SEISMIC RESPONSE OF A TYPICAL 3-LEGGED JACKET OF FIXED OFFSHORE PLATFORM IN MALAYSIA DUE TO PHILIPPINES EARTHQUAKE

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ABSTRACT

The offshore structural design practice in Malaysia only focus more on wind and wave effects analysis rather than seismic effect. At the east of Malaysia, the Philippine plate moves westward with an estimate velocity of 80mm/year and cause micro faults in Sabah. Thus, this thesis develops the earthquake ground motion due to Philippine earthquake for assessment of offshore platform in Malaysia. Besides, the adequacy of existing design of offshore platform in Malaysia is determined when subjected to earthquake loading. The analysis of behavior of the offshore platform structures of 3-legged fixed offshore structures under the earthquake effect is obtained to develop the earthquake design criteria for the offshore structures that are located in Malaysia region. The assessment of fixed offshore structure also covers the static and dynamic for the earthquake analysis by using the code of practice of "Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms (API RP-2A, 2000). As for designing the offshore platform, this analysis is considering the dead load, live load, environmental loads (wind, wave and current load) and earthquake load such that free vibration, time history and response spectrum. The SAP 2000 computer program has been used to check the steel structure based on Eurocode 3, 2005. The most critical member of jacket offshore platform for the analysis of the various load also determined by compared the element capacity with manual calculation. However, there are assumption has been made such that the structure is fixed to the ground and the geometry, material properties and section properties of the structure are represent almost the same from the actual structure.

ABSTRAK

Amalan reka bentuk struktur luar pesisir di Malaysia hanya memberi tumpuan lebih kepada analisis angin dan gelombang berbanding daripada kesan seismik. Di timur Malaysia, plat Filipina bergerak ke arah barat dengan anggaran halaju 80mm/tahun dan menyebabkan kerosakan mikro di Sabah. Oleh itu, tesis ini membentangkan penyelidikan gerakan gempa bumi akibat gempa bumi di Filipina untuk penilaian platform luar pesisir di Malaysia. Selain itu, kecukupan reka bentuk sedia ada platform luar pesisir di Malaysia ditentukan apabila dikenakan beban gempa bumi. Analisis kelakuan struktur platform luar pesisir berkaki 3 tetap di bawah kesan gempa bumi bagi membangunkan kriteria reka bentuk gempa bumi untuk struktur luar pesisir yang terletak di rantau Malaysia. Penilaian struktur luar pesisir tetap juga meliputi statik dan dinamik untuk analisis gempa bumi dengan menggunakan kod amalan "Cadangan Amalan Perancangan, Merekabentuk dan Membina Platform Luar Pesisir Tetap (API RP-2A, 2000). Bagi mereka bentuk platform luar pesisir, analisis ini menitikberatkan beban mati, beban hidup, beban alam sekitar (angin, ombak dan beban arus) dan beban gempa bumi seperti getaran bebas, sejarah masa dan analisis tindak balas spektrum. SAP 2000 merupakan program komputer yang telah digunakan untuk memeriksa struktur besi keluli berdasarkan Eurocode 3, 2005. Elemen platform luar pesisir jaket yang paling kritikal dianalisis dengan pelbagai beban yang ditentukan oleh kapasiti elemen yang dibenarkan dengan pengiraan manual. Walau bagaimanapun, terdapat beberapa andaian telah dibuat seperti struktur adalah tetap pada tanah dan geometri, sifat bahan dan sifat-sifat struktur yang memberi gambaran hampir sama dengan struktur sebenar.

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mm	Millimeter
N/mm^2	Newton per millimeter square
kg	Kilogram
N	Newton
kN	Kilo newton
kNm	Kilo newton meter
kN/m^2	Kilo newton per meter square
s	second
V_{Ed}	Maximum design shear force
$V_{c,Rd}$	Shear resistance
σ_s	Shear stress
$\sigma_{all,s}$	Allowable shear stress
M_{Ed}	Maximum external design moment
$M_{c,Rd}$	Moment resistance
σ_b	Bending stress
$\sigma_{all,b}$	Allowable bending stress

LIST OF ABBREVIATIONS

BS	British Standard
EN	European Standards
MS	Malaysia Standard
API	American Petroleum Institute
MMD	Meteorological Malaysia Department
E	Young Modulus
G	Shear Modulus
DL	Dead Load
LL	Live Load
EL	Environmental Load
TH	Time History
RS	Response Spectrum
WI	Wind Load
WA	Wave Load

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Most of the structural building in Malaysia is designed without considering of the earthquake effects such as Petronas Twin Tower (KLCC), KOMTAR Tower, Berjaya Times Square Tower and also offshore structure. There are no regulations requiring the tall building to be designed for earthquake in Malaysia as Malaysia does not lie in any presently demarcated seismic zone. However, Malaysia is located close to two most seismically active plate boundaries which are inter-plate boundary between Indo-Australian Plates and Eurasian Plates on the west and also the inter-plate boundary between Eurasian and Philippine Plates on the east (Husen, et al., 2013). These plates undergo many small movements against each other by time to time. The plates can slide horizontally against each other or pull away from each other or can be it coming towards each other causing one plate to dive beneath the other as in Figure 1.

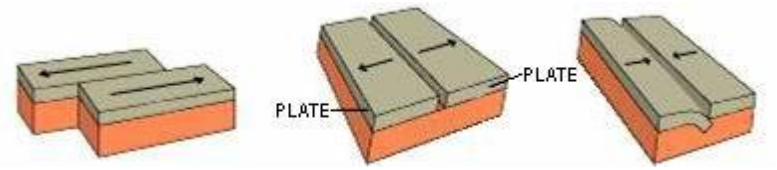

Figure 1.1: Types of plate's movement

Source: Ir Ng Pek Har, Hadi Golabi (2005)

The movements of involving large plates can cause the sudden movement that will results the huge energy to be released in the form of waves. These waves will travel inside the earth and along the ground which are felt by us as shakes and tremors. This is called an earthquake. The intersecting edges of the plates are called faults. Therefore, an earthquake is happen once there are both abrupt slide on a fault, causing earth trembling and emitted seismic vitality affected by the slide or through volcanic or magmatic movement or further unexpected pressure adjustments in the ground.

The tremor affects endangers such as ground shaking, liquefaction, surface faults, landslide, tsunami and also tectonic deformations. These all types of hazards depend on the geographical location, ground conditions and amount of tectonic activity along the faults. Geotechnical factors often exert a main influence on destruction patterns and loss of life in earthquake events (Aminaton Marto, et al., 2011). Along the transmission during seismic waves, the resonance effect would cause amplification behavior during upward propagation. The amplified waves make possible the soil liquefaction to be happens within the region (Marto, n.d., 2014). The impact and damage due to tsunami depends on some factors such as wave speed and height which are their coastal topography areas and also debris that carried by water (Ghobarah, et al., 2006).

Microzonation is the Mapping of seismic hazard at local scales to incorporate the effects of local geotechnical factors (Aminaton Marto, et al., 2011). At the east of Malaysia, the Philippine plate moves westward with an estimate velocity of 80mm/year and cause micro faults in Sabah (Mohd Rosaidi bin Che Abas, 2001). Sabah is the only state in Malaysia that exposed to earthquake activities if compared to other parts of Malaysia.

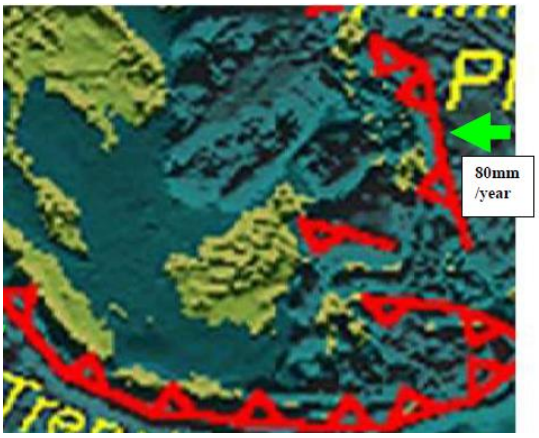

Figure 1.2: The movement of Philippine plate moves westward

Source: Mohd Rosaidi bin Che Abas (2001)

The Peninsular Malaysia, Sabah and Sarawak located just behind the active seismic area. Therefore, there is an effort to investigate the behavior of offshore structure to sustain earthquake effect. The study is also covering the 3 legs of offshore platform and by using the software of SAP 2000 to make a model for offshore structure.

1.2 PROBLEM STATEMENT

Nowadays, the offshore structural design practice in Malaysia only focus more on wind and wave effects analysis rather than seismic effect. We cannot guarantee others that our offshore platform is safe for earthquake effects. This is because the wind loads damage the structure by externally applied pressures, while earthquake damage is caused by internally generated inertial forces induced by vibration of the structure's mass.

Our country, Malaysia has to worry about the earthquake effects. Year by year, our neighboring tectonic plates which are Indian plate, the Australian plate, the Eurasian plate and the Philippine plates are moving and pushing our country. Eastern Sabah is prone to trembles affected by tremors in the Southern Philippines. In 1976, one of the worst earthquakes that happened when a reading of Richter scale is 5.8 of their magnitude temblor Lahad Datu, Sabah. The highest observed intensity in Lahad Datu and Kunak was assessed of about VII on MM scale.

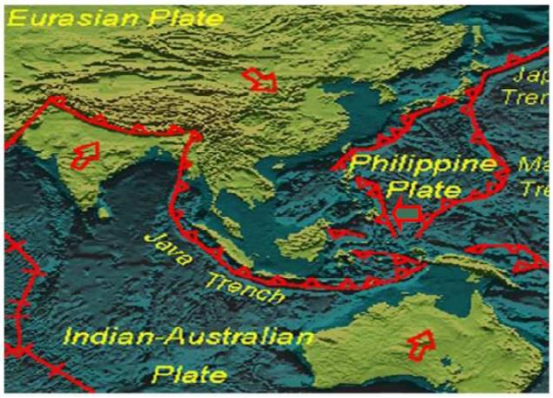

Figure 1.3: Major tectonic plates around Malaysia

Source: Mohd Rosaidi bin Che Abas (2001)

Furthermore, Sarawak also impaired by prolonged distance of tremor that started from the Straits of Macassar, Celebes Sea and Sulu Sea of the West of Philippine. The highest perceived Mercalli Intensity at Sarawak was estimated of about V on MM scale which produced by this distant earthquake. We are lucky that the earthquake effect does not cause much impact to our country. However, we must always be in precaution mode and get well prepared for the possibility of adversity earthquake occur and also damage of our structures. Thus, this research study will demonstrate the behavior of our offshore structures for 3 legs under earthquake effect. The offshore structure modelling analysis was using the computer software of SAP 2000.

1.3 RESEARCH OBJECTIVES

The main objective of this research is to estimate the earthquake ground motion due to Philippine earthquake for assessment of offshore platform in Malaysia, while the sub objectives of this research are:-

1. To determine the adequacy of existing design of offshore platform in Malaysia when subjected to earthquake loading.

2. To determine the earthquake design criteria for offshore platform located in Malaysia

1.4 SCOPE OF STUDY

1. The case study of the earthquake is around the area of Philippine and their effect to Malaysia.

2. The type of offshore used will be 3-legged fixed offshore platform.

3. Study the architectural drawing of a typical 3-legged jacket of fixed offshore platform

4. Analyze the data that provided from Malaysia Meteorology Department (MMD).

5. The computer software for offshore structure modelling analysis is SAP 2000.

1.5 RESEARCH SIGNIFICANCE

The significance of the research study is to identify the earthquake ground motion due to Philippine earthquake for assessment of offshore platform in Malaysia. Another purpose of this research study are to determine the adequacy of existing design of offshore platform in Malaysia when subjected to earthquake loading and also determine the earthquake design criteria for offshore platform located in Malaysia. The analysis of behavior of the offshore platform structures of 3-legged fixed offshore structures under the earthquake effect is obtained to develop the earthquake design criteria for the offshore structures that are located in Malaysia region. A hundreds of thousands of people could be saved if the structures are considering the earthquake effect by built it to withstand the shaking from the passage of seismic waves.

CHAPTER 2

LITERATURE REVIEW

2.1 EARTHQUAKE

Earthquake is one of the most destructive natural hazards that can cause many deaths. An earthquake happens when there is a sudden release of energy causes the ground to shake and vibrate, associated with passage of waves of energy that been released at its sources. Earthquakes sometimes can kill till hundreds of thousands of people and leveling entire town or cities just in a few minutes or seconds. The earthquake causes the secondary hazards such as shaking, landslides, tsunamis and liquefaction. Our earth is divided into about twelve large tectonic plates and there are moving relative to other. There are also many other smaller plates. Commonly, the earthquakes in the world occurs when two of these plates meet and then moving past each other.

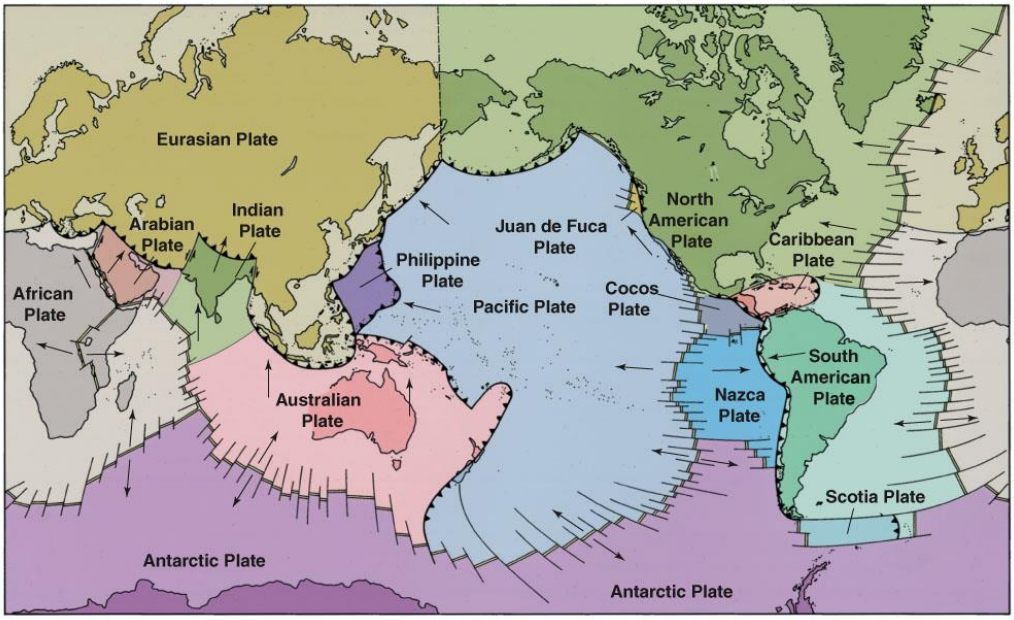

Figure 2.1: Earth map that showing the major divergent, convergent and transform plate boundaries and outlines of the continents

Source: Timothy Kusky (2008).

An earthquake originates from one place and later spreads out in all directions throughout the fault plane. The point in the Earth is called *focus* where the earthquake energy is released first and that will represents the area on one side of a fault that in fact moves relatively to the rocks on the other side of fault plane. While, the Earth's surface that lies through vertically above the focus is called *epicenter*. An earthquake can causes the significant defects and damages within 100-200km radius from the epicenter.

Even though Peninsular Malaysia is located in the stable Sunda Shelf and with low to medium seismic activity level, sometimes tremors can be felt from the large earthquakes that originated from the intersection areas of Eurasian plate and Indo-Australian plate near

Sumatra (Azlan Adnan, et al., 2005). The tremors that have been occurred can cause panic to the public people of several cities in Peninsular Malaysia which are Kuala Lumpur and Penang as for example, cases that have been reported on 2nd November 2002 which is the cracks on buildings in Penang due to earthquake. (Azlan Adnan, et al., 2005). While recently, in Kota Kinabalu, a mild earthquake, with a magnitude of 4.4 on the Richter scale, was recorded in Pulau Banggi, Kudat on October 24, 2014 (The Star Online, 2014)

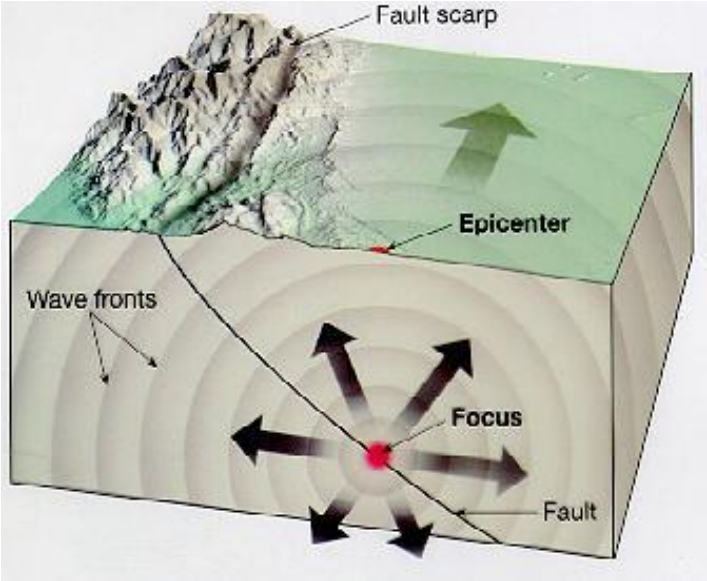

Figure 2.2: Mechanism of Earthquake

Source: Ir Ng Pek Har, Hadi Golabi (2005)

2.2 SEISMIC WAVE

As the big earthquake occurs, the surface of the Earth then eventually forms into waves that move throughout the surface, just as in the ocean. These waves can cause

extremely destructive or also can be pretty spectacular. These seismic waves' moves of all directions just like ripples or sound waves that been formed or moved across the water as a stone is thrown in a still pond. The ground will returns to its original shape just after the seismic waves have passed through the ground, meanwhile the structures of building or others things being destroyed. The people who have experienced the large earthquakes happens eventually seen waves of rock with several feet high that being moving toward them at very high speeds.

There are three types of seismic waves which are:-

1. Body waves

2. Surface waves

3. Rayleigh waves

The body waves are the seismic waves that can either radiate underground from the focus. While the surface waves are the seismic waves that can either radiate aboveground from the epicenter. In addition, the body waves travel throughout the whole body of the Earth and also move faster than surface waves. Surface waves will cause most of the destructive due to earthquakes as compared to body waves because as they pass, they actually change the shape of the surface of the Earth.

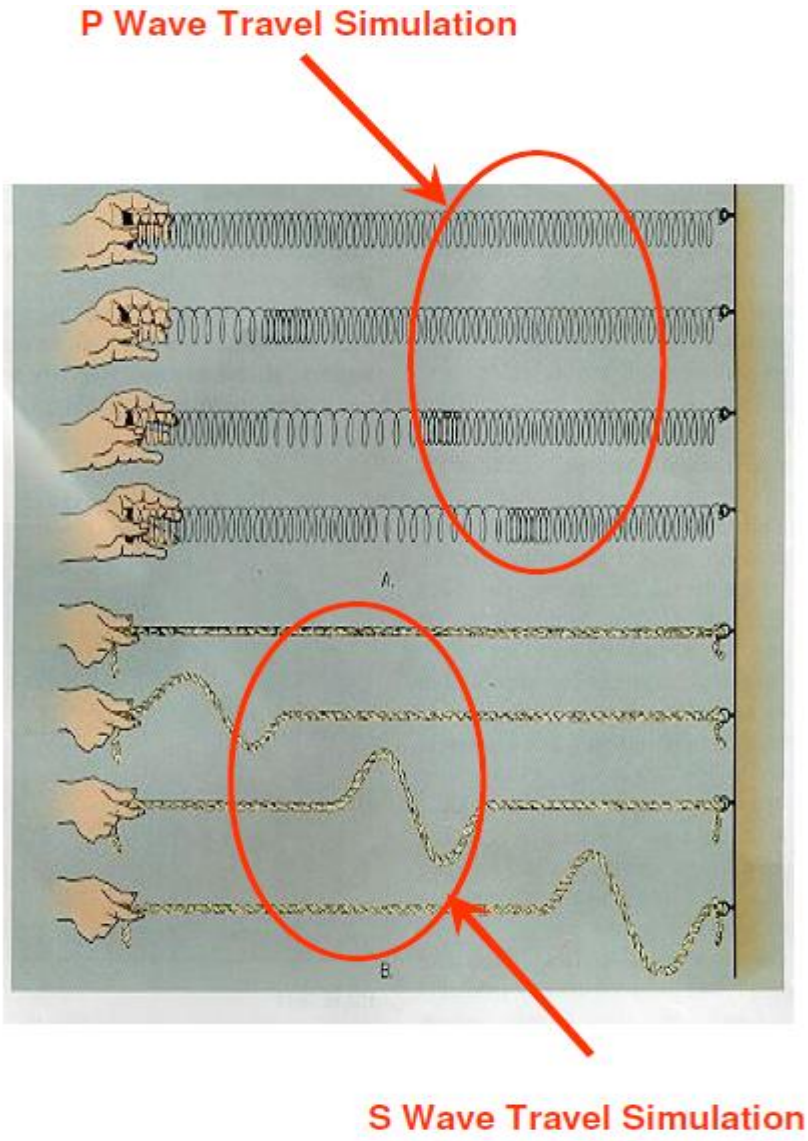

Figure 2.3: Analogy to seismic waves using slinky waves and ropes

Source: Ir Ng Pek Har, Hadi Golabi (2005)