SENSITIVITY STUDY OF ENVIRONMENTAL FORCES ON JACKET OFFSHORE STRUCTURE

by

Tengku Mohd Saifuddin bin Tuan Mohammad

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Civil Engineering)

DECEMBER 2008

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

SENSITIVITY STUDY OF ENVIRONMENTAL FORCES ON JACKET OFFSHORE STRUCTURE

TENGKU MOHD SAIFUDDIN BIN TUAN MOHAMMAD

CIVIL ENGINEERING
UNIVERSITI TEKNOLOGI PETRONAS

DECEMBER 2008

CERTIFICATION OF APPROVAL

SENSITIVITY STUDY OF ENVIRONMENTAL FORCES ON JACKET OFFSHORE STRUCTURE

by

Tengku Mohd Saifuddin bin Tuan Mohammad

A project dissertation submitted to the
Civil Engineering Programme
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
(CIVIL ENGINEERING)

Approved by,

____

(Assoc. Prof. Dr. Saied Saiedi)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

December 2008

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.

(TENGKU MOHD SAIFUDDIN BIN TUAN MOHAMMAD)

ABSTRACT

This project is sensitivity study of environmental forces on two jacket offshore structure. The main objective of the study is to study the sensitivity of the offshore platforms due to variations in wave, wind, current, earthquake and etc. As a result, several researches have been initiated. This final year project (Thesis) aims to investigate the sensitivity of jacket structures to environmental loadings.

In order to perform the research, a real-life jacket structure will be selected and modelled using SACS software package. The sensitivity of jacket structure to variation in design loads will be investigated by performing analysis on main members of this model. For the first semester, sensitivity studies of wave, wind and current have been carried out. Meanwhile, sensitivity studies of earthquake due to the jacket structure can be analyzed. Toward verifying the analysis outcomes and better understanding of the way in which offshore structures react to environmental forces, the sensitivity study of the whole TPDP-A (TOPAZ) platform has been analysed and discussed. Therefore, three (3) different arrangements have been modelled in order to compare with each other arrangements. For this project, environmental forces such as wave played a major influenced in modelling and designing the platform. Designing of the platform should consider the cost and reliability of the model platform. Herewith, capital cost (CAPEX) estimate can be decreased by designing the most suitable jacket platform. Therefore, environmental forces can affect the design of the offshore platform and the author hope that this sensitivity study report of environmental loadings will be a good guideline as compared to the other researchers.

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious, the Most Merciful. Praise to Him the Almighty that in His will and given strength, I managed to complete this Final Year Project within the given period. My deepest gratitude goes to my supervisor, Assoc. Prof. Dr. Saied Saiedi who continuously supported and guided me from the beginning to the end of my study on this topic. Here, I would like to express my full appreciation to UTP especially Civil Engineering Department who had constantly provided me with either formal or informal support throughout the study of this project. The last but not least, thanks to my beloved family and friends who motivated me to achieve this far. Thanks again to all, your kindness and helps will always be remembered.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

1.1 Background of Study

Offshore technology has experienced extremely rapid development since the 1940s, and a thorough understanding of the interaction of waves with offshore structure has now become vital factor in the safe and economical design of such structures. There has been a corresponding increase in research efforts to meet this need, but results are widely scattered throughout literature.

Due to natural depletion of oil/gas reserves on lands, continually increasing the demand for producing theses natural resources and knowing the fact that almost half of these resources are beneath the seas, a new branch in marine science, called Offshore technology is brought out, as a consequence of which various types of Offshore Platform are being developed.

Offshore platform is a house for workers and machinery required to drill and produce petroleum in the ocean. Offshore structure may be classified into two major types of bottom-supported and floating.

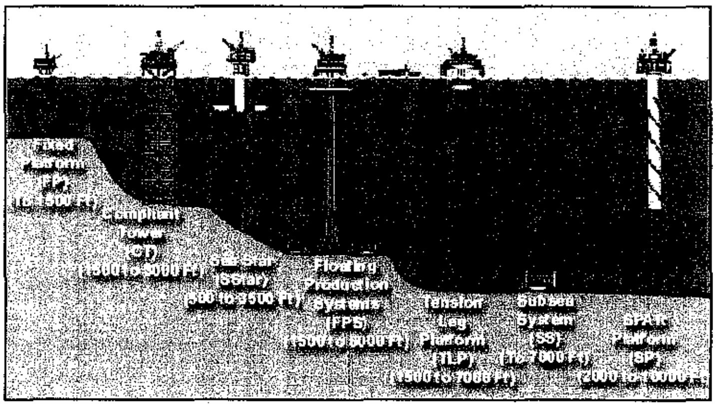

Figure 1.1: Offshore Drilling Platforms

Jacket is a type of bottom-supported fixed Structures. This type of structure is space framed structure with tubular members supported on piled foundations. It is used for moderate water depths up to 400 m. Typical offshore structure will have a deck structure containing a Main Deck, a Cellar Deck and a Helideck. The deck structure is supported by deck legs connected to the top of piles. The piles extend from above the Mean Low Water through the seabed and into the soil.

The present text is an effort in response to the clear need to assemble and organize the wide ranging research efforts pertinent to the central topic of wave forces on offshore structures. However, the intention is specifically not to present a compendium of experimental data and theoretical results. Rather, emphasis is placed on describing the vitally important physical concepts and underlying principles. Observations, laboratory and field experiments and theory have been kept continually in mind in the selection of topics and in their exposition. In fact, in many instances the understanding of the limitations of the theoretical and experimental results and a sound judgement are the designer's most important recipes.

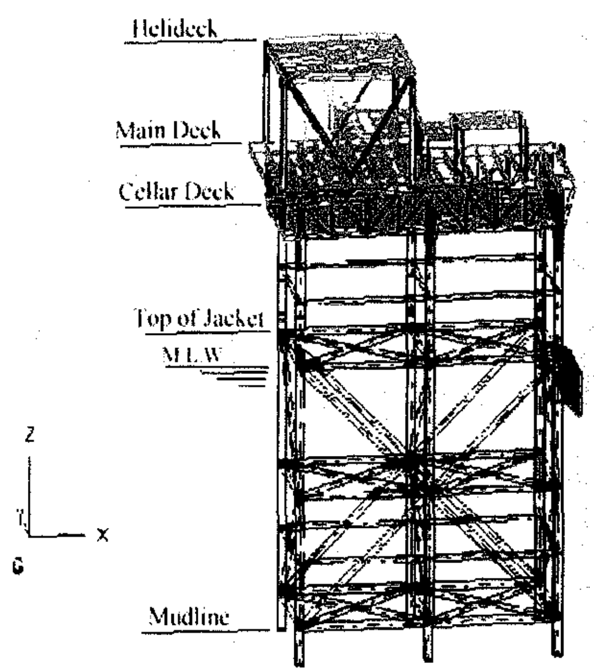

Figure 1.2: Jacket Structure

The text is intended to be both of fundamental interest to researchers, scientists and graduate students, as well as of immediate practical value to engineers involved in the design and construction of offshore structures. It may serve as a convenient text for graduate courses relating to environmental forces, as well as for self-study by engineers interested in problems of environmental forces on offshore structures.

The environmental loads to be accounted for include those due to wind, wave, current, etc. Below are some explanations about those loads:

- **Wind Loads.** The wind loads are the loads due to wind acting on the platform (topsides and superstructures) in the same direction as, and simultaneously with, the wave and current. For the analysis of the substructure, a one minute mean wind speed relating to design or operating conditions should be used. Basic wind speeds are to be referenced to +10 metres MSL.
- **Wave/Current Loads.** The wave/current loads are the total loads due to the wave and current acting on the platform simultaneously in the same direction. Indeed, it is desirable to provide selected modelled structures, which would not only facilitate specific tests of such structures, but also remain as a monitoring system for the various environmental loads. But, we consider doing the analysis of wave forces against modelled offshore platform.

1.2 Problem Statement

The ultimate objective of this study is to develop methods of design and construction which will help to produce structures which are safe, functional, economical and able to resist the forces induced by man and environmental over a required period of time. In order to achieve this goal, it is generally necessary to conduct research both in the laboratory and modelling of offshore structures, and to integrate fully these two complementary methods of investigation. The intended end result would then include the development of mathematical models, design rules and common sense recommendations to the development of offshore platform design and construction.

In order to advance the study of loading and response mechanisms, it is necessary, then, to resort also to laboratory experiments with idealized conditions. Once a simple model of the loading and response is established, one is then in a position to extend the model towards the model situation by considering the effects of additional parameters on the idealization and empiricism of the model.

1.3 Objectives of Study

The objectives of this study are as follows:

1) To study the sensitivity of the offshore platforms due to variations in wave, wind, current and earthquake, etc.
2) To identify relationship between measured forces and response.
3) To study the deflection of modelling offshore platforms.
4) To identify the theories used for environmental purposes.
5) Calculating the structural response.

1.4 Scope of Work

The scope of work for this project can be divided into five (5) elements such as:

1) <u>Literature Review</u>

   Various types of offshore structures in the literature review by other researchers have been studied for deeper understanding about the environmental forces on offshore structures.

2) <u>Development of Model</u>

   The model of TPDP-A platform has been modelled before being analysed. Therefore, sensitivity study of environmental forces due to impact in offshore structure can be studied thoroughly.

3) Analysis

Computer analysis has been handled to study the impact of environmental forces to the offshore structures like jacket. Therefore, analysis has been done by using SACS software with proper environmental data.

4) Result Analysis and Interpretation

Analyses of the results from SACS software are then interpreted and compared to those existing results.

5) Report Write Up

As for documentation of the whole project, a report containing five (5) chapters is produced.

1.5 Significance of Study

The significance of study for this project is to investigate the sensitivity of the offshore platform due to variations in wave, wind, current, and earthquake, etc. Thus, proper software for analysis such as SACS (Structural Analysis Computer System) software is used in order to study the impact of environmental forces on offshore platforms. A variety of Metocean data will be used while conducting this analysis.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

In designing the offshore structure, environmental load such as wave, current, wind and earthquake load should be taken into consideration. Therefore, the characteristics of environmental forces are elaborated in this chapter.

2.1.1 Wave Theory

For the design of offshore structures, the waves are characterized as regular waves with reasonable accuracy. Several wave theories are available for the purpose of determining the wave loads:

- Airy's Linear Theory
- Cnoidal Theory
- Solitary Wave Theory
- Stokes 5th Order Theory
- Stream Function Theory

The wave theory to be used is selected based on the water depth and wave height. Wave loading on a member is categorized into Drag, Inertia, Diffraction, Slamming and Vortex Shedding Induced load. If the member size is small < (1/5) x Wavelength, Morison's equation can be used to calculate the wave loading.

Morison's Equation:

$$F = C_M \frac{\rho \pi D^2}{4} \dot{v} + C_D \frac{\rho D}{2} v \mid v \mid$$

F is the wave force per unit length on a circular cylinder (N) v, |v| are water particle velocity normal to the cylinder, calculated with the selected wave theory at the cylinder axis (m/s) are water particle acceleration normal to the cylinder, calculated with the selected wave theory at the cylinder axis (m/s^2)

ρ is the water density (kg/m^3)

D is the member diameter, including marine growth (m)

C_D and C_M are drag and inertia coefficients, respectively.

In this form the equation is valid for fixed tubular cylinders. For the analysis of the motion response of a structure it has to be modified to account for the motion of the cylinder. The values of C_D and C_M depend on the wave theory used, surface roughness and the flow parameters. According to API-RP2A, C_D » 0.6 to 1.2 and C_M » 1.3 to 2.0.

2.1.2 Current Profile

User defined current profile defined from mudline upwards. Current stretching options include:

- Constant
- Linear
- Nonlinear

User defined current blockage. Blockage calculated automatically using a reference elevation.

2.1.3 Wind Load

Wind load are calculated on all members above the mean water level as per API-RP-2A guidelines. Typically a wind load for a 5-sec gust is considered for global loading on the decks. For shallow water fixed platforms (i.e. jacket type structures) wind loads contribute less than 10% of the total load.

$$u(z,t) = U(z) \times [1-0.41 \times I_u(z) \times ln(t/t_0)] \qquad (2.3.2\text{-}1)$$

where, $$U(z) = U_0 \times [1+ C \times ln(z/32.8)] \qquad (2.3.2\text{-}2)$$

$$C = 5.73 \times 10^{-2} \times (1 + 0.0457 \times U_0)^{1/2}$$

$$I_u(z) = 0.06 \times [1 + 0.0131 \times U_0] \times (z/32.8)^{-0.22} \qquad (2.3.2\text{-}3)$$

Where: z = height, t = gust duration

Uo = one hour wind speed at reference height of 10 meters (32.8 ft)

The motion of air is defined as wind. Air motion may be caused by gravity, deflective forces from the earth's rotation, or centrifugal forces due to the curvature of the wind path. Wind possesses kinetic energy. When a structure is placed in the path of the moving air so that wind is deflected from its path, then all or part of the kinetic energy is transformed into the potential energy of pressure. Wind forces on any structure therefore result from the differential pressure caused by the obstruction to the free flow of the wind. These forces-are functions of the wind velocity, orientation, area, and shape of tile structural elements. Wind forces on a structure are a dynamic problem, but for design purposes, it is sufficient to consider these forces as an equivalent static pressure. For an ideal fluid by Bernoulli's theorem,

$$\frac{\rho V_0^2}{2} + p_0 = \frac{\rho V^2}{2} + p$$

$$q_0 + P_0 = q + p$$

Where: ρ = Mass density of the air

p = Static pressure

V_o = Velocity of the approaching free flow

p,V = Static pressure and velocity at a point on the object

The term $\rho V^2/2$ designated by q is the dynamic pressure. Thus, the sum of the dynamic and static pressure is a constant at all points. Usually it is convenient to resolve the wind force into horizontal and vertical components and use dimensionless coefficients to define the magnitude of the forces:

$$F_D = C_D qA$$
$$F_L = C_L qA$$

Where: F_D, F_L = drag and lift force, respectively

C_D = Drag coefficient

C_L = Lift coefficient

A = Exposed area

The magnitude of C_D and C_L depends on the shape of the object and its orientation in the wind stream.

2.1.4 Earthquake

An earthquake is the result of a sudden release of energy in the Earth's crust that creates seismic waves. Earthquakes are recorded with a seismometer, also known as a seismograph. The moment magnitude of an earthquake is conventionally reported, or the related and mostly obsolete Richter magnitude, with magnitude 3 or lower earthquakes being mostly imperceptible and magnitude 7 causing serious damage over large areas. Intensity of shaking is measured on the modified Mercalli scale.

At the Earth's surface, earthquakes manifest themselves by shaking and sometimes displacing the ground. When a large earthquake epicenter is located offshore, the seabed sometimes suffers sufficient displacement to cause a tsunami. The shaking in earthquakes can also trigger landslides and occasionally volcanic activity.

In its most generic sense, the word earthquake is used to describe any seismic event whether a natural phenomenon or an event caused by humans that generates seismic waves. Earthquakes are caused mostly by rupture of geological faults, but also by volcanic activity, landslides, mine blasts, and nuclear experiments. An earthquake's point of initial rupture is called its focus or hypocenter. The term epicenter refers to the point at ground level directly above this.

2.2 Design Criteria

Environmental loads are dependent on conditions that change randomly with time, and are therefore characterized by stochastic processes. The structure should be designed for the maximum load that occurs due to the loading process during its design life. Because the process value at any point in time is random, the maximum value of the process is uncertain. Therefore, the specified design load is based on a probabilistic criterion—for example, the process value that has a 1 percent annual probability of being exceeded, or, equivalently, the value that has a return period of 100 yr. When two or more stochastic processes result in simultaneous loading, the structure must be designed for the maximum combined load. Because the maximum loads resulting from the individual processes are unlikely to coincide in time, the maximum combined load is generally less than the combined maxima of the individual loads.

Many design codes recognize this and allow for reductions in the maximum individual loads when they act in combination (e.g., CSA-S471, 1992); however, most codes give little guidance regarding the magnitude of the reduction for combinations of environmental loads. The Canadian Standards Association's CSA-S471 (1992) code for the design of fixed offshore structures has the most detailed criteria for environmental load combinations. It specifies reduced companion values of environmental process that are to be used in combination with the specified principal values of other environmental process. The companion process values recommended are based on simplifying assumptions regarding correlation between processes, and are referred to in the Code as a “first approximation.” Combinations of environmental processes are particularly relevant to offshore structures, for which combinations of wind, wave, current, earthquake, and ice loads often govern the design.

The lack of definitive guidance in the codes on the required design criteria leaves the engineer with two choices: either to develop design criteria from site-specific environmental data, or to use conservative solutions that ignore the potential reductions due to nonsimultaneous peaking of individual loads. The development of design criteria for combined environmental loads involves the derivation of the probability distributions of the maximum value of a random process that is defined as a combination of two or more random processes, which is then used, as mentioned earlier, to select a design combined load based on a specified probability of exceedance. The derivation of the distribution of maximum (or extreme) of a given random process, referred to as extremal analysis, is therefore an integral part of load combination analysis.

2.3 Environmental Forces

Wave, current, wind, and storm time are considered. Aerodynamic and hydrodynamic loadings are calculated according to API RP 2A guidelines (API 1993, 1995). Wave horizontal velocities are based on Stokes fifth-order theory. The user is able to specify directional spreading corrections for the wave velocities. The specified variation of current velocities with depth is stretched to the wave crest and modified to recognize the effects of structure blockage on the currents. The total horizontal water velocities are taken as the sum of the wave horizontal velocities and the current velocities. The maximum hydrodynamic force acting on the portions of structure below the wave crest are based on the fluid velocity pressure or drag component of the Morison equation from the structure elements are modelled as equivalent vertical cylinders that are located at the wave crest. Appurtenances (conductors, boat landings, risers) are modelled in a similar manner. For inclined members, the effective vertical projected area is determined by multiplying the product of member length and diameter by the cube of the cosine of its angle with the horizontal (to resolve horizontal velocities to normal to the member axis). For wave crest elevations that reach the lower decks, the horizontal hydrodynamic forces acting on the lower decks are computed based on the projected area of the portions of the structure that would be able to withstand the high pressures. The fluid velocities and pressures are calculated in the same manner as for the other submerged portions of the structure with the exception of the definition of the drag coefficient. In recognition of rectangular shapes of the structural members in the decks, a higher drag coefficient is taken. This value is assumed to be developed at a depth equal to two velocity heads (U2/g) below the wave crest. In recognition of the near wave surface flow distortion effects, the drag coefficient is assumed to vary linearly from its value at two velocity heads below the wave crest to zero at the wave crest (Hong. 1999).

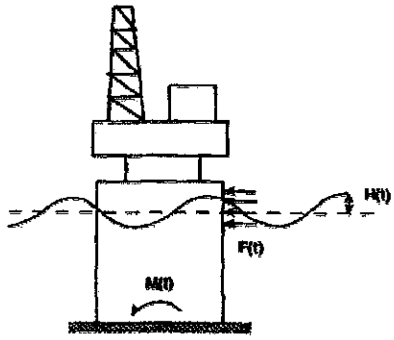

Figure 2.1: Illustration of a wave loading process, wave load, and load effect (Hong, 1999)

In this paper, we can see the results from seven second-generation analysis and verification studies of Gulf of Mexico template-type platforms. The verification cases include four eight-leg and one four-leg drilling and production platforms, and two, four-leg well protectors. These structures are identified as platforms A through G. Therefore, the analysis and results from three of these studies: platforms B, D, and E. Results for platforms A, C, F, and G have been detailed by Bea et al. (1995). Platforms B, D, and E were located within a few miles of the center of hurricane Andrew (1992). These platforms were subjected to the most intense storm loadings developed by this intense storm (Litton 1991). Hurricane Andrew was one of the most damaging hurricanes to strike the coast of the United States. During this storm, platform D failed while the seemingly identical bridge connected platform E did not failed. Platform B was so severely loaded that it was brought close to failure (there was very apparent yielding of joints at the top of the jacket).

The design of an offshore structure which is stronger in one direction than another may benefit from the use of directional wave criteria. But unless the meaning of directional criteria is carefully understood, the resulting structure may be less reliable than a structure designed using an omni-directional wave height (Hahn 1995).

Cumulative distribution functions of waves from various directional bands can be estimated easily enough by sorting the available wave height data into direction bins. If the strength of a structure in each direction is known, then the probability of survival of the structure due to waves from each direction band can be calculated from the probability distribution function of the wave heights in that direction band. The total probability of survival of the structure is then obtained by multiplying the probability of survival from all directions. There is no controversy about how such a reliability calculation should be made using directional wave height probability density functions.

The problem arises when directional criteria must be specified for a given return period. If we naively calculate the wave height with a 100-year wave return period in each direction band, then the 100-year wave height in one of the direction bands will be exceeded with a return period much less than 100 years. If the directional wave heights are factored up so that the wave height in the worst direction band equals the omni-directional wave height, the result is still unconservative compared to the omni-directional wave height (Hahn 1995).

In order to preserve the reliability given by designing to the omni-directional wave height, the product of the probabilities of nonexceedance from all of the direction bands must equal the omni-directional probability. The simplest way to do this is to make the probabilities in all of the direction bands equal. In this case, if there are n direction bands and we want the criteria for a y year return period, the wave height in each band must be exceeded at the ny level. It is very difficult to design a structure which exactly matches a directional wave height distribution. Some adjustment of the directional criteria so that failure from waves in one directional band is more probable than another may thus result in a more optimal structure. Such changes are permissible as long as they result in the same overall reliability (Bea and Pawsey 1991). Indeed, the final judge of a set of directional criteria must be a check on the reliability of the structure which is designed from it.

2.4 Predicted Wave Forces

The major conclusion we draw from the CTS results is that the *API RP 2A* guideline wave-force calculation process for the Gulf of Mexico based on regular, two-dimensional waves, kinematics determined using a Stokes fifth-order theory, and a Morison equation with $C_d = 0.7$ can produce conservative results for the maximum wave forces associated with the center of an intense hurricane (having highly directionally spread seas) and developed on conventional (shallow-to-moderate water depths) template-type platforms. A rational extension of this wave-force calculation process would incorporate storm currents and reduce the C_{ds} to approximately 0.5 to develop an unbiased estimator of the maximum wave forces in a highly directional sea.

A further improvement in and generalization of the process would be to incorporate explicit corrections to the two-dimensional wave kinematics to recognize three-dimensional wave directionality and spreading, and still include the storm-associated currents. This would imply a reduction of the wave kinematics by a factor in the range of 0.7-0.85 for an entire platform in an intense sea state with significant directional spreading (Bea and Pawsey 1991). In turn, the C_{ds} would need to be increased to the range of 0.6-0.8, more in keeping with the marine-fouled nature of the structure.

Recognition of shielding and blocking effects caused by the structure, and recognition of the effects of directional spreading and current effects on the drag coefficients, could provide additional improvements in the wave-force prediction process. For a storm-producing seas with little directional spreading, a conventional calculation process which is based on C_d = 0.7 and includes the storm associated currents can produce acceptable results for the maximum wave forces. The disparity between the CTS and OTS results for such conditions appears to be resolved in the recognition of differences in flow regimes (lower Rs and KCs for OTS), marine fouling (lighter in OTS), and the unique characteristics of the OTS measurement platform (contrasted with the full-scale CTS).

It should be recognized that a prototype platform and design hurricane wave and current will produce Rs in the range of 5 X 10-6 X 106 and KCs in excess of 50-100. The CTS and OTS measurement programs have given us some insights into maximum wave forces developed in such intense flow conditions. The data still leave many important questions unanswered. Additional measurement programs and additional analyses of existing data are needed to further resolve these questions. In summary, the writers' evaluation of recorded wave-force data and performance observations of platforms that have successfully survived intense hurricane wave and current loadings lead them to conclude that the present levels of design wave forces are warranted. Experience justifies the present *API-RP-2A* guideline wave-force calculation procedure for use in requalification of existing platforms in the Gulf of Mexico.

The characteristics of the wave force amplitude time histories are determined by the characteristics of the platform that the waves act on. In this study, the structural characteristics of an eight-leg template-type self-contained drilling and production platform in a water depth of 322 ft were used to generate the global horizontal force-time histories (Bea and Pawsey 1991). The irregular wave amplitude time histories were imposed broadside to the platform. Steady currents also were imposed broadside to the platform. The magnitude and depth profile of these currents were based on results from hindcast studies of the three hurricanes. The surface currents ranged from 0.5 m/s (1.5 ft/s) to1.1 m/s (3.5 ft/s) and decreased to 0.06 m/s (0.2 ft/s) to 0.15 m/s (0.5 ft/s) at the seafloor.

The Morison equation was used together with the revised API wave force guidelines to generate the hydrodynamic forces (API 1993; Hong and Nessim 1999). Water depth stretched linear wave theory was used to determine the kinematics of the irregular waves. Drag and inertia coefficients were used that recognized the effects of flow conditions (Reynolds numbers and Keulegan-Carpenter numbers), currents, marine fouling, directional spreading, shielding, and blockage.

An adaptation of the Morison equation was used to describe the wave forces that were developed when the crests of the waves reached the lower decks of the platform (George 2004). To generate the wave force time histories that included wave forces developed on the lower deck of the platform, the mean water depth was artificially raised to bring the highest crests in the wave record 10 ft into the lower deck of the platform. In this manner, global horizontal force-time histories were generated with and without the effects of wave crest loadings acting on the platform lower decks.

The records that incorporate deck wave forces have much sharper loading peaks. These force spikes (impulsie loadings) can be expected to have important effects on the dynamic response of a platform.

CHAPTER 3: METHODOLOGY / PROJECT WORK

3.1 Research Methodology

This chapter is allocated to explain the methodology that the author is using to achieve the objectives of the project. The summary of project stages is shown in Figure 3.1.

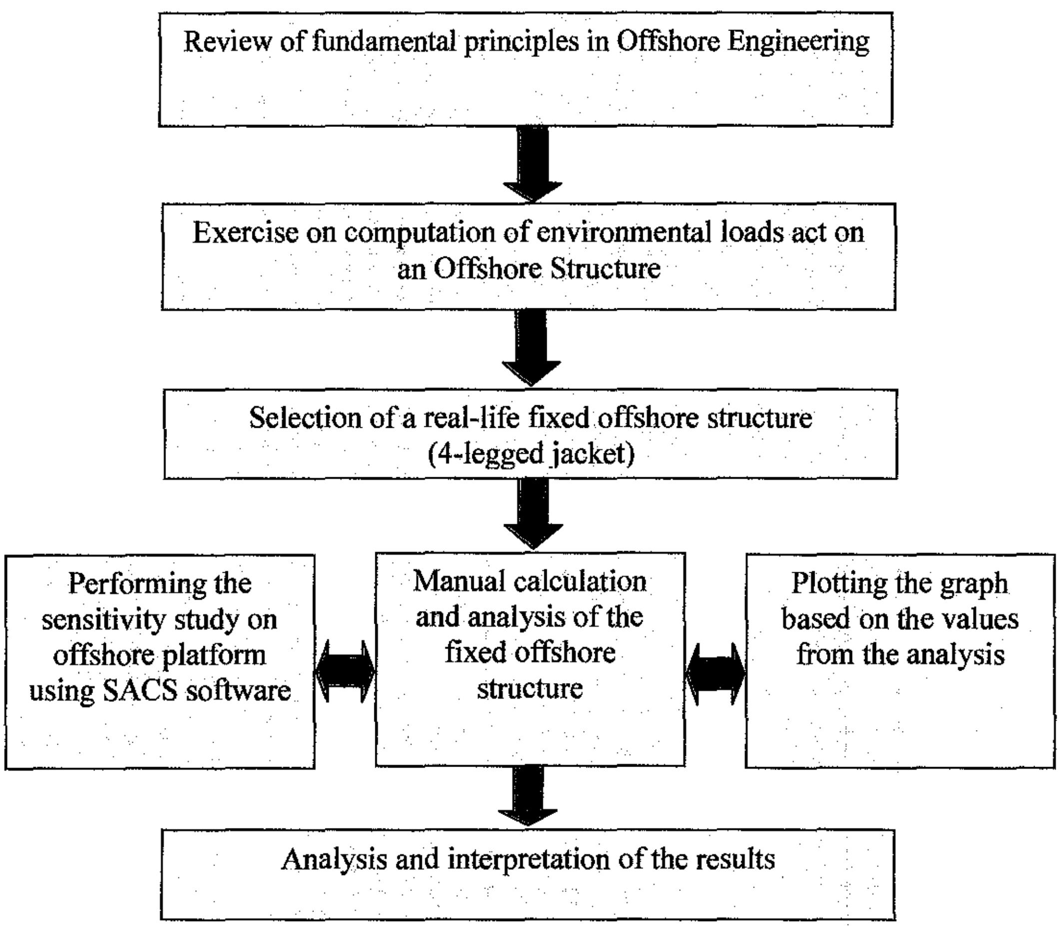

Figure 3.1 Summary of project stages

3.2 Project Activities

Tasks that are going to be conducted for this project:

1. Modelling the offshore structures by using (Structural Analysis Computer System) SACS software for analysis of loads and displacement.

   For generating wave and current forces, the following parameters are used in the analysis:

   a) 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.
   b) Wave kinematics factor of 1.00 is used for all conditions.
   c) Current blockage factor of 0.90 for all directions. Current stretching option in the analysis is assumed as non-linear.
   d) Eight (8) wave, current and wind directions around the platform are considered.

2. Compute manually the wave and current forces at leg of 4-legged jacket TOPAZ and wind forces at topsides above mean sea level.

3. Plot the sensitivity of wave and current due to maximum deflection and maximum shear forces.

4. Data comparison of difference 4-legged jacket bracing arrangement in order to analyze the failure and reliability of difference types of arrangement such as cross bracing and K-bracing.

5. Plot the graph for difference wave, current and wind properties against Unity Check.

6. Analyze the sensitivity of jacket offshore structure due to earthquake.

3.3 Introduction of TPDP-A (TOPAZ) Platform

PC Vietnam Limited (PCVL) is undertaking development of Topaz field, which is located approximately 164 km from Vung Tau Port; S.R Vietnam in Blocks 01 & 02, with a water depth of 41.1m. Topaz will be developed as a satellite platform. The platforms will be located approximately 16 km North East of Ruby field. It is envisaged to be a drilling platform which would accommodate 6 conductor slots. The design life of the platform is 15 years. The fatigue design life for the platform structure shall be 25 years. TPDP-A Topsides is comprises of the following deck levels; Main Deck level at TOS EL (+) 24.50m, Cellar Deck level at TOS EL (+) 18.50m and Sump Deck level at TOS EL (+) 8.00m.

The TPDP-A Topsides will be supported on four (4) legs welded to the pile transition pieces. The size of leg is 167.6cm and thickness of 30cm. The piles are fixed to the jacket at EL (+) 7000mm. Pile section below mudline is modelled in the soil data. The 1524 diameter with 50mm wall thickness piles are used for the piles below mudline elevation. A uniform pile penetration depth of 90m is used for all piles. The bracing arrangement used for this platform is K-bracing. Thus, the diameter is increased as the depth is become deeper. The dimension of upper bracing is 71.1cm and thickness of 3cm while for the bottom bracing is 91.4cm diameter and 2.0cm thickness. The environmental data used for the in-place analysis is based on 'Metocean Criteria at Pearl' supplied by PCVL. The MSL water depth for TPDP-A platform is 41.10m. The maximum and minimum tide for the operating and storm condition is 1.70m and 2.40m. However, for maximum storm surge for storm condition is 0.80m while operating is 0.30m. Therefore, the highest design water depth after the combination of MSL, tide and storm surge is 43.60m. The splash zone is defined from EL (-) 4000mm to EL (-) 5000mm.

The omni-directional wave height shall be used for normal operating and extreme storm conditions. For normal operating condition, the 1-year return period of maximum height, Hmax (7.6m), associated period, Tass (8.3s), significant wave height, Hs (3.9m), zero crossing period, Tz (6.3s) and peak wave period, Tp (8.9s) have been used. For extreme storm condition, the 100-year return period of maximum height, Hmax (14.7m), associated period, Tass (10.3s), significant wave height, Hs (7.5m) zero crossing period, Tz (7.9s) and peak wave period, Tp (11.1s) have been used. The current speed is increasing when the water depth is getting deeper. For operating condition, water depth of 0.41, 2.05, 20.55, 39.04 and 41.1 (m) are 0.14, 0.24, 0.52, 0.65 and 0.66 (m/s) have been used accordingly. For storm condition, water depth of 0.41, 2.05, 20.55, 39.04 and 41.1 (m) are 0.40, 0.60, 1.30, 1.60 and 1.70 (m/s) have been used accordingly. The wind speeds for 1-year design is 25 m/s and 100 year is 50 m/s. The values given are referenced to 10m elevation above MSL. The loads are based on the exposed area of the topside of TPDP-A platform. They are connected by structural wishbone members which allow the piles to move axially and transfer the lateral shear to the jacket without moment.

3.3.1 Platform Location Coordinates

The platform coordinates are given below. The origin for the coordinate axes is located at the geometric centre of the tripod structure.

Table 3.1: Platform location coordinates

Platform	Northing (m)	Easting (m)
TPDP-A	1 154 744	459 939

3.3.2 Environmental Data

Below are the details of environmental forces used when doing the analysis for sensitivity study on jacket structure.

The omni-directional wave height shall be used for normal operating and extreme storm conditions. For normal operating condition, the 1-year return period will be used. For extreme storm condition, the 100-year return period will be used. For mooring operating case, annual 90% non-exceedance wave shall be used.

Table 3.2: Omni-directional wave for normal operating and extreme storm conditions

Wave Parameter	1-year Return Period	100-year Return Period
Maximum Height, H_{max} (m)	7.6	14.7
Associated Period, T_{ass} (s)	8.3	10.3
Significant Wave Height, H_s (m)	3.9	7.5
Zero Crossing Period, T_z (s)	6.3	7.9
Peak Wave Period, T_p (s)	8.9	11.1

Table 3.3: Omni-directional wave for on-bottom condition

Wave Parameter	On-bottom Condition
Height, H (m)	3.0
Associated Period, T_{ass} (s)	6.2

The following current speeds (m/s) will be used. The current is assumed to be acting concurrently with the wave in the same direction. A 1/7 power current distribution profile will be assumed. The 1-year return period will be used for operating and operating with soft-mooring conditions. The 100-year return period will be used for extreme storm condition. For on-bottom condition, a uniform (with depth) current of 0.52 m/s shall be used.

Table 3.4: Current load for normal operating and extreme storm conditions

		Return Period	
d = waterdepth		1 year	100 year
Surface	1.00d	0.66	1.70
Near surface	0.95d	0.65	1.60
Mid-Depth	0.50d	0.52	1.30
Near Bottom	0.10d	0.24	0.60
Bottom	0.01d	0.14	0.40

The wind speeds for in-place analysis are given below. The values given are referenced to 10m elevation above MSL.

Table 3.5: Wind speeds for Inplace condition

Wind Speeds for Inplace Condition	Return Period	
	1 year	100 year
1-minute mean (m/s) for global topsides design	25	50
3 sec gust for local member design	30	57

The wind speed is assumed to be constant in all directions. Variation of wind speed with height shall be in accordance with API RP-2A.

```
*  METOCEAN SUMMARY                                                          *
*  ===============                                                           *
*     Environmental Data Study Report                                        *
*                                                                            *
*                                                                            *
*     WIND SPEED (1 min  mean)         = 100-YR STORM   =  50 m/s            *
*                                      = 1-YR STORM     =  25 m/s            *
*                                                                            *
*     MUDLINE LEVEL                    = 41.10 m                             *
*     M.S.L.                           = 0.0 m                               *
*     H.A.T.                           = 1.7 m                               *
*     L.A.T.                           = -2.4 m                              *
*     STORM SURGE    1 YEAR            = 0.3 m                               *
*     STORM SURGE 100 YEARS            = 0.8 m                               *
```

Figure 3.2: Metocean data for TPDP-A Platform

```
******************************************************************************
*                           WAVE AND CURRENT LOAD                            *
******************************************************************************
LOADCN  40
LOADLB  40 OPR WAVE & CURRENT AT   0.0 DEG
CURR
CURR       0.000   0.000   0.000           1.000          NL          AWP
CURR       0.410   0.140   0.000
CURR       2.050   0.240   0.000
CURR      20.550   0.520   0.000
CURR      39.040   0.650   0.000
CURR      41.100   0.660   0.000
WAVE
WAVE1.00STOK  7.60 43.10  8.30          0.00      D   0.00 10.00  36MS10 1 0
LOADCN  41
LOADLB  410PR WAVE & CURRENT AT  54.0 DEG
CURR
CURR       0.000   0.000  54.000           1.000          NL          AWP
CURR       0.410   0.140  54.000
CURR       2.050   0.240  54.000
CURR      20.550   0.520  54.000
CURR      39.040   0.650  54.000
CURR      41.100   0.660  54.000
WAVE
WAVE1.00STOK  7.60 43.10  8.30         54.00      D   0.00 10.00  36MS10 1 0
LOADCN  42
LOADLB  42 OPR WAVE & CURRENT AT  90.0 DEG
CURR
CURR       0.000   0.000  90.000           1.000          NL          AWP
CURR       0.410   0.140  90.000
CURR       2.050   0.240  90.000
CURR      20.550   0.520  90.000
CURR      39.040   0.650  90.000
CURR      41.100   0.660  90.000
WAVE
WAVE1.00STOK  7.60 43.10  8.30         90.00      D   0.00 10.00  36MS10 1 0
```

Figure 3.3: Wave and current load input for TPDP-A Platform in SACS software

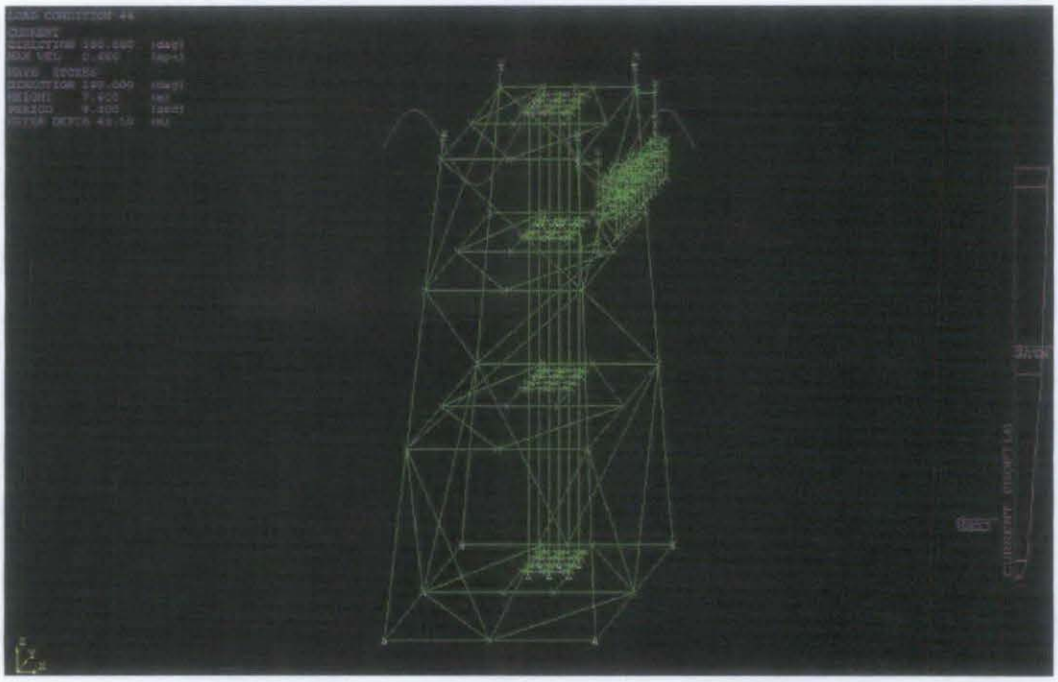

Figure 3.4: Wave and current load applied to jacket in SACS software (1-year return period)

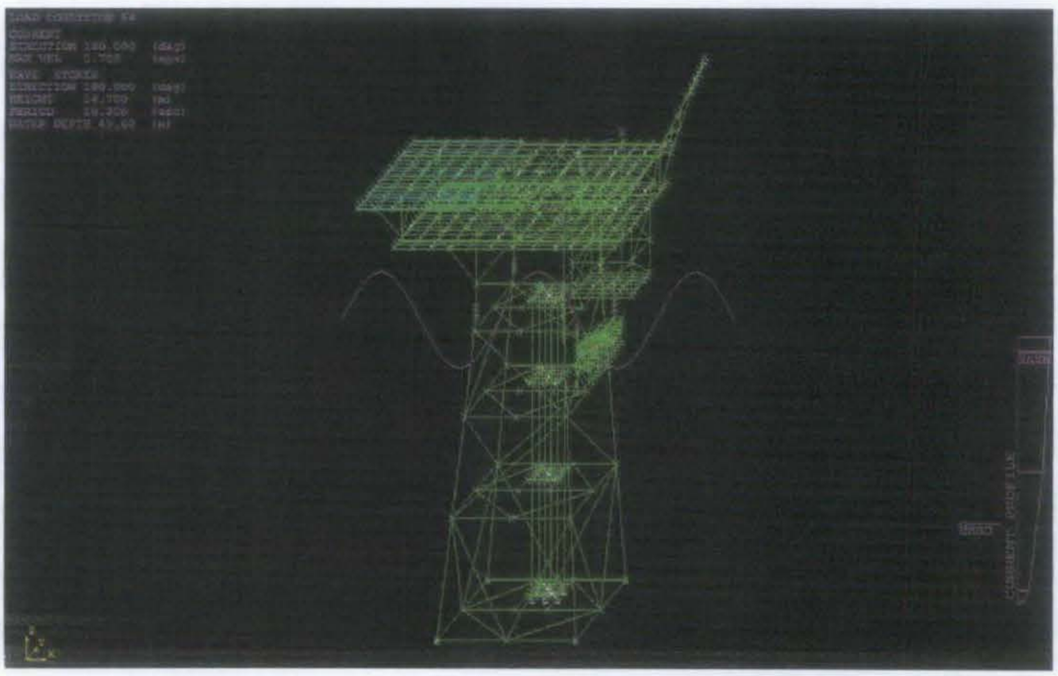

Figure 3.5: Wave and current load applied to jacket in SACS software (100-year return period)

```
*******************************************************************************
*                              WIND LOADING                                   *
*******************************************************************************
LOADCN   8
LOADLB   8 TOPSIDE WIND LOAD +X DIRECTION
LOAD    7003      7.55000                                   GLOB JOIN    WIND(+)X
LOAD    7015      7.55000                                   GLOB JOIN    WIND(+)X
LOAD    6015      7.55000                                   GLOB JOIN    WIND(+)X
LOAD    6011      7.55000                                   GLOB JOIN    WIND(+)X
LOAD    6003      7.55000                                   GLOB JOIN    WIND(+)X
LOAD    6000      7.55000                                   GLOB JOIN    WIND(+)X
LOAD    6018      7.55000                                   GLOB JOIN    WIND(+)X
LOAD    5009      7.55000                                   GLOB JOIN    WIND(+)X
LOAD    5003      7.55000                                   GLOB JOIN    WIND(+)X
LOAD    7018      7.55000                                   GLOB JOIN    WIND(+)X
LOAD    7000      7.55000                                   GLOB JOIN    WIND(+)X
LOADCN   9
LOADLB   9 TOPSIDE WIND LOAD +Y DIRECTION
LOAD    7003             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    6003             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    7041             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    6041             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    7079             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    6079             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    7117             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    6120             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    7158             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    7218             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    6218             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    6180             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    7256             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    6256             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    7294             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    5003             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    5017             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    5031             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    6221             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    6183             8.12000                            GLOB JOIN    WIND(+)Y
LOAD    6259             8.12000                            GLOB JOIN    WIND(+)Y
```

Figure 3.6: Wind load input for TPDP-A Platform in SACS software

Figure 3.7: Wind load in x-direction applied to jacket in SACS software

Figure 3.8: Wind load in y-direction applied to jacket in SACS software

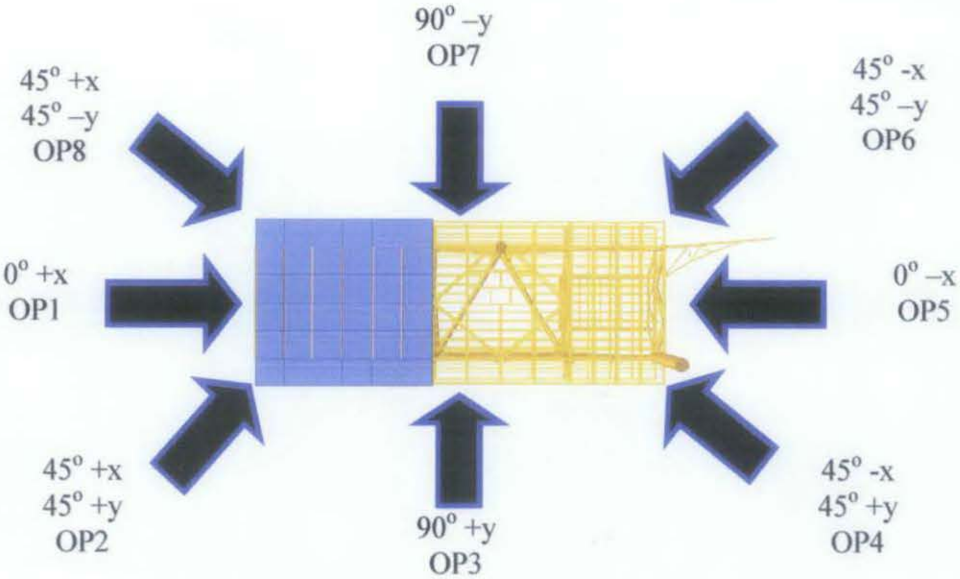

Figure 3.9: Omni-directional of wave and current loadings

```
dyr.inp
****************** TOPAZ DEVELOPMENT PROJECT********************************
*                                                                          *
*                                                   Date: AUGUST 2008      *
*  Project: CONCEPTUAL AND BASIC ENGINEERING SERVICES  No: P5173           *
*           FOR TOPAZ DEVELOPMENT PROJECT                                  *
*                                                                          *
****************************************************************************
DROPT SPEC        -41.10
SDAMP      5.0
STCMB   1.0  2.0    1 1.0
LOAD
SPLAPI      0.20 1.0  A  1.0 A  0.5 A CQC
RSFUNC 405DX 5.0 405DY 5.0 405DZ 5.0                              PG1WO
END
```

Figure 3.10: Dynamic Response Input file for earthquake analysis

From **Figure 3.10**, the dynamic response input file is used in order to do the analysis for earthquake. Therefore, this input file will be used separated with the wave and current loads.

3.3.3 Foundation Design

The inplace analysis has been performed using PSI routine of the SACS suite of programs. A pile diameter of 1219mm with 50mm wall thickness has been established with assumed target penetration depth of 80m. The material yield strength of the pile is 340 MPa. The foundation model also includes all the 4 conductor piles. A conductor penetration of 60m has been used in the analysis. These conductor piles have been idealized such that there are effective in resisting the lateral loads only. The axial load induced on these conductor piles will be limited to its own self weight. The jacket and conductor piles have been divided into 100 equal segments for the soil interaction analysis.

The soil data used for the inplace analysis are extracted from Geotechnical Site Investigation – Pearl Location, Block 01, Offshore Vietnam, S.R Vietnam. The input required for the soil pile interaction are the axial springs (i.e the T-Z curves), the pile tip bearing (as defined by Q-Z curves) the torsional capacities (the parameter input under this category are the soil unit skin friction values) and the lateral springs namely the P-Y curves. Additional input associated with defining the soil parameter is the unit conversion multipliers. These are elaborated in the Table 2.3.1 below. The soil properties from mudline over a depth of 0.9m have been ignored in order to account for the scour.

3.4 Use of Suitable Software (SACS)

Structural Analysis Computer System (SACS) is used to simulate the response of jacket structure to the environmental loads. SACS is a finite element structural analysis suite of programs for the offshore and civil engineering industries. SACS is capable of:

- Model the structure in 3D interactive environment
- Generate finite element models
- Analyze the structure statically and dynamically
- Calculate the joint displacements and element internal forces in static analysis mode

Figure 3.11: Logo of SACS software

3.5 Key Milestone / Gantt Chart

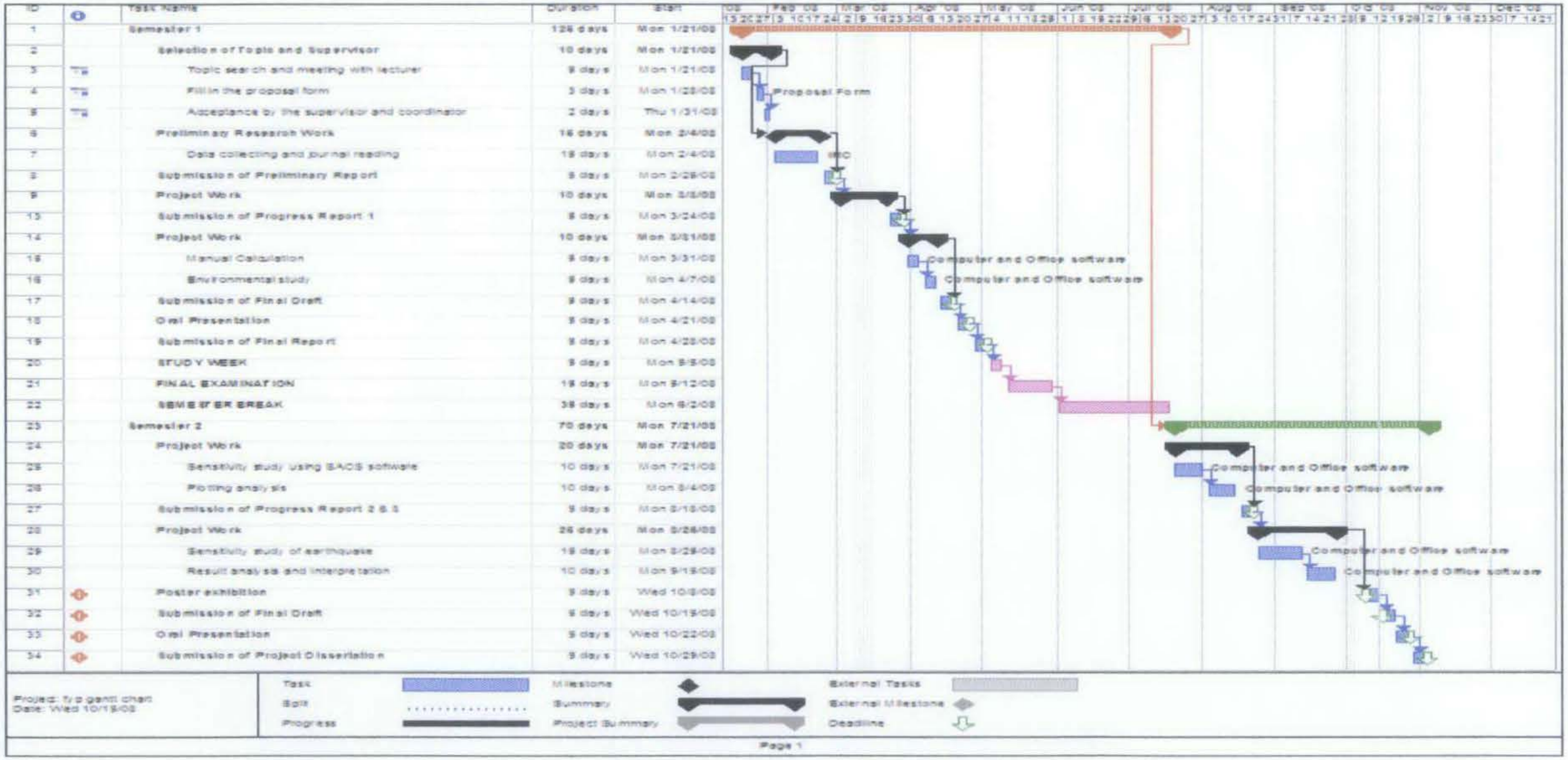

Figure 3.12: Key Milestone

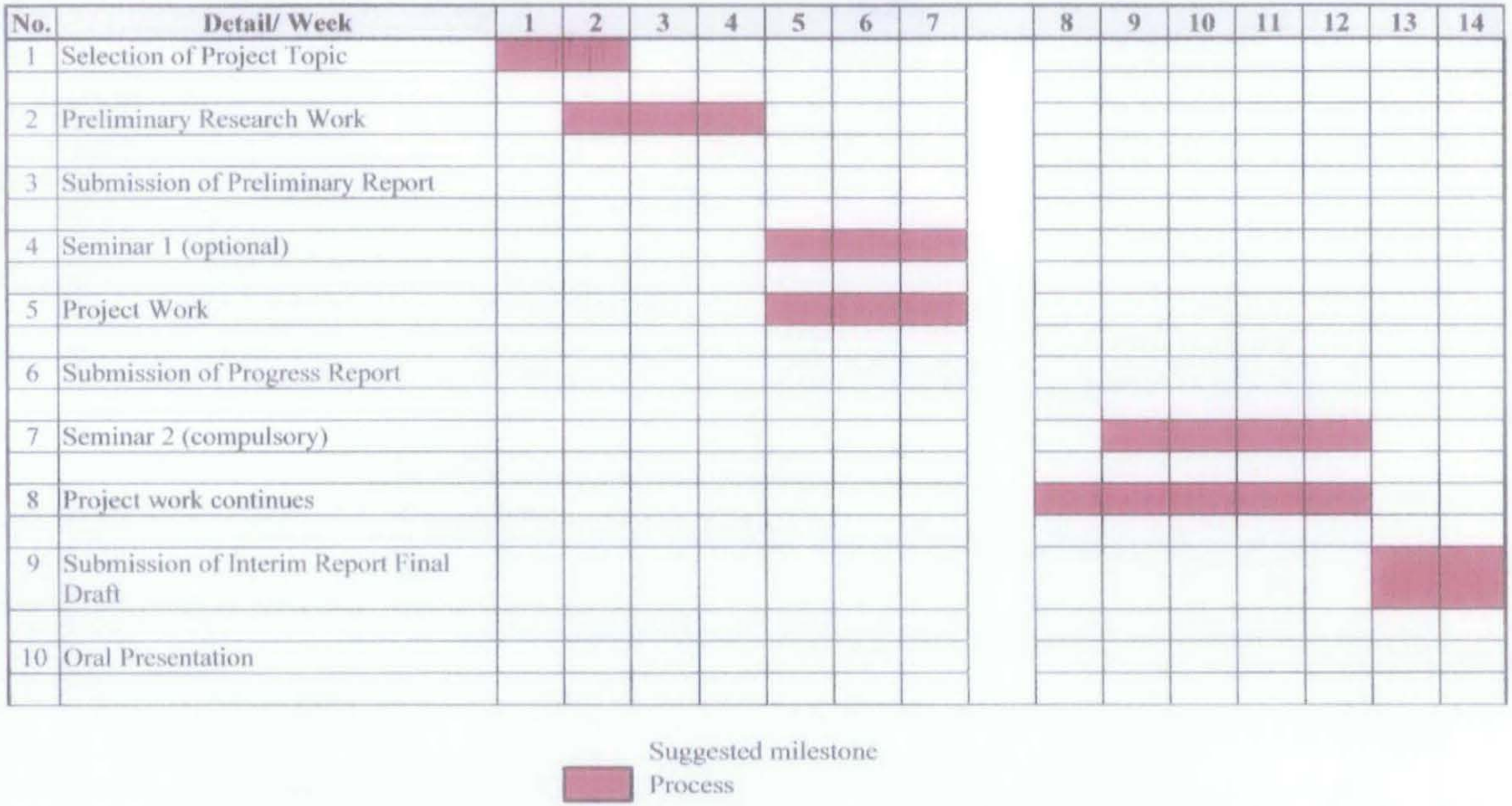

Figure 3.13: Gantt Chart

3.6 Tool/ Equipment

Table 3.6 below is the list of tool/equipment used in this project.

Table 3.6: List of tool/equipment

Tools / equipment	Pictures	Function	Features
SACS software		To analyze the sensitivity of offshore platform due to environmental forces	• Computer installed with this software is needed to do the analysis of offshore platform.

3.7 Hazard Analysis

One of the main factors that the writer is considered throughout the project in order to acquire the objective completely is Health, Safety and Environmental aspects of the project. The following is to describe how writer take into account this major issue in the project:

- All data that has been analyzed should be frequently save in order to prevent missing data due to unexpected events such as black-out, computer shut down, etc.
- Analysis done should be stored at same document or folder in order to make the systematic arrangement of files.
- Do not stay in front of computer for a long duration of time. This will affect the performance of our eyes and should be taken into consideration seriously.

3.7.1 Health, Safety and Environmental Aspects

Health, safety and environmental issues are a main factor that is focused on throughout this final project. The importance of this factor is:

- To prevent and eliminate the risk of injuries, health hazards and damage to properties.
- To identify steps towards the conservation and preservation of the environment.
- To minimize the unsafe act or unsafe conditioned.

Accordingly by identifying the hazard sources, the particular form in which that hazard occurs, the areas of workplace or work process where it occurs and the persons exposed to that hazard, the writer strived to prevent the risk of injuries, protect the environment and accomplish the project successfully.

3.7.2 Hazard Occurrence Situations and Methods of Prevention

As it is mentioned earlier, in this project, the hazards may occur in three main workplaces, which are manufacturing workshop, hydraulic laboratory and computer laboratory. The following sections describe the situations that may lead to accident in each workplace and the techniques to prevent them.

3.7.3 Computer Laboratory

Computer laboratory is used to perform the analysis on sensitivity study on environmental forces using SACS software. Uncomfortable physical environment, poor posture of body, uncomfortable furniture and using computer for long period without any break (Static posture) may cause injuries, illness and therefore endangering health at this laboratory.

Ergonomic is the applied science of equipment design intended to maximize productivity by reducing operator fatigue and discomfort. Ergonomic aims to reduce the potential of accidents, reduce the potential of injury and ill health, and improve performance and productivity. Ergonomic research is primarily performed by ergonomists who study human capabilities in relationship to their work demands.

Information derived from ergonomists contributes to the design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with the needs, abilities and limitations of people (IEA, 2000).

The following methods are used in order to improve the workplace arrangement and protect the health while working with computer:

- Lighting:
    - Retaining image quality
    - Shielding from direct or intense/bright light: using drapes, dark film, louvers.
    - Minimizing glare use screen filters

- Chairs:
    - Using a chair that is stable, mobile, swivels, and allows for operator movement.
    - Using a chair that provides substantial lower back support. The back support should be easy to adjust backward, forward, up, and down. A properly adjusted chair is important to help reduce or prevent discomfort on the back and should support the inward curve of the back.
    - Using a chair that has an adjustable seat height. Raise or lower the chair to a comfortable height such that the thighs are parallel to the floor and the knees are at a 90-degree angle. Rest the feet flat on the floor or use a footrest.
    - Using the armrests if they allow maintaining elbows at a 90-degree angle. If the armrests obstruct sitting posture, then adjust the armrests, use a chair that allows an erect posture, or use a chair without armrests.

- Work Surfaces:

    - Adjusting the work surface (table) so that the keyboard is at the correct height to maintain the best posture (elbows at keyboard height with the forearms parallel to the floor). If possible, use a split-level design table that has an adjustable top height: the lower level for the keyboard and mouse or trackball and the upper level for the VDT monitor. The height of each level should adjust separately.
    - Using a table large enough to hold the keyboard, monitor, wrist rest, mouse or trackball, and a document holder or all necessary documents.
    - Keeping adequate clearance under the table for leg length, knee height, and thighs.

- VDT Monitors:

    - Positioning the VDT monitor directly in front and in line with the keyboard.
    - Positioning the VDT at a comfortable viewing distance (18-24 inches from the eyes), viewing height (top of the display screen at or slightly below eye level), and viewing angle (10-15 degrees below the horizontal line of sight).
    - Using a VDT monitor that tilts and rotates.
    - Using a VDT monitor that has adjustable contrast and brightness. Adjust the contrast to a high level and the brightness to a low level to minimize or prevent eyestrain.
    - Keeping the display screen or glare shield clean because dust reduces character clarity and reflects light.

- Keyboards:

    - Using a keyboard that is detached from the VDT monitor.
    - Positioning the keyboard directly in front of your torso.

  - Positioning the keyboard approximately at elbow height.
  - Adjusting the keyboard angle to a comfortable position; keep the wrists straight and in line with the forearm. The control to adjust the angle is located at the rear of the keyboard.

- Other Input Devices:

  - When using a mouse, trackball, or special keypads, placing the wrist in a neutral position. Rest the arm and hand close to the body and at the natural elevation. Do not reach forward, outward or raise the shoulders.
  - Using the whole arm to move the input device instead of just the wrist.
  - If the arm is resting on the table edge (hard work surface) when using the mouse or trackball, then using a mousepad rest to provide cushion.

- Wrist Rests/Pads:

  - Using a wrist rest for support to help maintain a neutral wrist position.
  - Using a wrist rest for cushioning to protect the wrist from resting on a hard or sharp work surface. Note that wrist rests are designed to be used during pauses in typing.

- Footrests:

  - Using a footrest that has an adjustable height and heel stop.
  - Using a footrest that is large enough to allow for movement.

- Printers:

  - Using a printer with a low noise level.
  - Locating the paper supply where it can be easily reached.

- Exercises:
  - For the eyes, looking away from the work to a distant point at least every hour.
  - For the body, stretching the neck, shoulders, back, legs, arms, and fingers at least twice a day. Standing up and walking around often to increase blood flow circulation.

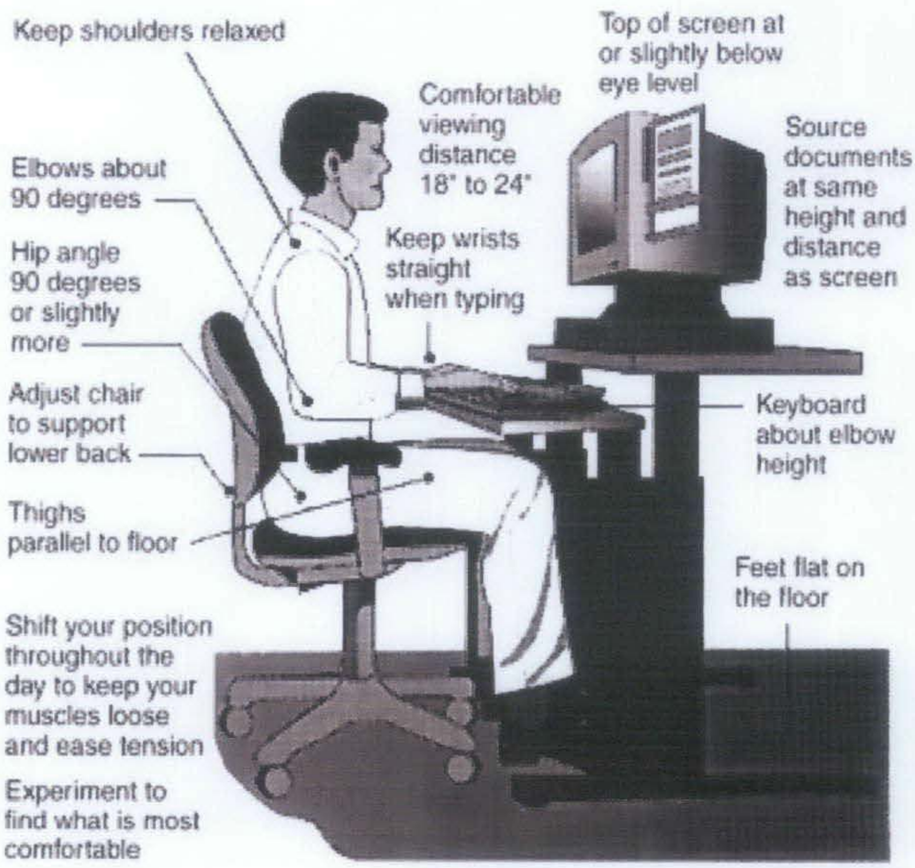

Figure 3.14: Preferred posture at a computer workstation

CHAPTER 4: RESULTS AND DISCUSSION

This chapter is allocated to present and discuss the results obtained from performing the simple calculation of the environmental loads on fixed platform, modelling and analyzing using SACS software and producing the sensitivity graph of environmental loads on TOPAZ platform.

4.1 Performing Simple Calculation

In order to understand the process of analysis and verify the results obtained from SACS software, a simple calculation is produced. This calculation allows the calculation of 4-legged jacket offshore structure under major environmental loads including waves, winds and currents. However, analysis due to earthquake will be analyzed in order to check its sensitivity towards the jacket structure.

4.1.1 Formulas

In developing the spreadsheet, the following analytical formulas are used to compute environmental loads on fixed offshore structure. It should be mentioned that these formulas are taken from fluid mechanics texts and standards for offshore platform design.

$$\frac{V_h}{V_H} = \left(\frac{h}{H}\right)^{\frac{1}{n}} \qquad \textbf{(4.1)}$$

V_h is the wind velocity at height h, V_H is the wind velocity at reference height H, typically10m above mean water level, 1/n is 1/13 to 1/7, depending on the sea state, the distance from land and the averaging time interval. It is approximately equal to 1/13 for gusts and 1/8 for sustained winds in the open ocean.

$$F_{Current} = \frac{1}{2}\rho_{Water} C_D A U_{Current}{}^2 \quad \textbf{(4.2)}$$

$$F_{Wind} = \frac{1}{2}\rho_{Air} C_S A U_{Wind}{}^2 \quad \textbf{(4.3)}$$

P is the wind density (p = 1.225kg/m^3)

Cs is the shape coefficient (Cs = 1.5 for beams and sides of buildings, Cs = 0.5 for cylindrical sections and Cs = 1.0 for total projected of platform)

$$F_{Wave} = F_i + F_D \quad \textbf{(4.4)}$$

$$F_i = C_M \rho_{Water} g \frac{\pi D^2}{4} H K_i \quad \textbf{(4.5)}$$

$$F_D = \frac{1}{2} C_D \rho_{Water} g D H^2 K_D \quad \textbf{(4.6)}$$

$$K_i = \frac{1}{2}\tanh(\frac{2\pi d}{L}) K_D = \frac{1}{4} n \quad \textbf{(4.7)}$$

$$n = \frac{C_g}{C} = \frac{1}{2}(1 + \frac{4\pi d / L}{\sinh[4\pi d / L]}) \quad \textbf{(4.8)}$$

$$L = \frac{gT^2}{2\pi}\sqrt{\tanh(\frac{4\pi^2 d}{T^2 g})} \quad \textbf{(4.9)}$$

$$\begin{cases} C_D = 1.2 - \dfrac{(R_e - 2(10)^5}{6(10)^5} & \text{for } 2(10)^5 < R_e \text{ -}5(10)^5 \\ C_D = 0.7 & \text{for } 5(10)^5 < R_e \end{cases} \tag{4.10}$$

$$\begin{cases} C_M = 2.5 - \dfrac{R_e}{5(10)^5} & \text{for } 2.52(10)^5 < R_e \text{ -}5(10)^5 \\ C_M = 1.5 & \text{for } 5(10)^5 < R_e \end{cases} \tag{4.11}$$

$$\mathrm{Re} = \frac{u_0 D}{\upsilon} \tag{4.12}$$

$$\text{Base shear} = F_{Wave} + F_{Wind} + F_{Current} \tag{4.13}$$

4.2 Bracing Arrangement

There are 3 different bracing arrangements which are:

Figure 4.1: K-bracing

Figure 4.2: X-bracing (Arrangement 1)

Figure 4.3: X-bracing (Arrangement 2)

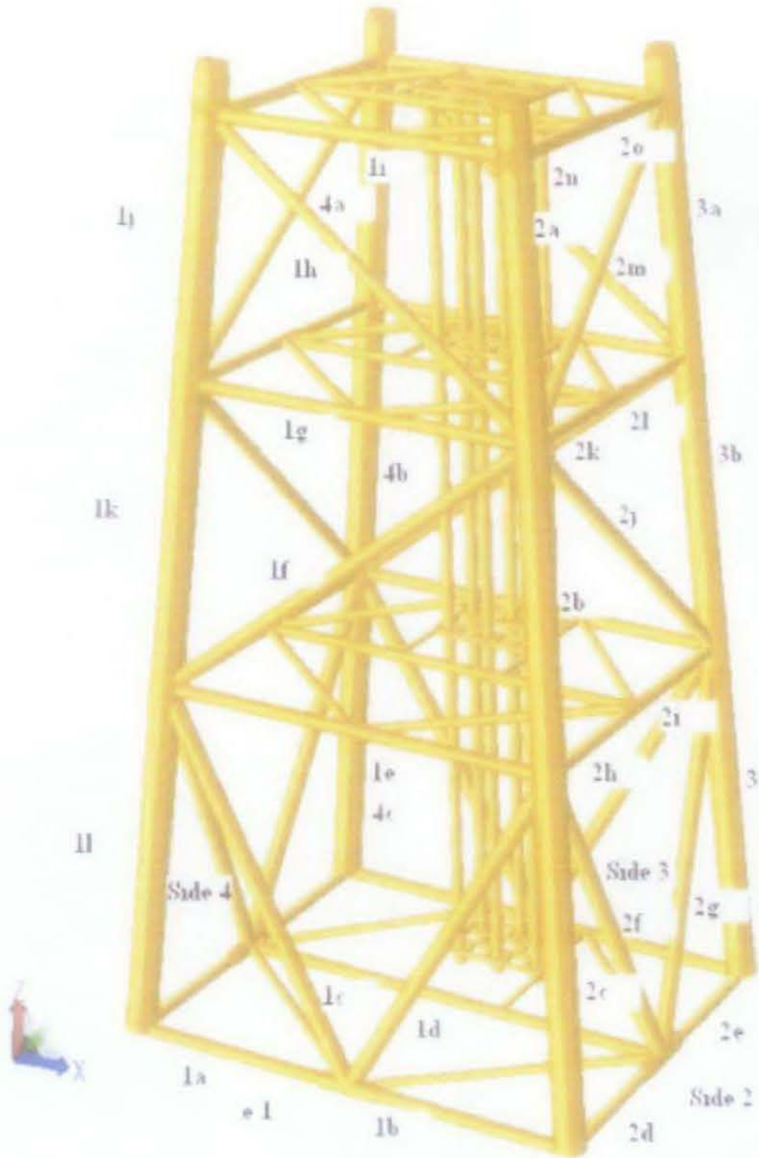

Figure 4.4: Jacket structure with member name

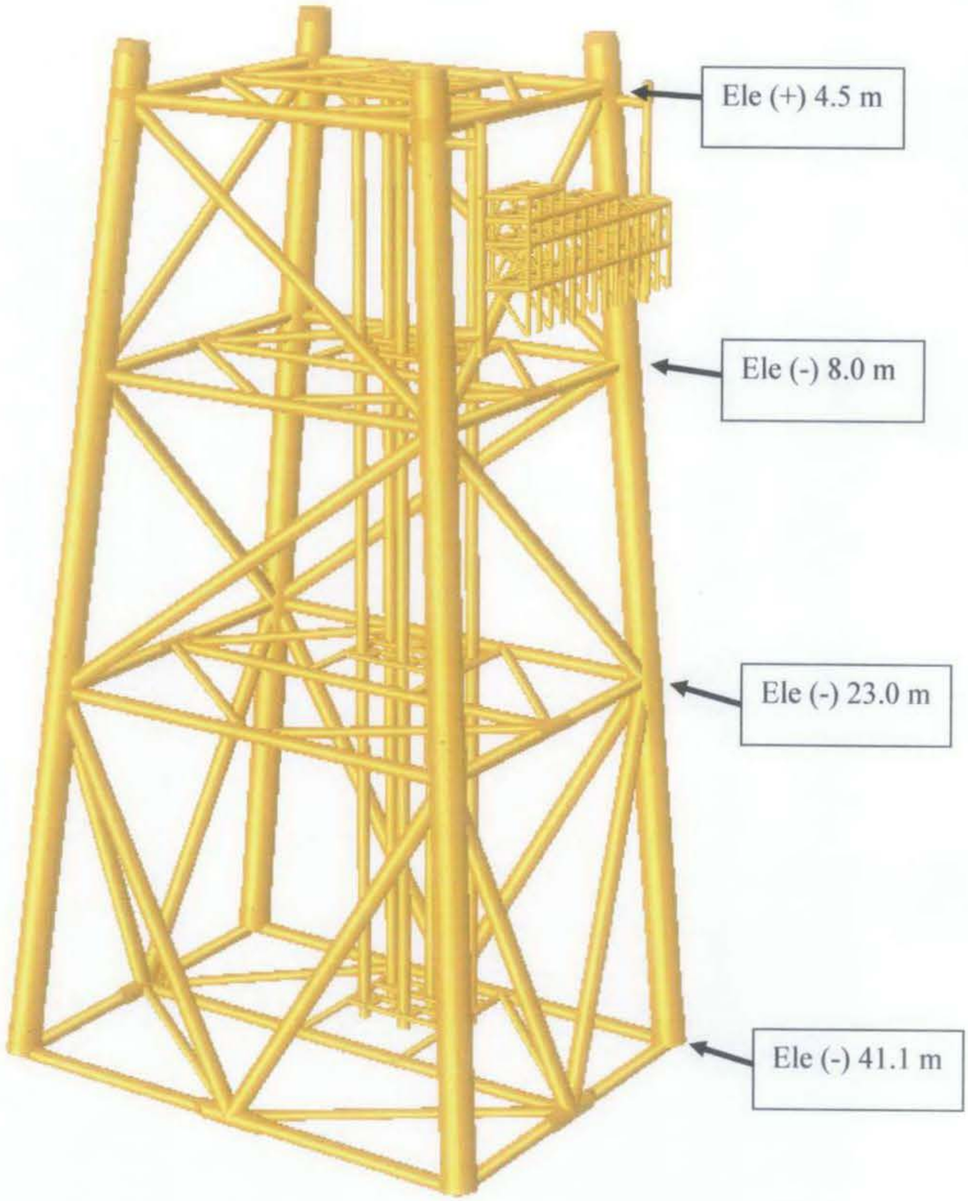

Figure 4.5: Jacket structure with boat landing

4.3 Simulated Response of the Jacket Structure Using SACS

The unity check is the ratio of actual stress to the allowable stress. The stresses consist of Euler, axial, bending at y and z-axis and torsional stress. All the figures are the sensitivity studies of Unity Check due to a few cases such as wave height (H), wave period (T), wind speed (V), current (C), braces arrangement, diameter (d) and thickness (t) of TOPAZ platform. As it can be observed from this figure, the worst location of this platform is due to the wave loads and the least portion is caused by current.

Therefore, the wave loads play a major role to the sensitivity of this platform. Although, the worst location of TOPAZ platform is at jacket structure and it is varied in leg and braces location. The highest unity check in the k-bracing, x-bracing arrangement 1 and x-bracing arrangement 2 are 0.94, 1.16 and 1.15 accordingly. The maximum deflection of this platform is 6.608cm in y-axis. Most of the highest unity check is due to axial forces. However, for this project, 3 bracing arrangement for TOPAZ platform has been conducted to analyzed the sensitivity studies of this platform. There are k-bracing, x-bracing arrangement 1 and x-bracing arrangement 2. An analysis due to the earthquake can be conducted in order to check its sensitivity to the jacket structure. The data of sensitivity result of earthquake will be further recorded and discussed.

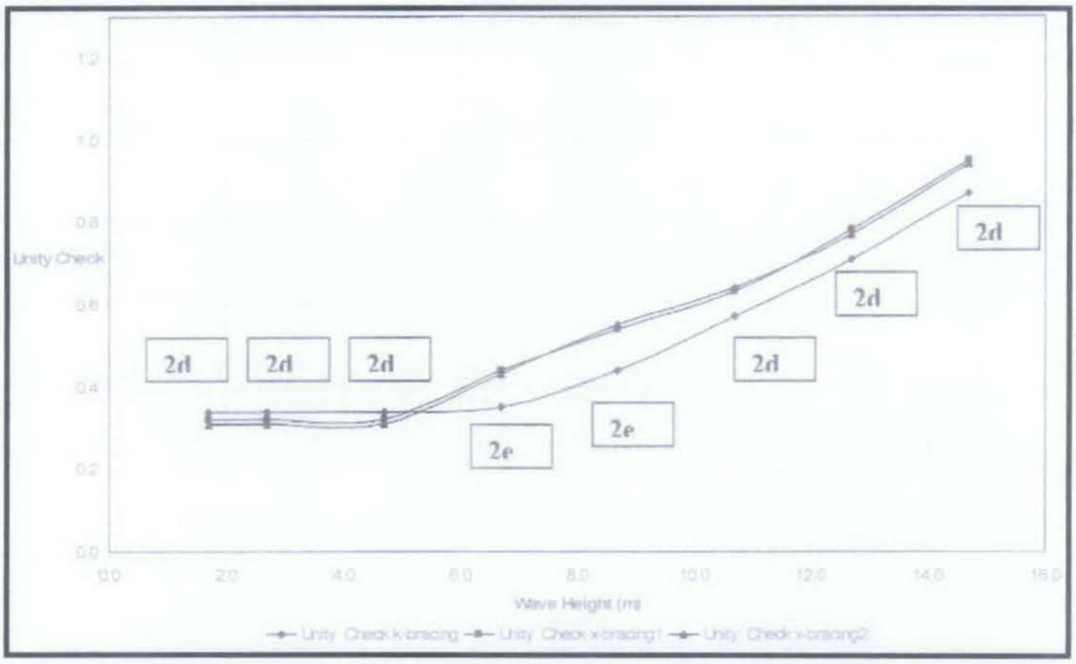

Figure 4.6: Unity Check (UC) versus Wave Height (m)

From **Figure 4.6**, we can see that the unity check is increased with the wave height. The location of higher unity check is at 2d and it is located at the bottom part of the jacket. However, bracing arrangement of k-bracing has shown the lowest unity check. Therefore, k-bracing is more suitable for this sensitivity study of wave height.

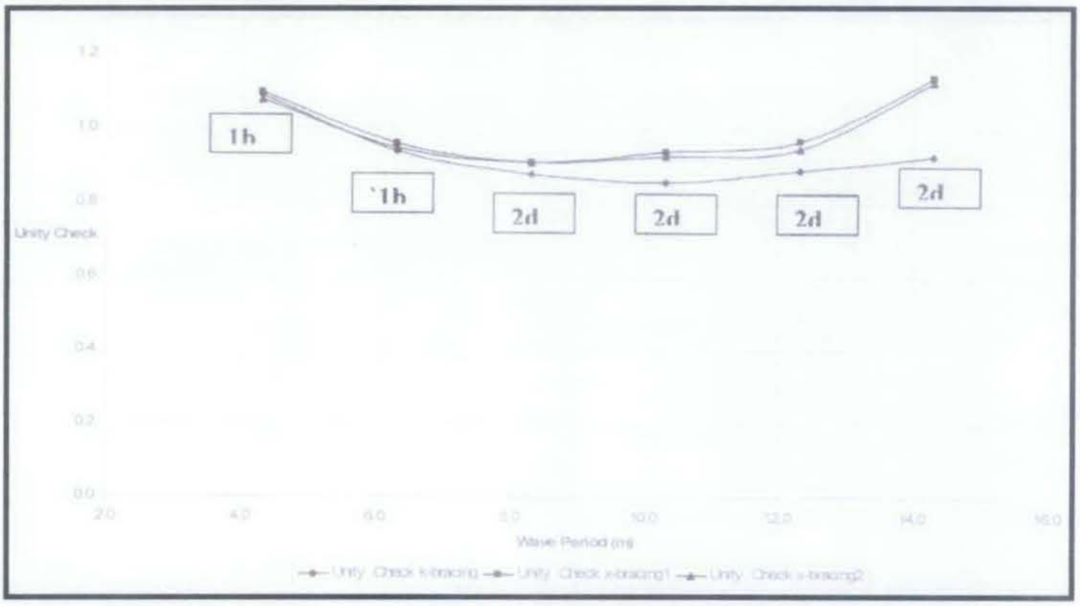

Figure 4.7: Unity Check (UC) versus Wave Period (s)

From **Figure 4.7**, we can see that the unity check is decreased ad then increased against the wave period. The location of higher unity check is at 2d and it is located at the bottom part of the jacket. However, bracing arrangement of k-bracing has shown the lowest unity check. K-bracing has slightly increased after the wave period of 10 s. Therefore, k-bracing is more suitable for this sensitivity study of wave period.

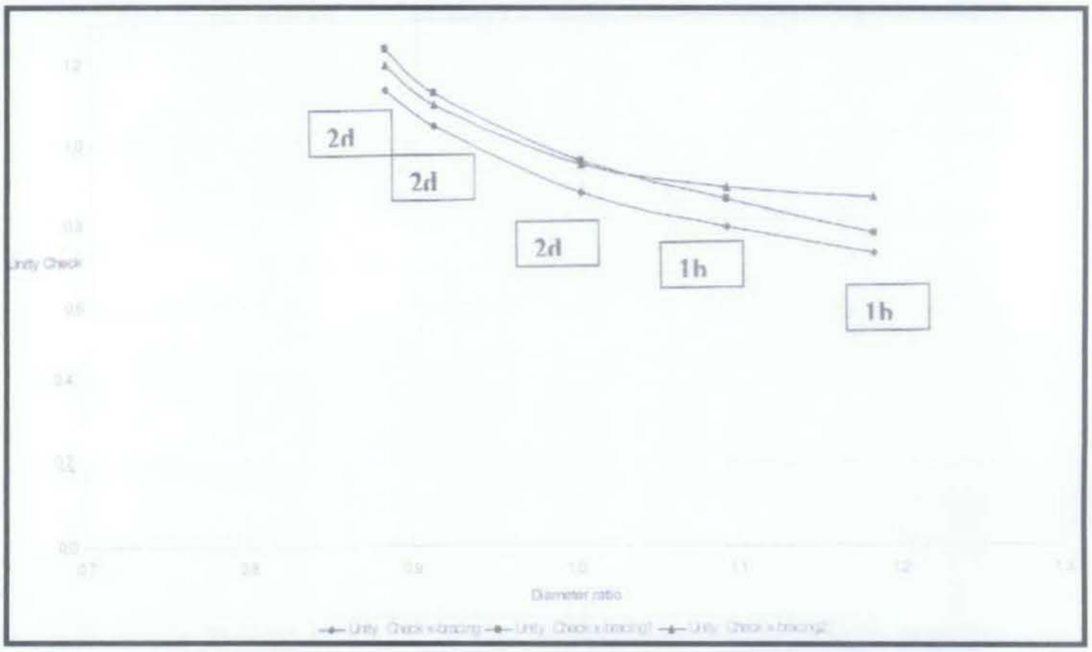

Figure 4.8: Unity Check (UC) versus Diameter ratio

From **Figure 4.8**, we can see that the unity check is decreased with the diameter ratio. The location of higher unity check is at 2d and it is located at the bottom part of the jacket. However, bracing arrangement of k-bracing has shown the lowest unity check. Therefore, k-bracing is more suitable for this sensitivity study of diameter ratio.

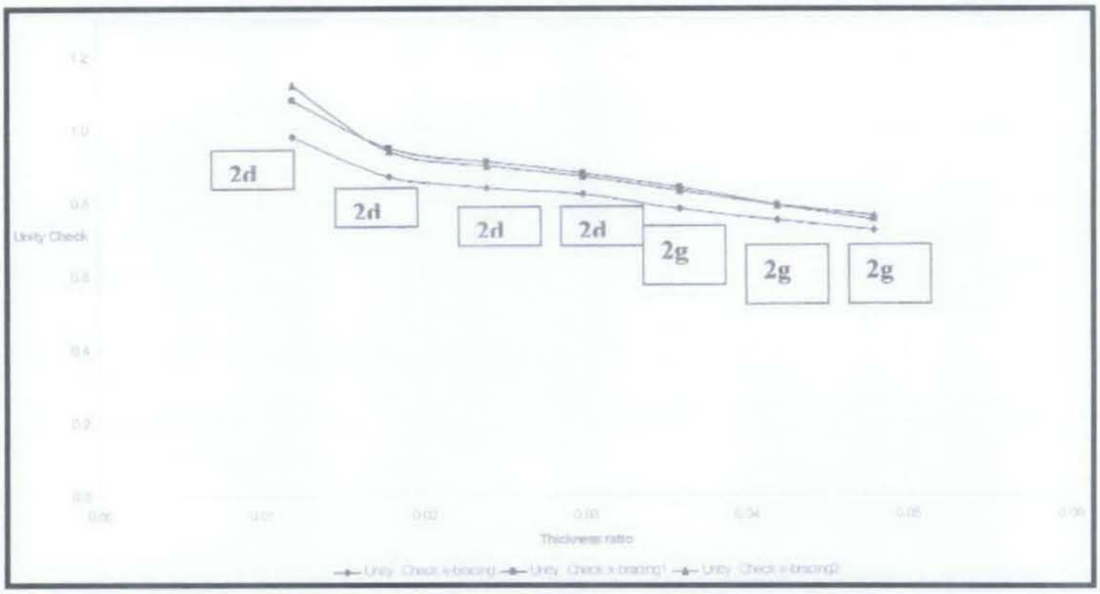

Figure 4.9: Unity Check (UC) versus Thickness ratio

From **Figure 4.9**, we can see that the unity check is decreased with the thickness ratio. The location of higher unity check is at 2d and it is located at the bottom part of the jacket. However, bracing arrangement of k-bracing has shown the lowest unity check. Therefore, k-bracing is more suitable for this sensitivity study of thickness ratio.

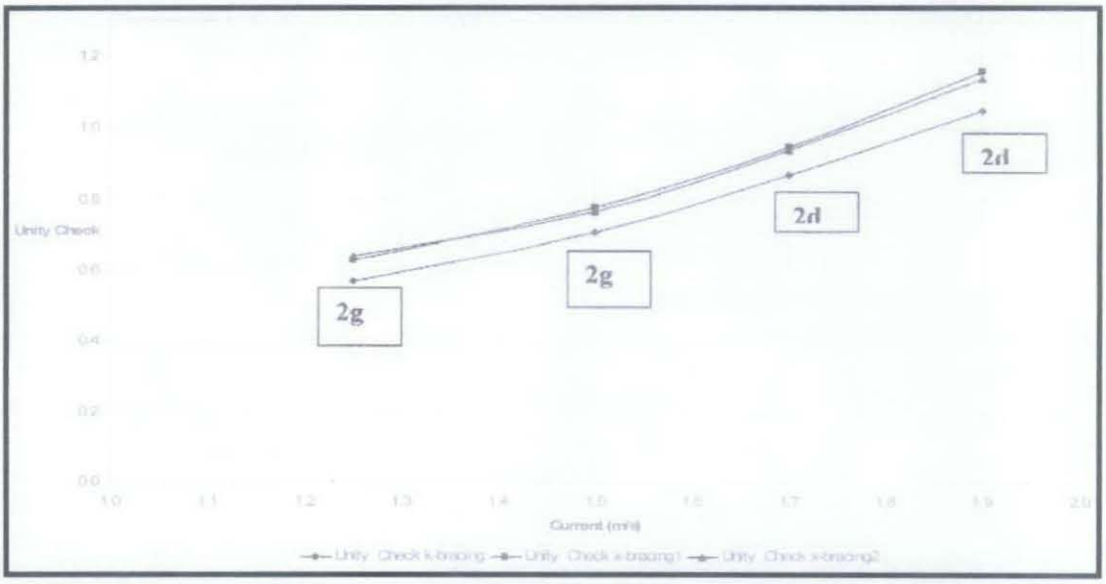

Figure 4.10: Unity Check (UC) versus Current (m/s)

From **Figure 4.10**, we can see that the unity check is increased with the current. The location of higher unity check is at 2d and it is located at the bottom part of the jacket. However, bracing arrangement of k-bracing has shown the lowest unity check. Therefore, k-bracing is more suitable for this sensitivity study of current.

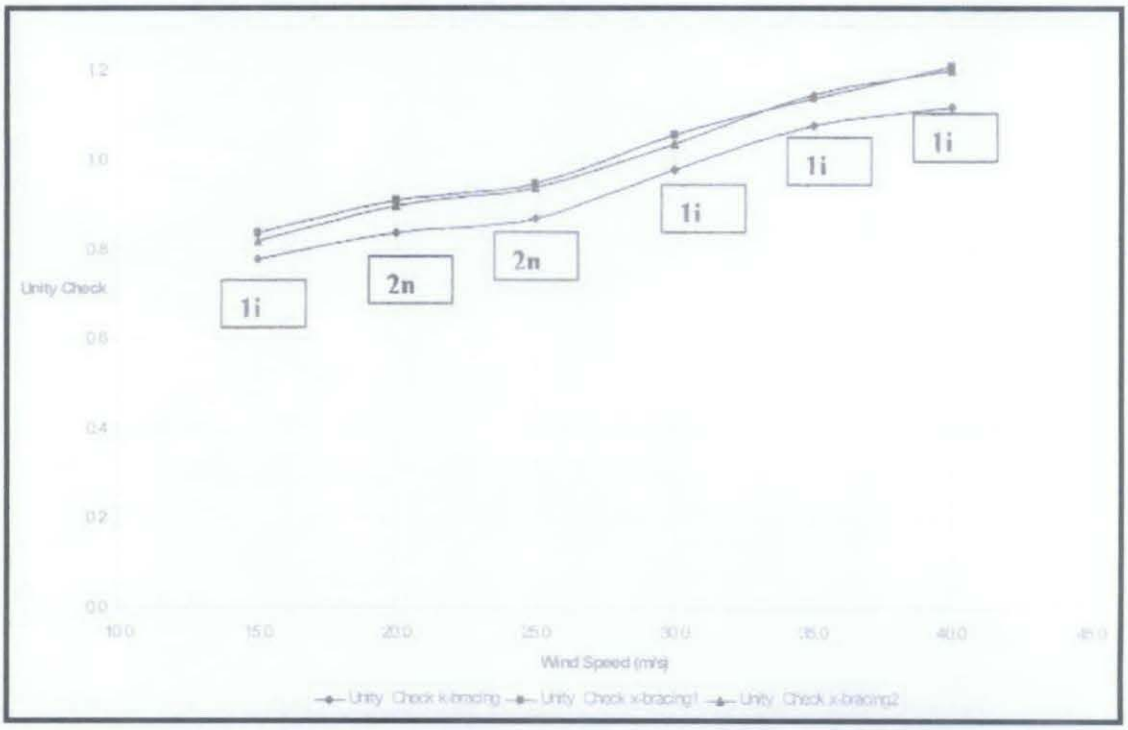

Figure 4.11: Unity Check (UC) versus Wind Speed (m/s)

From **Figure 4.11**, we can see that the unity check is increased with the wind speed. The location of higher unity check is at 1i and it is located at the upper part of the jacket. However, bracing arrangement of k-bracing has shown the lowest unity check. Therefore, k-bracing is more suitable for this sensitivity study of wind speed.

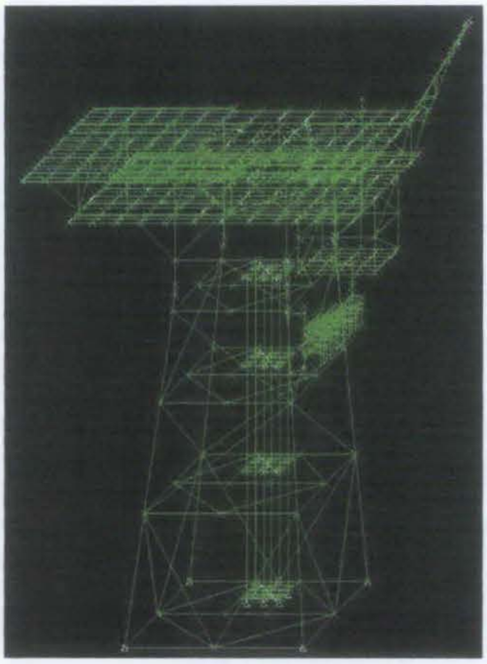

Figure 4.12: Model view of the Jacket structure

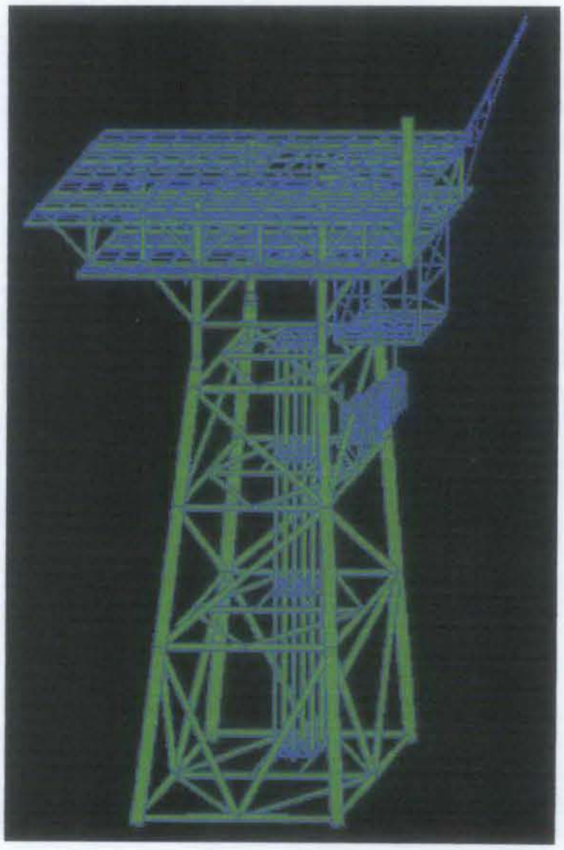

Figure 4.13: 3D solid view of the Jacket structure

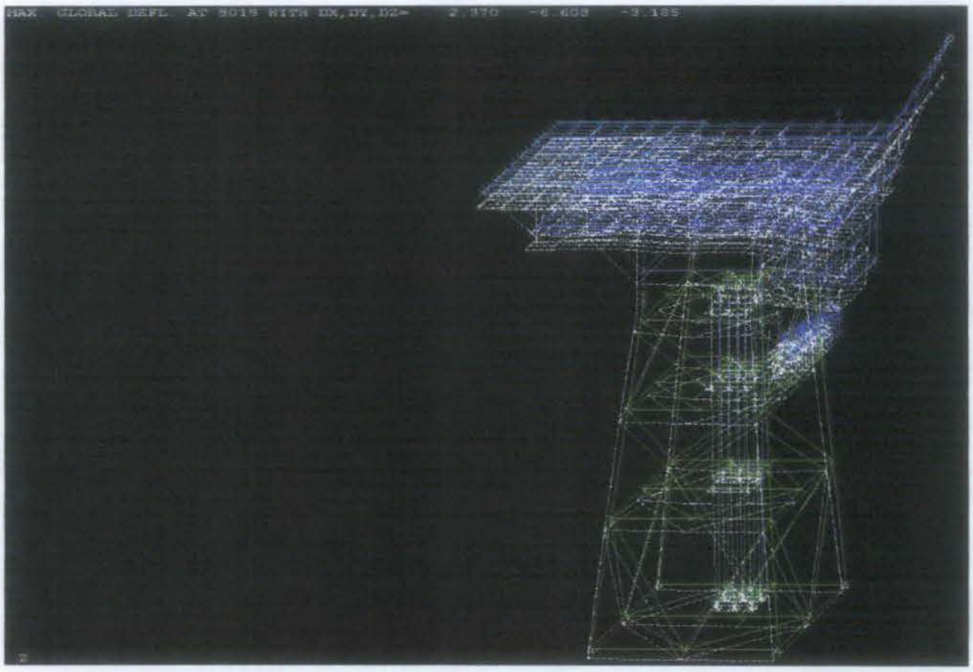

Figure 4.14: Deflection of the Jacket structure under environmental loads

From **Figure 4.14**, we can see that the deflection of the whole structure at x-axis is 3.186 cm while 6.608 cm for the y-axis. For this case, the data of deflection has shown the acceptable deflection for the whole structure.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The sensitivity study of environmental loads has been studied and it shows a variation of unity check (UC) contribution to the TOPAZ platform. Below are few conclusions obtained from this study.

1) The suitable bracing design for this platform is k-bracing and the cost for constructing this platform will definitely reduced because of least steel used.
2) The worst location of this platform is caused by wave loads.
3) The worst location of TPDP-A (TOPAZ) platform is at jacket structure and it is varied in leg and braces location.
4) The highest unity check in the k-bracing, x-bracing arrangement 1 and x-bracing arrangement 2 are 0.94, 1.16 and 1.15 accordingly.
5) The maximum deflection of this platform is 6.608 cm in y-axis.
6) The maximum deflection in x-axis of this platform is 3.186 cm.
7) Most of the highest unity check is due to the axial forces.
8) Earthquake analysis can be done by using SACS (Structural Analysis Computer System) software.

5.2 Recommendation

Throughout the study of sensitivity study on jacket structure offshore platforms, there are few things need to be considered and apply to improve the study of sensitivity study on environmental forces. The recommendations are;

1) A scale-down model should be built in order to do some experiments in the laboratory.
2) The experiments must be carried out in wave flume in order to further study about the deflection of the model platform.
3) A suitable material in making the scale-down model should be analyzed in order to have its strength, diameter, thickness, and the most important things is the deflection of the model can be analyzed.
4) The spreadsheet of environmental loads should be prepared in order to compare with the analysis in SACS software.
5) The further sensitivity study should be carried out in order to get the precise value and more accurate data for this project.
6) The graph of the sensitivity study should be varied in order to have clearer view of the presented data. The suggested graph is 3-dimensional graph.

REFERENCES

AISC, "Manual of Steel Construction – Allowable Stress Design", AISC-ASD 9th Edition 1989.

API, "Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms - Working Stress Design", API RP2A-WSD 21st Edition, December 2000.

Bea, R.G., Fellow, ASCE, 1996, "Nonlinear Performance of Offshore Platforms in Extreme Storm Waves", *Journal of Waterway, Port, Coastal and Ocean Engineering*, Vol 112, 68-74

Bea, R.G., Pawsey, S.F., Members, ASCE, and Litton R.W., 1991, "Measured and Predicted Wave Forces on Offshore Platforms", *Journal of Waterway, Port, Coastal and Ocean Engineering*, Vol 117, 511-532

Bea, R. G., and Young, C. N. (1993). "Loading and capacity effects on platform performance in extreme waves and earthquakes." *Proc., Offshore Tech. Conf, OTC NO. 7140,* Vol. 3, Offshore Technology Conference, Richardson, Tex., 1 - 16.

Borgman, L. E., and Yfantis, E. (1979). "Three-dimensional character of waves and forces." *Proc. Civ. Engrg. Oceans IV,* 2, ASCE, 791-804.

Chakrabarti S.K., Handbook of Offshore Engineering, Vol. I, Offshore Structure Analysis, Inc., Plainfield, Illionois, USA, 2005

Design Parameters and Environmental Data for Topaz Development Project, Rev. 1, 5th October 2007.

Donald F. Young and Theodore H. Okiishi, A Brief Introduction to Fluid Mechanics, 3rd edition, Wiley, 2004

Forristall, G. Z. (1974). "Three-dimensional structure of storm generated currents." *J. Geophys. Res.,* 79(18), 101-123.

George, Z. Forristall, 2004, "On the Use of Directional Wave Criteria", *Journal of Waterway, Port, Coastal and Ocean Engineering,* Vol 130, 270-275

Geotechnical Site Investigation – Pearl Location, Block 01, Offshore Vietnam, S.R. Vietnam by Fugro Singapore Pte. Ltd., Report No: 06011S-1 for Petronas Carigali Vietnam Ltd, 1 August 2006.

Hahn, G.D., Member, ASCE, 1995, "Concepts for Wave-Excited Offshore Structures", *Journal of Structural Engineering,* Vol 121, 1427-1435

Hong, H.P., Nessim, M.A. and Jordaan, I.J, 1999, "Environmental Loads Factors for Offshore Structures" *Journal of Offshore Mechanics and Arctic Engineering,* Vol 121, 261-267

Paliou, C., Shinozuka, M., and Chen, Y.N., 1990, "Reliability and Redundancy of Offshore Structures", *Journal of Engineering Mechanics,* Vol116, 359-379

PETRONAS, "Design of Fixed Offshore Structures", PTS 20.073, December 1983 and "Supplementary to PTS 20.073", Rev. 4, August 2005.

APPENDICES

APPENDIX A
CALCULATION

Wind Speed Calculation (TPDP-A (TOPAZ) Platform)

Wind Criteria

1 hour wind speed at 32.8ft (10m) above sea level , U_0 = 21 m/s = 68.90 ft/s

Reference height, z_0 = 10 m = 32.8 ft

Gust period, t = 60 sec

$$\therefore u(z,t) = u(z) \times [1 - 0.41 x I_u(z) x \ln(t/t_0)]$$
$$where, u(z) = u_0 \times [1 + c \times \ln(z/32.8)]$$
$$c = 5.73 \times 10^{-2} \times [1 + 0.0457 \times U_0]^{\frac{1}{2}}$$
$$I_u(z) = 0.06 \times [1 + 0.0131 \times U_0] \times (z/32.8)^{-0.22}$$

Design wind speed,

For direction X and Y at elevation 21.5m → 70.5 ft

$$I_u(z) = 0.06 \times [1 + 0.0131 \times 68.90] \times (70.5/32.8)^{-0.22} = 0.0965$$
$$c = 5.73 \times 10^{-2} \times [1 + 0.0457 \times 68.90]^{\frac{1}{2}} = 0.1167$$
$$u(z) = 68.90 \times [1 + c \times \ln(70.5/32.8)] = 75.05$$
$$u(z,t) = 75.05 \times [1 - 0.41 x 0.0965(z) x \ln(60/3600)] = 87.20 ft/s = 26.6 m/s$$

For direction X and Y at elevation 21.513.25m → 43.5 ft

$$I_u(z) = 0.06 \times [1 + 0.0131 \times 68.90] \times (43.5/32.8)^{-0.22} = 0.1073$$
$$c = 5.73 \times 10^{-2} \times [1 + 0.0457 \times 68.90]^{\frac{1}{2}} = 0.1167$$
$$u(z) = 68.90 \times [1 + c \times \ln(43.5/32.8)] = 71.16$$
$$u(z,t) = 71.16 \times [1 - 0.41 x 0.1073(z) x \ln(60/3600)] = 83.98 ft/s = 25.6 m/s$$

Then, calculate the wind force, $F = (\rho/2)u^2 C_s A$; $\rho = 1.226$ kg/m^3

1) For direction X at elevation 21.5 m

Height = 6 m

Width = 20.6 m

C_s = 1.0 for total projected area of platform

A = 6 m x 20.6 m = 123.60 m^2

$$F = \left[\left(\frac{1.226}{2}\right) \times 26.6^2 \times 1.0 \times (123.60)\right] \Big/ 1000 = 53.60kN$$

2) For direction X at elevation 13.25 m

Height = 10.5 m

Width = 7.0 m

C_s = 1.0 for total projected area of platform

A = 10.5 m x 7.0 m = 73.5 m^2

$$F = \left[\left(\frac{1.226}{2}\right) \times 25.6^2 \times 1.0 \times (73.50)\right] \Big/ 1000 = 29.53kN$$

3) For direction Y at elevation 21.5 m

Height = 6 m

Width = 47.766 m

C_s = 1.0 for total projected area of platform

A = 6 m x 47.766 m = 286.60 m^2

$$F = \left[\left(\frac{1.226}{2}\right) \times 26.6^2 \times 1.0 \times (286.60)\right] \Big/ 1000 = 124.12kN$$

4) <u>For direction Y at elevation 13.25 m</u>

Height = 10.5 m

Width = 11.0 m

C_s = 1.0 for total projected area of platform

A = 10.5 m x 11.0 m = 115.50 m^2

$$F = \left[\left(\frac{1.226}{2} \right) \times 25.6^2 \times 1.0 \times (115.50) \right] \Big/ 1000 = 46.39 kN$$

Therefore, Total F_x= 53.6 kN + 29.53 kN = <u>83.13 kN</u>

Total F_y= 124.12 kN + 46.39 kN = <u>170.51 kN</u>

Current Calculation (TPDP-A (TOPAZ) Platform)

From the Metocean data,

At,

Elevation above mudline (m)	Current velocity (m/s)
0.41	0.4
2.05	0.6
20.55	1.3
39.04	1.6
41.10	1.7

Thus, current force

$\rho = 1000$ kg/m^3 ; outside diameter of leg = 163 cm ; r = 81.5 cm = 0.815 m

$$F_{0.41m} = \left[\left(\frac{1000}{2}\right)\times 0.4^2 \times 1.0 \times (2\pi \times 0.815m \times 0.41)\right] \Big/ 1000 = 0.17kN$$

$$F_{2.05m} = \left[\left(\frac{1000}{2}\right)\times 0.6^2 \times 1.0 \times (2\pi \times 0.815m \times 2.05)\right] \Big/ 1000 = 1.89kN$$

$$F_{20.55m} = \left[\left(\frac{1000}{2}\right)\times 1.3^2 \times 1.0 \times (2\pi \times 0.815m \times 20.55)\right] \Big/ 1000 = 88.92kN$$

$$F_{39.04m} = \left[\left(\frac{1000}{2}\right)\times 1.6^2 \times 1.0 \times (2\pi \times 0.815m \times 39.04)\right] \Big/ 1000 = 255.89kN$$

$$F_{41.10m} = \left[\left(\frac{1000}{2}\right)\times 1.7^2 \times 1.0 \times (2\pi \times 0.815m \times 41.10)\right] \Big/ 1000 = 304.12kN$$

Wave Calculation (TPDP-A (TOPAZ) Platform)

Morison's Equation

$$F = C_M \frac{\rho \pi D^2}{2} v' + C_D \frac{\rho D}{2} v \mid v \mid$$

C_M = inertia coefficient (for slender structures)

v' = acceleration (m/s^2)

v or |v| = horizontal velocity (m/s)

F = wave force per unit length on a circular cylinder (N)

H = wave height = 7.6 m

T = wave period = 8.3 s

L = cT , c = 0.6 m/s, Member diameter = 163 cm = 1.63 m

= (0.63 m/s) x 8.3 s

= 4.98 m

(D/L) = 1.63/ 4.98 = 0.3273

D = member diameter

L = wave length

C_D = Normal drag coefficient for clean members = 0.65

C_M = Normal inertia coefficient for clean cylinders = 1.6

$$F = \left[(1.6) \times \left(\frac{(1000 kg/m^3) \times \pi \times 1.63^2}{4} \right) \times \left[(0.6 m/s) \times \frac{1}{8.3 s} \right] \right] +$$
$$\left[0.65 \times \left(\frac{1000 kg/m^3 \times 1.63}{2} \right) \times 1.6 \times 1.6 \right]$$
$$= 241.36 + 1356.16$$
$$= 1597.52 kg = 15671.67 N$$
$$= 15.67 kN$$

APPENDIX B

DATA OF SENSITIVITY GRAPH

Table for Unity Check (UC) versus Wave Height (m) at current = 0.7

Unity Check K-bracing	Unity Check X-bracing1	Unity Check X-bracing2	H At current = 0.7 m/s	Member with higher UC for K-bracing
0.87	0.95	0.94	14.70	2d
0.71	0.78	0.77	12.70	2d
0.57	0.63	0.64	10.70	2d
0.44	0.54	0.55	8.70	2e
0.35	0.44	0.43	6.70	2e
0.34	0.32	0.31	4.70	2d
0.34	0.32	0.31	2.70	2d
0.34	0.32	0.31	1.70	2d
0.00	0.00	0.00		

Table for Unity Check (UC) versus Wave Height (m) at current = 1.0

Unity Check K-bracing	Unity Check X-bracing1	Unity Check X-bracing2	H At current = 1.0 m/s	Member with higher UC for K-bracing
0.89	0.96	0.95	14.70	2d
0.74	0.79	0.76	12.70	2d
0.62	0.65	0.64	10.70	2d
0.48	0.56	0.53	8.70	2e
0.37	0.47	0.43	6.70	2e
0.35	0.33	0.33	4.70	2d
0.35	0.33	0.33	2.70	2d
0.35	0.33	0.33	1.70	2d
0.00	0.00	0.00		

Table for Unity Check (UC) versus Wave Height (m) at current = 1.3

Unity Check K-bracing	Unity Check X-bracing1	Unity Check X-bracing2	H At current = 1.3 m/s	Member with higher UC for K-bracing
0.88	0.97	0.96	14.70	2d
0.73	0.81	0.80	12.70	2d
0.58	0.67	0.65	10.70	2d
0.46	0.57	0.56	8.70	2e
0.38	0.49	0.46	6.70	2e
0.36	0.34	0.33	4.70	2d
0.36	0.34	0.33	2.70	2d
0.36	0.34	0.33	1.70	2d
0.00	0.00	0.00		

Table for Unity Check (UC) versus Wave Period (m/s) at current = 0.7

Unity Check K-bracing	Unity Check X-bracing1	Unity Check X-bracing2	H At current = 0.7 m/s	Member with higher UC for K-bracing
0.93	1.14	1.13	14.30	1b
0.89	0.97	0.95	12.30	1b
0.86	0.94	0.93	10.30	2d
0.88	0.91	0.91	8.30	2d
0.94	0.96	0.95	6.30	2d
1.09	1.10	1.08	4.30	2d
0.00	0.00	0.00		

Table for Unity Check (UC) versus Wave Period (m/s) at current = 1.0

Unity Check K-bracing	Unity Check X-bracing1	Unity Check X-bracing2	H At current = 1.0 m/s	Member with higher UC for K-bracing
0.94	1.15	1.14	14.30	1b
0.90	0.98	0.97	12.30	1b
0.87	0.96	0.95	10.30	2d
0.87	0.93	0.91	8.30	2d
0.96	0.97	0.96	6.30	2d
1.11	1.11	1.11	4.30	2d
0.00	0.00	0.00		

Table for Unity Check (UC) versus Wave Period (m/s) at current = 1.3

Unity Check K-bracing	Unity Check X-bracing1	Unity Check X-bracing2	H At current = 1.3 m/s	Member with higher UC for K-bracing
0.94	1.16	1.15	14.30	1b
0.90	0.99	0.98	12.30	1b
0.87	0.98	0.97	10.30	2d
0.93	0.95	0.93	8.30	2d
1.03	0.98	0.96	6.30	2d
1.13	1.13	1.13	4.30	2d
0.00	0.00	0.00		

Table for Unity Check (UC) versus Wind Speed (m/s)

Unity Check K-bracing	Unity Check X-bracing1	Unity Check X-bracing2	V Wind Speed (m/s)	Member with higher UC for K-bracing
0.78	0.84	0.82	15.00	1i
0.84	0.91	0.90	20.00	1i
0.87	0.95	0.94	25.00	1i
0.98	1.06	1.04	30.00	2n
1.08	1.14	1.15	35.00.	2n
1.12	1.21	1.20	40.00	1i
0.00	0.00	0.00		

Table for Unity Check (UC) versus Current (m/s)

Unity Check K-bracing	Unity Check X-bracing1	Unity Check X-bracing2	C Current (m/s)	Member with higher UC for K-bracing
1.05	1.16	1.14	1.90	2d
0.87	0.95	0.94	1.70	2d
0.71	0.78	0.77	1.50	2g
0.57	0.63	0.64	1.25	2g
0.00	0.00	0.00		

Table for Unity Check (UC) versus Diameter ratio

Unity Check K-bracing	Unity Check X-bracing1	Unity Check X-bracing2	Dimension Leg	Dimension Leg (cm)	Member with higher UC for K-bracing
1.13	1.23	1.19	0.88	147.30	2d
1.04	1.12	1.09	0.91	152.40	2d
0.87	0.95	0.94	1.00	167.60	2d
0.78	0.85	0.88	1.09	182.90	1b
0.71	0.76	0.85	1.18	198.10	1b
0.00	0.00	0.00			

Table for Unity Check (UC) versus Thickness ratio

Unity Check K-bracing	Unity Check X-bracing1	Unity Check X-bracing2	Dimension Leg	Dimension Leg (cm)	Member with higher UC for K-bracing
0.98	1.08	1.12	0.012	20.00	2d
0.87	0.95	0.94	0.018	30.00	2d
0.84	0.91	0.90	0.024	40.00	2d
0.82	0.88	0.87	0.030	50.00	2d
0.78	0.84	0.83	0.036	60.00	2g
0.75	0.79	0.79	0.042	70.00	2g
0.72	0.75	0.76	0.048	80.00	2g
0.00	0.00	0.00			