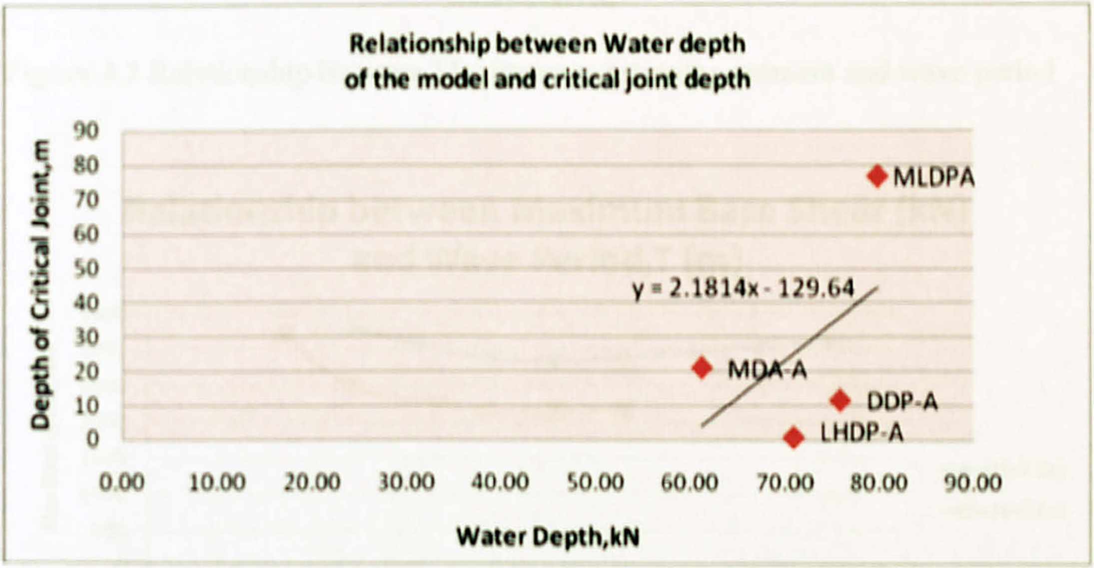

Figure 4.2 Relationship between Water Depth of the model and critical depth

2. Constant wave height (m) and variations of Wave Period (s)

For the second part of the analysis, the jacket will be subjected to different wave loads by taking a fixed value of H = 7.8m and varying the wave period, T between T=6.0s and T=20.0s. A second value of fixed H= 6.4m, with T varying from 4.0s to 14.0s are also being relate. The results focused on the maximum moment and shear of the jackets. Figure 4.3 and 4.4 shows the relationship of both maximum overturning moment and base shear with the corresponding wave period.

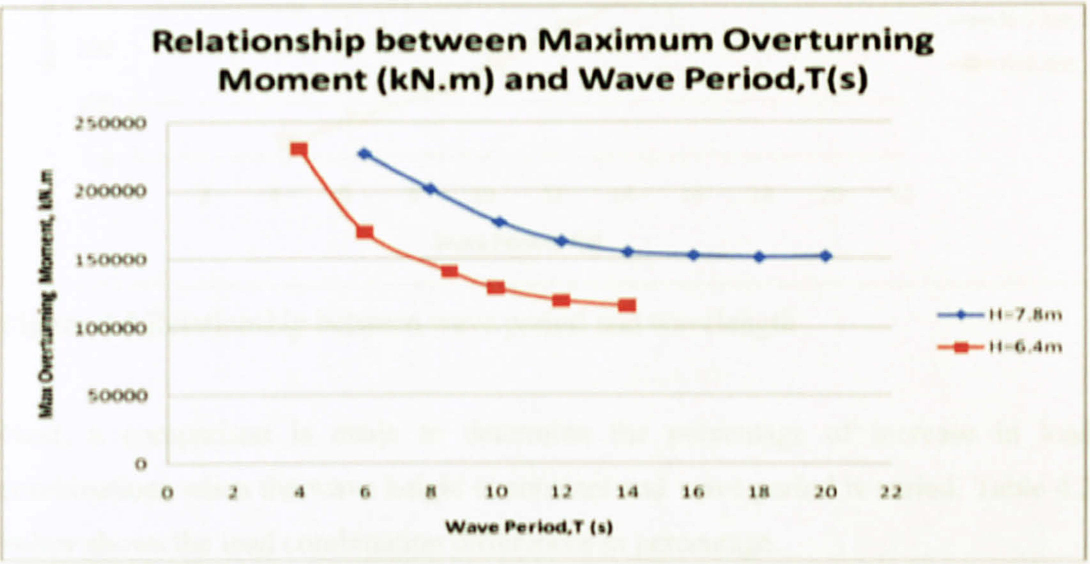

Figure 4.3 Relationship between Maximum overturning moment and wave period

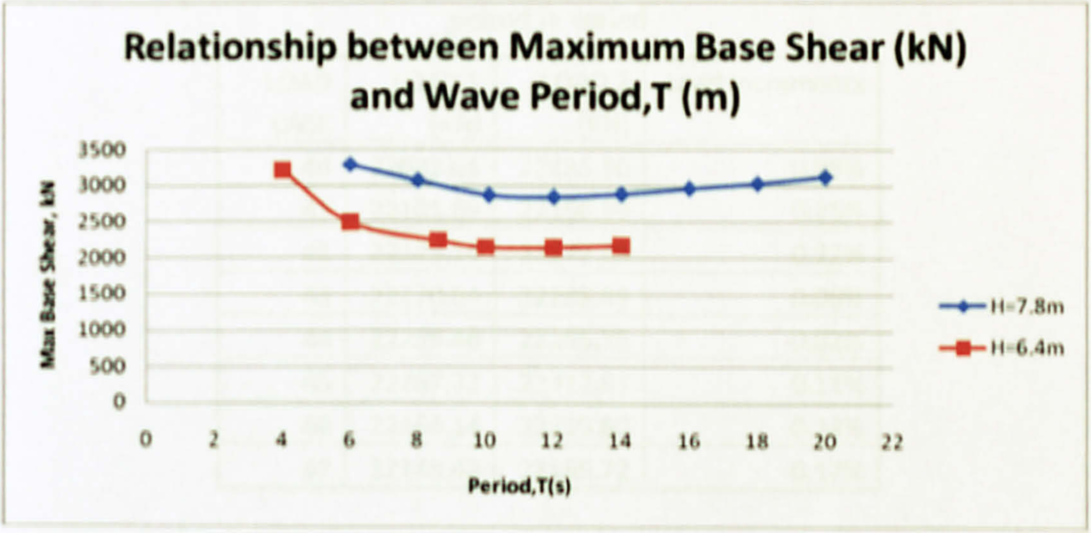

Figure 4.4 Relationship between Maximum Base Shear and wave period

Figure 4.5 below are the relationship between wave period and wavelength for confimation regarding the relationship between the two parameters.

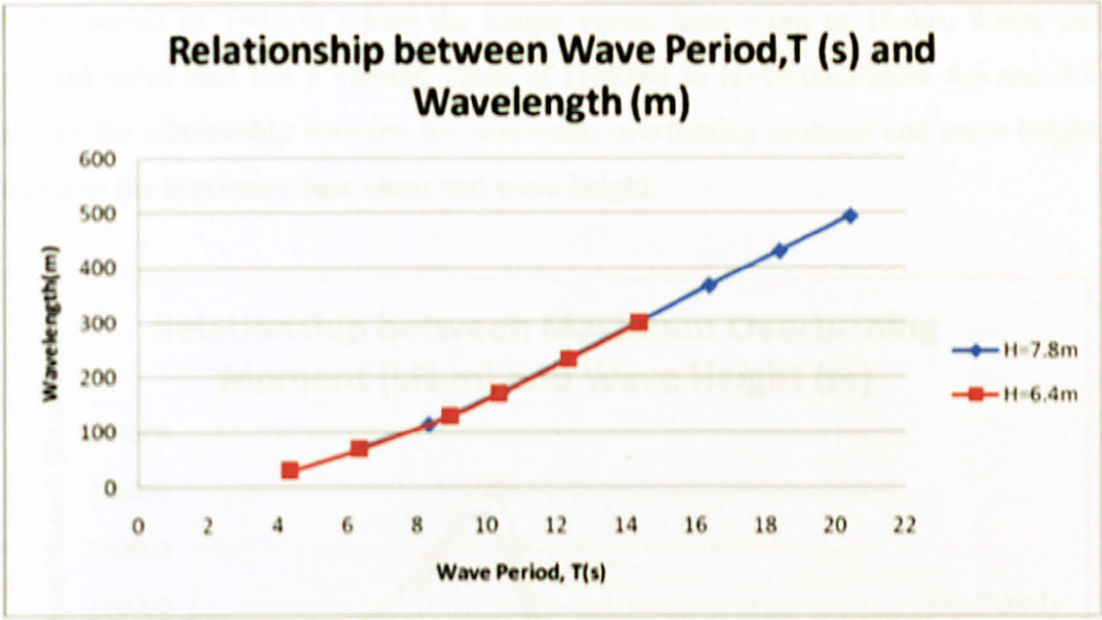

Figure 4.5 Relationship between wave period and wavelength

Next, a comparison is made to determine the percentage of increase in load combinations when the wave height is constant and wave period is varied. Table 4.2 below shows the load combination differences in percentage.

Table 4.2 Load Combination differences when wave height is constant and wave period is varied

LOAD CASE	LOAD 1 (KN)	LOAD 2 (KN)	Load Increments
40	22022.01	22235.50	0.96%
41	22101.69	22156.89	0.25%
42	22129.74	22177.88	0.22%
43	22270.94	22288.65	0.08%
44	22259.46	22255.75	-0.02%
45	22287.32	22312.93	0.11%
46	22166.14	22219.80	0.24%
47	22148.42	22185.72	0.17%

Average Load Increment: 0.25%

3. Fixed wave period, T and variations of wave height, H (m)

Next, the jacket is being subjected to another wave loads. This time, with a fixed wave period of T=10.1s where the height varies from 6.0m to 16.0m. While the second wave load has a varying value of H=6.0m to H=16.0m.Figure 4.6 and 4.7 shows the relationship between the maximum overturning moment and wave height and also the maximum base shear and wave height.

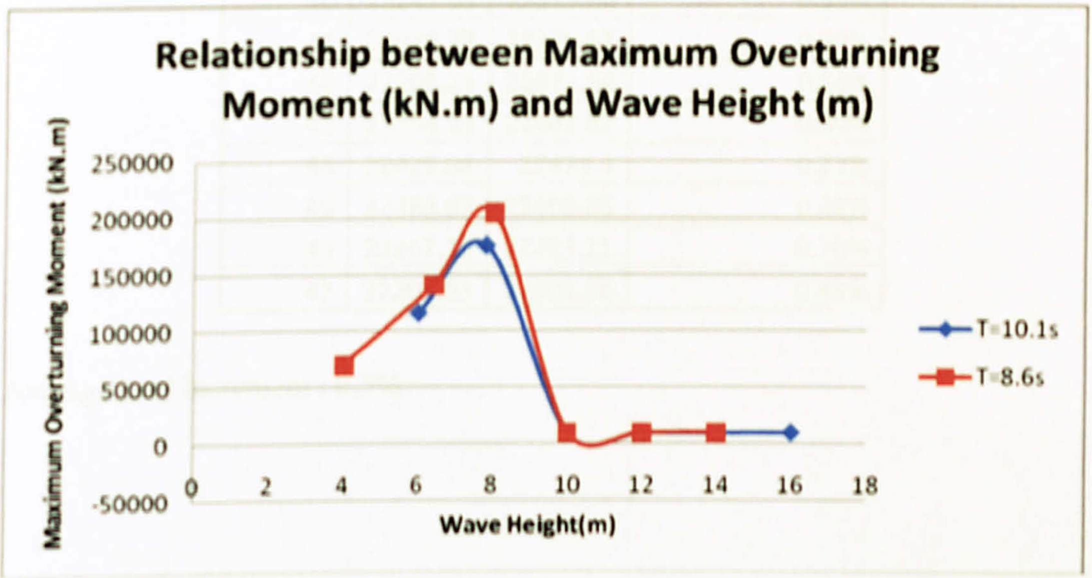

Figure 4.6 Relationship between Maximum Overturning Moment and wave height

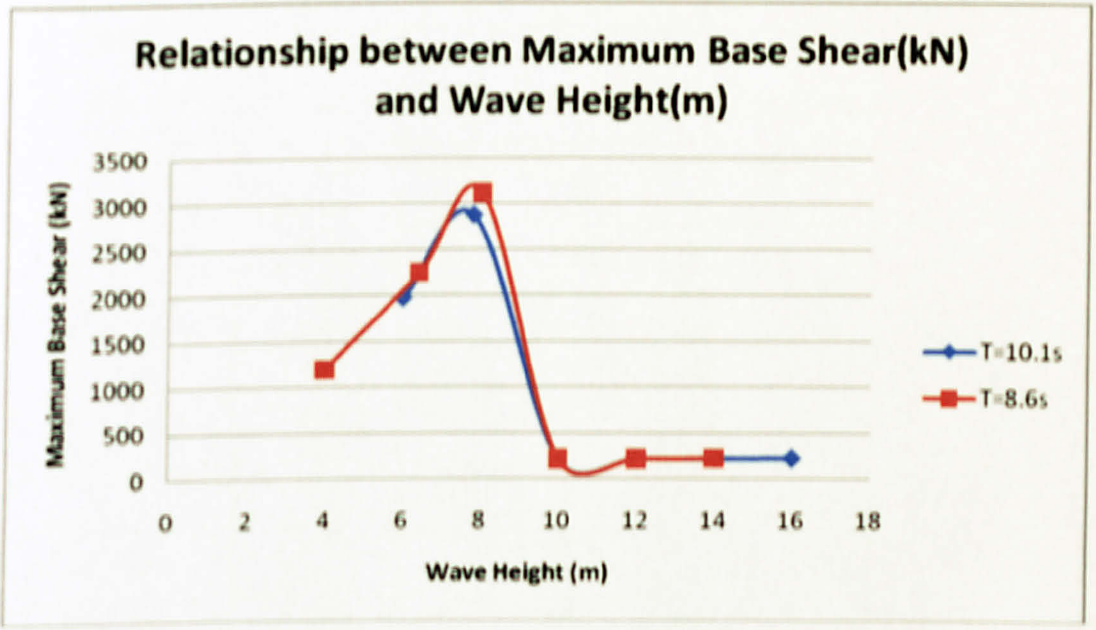

Figure 4.7 Relationship between Maximum Base Shear and wave height

Same as the previous result, a comparison has been to determine the percentage of increase in load combinations when the wave height is constant and wave period is varied. Table 4.3 below shows the load combination differences in percentage.

Table 4.3 Load Combination differences when wave height is constant and wave period is varied

LOAD CASE	LOAD 1 (KN)	LOAD 2 (KN)	Load Increments
40	22245.95	22319.86	0.33%
41	22025.33	22230.61	0.92%
42	22205.23	22322.64	0.53%
43	22354.33	22442.87	0.39%
44	22425.04	22474.4	0.22%
45	22388.67	22496.66	0.48%
46	22267.15	22423.11	0.70%
47	22201.93	22301.55	0.45%

Average load increment : 0.5%

4. Percentage increase in wind and current loads

Next, is to study the relationship between percentage increase in wind and current loads with respect to the maximum moment, shear and UC increase. Table 4.4 and 4.5 below is used to

Table 4.4 Increment of current velocity by percentage

Elevation Above Mudline (m)	Current Velocity (m/s)	Increment of Current Loads by Percentage (%)			
		20	40	60	80
0.00	0.000	0.0000	0.0000	0.0000	0.0000
0.76	0.360	0.4320	0.5040	0.5760	0.6480
5.00	0.400	0.4800	0.5600	0.6400	0.7200
10.00	0.442	0.5304	0.6188	0.7072	0.7956
20.00	0.488	0.5856	0.6832	0.7808	0.8784
30.00	0.517	0.6204	0.7238	0.8272	0.9306
40.00	0.538	0.6456	0.7532	0.8608	0.9684
50.00	0.556	0.6672	0.7784	0.8896	1.0008
55.00	0.563	0.6756	0.7882	0.9008	1.0134
60.00	0.571	0.6852	0.7994	0.9136	1.0278
65.00	0.577	0.6924	0.8078	0.9232	1.0386
70.00	0.583	0.6996	0.8162	0.9328	1.0494
73.00	0.587	0.7044	0.8218	0.9392	1.0566
75.00	0.589	0.7068	0.8246	0.9424	1.0602
75.90	0.590	0.7080	0.8260	0.9440	1.0620

Table 4.5 Increment of wind velocity by percentage

Wind Velocity (ms)	Increment of Wind Loads by Percentage (%)			
	20	40	60	80
1.630	1.956	2.282	2.608	2.934
4.880	5.856	6.832	7.808	8.784
5.650	6.780	7.910	9.040	10.170
2.400	2.880	3.360	3.840	4.320
1.230	1.476	1.722	1.968	2.214
6.510	7.812	9.114	10.416	11.718
2.000	2.400	2.800	3.200	3.600
3.400	4.080	4.760	5.440	6.120
5.400	6.480	7.560	8.640	9.720
2.000	2.400	2.800	3.200	3.600

Next, the current and wind loads are being combined and increased by percentage to find out its relationship with the maximum moment and also maximum shear. Figure 4.8 and 4.9 below shows the the results of the relationships.

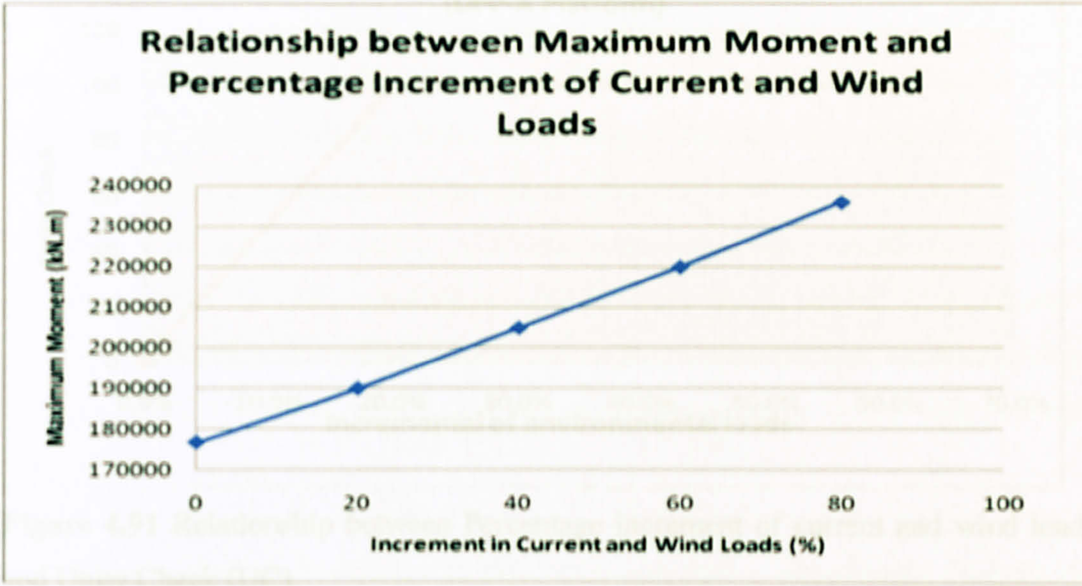

Figure 4.8 Relationship between Maximum Moment and Percentage increment of current and wind loads

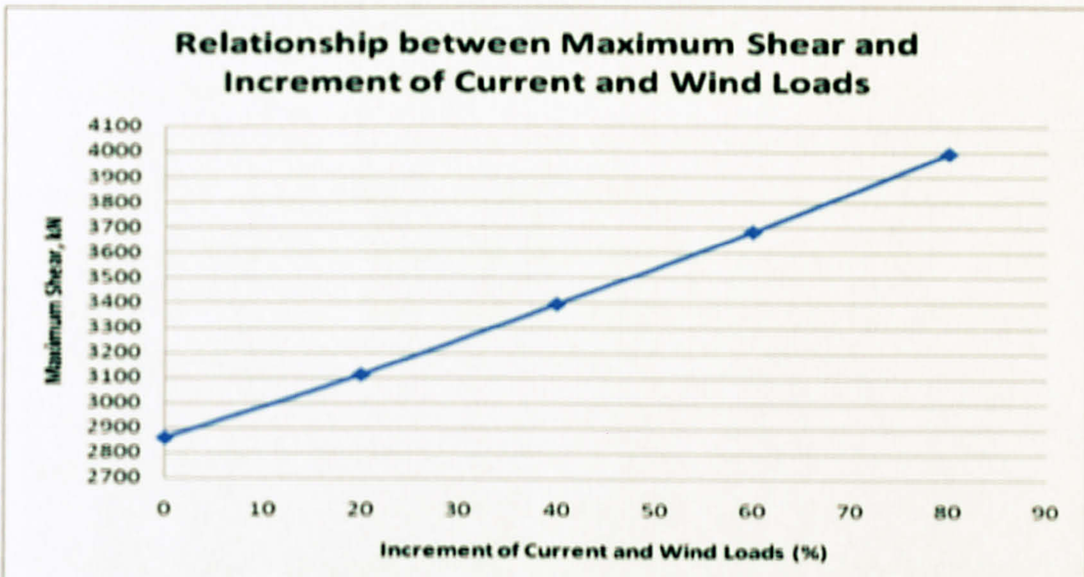

Figure 4.9 Relationship between Maximum Shear and Percentage increment of current and wind loads

Lastly is the relationship between the increment of the loads against the unity check of the critical joint. It can be seen in Figure 4.91.

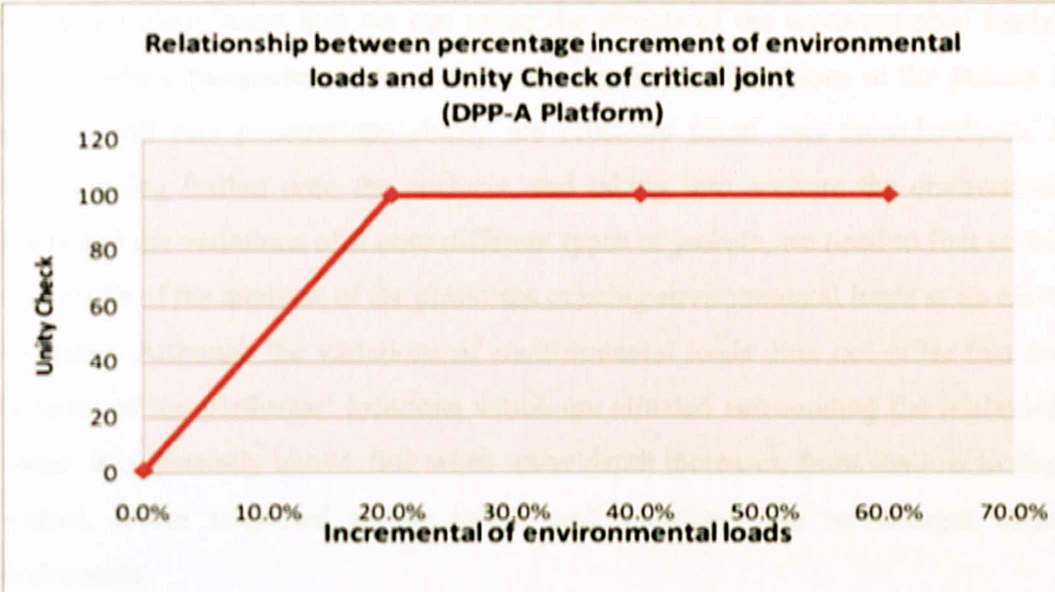

Figure 4.91 Relationship between Percentage increment of current and wind loads and Unity Check (UC)

4.2 Discussion

There are many ways that we can relate the effects of the environmental loads on jackets where parameters such as the water depth, configurations of the jackets and its leg, soil pile penetrations ability are crucially taken into considerations. But before going further onto the analysis, and taking into account the environmental loads and the variations of it onto different types of jackets, we need to first consider the results of the analysis of the platforms existing environmental loads at its existing locations. Although the variations of environmental loads does not differ that much because of the platforms' locations which are situated surrounding the Malaysian's water, it is generally known that when water depth increases, from shallow to deeper waters, forces subjected to the jacket wall increases due to stronger currents underneath.

As the topic requires generations of new environmental loadings based on different locations, a study on load formulations are very important and need to be first mastered before going deep into the analysis phases. Thus, given below are some of the summarizations of the load generations of environmental loadings. Based on PTS, in general, two principal conditions are considered during the global design of structures. These are the storm (extreme event) condition and the operational (normal) condition. Normal condition is based on the effects of all dead loads and functional loads in combination with the simultaneous and collinear occurrence of 1 year return period environmental loads while extreme event condition are based on the effects of the same loads with an occurrence of 100years return period environmental loads.

Wind Loads

The wind load for storm conditions will be modelled by factoring the operating wind load shown below:

$(F_{\text{wind storm}}) = (F_{\text{wind operating}}) \times (V_{\text{storm}})^2/(V_{\text{operating}})^2$

Where V = design wind speed, F = wind force.

The factor of storm wind load over operating wind load is as follows:

- Topside design = $(40^2/22^2) = 4.0$

For diagonal wind = (Sin □°)^2 or (Cos □°)^2 and is dependent on the topside average base dimension.

Wave and Current Loads

For generating wave and current forces, the following parameters are used in the analysis, Stoke's fifth-order (5^{th}) wave theory for the wave load generation. The wave crest position is selected by stepping the wave through the structure to select the wave position corresponding to the maximum overturning moment or maximum base shear.

Below are the elaborations on the results obtained for the project's analysis.

1. Existing Environmental Loads

Basically, all four platform jackets are being analyzed using their original environmental loads and relationships are being formed between depth of critical joints and total weight. Another relationship was between critical joint depth and water depths. The critical joint was uniform throughout the analysis. A linear relationship between the parameters can be observed. Basically, under high total weight, the critical joint depth will increase as more loads are being subjected and pushed downwards towards the mud line and causes stress to the joints. Apart from that, the depth of critical joint also increases with increasing water depths. Deeper water means higher and stronger currents thus resulting in an increase in the critical joint depth.

2. Fixed wave height (m) and variations of wave period (s)

Relationships have been made between maximum shear and moment with respect to different wave period(s). Basically, based on the given graph of wavelength versus wave period, they are directly proportional. Thus, when the wave period is varied, the conditions became calm from harsh environment as the wavelengths are getting bigger and longer. This can be seen from the graphs attached. When the wave period is increase, the maximum shear which originally was high in value, started to decrease until a certain point where it became stable before going up again. The lowest point of max shear is basically the optimum value of wave period for that particular wave height. Same goes to the relationship between maximum moment and wave period. There is also an increase of 0.25% in loads when period are changed. It is known from a journal that "when the wave period increases, both the particle velocity at the mean water level and rate of decay with depth reduce. At low periods, this leads to a reduction in the total forces acting on the rig but at higher period, there is an increase in total force" (Niels Jacob Tarp Johansen, 2003)

3. Fixed wave period, T and variations of wave height, H (m)

The graph shows relationships between maximum shear and moment with respect to variations of wave height. Generally, when the wave period is fixed, and the wave height is varied, and increased, the situation becomes much harsher. Differs from what have been studied in 2. Both graphs show a similar pattern in the loadings with increasing wave height. For the load combinations, it is seen that there is an increase of 0.5% on the overall load of the jacket when the height is varied. A study backs up the trend of the outcome results with a statement of "The event of having a largest force occurring from the non largest wave height is possible when the uncertainty in the force analysis is included, or when the wave force model also includes random variables for current, wind and wave period" (D. Faulkner)

4. Percentage increase in wind and current loads

When the wind and current loads are being increase by percentage, it is seen that both moment and shear increases linearly. This means that the structure is obviously experiencing a larger amount of forces which will causes failure. This can be seen in the UC relationship for a particular critical joint. The UC originally was 1.154 and when loads are increase, the UC values shoot up tremendously to 100 over. In design phases, this willl generally means fail and either adding stiffeners or increasing the diameter of the members are highly recommended. Wind and current loads are combined together as usually wind loads only contribute 10% to the total weight or forces of the platforms.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From this study, the following conclusions are made for the response of the jackets under different environmental loading conditions.

- The depths of critical joints are highly affected by the water depth and total weight of the platforms.
  - As the water depth and total weight of platform increases, the depth of the critical joint increases (Linear Relationship).
  - The depth of the critical joint for a jacket will not change with increasing loads as the existing joint will only increase in the unity check.
- Changing the parameters of the waves, currents and wind has a significant impact on the resulting forces and moments of the jackets.
  - When the wave height is fixed, and period varies, the value of the overturning moment and base shear gradually decreases with increasing period until it reaches an optimum value before rising up again in moment and shear.
  - When the wave period is fixed and height varies, the trends differs as the value of maximum overturning moment and base shear firstly increase and reduced before reaching a constant value of forces.
  - There is a linear relationship between the wavelength and wave height based on the analysis
  - There is an increase in load combinations of 0.25% when the wave period is constant and 0.5% increase in loads when the wave height is constant.

After going through several analyses to fulfill the objective of the project, the author can say that the objective of this project has been met.

5.2 Recommendation

It is recommended that more models are used for the analysis as to compare between the results. It is encouraged that the models are of a different structural configurations, locations, and environmental loadings so that more variations of results can be obtained and compared.

It is also recommended that instead of doing just software based project, an experimental project can also be conducted as to find out the real environmental loadings conditions such as waves and current and also the effects of these structures under those situation.

The project also should not be restricted only to In-Place analysis but can be further research for other analysis such as during lifting, fatigue, and also sensitivity studies as to study the trends of the forces under different environmental loading conditions.

Furthermore, the load combinations of the analysis should be check and researched as this could give some hindsight on the load combinations for both load and resistance factor design (LRFD) and compare them with the working stress design (WSD).

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APPENDICES

Appendix I

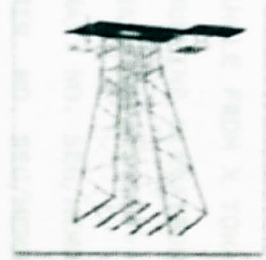
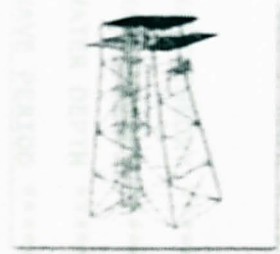
GANTT CHART

Table 1.0 Milestone for the First Semester of 2-Semester Final Year Project

No.	PROJECT FLOW/ TASK	WEEK															
		1	2	3	4	5	6	7	8		9	10	11	12	13	14	15
1	Title Selection and Proposal																
2	Preliminary Research Work																
3	Submission of Preliminary Report																
4	Seminar 1																
5	Project Work • Literature Reviews • SACS Modelling • Design Analysis									Mid Semester Break							
6	Submission of Progress Report																
7	Seminar 2																
8	Submission of Interim Report Final Draft																
9	Oral Presentation																

Table 2.0 Milestone for the First Semester of 2-Semester Final Year Project

No.	PROJECT FLOW/ TASK	WEEK														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Project Work Continue • Literature Reviews • SACS Modelling • Design Analysis															
2	Submission of Combined Progress Report															
3	Project Work Continue • Literature Reviews • SACS Modelling • Design Analysis										Mid Semester Break					
4	Seminar / Talk															
5	Project Work Continue • Literature Reviews • SACS Modelling • Design Analysis															
6	Poster Presentation															
7	Dissertation Report Submission															
8	Oral Presentation															

METHODS	EXPLANATIONS
LITERATURE REVIEWS AND DATA GATHERING	• Research on Journals • Familiarization of SACS Software • Finding Models
SACS MODELLING	 LHDP-A  MLDP-A  DPP-A  MDA
DESIGN ANALYSIS	1 Study relationships between Total Weight and Water Depth with the critical joint depth 2 Study relationships between different environmental loading conditions: •Wave, Current and Wind and its effects on : • *Maximum Overturning Moment* • *Maximum Base Shear*
SACS OUTPUT LIST(RESULTS)	Graphical Presentation Analyze results

Appendix III

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SACS Release 5.2                                            UTP
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            *********** EDI/SACS IV SEASTATE PROGRAM ***********
DATE 14-APR-2009  TIME 01:21:40   SEA PAGE    86

                ** DUYONG-A INPLACE RE-ANALYSIS **

                    **** WAVE DESCRIPTION FOR LOAD CASE   17 ****

                        OPER. WAVE & CURR. 0 DEG

                        WAVE THEORY ************ STOKES 5TH
                        WAVE HEIGHT ************    6.000 M
                        WATER DEPTH ************   75.900 M
                        WAVE PERIOD ************   10.456 SECS
                        WAVE LENGTH ************  171.973 M
                        ANGLE FROM X TOWARD Y **    0.000 DEGREES
                        MUDLINE ELEVATION ******  -75.900 M
                        WAVE CELERITY **********   16.447 M /SEC
                        MAX. NO. SEG/MEMBER ****      10
                        MIN. NO. SEG/MEMBER ****       1
                        UNMODIFIED WAVE PERIOD     10.100 SECS
                        WAVE SPREADING FACTOR **    0.900
                        CREST POSITION DETERMINED BY MAXIMUM SHEAR

                        STARTING CREST POSITION     0.000 M
                        NO. STEPS **************      72
                        STEP SIZE **************    2.389 M
                        CREST WATER DEPTH ******    79.07 M
                        TROUGH WATER DEPTH *****    73.07 M
1
SACS Release 5.2                                            UTP
                            ID=99990000
            *********** EDI/SACS IV SEASTATE PROGRAM ***********
DATE 14-APR-2009  TIME 01:21:40   SEA PAGE    87

                ** DUYONG-A INPLACE RE-ANALYSIS **

                    ********** SEASTATE LOADS FOR WAVE PASSING THROUGH
STRUCTURE **********
```

OPER. WAVE & CURR. 0 DEG

LOAD CONDITION	CREST POSITION M	CREST POSITION DEG	LOAD	MUDLINE ELEVATION
MAXIMUM MOMENT ABOUT MUDLINE	162.42	340.00	103869.266 KN-M	-75.90 M
MAXIMUM SHEAR AT MUDLINE	162.42	340.00	1795.181 KN	-75.90 M
MINIMUM MOMENT ABOUT MUDLINE	52.55	110.00	-44966.617 KN-M	-75.90 M
MINIMUM SHEAR AT MUDLINE	50.16	105.00	-853.147 KN	-75.90 M
MAXIMUM FORCE UPWARD	107.48	225.00	352.108 KN	-75.90 M
MAXIMUM FORCE DOWNWARD	16.72	35.00	-497.733 KN	-75.90 M

****** LOAD CASE GENERATED FOR WAVE CREST POSITION RESULTING IN THE MAXIMUM SHEAR AT MUDLINE ******

SACS Release 5.2 UTP

ID=99990000

*********** EDI/SACS IV SEASTATE PROGRAM ***********

DATE 14-APR-2009 TIME 01:21:40 SEA PAGE 88

** DUYONG-A INPLACE RE-ANALYSIS **

****** RESULTS FOR LOAD CASE 17 ******

OPER. WAVE & CURR. 0 DEG

****** SUMMATION OF FORCES AND MOMENTS FOR LOAD CASE 17 ******

(MOMENTS ABOUT MUDLINE AT ELEVATION -75.90 M.)

	SUM FX	SUM FY	SUM FZ	SUM MX	SUM MY	SUM MZ
	KN	KN	KN	KN-M	KN-M	KN-M
PLATE HYDRODYNAMIC	0.000	0.000	0.000	0.000	0.000	0.000
SEASTATE GENERATED	1804.026	-3.614	-90.569	523.779	103882.586	-533.014
USER INPUT	0.000	0.000	0.000	0.000	0.000	0.000

SACS Release 5.2 UTP ID=99990000 DATE 13-APR-2009 TIME 21:51:46 JCN PAGE 495

** DUYONG-A INPLACE RE-ANALYSIS **

** J O I N T   C A N   S U M M A R Y **
(UNITY CHECK ORDER)

JOINT	ORIGINAL DIAMETER (CM)	ORIGINAL THICKNESS (CM)	ORIGINAL YLD STRS (N/MM2)	ORIGINAL LOAD UC	ORIGINAL STRN UC	LOAD DESIGN DIAMETER (CM)	LOAD DESIGN THICKNESS (CM)	LOAD DESIGN YLD STRS (N/MM2)	LOAD DESIGN LOAD UC	STRENGTH DESIGN DIAMETER (CM)	STRENGTH DESIGN THICKNESS (CM)	STRENGTH DESIGN YLD STRS (N/MM2)	STRENGTH DESIGN STRN UC
315	116.840	1.270	240.000	0.724	2.881	116.840	1.270	240.000	0.724	116.840	2.170	240.000	0.987
316	116.840	1.270	240.000	0.280	2.881	116.840	0.970	240.000	0.634	116.840	2.170	240.000	0.987
515	116.840	1.270	240.000	0.350	2.881	116.840	0.970	240.000	0.651	116.840	2.170	240.000	0.987
516	116.840	1.270	240.000	0.477	2.881	116.840	1.270	240.000	0.477	116.840	2.170	240.000	0.987
716	116.840	1.270	240.000	0.495	2.881	116.840	1.270	240.000	0.495	116.840	2.170	240.000	0.987
917	106.680	1.270	240.000	0.846	2.710	106.680	1.270	240.000	0.846	106.680	2.170	240.000	0.928
517	106.680	1.270	240.000	0.537	2.013	106.680	1.270	240.000	0.537	106.680	1.870	240.000	0.938
718	106.680	1.270	240.000	1.148	1.969	106.680	1.570	240.000	0.628	106.680	1.870	240.000	0.908
112	55.880	1.270	240.000	0.171	1.647	55.880	0.670	240.000	0.765	55.880	1.870	240.000	0.760
114	55.880	1.270	240.000	0.121	1.647	55.880	0.670	240.000	0.488	55.880	1.870	240.000	0.760
117	55.880	1.270	240.000	0.172	1.647	55.880	0.670	240.000	0.767	55.880	1.870	240.000	0.760
119	55.880	1.270	240.000	0.121	1.647	55.880	0.670	240.000	0.501	55.880	1.870	240.000	0.760
213	116.840	1.270	240.000	0.317	1.588	116.840	0.970	240.000	0.545	116.840	1.870	240.000	0.732
217	116.840	1.270	240.000	0.298	1.588	116.840	0.970	240.000	0.512	116.840	1.870	240.000	0.732
915	26.100	0.670	240.000	0.059	1.558	26.100	0.370	240.000	0.196	26.100	0.970	240.000	0.743
916	26.100	0.670	240.000	0.052	1.558	26.100	0.370	240.000	0.173	26.100	0.970	240.000	0.743
211	116.840	1.270	240.000	0.441	1.557	116.840	1.270	240.000	0.441	116.840	1.870	240.000	0.718
215	116.840	1.270	240.000	0.451	1.557	116.840	0.970	240.000	0.978	116.840	1.870	240.000	0.718
921	50.800	1.270	240.000	0.378	1.498	50.800	0.970	240.000	0.728	50.800	1.570	240.000	0.980
101	35.560	0.953	240.000	0.332	1.473	35.560	0.653	240.000	0.830	35.560	1.253	240.000	0.853
102	35.560	0.953	240.000	0.196	1.473	35.560	0.653	240.000	0.430	35.560	1.253	240.000	0.853
103	35.560	0.953	240.000	0.202	1.473	35.560	0.653	240.000	0.446	35.560	1.253	240.000	0.853
106	35.560	0.953	240.000	0.451	1.473	35.560	0.953	240.000	0.451	35.560	1.253	240.000	0.853
108	35.560	0.953	240.000	0.218	1.473	35.560	0.653	240.000	0.716	35.560	1.253	240.000	0.853
134	35.560	0.953	240.000	0.072	1.473	35.560	0.353	240.000	0.740	35.560	1.253	240.000	0.853
139	35.560	0.953	240.000	0.228	1.473	35.560	0.653	240.000	0.782	35.560	1.253	240.000	0.853
143	35.560	0.953	240.000	0.081	1.473	35.560	0.353	240.000	0.716	35.560	1.253	240.000	0.853
160	35.560	0.953	240.000	0.126	1.473	35.560	0.653	240.000	0.276	35.560	1.253	240.000	0.853
161	35.560	0.953	240.000	0.305	1.473	35.560	0.653	240.000	0.734	35.560	1.253	240.000	0.853
162	35.560	0.953	240.000	0.113	1.473	35.560	0.653	240.000	0.299	35.560	1.253	240.000	0.853
163	35.560	0.953	240.000	0.296	1.473	35.560	0.653	240.000	0.791	35.560	1.253	240.000	0.853
164	35.560	0.953	240.000	0.334	1.473	35.560	0.653	240.000	0.966	35.560	1.253	240.000	0.853
166	35.560	0.953	240.000	0.138	1.473	35.560	0.653	240.000	0.300	35.560	1.253	240.000	0.853
167	35.560	0.953	240.000	0.332	1.473	35.560	0.953	240.000	0.332	35.560	1.253	240.000	0.853
168	35.560	0.953	240.000	0.111	1.473	35.560	0.653	240.000	0.284	35.560	1.253	240.000	0.853
169	35.560	0.953	240.000	0.200	1.473	35.560	0.653	240.000	0.440	35.560	1.253	240.000	0.853
170	35.560	0.953	240.000	0.251	1.473	35.560	0.653	240.000	0.671	35.560	1.253	240.000	0.853
171	35.560	0.953	240.000	0.450	1.473	35.560	0.953	240.000	0.450	35.560	1.253	240.000	0.853
173	35.560	0.953	240.000	0.196	1.473	35.560	0.653	240.000	0.424	35.560	1.253	240.000	0.853
174	35.560	0.953	240.000	0.339	1.473	35.560	0.653	240.000	0.824	35.560	1.253	240.000	0.853
175	35.560	0.953	240.000	0.191	1.473	35.560	0.653	240.000	0.423	35.560	1.253	240.000	0.853
176	35.560	0.953	240.000	0.240	1.473	35.560	0.653	240.000	0.552	35.560	1.253	240.000	0.853
177	35.560	0.953	240.000	0.081	1.473	35.560	0.353	240.000	0.690	35.560	1.253	240.000	0.853
178	35.560	0.953	240.000	0.574	1.473	35.560	0.953	240.000	0.574	35.560	1.253	240.000	0.853
180	35.560	0.953	240.000	0.183	1.473	35.560	0.653	240.000	0.198	35.560	1.253	240.000	0.853
183	35.560	0.953	240.000	0.245	1.473	35.560	0.653	240.000	0.561	35.560	1.253	240.000	0.853
184	35.560	0.953	240.000	0.081	1.473	35.560	0.353	240.000	0.672	35.560	1.253	240.000	0.853
185	35.560	0.953	240.000	0.576	1.473	35.560	0.953	240.000	0.576	35.560	1.253	240.000	0.853
187	35.560	0.953	240.000	0.140	1.473	35.560	0.653	240.000	0.308	35.560	1.253	240.000	0.853
188	35.560	0.953	240.000	0.344	1.473	35.560	0.953	240.000	0.344	35.560	1.253	240.000	0.853

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** DUYONG-A INPLACE RE-ANALYSIS **

** J O I N T   C A N   S U M M A R Y **
(UNITY CHECK ORDER)

JOINT	ORIGINAL DIAMETER (CM)	ORIGINAL THICKNESS (CM)	ORIGINAL YLD STRS (N/MM2)	ORIGINAL LOAD UC	ORIGINAL STRN UC	LOAD DESIGN DIAMETER (CM)	LOAD DESIGN THICKNESS (CM)	LOAD DESIGN YLD STRS (N/MM2)	LOAD DESIGN LOAD UC	STRENGTH DESIGN DIAMETER (CM)	STRENGTH DESIGN THICKNESS (CM)	STRENGTH DESIGN YLD STRS (N/MM2)	STRENGTH DESIGN STRN UC
189	35.560	0.953	240.000	0.111	1.473	35.560	0.653	240.000	0.300	35.560	1.253	240.000	0.853
194	35.560	0.953	240.000	0.111	1.473	35.560	0.653	240.000	0.245	35.560	1.253	240.000	0.853
195	35.560	0.953	240.000	0.306	1.473	35.560	0.653	240.000	0.745	35.560	1.253	240.000	0.853
196	35.560	0.953	240.000	0.118	1.473	35.560	0.653	240.000	0.315	35.560	1.253	240.000	0.853
197	35.560	0.953	240.000	0.299	1.473	35.560	0.653	240.000	0.802	35.560	1.253	240.000	0.853
198	35.560	0.953	240.000	0.334	1.473	35.560	0.653	240.000	0.973	35.560	1.253	240.000	0.853
233	35.560	0.953	240.000	0.297	1.473	35.560	0.653	240.000	0.674	35.560	1.253	240.000	0.853
709	116.840	1.270	240.000	0.572	1.424	116.840	1.270	240.000	0.572	116.840	1.570	240.000	0.932
715	116.840	1.270	240.000	0.631	1.424	116.840	1.270	240.000	0.633	116.840	1.570	240.000	0.932
572	35.560	0.953	240.000	0.118	1.401	35.560	0.353	240.000	0.983	35.560	1.253	240.000	0.810
575	35.560	0.953	240.000	0.091	1.401	35.560	0.353	240.000	0.760	35.560	1.253	240.000	0.810
586	35.560	0.953	240.000	0.102	1.401	35.560	0.353	240.000	0.854	35.560	1.253	240.000	0.810
593	35.560	0.953	240.000	0.126	1.401	35.560	0.653	240.000	0.270	35.560	1.253	240.000	0.810
6015	35.560	1.270	240.000	0.102	1.397	35.560	0.670	240.000	0.319	35.560	1.570	240.000	0.914
960	34.360	0.987	240.000	0.137	1.376	34.360	0.687	240.000	0.281	34.360	1.287	240.000	0.809
961	34.360	0.987	240.000	0.109	1.376	34.360	0.687	240.000	0.229	34.360	1.287	240.000	0.809
962	34.360	0.987	240.000	0.101	1.376	34.360	0.687	240.000	0.221	34.360	1.287	240.000	0.809
963	34.360	0.987	240.000	0.105	1.376	34.360	0.387	240.000	0.989	34.360	1.287	240.000	0.809
964	34.360	0.987	240.000	0.110	1.376	34.360	0.687	240.000	0.219	34.360	1.287	240.000	0.809
966	34.360	0.987	240.000	0.124	1.376	34.360	0.387	240.000	0.853	34.360	1.287	240.000	0.809
967	34.360	0.987	240.000	0.220	1.376	34.360	0.687	240.000	0.514	34.360	1.287	240.000	0.809
968	34.360	0.987	240.000	0.105	1.376	34.360	0.687	240.000	0.225	34.360	1.287	240.000	0.809
969	34.360	0.987	240.000	0.164	1.376	34.360	0.687	240.000	0.340	34.360	1.287	240.000	0.809
970	34.360	0.987	240.000	0.112	1.376	34.360	0.387	240.000	0.890	34.360	1.287	240.000	0.809
971	34.360	0.987	240.000	0.298	1.376	34.360	0.687	240.000	0.628	34.360	1.287	240.000	0.809
973	34.360	0.987	240.000	0.140	1.376	34.360	0.687	240.000	0.290	34.360	1.287	240.000	0.809
974	34.360	0.987	240.000	0.219	1.376	34.360	0.687	240.000	0.501	34.360	1.287	240.000	0.809
975	34.360	0.987	240.000	0.100	1.376	34.360	0.687	240.000	0.211	34.360	1.287	240.000	0.809
976	34.360	0.987	240.000	0.166	1.376	34.360	0.687	240.000	0.345	34.360	1.287	240.000	0.809
977	34.360	0.987	240.000	0.064	1.376	34.360	0.387	240.000	0.453	34.360	1.287	240.000	0.809
978	34.360	0.987	240.000	0.112	1.376	34.360	0.687	240.000	0.647	34.360	1.287	240.000	0.809
980	34.360	0.987	240.000	0.139	1.376	34.360	0.687	240.000	0.289	34.360	1.287	240.000	0.809
981	34.360	0.987	240.000	0.251	1.376	34.360	0.687	240.000	0.523	34.360	1.287	240.000	0.809
982	34.360	0.987	240.000	0.091	1.376	34.360	0.387	240.000	0.871	34.360	1.287	240.000	0.809
983	34.360	0.987	240.000	0.106	1.376	34.360	0.387	240.000	0.933	34.360	1.287	240.000	0.809
984	34.360	0.987	240.000	0.062	1.376	34.360	0.387	240.000	0.422	34.360	1.287	240.000	0.809
985	34.360	0.987	240.000	0.240	1.376	34.360	0.687	240.000	0.490	34.360	1.287	240.000	0.809
987	34.360	0.987	240.000	0.114	1.376	34.360	0.387	240.000	0.906	34.360	1.287	240.000	0.809

Appendix V

Subject: Metocean Design Data at MLTTB Sites

Attention: A Hamid A Karim, Head, Offshore Facilities MLTTB

From: Tuen Kwong Lum,
Metocean Unit, DCE/2

Our Ref: DCE2/Met/2006/MLTTB
Date: 29 May 2006

1. LOCATION AND WATER DEPTH AT MLTTB SITES:

Platform	Latitude	Longitude	Water Depth (m) MSL
Melor	6°10'45.213"N	104°04'29.911"E	76.6
Laho	6°19'40.485"N	104°02'09.953"E	70.0
Tangga	5°56'37.881"N	104°17'26.439"E	63.8
Tangga Barat	5°57'19.585"N	104°11'43.865"E	72.2

2. TIDE AND STORM SURGE

Tidal data at the MLTTB sites is based on measured tidal data by a SAAB sensor at Dulang B platform. The derived tidal information is relevant for the nearby MLTTB sites

2.1 TIDES:

The following data are referred to Mean Sea Level at Dulang site

Highest Astronomical Tide	HAT : 1.06m
Mean Sea Level	MSL : 0.0m
Lowest Astronomical Tide	LAT : -1.13m

2.2 SURGE

Data source: PCSB- ExxonMobil joint study (Ref.1)

	RETURN PERIOD			
	1-Yr.	10-Yr.	50-Yr.	100-Yr.
Positive Storm Surge (cm)	40	60	65	70

3. WIND

3.1 Data sources:

(i) PCSB-ExxonMobil joint study (Ref.1)
(ii) SEAMOS Operational Update Project (Ref.2)
(iii) Joint Typhoon Centre's publication Typhoon Vamei (Ref.3)

(iv) Symposium On Asia Monsoon 2006 (Ref.4)
(v) Conversion factors on wind speed to various sampling interval (Ref.5)

3.2 All angles (and directional sectors) in this report refer to true magnetic north.

3.3 Omni-directional wind criteria (10m above MSL)

Wind speed m/s	1-year	10-year	50-year	100-year
1-hour mean	16	20	22	
10-min mean	17	22	24	
1-min mean	19	24	26	38
3-sec gust	21	26	26	55*

Note *: This report recommends this gust wind speed associated with the occurrence of minimum-scale typhoon event in PMO. Prior to the landfall of Typhoon Vamei 2001 at southern Johor, tropical meteorologists would ot envisage the formation of a typhoon at near-equatorial areas of Malaysia. Vamei was confirmed to be a typhoon by high quality satellite cloud pictures and verified in-situ measurement by a passing USA naval fleet. Lowest pressure of Vamei was extrapolated at 976mb with observed gust of 50 knots (Ref.3). Such satellite cloud pictures and in-situ verification were not possible before the 1960 to detect other previous typhoons similar to Vamei that could have occurred over Malaysia/ PMO. As formation of Vamei was attributed to the advection of absolute vorticity from higher latitudes towards its formation area near to water off southern Sarawak (Ref.4), and such advections are not uncommon during a NE monsoon (typhoon season), it is prudent then this report recommends the passage of a typhoon in PMO in a 100-year event. However, as such a typhoon is fast moving, effect felt would only be strong wind speed of short sampling duration.

3.4 **Wind Rose and Freqnency Distribution of Wind occurrences**

Figs. 1 and 2 are the directional distribution of wind in percentage and number of events respectively at MLTTB.

4. WAVE

4.1 Data sources:
(i) PCSB-ExxonMobil joint study (Ref.1)
(ii) Measured wave data at May 1999 till Dec 2003

4.2 Definition of terms
(i) Hs = Significant wave height, meter (m)
(ii) Tz = Zero crossing period, sec (s)
(iii) Tp = Peak wave period, sec (s)
(iv) Hmax = Most probable individual maximum wave height, meter (m)
(v) Tass = period of the Hmax, sec (s)

4.3 **Directional wave criteria**

Wave parameters	1 -YEAR CRITERIA (Directions FROM)			
	015 - 080	081 - 230	231 - 280	281 - 014
Hs	3.9	1.6	1.5	1.6
Tz	6.5	4.3	3.9	4.4
Tp	9.2	6.1	5.5	6.2
Hmax	7.5	3.2	3.0	3.1
Tass	8.1	5.7	5.3	5.6

Wave parameters	10 -YEAR CRITERIA (Directions FROM)			
	015 - 080	081 - 230	231 - 280	281 - 014
Hs	4.5	2.2	2.2	2.7
Tz	6.9	4.8	4.8	5.4
Tp	9.7	6.8	6.7	7.6
Hmax	8.9	4.3	4.3	5.2
Tass	8.9	6.4	6.4	6.0

Wave parameters	50-YEAR CRITERIA (Directions FROM)			
	015 - 080	081 - 230	231 - 280	281 - 014
Hs	4.8	2.4	2.6	3.7
Tz	7.0	5.1	5.5	6.0
Tp	9.9	7.2	7.7	8.5
Hmax	9.7	4.9	5.3	7.0
Tass	8.6	6.7	6.7	7.5

Wave parameters	100-YEAR CRITERIA (Directions FROM)			
	015 - 080	081 - 230	231 - 280	281 - 014
Hs	4.9	2.5	3.3	3.9
Tz	7.0	5.2	6.2	5.4
Tp	9.9	7.3	8.7	7.6
Hmax	9.9	5.1	6.6	8.7
Tass	8.7	6.8	7.6	7.7

4.4 Figs. 3 and 4 are wave directional distributions based on model data (Ref. 2), while Figs. 5 and 6 are omni-directional wave scatter diagrams based on measured data.

5. **CURRENT**

5.1 Data source:

Ref.1 and measured data program of ExxonMobil

The derived profile in Ref 2 associated with storm events are similar to the highly sheared profile of the power 1/3 of the log profile. The speed at depth below surface is then derived extrapolated from surface downwards at power 1/3 profile.

5.1 Independent Directional Current Criteria **(cm/s)** for various return periods:

	1-YEAR Directional Current Criteria in cm/sec , flow directions TOWARDS				
Layer in column	Ht above seabed	**001-090**	**091-180**	**181-270**	**271-360**
Surface	1.0 •D	90	60	85	60
Mid depth	0.5 •D	70	50	70	50
Near bottom	0.1 •D	35	20	30	20
Near Seabed	0.01•D	5	5	5	5
D= water depth					

	10-YEAR Directional Current Criteria in cm/sec flow directions TOWARDS				
Layer in column	Ht above seabed	**001-090**	**091-180**	**181-270**	**271-360**
Surface	1.0 •D	110	75	110	75
Mid depth	0.5 •D	85	60	85	60
Near bottom	0.1 •D	40	30	40	30
Near Seabed	0.01•D	10	5	10	5
D= water depth					

	50-YEAR Directional Current Criteria in cm/sec , flow directions TOWARDS				
Layer in column	Ht above seabed	**001-090**	**091-180**	**181-270**	**271-360**
Surface	1.0 •D	115	85	130	80
Mid depth	0.5 •D	90	65	100	65
Near bottom	0.1 •D	40	30	50	30
Near Seabed	0.01•D	10	5	10	5
D= water depth					

	100-YEAR Directional Current Criteria in cm/sec , flow directions TOWARDS				
Layer in column	Ht above seabed	**001-090**	**091-180**	**181-270**	**271-360**
Surface	1.0 •D	120	90	135	85
Mid depth	0.5 •D	95	70	110	70
Near bottom	0.1 •D	45	35	50	30
Near Seabed	0.01•D	10	10	10	5
D= water depth					

5.2 Figs.7 and 8 are the current directional distributions at level 2m below MSL and 3m above seabed respectively.

6. SEA BED TEMPERATURE

The range of near sea bed current at the water depth of MLTTB is recommended as below:

Maximum temperature: 26 deg C
Minimum temperature : 20 deg C

7. REFERENCES:

(i) PCSB-ExxonMobil joint Study Nov 2005. ExxonMobil Upstream Research Company.

(ii) SEAMOS Operational Update Study, 1999, Oceanweather INC.

(iii) Joint Typhoon Centre's publication Typhoon Vamei.

(iv) Symposium On Asia Monsoon April 2006. Malaysian meteorological Department.

(v) Acts, Regulations and Provisions for the Petroleum. Vol. 2. Norwegian Petroleum Directorate, 1998.