Faculty of Engineering

Site-Specific Ground Responses Analysis at Offshore of Bintulu, Sarawak

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Site-Specific Ground Responses Analysis at Offshore of Bintulu, Sarawak

CHONG KONG CHENG

A final year project report submitted in partial fulfilment of
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ABSTRACT

Engineers have started to consider seismic design for structures in Malaysia since several evidences proven that Malaysia is no longer free from seismic hazard. The establishment of Malaysia National Annex to Eurocode 8 (MS EN 1998-1:2015) indirectly advised engineers in Malaysia to treat seismic design as a requirement in building design. Hence seismic hazard analysis for critical structure such as power plant and oil plantation are important to ensure it can sustain earthquake as failure of such critical structure will lead to pollution of the environment. The main objective of this research is to establish the seismic design response spectra for offshore structure in Malaysia. For site-specific ground response analysis, steps are followed starting with extraction of soil data from soil investigation report, determine the suitable input ground motions, conducting ground response analysis using equivalent linear approach and lastly develop the site-specific response spectra. In this study it was found that site-specific ground response analysis provided better seismic amplification factor and design response spectrum since it utilises the actual local soil data extracted from site investigation report compared to the simplified design response spectrum provided by the code. BH5_GM6 recorded the highest amplification factor of 6.471. The second peak recorded for near-field earthquakes has the amplification factor of 5.241 by BH4_GM6. Whereby for far-field earthquakes, BH5_GM1 recorded highest amplification factor of 7.253 and BH4_GM1 recorded the second highest peak of 6.173. The soil factor S from the design response spectrum for offshore of Bintulu are higher than the soil factor S of Malaysia National Annex. This could be due to the limitation of National Annex that consider the average of soil investigation data.

ABSTRAK

Jurutera telah mula mempertimbangkan reka bentuk seismik untuk struktur di Malaysia sejak beberapa bukti membuktikan bahawa Malaysia tidak lagi bebas daripada bahaya seismik. Penubuhan Malaysia National Annex untuk Eurocode 8 (MS EN 1998-1: 2015) secara tidak langsung dinasihatkan jurutera di Malaysia untuk merawat reka bentuk seismik sebagai keperluan dalam reka bentuk bangunan. Analisis seismik terhadap struktur kritikal seperti loji kuasa dan perladangan minyak adalah penting untuk memastikan ia boleh menahan kesan gempa bumi kerana kegagalan struktur yang kritikal akan membawa kepada pencemaran alam sekitar. Objektif utama kajian ini adalah untuk mewujudkan seismik balas reka bentuk spektrum untuk struktur luar pesisir di Malaysia. Untuk analisis sambutan tanah khusus tapak, langkah-langkah yang diikuti bermula dengan pengekstrakan data tanah dari laporan siasatan tanah, menentukan sesuai usul tanah input, menjalankan analisis sambutan tanah menggunakan pendekatan linear bersamaan dan akhir sekali membangunkan tindak balas spektrum khusus tapak. Dalam kajian ini didapati bahawa analisis sambutan tanah khusus tapak disediakan lebih baik seismik faktor amplifikasi dan tindak balas reka bentuk spektrum sejak ia menggunakan data tanah tempatan sebenar dipetik daripada laporan penyiasatan tapak berbanding spektrum gerak balas reka bentuk yang mudah disediakan oleh kod. BH5_GM6 mencatatkan faktor amplifikasi tertinggi 6,471. Puncak kedua maklumat untuk gempa bumi berhampiran-bidang mempunyai faktor penguatan daripada 5,241 oleh BH4_GM6. Mana untuk gempa bumi jauh-bidang, BH5_GM1 mencatatkan faktor amplifikasi tertinggi 7,253 dan BH4_GM1 direkodkan puncak kedua tertinggi 6,173. Faktor tanah S daripada spektrum sambutan reka bentuk untuk luar pesisir Bintulu adalah lebih tinggi daripada faktor tanah S Malaysia National Annex. Ini mungkin disebabkan oleh had Annex Negara yang mengambil kira purata data penyiasatan tanah.

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CHAPTER 1

INTRODUCTION

1.1 General Background

Ranau has been struck by a Mw = 5.9 earthquake on 5^{th} June 2015 which took away 18 lives and this event has led to the concern about seismicity in Malaysia. The claim of Malaysia is a blessed country that free from life threatening earthquake has become questionable. Malaysia National Annex to Eurocode 8 for Design of Structures for Earthquake Resistance has been published in year 2017 for engineering practice in Malaysia in order to minimize the damage of earthquake to the public.

Although Malay Peninsular is said to be located on the stable part of Eurasian Plate as shown in Figure 1-1, shakings were felt by the peoples in tall buildings in Kuala Lumpur mainly because of huge earthquake originate from Sumatra (Balendra & Li, 2008). Apart from Peninsular Malaysia, Shah et al. (2018) added that Sabah & Sarawak are located on the Sunda plate, which encaged by Philippine sea plate and Indo-Australian plate as shown in Figure 1-1. As mentioned above, the seismically active countries such as Philippines and Indonesia that surrounded Malaysia are known to be a source of far field earthquake. Distant ground motions originate from the Sumatran fault, the Philippines plate as well as the Makassar straits have induced significant impact on the seismic hazard in Malaysia.

Apart from far field earthquake originated from neighbouring countries, Malaysia is also subjected to earthquake from local origin mainly on the part of East Malaysia (Sabah & Sarawak). In Sarawak, Tubau fault, Bukit Mersing fault, and Lupar fault are seismically active (Adnan, 2015). While Sabah is in the area of relatively high seismicity due to many fault zones within Sabah region such as Belait fault zone, Jerudong fault zone and Kundasang-Ranau fault zone (Looi et al., 2018).

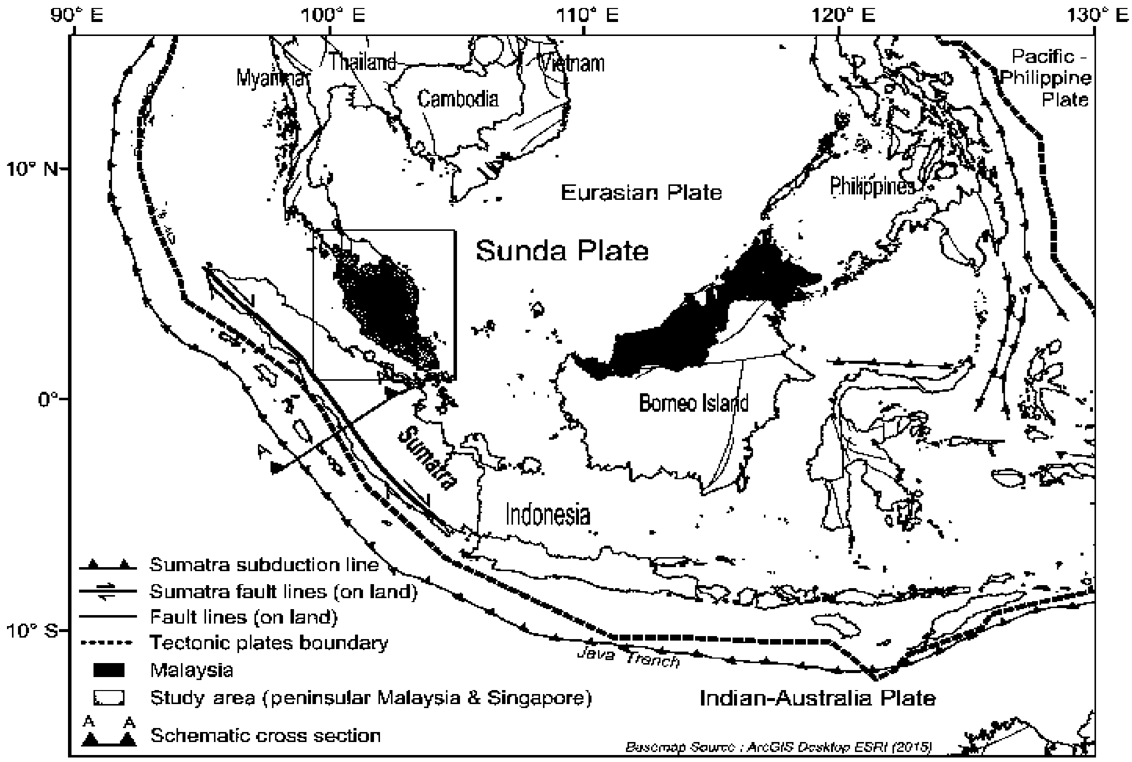

Figure 1-1: Locality of Malaysia on the Sunda Plate, with the tectonic setting around Malaysia and fault lines on land (Source: Loi et al., 2018).

The existing Bintulu Tanjung Kidurong Power Station is in between the Petronas MLNG and Murphy Oil which is 9 km away from the northeast of Bintulu Town. The new power plant will occupy an area of 1.5 hectares approximately, located within the boundary of existing power plant. While at the offshore of Bintulu consists of petroleum platform that also required consideration of seismic design. Future seismic event may cause failure in power plant and also offshore petroleum platform, creating a disastrous impact to the servicing area of said power plant and producing pollution to the sea near petroleum platform. The breakdown of power plant will lead to unfunctional hospitals, airport, hotels, factories and schools which influenced the consumers and also the state economy values. While the failure of petroleum platform due to seismicity will lead to serious pollution which will influence the aquatic life around the area.

According to Razak et a. (2018), the offshore structures design in Malaysia is based on API RP-2A WSD, but earthquake zoning data for offshore Malaysia is not provided by this code. As shown in Figure 1-2, the 5% damped spectral response acceleration at 1.0s oscillator periods abstracted from the ISO 19901-2 provide a spectral response of 0.02 g for offshore Malaysia which is the only guidance to be followed for earthquake at offshore Malaysia.

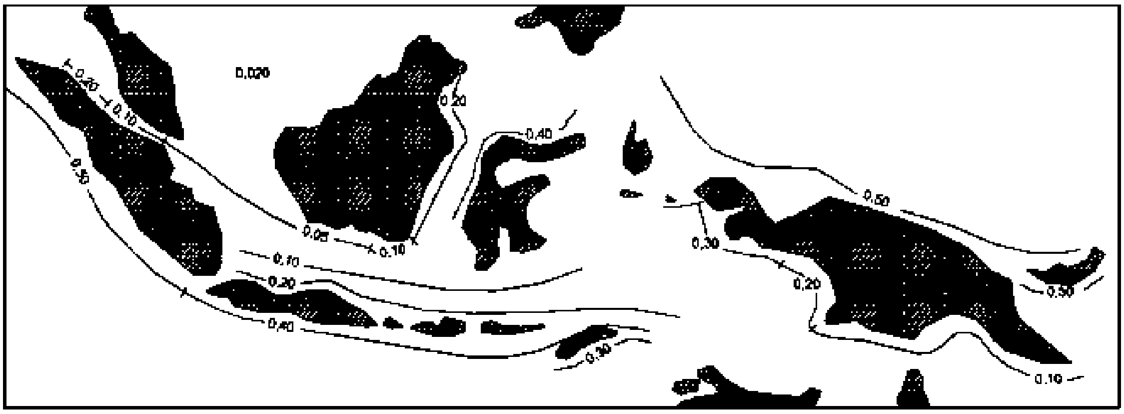

Figure 1-2: Seismic map for offshore Malaysia at 0.1sec oscillator period for 5% damping (Source: ISO 19901-2).

1.2 Problem Statement

In the past, adopting British Standard (BS) and Eurocode (EC) for structural design are known to be a common engineering practice in Malaysia due to the building structures are only affected by low seismicity activities occurring in Malaysia. However, especially after the 2015 Sabah earthquake that struck on Ranau, Sabah, Malaysia. Researcher as well as the Malaysian Meteorology Department started to be concern about the Seismicity in Malaysia as it is no longer free from the Earthquake Disaster especially in East Malaysia. At the end of 2017, Malaysia National Annex to Eurocode 8 for Design of Structures for Earthquake Resistance has been established for local engineering practitioners.

Design provisions using the Code design parameters do not represent an actual representative for a life-line facility. The method of seismic hazard assessment that applied in certain region does not completely represents the situation in other regions since each place are different in characteristics. In Malaysia, researcher have been focusing on generate fragility curves for existing structures which are mostly public buildings. This study will emphasise on the power plant as a critical lifeline structure to supply electricity for Bintulu town.

1.3 Aims and Objectives of the Research

This research aims to carry out site specific ground response analysis in order to develop seismic design response spectra using borehole data from offshore of Bintulu, Sarawak and determine the soil amplification factor for the local site conditions. The objectives of this research are as follow:

i. To perform site specific ground response analysis using 1-D equivalent linear earthquake responses analysis method using the soil data from local soil investigation at offshore.

ii. To develop horizontal elastic design response spectrum and determine the soil amplification factor for the local site conditions.

1.4 Scope of Research

This research represents the study on a site-specific ground response analysis which are important in the seismic design or consideration of power plant structures. Following are the scope of this research:

i. The soil data are collected from 3 boreholes situated at offshore of Tanjung Kidurong Power Plant, Bintulu Sarawak's project and 5 boreholes using Cone Penetration Test at offshore of Bintulu region.

ii. The local site effect analysis considering one-dimensional equivalent linear earthquake analysis method.

iii. The ground motions at bedrock are extracted from PEER website. The magnitude of earthquake data applied for this research are ranging from 4.5 to 7.5 Mw.

1.5 Significant of the Research

Vulnerability to seismic activity in several parts of East Malaysia catalysed this particular study, the emerging seismic activity is threatening the lifeline facilities, the existing and any of the future proposed critical structures. In this research, the responses of local soil condition towards earthquake ground motion of Tanjung kidurong powerplant and the proposed petroleum plantation are in concern. The representable or crucial seismic parameters that are required in the design of structure are derived using site specific response spectrum based on specific project soil data.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Lack of ground motion records in a low seismicity region such as Malaysia represent the major issue in developing a seismic hazard map in the past. But with the significant earthquake with 6.0 moment magnitude recorded in Ranau, Sabah on June 2015, and the most recent 2018 earthquake that hit Niah, South of Miri with moment magnitude of 3.9. East Malaysia is prone to be seismically active than West Malaysia and it is noteworthy in developing an updated seismic hazard map especially for East Malaysia. This section covers the basic theory of earthquake (fault movements, sources of earthquake, earthquake measuring scales), earthquake in Philippines and Makassar Straits, seismicity in Malaysia, previous study of seismic hazard assessment, and seismic microzonation,. This literature review is divided into 4 main sections:

Stage 1 : Earthquakes

Stage 2 : Seismic Hazard Assessment

Stage 3 : Seismic Microzonation

2.2 Earthquakes

Rupture of fault that occurred in the earth's crust is commonly understood as the cause of an earthquake. There are various fault movements known as Normal fault, Reverse fault, Strike-slip fault and Combination fault as shown in Figure 2 -1. Normal fault is formed when two earth blocks are separated, due to tensile stress field as two blocks moving away from each other. Reverse fault in contrast, is generated by compressional stress when heavier oceanic plate subduct below a continental plate that comparatively less dense than the ocean plate (Towhata, 2008).

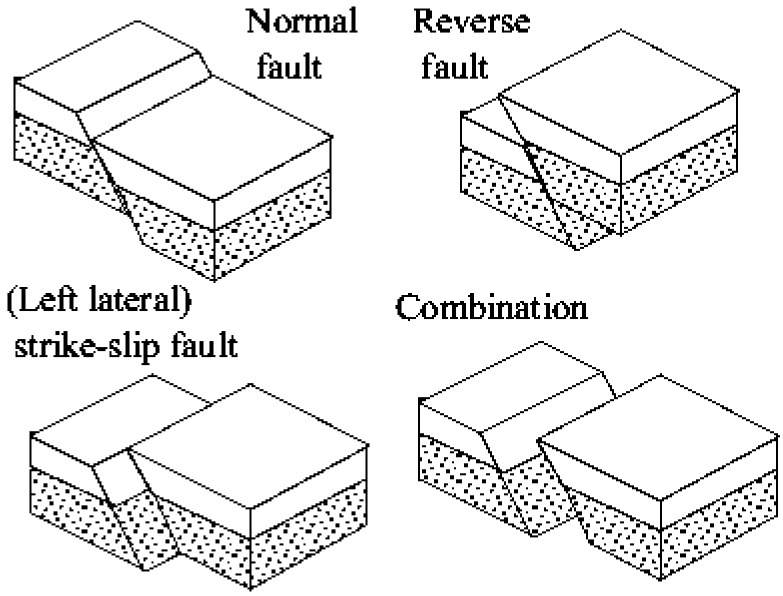

Figure 2-1 Type of faults (Source: Towhata, 2018)

Earthquake at divergent plate boundaries on normal faults represent the least significant impact when compared to other types of earthquakes. According to the fact that high temperatures that found in young crust will reduce the extension depth, largest earthquake that occur on divergent plate are relatively small when compared with earthquakes at other types of plate-boundaries. (Beroza & Kanamori, 2015).

According to Beroza & Kanamori (2015), Seismicity of the Earth were dominated by earthquakes that originated from convergent plates. The depth extend of seismogenic zone is greatly influenced by the temperature of the crust, relatively cool crust contribute to lower temperature at depth will increase extension depth of the seismogenic zone. It is observed that significant amount of large earthquakes having magnitude of 8 and above, tends to occur with reverse faulting mechanism near convergent plate boundaries.

Beroza & Kanamori (2015) said that the seismic waves are first generated at the temporary and spatial coordinates known as earthquake's hypocentre. In other words, the location where rupture occurs is known as hypocentre while the place above hypocenter at the Earth's surface named as epicentre (Towhata, 2008).

The intensity of shaking is the strongest at the seismic fault or where the rupture start and generated earthquake, the intensity will decrease as the distance increases from the source of earthquake. The effects of distance have quantitative influences on engineering practice hence characterising the distance quantitatively is crucial as shown in Figure 2-2.

The epicentral distance (D2) has been used in many situations as compared to the other indices of distance. However, it is important to consider the distance to the edge of a fault (D4) especially when the distance between site of interest and the fault is short but large distance between the site and epicentre, this might lead to relentless intensity of shaking (Towhata, 2008).

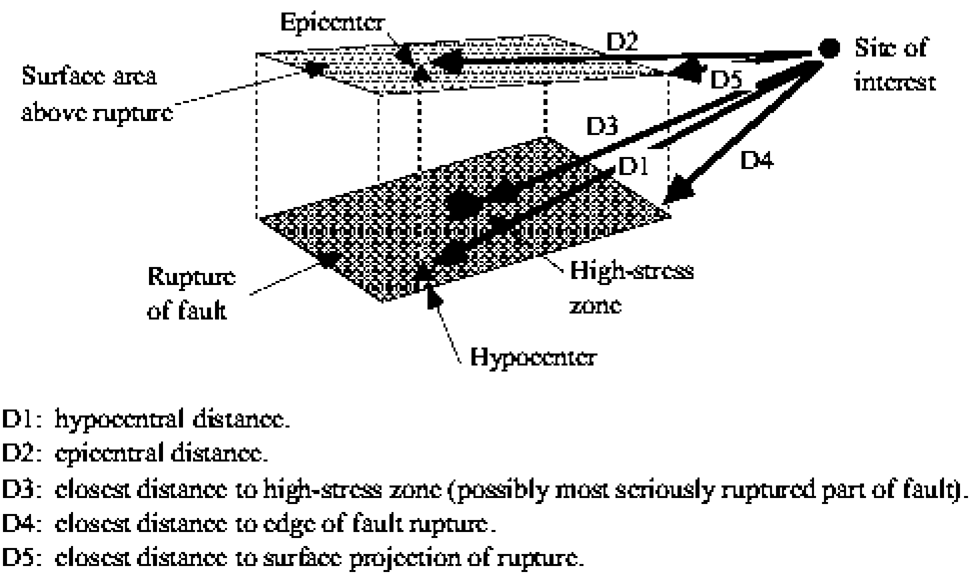

Figure 2-2: Distance parameters. (Source: Joyner and Boore, 1996)

2.2.1 Measuring Earthquake

One of the oldest measure on the size of earthquake known as Earthquake intensity is based on the qualitative description of the earthquake's effects at a specific location according to the information collected by observing damage and human reactions. The Rossi-Forel (RF) scale of intensity was establish in the 1880s and has been widely used for many years, it outlined the intensities with values ranging from I to X. Although it has been predominantly replaced by the Modified Mercalli Intensity (MMI) scale in English-speaking countries that established by Mercalli, the italian seismologist. While the other intensity scale like the Japanese Meteorological Agency (JMA) and the Medvedev-Spoonheuer-Karnik (MSK) scale are used in japan and central & eastern of Europe respectively (Kramer, 1996). Table 2-1 shows the example of MMI scale while Figure 2-3 shows the comparison of different earthquake intensity scale.

Table 2-1: Modified Mercalli Intensity (MMI) scale. (Source: Kramer, 1996)

I	Not felt except by a very few under especially favourable circumstances
II	Felt by only a few persons at rest, especially on upper floors of buildings; delicately suspended objects may swing
III	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake; standing motor cars may rock slightly; vibration like passing of truck; duration estimated
IV	During the day felt indoors by many, outdoors by few; at night some awakened; dishes, windows, doors disturbed; walls make cracking sound; sensation like heavy truck striking building; standing motor cars rocked noticeably
V	Felt by nearly everyone, many awakened; some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned; disturbances of trees, piles, and other tall objects sometimes noticed; pendulum clocks may stop
VI	Felt by all, many frightened and run outdoors; some heavy furniture moved; a few instances of fallen plaster or damaged chimneys; damage slight