UNITY CHECK OF TYPICAL OFFSHORE WELLHEAD PLATFORM IN MALAYSIA USING ACEH EARTHQUAKE LOADING DATA AND SAP2000

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

This thesis is dedicated to my dear parents

who have given me the strength, motivation, and encouragement

so that I may pursue my aspirations with confidence and dedication.

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ABSTRAK

Satu daripada gempa bumi serantau yang paling kritikal dengan membawa impak bencana adalah gempa bumi berskala magnitud momen 9.1 yang berlaku di pantai barat Banda Aceh, Sumatera Utara telah menjana tsunami Lautan Hindi yang dahsyat pada 26 Disember 2004. Selain itu, beberapa gempa bumi tempatan juga berlaku di Bukit Tinggi, Pahang dan Ranau, Sabah menurut Jabatan Meteorologi Malaysia (METMalaysia). Walau bagaimanapun, industri minyak dan gas memainkan peranan penting dalam ekonomi Malaysia kerana memberi sumbangan yang besar kepada produk domestik kasar negara. Sebenarnya, struktur luar pesisir tetap di rantau Malaysia hanya mengambil kira beban angin, beban gelombang, dan beban semasa dan bukannya beban gempa bumi. Objektif kajian ini adalah untuk melakukan pemeriksaan struktur bagi setiap elemen dalam platform luar pesisir apabila dilanda oleh pemuatan gempa bumi 2004 Aceh. Semua beban alam sekitar seperti gelombang, angin, dan beban semasa telah direka dengan merujuk kepada kriteria reka bentuk American Petroleum Institute (API). Perisian komputer SAP2000 telah dipilih untuk membuat model dan menganalisis struktur luar pesisir. Terdapat tiga jenis analisis yang telah dilakukan dalam kajian ini iaitu analisis getaran bebas, analisis sejarah masa, dan analisis spektrum tindak balas. Data gempa sejarah masa dari 2004 gempa bumi Aceh telah digunakan dalam melakukan analisis sejarah masa. Untuk analisis spektrum tindak balas, analisis ini dilakukan dengan menggunakan lengkung spektrum tindak balas di Eurocode 8. Kesimpulannya, platform luar pesisir di Malaysia terletak di bawah keadaan yang selamat apabila dilanda oleh aktiviti seismik yang rendah berdasarkan kajian ini.

ABSTRACT

One of the most significant regional earthquakes which brought catastrophic impacts is the magnitude of Mw= 9.1 earthquake which occurred on the western coast of Banda Aceh, North Sumatera had generated a massive Indian Ocean tsunami on December 26th, 2004. Apart from that, several local earthquakes also occurred in Bukit Tinggi, Pahang and Ranau, Sabah according to Malaysian Meteorological Department (METMalaysia). However, oil and gas industry plays a vital role in Malaysian economy due to the significant contribution to the country's gross domestic product. In fact, the existing fixed offshore structure in Malaysia region only take into considerations the wind load, wave load, and current load rather than earthquake load. The objective of this study is to perform unity check for every element of offshore wellhead platform when subjected to 2004 Aceh earthquake loading. All the environmental loads such as wave, wind, and current load have been designed by referring the American Petroleum Institute (API) design criteria. The computer software SAP2000 is selected to model and analyze the offshore structure. There are three types of analysis that have been performed in this study which are the free vibration analysis, time history analysis, and response spectrum analysis. The time history of earthquake data from 2004 Aceh earthquake has been used in performing time history analysis. For the response spectrum analysis, the analysis was performed by using response spectra curves in Eurocode 8. As a result, the offshore wellhead platforms in Malaysia are situated under a safe condition when subjected to low seismic activity based on the study.

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LIST OF SYMBOLS

km	Kilometer
km^2	Kilometer square
%	Percent
°C	Degree Celcius
m	Meter
s or sec	Second
µm	Micrometer
°	Degree
cm/yr	Centimeter per year
m^2	Meter square
Ø	Diameter
mm	Millimeter
N/mm^2	Newton per millimeter square
MN	Mega Newton
m/s	Meter per second
ft/s	Feet per second
ft	Feet
N	Newton
kg/m^3	Kilogram per meter cube
N/m	Newton per meter
N/m^3	Newton per meter cube
m/sec^2	Meter per second square
m/sec	Meter per second
g	Peak ground acceleration
Hz	Hertz
kN	Kilonewton
kN/m^2	Kilonewton per meter square
kNm	Kilonewton meter

LIST OF ABBREVIATIONS

Mw	Moment Magnitude Scale
METMalaysia	Malaysian Meteorological Department
NEIC	National Earthquake Information Center
IEM	Institution of Engineers, Malaysia
BS	British Standard
EN	European Norm
API	American Petroleum Institute
GPD	Gross Domestic Product
USGS	United States Geological Survey
MMI	Modified Mercalli Intensity
A	Area
ML	Local Magnitude Scale
Ms	Surface Wave Magnitude Scale
M0	Seismic Moment
FPSO	Floating, Production, Storage, and Offloading System
MTJA	Malaysia-Thailand Joint Authority
SDOF	Single Degree of Freedom
W.T.	Wall Thickness
MSL	Mean Sea Level
CD	Drag Coefficient
Cm	Inertia Coefficient
DL	Dead Load
LL	Live Load
EL	Environmental Load
TH	Time History
RS	Response Spectrum
GUI	Graphical User Interface
T	Natural Period
f	Natural Frequency
VEd	Shear force
fv	Shear stress
Fv	Allowable shear stress capacity
MEd	Bending moment

fb	Bending stress
Fb	Allowable bending stress capacity

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Earthquakes are one of the greatest natural hazards to life and property. In ancient times, earthquakes have destroyed countless cities and villages around the world that has led to injury, loss of life, and causing homelessness for the people. There are three different types of damaging effects to a structure by earthquakes. One of the damaging effects of earthquakes is ground failures. The examples of ground failures are surface faulting, ground cracking, ground subsidence, landslides, and soil liquefaction. Another damaging effect is the indirect effects caused by earthquakes. The most common phenomenon are tsunamis, seiches, and fires. For example, an earthquake with a magnitude of M_w= 9.1 which occurred on the western coast of Banda Aceh, North Sumatera had generated a massive Indian Ocean tsunami on December 26th, 2004. The tsunami had struck the coast of several countries in Southeast Asia and East Africa which included Indonesia, Sri Lanka, Thailand, Maldives, Somalia, Myanmar, Malaysia, and Seychelles (Villaverde, 2009). Around 220,000 people were killed in the incident, making it the one of the deadliest natural disaster in modern history (McCall, 2014). Ground shaking is the third effect and may be considered as the most damaging effect on structures. During the earthquakes, the ground moves vertically and horizontally in a violent manner that will affect the structures. The structures resting on the shaking ground experience the motions at the base and thus large stresses and deformations will occur to the structures throughout the process. If the ground shaking that happened is strong enough, it will lead to the partial or total collapse of the structure.

In Malaysia, most of the Malaysian citizens are not aware of earthquake hazards because the active seismic fault zone is located about 350 km away from Malaysia. In general, significant damages can be caused by an earthquake within 100-200 km radius from the epicenter and the amplitudes of incoming seismic shear waves will become generally small at a further distance. This is the reason why earthquake engineering in Malaysia is relatively behind compared to other engineering fields due to our less profound earthquake history. Although Peninsular Malaysia is located on the stable Sunda Shelf with low to medium seismic activity level, Malaysia is surrounded by high seismicity regions at the east, west, and south parts as shown in Figure 1.1.

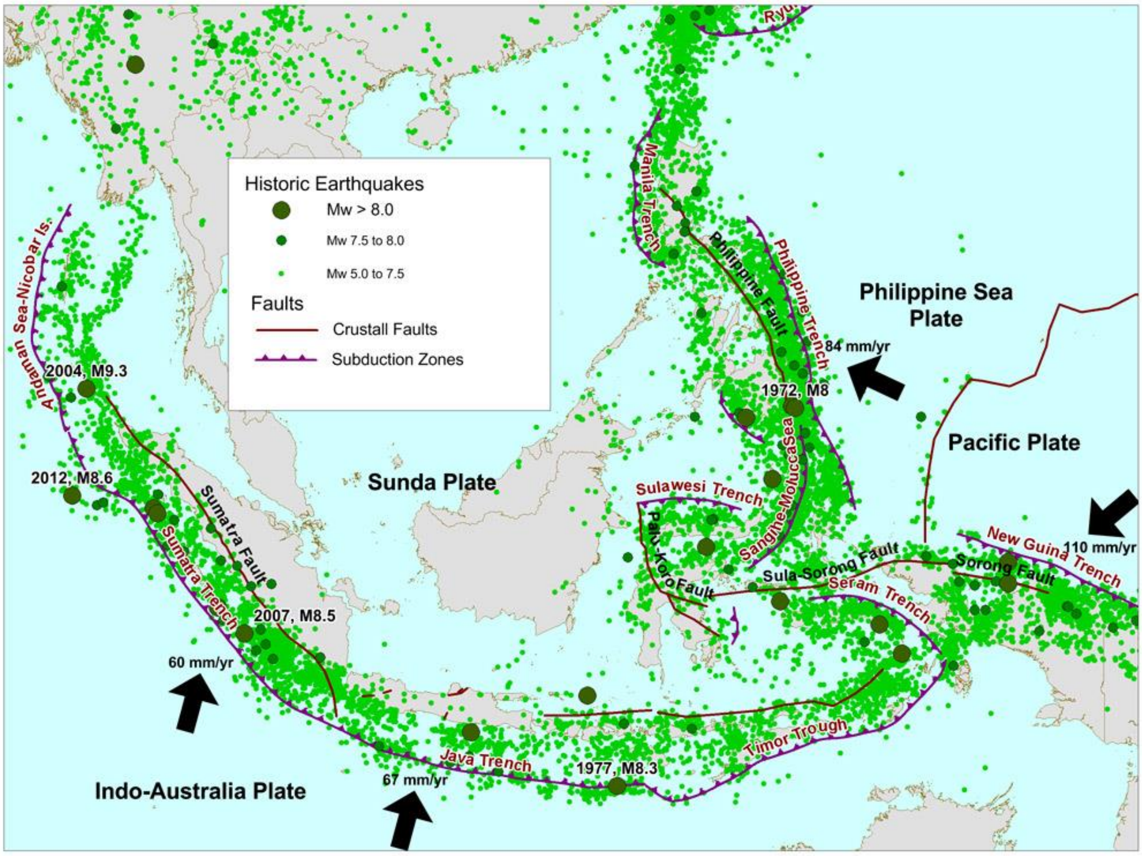

Figure 1.1 Active faults and historical seismicity in the Southeast Asia region

Source: AIR (Bingming Shen-Tu, 2016)

The two most seismically active plate boundaries are situated close to Malaysia which is the subduction zones between the Eurasian and Philippines plates at the east region. At the west and south parts, the high seismicity region is associated with the subduction zones between the Indo-Australian and Eurasian plates. However, several tremors due to the active seismic area from Sumatra has been reported along the west coast of Peninsular Malaysia (Adnan, Hendriyawan, Marto, & Irsyam, 2005). For instance, Malaysian Meteorological Department (METMalaysia) reported that the earthquake near Sumatra on November 2nd, 2002 had caused tremors to several cities in

Peninsular Malaysia which included Penang and Kuala Lumpur. Thus, several cracks on buildings had also been reported in Penang due to the Sumatra earthquake hazard. Apart from that, Bukit Tinggi and Sabah also experienced earthquake of local origin. This is related to the existence of an active fault in Peninsular Malaysia and East Malaysia that is associated with these local earthquakes. According to the Malaysian Meteorological Department (METMalaysia), a magnitude of 5.9 Scale Richter moderate earthquake had struck Ranau, Sabah on June 5th, 2015, has taken eighteen unfortunate lives and caused significant damage to properties (Shah, 2016). This earthquake was considered the strongest to affect Malaysia since 1976.

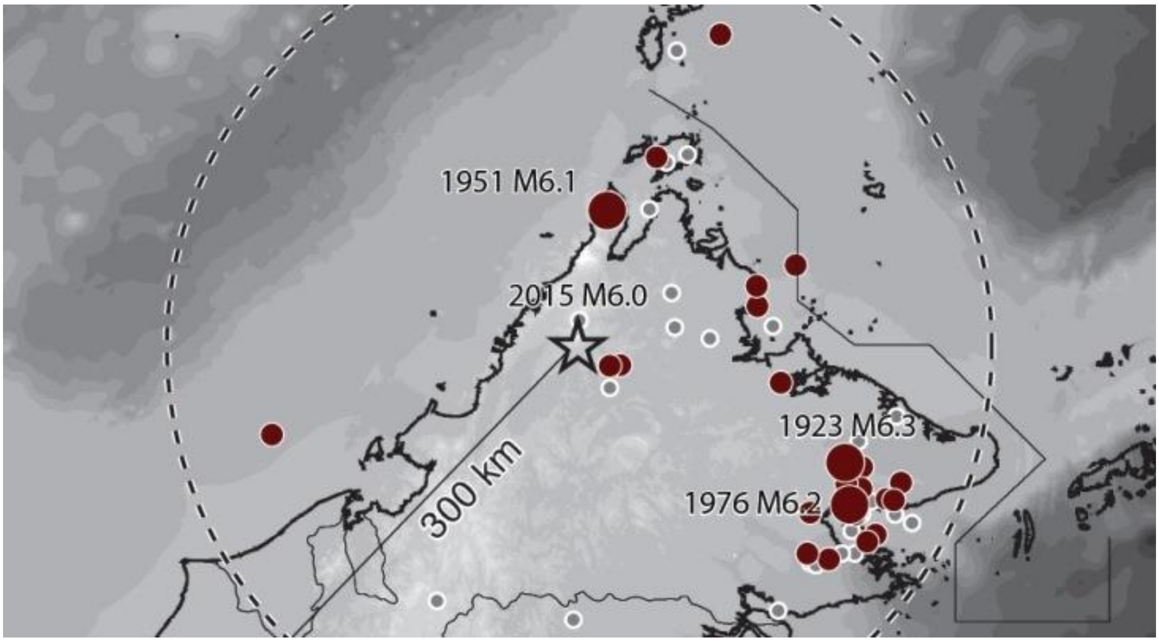

Figure 1.2 Earthquake epicenters map in Sabah over the past century
Source: National Earthquake Information Center (NEIC) catalog

In this modern era, earthquakes not only threaten the lives of people, properties and infrastructures, but it can also impact the economy adversely. Crude oil, petroleum, and natural gas products are the main sources of energy supply in Malaysia. Malaysia is ranked the second largest producer of petroleum and other liquids in Southeast Asia after Indonesia (EIA, 2017). Besides that, Malaysia ranked third as liquefied natural gas (LNG) exporter after Qatar and Australia in 2016 (EIA, 2017). Ministry of International Trade and Industry stated that Malaysia has the 23rd largest oil reserves and 14th largest gas reserves in the world (MITI, 2015). It can be clear that the bulk of economic growth of Malaysia depends on the energy industry which has accounted for nearly 20% of the country's total gross domestic product in recent years (PWC, 2016). In 1910, Shell

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