Structural Responses of Kumang Cluster Jacket Platform Subject to Seismic Ground Acceleration and Wave Forces

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DISSERTATION

David Flöck, Exchange Student, (20504)

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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750Tronoh
Perak Darul Ridzuan,

MALAYSIA

FH Mainz – University of Applied Sciences
Holzstraße 36
55116 Mainz,

GERMANY

CERTIFICATION OF ORIGINALTY

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.

DAVID FLÖCK

CERTIFICATION APPROVAL

Structural Response of Kumang Cluster Jacket platform subject to seismic ground acceleration and wave force

by

David Flöck

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Assoc. Prof. Ir. Dr. Mohd Shahir Liew

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ABSTRACT

In this paper, the effect of seismic ground acceleration on offshore platforms in the Malaysian waters will be investigated. In the Malaysian region of South China Sea, the conventional practice applied to design offshore structures is to assume that forces induced on the offshore structures due to waves control the overall response of the structures. Seismic analysis is not conducted since Malaysia is not located in a seismic sensitive zone. Local standards have been lacking in recommendation to include seismic ground motion in the design. However, recent earthquake events from far field have been felt by the platform operators in Malaysia waters and new perceptions in the field question the validity of this assumption. A row of computer driven dynamic spectral earthquake analyses will be carried out for a jacket-type fixed offshore platform (Kumang Cluster F9JT-a) using the finite element software SACS. By incrementally changing the inputs for ground acceleration, the dynamic behaviour of the 3D model of the platform is then investigated. The result will define the threshold, at which the ground motion induced forces control the structure. Further, a combined analysis of both seismic and wave forces will be carried out, as to define how the two differently induced forces contribute to the resulting stresses and deflection of structural members respectively. Lastly, the integrity of the structure will be determined by defining return periods for significant earthquake events.

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1. INTRODUCTION

This report deals with the issue of the integration of seismic criteria in the design of offshore structures, located in Malaysian waters of the South China Sea.

In the following, the introduction will explain the background, state the problems attached and define the objectives and scope of study. Furthermore, this report includes a literature review on related topics, an explanation of the methodology used, and discussions of the results. In the end it will conclude all results and give a recommendation on how to handle the issue.

1.1 Background

In the past years severely damaging earthquakes have proven what impacts the forces, induced by the ground acceleration, have on all structures. Kumang Cluster F9JT-A Platform is located in Sarawak, in the eastern territories of Malaysia. Although no Malaysian regions, neither onshore nor offshore, can be defined as seismically active, platform operators have felt impacts from far field earthquakes originating for example in the Sumatra Subduction Zone and Sumatra fault, which are heavily seismic active zones. Short period compression waves triggered from earthquakes in these regions travel far underground. Rigid structures, such as a Jacket Type offshore structure, are especially prone to these types of waves due to their fundamental period. However, lack of data on seismic activity for the South China Sea makes it hard to evaluate the risk of earthquakes.

A collapse of an offshore oil production structure would be a major environmental hazard and has to be prevented at all costs. Hence, to ensure a structures integrity it is important to check which criteria control the design. Usually design criteria are based on assumptions considering this fact.

For offshore structures in the South China Sea there are three important standards defining the design criteria for the regions: The *PETRONAS Technical Standard* (PTS) implemented and revised regularly by PETRONAS Carigali, one of the main employer in the offshore oil and gas industry of Malaysia, the *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Working Stress* implemented and revised by the American Petroleum Institute (API) and lastly different ISO standards (e.g. *ISO 19902:2007*, *ISO 19901-02:2004*).

In Malaysian region of the South Asian Sea seismic design is mostly neglected. This is due to the fact that the PTS consulted for offshore projects in this area do not include any recommendation on seismic design. So far this was justified by assuming that wave forces, control the design of structures.

1.2 Problem Statement

Recent research justifies questioning the assumption that seismic criteria can be neglected completely in the design of offshore platforms. One research states that ocean waves do not always act as a damping medium for seismic loads as was assumed so far. Seismic and ocean waves acting simultaneously in different direction might even increase each other's impacts. In addition, the *Seismic Hazard Study for offshore Sabah, Sarawak and West Malaysia* carried out by the Italian consultancy D'Appolonia found values to describe the seismic activity and return period for seismic activities. These values update and exceed the so far utilized values from ISO or GSHAP (Global Seismic Hazard Assessment Program).

Hence, it cannot be said with accuracy if the assumption made so far is correct, or if seismic ground motion already is of a magnitude that it can harm the structure.

1.3 Objectives and Scope of Study

1.3.1 Objective One

Ascertaining threshold on controlling ground acceleration versus wave forces.

The structure will be analysed in twos steps:

1) Computer driven static analysis will be carried. By applying loads caused by operating wave a threshold will be defined.

2) By conducting incremental computer driven dynamic earthquake analysis a threshold acceleration will be ascertained at which ground motion causes the similar responses as operating wave forces.

1.3.2 Objective Two

Study on combined effects of ground acceleration with wave forces.

By applying both static equivalent earthquake forces and wave induced forces the combined effects can be studied. The effects will be compared to responses induced under different conditions, and the structures safety evaluated.

1.3.3 Objective Three

Determining the integrity of the platform subject to seismic loads using values recommended by 'D'Applonia Report'.

Determining the probability of an earthquake with the magnitude to reach the threshold acceleration using data from the D'Appolonia Report on 'Seismic Hazard Study for Offshore Sabah, Sarawak and West Malaysia' and extreme values distribution.

2 LITERATURE REVIEW

2.1 Seismicity and Earthquakes

Seismicity is the field that deals with the movements of the outer most layer of the earth, the stratum. It is separated into many different parts, the tectonic plates which are constantly moving on the liquid core of the earth. Under normal circumstances those movements are not perceptible but under special conditions the earth's tremors are not only perceptible but can have devastating impacts on buildings and structures. These events are called earthquakes.

In its briefing papers the ATC/SEAOC Joint venture, published in 1999 deals among others with the origins of these seismic activities and especially earthquakes. It describes their origin, spread, characteristics and factors. Although it is older than ten years in terms of recentness, it can still be considered contemporary. Also, the two publishers that provided this paper ('*American Technology Council'* and '*Structural Engineers Association Of California'*) are knowledgeable organisation which allows to evaluate the reference as reliable.

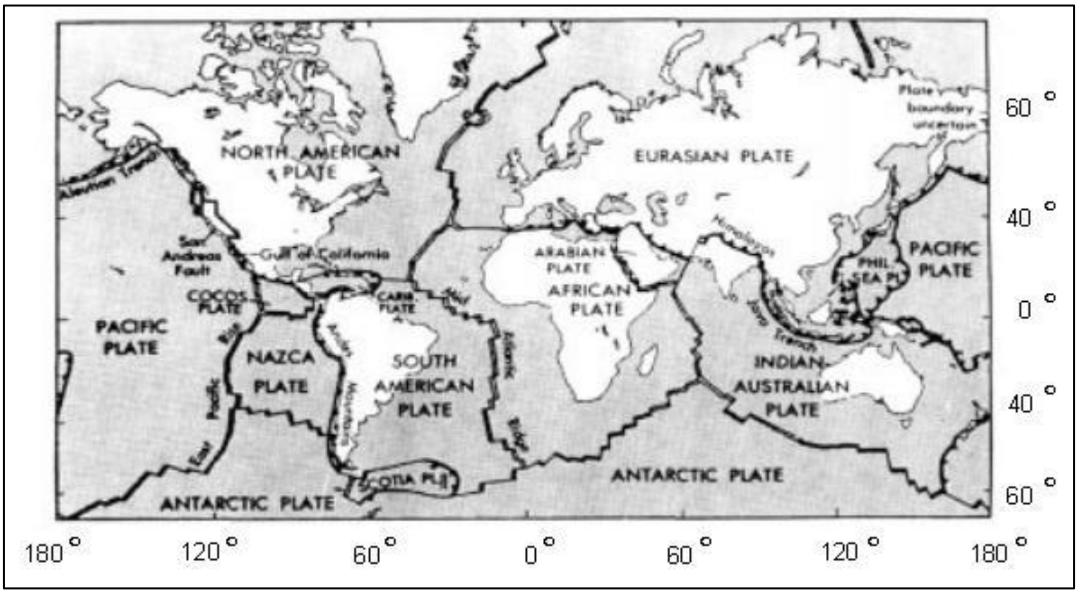

Figure 2 - 1 Tectonic Plates and Boundaries

The '*briefing paper A'* states that earthquakes mostly origin from faults within the outer crust. The majority of these faults can be found at the boundaries of the different sections of the crust, the tectonic plates, (Figure 2-1) but new faults are continuously discovered usually after unexpected earthquakes. (ATC/SCEAOC, Part A, 1999)

Furthermore, it states that earthquakes travel through the stratum´s surface like the waves created if you drop a pebble into still water. (ATC/SCEAOC, Part A, 1999) If you compare this to what D. Adam und I. Paulmichl state in their article on *'Earthquake – soil-structure interaction'* published in an Austrian engineering magazine in 2010 you will realize this is true only for special kinds of ground waves. All in all, they differentiate between four types of waves:

- Longitudinal compression waves (P-waves)
- Transverse distortional waves (S-waves)
- Rayleigh waves (R-waves)
- Love waves (L-waves)

Both P-waves and S-waves are so called body waves and travel within the ground whereas R-waves and L-waves travel at the surface of the earth's crust.

They further state that in greater distances to the hypocenter usually the R-waves have the biggest impact on structures and buildings. These waves emerge due to the interference of the compression waves and the vertically polarized distortional waves. They are often described as the *'rolling tremor'* during an earthquake and are very destructive as they can exceed any other wave's amplitude. (Adam et al., 2010)

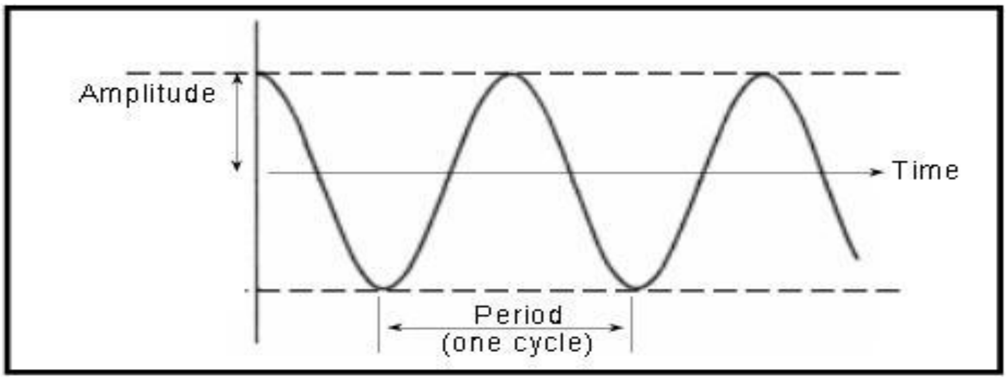

Figure 2 - 2 Relationship of Amplitude and Period

All waves, according to the ATC/SCEAOC briefing paper, have two main characteristics to describe them: their amplitude (size) and their period(time) (see Figure 2-2). (ATC/SCEAOC, Part A, 1999)

These characteristics are influenced by three major factors: the distance to the hypocenter of the earthquake, the magnitude of the total released energy and the geological conditions at the site, the type of soil or rock. (ATC/SCEAOC, Part A, 1999)

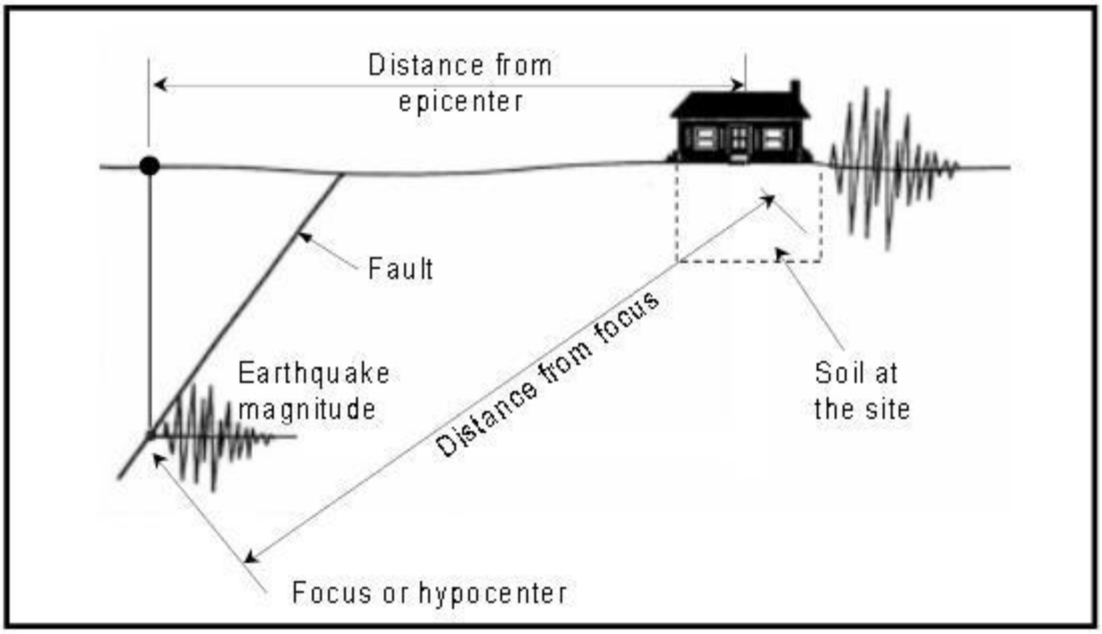

Figure 2 - 3 Earthquake Characteristics

2.2 Seismicity in Malaysia

2.2.3 Seismicity in Malaysia

The location of Malaysia on the Eurasian-Sunda Plate can, in general, be defined as stable. The ground acceleration detected in Malaysia is of a low or moderate magnitude according to ISO 19901-2, depending on the research the acceleration value is taken from. Nevertheless, buildings on soft soil can occasionally be subjected to earthquake tremors. This is a consequence to far-field effects of earthquakes in two earthquake faults in Indonesia: the Sumatra subduction zone and the Sumatra Fault. (Belandra et al., 2008; ISO, 2004).

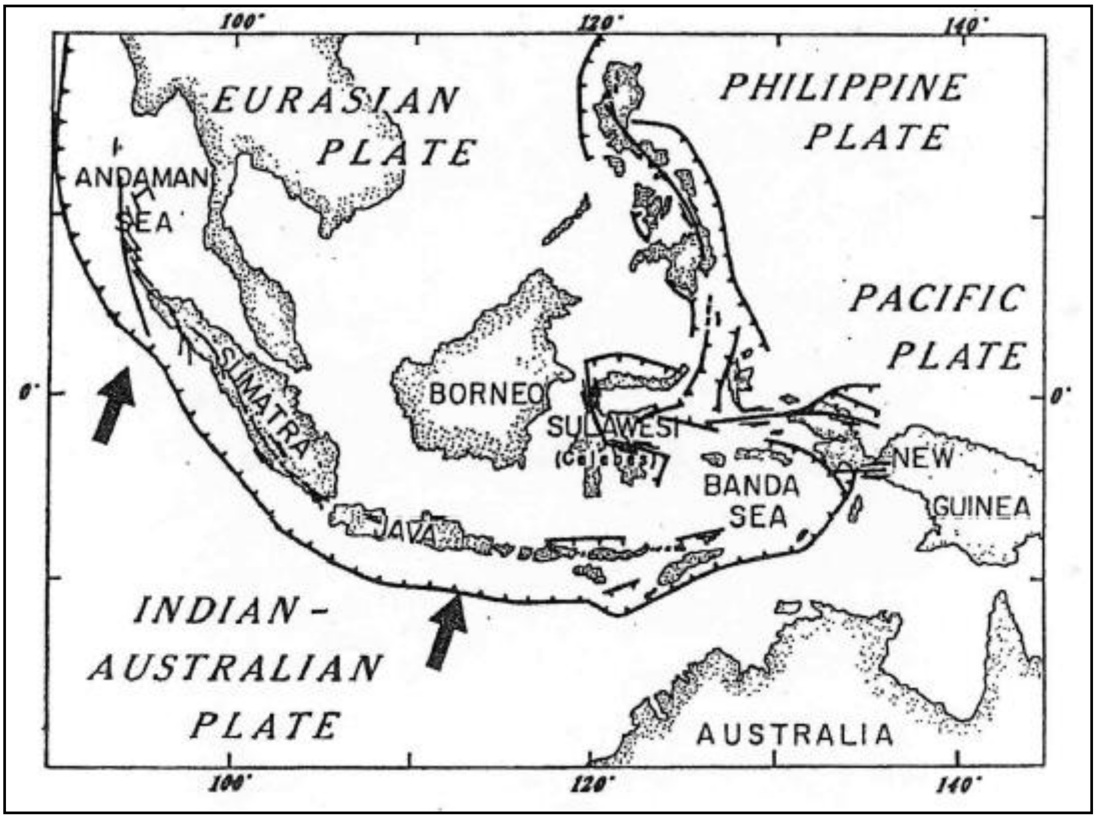

Figure 2 - 4 Sumatra Fault and Subduction Zone

The worst case earthquake scenarios described by Belandra et al. are a M_w =9.5 for the Sumatra subduction zone, and a M_w =7.8 for Sumatra fault. (Belandra et al., 2008).

Furthermore, the member of the Department of Civil Engineering of the National University of Singapore explains that Malaysia is mostly affected by low frequency, as the long period (high frequency) waves are damped out before they reach Malaysian territories. Their robustness to energy dissipation of low frequency waves allows them to travel farther distances. These waves are amplified due to resonance immensely if they travel through soft soils in Peninsula Malaysia. If the structures the waves encounter possess a natural period close to the one of the waves, resonance is caused and the residence can feel the effects of the earthquake. (Belandra, 2008).

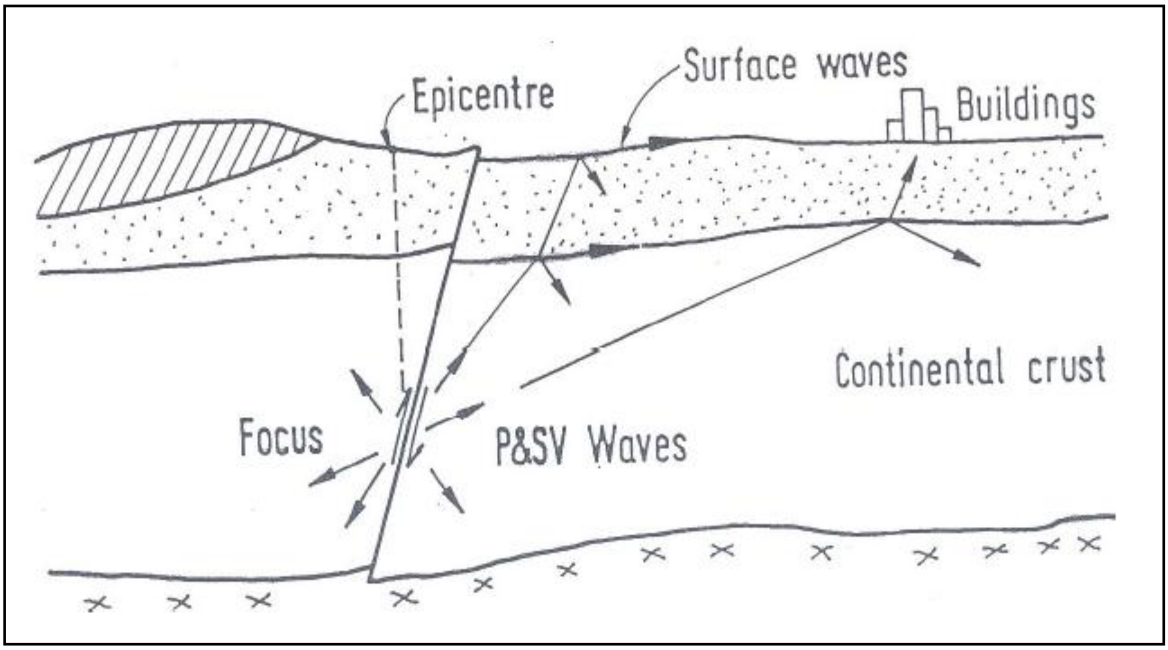

Figure 2 - 5 Far-Field Effect

Still the general hazard risk across Malaysia can be described as low to moderate, although the hazard across Sumatra is higher due to the proximity of the two earthquake-causing structures and although the hazard of Malaysia is hard to assess due to inadequate attenuation relations. (Petersen, et al., 2004).

2.2.3 Seismicity in Offshore Malaysia

Just recently, in 2008, the Italian consultant *'D'Appolonia'* investigated in the field of seismic activities in five Malaysian territories of the South China Sea. On Behalf of Shell and PETRONAS Carigali, the two most important operator in the business for that region, they carried out a *Probabilistic Seismic Hazard Assessment* (PSHA) and thereby achieved three aims: they established a framework for seismic design criteria, developed a seism tectonic model applicable for the wide range of interest and finally performed the PSHA. Thereby they found values for the peak ground acceleration (PGA). (Poggi et. Al., 2008)

But still the prediction of values for some of the regions was still hard to find due to a lack of monitoring and knowledge on seismic activities. Thus the consultant came up with a logic tree that closes these gaps and allows defining values of a minimal accuracy.

The main conclusions of the study for the Sarawak Region are:

- PGA for a 475 year return period is 0.04-0.044 g;
- PGA for a 1000 year return period is 0.071 g;
- PGA for a 2475 year return period is 0.122 g
- The ratio of spectral acceleration at 5 Hz to PGA is of the order 1.4;
- The predicted mean values by this PSHA (at5 Hz 0.097 g) are nearly two times the values suggested by ISO (at 5 Hz 0.05);
- The values are higher than those from Global Seismic Hazard Assessment Program (GSHAP);
- Due to lack of knowledge and monitoring of seismic activity there is an uncertainty to the values.

(Poggi, P et. al, 2008; ISO, 2004; McCue, 1999)

2.3 F9JT - A Kumang Cluster Jacket Type Platform.

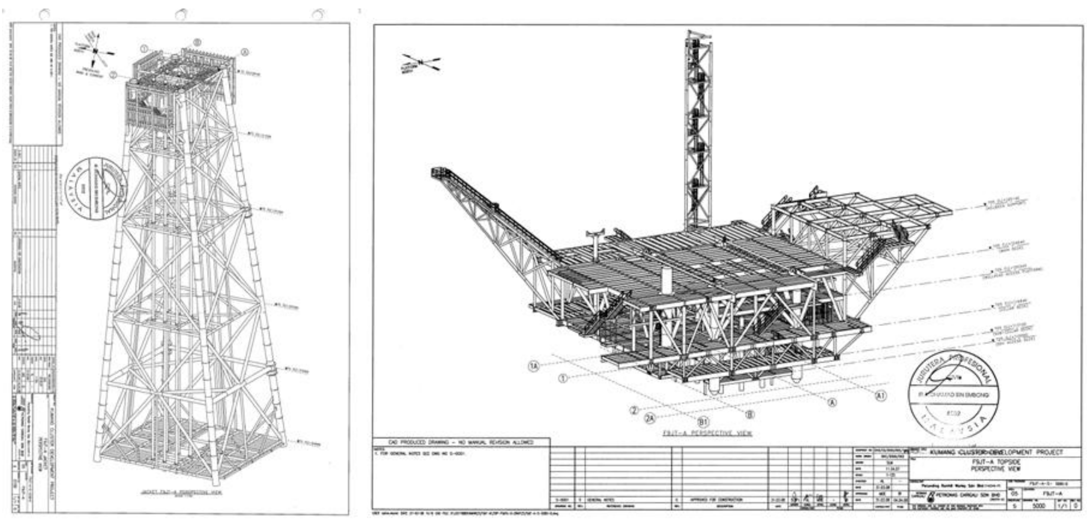

Figure 2 - 6 F9JT - A Jacket and Topside

F9JT-A, the platform that is used for this research, is a typical Jacket-type fixed offshore platform. The 1,380 MT heavy substructure consists of four (4) legs that are interconnected in order to form a three-dimensional truss. It operates in shallow water (water depth of 94.8 m) and is designed for unmanned operation. The Topside consists of six decks (heli deck, main deck, mezzanine Deck, cellar deck, sub cellar deck and SDV access deck), and the total area of the main deck is approximately 1,169.93 m^2 and the weight 1,350 MT. It was designed by MMC Oil & Gas Engineering Sdn. Bhd. for the client PETRONAS Carigali Sdn. Bhd. in Kumang field, which is located about 200 km from the MLNG plant offshore Bintulu, Sarawak. Its location allows to take D'Appolonia's values at the Master Point of the Sarawak field. (MMC, 2013; Ranhill Worley, 2008; Poggi et. Al., 2008).

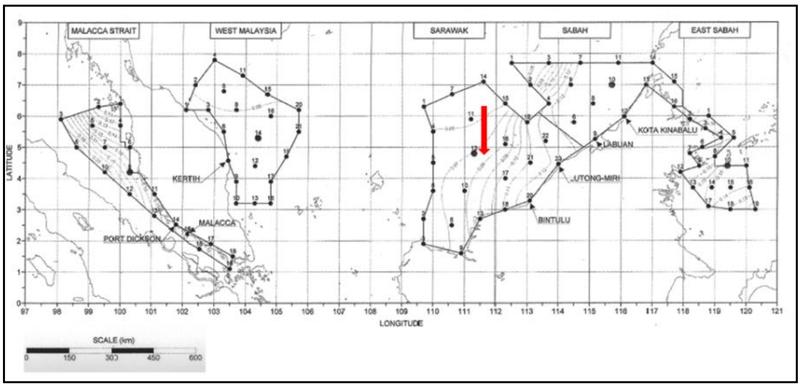

Figure 2 - 7 Location of Kumang Cluster

2.4 Standards and Regulations

Usually, standards and regulations have a simple task: they shall recommend approaches to design and produce the craft. They mostly are based on research, axioms or experience in the respective field. Companies and organizations providing such standards and regulations mostly are either responsible to just provide these papers (e.g. ISO) or they are specialized in the field (e.g API, PETRONAS Carigali). Furthermore they are revised in regular intervals to meet the newest state of the art. (PTS, 2010)

For offshore projects in Malaysian territories of the South China Sea, there are different standards used: the *PETRONAS Technical Standards* (PTS, currently Revision number 6) and the *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Working Stress* (21 st Edition 2007). Both of them explain approaches to design offshore structures, from start of planning phase to the end of the installation phase.

In contrary to the API standard, the PTS does not include any seismic design. It does state that if it is incomplete other standards should be consulted, but not, if this is necessary for seismic loadings. The API on the other hand includes a chapter on seismic design. It states among others recommendation on preliminary considerations, strength requirements and ductility requirements for dealing with earthquake loadings. It defines two earthquake events to which a structure has to be safe to different extends. The strength earthquake requirements are checked at a Ground acceleration corresponding to a 100 to 200 year return period (SLE), whereas the ductility check is done for an 1,000 to 5,000 year return (DLE). (Abraham, 2005; API, 2005)

The last part of this chapter deals with chapter 11 of ISO 19902:2007. It elaborates on seismic design considerations. It explains that a two-level seismic design procedure should be applied: first the structure's strength and stiffness should be designed for ultimate limit state (ULS). The loads the platform is subjected to should be from an extreme level earthquake (ELE) which is equivalent to API's SLE. Under these conditions the platform should encounter little or no damage. The second check following is on the reserve strength of the structure. The platform should be designed in a way that it provides a reserve in strength and energy dissipation requirements even if subjected to abnormal earthquake loads (ALE) which is equivalent to API's DLE. Although the structure may suffer substantial damage, structural failures that could cause loss of life and harm the environment should not occur. (ISO, 2007)

2.5 Responses of Structures to Seismic Forces.

2.3.1 General

A structure has to withstand different types of loadings during an earthquake. Predominantly these forces are horizontal, or lateral forces. Admittedly, an earthquake also induces vertical forces into a structure, but those are only considered in special cases as it mostly can be assumed that the structures self weight can counteract these forces. (ATC/SEAOC, Part B, 1999)

The magnitude of the loads imposed onto the structure can be derived from *Newton's second law of motion*, $F = m * a$, which relates the imposed force (F) to the total mass (m) of all the structure's elements (structural and non-structural) and the horizontal acceleration (a) due to seismic activity. This ground acceleration is expressed as a fraction of the gravitational acceleration (g) (9.81$^{m}/_{s^2}$). (ATC/SEAOC, Part B, 1999).

For the design of a building structure, it is important to consider that seismic forces do not just act in one direction. It can be assumed that the horizontal forces will split into forces acting in orthogonal directions (e.g. x-Axis and y-Axis). The forces acting along the direction of walls are called in-plane whereas the forces acting orthogonal to the walls are called out of plane forces. (ATC/SEAOC, Part B, 1999).

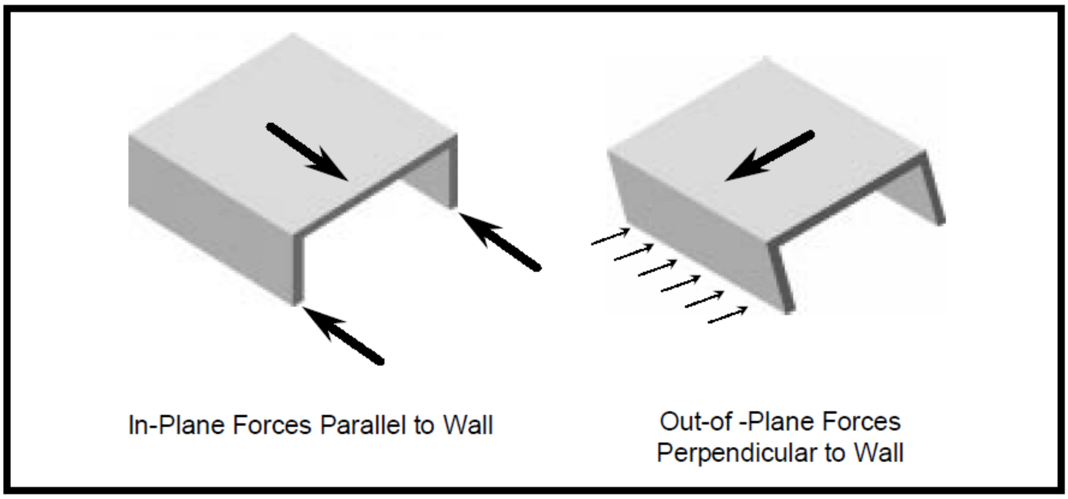

Figure 2 - 8 Lateral Earthquake Forces

The definition of the forces acting on a building is rather straight forward, whereas the definition of the responses is somehow harder. To generalize them is shear impossible as they are dependent on the specific response characteristics of the structural system used. Two central factors are the fundamental period of the building and its shape. (ATC/SEAOC, Part A, 1999).

If the fundamental period is similar or equal to great portions of the earthquakes period this causes resonance and will lead to the amplification of earthquake forces intensity. This natural frequency is related to the stiffness of the structure, its total weight and the overall height. Most of the earthquakes energy is contained in short-period waves. Thus, rigid, short period buildings have to be designed for greater forces then flexible structures which possess longer periods. Stiff components have to be designed stronger as they will attempt to resist stronger forces. (ATC/SEAOC, Part A, 1999).

The shape of the structure also contributes greatly to the effects on the structure. Simple rectangular shapes will lead to simple forces. The more irregularities a building has (horizontally: e.g. L or T shaped buildings; vertically: level offset) the more prone it is to failure (ATC/SEAOC, Part A, 1999).

The total resisting force (inertia) opposed to the loadings depends on the structure's mass. Similar to the load accumulation on columns in the lower floors, the lateral resisting forces counteracting the ground motion concentrate at the base. The final resisting forces at the foundation level are also related to the mass above and is called *base shear.* (ATC/SEAOC, Part A, 1999).

Steel structures in general are considered as suitable for forces induced by high seismicity. The steel's strength and ductility guaranteed by the fabricators allows it to withstand those forces. (Mazzoline et. Al, 2000)

2.3.2 Offshore

This chapter provides a justification to the research to be carried out in this Final Year Project. The two papers referred to both deal with the topic of responses of Offshore Structures to seismic forces. The Authors of both articles (Venkataramana et al., 1988; Bargi et al., 2011) present their research results on the topic carried out in two Universities.

Venkatarmana's research was carried out in Kyoto University, Japan. He states that the random sea waves on an offshore structure act as a damping medium and, hence, reduce their impact. (Venkataramana et al., 1988).

Bargi et al. described a different behaviour. His nonlinear dynamic analysis carried out at the University of Tehran, Iran shows in its result that a combined impact of longitudinal components of earthquakes and wave forces acting in different directions will cause an increase on the response of the structure. (Bargi et al., 2011).

This contradiction might show the reason why new design criteria for earthquake resistant construction in offshore structures are necessary. Until recently it was assumed that waves decrease the impacts of earthquake induced forces. However, if Bargi's research is correct the design criteria should be adapted.

2.6 Seismic Load Distribution

As described before, the earthquake itself does not act as a force on the structure. The earthquake moves the ground, the ground accelerates the structure leading to a vibration of the structure. Even if all forces are summed up in the base shear there is not one concentrated force at one specific point of the structure. The forces contributing to the base shear are distributed over the total height. They are based on both mass and height at the level. If the structure's weight is distributed uniformly over the height of the structure the final distribution of the loading could be assumed as triangular shaped, having the biggest value at the top and a magnitude equal to zero at the bottom. However in normal cases the weight of structures is more concentrated at certain levels. Though the general trend of load distribution is also triangular shaped the level with a higher mass concentration will experience a higher loading. The higher this concentration, the bigger the resulting forces. (ATC/SEAOC, Part A, 1999; Bangash, 2011).

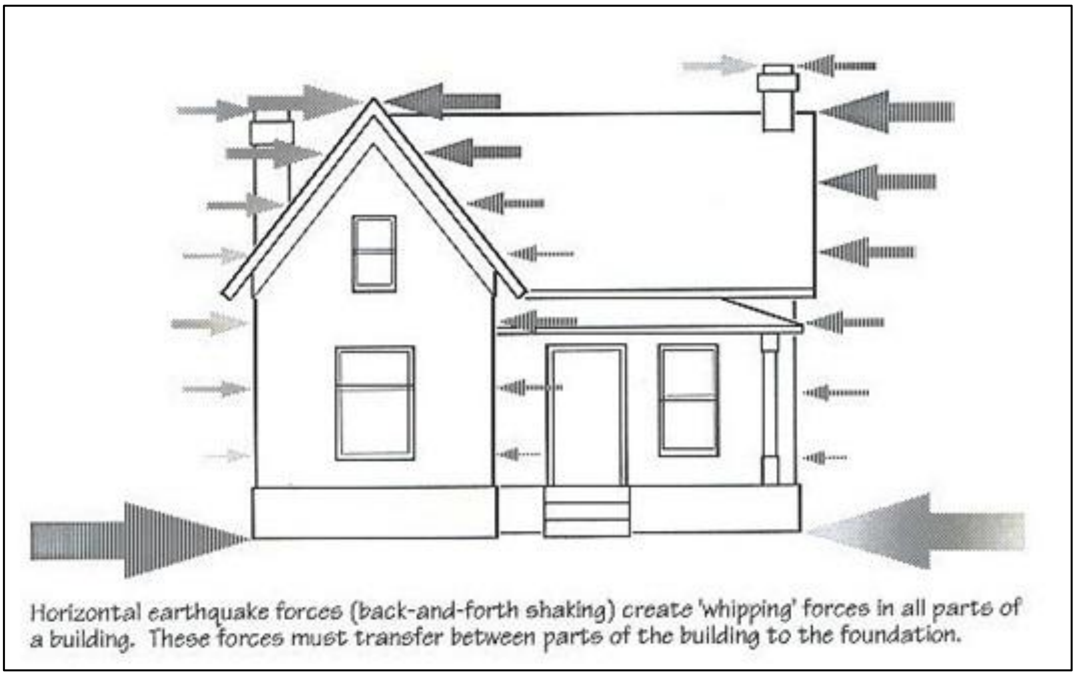

Figure 2 - 9 Qualitative distribution of lateral earthquake forces.

To assume that the forces act laterally on the different floor diaphragms is valid, since the forces will act most strongly where they meet the biggest resistance. As for lateral forces the diaphragms perform best in withstanding them, the biggest resistance can be met there. (Bangash, 2011).

To define the forces acting on a diaphragm at a certain level information on the total base shear, the structure fundamental period, mass concentration and height have to be given. (UBC-91, 1991)

2.7 Elastic Modal Response Spectrum Method

There are different categories and types of dynamic seismic analysis:

1) linear (elastic) dynamic analysis

   - Elastic modal response spectrum method

   - Numerical integration linear time history method

2) Nonlinear (inelastic) dynamic analysis
   - Inelastic response history analysis

The here discussed Spectral Analysis is used to compute the maximal structural responses. As Saatcioglu et Al state in their report this type of analysis is conducted for: 1) single-degree-of-freedom structures or 2) for buildings where it can be assumed that if subjected to seismic loads they will behave in the first mode (for buildings applications, the dominant first mode shape resembles the flexural deformation of a cantilever beam). (Saatcioglu, 2003).

A value for structural damping should be chosen. It should be assumed between two (2) and three (3) percent but should not be bigger than five (5) percent or equal to zero.

Normally, this method should not be applicable for high-rise buildings since they can develop more modes. But the treatment for high-rise structures as a single-degree-of-freedom can be possible. This treatment would be based on the predominant first mode responses. This also means that for the structure's sections with other modes would only be based on approximations for the responses. This can be assumed as the significance of the modes diminishes very fast, and is mostly negligible. Therefore it often is sufficient if only the first three modes are considered, as long as their combined mass covers more than 90 percent of the total effective mass. (Saatcioglu, 2003).

After selecting all important modes, the response can be computed as follows: all contributing modes are superimposed in accordance to their participation. This means that all responses of the structure can be modelled as a variety of single-degree-of-freedom responses in line with their individual properties and contribution as to the total responses. (Saatcioglu, 2003).

2.8 Extreme Value Distribution

The in the following described method can be used in risk management. Extreme Value Distribution is a theoretical approach to determine the period in which an earthquake event returns. It uses models to define when events of low probability can occur again. There are three different types of Extreme Value Distribution, type I, type II and type III, and different mathematicians (e.g. Emil Gumbel) found a variety of equation describing this problem. (Frage Alves, 2010)

Gumbel's method (Type I) helps to find a logarithmical function that can relate a recurrence rate to ground acceleration. In order to accomplish that data have to be at hand about other earthquake events. The return period and corresponding ground acceleration have to be available. These can be marked on a semi-logarithmical graph (x-Axis: return period, logarithmically divided; y-Axis: Ground acceleration, uniform distribution). By drawing a best fit line into this graph the logarithmic function can be found by defining the linear function of the type $f_x = m*x+b$ of this graph and converting the slope m into a logarithmic element. Another approach to obtain value is by reading it directly from the graph. (Sleeper, 2007)

3. METHODOLOGY

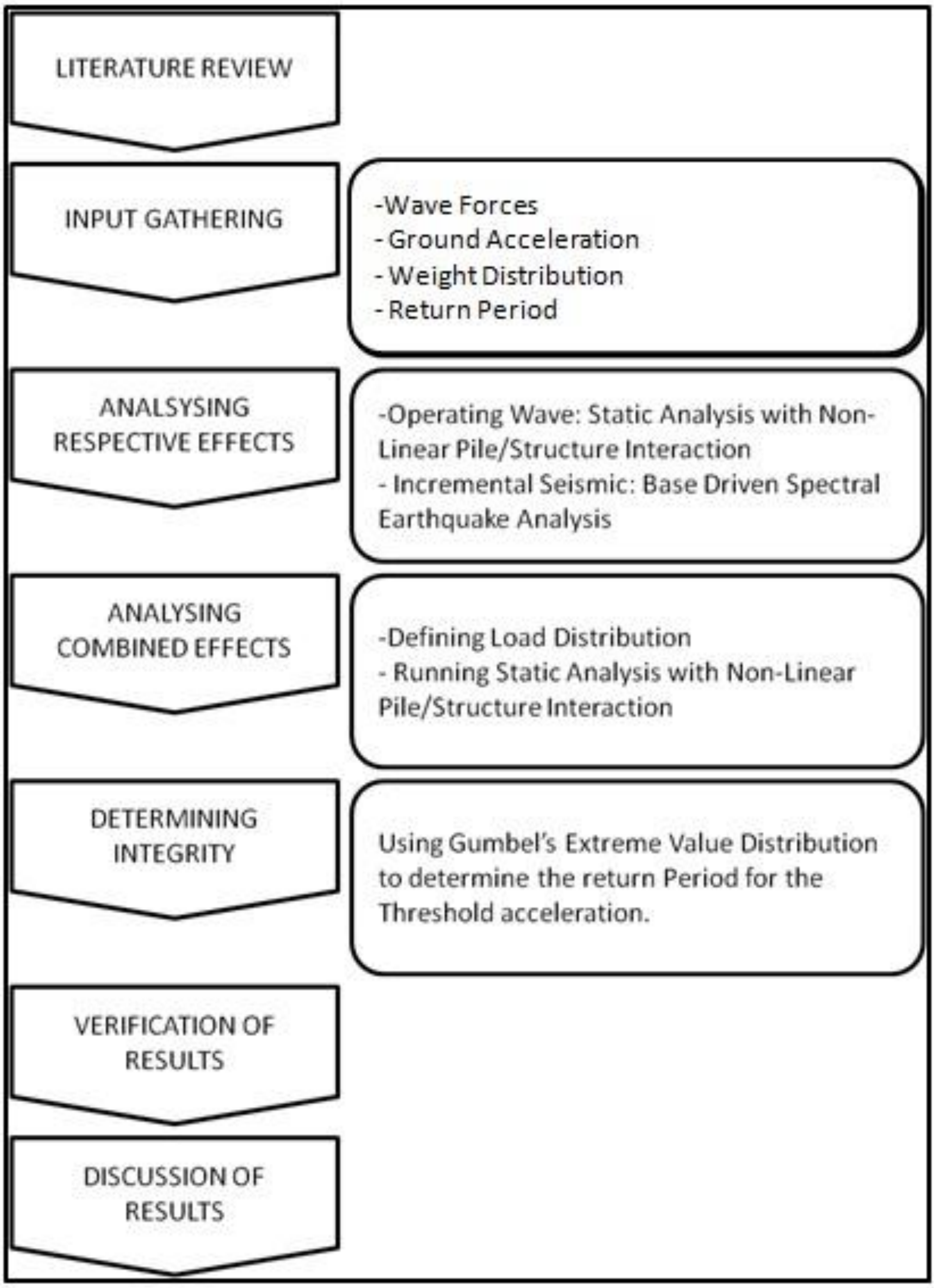

Figure 3 - 1 Methodology Flow

3.1 Input Gathering

3.1.1 Input for Operating Wave Condition

The inputs for the Static Analysis with Non-Linear Pile/Structure Interaction (PSI) are retrieved from the consultant's SACS input files.

As to match the research done in this paper, it is required to edit them. The aim is only to include wave as metocean criteria. Hence, all inputs from wind and current are redundant and can be erased.

3.1.2 Input for Seismic Analysis

The inputs required for the Base Driven Spectral Earthquake Analysis (Spectral Analysis) are overall modal damping, fluid damping, soil type and ground acceleration.

The overall modal damping can be taken as three (3) percent. Fluid damping is not included. (Saatcioglu, 2003; Bargi et Al, 2011).

API specifies three soil types for spectral earthquake analysis. The soil below the structure was investigated prior, with the result that it is based on clay and sand up to a depth of approximately 180 meters. (Ranhill Worley,2008). This allows to define the soil as *Deep Strong Alluvium* (type C) in correspondence with API, as it consists of competent sands, silts and stiff clays in a depth exceeding 200 feet. (API, 2005).

Ground acceleration can be taken from different Sources. The Global Seismic Hazard Assessmet Program (GSHAP) recommends a value of 0.02 g for a 475 year return period (McCue, 1999). ISO recommends a value of 0.05 g for a 1,000 year return Period (ISO 19901-2:2004, 2004). The D'Appolonia Report provides more recommendation: 0.044 g for a 475 year return period; 0.071 g for a 1,000 year return period and 0.122 g for a 2,475 year return Period. (Poggi et al., 2008)

To run the analysis a total of four input files is required. The *Modal Input* file can be created by altering the one provided by the consultant. The *Spectral Input* file has to be written by the author. The information defined in this file are modal damping, fluid damping, ground acceleration and soil type. The *Mode Shape File* and the *Dynamic Mass File* have to be retrieved using SACS 5.3 software.

3.2.3 Weight distribution

The weight distribution is retrieved from *Detailed Design Services For Kumang Cluster Development Project.* (Ranhill Worley, 2008). The weights are respectively taken for topside and jacket.

3.2 Analysing Respective Effects

3.2.1 Static Analysis for Wave under operating conditions.

All analysis will be carried out using Bentleys SACS 5.3 software. *"SACS is an integrated finite element structural analysis suite of programs that uniquely provides for the design, fabrication, installation, operations, and maintenance of offshore structures, including oil platforms and wind farms. Thirty-eight years of focus on these specialized requirements have made SACS the analysis mainstay for most of the world's offshore engineers. Virtually all of the world's energy companies specify SACS software for use by their engineering firms across the lifecycle of fixed offshore platforms"*, (Bentley, 2013).

SACS 5.3 provides a row of static analyses that can be used. The author uses the *Static Analysis with Non-Linear Pile/Structure Interaction* as it takes the actual support condition into consideration.

The Analysis is run using the inputs stated in chapter 3.2.1. The software applies loads in nine (9) Load Combinations from eight (8) directions, every 45° as shown in Figure 3.2.

From the *'Postvue Data Base Directory'*, an interactive graphic post-processor the respective displacements and forces can be retrieved. With this output the maximal mean leg displacement and maximal total forces are determined.

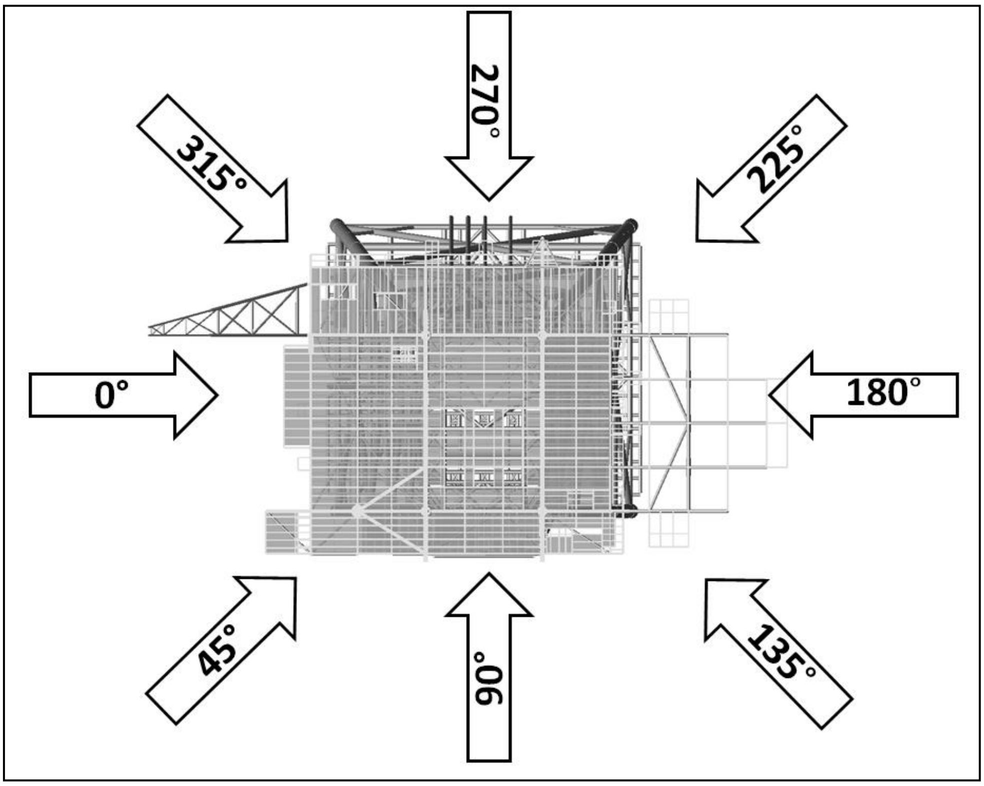

Figure 3 - 2 Loading Directions

3.2.2 Dynamic Analysis for Spectral Ground Acceleration

To determine leg-displacements and forces that can be compared to the ones found in the static PSI analysis, a row of *Base Driven Spectral Earthquake Analyses* is run. The analysis type utilises the elastic modal response spectrum method. At first the standard and research recommended values for peak ground acceleration will be put in and eventually other values in incremental and iterative steps to determine the threshold at which ground motion controls the structure. The threshold is reached when the earthquake induced displacements are equal to the displacements found in the static PSI analysis.

All four input files explained before are used. For the incremental steps only the *Spectral Input File* has to be changed for every incrementation as the only changing parameter is the ground acceleration.

SACS provides as an output a listing file that gives information on the maximal joint displacement, the base shear (total lateral force) for every 45° degree and the respective portion of the base shear acting in x- and y-direction for every 45°.

3.3 Analysing Combined Effects

3.3.1 Earthquake Load distribution

The load distribution of ground motion induced forces is incremental over the height of the structure. The total sum of all lateral forces is the base shear. The forces concentrate at places of high weight concentration. To simplify the distribution, equivalent loads are calculated for each floor diaphragm respectively in accordance to Uniform Building Code 1991, the standard applied in the USA. (UBC-91, 1991). As the weight is known only for two parts, namely the topside and the substructure, those are assumed to be the floors. The calculated loads are applied at a height of eight meters and 52.5 meters above average water level (topside) and 75 meters below average water level (substructure).

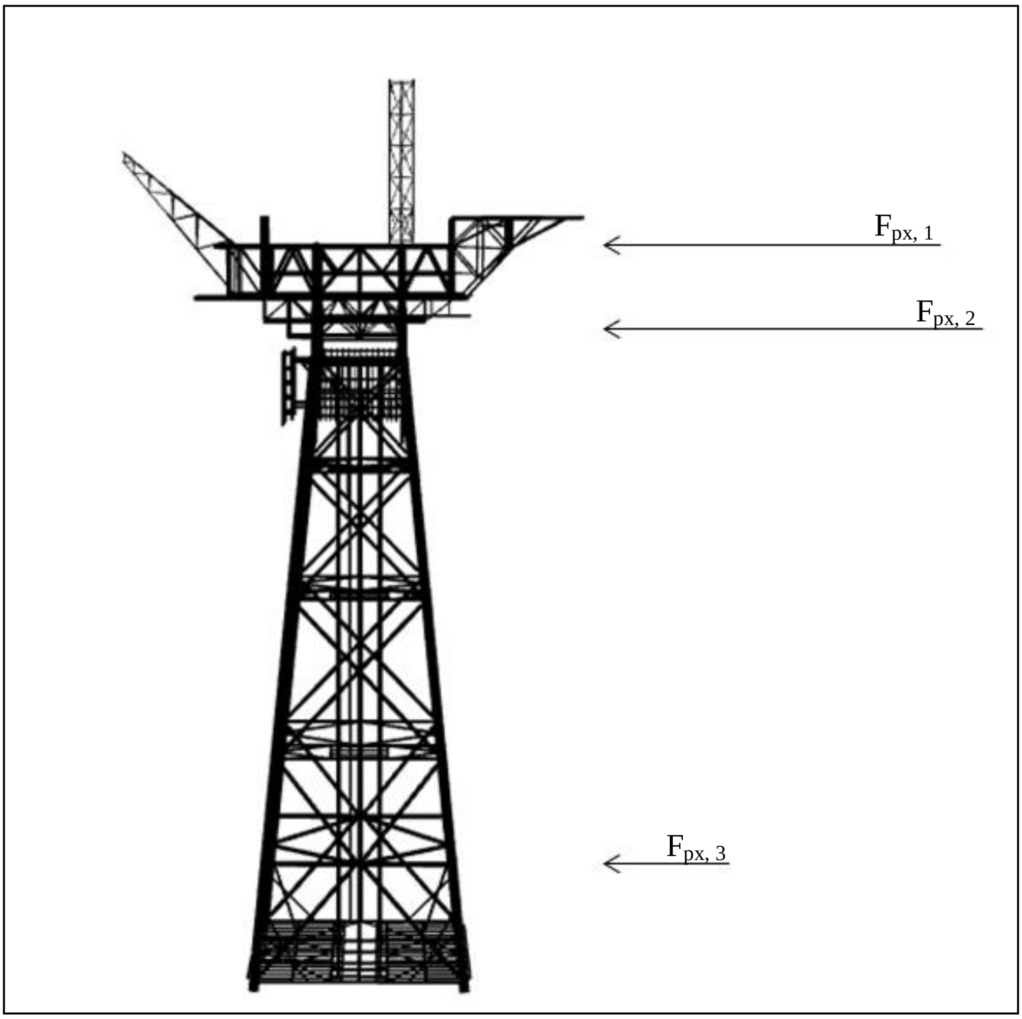

Figure 3 - 3 Qualitative earthquake Load Distribution for Research

As the base shear has components in both x- and y-direction, forces are computed respectively using equations 3.1, 3.2 and 3.3. (Bangash, 2011)

$$F_{px} = \frac{F_t + \sum_{i=x}^{N} F_i}{\sum_{i=x}^{N} W_i} * W_{px} \quad \text{(Eq 3.1)}$$

$$F_t = 0.07 * T * V \quad \text{(Eq. 3.2)}$$

$$F_x = (V - F_t) * \frac{W_x h_x}{\sum_{i=1}^{N} W_i h_i} \quad \text{(Eq. 3.3)}$$

Where:

x = level from base

N = total number of floors

F_{px} = forces at diaphragm

V = total base shear

h_x = height to level x from base

W_x = weight at level from top

W_{px} = weight of diaphragm and attached parts of the structure

3.3.2 Static Analysis of Combined Effects

For this analysis again the Static PSI Analysis is utilised. The same input files are used as in the analysis for operating wave condition and the equivalent static maximal earthquake loads are included. For simplification the load will be concentrated onto joints. Although this is not correct it suffices for the present research.

The same loads are applied for opposite directions. This has to be done because earthquake forces are not static but dynamic. They are motion based and act alternately in reverse direction. Thus the worst case scenario in terms of biggest induced force and biggest created displacement can be investigated.

The analysis is carried out for a total number of four (4) different ground accelerations. The values taken are those recommended by D'Appolonia for a return period of 475 years 1,000 year and 2,475 years and for the previously found threshold ground acceleration.

The analyses create again Postvue Data Base Directories which produce the resulting leg-displacements and forces. Those values are compared to the same displacements and forces induced by the actual *Storm*- and *Operating Conditions* used during the designing process.

3.4 Determining the Integrity

The integrity of Kumg Cluster F9JT A is determined using Gumbel's *Extreme Value Distribution*.(SLEEPER, 2007)

As the necessary values (ground acceleration and return period) for three Earthquake events (475 year return period, 0.044g; 1,000 year return period, 0.071 g; 2,475 year return period, 0.122 g) are known a graph representing the value distribution can be drawn with the help of Microsoft Excel. Gumbel's Extreme Value distribution uses logarithmical functions to define the values. By drawing the graph in excel the software finds this function.

Using this method the return period for the threshold ground acceleration can be defined. This number is evaluated by comparing it to the return period for an Abnormal Earthquake Event as defined by ISO. (ISO 19902:2007, 2011).

4. RESULTS AND DISCUSSION

4.1 Results

<u>4.1.1 Lateral Forces due to operating wave forces</u>

The interpretation of the results generated by SACS in this Analysis is very straightforward. SACS generates different outputs. One of them is a *'Postvue Data Base Directory'* (Postvue). This is an interactive graphic post-processor that produces and displays all required joint displacements and applied forces.

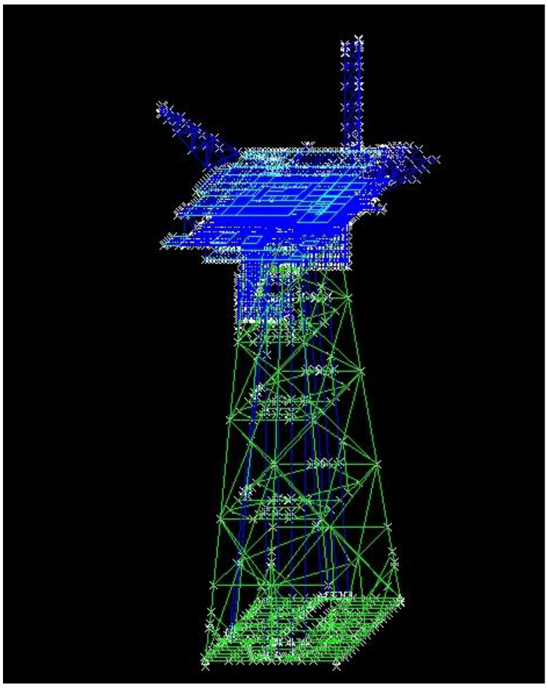

Figure 4 – 1 Postvue Data Base Directory

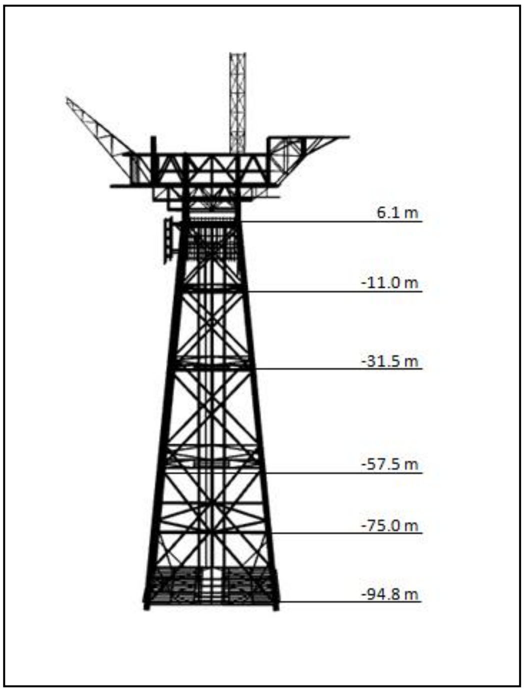

Figure 4 – 2 Leg-Joint Elevation from Average Water Level

In a listing file the Postvue presents the summation of the total forces acting in the three (3) dimensions. Table 4 – 1 summarises the total lateral acting forces.

Table 4 – 1 Total Lateral Forces due to Operating Wave

LOAD COM- BINATION	Name	OP01	OP02	OP03	OP04	OP05	OP06	OP07	OP08	OP09
	Direction	0°	45°	90°	135°	180°	225°	270°	270°	315°
FORCE	[kN]	4256	3974	3741	3739	4152	3835	3876	3876	3925

4.1.2 Maximum Joint Displacements due to operating wave forces

The displacements are gathered at different joints. Firstly the tool to find the maximum displacements in all nine (9) load combinations is used. This tool presents a total of four (4) different displacements: respectively for all three dimensions (X, Y, Z) and the total Displacement.

Table 4 – 2 Maximal Joint Displacements due to Operating Wave.

KUMANG CLUSTER DEVELOPMENT PROJECT				DATE	06.11.2013 TIME	22:37:54		
	MAXIMUM JOINT DISPLACEMENTS							
LOAD	DEFL(X)		DEFL(Y)		DEFL(Z)		DEFL(T)	
COND	JOINT	(CM)	JOINT	(CM)	JOINT	(CM)	JOINT	(CM)
OP01	A031	8.172	9047	-11.539	7406	-16.635	7406	20.583
OP02	A031	5.149	5001	-2.395	7406	-16.453	7406	16.897
OP03	9047	-8.915	1023	4.318	7406	-17.665	7406	18.142
OP04	9045	-16.946	9043	-3.16	7406	-19.227	9045	23.365
OP05	1025	-20.448	9047	-11.471	7406	-20.172	9047	28.37
OP06	1025	-16.479	9047	-20.962	7406	-20.186	9047	30.686
OP07	9045	-9.022	9047	-24.231	7406	-19.067	9047	29.052
OP08	9045	-9.055	9047	-22.898	7406	-18.967	7406	28.166
OP09	A031	5.093	9047	-20.745	7406	-17.645	7406	25.78

As can be read from Table 4 - 2 the same eight (8) joints return repeatedly. The locations of these Joints are depicted in Figure 4 – 3. If you compare this to Figure 4 – 1 it gets obvious that those displacements are not from importance since only the green marked members can have an influence on the structural stability. A failure of the blue highlighted members will not lead to a collapse of the structure. Thus, in the next step joints at the ends of such members that contribute to the structures stability are investigated.

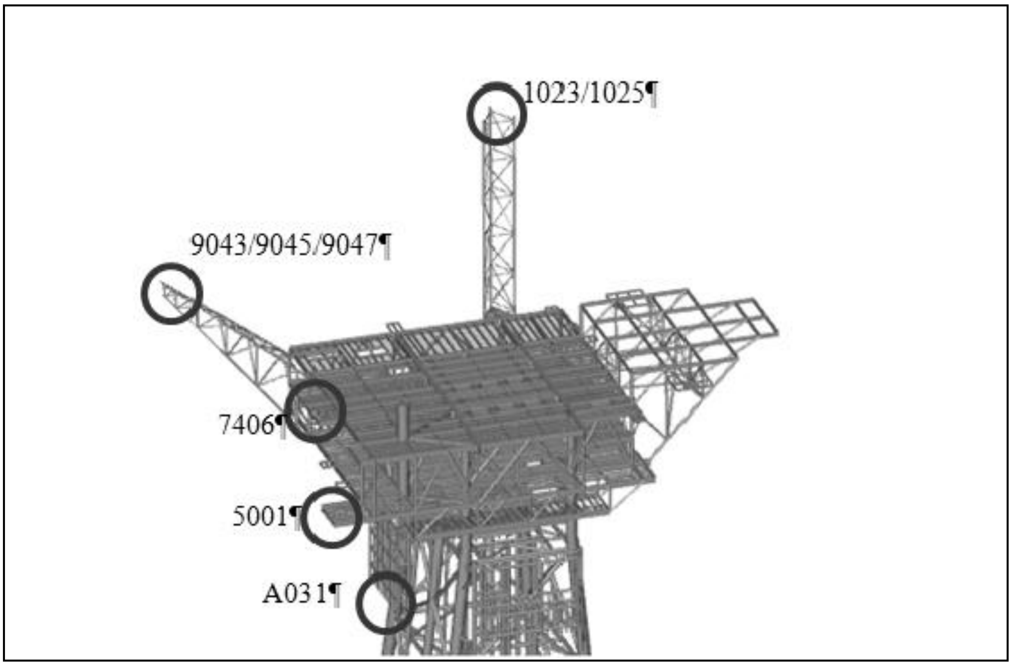

Figure 4 – 3 Location of Joints with Maximum Displacements

4.1.3 Displacement of Joints in Legs due to wave forces

The displacements at six joints of each leg are gathered. The height of the joints in correspondence to the average water level is depicted in Figure 4 – 2.

Applying the method explained in the preceding, all displacements for the leg joints due to wave forces are gathered and put into one table. The mean displacements of all four joints on one level are calculated for each Load Combination and by comparison the Load Combination with the biggest displacement is determined.

Table 4 – 3 Mean Displacements of Leg Joints

LOAD COMBINATION		JOINT DEPTH [m]					
		-94.8	-75	-57.5	-31.5	-11	6.1
Name	Direction	DISPLACEMENTS [cm]					
OP01	0°	2.388	3.973	5.493	7.890	10.051	11.641
OP02	45°	1.721	2.539	3.220	4.247	5.132	5.707
OP03	90°	1.450	3.220	2.161	2.787	3.359	3.895
OP04	135°	1.623	2.475	3.501	5.372	7.173	8.790
OP05	180°	2.269	3.836	5.610	8.612	11.453	13.834
OP06	225°	2.878	4.961	7.230	11.002	14.461	17.212
OP07	270°	3.214	5.549	7.995	11.996	15.572	18.285
OP08	270°	3.217	5.493	7.837	11.647	15.030	17.541
OP09	315°	2.963	5.096	7.287	10.840	14.016	16.411

4.1.4 Lateral Forces due to Seismic Ground Acceleration

The summation of all lateral forces due to seismic ground acceleration is the Base Shear. SACS 5.3 provides a listing file that presents the base shear for all eight directions that F9JT-A is analysed on. In all incremental steps the forces acting in 45° and 225° are of the highest value. These opposite forces are of the same magnitude because the motion during an earthquake is reverse. Hence, the ground accelerates the structure reversely equal.

The incremental steps to define the threshold are:

- 0.02g (Mc Cue 1999; PGA 475 year return period)
- 0.044g (D'Appolonia, PGA 475 year return period)
- 0.05g (ISO Maps, 5HZ 1000 year return period)
- 0.071g (D'Appolonia; PGA 1000 year retrun period)
- 0.097g (D'Appolonia; 5Hz 1000 year retrun period)

- 0.122g (D'Appolonie; PGA 2475 year return period)
- 0.150g
- 0.200g
- 0.175g
- 0.180g

The base shear for chosen steps are shown in Table 4 – 4. With their help the equivalent static loads at the three diaphragms described in Chapter 3.3.1 (see Figure 3 – 3) can be computed using the method recommended by UBC-91 and also explained in chapter 3.3.1. The structures fundamental period is determined by SACS for the first mode shape and is of the value 1.761 seconds. Other important information to compute the equivalent loads are summarised in Table 4 – 5.

Table 4 – 4 Base Shear

Ground Acceleration	Force Direction	X	Y	TOTAL
0.044g	45°/225°	2430.352	3686.324	4415.382
0.071g	45°/225°	3921.706	5948.396	7124.829
0.097g	45°/225°	5357.839	8126.693	9733.939
0.122g	45°/225°	6738.706	10221.161	12242.642
0.180g	45°/225°	9942.358	15080.412	18062.926

Table 4 – 5 Details on Weight and Height of Kumang Cluster F9JT-A Platform

PART	WEIGHT [kN]	HEIGHT [m]
Topside	44615.18	44.50
Jacket	17841.79	102.80
Σ	62456.74	147.30

With the help of these values the components and the total lateral forces can be defined.

Table 4 – 6 Lateral Forces due to Seismic Ground Acceleration.

Ground Acceleration	Force Direction	Total Top	Total Sub	Total Force
		[kN]		
0.044g	45°/225°	1990.739	343.584	2334.323
0.071g	45°/225°	3212.333	554.420	3766.753
0.097g	45°/225°	4388.688	757.449	5146.137
0.122g	45°/225°	5519.773	952.664	6472.437
0.180g	45°/225°	6786.625	1171.312	7957.936

4.1.5 Displacement of Joints in Legs due to Seismic Ground Acceleration

Table 4 – 7 Mean Leg Displacement due to forces at various ground acceleration.

GROUND ACCELERATION	**JOINT DEPTH [m]**					
	-94.8	-75	-57.5	-31.5	-11	6.1
factor of g	**DISPLACEMENTS [cm]**					
0.020	0.000	0.411	0.846	1.323	1.708	2.043
0.044	0.000	0.899	1.849	2.912	3.745	4.493
0.071	0.000	1.449	2.925	4.657	5.938	7.067
0.097	0.000	1.983	4.108	6.411	8.386	9.906
0.122	0.000	2.494	5.162	8.074	10.384	12.459
0.150	0.000	3.064	6.347	9.929	12.767	15.319
0.200	0.000	4.088	8.463	13.236	17.111	20.424
0.175	0.000	3.577	7.404	11.581	14.877	17.856
0.180	0.000	3.679	7.617	11.912	15.321	18.382

The same SACS generated listing file that was used to get the base shear values can also be utilised to define the mean displacement of the leg-joints. The software provides only the maximal displacement, already summing up the number of specified mode shapes, according to their mass participation. The mean leg displacement at various joints is depicted in Table4 – 7.

4.1.6 Static Analysis with a loading combining forces due to wave with seismic ground acceleration

After defining all inputs for this analysis in Chapter 4.1, this step is rather straight forward. The equivalent lateral earthquake loads defined in Chapter 4.1.4 are applied on joints at the centre of the outer horizontal members, together with all other loads (all vertical, wave only metocean) used for the static analysis. At first they are applied from 45° and afterwards from 225°, as to make sure both reverse options are taken into account. This is repeated for three (3) ground acceleration values:

- 0.044g, lowest value recommended by D'Appolonia (Poggi et. Al., 2008);
- 0.122g, highest value recommended by D'Appolonia (Poggi et. Al., 2008);
- 0.180g, threshold at which ground motion controls wave forces.

These values are taken to calculate the effects as to following reasons:

0.044g: ISO 19902:2007 recommends to check for the ultimate limit state (ULS) taken data for an Extreme Earthquake Event (ELE) which has a 100 year return period. As there are no recommended data on such an earthquake event the author choose to take the recommended event with the shortest return period. For the Sarawak region in which Kumang field is located there are several recommendation by different research. The value recommended by the Italian consultant D'Appolonia is the biggest value and it is of the order 0.044g. (Poggi et. Al., 2008; ISO, 2011)

0.122g: Of all recommendation reviewed this value recommended in *Seismic Hazard Study for offshore Sabah, Sarawak and West Malysia, Addendum Report Probabilistic Hazard Assessment for Malacca Strait and East Sabah* by the Italian consultant D'Appolonia for an earthquake event corresponding to a 2,475 year return period is of the biggest value. Furthermore it is in the range of being defined as a ductility level earthquake (DLE) as to API. (Abraham, 2005; Poggi et. Al., 2008)

0.180g: Is the threshold acceleration found in the preceding at which ground motion controls the structure rather than wave forces. Furthermore in the chapter on the determination of the platform's integrity it is shown, that this value corresponds to a return period that exceeds API's definition of a ductility level earthquake (1,000 – 5,000 year recurrence). (Abraham, 2005)

As a means of evaluation, the structures maximal lateral forces and displacements due to Operating and Storm Condition (as to consultant's details) are also gathered. For D'Appolonia's biggest recommended value and the threshold acceleration of 0.180g the ratio for Unity Check (UC) for important structural elements are reviewed from the Postvue database and can be found in the Appendices.

Table 4 – 8 max. lateral forces and displacements under various condition

CONDITION	max. Force		Max. mean leg Displacement	
	Load Case Direction	[kN]	Load Case Direction	[kN]
Operating, Wave Only	0°	4556.62	270°	18.285
Operating, All Metocean	0°	6437.72	270°	23.185
Operating Wave and Seismic @ 0.044g	45°	6741.02	270°	23.339
Storm Metocean	0°	9761.40	270°	30.017
Operating Wave and Seismic @ 0.122g	45°	10415.95	270°	31.680
Operating Wave and Seismic @ 0.180g	45°	13338.65	270°	42.643

Furthermore, the mean ratio of displacement due to the combined inputs at 0.044g to the displacements due to wave only is calculated to show, which force controls.

$$\frac{\delta_{wave\,\&\,seismic}}{\delta_{wave}} \qquad \text{(Eq. 4.1)}$$

The found ratios are:

- 45°: 0.69
- 225°:1.28

4.1.7 Defining Return Periods

The determination of integrity is done, by determining a function that describes the relation between return period and ground acceleration. As explained in chapter 3.4 Gumbel's extreme value distribution is used and the graph created with the help of '*Microsoft Excell'*.

$$a_{Ground} = 0.046 * \ln(T) - 0.2522 \qquad \text{(Eq. 4.2)}$$

Where:

a_{Ground} = Ground acceleration [g]

T = Return period [a]

With the help of the produced functions that can be found in Figure 4 - 4 the return period corresponding to special ground acceleration can be determined and vice versa. The threshold acceleration can thusly be matched to an earthquake event with an 8,876.5 year return period.

The ground acceleration during an Abnormal Earthquake Event as defined in ISO 19902:2007 according to this calculation would be 0.186g.

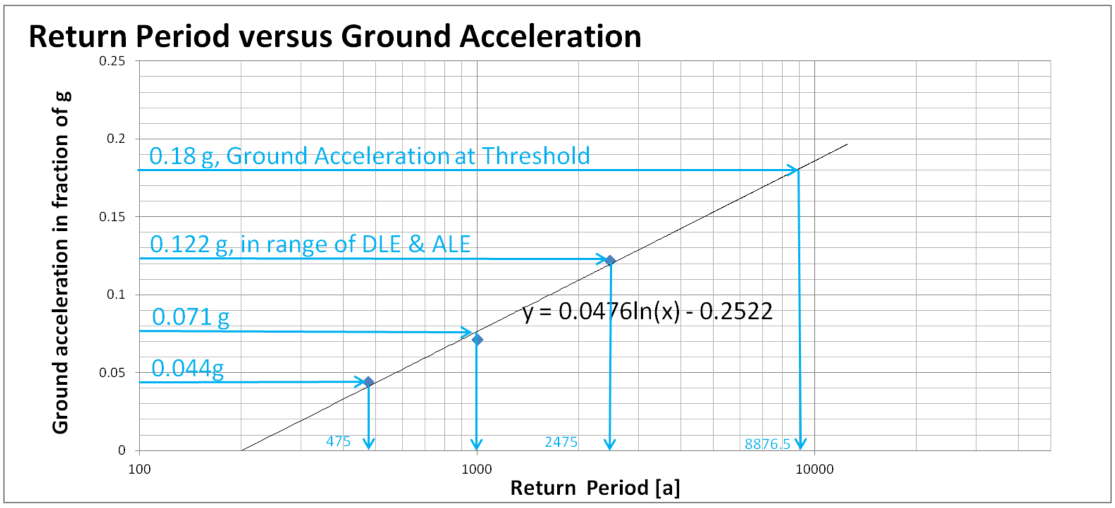

Figure 4 – 4 Extreme Value Distribution; Return Period versus Ground Acceleration

4.2 Discussion of Results

4.2.1 Ascertaining threshold on controlling ground acceleration versus wave forces

The first decision the author has to make is, should the threshold be defined in terms of total lateral loading or in terms of displacements. If you compare the maximal value for external lateral forces due to operation wave, which is of the value of 4256 kN (compare Table 4 – 1), to the values presented in Table 4 – 4 you can see that the threshold would be between 0.097g and 0.071g.

If you compare the values for displacement as is done in Figure 4 – 5 it can be seen, that the threshold at which ground acceleration starts to control the structural responses in terms of displacement is of a value of 0.180g.

However, the lateral forces due to seismic acceleration, different to those induced by waves, are distributed over the whole height of the structure. Thus, the stresses induced into the structural elements are not as concentrated as those induced due to wave; those act very focused close to the water level. Furthermore, the biggest part of the forces act on the topside, as the forces increase the higher it gets and the bigger the mass concentration is. As the topside can suffer some damage, without leading to a collapse, loss of life or major environmental hazards this is not a big issue. Hence, defining the threshold in terms lateral forces is not representative.

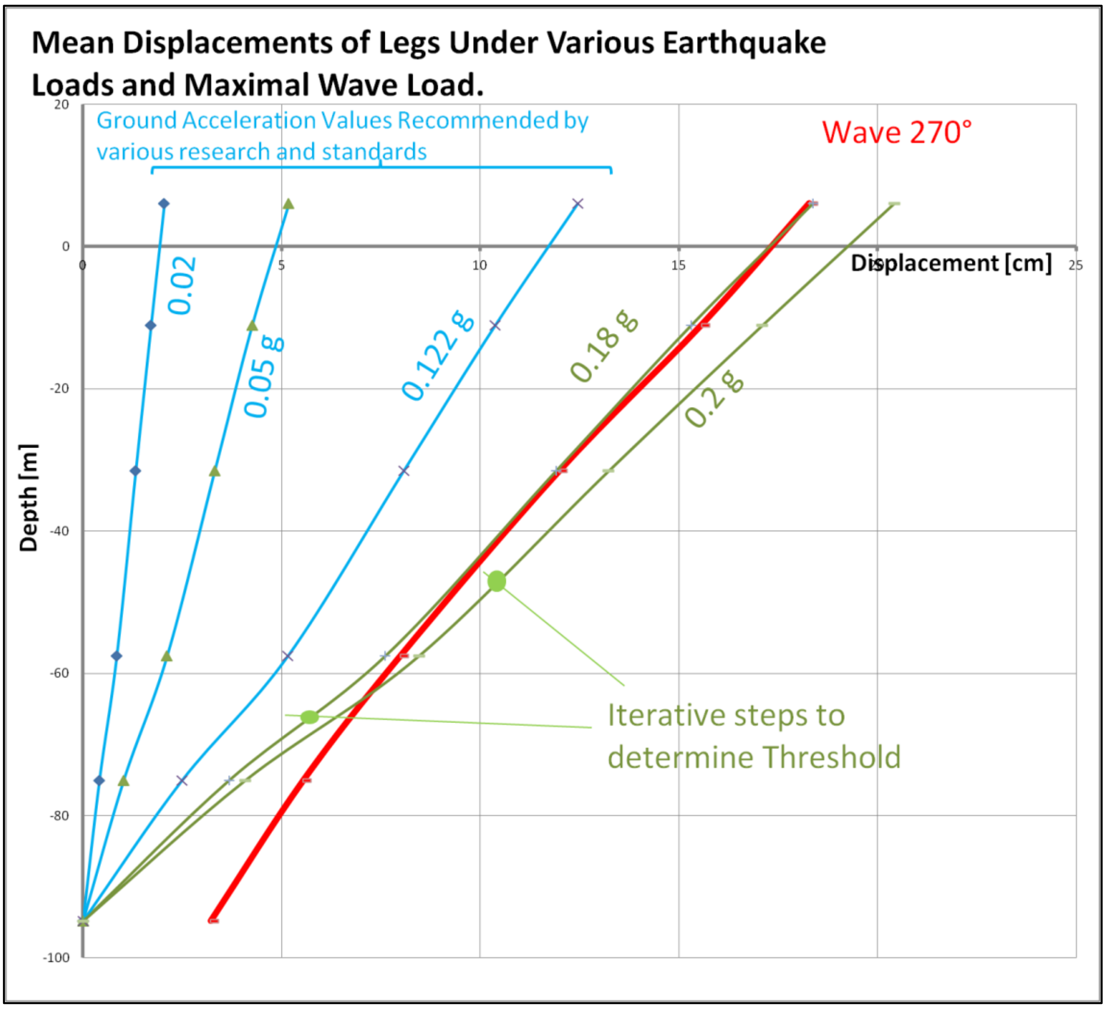

Figure 4 – 5 Comparison of Leg Dosplacements

By contrast, defining it in terms of displacement is very conclusive. The displacement induced into a structure is caused by its internal forces or stresses. The internal forces are the fractions of the external forces that are applied on the respective member itself. By knowing these internal forces we can define the unity check which shows, how much of its capacity is used. Thus, defining the threshold in terms of displacements is a good means.

By the use of incremental steps and finally iteration the author defines the threshold to be at a ground acceleration of 0.180g. This value seems to be quite convincing.

It is a value that, if corresponding to a 1,000 year return period, can be defined as moderate. (Abraham, 2005). As rigid structures, such as jacket type offshore structures, are prone to damage due to the earthquake waves, F9JT-A can already suffer it under such moderate ground accelerations. Malaysia, however, is located in a seismically stable region of the Sunda Plate. Hence, it is reasonable, that such ground acceleration is not experienced in a very long time, which is true for an acceleration of 0.180g. The return period corresponding to this earthquake event is 8,876.5 years.

4.2.2 Study on combined effects of ground acceleration with wave forces

By comparing the various forces and displacements, the structure's safety under the respective condition can be determined.

It can be said with certainty that the Platform can withstand the ultimate limit state (ULS) check as required by ISO standards. The displacements and forces of a combination of seismic at a 475 year return earthquake event and operating wave is far below the responses due to storm criteria. The structure can withstand the loading without taking damage. The extreme earthquake event required by ISO even corresponds only to a return period of 100 years. Thus the responses at an extreme earthquake event are even lower.

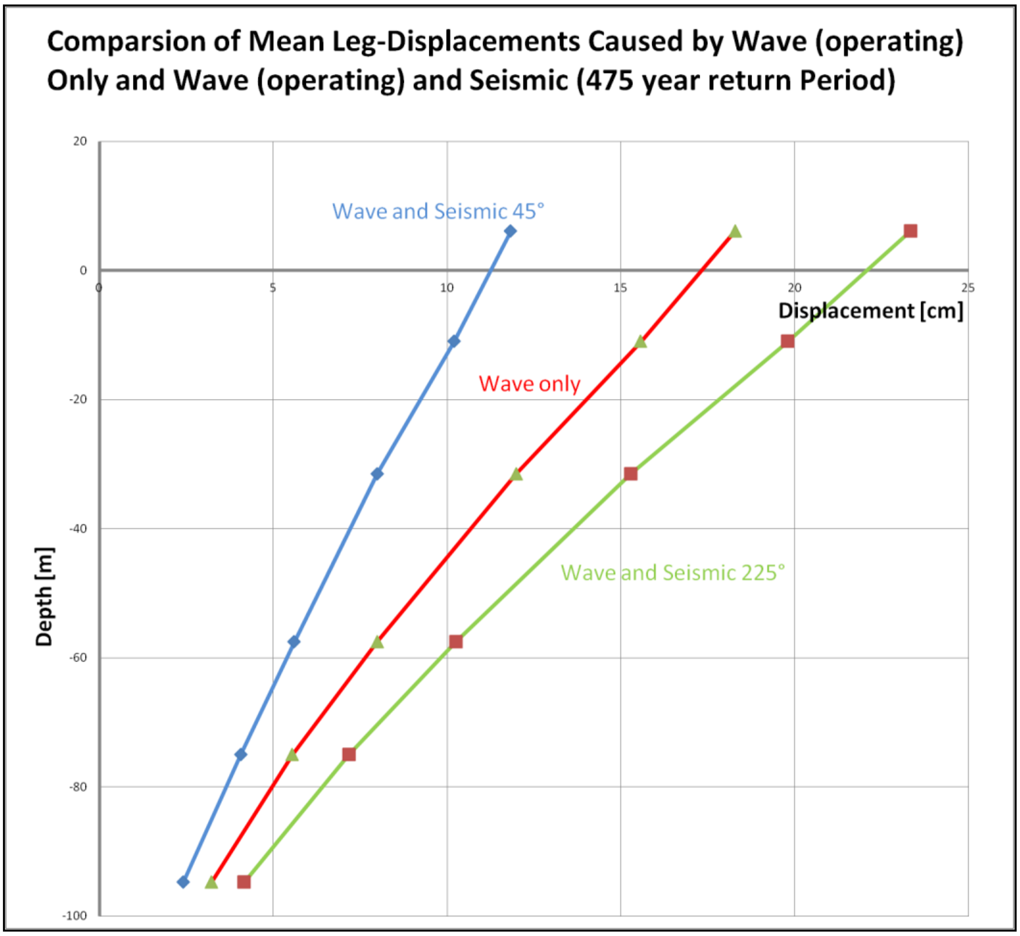

Figure 4 – 6 Displacement due to Combined Effect

Hence, defining wave as the controlling force is very logically. The displacement induced to the structure at this ground acceleration creates, in the worst case scenario (225°), only 28 per cent of what the wave forces creates alone.

The biggest return period recommended in the report prepared by Italian consultancy D'Appolonia corresponds to a return period of 2,475 years and is already in the range of a ductility level earthquake (DLE) as defined by API. Thus, the structure may already suffer damage. However, the maximal displacements the structure suffers at this level if combined with operating wave forces exceeds the value of storm metocean criteria only by 1.7 cm. So the responses are rather similar. Reviewing the Unity Check of important structural members subject to this loading shows, that the structure is still safe. Although the UC exceeds the maximal value of 1.0 in four cases, two can be justified by the fact that the simplification used for earthquake loading concentrates the equivalent static loads onto joints and these two members are in direct adjacency to these loads. The other two are also close to this concentrated load, however they are also under compression; thus, it might be that they suffer damage. However, the UC value for these members only exceeds the limit of 1.0 by 0.022 and 0.052. If the location of the concentrated load is shifted slightly towards the top, where they actually are acting, these values already decrease. But as some damage is allowed, as long as the reserve strength prevents a collapse, it is safe to assume, that the structure, after all, is safe.

For the last earthquake event, corresponding to the threshold acceleration, API's design recommendation does not even consider it. Even if it did, most member Unity Check values are below 1.0, thus they are safe. And an event, at which both this earthquake and the operating wave act together, is even more unlikely, as the operating wave is only experienced once a year. Thus, even if it would be subject to such an earthquake, the structure's responses would, most probably, be lesser, as the wave forces would also be of smaller value.

4.2.3 Determining the integrity of the platform subject to seismic loads using values recommended by 'D'Applonia Report'

The results shown prove that the integrity of the structure is safe. The extreme earthquake event with a return period of 100 years does not even have a value. The structure thus is safe as to these requirements.

The threshold acceleration however exceeds API's recommendation to carry out the check on ductility requirements. Thus the threshold acceleration corresponds to an earthquake which probability is so low, that these design recommendations do not even take it into consideration. The ground acceleration of an earthquake event that fits into API's range for a ductility level earthquake is 0.122 (2,475 years return), only approximately 70 percent of the ground acceleration of the threshold level. Thus it is highly unlikely that Kumang Cluster jacket platform would experience it.

5. CONCLUSION AND RECOMMENDATION

5.1 Summary of Contents

This report, prepared within the scope of the Final Year Project, has dealt with the topic of structural responses of fixed offshore platforms. In more details it dealt with issue of integrating seismic criteria in the design of a Jacket Type Offshore Structure located in the South China Sea, 200 kilometres north of the shore of Bintulu, Sarawak. The research carried out in this study proves, that wave forces are, as assumed so far, the controlling forces for Kumang Cluster F9JT-A.

To prepare the research a literature review was carried out addressing related topics such as Seismicity, Seismicity in Malysia, F9JT-A Kumang Cluster Jacket Type Platform, Standards and Regulations, Responses of Structures to Seismic Forces, Seismic Load Distribution, Elastic Modal Response Spectrum Method and Extreme Value Distribution. Furthermore, the used methodologies were outlined and the required tools justified. In the following, all results from the various research steps were presented and discussed.

5.2 Conclusion

As Malaysia's offshore regions can in general be described as seismically stable the result that wave does control the responses is not surprising. Although far field earthquake originating in seismically active zones like Sumatra Fault or Sumatra Subduction Zone affect Malaysia's offshore structures, the acceleration of the compression waves reaching Kumang field are not of magnitudes controlling the structural design.

By running a Static Analysis with Non-Linear Pile/Structure Interaction in SACS 5.3, an integrated finite element structural analysis software, a threshold was defined, up to which operating wave forces control the structural design of the investigated platform. The analysis type was chosen as it gives more accurate results especially in terms of displacements. The Non-Linear Pile/Structure Interaction considers more realistic support condition.

In the next step the threshold acceleration from which onwards ground motion controls the platforms responses was ascertained. To find this acceleration, a Dynamic Base Driven Earthquake Analysis was conducted, again using Bentley's SACS 5.3 software. This analysis type uses the 'elastic modal response spectrum method'. It can be utilised as the structure responds primarily in its first three mode shapes, similar to a cantilever. In this step the inputs for ground acceleration were incrementally changed, first using recommended values from different research and standards, then freely choosing further steps. By final iterative procedure the threshold acceleration was determined at a level of 0.180g. The author defined the threshold in terms of displacements rather than lateral loadings, as the occurring displacements indicate internal reactions of the structure and rule out inaccuracies due to different load distributions. By this the first objective, '*Ascertaining threshold on controlling ground acceleration versus wave forces',* was addressed and fulfilled.

As SACS 5.3 also provides the total base shear for all investigated eight directions, the earthquake loading could be defined into equivalent lateral forces. With the help of the American Standard UBC-91 these forces were computed for different earthquake events and applied to the structure, combined with the operating wave conditions. Only the worst case seismic reverse option (acting in 45° and 225°) were considered, whereas all operating conditions were applied. The resulting displacements were compared to the displacements due to the actual design conditions used by the consultant. The comparison resulted in the prove, that F9JT-A is safe even under combined conditions. For the Ultimate Limit State (ULS) no problem was found. The requirements under a ductility level earthquake are also met. Accomplishing this step fulfilled Objective number two, '*Study on combined effects of ground acceleration with wave forces'.*

At the end of the research a graph was plotted using Gumbel's extreme value distribution. This graph and the corresponding function can relate ground acceleration and return periods. With the help of these tools the return period of the threshold acceleration of 0.180g was defined. It is of the value 8,876.5 years. The values exceeds API's ductility level earthquake (DLE) that corresponds to a return period of 1,000 to 5,000 years. The ground acceleration of this earthquake has a value which can still be characterised as moderate (Compare D'Appolonia's recommendation for 2,475 year return). Thus, objective number three *'Determining the integrity of the platform subject to seismic loads using values recommended by 'D'Applonia Report''* was also accomplished.

Considering the found results, Kumang Cluster F9JT-A can be characterised as safe for the described seismic activities. The threshold ground acceleration will not be experienced in a very long period of time and even exceeds the API's limits to be considered in structural design. The ISO defined extreme earthquake event used to check the Ultimate Limit State will not induce the same responses as the operating wave conditions; much less the operating metocean conditions or extreme storm conditions. This proves that wave is indeed the controlling force. Furthermore, the combined effects of both, operating wave, which has a one year return period and various ground motions, at 475 year, 2,745 year and 8876.5 year return period, showed, that the structure will withstand their damage for a long time and a major environmental hazard is prevented.

5.3 Recommendation

The case study conducted in this research can prove that the investigated platform in Kumang Field is safe; however, this cannot be generalized for all offshore structures in Malaysian waters of the South China Sea. Not only do the parameters considered in this research (ground acceleration, return period, soil type) differ regionally and for different structures, also the characteristics of the structures are always different. Especially the support system of a structure, height and mass concentration contribute to their behaviour and responses under seismic loading.

Furthermore, the research in the field of seismicity, also in Malaysia, is constantly deveoping and finds new insights continuously. The D'Appolonia Report as one example found new values for ground acceleration for Malaysian offshore regions. Also a very recent research, published in 'Science', a scientific magazine that could change the understanding of earthquakes fundamentally. The results found by a team of 38 researches proves, that soft clayey soil acted as a lubricant in 2010 earthquake, that destroyed vast regions of Japan, and lead to the experienced, unpredicted earthquake magnitude.

These new insights give reason to reconsider the decision not to include seismic design recommendation at all in local design criteria. Although only a few offshore structures will need to be designed for seismic it has to be defined, under which conditions ground motion has to be considered as to prevent loss of live and also major environmental hazards. The incident 2010 at *'Deepwater Horizone'*, one of BP's offshore platforms in the Gulf of Mexico proved that such disasters have to be prevented at all costs.

Although currently Malaysia's offshore structures often are overdesigned and will seldom suffer damage due to ground acceleration, further research, based on more case studies and including other important parameters as stated above should be carried out to form an empirical basis that can help to define seismic design criteria. They will help to design offshore structures more accurately to their actual needs by ruling out uncertainties to some extent, and thus, help preventing overdesigned, uneconomical structures.

6 REFERENCES

Abraham, M. (2005, May 2-5). *Comparison of ISO and API Seismic Design Guidelines Using 3 Existing Offshore Platforms.* Presented ond Offsore Technology Conference (OTC) in Houston, Texas 2005. Retrieved 02/12/2013 from, http://e-book.lib.sjtu.edu.cn/otc-2005/pdfs/otc17285.pdf

Adam, U. & Paulmichl. I (03/2008). Earthquake – soil-structure interaction. *Österr. Ingenieur- und Architekten-Zeitschrift, 155. Jg., Heft 1-3/2010 und Heft 4-6/2010,* pp 59-67.

American Petroleum Institute (API). (2005). *RP 2A-WSD: Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms – Working Stress.* USA: IHS.

ATC/STEAOC, Intr. (1999). *Built to Resist Earthquakes.* Retrieved from http://www.atcouncil.org/pdfs/atc48TOC.pdf

ATC/STEAOC, Part A. (1999). *Briefing Paper 1 Building Safely and Earthquakes Part A: Earthquakes Shaking and Building Response.* Retrieved from https://www.atcouncil.org/pdfs/bp1a.pdf

ATC/STEAOC, Part B. (1999). *Briefing Paper 1 Building Safely and Earthquakes Part B: Erathquake Forces in Buildings*. Retrieved from https://www.atcouncil.org/pdfs/bp1b.pdf

ATC/STEAOC, Part C. (1999). *Earthquake Resisting Systems.* Retrieved from https://www.atcouncil.org/pdfs/bp1c.pdf

ATC/STEAOC, Part D. (1999). *The Seismic Load Path.* Retrieved from https://www.atcouncil.org/pdfs/bp1d.pdf

Balendra. T., Z. Li (2008). Seismic Hazard of Singapore and Malaysia. *EJSE International.* Retrieved from http://www.ejse.org/Archives/Fulltext/2008/Special1/200805.pdf

Bangash, M.Y.H. (2011). *Earthquake Resistant Buildings.* Heidelberg, Germany: Springer-Verlag.

Bargi, K & Hosseini, S. R. & Tadayon, M.H, & Sharifian, H. (2011). Seismic Response of a Typical Fixed Jacket-Type Offshore Platform (SPD 1) under Sea Waves. *Open Journal of Marine Science, 2011, 1* (36-42). Retrieved from www.SciRP.org/journal/ojms

Bentley. (2013). *Bentley Systems has acquired the SACS business from Engineering Dynamics, Incorporated.* Retrieved from http://www.sacs-edi.com/

Chakrabarti, S.K. (1987). *Hydrodynamics of Offshore Structures.* Southampton, UK: WIT Press

Fraga Alves, I., Neves. C. (2010). *Extreme Value Distribution.* Retrieved, 23/08/2013, from http://docentes.deio.fc.ul.pt/fragaalves/FRAGA_ALVES_LEXICON.pdf

OffshoreEnergyToday.com. (2011). *Subsea 7 Wins Contract for Work on Petronas' Kumang Cluster Project, Malaysia.* Retrieved 20/08/2013, from http://www.offshoreenergytoday.com/subsea-7-wins-contract-for-work-on-petronas-kumang-cluster-project-malaysia/

International Organization for Standardization (ISO). (2004). *ISO 19902:2004. Petroleum and natural gas industries -- Specific requirements for offshore structures - Part 2: Seismic design procedures and criteria.* USA: ISO

International Organization for Standardization (ISO). (2011). *ISO 19902:2007.* USA: ISO.

International Organization for Standardization (ISO). (2013). *Abstract.* Retrieved from http://www.iso.org/iso/catalogue_detail.htm?csnumber=27507Petroliam

Mazzolini, F.M. & Gioncu, V. (Eds.). (2000).*Seismic Resistant Steel Structures.* Italy: Springer Wien New York.

McCue K.F. 1999, Seismic Hazard Mapping in Australia, the Southwest Pacific and Southeast Asia, Annali di Geofisica, 42 (6), pp. 1191-1198.

MMC Oil & Gas Engineering Sdn Bhd. (2013). *Conceptual Design & Engineering Services For Kumang Cluster Development Project.* Retrieved 20/08/2013, from http://www.mmcog.com/projects/conceptual-design-engineering-services-for-kumang-cluster-development-project

Mineral and Geosciences Department Malaysia. (2009). *ASSESSMENT OF THE SEISMIC THREATS TO MALAYSIA FROM MAJOR EARTHQUAKES IN THE SOUTHEAST ASIAN REGION AND SEISMOTECTONIC MAP OF MALAYSIA AND FAULT LINE/ZONE STUDY*. Forum on Seismic and Tsunami Hazards and Risks Study in Malysia, 29/09/2009 PICC Putrajayah.

Nasional Berhad (Petronas). (2010). *PTS 34.19.10.30: Design of Fixed Offshore Structures.* Malaysia: Petronas.

Petersen, et al., (2004*). Probabilistic seismic hazard analysis for Sumatra, Indonesia and across the Southern Malaysian Peninsula.* Retrieved 18/08/2013, from www.sciencedirect.com

Poggi, P & Del Guidice, T & Traverso, C.M. & Johnson, W.J. (2008). *Seismic Hazard Study for offshore Sabah, Sarawak and West Malysia, Addendum Report Probabilistic Hazard Assessment for Malacca Strait and East Sabah.* (Client Doc. No. 4719433-ST-ET-003 Rev. 0). Genoa: D'Appolonia.

Poggi, P & Del Guidice, T & Traverso, C.M. & Johnson, W.J. (2008). *Seismic Hazard Study for offshore Sabah, Sarawak and West Malysia, Report Probabbilistic Hazard Assessment.* (Client Doc. No. 4719433-ST-ET-003 Rev. 0). Genoa: D'Appolonia.

Ranhill Worley. (2008). *Detailed Design Services For Kumang Cluster Development Project.* (4211188-ST-ET-1004)

Saatcioglu M., Humar J. (2003). *Dynamic analysis of buildings for earthquake resistant design.* Retrieved 20/08/2013, from http://www.caee.uottawa.ca/Publications/NBCC%202005/PDF%20FILES/Saatcioglu_Doc.pdf

Sleeper, A.D. (2007). *Six Sigma – Distribution Modeling.* San Francisco, USA: McGraw-Hill Companies Inc.

Uniform Building Code Standards, 1991 (UBC-91). (1991). USA: Intl Code Council.

Venkataramana, K & Yamada, Y. & Kawana, K. & Iemura, H. (1988). *Seismic Response of Offshore Structures in Random Seas.* (10-1-28). Retrieved 27/06/2013 from http://www.iitk.ac.in/nicee/wcee/article/9_vol6_433.pdf

Appendix I:

LOAD COMBINATIONS

LOAD CASE	DESCRIPTION	LOAD CASE COMBINATION																		DYN MODEL FILE	
		OP01		OP02		OP03		OP04		OP05		OP06		OP07		OP08		OP09			
		ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP
1	Primary Steel WT (SACS generated)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
2	Jacket Appurtencancs DRY WT																			X	
3	Jacked Post Installed Appurtanences DRY WT																			X	
4	Topside MISC. WT	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5	Blanket WT																				
6	Area Live Load	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
7	Crane Dead Load	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
8	Crane Live Load	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
9	Crane Moment Along X-Axis			X	X	X	X	X	X			X	X	X	X	X	X	X	X		
10	Crane Moment Along Y-Axis	X	X	X	X			X	X	X	X	X	X					X	X		
11	Pipipng & Equipment DRY WT	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
12	Electrical & Instruments DRY WT																			X	
13	Pipipng & Equipment OPER WT	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
14	Electrical & Instruments OPER WT	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
15	Pipipng & Equipment HYDRO WT																				
16	Widowmaker	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
18	J-Tube DRY WT																			X	
19	STORM Rig Reaction Well #0100																				
20	STORM Rig Reaction Well #0105																				
21	STORM Rig Reaction Well #0110																				
22	STORM Rig Reaction Well #0120																				
23	STORM Rig Reaction Well #0125																				
24	STORM Rig Reaction Well #0130																				
25	STORM Rig Reaction Well #0140																				
26	STORM Rig Reaction Well #0145																				
27	STORM Rig Reaction Well #0150																				
28	OPER Rig Reaction Well #0100											X	X								
29	OPER Rig Reaction Well #0105									X	X										
2A	Jacket Appurtencancs SUBMERGED WT	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
30	OPER Rig Reaction Well #0110							X	X												

LOAD CASE	DESCRIPTION	LOAD CASE COMBINATION																		DYN MODEL FILE	
		OP01		OP02		OP03		OP04		OP05		OP06		OP07		OP08		OP09			
		ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP
31	OPER Rig Reaction Well #0120													X	X						
32	OPER Rig Reaction Well #0125															X	X				
33	OPER Rig Reaction Well #0130					X	X														
34	OPER Rig Reaction Well #0140																	X	X		
35	OPER Rig Reaction Well #0145	X	X																		
36	OPER Rig Reaction Well #0150			X	X																
37	Upward LL 10kN/m² @ well#0100/0120	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
38	Upward LL 10kN/m² @ well#0105/0125																				
39	Upward LL 10kN/m² @ well#0110/0130																				
3A	Jacked Post Installed Appurtanences SUBMETGED W	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
40		X		X				X		X		X						X			
41				X		X		X				X		X		X		X			
42		X		X				X		X		X						X			
43				X		X		X				X		X		X		X			
44												X									
45										X											
46								X													
47																					
48																					
49	WIND LOADINGS																				
50																		X			
51		X																			
52				X																	
53												X									
54																					
55								X													
56														X							
57																X					
58						X															
59																		X			

LOAD CASE	DESCRIPTION	LOAD CASE COMBINATION																		DYN MODEL FILE	
		OP01		OP02		OP03		OP04		OP05		OP06		OP07		OP08		OP09			
		ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP
60	WIND LOADINGS																				
61				X																	
62	STORM WAVE AND CURRENT LOADINGS																				
63																					
64																					
65																					
66																					
67																					
68																					
69																					
70	OPER Wave & Current 0°	X	X																		
71	OPER Wave & Current 45°			X	X																
72	OPER Wave & Current 90°					X	X														
73	OPER Wave & Current 135°							X	X												
74	OPER Wave & Current 180°									X	X										
75	OPER Wave & Current 225°											X	X								
76	OPER Wave & Current 270°													X	X	X	X				
77	OPER Wave & Current 315°																	X	X		
82	Mooring X Direction																				
83	Mooring Y Direction																				
90	Inertia OPER Wave & Current 0°	X		X																	
91	Inertia OPER Wave & Current 90°			X		X		X													
92	Inertia OPER Wave & Current 180°							X		X		X									
93	Inertia OPER Wave & Current 270°											X		X		X		X			
94	Inertia STORM Wave & Current 0°																				
95	Inertia STORM Wave & Current 90°																				
96	Inertia STORM Wave & Current 180°																				
97	Inertia STORM Wave & Current 270°																				
101	Helicopter Dead Load	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
11A	FUTURE Pipipng & Equipment DRY WT	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	

LOAD CASE	DESCRIPTION	LOAD CASE COMBINATION																		DYN MODEL FILE	
		OP01		OP02		OP03		OP04		OP05		OP06		OP07		OP08		OP09			
		ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP	ORIG	FYP
12A	FUTURE Electrical & Instruments DRY WT (EMPTY)																				
13A	FUTURE Pipipng & Equipment OPER WT	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
14A	FUTURE Electrical & Instruments OPER WT (EMPTY)																				
15A	FUTURE Pipipng & Equipment HYDRO WT																				
18A	Riser/J-Tube SUBMERGED WT	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X

Appendix II:

STATIC WAVE RESULTANT DISPLACEMENT

	Dir	Depth	LEG 1					
	x+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 1					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
OP1		-94.8	101	OP01	1.1765	-1.2740	-1.7305	2.449869078
		-75	201	OP01	2.4803	-2.3790	-2.2821	4.125470822
		-57.5	301	OP01	3.3330	-3.7355	-2.7278	5.701205319
		-31.5	401	OP01	4.9901	-5.6115	-3.445	8.261843333
		-11	501	OP01	6.3193	-7.3267	-4.0056	10.47181535
		6.1	601	OP01	7.2744	-8.5369	-4.4188	12.05493054
	x+		?					
	y-			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 1					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP2		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	101	OP02	0.8086	-0.2972	-1.2628	1.52866793
		-75	201	OP02	1.6603	-0.4313	-1.6998	2.414940128
		-57.5	301	OP02	2.1472	-0.7800	-2.0477	3.067889035
		-31.5	401	OP02	3.1476	-1.0063	-2.6308	4.223876666
		-11	501	OP02	3.9082	-1.2498	-3.0978	5.141244219
		6.1	601	OP02	4.4375	-1.4511	-3.4441	5.801631001
			?					
	y-			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 1					
						JOINT DIS	PLACEMENT	cm
				LOAD	********	cm	**********	Resultant
OP3		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	
		-94.8	101	OP03	0.1692	0.0141	-1.6105	1.619425114
		-75	201	OP03	0.1104	0.2089	-2.031	2.044697623
		-57.5	301	OP03	-0.3084	0.1377	-2.3545	2.37860087
		-31.5	401	OP03	-0.7711	0.4293	-2.8812	3.013338205
		-11	501	OP03	-1.3275	0.6065	-3.2743	3.584848531
		6.1	601	OP03	-1.8268	0.6373	-3.552	4.0447563
	x-		?					
	y-			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 1					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP4		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	101	OP04	-0.3712	-0.4331	-2.4138	2.480281333
		-75	201	OP04	-1.2409	-0.5850	-2.8775	3.18779925
		-57.5	301	OP04	-2.5128	-1.0422	-3.2259	4.219807518
		-31.5	401	OP04	-4.3155	-1.2637	-3.7504	5.855422965
		-11	501	OP04	-6.0953	-1.5574	-4.0935	7.505659138
		6.1	601	OP04	-7.5544	-1.8428	-4.314	8.892438766

OP5	x-		⍰					
				D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 1					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	101	OP05	-0.6761	-1.2704	-3.308	3.607477148
		-75	201	OP05	-1.9215	-2.3222	-3.8595	4.896990437
		-57.5	301	OP05	-3.6062	-3.7241	-4.278	6.72122632
		-31.5	401	OP05	-5.9887	-5.4099	-4.876	9.429046702
		-11	501	OP05	-8.2979	-7.0270	-5.2367	12.06884006
		6.1	601	OP05	-10.1262	-8.2305	-5.462	14.14618326
OP6	x-		⍰					
	y+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 1					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	101	OP06	-0.2497	-2.2032	-3.722	4.33240399
		-75	201	OP06	-0.9502	-4.2605	-4.3758	6.180806252
		-57.5	301	OP06	-2.1730	-6.6771	-4.8826	8.552507011
		-31.5	401	OP06	-3.7563	-10.0157	-5.613	12.08014094
		-11	501	OP06	-5.3656	-13.0956	-6.078	15.40215851
		6.1	601	OP06	-6.6447	-15.2955	-6.3919	17.85947211
OP7			⍰					
	y+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 1					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	101	OP07	0.3345	-2.6652	-3.4322	4.358345802
		-75	201	OP07	0.4587	-5.0949	-4.1153	6.565371718
		-57.5	301	OP07	0.0503	-7.8570	-4.6562	9.133190983
		-31.5	401	OP07	-0.2024	-11.8324	-5.4441	13.02631492
		-11	501	OP07	-0.6135	-15.4448	-5.9707	16.57007809
		6.1	601	OP07	-0.9806	-17.9593	-6.3304	19.067564
OP8			⍰					
	y+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 1					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	101	OP08	0.3392	-2.7247	-3.3079	4.298982338
		-75	201	OP08	0.4569	-5.0758	-3.9692	6.45964797
		-57.5	301	OP08	0.0539	-7.7250	-4.4919	8.93620142
		-31.5	401	OP08	-0.2063	-11.5004	-5.245	12.64166859
		-11	501	OP08	-0.6204	-14.9118	-5.7407	15.99069454
		6.1	601	OP08	-0.9997	-17.2124	-6.072	18.27936809

	x+		?					
	y+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 1					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP9		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	101	OP09	0.8418	-2.2371	-2.6997	3.605776441
		-75	201	OP09	1.7121	-4.2997	-3.3494	5.712896539
		-57.5	301	OP09	2.0858	-6.6775	-3.8727	7.996084866
		-31.5	401	OP09	3.0661	-10.1478	-4.6634	11.5812829
		-11	501	OP09	3.7762	-13.3074	-5.2304	14.78863298
		6.1	601	OP09	4.2629	-15.5313	-5.628	17.06071452
	Dir	Depth	LEG 2					
	x+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 2					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
OP1		-94.8	102	OP01	1.1657	-1.1498	-0.6265	1.753111172
		-75	202	OP01	2.3343	-2.3626	-1.0651	3.487875178
		-57.5	302	OP01	3.1517	-3.4536	-1.4332	4.890258489
		-31.5	402	OP01	4.5512	-5.4472	-2.1687	7.42217414
		-11	502	OP01	5.9661	-7.1420	-2.8864	9.743398697
		6.1	602	OP01	6.8674	-8.6097	-3.5057	11.55759704
	x+		?					
	y-			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 2					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP2		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	102	OP02	0.8261	-0.1572	-1.1245	1.404155725
		-75	202	OP02	1.6668	-0.4082	-1.5753	2.329467658
		-57.5	302	OP02	2.0918	-0.4920	-1.9138	2.877554809
		-31.5	402	OP02	2.9746	-0.8500	-2.5461	4.006665742
		-11	502	OP02	3.8168	-1.0616	-3.0936	5.026461754
		6.1	602	OP02	4.3059	-1.5209	-3.5767	5.800577084
			?					
	y-			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 2					
						JOINT DIS	PLACEMENT	cm
				LOAD	********	cm	**********	Resultant
OP3		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	
		-94.8	102	OP03	0.161	0.202	-1.7715	1.790233853
		-75	202	OP03	0.1046	0.2401	-2.2298	2.245127437
		-57.5	302	OP03	-0.3872	0.4956	-2.5493	2.625732981
		-31.5	402	OP03	-0.8988	0.6138	-3.1174	3.301934984
		-11	502	OP03	-1.4338	0.8113	-3.5468	3.910726323
		6.1	602	OP03	-1.9611	0.5683	-3.9419	4.439307796

	x-		⍰					
	y-			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 2					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP4		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	102	OP04	-0.5085	-0.1953	-2.2218	2.287599086
		-75	202	OP04	-1.4356	-0.5479	-2.7135	3.118368808
		-57.5	302	OP04	-2.7801	-0.5995	-3.0545	4.173526867
		-31.5	402	OP04	-4.6368	-1.0401	-3.647	5.990186245
		-11	502	OP04	-6.5135	-1.3308	-4.0591	7.789287753
		6.1	602	OP04	-8.0311	-1.9011	-4.4342	9.368824796
	x-		⍰					
				D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 2					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP5		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	102	OP05	-0.9108	-1.0102	-2.0409	2.452617681
		-75	202	OP05	-2.2317	-2.2850	-2.5679	4.098270403
		-57.5	302	OP05	-3.8957	-3.2291	-2.963	5.8636963
		-31.5	402	OP05	-6.3183	-5.1595	-3.6437	8.934086681
		-11	502	OP05	-8.8233	-6.7980	-4.1279	11.87867776
		6.1	602	OP05	-10.8183	-8.2793	-4.5356	14.3580671
	x-		⍰					
	y+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 2					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP6		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	102	OP06	-0.5727	-1.9622	-1.3085	2.427011821
		-75	202	OP06	-1.4266	-4.2288	-1.8581	4.834301667
		-57.5	302	OP06	-2.5778	-6.1905	-2.3114	7.092948121
		-31.5	402	OP06	-4.3098	-9.7556	-3.1224	11.11285243
		-11	502	OP06	-6.1544	-12.8655	-3.7811	14.7544721
		6.1	602	OP06	-7.6915	-15.3509	-4.3176	17.70454667
			⍰					
	y+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 2					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP7		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	102	OP07	0.0464	-2.4647	-0.7716	2.583072901
		-75	202	OP07	-0.0589	-5.0709	-1.2842	5.231315863
		-57.5	302	OP07	-0.4092	-7.4323	-1.7347	7.643017207
		-31.5	402	OP07	-0.9182	-11.5902	-2.5917	11.91187375
		-11	502	OP07	-1.4852	-15.2347	-3.3716	15.67385051
		6.1	602	OP07	-2.0564	-18.0401	-4.0126	18.59502481

			□					
	y+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 2					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
OP8		-94.8	102	OP08	0.0412	-2.5224	-0.8368	2.657900194
		-75	202	OP08	-0.0640	-5.0511	-1.3614	5.231741313
		-57.5	302	OP08	-0.4272	-7.2989	-1.8149	7.533279701
		-31.5	402	OP08	-0.9378	-11.2553	-2.6808	11.60809784
		-11	502	OP08	-1.5067	-14.7017	-3.4669	15.17990525
		6.1	602	OP08	-2.0706	-17.3010	-4.1112	17.90290342
	x+		□					
	y+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 2					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
OP9		-94.8	102	OP09	0.7425	-2.0858	-0.535	2.277738547
		-75	202	OP09	1.3895	-4.2827	-0.9817	4.608249606
		-57.5	302	OP09	1.7885	-6.3373	-1.3842	6.728752721
		-31.5	402	OP09	2.4757	-9.9489	-2.1922	10.48405659
		-11	502	OP09	3.1885	-13.1130	-2.9863	13.82155161
		6.1	602	OP09	3.5813	-15.6052	-3.6574	16.42329296
	Dir	Depth			Leg 3			
	x+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 3					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
OP1		-94.8	103	OP01	1.2717	-0.9305	-1.4076	2.112910055
		-75	203	OP01	2.3438	-2.1630	-1.8351	3.679614035
		-57.5	303	OP01	3.4226	-3.1497	-2.188	5.140247548
		-31.5	403	OP01	4.7089	-5.0687	-2.7735	7.453707879
		-11	503	OP01	6.1065	-6.7139	-3.1653	9.611707421
		6.1	603	OP01	6.7829	-8.1394	-3.504	11.1595511
	x+		□					
	y-			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 3					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
OP2		-94.8	103	OP02	0.9743	-0.1172	-1.6382	1.909632313
		-75	203	OP02	1.6780	-0.3631	-2.0327	2.660713231
		-57.5	303	OP02	2.4438	-0.3771	-2.3316	3.398635228
		-31.5	403	OP02	3.1638	-0.6807	-2.8236	4.294845735
		-11	503	OP02	3.9700	-0.8972	-3.1331	5.136358968
		6.1	603	OP02	4.2139	-1.2948	-3.4188	5.57867849

			?					
	y-			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 3					
						JOINT DIS	PLACEMENT	cm
				LOAD	********	cm	**********	Resultant
OP3		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	
		-94.8	103	OP03	0.3198	0.1698	-1.2259	1.278254626
		-75	203	OP03	0.1157	0.2450	-1.5945	1.617356405
		-57.5	303	OP03	-0.0158	0.4843	-1.8797	1.941151261
		-31.5	403	OP03	-0.7068	0.6604	-2.3612	2.551658253
		-11	503	OP03	-1.2717	0.8576	-2.7002	3.105443397
		6.1	603	OP03	-2.0475	0.7749	-3.0102	3.722100254
	x-		?					
	y-			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 3					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP4		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	103	OP04	-0.3604	-0.1761	-0.6975	0.8046152
		-75	203	OP04	-1.4250	-0.4084	-1.053	1.818302659
		-57.5	303	OP04	-2.4306	-0.5353	-1.3527	2.832694784
		-31.5	403	OP04	-4.4522	-0.8835	-1.8936	4.91816816
		-11	503	OP04	-6.3459	-1.1322	-2.3481	6.860458969
		6.1	603	OP04	-8.1157	-1.4620	-2.7467	8.691742712
	x-		?					
				D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 3					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP5		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	103	OP05	-0.8015	-0.9937	-0.3163	1.315251926
		-75	203	OP05	-2.2232	-2.0322	-0.6374	3.078755242
		-57.5	303	OP05	-3.6257	-3.0437	-0.9452	4.827340181
		-31.5	403	OP05	-6.1671	-4.8390	-1.5584	7.992349715
		-11	503	OP05	-8.6624	-6.4045	-2.1606	10.98740126
		6.1	603	OP05	-10.8878	-7.6752	-2.6919	13.59040873
	x-		?					
	y+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 3					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP6		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	103	OP06	-0.5078	-1.8029	-0.2062	1.884364001
		-75	203	OP06	-1.4221	-3.7818	-0.5246	4.074258805
		-57.5	303	OP06	-2.3926	-5.7413	-0.8565	6.278586839
		-31.5	403	OP06	-4.1961	-9.1326	-1.5305	10.16632029
		-11	503	OP06	-6.0129	-12.1271	-2.2045	13.71427508
		6.1	603	OP06	-7.7511	-14.4657	-2.7976	16.64820091

			▯					
	y+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 3					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP7		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	103	OP07	0.0955	-2.1437	-0.4045	2.1836186
		-75	203	OP07	-0.0560	-4.5575	-0.7824	4.624509921
		-57.5	303	OP07	-0.2514	-6.8642	-1.1574	6.965631225
		-31.5	403	OP07	-0.8143	-10.8671	-1.8763	11.05791339
		-11	503	OP07	-1.3549	-14.3803	-2.5382	14.66530741
		6.1	603	OP07	-2.1185	-17.1004	-3.1077	17.50912681
			▯					
	y+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 3					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP8		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	103	OP08	0.0994	-2.1946	-0.4583	2.244145363
		-75	203	OP08	-0.0600	-4.5332	-0.8498	4.612554854
		-57.5	303	OP08	-0.2480	-6.7264	-1.2289	6.842233274
		-31.5	403	OP08	-0.8197	-10.5267	-1.9569	10.73837877
		-11	503	OP08	-1.3637	-13.8391	-2.623	14.15134253
		6.1	603	OP08	-2.1383	-16.3561	-3.1932	16.80151363
	x+		▯					
	y+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 3					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP9		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	103	OP09	0.8044	-1.7717	-0.7947	2.101791698
		-75	203	OP09	1.3947	-3.9376	-1.228	4.354063143
		-57.5	303	OP09	1.9732	-5.9120	-1.6236	6.440600842
		-31.5	403	OP09	2.5934	-9.4225	-2.3209	10.04469047
		-11	503	OP09	3.3165	-12.4887	-2.878	13.23819036
		6.1	603	OP09	3.5124	-14.9289	-3.3501	15.69815846
	Dir	Depth	LEG 4					
	x+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 4					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
OP1			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	104	OP01	1.3542	-1.1201	-2.7194	3.237841567
		-75	204	OP01	2.4912	-2.1920	-3.183	4.598089869
		-57.5	304	OP01	3.7005	-3.5462	-3.5619	6.241503529
		-31.5	404	OP01	5.1743	-5.2475	-4.0746	8.420926428
		-11	504	OP01	6.4782	-6.8344	-4.3597	10.37704595
		6.1	604	OP01	7.2088	-8.1591	-4.5312	11.79277252

	x+		?					
	y-			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 4					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP2		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	104	OP02	0.9450	-0.2871	-1.7848	2.039843732
		-75	204	OP02	1.6685	-0.3922	-2.1526	2.751617679
		-57.5	304	OP02	2.4397	-0.7202	-2.4537	3.534327067
		-31.5	404	OP02	3.2985	-0.8350	-2.8859	4.461585599
		-11	504	OP02	4.0443	-1.0034	-3.1518	5.224654753
		6.1	604	OP02	4.3788	-1.2939	-3.3217	5.646393321
			?					
	y-			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 4					
						JOINT DIS	PLACEMENT	cm
				LOAD	********	cm	**********	Resultant
OP3		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	
		-94.8	104	OP03	0.2945	0.0456	-1.0705	1.111206488
		-75	204	OP03	0.1173	0.2219	-1.401	1.423305976
		-57.5	304	OP03	-0.0351	0.2268	-1.6814	1.696990339
		-31.5	404	OP03	-0.6286	0.5419	-2.1239	2.280294889
		-11	504	OP03	-1.1984	0.7781	-2.4474	2.833966995
		6.1	604	OP03	-1.8872	0.7890	-2.6809	3.372131322
	x-		?					
	y-			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 4					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP4		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	104	OP04	-0.2318	-0.2592	-0.8524	0.920598523
		-75	204	OP04	-1.2332	-0.4234	-1.2038	1.774594106
		-57.5	304	OP04	-2.2163	-0.7258	-1.5126	2.77969964
		-31.5	404	OP04	-4.1633	-0.9743	-2.0124	4.72568314
		-11	504	OP04	-5.9569	-1.1960	-2.4058	6.534749211
		6.1	604	OP04	-7.6125	-1.4552	-2.703	8.208164977
	x-		?					
				D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 4					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP5		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	104	OP05	-0.4973	-1.0605	-1.2334	1.700953585
		-75	204	OP05	-1.9111	-2.0402	-1.6951	3.269263412
		-57.5	304	OP05	-3.2387	-3.2223	-2.0994	5.027909639
		-31.5	404	OP05	-5.8053	-4.9316	-2.7283	8.091094335
		-11	504	OP05	-8.1372	-6.4673	-3.211	10.87890225
		6.1	604	OP05	-10.1897	-7.6691	-3.5689	13.24319176

	x-		?					
	y+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 4					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP6		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	104	OP06	-0.0317	-1.8919	-2.1559	2.868483103
		-75	204	OP06	-0.9394	-3.7902	-2.7151	4.756033685
		-57.5	304	OP06	-1.7364	-5.9769	-3.1978	6.997452637
		-31.5	404	OP06	-3.5451	-9.2548	-3.8984	10.64972204
		-11	504	OP06	-5.1895	-12.2129	-4.3837	13.97507289
		6.1	604	OP06	-6.7156	-14.4699	-4.7181	16.63543678
			?					
	y+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 4					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP7		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	104	OP07	0.5639	-2.2761	-2.9011	3.730280905
		-75	204	OP07	0.4689	-4.5725	-3.494	5.773704137
		-57.5	304	OP07	0.5075	-7.1846	-3.9952	8.236361845
		-31.5	404	OP07	0.0144	-11.0300	-4.692	11.9864912
		-11	504	OP07	-0.4352	-14.4898	-5.1335	15.37844353
		6.1	604	OP07	-1.0499	-17.0989	-5.426	17.96986776
			?					
	y+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 4					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP8		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	104	OP08	0.5590	-2.3286	-2.7767	3.666731767
		-75	204	OP08	0.4663	-4.5491	-3.3476	5.667289675
		-57.5	304	OP08	0.4934	-7.0479	-3.8307	8.036827761
		-31.5	404	OP08	-0.0015	-10.6918	-4.4945	11.59806534
		-11	504	OP08	-0.4545	-13.9510	-4.908	14.79612906
		6.1	604	OP08	-1.0632	-16.3467	-5.1759	17.17949173
	x+		?					
	y+			D	ATE 8-OCT	-2013 TIME	11:17:50	
			Leg 4					
						JOINT DIS	PLACEMENTS	
				LOAD	********	cm	**********	cm
OP9		m	JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	104	OP09	1.0594	-1.9430	-3.1685	3.864837592
		-75	204	OP09	1.7232	-3.9605	-3.7353	5.710292863
		-57.5	304	OP09	2.5233	-6.2975	-4.2046	7.981491734
		-31.5	404	OP09	3.2780	-9.6069	-4.8483	11.24916995
		-11	504	OP09	3.9520	-12.6146	-5.2332	14.21734221
		6.1	604	OP09	4.1913	-14.9451	-5.4853	16.4624277

Appendix III:

DYNAMIC SPECTRAL RESULTANT DISPLACEMENT

	Dir	Depth	LEG 1					
0.2 g								
			Leg 1					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	101	OP01	0.0000	0.0000	0	0
		-75	201	OP01	3.0140	2.5280	0.792	4.0127601
		-57.5	301	OP01	6.5610	5.7770	1.403	8.8537483
		-31.5	401	OP01	10.5760	8.1080	1.973	13.471606
		-11	501	OP01	13.8320	9.3820	2.148	16.851114
		6.1	601	OP01	16.3910	10.9870	2.111	19.845286
0.15 g								
			Leg 1					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	101	OP01	0.0000	0.0000	0	0
		-75	201	OP01	2.2600	1.8960	0.592	3.0088004
		-57.5	301	OP01	4.9210	4.3330	1.052	6.64062
		-31.5	401	OP01	7.9230	6.0810	1.48	10.096677
		-11	501	OP01	10.3740	7.0370	1.611	12.638614
		6.1	601	OP01	12.2930	8.2400	1.584	14.883699
0.122 g								
			Leg 1					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	101	OP01	0.0000	0.0000	0	0
		-75	201	OP01	1.8390	1.5420	0.483	2.4480551
		-57.5	301	OP01	4.0020	3.5240	0.856	5.4006774
		-31.5	401	OP01	6.4510	4.9460	1.204	8.2175381
		-11	501	OP01	8.4380	5.7230	1.31	10.279527
		6.1	601	OP01	9.9980	6.7020	1.288	12.105195
0.097 g								
			Leg 1					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	101	OP01	0.0000	0.0000	0	0
		-75	201	OP01	1.4620	1.2260	0.384	1.9462723
		-57.5	301	OP01	3.1820	2.8020	0.68	4.294034
		-31.5	401	OP01	5.1290	3.9330	0.957	6.5338334
		-11	501	OP01	6.7090	4.5500	1.042	8.1730622
		6.1	601	OP01	7.9500	5.3290	1.024	9.6254515

			Leg 1					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.071 g		-94.8	101	OP01	0.0000	0.0000	0	0
		-75	201	OP01	1.0700	0.8970	0.281	1.4242437
		-57.5	301	OP01	2.3290	2.0510	0.498	3.1430632
		-31.5	401	OP01	3.7540	2.8780	0.7	4.7817779
		-11	501	OP01	4.9110	3.3310	0.762	5.9828192
		6.1	601	OP01	5.8190	3.9000	0.75	7.0450877
			Leg 1					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.05 g		-94.8	101	OP01	0.0000	0.0000	0	0
		-75	201	OP01	0.7530	0.6320	0.198	1.0028145
		-57.5	301	OP01	1.6400	1.4440	0.351	2.2131283
		-31.5	401	OP01	2.6640	2.0270	0.493	3.3835889
		-11	501	OP01	3.4580	2.3460	0.537	4.213057
		6.1	601	OP01	4.0980	2.7470	0.528	4.961693
			Leg 1					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.044 g		-94.8	101	OP01	0.0000	0.0000	0	0
		-75	201	OP01	0.6630	0.5560	0.174	0.882599
		-57.5	301	OP01	1.4430	1.2710	0.309	1.9476065
		-31.5	401	OP01	2.3270	1.7840	0.434	2.9641088
		-11	501	OP01	3.0430	2.0640	0.473	3.7072461
		6.1	601	OP01	3.6060	2.4170	0.465	4.3659306
			Leg 1					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.02 g		-94.8	101	OP01	0.0000	0.0000	0	0
		-75	201	OP01	0.3010	0.2530	0.079	0.4010623
		-57.5	301	OP01	0.6560	0.5780	0.14	0.885449
		-31.5	401	OP01	1.0580	0.8110	0.197	1.3475511
		-11	501	OP01	1.3830	0.9830	0.215	1.7103225
		6.1	601	OP01	1.6390	1.0990	0.211	1.9846015

			Leg 1					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.175 g		-94.8	101	OP01	0.0000	0.0000	0	0
		-75	201	OP01	2.6370	2.2120	0.693	3.5109774
		-57.5	301	OP01	5.7410	5.0550	1.227	7.7471049
		-31.5	401	OP01	9.2540	7.0950	1.726	11.787901
		-11	501	OP01	12.0130	8.2100	1.879	14.671295
		6.1	601	OP01	14.3420	9.6130	1.847	17.364163

			Leg 1					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.18 g		-94.8	101	OP01	0.0000	0.0000	0	0
		-75	201	OP01	2.7130	2.2750	0.713	3.6116981
		-57.5	301	OP01	5.9050	5.1990	1.262	7.9681409
		-31.5	401	OP01	9.5180	7.2970	1.776	12.124055
		-11	501	OP01	12.4490	8.4440	1.933	15.166253
		6.1	601	OP01	14.7520	9.8880	1.9	17.860684
	Dir	Depth	LEG 2					
			Leg 2					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.2 g		-94.8	102	OP01	0.0000	0.0000	0	0
		-75	202	OP01	3.6020	2.4700	0.479	4.3937165
		-57.5	302	OP01	7.0340	4.8650	0.923	8.6021689
		-31.5	402	OP01	10.9820	7.8110	1.544	13.564659
		-11	502	OP01	15.1700	9.2100	1.678	17.826068
		6.1	602	OP01	18.7700	10.9890	1.742	21.819844
			Leg 2					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.15 g		-94.8	102	OP01	0.0000	0.0000	0	0
		-75	202	OP01	2.7020	1.8520	0.359	3.2953891
		-57.5	302	OP01	5.2750	3.6490	0.692	6.4513324
		-31.5	402	OP01	8.2360	5.8880	1.158	10.19025
		-11	502	OP01	11.3780	6.9070	1.258	13.369671
		6.1	602	OP01	14.0770	8.2470	1.306	16.367058

			Leg 2					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.122 g		-94.8	102	OP01	0.0000	0.0000	0	0
		-75	202	OP01	2.1970	1.5060	0.292	2.6795725
		-57.5	302	OP01	4.2900	2.9680	0.563	5.2469127
		-31.5	402	OP01	6.6990	4.7650	0.942	8.2746112
		-11	502	OP01	9.2540	5.6180	1.024	10.874144
		6.1	602	OP01	11.4500	6.7030	1.063	13.310247
			Leg 2					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.097 g		-94.8	102	OP01	0.0000	0.0000	0	0
		-75	202	OP01	1.7470	1.1980	0.232	2.1309709
		-57.5	302	OP01	3.4110	2.3600	0.448	4.171957
		-31.5	402	OP01	5.3260	3.7880	0.749	6.5784665
		-11	502	OP01	7.9580	4.4670	0.814	9.1622295
		6.1	602	OP01	9.1030	5.3300	0.845	10.582416
			Leg 2					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.071 g		-94.8	102	OP01	0.0000	0.0000	0	0
		-75	202	OP01	1.2790	0.8770	0.17	1.5600865
		-57.5	302	OP01	2.4970	1.7270	0.328	3.0537063
		-31.5	402	OP01	3.8990	2.7730	0.548	4.8158108
		-11	502	OP01	5.3850	3.2690	0.596	6.3277012
		6.1	602	OP01	6.6630	3.9010	0.618	7.7456629
			Leg 2					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.05 g		-94.8	102	OP01	0.0000	0.0000	0	0
		-75	202	OP01	0.9010	0.6170	0.12	1.0985855
		-57.5	302	OP01	1.7580	1.2160	0.231	2.1500188
		-31.5	402	OP01	2.7450	1.9530	0.386	3.390904
		-11	502	OP01	3.7930	2.3020	0.419	4.4566371
		6.1	602	OP01	4.6920	2.7470	0.435	5.454365

0.044 g								
			Leg 2					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	102	OP01	0.0000	0.0000	0	0
		-75	202	OP01	0.7920	0.5430	0.105	0.9659907
		-57.5	302	OP01	1.5470	1.0700	0.203	1.8919086
		-31.5	402	OP01	2.4160	1.7180	0.34	2.9839873
		-11	502	OP01	3.3370	2.0260	0.369	3.9212761
		6.1	602	OP01	4.1290	2.4180	0.383	4.800214
0.02 g								
			Leg 2					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	102	OP01	0.0000	0.0000	0	0
		-75	202	OP01	0.3600	0.2470	0.048	0.4392186
		-57.5	302	OP01	0.7030	0.4860	0.092	0.8595749
		-31.5	402	OP01	1.0980	0.7810	0.154	1.3562009
		-11	502	OP01	1.5170	0.9210	0.168	1.7826256
		6.1	602	OP01	1.8770	1.0990	0.174	2.1820188

0.175 g								
			Leg 2					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	102	OP01	0.0000	0.0000	0	0
		-75	202	OP01	3.1520	2.1610	0.419	3.8445528
		-57.5	302	OP01	6.1540	4.2570	0.808	7.5263955
		-31.5	402	OP01	9.6090	6.8350	1.351	11.86909
		-11	502	OP01	13.2740	8.0590	1.468	15.598127
		6.1	602	OP01	16.4240	9.6160	0.174	19.032748

0.18 g								
			Leg 2					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
		-94.8	102	OP01	0.0000	0.0000	0	0
		-75	202	OP01	3.2420	2.2230	0.431	3.9544979
		-57.5	302	OP01	6.3300	4.3780	0.851	7.7433833
		-31.5	402	OP01	9.8840	7.0300	1.39	12.208458
		-11	502	OP01	13.6530	8.2890	1.51	16.043442
		6.1	602	OP01	16.8930	9.8900	1.568	19.637825

	Dir	Depth	Leg 3					
			Leg 3					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.2 g		-94.8	103	OP01	0.0000	0.0000	0	0
		-75	203	OP01	3.6140	2.2140	-0.222	4.2440636
		-57.5	303	OP01	7.0990	4.9200	-0.282	8.6418589
		-31.5	403	OP01	10.9520	7.3430	-0.201	13.187356
		-11	503	OP01	15.1340	8.3750	0.135	17.297306
		6.1	603	OP01	18.7770	9.4960	0.626	21.050929
			Leg 3					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.15 g		-94.8	103	OP01	0.0000	0.0000	0	0
		-75	203	OP01	2.7010	1.6600	-0.167	3.1747268
		-57.5	303	OP01	5.3240	3.6900	-0.212	6.4812051
		-31.5	403	OP01	8.2140	5.5070	-0.15	9.8903663
		-11	503	OP01	11.3500	6.2810	0.101	12.972419
		6.1	603	OP01	14.0830	7.1220	0.465	15.788287
			Leg 3					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.122 g		-94.8	103	OP01	0.0000	0.0000	0	0
		-75	203	OP01	2.2040	1.3500	-0.136	2.5881677
		-57.5	303	OP01	4.3300	3.0010	-0.172	5.271099
		-31.5	403	OP01	6.6810	4.4790	-0.122	8.0443823
		-11	503	OP01	9.2310	5.1090	0.082	10.550828
		6.1	603	OP01	11.4540	5.7930	0.378	12.841178
			Leg 3					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.097 g		-94.8	103	OP01	0.0000	0.0000	0	0
		-75	203	OP01	1.7530	1.0740	-0.108	2.0586765
		-57.5	303	OP01	3.4430	2.3860	-0.37	4.2052521
		-31.5	403	OP01	5.3120	3.5010	-0.097	6.3626845
		-11	503	OP01	7.3400	4.0620	0.065	8.3892591
		6.1	603	OP01	9.1070	4.6060	0.301	10.20996

			Leg 3					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.071 g		-94.8	103	OP01	0.0000	0.0000	0	0
		-75	203	OP01	1.2830	0.7710	0.042	1.4974291
		-57.5	303	OP01	2.1860	1.6700	0.095	2.7525481
		-31.5	403	OP01	3.7030	2.5790	0.175	4.51598
		-11	503	OP01	4.8900	2.9590	0.265	5.7217136
		6.1	603	OP01	5.8280	3.3640	0.352	6.7383962
			Leg 3					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.05 g		-94.8	103	OP01	0.0000	0.0000	0	0
		-75	203	OP01	0.9030	0.5530	-0.056	1.0603556
		-57.5	303	OP01	1.7750	1.2300	-0.071	2.1606865
		-31.5	403	OP01	2.7380	1.8360	-0.05	3.2969744
		-11	503	OP01	3.7830	2.0940	0.034	4.3240121
		6.1	603	OP01	4.6940	2.9740	0.155	5.558987
			Leg 3					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.044 g		-94.8	103	OP01	0.0000	0.0000	0	0
		-75	203	OP01	0.7950	0.4870	-0.049	0.9335925
		-57.5	303	OP01	1.5020	1.0830	-0.062	1.8527647
		-31.5	403	OP01	2.4090	1.6150	-0.044	2.9005934
		-11	503	OP01	3.3290	1.8420	0.03	3.8047477
		6.1	603	OP01	4.1310	2.0890	0.136	4.631153
			Leg 3					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.02 g		-94.8	103	OP01	0.0000	0.0000	0	0
		-75	203	OP01	0.3010	0.2210	-0.22	0.4334074
		-57.5	303	OP01	0.7100	0.4920	-0.028	0.8642615
		-31.5	403	OP01	1.0950	0.7340	-0.02	1.3184009
		-11	503	OP01	1.5130	0.8370	0.013	1.7291348
		6.1	603	OP01	1.8780	0.9500	0.062	2.1055232

			Leg 3					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.175 g		-94.8	103	OP01	0.0000	0.0000	0	0
		-75	203	OP01	3.1620	1.9370	-0.194	3.7131993
		-57.5	303	OP01	6.2110	4.3050	-0.247	7.5611213
		-31.5	403	OP01	9.5830	6.4250	-0.176	11.538869
		-11	503	OP01	13.2420	7.3280	0.118	15.134863
		6.1	603	OP01	16.4300	8.3090	0.542	18.419504

			Leg 3					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.18 g		-94.8	103	OP01	0.0000	0.0000	0	0
		-75	203	OP01	3.2520	1.9920	-0.2	3.8188438
		-57.5	303	OP01	6.3890	4.4280	-0.254	7.7775974
		-31.5	403	OP01	9.8570	6.6090	-0.181	11.868955
		-11	503	OP01	13.6200	7.5370	0.121	15.566805
		6.1	603	OP01	16.9000	8.5470	0.558	18.946572

	Dir	Depth	LEG 4					
			Leg 4					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.2 g		-94.8	104	OP01	0.0000	0.0000	0	0
		-75	204	OP01	2.9960	2.1730	0.118	3.7029541
		-57.5	304	OP01	6.1570	4.7030	0.269	7.7523686
		-31.5	404	OP01	10.4300	7.2640	0.492	12.719774
		-11	504	OP01	13.7740	8.9950	0.746	16.467836
		6.1	604	OP01	16.4160	9.4770	0.99	18.981009

			Leg 4					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.15 g		-94.8	104	OP01	0.0000	0.0000	0	0
		-75	204	OP01	2.2470	1.6300	0.088	2.7773464
		-57.5	304	OP01	4.6170	3.5270	0.202	5.8135378
		-31.5	404	OP01	7.8230	5.4480	0.369	9.5402408
		-11	504	OP01	10.3310	6.2520	0.559	12.088405

		6.1	604	OP01	12.3120	7.1070	0.743	14.235408

			Leg 4					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.122 g		-94.8	104	OP01	0.0000	0.0000	0	0
		-75	204	OP01	1.8280	1.3260	0.072	2.2594344
		-57.5	304	OP01	3.7560	2.8690	0.164	4.7292275
		-31.5	404	OP01	6.3620	4.4310	0.3	7.7587889
		-11	504	OP01	8.4020	5.0850	0.455	9.8314726
		6.1	604	OP01	10.0140	5.7810	0.604	11.578643
			Leg 4					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.097 g		-94.8	104	OP01	0.0000	0.0000	0	0
		-75	204	OP01	1.4530	1.0540	0.057	1.7959326
		-57.5	304	OP01	2.9860	2.2810	0.13	3.7597948
		-31.5	404	OP01	5.0590	3.5230	0.239	6.1694514
		-11	504	OP01	6.6810	4.0430	0.362	7.8174583
		6.1	604	OP01	7.9620	4.5960	0.48	9.2058166
			Leg 4					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.071 g		-94.8	104	OP01	0.0000	0.0000	0	0
		-75	204	OP01	1.0640	0.7710	0.042	1.3146486
		-57.5	304	OP01	2.1860	1.6700	0.095	2.7525481
		-31.5	404	OP01	3.7030	2.5790	0.175	4.51598
		-11	504	OP01	4.8900	2.9590	0.265	5.7217136
		6.1	604	OP01	5.8280	3.3640	0.352	6.7383962
			Leg 4					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.05 g		-94.8	104	OP01	0.0000	0.0000	0	0
		-75	204	OP01	0.7490	0.5430	0.029	0.925576
		-57.5	304	OP01	1.5390	1.1760	0.067	1.9380366
		-31.5	404	OP01	2.6080	1.8160	0.123	3.1803536
		-11	504	OP01	3.4440	2.0840	0.186	4.029738
		6.1	604	OP01	4.1040	2.3690	0.248	4.7451534

			Leg 4					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.044 g		-94.8	104	OP01	0.0000	0.0000	0	0
		-75	204	OP01	0.6590	0.4780	0.026	0.8145189
		-57.5	304	OP01	1.3540	1.0350	0.059	1.7052924
		-31.5	404	OP01	2.2950	1.5980	0.108	2.7986234
		-11	504	OP01	3.0300	1.8340	0.164	3.5456102
		6.1	604	OP01	3.6120	2.0850	0.218	4.1762774

			Leg 4					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.02 g		-94.8	104	OP01	0.0000	0.0000	0	0
		-75	204	OP01	0.3000	0.2170	0.012	0.3704497
		-57.5	304	OP01	0.6160	0.4700	0.027	0.7752967
		-31.5	404	OP01	1.0430	0.7260	0.049	1.2717413
		-11	504	OP01	1.3770	0.8340	0.075	1.6116172
		6.1	604	OP01	1.6420	0.9480	0.099	1.8985966

			Leg 4					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.175 g		-94.8	104	OP01	0.0000	0.0000	0	0
		-75	204	OP01	2.6220	1.9010	0.103	3.2402614
		-57.5	304	OP01	5.3870	4.1150	0.235	6.7829359
		-31.5	404	OP01	9.1260	6.3560	0.43	11.129578
		-11	504	OP01	12.0530	7.2930	0.653	14.102804
		6.1	604	OP01	14.3640	8.2920	0.867	16.608234

			Leg 4					
						JOINT DIS	PLACEMENTS	
		m		LOAD	********	cm	**********	cm
			JOIN	T COND	DEFL(X)	DEFL(Y)	DEFL(Z)	Resultant
0.18 g		-94.8	104	OP01	0.0000	0.0000	0	0
		-75	204	OP01	2.6960	1.9560	0.106	3.3325048
		-57.5	304	OP01	5.5410	4.2330	0.242	6.977072

		-31.5	404	OP01	9.3870	6.5370	0.443	11.447462
		-11	504	OP01	12.3970	7.5020	0.671	14.505718
		6.1	604	OP01	14.7740	8.5290	0.891	17.082412

Appendix IV:

LOAD SUMMATION

0.180 g, 45°

DATE 29-NOV-201 3 TI ME 19:54:49

KUMANG CLUSTER D EVELOPMENT PROJECT

LOAD SUM MATION REPORT

Load Condition OP01

The sum of forces at the origin are:

Fx = 9812.76	Fy = 7933.13	Fz = -64041.92
Mx = -78122.98	My = -97023.85	Mz = -8434.9

The center of for ces is:

For X forces:	X	= -8.035	Y	0.871	Z =	-1.009
For Y forces:	X	= 0.014	Y	-8.537	Z =	2.282
For Z forces:	X	= -1.41	Y	0.937	Z =	7.273

Load Condition OP02

The sum of forces at the origin are:

Fx = 8305.17	Fy = 11143.24	Fz = -63623.42
Mx = -95591.27	My = -92778.77	Mz = -10070.55

The center of for ces is:

For X forces:	X	= -9.416	Y	0.774	Z =	-0.851
For Y forces:	X	= -0.327	Y	-5.621	Z =	-0.811
For Z forces:	X	= -1.382	Y	1.609	Z =	7.344

Load Condition OP03

The sum of forces at the origin are:

Fx = 5253.72	Fy = 12260.42	Fz = -63485.25
Mx = -80954.54	My = -115326.8	Mz = -9018.22

The center of for ces is:

For X forces:	X	= -14.111	Y	0.496	Z =	2.161
For Y forces:	X	= -0.523	Y	-5.037	Z =	-1.742
For Z forces:	X	= -1.995	Y	1.562	Z =	7.371

Load Condition OP04

The sum of forces at the origin are:

Fx = 2360.61	Fy = 10974.31	Fz = -63690.95
Mx = -97955.73	My = -141310.38	Mz = -3243.2

The center of for ces is:

For X forces:	X	= -28.7	Y	-1.277	Z =	11.462
For Y forces:	X	= -0.57	Y	-5.537	Z =	-0.562
For Z forces:	X	= -2.608	Y	1.599	Z =	7.312

Load Condition OP05

The sum of forces at the origin are:

Fx = 789.68	Fy = 7929.88	Fz = -63841.05
Mx = -77014.16	My = -137209.16	Mz = 2705.62

The center of for	ces is:				
For X forces: X	= -80.121	Y	-3.554	Z =	39.034
For Y forces: X	= -0.013	Y	-8.542	Z =	2.285
For Z forces: X	= -2.582	Y	0.923	Z =	7.282
Load Condition	OP06				
The sum of forces	at the origin are:				
Fx = 2339.25	Fy = 4914.09	Fz = -63856.89			
Mx = -48209.44	My = -144311.64	Mz = 6016.74			
The center of for	ces is:				
For X forces: X	= -28.733	Y	0.226	Z =	10.68
For Y forces: X	= 1.332	Y	-14.359	Z =	7.067
For Z forces: X	= -2.616	Y	0.246	Z =	7.275
Load Condition	OP07				
The sum of forces	at the origin are:				
Fx = 5262.65	Fy = 4096.37	Fz = -63786.0			
Mx = -56756.74	My = -116449.1	Mz = 4795.38			
The center of for	ces is:				
For X forces: X	= -14.057	Y	0.504	Z =	2.149
For Y forces: X	= 1.818	Y	-18.504	Z =	10.097
For Z forces: X	= -2.003	Y	0.291	Z =	7.301
Load Condition	OP08				
The sum of forces	at the origin are:				
Fx = 5262.65	Fy = 3630.69	Fz = -63786.0			
Mx = -110143.72	My = -116449.1	Mz = 4795.38			
The center of for	ces is:				
For X forces: X	= -14.057	Y	0.504	Z =	2.149
For Y forces: X	= 2.051	Y	-21.051	Z =	12.318
For Z forces: X	= -2.003	Y	1.075	Z =	7.301
Load Condition	OP09				
The sum of forces	at the origin are:				
Fx = 8020.46	Fy = 4856.72	Fz = -63957.32			
Mx = -50206.75	My = -90823.67	Mz = -2462.22			
The center of for	ces is:				
For X forces: X	= -9.674	Y	0.719	Z =	-0.555
For Y forces: X	= 0.681	Y	-14.798	Z =	7.393
For Z forces: X	= -1.386	Y	0.259	Z =	7.277

0.122 g, 45°

DATE 29-NOV-201 3 TI ME 18:58:49

KUMANG CLUSTER D EVELOPMENT PROJECT

LOAD SUM MATION REPORT

Load Condition OP01

The sum of forces at the origin are:

Fx = 8170.71	Fy = 5442.46	Fz = -64041.92		
Mx = -66693.05	My = -104559.4	Mz = -7858.9		

The center of forces is:

For X forces: X	= -6.846	Y	0.976	Z =	-2.134
For Y forces: X	= 0.021	Y	-8.618	Z =	1.226
For Z forces: X	= -1.41	Y	0.937	Z =	7.273

Load Condition OP02

The sum of forces at the origin are:

Fx = 6663.12	Fy = 8652.57	Fz = -63623.42
Mx = -84161.38	My = -100314.33	Mz = -9494.55

The center of forces is:

For X forces: X	= -8.3	Y	0.878	Z =	-2.192
For Y forces: X	= -0.421	Y	-4.832	Z =	-2.365
For Z forces: X	= -1.382	Y	1.609	Z =	7.344

Load Condition OP03

The sum of forces at the origin are:

Fx = 3611.66	Fy = 9769.75	Fz = -63485.25
Mx = -69524.63	My = -122862.32	Mz = -8442.22

The center of forces is:

For X forces: X	= -14.185	Y	0.563	Z =	1.057
For Y forces: X	= -0.656	Y	-4.19	Z =	-3.356
For Z forces: X	= -1.995	Y	1.562	Z =	7.371

Load Condition OP04

The sum of forces at the origin are:

Fx = 718.55	Fy = 8483.64	Fz = -63690.95
Mx = -86525.86	My = -148845.91	Mz = -2667.2

The center of forces is:

For X forces: X	= -62.414	Y	-4.998	Z =	27.167
For Y forces: X	= -0.738	Y	-4.708	Z =	-2.074
For Z forces: X	= -2.608	Y	1.599	Z =	7.312

Load Condition OP05

The sum of forces at the origin are:

Fx = -852.37	Fy = 5439.21	Fz = -63841.05
Mx = -65584.22	My = -144744.66	Mz = 3281.62

The center of forces is:

For X forces: X	= 47.359	Y	3.969	Z =	-27.322
For Y forces: X	= -0.019	Y	-8.625	Z =	1.23
For Z forces: X	= -2.582	Y	0.923	Z =	7.282

Load Condition OP06

The sum of forces at the origin are:

Fx = 697.2	Fy = 2423.42	Fz = -63856.89
Mx = -36779.56	My = -151847.16	Mz = 6592.74

The center of for ces is:

For X forces: X	= -63.554	Y	-0.068	Z =	25.024
For Y forces: X	= 2.701	Y	-20.525	Z =	9.614
For Z forces: X	= -2.616	Y	0.246	Z =	7.275

Load Condition OP07

The sum of forces at the origin are:

Fx = 3620.6	Fy = 1605.7	Fz = -63786.0
Mx = -45326.86	My = -123984.62	Mz = 5371.38

The center of for ces is:

For X forces: X	= -14.107	Y	0.573	Z =	1.043
For Y forces: X	= 4.637	Y	-34.24	Z =	18.64
For Z forces: X	= -2.003	Y	0.291	Z =	7.301

Load Condition OP08

The sum of forces at the origin are:

Fx = 3620.6	Fy = 1140.02	Fz = -63786.0
Mx = -98713.84	My = -123984.62	Mz = 5371.38

The center of for ces is:

For X forces: X	= -14.107	Y	0.573	Z =	1.043
For Y forces: X	= 6.531	Y	-48.778	Z =	29.204
For Z forces: X	= -2.003	Y	1.075	Z =	7.301

Load Condition OP09

The sum of forces at the origin are:

Fx = 6378.41	Fy = 2366.05	Fz = -63957.32
Mx = -38776.88	My = -98359.2	Mz = -1886.22

The center of for ces is:

For X forces: X	= -8.573	Y	0.814	Z =	-1.88
For Y forces: X	= 1.398	Y	-21.576	Z =	10.345
For Z forces: X	= -1.386	Y	0.259	Z =	7.277

0.044 g, 45°

DATE 29-NOV-201 3 TI ME 18:45:34

KUMANG CLUSTER D EVELOPMENT PROJECT

LOAD SUM MATION REPORT

Load Condition OP01

The sum of forces at the origin are:

Fx = 5859.95	Fy = 1937.55	Fz = -64041.92
Mx = -62977.7	My = -107009.02	Mz = -6545.24

The center of for	ces is:					
For X forces: X	= -4.025	Y	1.136	Z	=	-3.394
For Y forces: X	= 0.058	Y	-8.926	Z	=	1.525
For Z forces: X	= -1.41	Y	0.937	Z	=	7.273
Load Condition	OP02					
The sum of forces	at the origin are:					
Fx = 4352.36	Fy = 5147.65	Fz = -63623.42				
Mx = -80446.03	My = -102763.96	Mz = -8180.88				
The center of for	ces is:					
For X forces: X	= -5.273	Y	1.043	Z	=	-3.918
For Y forces: X	= -0.708	Y	-2.371	Z	=	-4.698
For Z forces: X	= -1.382	Y	1.609	Z	=	7.344
Load Condition	OP03					
The sum of forces	at the origin are:					
Fx = 1300.9	Fy = 6264.83	Fz = -63485.25				
Mx = -65809.3	My = -125311.98	Mz = -7128.56				
The center of for	ces is:					
For X forces: X	= -14.511	Y	0.552	Z	=	1.051
For Y forces: X	= -1.023	Y	-1.808	Z	=	-5.827
For Z forces: X	= -1.995	Y	1.562	Z	=	7.371
Load Condition	OP04					
The sum of forces	at the origin are:					
Fx = -1592.21	Fy = 4978.73	Fz = -63690.95				
Mx = -82810.49	My = -151295.55	Mz = -1353.53				
The center of for	ces is:					
For X forces: X	= 7.847	Y	3.081	Z	=	-10.722
For Y forces: X	= -1.257	Y	-2.075	Z	=	-4.28
For Z forces: X	= -2.608	Y	1.599	Z	=	7.312
Load Condition	OP05					
The sum of forces	at the origin are:					
Fx = -3163.13	Fy = 1934.29	Fz = -63841.05				
Mx = -61868.87	My = -147194.3	Mz = 4595.29				
The center of for	ces is:					
For X forces: X	= 2.533	Y	1.485	Z	=	-6.588
For Y forces: X	= -0.052	Y	-8.947	Z	=	1.537
For Z forces: X	= -2.582	Y	0.923	Z	=	7.282
Load Condition	OP06					
The sum of forces	at the origin are:					
Fx = -1613.56	Fy = -1081.49	Fz = -63856.89				
Mx = -33064.2	My = -154296.8	Mz = 7906.4				

The center of for	ces is:					
For X forces: X	= 7.41	Y	0.844	Z	=	-9.294
For Y forces: X	= -6.052	Y	18.615	Z	=	-18.107
For Z forces: X	= -2.616	Y	0.246	Z	=	7.275
Load Condition	OP07					
The sum of forces	at the origin are:					
Fx = 1309.84	Fy = -1899.22	Fz = -63786.0				
Mx = -41611.53	My = -126434.33	Mz = 6685.05				
The center of for	ces is:					
For X forces: X	= -14.293	Y	0.58	Z	=	1.012
For Y forces: X	= -3.92	Y	13.358	Z	=	-13.803
For Z forces: X	= -2.003	Y	0.291	Z	=	7.301
Load Condition	OP08					
The sum of forces	at the origin are:					
Fx = 1309.84	Fy = -2364.89	Fz = -63786.0				
Mx = -94998.37	My = -126434.33	Mz = 6685.05				
The center of for	ces is:					
For X forces: X	= -14.293	Y	0.58	Z	=	1.012
For Y forces: X	= -3.148	Y	10.994	Z	=	-12.507
For Z forces: X	= -2.003	Y	1.075	Z	=	7.301
Load Condition	OP09					
The sum of forces	at the origin are:					
Fx = 4067.65	Fy = -1138.87	Fz = -63957.32				
Mx = -35061.52	My = -100808.87	Mz = -572.56				
The center of for	ces is:					
For X forces: X	= -5.49	Y	0.954	Z	=	-3.55
For Y forces: X	= -2.905	Y	18.826	Z	=	-18.23
For Z forces: X	= -1.386	Y	0.259	Z	=	7.277

Storm Metocean

Load Condition	ST01					
The sum of forces	at the origin are:					
Fx = 9758.66	Fy = -26.84	Fz = -63962.73				
Mx = -61985.43	My = -173495.38	Mz = -17210.99				
The center of for	ces is:					
For X forces: X	= -1.307	Y	1.765	Z	=	-8.742
For Y forces: X	= -0.628	Y	18.72	Z	=	-27.706
For Z forces: X	= -1.379	Y	0.957	Z	=	7.175

Load Condition	ST02				
The sum of forces	at the origin are:				
Fx = 6582.92	Fy = 6834.78	Fz = -63829.23			
Mx = -38820.36	My = -147577.19	Mz = -21054.13			
The center of for	ces is:				
For X forces: X	= -1.253	Y	1.949	Z =	-9.411
For Y forces: X	= -1.204	Y	2.335	Z =	-9.936
For Z forces: X	= -1.341	Y	1.672	Z =	7.21
Load Condition	ST03				
The sum of forces	at the origin are:				
Fx = -8.24	Fy = 9562.27	Fz = -63387.6			
Mx = -3625.13	My = -125500.92	Mz = -14032.52			
The center of for	ces is:				
For X forces: X	= 72.03	Y	6.23	Z =	-7.213
For Y forces: X	= -1.473	Y	1.956	Z =	-10.282
For Z forces: X	= -1.981	Y	1.608	Z =	7.321
Load Condition	ST04				
The sum of forces	at the origin are:				
Fx = -6489.78	Fy = 6730.07	Fz = -63599.25			
Mx = -43266.59	My = -109873.65	Mz = 2353.83			
The center of for	ces is:				
For X forces: X	= -1.317	Y	1.953	Z =	-8.669
For Y forces: X	= -1.534	Y	2.309	Z =	-9.283
For Z forces: X	= -2.612	Y	1.663	Z =	7.253
Load Condition	ST05				
The sum of forces	at the origin are:				
Fx = -9581.86	Fy = -30.56	Fz = -63849.58			
Mx = -60920.61	My = -80951.47	Mz = 16444.3			
The center of for	ces is:				
For X forces: X	= -1.603	Y	1.718	Z =	-8.697
For Y forces: X	= 0.535	Y	18.249	Z =	-26.266
For Z forces: X	= -2.573	Y	0.942	Z =	7.177
Load Condition	ST06				
The sum of forces	at the origin are:				
Fx = -6497.22	Fy = -6505.93	Fz = -64101.33			
Mx = -46681.23	My = -115793.11	Mz = 20487.06			
The center of for	ces is:				
For X forces: X	= -1.561	Y	1.406	Z =	-7.918
For Y forces: X	= -1.745	Y	1.741	Z =	-4.94
For Z forces: X	= -2.609	Y	0.227	Z =	7.099

Load Condition ST07

The sum of forces at the origin are:

Fx = 11.79	Fy = -9241.9	Fz = -64084.91
Mx = -71138.36	My = -126830.59	Mz = 15104.35

The center of forces is:

For X forces:	X = -38.115	Y	3.777	Z =	-6.314
For Y forces:	X = -1.639	Y	1.975	Z =	-5.706
For Z forces:	X = -1.978	Y	0.287	Z =	7.102

Load Condition ST08

The sum of forces at the origin are:

Fx = 11.79	Fy = -9241.9	Fz = -64084.91
Mx = -121162.72	My = -126830.59	Mz = 15104.35

The center of forces is:

For X forces:	X = -38.115	Y	3.777	Z =	-6.314
For Y forces:	X = -1.639	Y	2.043	Z =	-5.706
For Z forces:	X = -1.978	Y	1.068	Z =	7.102

Load Condition ST09

The sum of forces at the origin are:

Fx = 6316.15	Fy = -6562.61	Fz = -64110.43
Mx = -49306.4	My = -140898.03	Mz = -2267.81

The center of forces is:

For X forces:	X = -1.193	Y	1.655	Z =	-8.681
For Y forces:	X = -1.248	Y	1.956	Z =	-5.179
For Z forces:	X = -1.343	Y	0.239	Z =	7.113

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Load Condition OP01

The sum of forces at the origin are:

Fx = 6437.82	Fy = -36.26	Fz = -64118.15
Mx = -60715.57	My = -125044.7	Mz = -9799.46

The center of forces is:

For X forces:	X = -1.113	Y	1.532	Z =	-6.013
For Y forces:	X = -1.689	Y	13.432	Z =	-18.184
For Z forces:	X = -1.396	Y	0.937	Z =	7.255

Load Condition OP02

The sum of forces at the origin are:

Fx = 4321.14	Fy = 4491.88	Fz = -63851.39
Mx = -73375.12	My = -111906.55	Mz = -13410.81

The center of for	ces is:					
For X forces: X	= -1.348	Y	1.853	Z	=	-6.199
For Y forces: X	= -1.203	Y	2.217	Z	=	-7.478
For Z forces: X	= -1.368	Y	1.64	Z	=	7.311
Load Condition	OP03					
The sum of forces	at the origin are:					
Fx = -2.09	Fy = 6146.34	Fz = -63840.71				
Mx = -55012.19	My = -127539.29	Mz = -9943.84				
The center of for	ces is:					
For X forces: X	= 302.152	Y	13.259	Z	=	2.485
For Y forces: X	= -1.622	Y	2.684	Z	=	-8.072
For Z forces: X	= -1.998	Y	1.589	Z	=	7.312
Load Condition	OP04					
The sum of forces	at the origin are:					
Fx = -4224.82	Fy = 4397.27	Fz = -63616.13				
Mx = -72101.36	My = -142107.09	Mz = 194.5				
The center of for	ces is:					
For X forces: X	= -1.407	Y	1.703	Z	=	-6.449
For Y forces: X	= -1.592	Y	2.076	Z	=	-7.716
For Z forces: X	= -2.627	Y	1.631	Z	=	7.343
Load Condition	OP05					
The sum of forces	at the origin are:					
Fx = -6316.22	Fy = -38.41	Fz = -63980.3				
Mx = -59753.87	My = -131950.41	Mz = 9542.24				
The center of for	ces is:					
For X forces: X	= -1.893	Y	1.52	Z	=	-5.914
For Y forces: X	= 1.442	Y	13.28	Z	=	-17.73
For Z forces: X	= -2.597	Y	0.923	Z	=	7.267
Load Condition	OP06					
The sum of forces	at the origin are:					
Fx = -4228.35	Fy = -4421.92	Fz = -63992.1				
Mx = -37987.2	My = -146425.59	Mz = 12940.11				
The center of for	ces is:					
For X forces: X	= -1.711	Y	1.161	Z	=	-5.695
For Y forces: X	= -1.816	Y	1.626	Z	=	-6.001
For Z forces: X	= -2.629	Y	0.214	Z	=	7.251
Load Condition	OP07					
The sum of forces	at the origin are:					
Fx = 7.52	Fy = -6198.3	Fz = -63880.47				
Mx = -56467.79	My = -127849.11	Mz = 10200.34				

The center of for	ces is:				
For X forces: X	= -44.459 Y	3.73	Z	=	-4.863
For Y forces: X	= -1.65 Y	2.525	Z	=	-6.896
For Z forces: X	= -2.001 Y	0.264	Z	=	7.278
Load Condition	OP08				
The sum of forces	at the origin are:				
Fx = 7.52	Fy = -6198.3	Fz = -63880.47			
Mx = -106554.88	My = -127849.11	Mz = 10200.34			
The center of for	ces is:				
For X forces: X	= -44.459 Y	3.73	Z	=	-4.863
For Y forces: X	= -1.65 Y	2.576	Z	=	-6.896
For Z forces: X	= -2.001 Y	1.048	Z	=	7.278
Load Condition	OP09				
The sum of forces	at the origin are:				
Fx = 4067.55	Fy = -4474.58	Fz = -64054.84			
Mx = -39852.55	My = -111624.23	Mz = -712.06			
The center of for	ces is:				
For X forces: X	= -1.303 Y	1.474	Z	=	-6.445
For Y forces: X	= -1.181 Y	1.909	Z	=	-6.169
For Z forces: X	= -1.368 Y	0.226	Z	=	7.251