CRITICAL MEMBER ANALYSIS OF WELLHEAD OFFSHORE PLATFORM DUE TO EL CENTRO EARTHQUAKE

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the Bachelor Degree in Civil Engineering

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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Thesis submitted in fulfillment of the requirements
for the award of the
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DEDICATION

This thesis is proudly dedicated to

My beloved parent
Leng So Hua and Yeoh Ley Peng
For their great support, pray, love and care

My supervisor
Ir. Dr. Saffuan
For his excellent guidance, advice, and motivation

Making me who I am today

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ABSTRAK

Kajian ini berkenaan dengan analisis seismik ahli struktur luar pesisir yang kritikal di Malaysia dengan matlamat untuk mengira maklum balas dan menilai kapasiti rintangan struktur untuk memuatkan gempa bumi. Walau bagaimanapun, keadaan sempadan struktur luar pesisir dianggap sebagai tetap kepada tanah dan interaksi tanah telah diabaikan. Kajian ini dijalankan kerana gegaran berlaku di Malaysia telah dilaporkan beberapa kali yang disebabkan oleh gempa Sumatra dan Filipina. Oleh itu, jurutera-jurutera bimbang tentang kelemahan seismik struktur luar pesisir kerana kekurangan pertimbangan pemuatan seismik dalam prosedur reka bentuk bangunan Malaysia. Dengan ini, platform luar pesisir telah dianalisis dengan menggunakan SAP2000 di bawah pelbagai jenis analisis termasuk Analisis Getaran Bebas (FVA), Spektrum Respon (RS) dengan menggunakan lengkung spektrum tindak balas Eurocode 8 dan Analisis Sejarah Masa (THA) memandangkan data gempa El Centro 1940. Kod reka bentuk yang digunakan untuk struktur keluli ialah Eurocode 3. Data-data faktor alam sekitar yang dipertimbangkan adalah seperti ketinggian gelombang, tempoh gelombang, halaju arus dan pecutan gerak tanah. Angkutan alam sekitar seperti gelombang dan beban angin telah direka dengan merujuk kepada kriteria reka bentuk API (American Petroleum Institute). Sebagai kesimpulannya, struktur luar pesisir adalah stabil dan mampu menahan kepada gempa bumi. Reka bentuk struktur luar pesisir dapat memberikan ketahanan yang mencukupi terhadap kesan seismik dan sebahagian besar strukturnya berada dalam keadaan baik.

ABSTRACT

The paper deals with the seismic analysis of a critical member of wellhead offshore platform in Malaysia with the aim to compute the response and assess the resistance capacity of the structure to earthquake loading. However, the boundary condition of the offshore structure is assumed as fixed to the ground and soil interaction has been neglected. This study is conducted due to tremors occurred in Malaysia caused by Sumatra and Philippine earthquakes have been reported several times. Thus, engineers are concerned about the seismic vulnerability of offshore structures due to lack of earthquake consideration in Malaysia's building design procedure. With this, wellhead offshore platform is analyzed using Finite Element Modelling (FEM) by SAP2000 software under different types of analyses including Free Vibration Analysis (FVA), Response Spectrum (RS) by using response spectra curves of Eurocode 8 and Time History Analysis (THA) considering El Centro 1940 earthquake data. The design code for the steel frame is Eurocode 3. All the environmental factors data are given such as ranges of wave height, wave period, current velocity and ground motion acceleration. The environmental loadings such as wave and wind load have been designed by referring API (American Petroleum Institute) design criteria. In conclusion, wellhead offshore platform is stable and capable to withstand the earthquake. It can be concluded that the design of the offshore structures can provide sufficient resistance against seismic effects and most of the part of the structure was in good condition.

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LIST OF SYMBOLS

km	kilometer
cm/yr	centimeter per year
m/s^2	metre per square second
Hz	hertz
m	meter
Nm	Newton meter
Mm	Millimetre
N	Newton
Kg/m^3	kilogram per cubic meter
m/s	meter per second
m^2	square meter
MPA	Mega Pascal
G	Gal
Hz	Hertz
N/m^3	Newton per cubic meter
MN	Mega newton
s	second

LIST OF ABBREVIATIONS

GDP	Gross Domestic Product
BS	British Standard
EC	Eurocode
ISO	International Organization for Standardization
API	American Petroleum Institute
P	Primary
S	Secondary
L	Love
R	Rayleigh
v	Poisson's ratio
E	Young's modulus
G	Shear modulus
P	Density
M_L	Local magnitude
m_b	Body wave magnitude
A	Maximum amplitude (in microns)
T	Period (in seconds)
M_s	Surface wave magnitude
M_w	Moment magnitude
A	Fault area
U	longitudinal displacement of fault (in m)
M_o	Seismic moment (in Nm)
MMI	Modified Mercalli Intensity
PGA	Peak ground acceleration
PGV	Peak ground velocity
US	United State
ATC	Applied Technology Council
FPU	Floating production unit
FPSO	Floating production, storage and offloading
DLE	Ductility Level Earthquake
PSHA	Probabilistic Seismic Hazard Assessment
DSHA	Deterministic Seismic Hazard Assessment
CEN	European Committee for Standardization
ELE	Extreme level Earthquake
ALE	Abnormal Level Earthquake
ULS	Ultimate limit state
V	Self-weight of topside
$\mathrm{M_v}$	Moment with eccentric loading of platform
$\mathrm{L_b}$	Lateral wind load
$\mathrm{L_c}$	Lateral current load
$\mathrm{L_w}$	Lateral wave load
$\mathrm{M_b}$	Moment related to wave loadings
$\mathrm{M_c}$	Moment related to current loadings
$\mathrm{M_w}$	Moment related to wind loadings
D, Ø	Diameter
L	Length
ω	Circular frequency (in rad/sec)
f	Number of vibration (Hertz or cycle/sec)

T	Time required to complete one cycle of vibration
W.T	Wall thickness
$u(z, t)$	Design wind speed
z	Height above sea level
$U(z)$	1 hour mean wind speed
I_u(z)	Turbulence intensity
F	Wind drag force
P	Density of air
U	Wind speed
C_s	Shape coefficient
A	Area of object
F_w	Hydrodynamic force vector per unit length
F_D	Drag force per unit length
C_d	Drag coefficient
C_m	Inertia coefficient
U_{mo}	Maximum horizontal particle velocity at storm mean water level
T_{app}	Apparent wave period
D	Platform leg diameter at storm mean water level
G	Gravity acceleration
FVA	Free vibration analysis
DL	Dead load
LL	Live load
EL	Environmental load
TH	Time history
RS	Response spectrum
f_y	Yield strength
f_u	Ultimate strength
γ_{M0}, γ_{M1}, γ_{M2}	Partial factor
W_{pl}	Plastic section modulus
$M_{c,Rd}$	Design bending resistance
$M_{pl,Rd}$	Design plastic bending resistance
$V_{c,Rd}$	Design shear resistance
$V_{pl,Rd}$	Design plastic shear resistance
χ	Reduction factor for bucking mode
λ	Non-dimensional slenderness
λ_1	Relative slenderness
ε	Strain
L_{cr}	Buckling length
i	Radius of gyration
α	Imperfection factor
V_{Ed}	Design shear force
f_v	Shear stress
$V_{b,RD}$	Allowable shear force
F_v	Allowable shear stress
M_{Ed}	Design moment
f_b	Bending stress
$M_{b,RD}$	Allowable bending moment
F_b	Allowable bending stress

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Malaysia is the third-largest exporter of liquefied natural gas in the world and the second largest oil and natural gas manufacturer in Southeast Asia (US. Energy, Information Administration, 2011). In spite of the low price of global crude oil, Oil and Gas sector is still playing a crucial role in our country because it subsidizes around 20 to 30 % to the Gross Domestic Product (GDP) in Malaysia. It recognized as an important and priority sector by Petroliam Nasional Bhd (PETRONAS, the National Oil Company) and Malaysia's Government due to the massive multiplier effect developed by this sector with more than 3,500 companies that work in oil and gas (O&G) in Malaysia (PWC, 2016). This showed that the petroleum industry is still a major element of the worldwide economy.

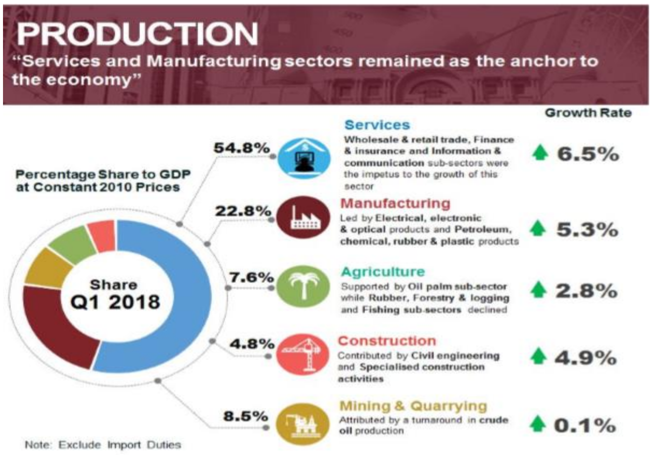

Figure 1.1 Gross Domestic Products First Quarter 2018

Sources: Department of Statistic Malaysia, 2018

The processes involved in petroleum industry are exploration, extraction, refining, transporting, and marketing of petroleum product. Petroleum, as known as crude oil and natural gas which are a mixture of hydrocarbon molecules that made up by the dead bodies of plants and animals, mostly was the small marine life that had lived millions of years ago. Basically, these petroleum reservoirs are located at thousands of feet below the surface. Hence, drilled wells are required to install to the reservoirs in order to reveal or determine oil and gas for multiple functions development and economic uses. Generally, one or more exploratory wells and several development wells may require for a sizable petroleum reservoir. An exploratory well is to identify petroleum reservoir purposes while development well is to manufacture discovered oil and gas. Oil and gas reserves is the volumes of oil and gas discovered within the petroleum reservoir (Light, 2011).

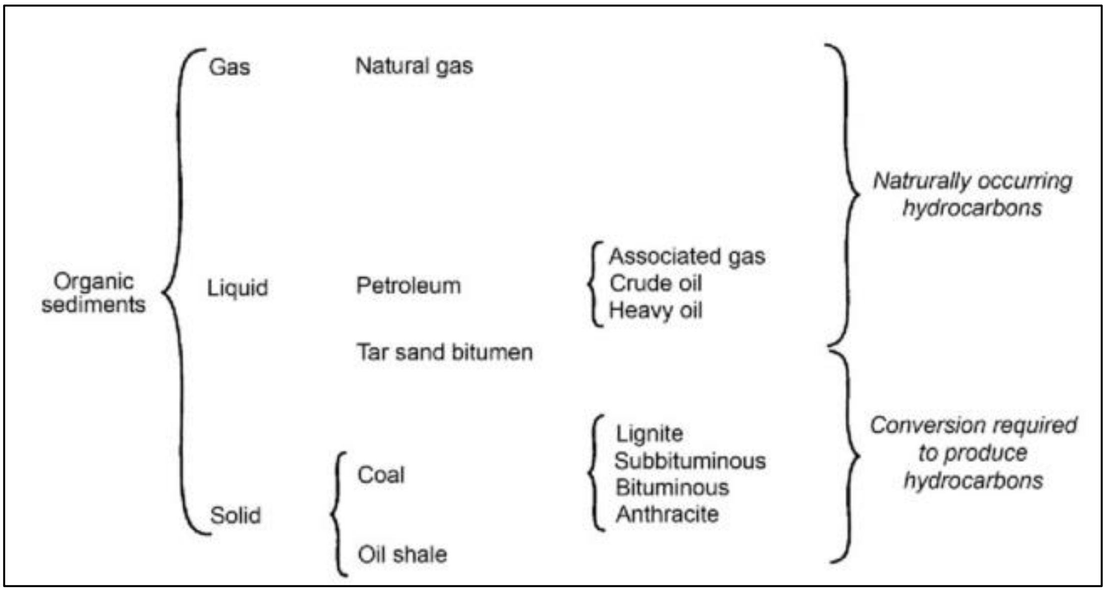

Figure 1.2 Relationship of crude oil to other fossil fuels

Sources: (Speight, 2015)

There are two advanced drilling techniques for oil and gas: offshore drilling and onshore drilling. Onshore drilling indicates that the deep holes are drilling under the earth’s surface while offshore drilling refers to drilling underneath the seabed. In term of cost, onshore drilling will be more economical than offshore drilling as the timeline of the contract is often shorter. However, offshore drilling is adopted in Malaysia as most of the reserves are discovered beneath the seabed (US. Energy, Information Administration, 2011). Unlike onshore drilling, offshore drilling will be facing more challenges on the stability issues due to the shear depth of water before reaching the seabed. Hence, the platform must remain stable and secure by facilitating some anchoring to the ocean floor. These platforms use either in the fixed or floating platform.

The types of offshore drilling platforms including fixed platform, compliant towers, sea star, floating production system, tension leg platform, subsea platform and SPAR platform (Devold, 2002).

(a) (b)

Figure 1.3 a) Onshore drilling and b) offshore drilling

Sources: Devold, 2002; Speight, 2015

The design lifetime of the offshore structures must be at least 25 years or more depending on the reservoir capacity. Offshore platforms are either constructed in huge steel or concrete structures to explore and extract the oil and gas from the petroleum reservoir. In terms of the response of the structure and loading system, it leads to the construction of offshore structures is more complicated compared with onshore structures. This is because of the high level of uncertainties and high dependency on the environment condition that increases the complexity of design and construction process as the offshore structure used have been extended from shallow to deep water (Mukhlas et al., 2016). This is the most challenging and inventive task for the engineers to design the best offshore structure platform that is reconcilable with that tremendous environmental condition (A S Kharade; and S V Kapadiya, 2014).

However, there are some design considerations that are crucial for engineers to be taken humourlessly such as the peak loads created by cyclone wind, strong waves and seismic load as well. According to Marto, Tan, Kasim, & Mohd.Yunus, (2013), although Malaysia is considered as relatively low seismicity but it is important for engineers to take into account to the design as Malaysia is bordered by the most two seismically active plate boundaries which are on the west and east from the inter-plate boundary between the Indo-Australian and Eurasian Plates and the inter-plate boundary

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