INFLUENCE OF PEAK GROUND ACCELERATION AND CONCRETE GRADE ON SEISMIC DESIGN OF RC HOSPITAL BUILDING

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STUDENT'S DECLARATION

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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ABSTRAK

Sembilan belas kilometer di bawah paras laut pada awal 26 Disember 2004, gempa bumi 9.1 magnitud telah mengguncang laut di pantai Sumatra, di barat laut mencapai kepulauan Indonesia. Lebih daripada 227,000 orang diisytiharkan mati atau hilang dalam seminggu selepas tragedi yang menjejaskan 14 buah negara di dua benua. Pada 5 Jun 2015, gempa bumi berkekuatan 5.9 mencecah Sabah, membunuh 18 orang di Gunung Kinabalu. Ia dikatakan sebagai gempa kedua yang terkuat yang melanda Sabah selepas gempa bumi tahun 1976 berukuran 6.2 pada skala Richter yang berlaku berhampiran Lahad Datu. Gempa bumi tahun 2015 dirasai di seluruh negeri dan lebih daripada 100 gempa susulan dilaporkan sepanjang tahun Berikutan tragedi gempa di Sabah, terdapat kebimbangan bahawa gempa bumi juga boleh melanda Semenanjung Malaysia dan mengikut pakar geologi, kebimbangan seperti itu tidak salah. Persepsi umum yang mengatakan bahawa Semenanjung Malaysia selamat kerana kita jauh dari Lingkaran Api Pasifik yang mengelilingi kita, tetapi dalam beberapa tahun kebelakangan ini, terdapat bukti gempa bumi dengan titik fokus atau epicentres tepat di bawah kaki kita, disebabkan oleh pengaktifan semula garisan kesalahan lama. Garis kegagalan ini seolah-olah telah diaktifkan semula oleh sempadan plat tektonik aktif dan ini telah menyebabkan kebimbangan kerana banyak struktur di bandar tidak dibina dan direka untuk menahan gempa bumi. Punca-punca pengaktifan semula garis-garis kerosakan di Malaysia adalah kerana ia dikelilingi oleh begitu banyak sempadan plat tektonik yang aktif dan Rak Sunda, yang negara itu duduk, dimampatkan. Semenanjung Malaysia terletak di tengah-tengah rak, yang juga dikenali sebagai Sundaland, yang menyerap semua tekanan dari sekelilingnya. Cepat atau lambat, bumi perlu mencari beberapa pelepasan dengan memecah sistem talian kesalahan lama. Oleh kerana kesan bahaya ini, struktur perlu direka untuk menahan daya dinamik dari gempa bumi. Apabila struktur direka untuk menahan gempa bumi, kerosakan struktur tidak akan terlalu teruk berbanding dengan struktur konvensional. Kesan pelaksanaan reka bentuk seismik terhadap kos bahan menjadi topik penting untuk disiasat. Berhubung dengan itu, kajian ini membincangkan reka bentuk seismik 3 tingkat dan 5 tingkat bangunan hospital konkrit bertentangan dengan pertimbangan magnitud yang berbeza dari Peak Ground Acceleration (PGA) dan gred konkrit yang berlainan. Objektif kajian ini adalah untuk menentukan perbandingan jumlah pengukuhan besi yang diperlukan berdasarkan kepada dua parameter yang dinyatakan di atas berbanding reka bentuk bukan seismik. Dua belas model bangunan hospital dengan pertimbangan berbeza PGA dan gred konkrit dipertimbangkan. 6 model digunakan untuk magnitud PGA = 0.08g bersama dengan gred konkrit 25, dan 6 model lain digunakan untuk magnitud PGA = 0.16g bersama dengan gred konkrit 35. Untuk magnitud yang berbeza PGA bagi 3 tingkat bangunan, hasil menunjukkan bahawa perbezaan peratusan pengukuhan besi yang diperlukan berbanding reka bentuk bukan seismik untuk rasuk dan lajur keseluruhan bangunan telah meningkat dari 44% kepada 156% bagi PGA bersamaan dengan 0.08g dan 0.16g masing-masing. Sementara untuk gred konkrit yang berbeza di bangunan 3 tingkat, hasil menunjukkan bahawa perbezaan peratusan pengukuhan keluli yang diperlukan berbanding dengan reka bentuk bukan seismik telah menurun sebanyak 21% daripada gred konkrit 25 kepada gred konkrit 35.

ABSTRACT

Nineteen miles below sea level in the early hours of December 26, 2004, a 9.1-magnitude earthquake shook the seas near the coast of Sumatra, in the northwestern reaches of the Indonesian archipelago. More than 227,000 people were declared dead or missing in the weeks after the tragedy that affected 14 countries across two continents. On June 5, 2015, a 5.9-magnitude earthquake rattled Sabah, killing 18 people on Mount Kinabalu. It was said to be the second powerful quake to hit Sabah after the 1976 earthquake measuring 6.2 on the Richter scale that occurred near Lahad Datu. The 2015 earthquake was felt across the state and more than 100 aftershocks were reportedly recorded throughout the year. Following the quake tragedy in Sabah, there have been concerns that an earthquake may also hit Peninsular Malaysia and according to a geological expert, such misgivings are not misplaced. The general perception has always been that Peninsular Malaysia was safe because we are far from the Pacific Ring of Fire which surrounds us, but in recent years, there is evidence of earthquakes with focal points or epicentres right under our feet, due to the reactivation of old fault lines. These fault lines seem to have been reactivated by active tectonic plate boundaries and this has caused a concern since many structures in the city were not built and designed to withstand earthquakes. The causes of the reactivation of fault lines in Malaysia is because it is surrounded by so many active tectonic plate boundaries and the Sunda Shelf, which the country sits on, is being compressed. Peninsular Malaysia is at the centre of the shelf, also known as Sundaland, which is absorbing all the stress from around it. Sooner or later, the earth has to find some release by breaking through old fault line systems. Due to this hazard effect, the structures need to be designed to resist the dynamic forces from the earthquakes. When the structure is designed to resist earthquake, the damage of the structure will not be too severe compared to the conventional structures. The effect of seismic design implementation on cost of materials is became an important topic to be investigated. In relation to that, this study discusses on the seismic design of 3 storey and 5 storey of reinforce concrete hospital building with consideration of different magnitude of Peak Ground Acceleration (PGA) and different grade of concrete. The objectives of this study are to determine the comparison on the amount of steel reinforcement required based on the two different parameters mentioned above compared to non-seismic design. Twelve models of hospital buildings with consideration of different PGA and concrete grade are considered. 6 models are used for magnitude of PGA equal to 0.08g along with concrete grade 25, and 6 other models are used for magnitude of PGA equal to 0.16g along with concrete grade 35. For different magnitude of PGA in 3 storey building, the results show that the percentage difference of steel reinforcement required compared to non-seismic design for beam and column of the whole building had increased from 44% to 156% for PGA equals to 0.08g and 0.16g respectively. While for different grade of concrete in 3 storey building, the results show that the percentage difference of steel reinforcement required compared to non-seismic design had decreased by 21% from concrete grade 25 to concrete grade 35 respectively.

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LIST OF SYMBOLS

a_g	Design ground acceleration
a_{gR}	Reference peak ground acceleration
As_{prov}	Total area of steel provided
C_t	Coefficient
d_{bL}	Diameter of longitudinal bar
d_{bw}	Diameter of shear or confinement bar
f_{cd}	Design value of concrete compressive strength
f_{ck}	Characteristic cylinder strength of concrete
f_y	Yield strength of reinforcement
g	Acceleration due to gravity, m/s^2
G_k	Dead load
K_w	Reflecting factor
m	mass of structure
M_{Ed}	Bending moment
M_w	Magnitude of earthquake intensity
q	Behaviour factor
Q_k	Live load
q_o	Basic value of behavior factor
S	Soil factor
$Sd(T_1)$	Ordinate of the design spectrum at period
T_1	Fundamental period of vibration
T_B	Lower limit of the period of the constant spectral acceleration
T_C	Lower limit of the period of the constant spectral acceleration
T_D	Beginning of the constant displacement response range of the spectrum
γ_1	Importance factor
λ	Correction factor

LIST OF ABBREVIATIONS

BS	British Standard
DCL	Ductility Class Low
DCM	Ductility Class Medium
DCH	Ductility Class High
JKR	Jabatan Kerja Raya
NS	Non-Seismic
PGA	Peak Ground Acceleration
RC	Reinforced Concrete
SDOF	Single Degree of Freedom

CHAPTER 1

INTRODUCTION

1.1 Background

The surface of the earth is like a giant puzzle, and all the pieces that make up this puzzle are called tectonic plates. Although these giant rock puzzle pieces fit together very nicely, they don't stay in place because they are floating on the layer below us, the mantle. The plates float around on the mantle and the movement of the plates is incredibly slow, but since the plates are so big, when they bump into and rub against each other, we get massive events like volcanoes and earthquakes. And along these plate boundaries, we find faults.

An earthquake is what happens when there is a movement along a fault plane or breaking of the tectonic plates which will cause a sudden violent shaking and vibration of the earth surface. Tectonic plates refer to a huge rock pieces within the earth's crust. The plates are usually marked by fractures or fault lines formed when the plates tear apart or slide or collide past each other. According to Bruce A. Bolt (2018), tectonic earthquakes are explained by the so-called elastic rebound theory, formulated by the American geologist, Harry Fielding Reid after the San Andreas Fault ruptured in 1906, generating the great San Francisco earthquake. According to the theory, a tectonic earthquake occurs when strains in masses have accumulated to a point where the resulting stresses exceed the strength of the rocks, and sudden fracturing results.

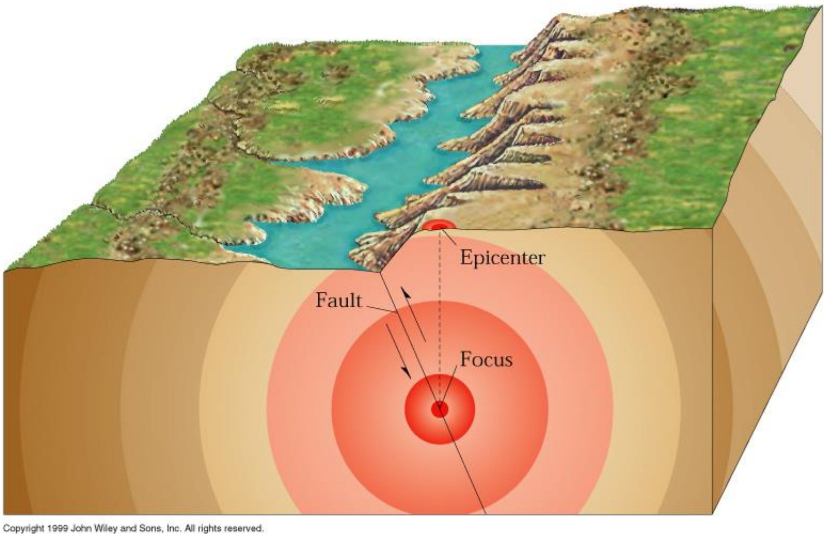

Figure 1.1 The point within Earth where the rupture starts is known as the focus.

In truth, however, our planet's seemingly stable surface is made up of enormous pieces of rock that are slowly but constantly moving. Those pieces continually collide with and rub against one another, and sometimes their edges abruptly crack or slip and suddenly release huge amounts of pent-up energy. These unsettling events are called earthquakes, and small ones happen across the planet every day, without people even noticing. But every so often, a big earthquake occurs, and when that happens, the pulses of energy it releases, called seismic waves. This results in a change of the earth's interior masses which send out powerful shock waves with enough force to alter the surface of the earth. The shock waves can thrust up cliffs and open huge cracks on the ground leading to an earthquake event which can wreck almost unfathomable destruction and kill and injure many thousands of people.

Almost every year, earthquakes are recorded in various part of the world. Since the shear and tear forces are always constant within the earth's plate tectonics, earthquakes can occur at any time. Thousands of minor tremors often take place just because of these constant movements. Earthquakes can cause serious destruction to property, injury to people and even kills. Earthquakes can range in size from those that are so weak that they cannot be felt to those violent enough to toss people around and destroy whole cities.

Generally, earthquakes can cause significant damages within 100-200km radius from the epicentre. At further distance, amplitudes of incoming seismic shear waves are generally small. According to Natoli (2005), earthquake intensity generally decreases with increasing distance away from epicentre because seismic wave amplitude gradually died down as the waves travel through the earth. However, the “Bowl of Jelly” phenomenon, as what had happened to Mexico City in 1984 has opened people eyes to be more aware and considered this issue more seriously. The phenomenon has shown that even though an earthquake occurred at a far distance, it can have a significant effect due to long period component of the shear waves (Adnan et al., 2005).

The general perception has always been that Peninsular Malaysia was safe because we are far from the Pacific Ring of Fire which surrounds us, but in recent years, there is evidence of earthquakes with focal points or epicentres right under our feet, due to the reactivation of old fault lines. Malaysia is surrounded by so many active tectonic plate boundaries and the Sunda Shelf, which the country sits on, is being compressed.

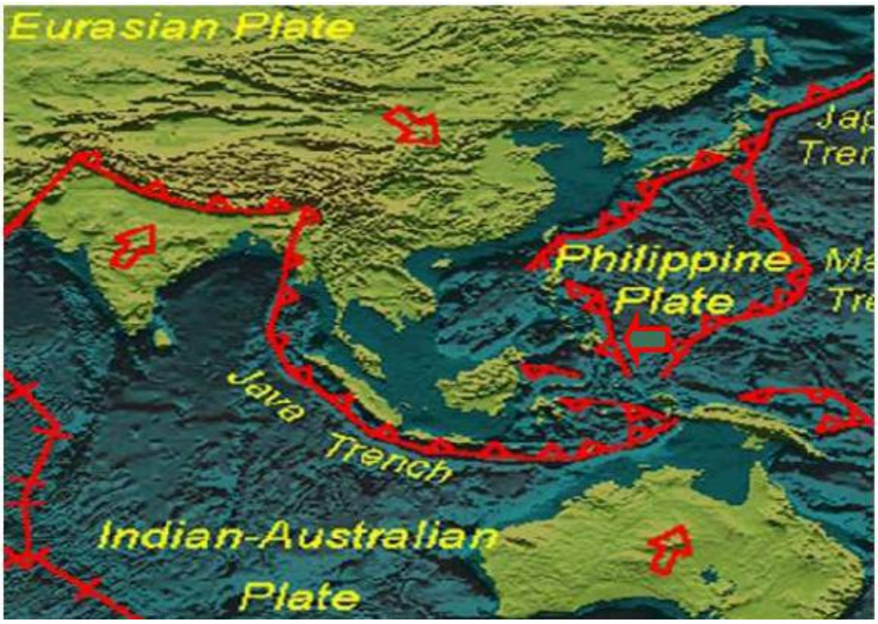

Figure 1.2 Major tectonic plates around Malaysia.

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