STRUCTURAL PERFORMANCE OF KOLEJ KEDIAMAN TUN MUSTAPHA DUE TO EARTHQUAKE

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FACULTY OF ENGINEERING
UNIVERSITI MALAYSIA SABAH

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STRUCTURAL PERFORMANCE OF KOLEJ KEDIAMAN TUN MUSTAPHA DUE TO EARTHQUAKE

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ABSTRACT

The majority of buildings constructed in Sabah are reinforced concrete structures. These existing buildings are designed according to the British Standard code of Practice (BS8110) without the consideration of seismic provisions. Consequently, this makes the existing building susceptible to potential seismic hazards. This research focuses on the Blok M (4-storey and 3-storey) of Kolej Kediaman Tun Mustapha in Universiti Malaysia Sabah, Kota Kinabalu. PROTA software was utilized to develop the models of the Blok M buildings. Response spectrum method was performed to obtain lateral displacements of storey for both buildings. The Interstorey Drift Ratio (%) was calculated based on the storey displacement and the performance level is evaluated based on FEMA 346 (2000). The lateral displacement was directly proportional to the height of the buildings. structural performance levels of KKTM residential buildings were determined as Immediate Occupancy (IO) where it is determined to be safe to use after an earthquake.

ABSTRAK

Kebanyakan bangunan yang dibina di Sabah dihasilkan daripada struktur kokrit bertetulang. Bangunan yang sedia ada ini dibina berdasarkan British Standard Code of Practice (BS8110) tanpa mengira peruntukan seismik. Disebabkan oleh itu, bangunan sedia ada ini terdedah kepada kemungkinan bahaya seismik. Kajian ini berfokus kepada Blok M (3 tingkat dan 4 tingkat) di Kolej Kediaman Tun Mustapha bertempat di Universiti Malaysia Sabah, Kota Kinabalu. Perisian digital PROTA akan digunakan untuk membina model bangunan Blok M dan memeriksa anjakan tingkat yang berlaku dalam struktur bentuk bangunan. Response Spectrum Method akan digunakan untuk menghasilkan data anjakan tingkat untuk kedua-dua bangunan. Data Interstorey Drift Ratio (%) akan digunakan untuk menentukan menilai Tahap prestasi dinilai berdasarkan FEMA 346 (2000). Tahap prestasi struktur termasuk, Immediate Occupancy (IO), Life Safety (LS), dan Collapse Prevention (CP). Anjakan sisi adalah berkadar terus dengan ketinggian bangunan dan tahap prestasi bangunan KKTM ditentukan ialah Immediate Occupancy (IO).

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LIST OF ABBREVIATION

G+10	10-Storey
G+25	20-Storey
BS	British Standard
MYR	Malaysian Ringgit
IEM	Institution of Engineers
TC	Technical Committee
IDA	Incremental Dynamic Analysis
PGA	Peak Ground Acceleration
IDR	Interstorey Drift Ratio
TBD	To Be Determined

CHAPTER 1

INTRODUCTION

1.1 Overview

Earthquakes are one of the deadliest natural disasters, resulting in a large number of fatalities, destruction of infrastructures, and loss nation's economy. An earthquake strikes with no recognized warning and are extremely indefinite as to source, extent, and duration, regardless of the time of the day. Earthquakes can cause buildings and bridges to collapse, as well as disrupting gas, electric, and phone service. Depending on its size, the aftermath of an earthquakes can also cause devastating landslides, avalanches, flash floods, fires, and massive, devastating ocean waves or tsunamis.

More than 500,000 earthquakes are recorded throughout the world every year (Ramirez et al, 2005). According to Daniell et al. (2017), earthquakes have caused over 2.32 (2.18-2.73) million fatalities since 1900 to 2015. They are also responsible for about 5.3 trillion MYR in human capital-related economic losses and 14.7 trillion MYR in overall economic expenses across the globe. Table 1 exemplify earthquakes in the 20^{th} century that caused wide-spread casualties and significant loss of assets. The number of recorded victims of varying earthquake magnitudes are not only attributed to population growth, but also the consequence of locations of victims, epicentre location and building codes (Tang et al. 2017).

Large earthquakes are linked to significant injuries in addition to fatalities. Earthquake-related injuries can vary from minor scrapes and bruises to more serious injuries include severe fractures, internal organ damage, and burns. Other injuries such as crush injuries are related to building construction design materials. Multi-storey buildings made of concrete resulted in crush injuries than other building construction. For the large majority of earthquakes incidents, structural damage is primarily cause of injuries and deaths (Spence et al., 2011).

Malaysia is considered to have the low seismicity profile and it is located on the Eurasian plate, and closer to the two interpolate boundaries which are the Australian Plates in the west and the Philippines Plate in the east. However, contrary to the common belief that Malaysia is seismically free, evidence shows that Malaysia is not immune to seismic risks. Malaysia is surrounded with a very active seismic bay on the west and east, thus potentially at risk of facing earthquake disasters. In recent case, a 5.9-magnitude quake hit Sabah on June 5th, 2015. The earthquake took the lives of 18 climbers on Mount Kinabalu and induce damages which includes rock fall, mudslides, structural deformation to buildings and landslide (Figure 1.1).

Figure 1.1 : Landslide After The 2015 Ranau Earthquake
Source : Foong *et al.* (2017)

Seismic occurrences of moderate scale (M5–M6) that occurred in Malaysia in the 1900s have been reported. The impacted regions in Sabah were primarily sparsely inhabited places (e.g., M5.3 in 1966 near Ranau, M6.2 and M5.7 in 1976 and 1994, respectively, near Lahad Datu). Because of the limited population in the impacted regions and the lack of significant designed building structures, these early disasters received little attention. Those incidents have faded from memory over time. However, The Aceh M9.1–9.3 and Nias M8.6 megathrust subduction (interplate) earthquakes, which occurred offshore of Sumatra in 2004 and 2005, respectively, were major occurrences. Although the epicentres of these earthquakes were roughly 600 kilometers away from Peninsular Malaysia, many people living along the Peninsular's west coast felt the tremors. Given the public's concern, the Civil and Structural Engineering Technical Division of the Institution of Engineers of Malaysia (IEM) took the initiative to prepare a position paper which was published in 2008. The position paper expressed worry about the Malaysian engineering industry's lack of readiness in earthquake design. To mitigate the possible dangers, certain short- and long-term interventions are suggested.

The Department of Standards Malaysia chose IEM as the standards-writing organization for the Malaysia NA to EC8 in 2008. To research the seismic danger in Malaysia, a Technical Committee (TC) on earthquakes established Working Group 1 (WG1). While the original emphasis was on distant interpolate earthquakes caused by offshore sources, attention has been directed to local intraplate earthquake occurrences that occurred inside the peninsular. The M4.2 seismic tremor that struck Bukit Tinggi, some 30 kilometers from Kuala Lumpur, Malaysia's capital city, in 2007–2009 is an example of such an incident. In recommendations made by the working group formed within the Institution of Engineers Malaysia (IEM) in the Draft NA to EC8 for public comments (2016), a minimum level of the reference peak ground acceleration on rock of 0.07g was specified for Peninsular Malaysia and Sarawak, and 0.12g for most of Sabah. In late 2017, Malaysia has finally enacted on its first code of practice for the seismic design of buildings following the release of Malaysian National Annex (NA) of Eurocode 8 (EC8 or MS EN1998-1) (Looi et al., 2019).

The 2015 Ranau earthquake has caused a lot of natural hazards to occur such as landslides and rockfall, as well as building destruction, loss of life, and disturbance in daily life of the community. It took months and some need years to recover. This incident further demonstrates that Kota Kinabalu are likely exposed to serious seismic threat in the future. Hence, it is critical that performance assessments of buildings in Kota Kinabalu is needed so that proper measures can be taken to minimize the negative impacts.

1.2 Research Problem

The majority of buildings constructed in Sabah are reinforced concrete structures. These existing buildings are designed according to the British Standard code of Practice (BS8110) without the consideration of seismic provisions. Consequently, this makes the existing building susceptible to potential seismic hazards. This type of structure suffered significant damage in the aftermath of the 2015 Ranau earthquake.

Many RC buildings in Sabah particularly in Ranau, experienced structural damages where some buildings deemed inhabitable and needed to be demolished or temporally closed. This event demonstrated the necessity of understanding the safety levels and seismic vulnerability of existing structures in Sabah. University Malaysia Sabah (UMS), located in Kota Kinabalu, are one of the most occupied areas in Sabah. It is home to numerous residential buildings that is inhabited by thousands of university students. The potential risk of damages to these buildings are difficult to predict as there are no past studies conducted to investigate the structural deformation and performance level. Therefore, to mitigate loses and damage, performance levels of existing building should be determined to determine safety of buildings after an earthquake. In addition, identifying the performance levels of structure can facilitate proactive measures for vulnerable structures to withstand seismic activity, for instance by providing additional beam or column supports as well as retrofitting works.

1.3 Problem Statement

The objective of this study is:

a) To examine story displacement of the residential building of Kolej Kediaman Tun Mustapha of University Malaysia Sabah due to earthquake
b) To determine the performance level of the residential building of Kolej Kediaman Tun Mustapha Blok M due to earthquake

1.4 Significance of Study

This research utilised the use of PROTA software to provide insights on the structural performance of residential building of Kolej Kediaman Tun Mustapha in Universiti Malaysia Sabah under earthquake. Besides that, this study will provide knowledge and awareness to stakeholders on the importance of earthquake consideration in existing building for retrofitting works and maintenance.

1.5 Scope of Study

This research focuses on the residential building of Kolej Kediaman Tun Mustapha in Universiti Malaysia Sabah, Kota Kinabalu. These buildings are 4-storey and 3-storey residential building with a height of 12.7 m and 9.7m tall, respectively. The buildings were designed according to the BS 8110: 1997 without earthquake provisions.

For the first objective, PROTA software was utilized to develop the model of the Blok M 4-storey and 3-storey residential building. PROTA software was used for modelling and to determine the lateral displacement of building subjected to varying ground motion through response spectrum analysis.

For the second objective, the data output from the first objective which is the Interstorey Drift Ratio (%) was used to determine the performance level of residential building. The performance level was evaluated based on FEMA 346 (2000). The structural performance levels include Immediate Occupancy (IO), Life Safety (LS), and Collapse Prevention (CP).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discuss on the basic definition of earthquakes and how it formed. It also describes the different levels of magnitudes of earthquake and its affect. Besides that, the history of earthquake occurrences is described in detail, particularly in Peninsular Malaysia, Sarawak and Sabah. This chapter also consist of the potential structural damage of reinforced concrete structure during an earthquake and introduce the different categories of seismic analysis methods.

2.2 Earthquake Overview

Earthquake is described as the shaking or vibration of the ground surface in response to the sudden release of energy caused by fault movement. Typically, earthquakes occur in the upper ten kilometres of the earth's crust. They arise as a consequence of frictional instabilities that cause stress, accumulated by large-scale plate motions over periods of hundreds of years, to be relieved in sudden stick-slip events, resulting in radiation of seismic energy and ground shaking. Earthquakes can also be triggered by volcanic or magmatic activity or other sudden stress changes in the earth (Stein and Wysession 2009; Bolt 1988).

Earthquakes are categorized into two; intraplate earthquake and interplate earthquakes. Intraplate earthquakes occur within the interior of a tectonic plate (Johnston & Kanter, 1990; Richter, 1958; Wysession, et al., 1995), meanwhile interpolate earthquakes occurs at the boundary between two tectonic plates. In generally, intraplate earthquakes are caused by reactivation of old rifts (Schulte & Mooney, 2005). the magnitude of intraplate earthquakes is limited compared to interpolate earthquakes, but they still pose a threat of fatal destruction if they occur near vulnerable urban areas. The largest intraplate event, for example, was the Mw 7.7 Gujarat earthquake in Western India on January 26, 2001. The epicentre was near Bhuj's north-eastern outskirts. Over 8,792 communities were hit by the quake, with a total of 20,005 people killed (Saito, et al. 2004).

In the other hand, Interplate earthquakes, occurs along the edge of the interacting plates, contribute more than 90 % of the world's release of seismic energy. There are three (3) types of faults (Refer Figure 2.1): normal, reverse, and strike-slip fault. A normal fault is one in which the rocks above the fault plane, or hanging wall, move down relative to the rocks below the fault plane, or footwall. A reverse fault is one in which the hanging wall moves up relative to the footwall. Meanwhile strike-slip fault occurs when rocks on either side of a nearly vertical fault plane move horizontally.

One of the largest interplate earthquake was the 2011 Tohoku earthquake, occurred on March 11th, 2011, along the Japan Trench with Mw 9.0 (Suzuki et al. 2011). The rupture of a section of the subduction zone linked with the Japan Trench caused this earthquake, which triggered massive destructive tsunamis that reached the Pacific coast of Northeast Japan, causing inconceivable damage (Usami, et al. 2018).

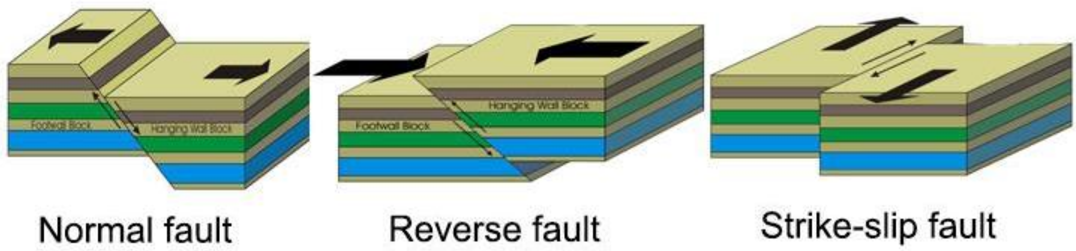

Figure 2.1 : **Types of Faults**
Source : Yön *et al.* (2017)