FRAMEWORK FOR SEISMIC VULNERABILITY ASSESSMENT OF REINFORCED CONCRETE BUILDINGS IN SABAH

ALLY EASTER ALAN

FACULTY OF ENGINEERING

UNIVERSITI MALAYSIA SABAH

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NAME : ALLY EASTER ALAN

MATRIC NO. : BK18110132

TITLE : FRAMEWORK FOR SEISMIC VULNERABILITY ASSESSMENT OF REINFORCED CONCRETE BUILDING IN SABAH

DEGREE : BACHELOR DEGREE OF CIVIL ENGINEERING

DATE OF VIVA : JULY 2022

VERIFIED BY;

SUPERVISOR

Ts. Dr. Noor Sheena Herayani binti Harith

Signature

DR. NOOR SHEENA
HERAYANI HARITH
Senior Lecturer
Faculty of Engineering (Civil)
Universiti Malaysia Sabah

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ABSTRACT

Sabah is one of the most seismically active states in Malaysia, and has long been renowned as an earthquake hotspot. The goal of this study was to assess the damage potential and develop a map with damage potential grades of structures in Sabah's even districts: Kota Kinabalu, Papar, Ranau, Kudat, Tawau, Lahad Datu, and Semporna. Furthermore, the vast majority of the structures in Sabah were constructed without consideration for earthquake safety. Consequently, the Rapid Visual Screening (RVS) approach was selected to find potentially damaging concrete structures throughout Sabah, as it has been shown to be useful in assessing building seismic susceptibility. According to the finding, Kota Kinabalu has 137 structures categorised as having a damage hazard of grade 3 to 4 grades majority of buildings in Tawau, Semporna, and Lahad Datu have a Grade 2 damage potential, but some have a Grade 5 damage potential. In the districts of Papar, Ranau and Kudat, a total of 19 structures were identified as vulnerable, with a potential for Grade 3 damage.

ABSTRAK

(Rangka Kerja Penilaian Kerendahan Seismik Bangunan Konkrit bertetulang di Sabah)

Sabah adalah salah satu negeri yang paling aktif secara seismik di Malaysia, dan telah lama terkenal sebagai kawasan panas gempa bumi. Matlamat kajian ini adalah untuk menilai potensi kerosakan dan menghasilkan peta dengan gred potensi kerosakan struktur di daerah-daerah Sabah: Kota Kinabalu, Papar, Ranau, Kudat, Tawau, Lahad Datu, dan Semporna. Tambahan pula, sebahagian besar struktur di Sabah telah dibina tanpa mengambil kira faktor keselamatan gempa bumi. Oleh itu, pendekatan Rapid Visual Screening (RVS) telah dipilih untuk mencari struktur konkrit yang berpotensi untuk mengalami kerosakan akibat gempa bumi di seluruh Sabah, kerana ia telah terbukti berguna dalam menilai kerentanan seismik bangunan. Berdasarkan penemuan, Kota Kinabalu mempunyai 137 struktur yang dikategorikan mempunyai bahaya kerosakan gred 3 hingga 4. Majoriti bangunan di Tawau, Semporna, dan Lahad Datu mempunyai potensi kerosakan Gred 2, tetapi ada yang mempunyai potensi kerosakan Gred 5. Di daerah Papar, Ranau dan Kudat, sebanyak 19 struktur dikenal pasti terdedah dan berpotensi mengalami kerosakan Gred 3.

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LIST OF ABBREVIATION

C1	-	Moment-resisting concrete frame structures
C2	-	Buildings with concrete shear walls
C3	-	Unreinforced masonry infill walls in concrete frame buildings
PC1	-	Concrete structures with a slant
PC2	-	Structures made of precast concrete
RM1	-	Buildings made of reinforced masonry with flexible floor and roof diaphragms
RM2	-	Buildings made of reinforced masonry with rigid floor and roof diaphragms
RVS	-	Rapid Visual Screening
S1	-	Buildings with steel moment-resisting frames
S2	-	Steel-framed buildings that are braced
S3	-	Buildings made of light metal
S4	-	Shear walls made of cast-in-place concrete in steel frame buildings
S5	-	Buildings with unreinforced masonry infill walls are made of steel frames.
URM	-	Buildings with unreinforced masonry bearing walls
W1	-	Residential and industrial structures with a light wood frame of 500 square feet or less
W2	-	Buildings with a floor area of more than 5000 square feet made of wood.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Earthquake is a tectonic or volcanic phenomena that indicates rock movement and causes the ground to shake or tremble. The earthquake struck without notice. Earthquake strikes can last for days, weeks, months, or even years. The impacts of an earthquake can be widespread, as they usually result in a tsunami that damages areas thousands of kilometres away. Earthquakes are principally caused by the Earth's internal heat. Large circulation cells form in the Earth's mantle when heat from within the earth tries to escape to the surface, where it travels upward. The motion of tectonic plates is driven by the circulation cell's flow. According to (Mohamad, Yunus, & Harith, 2018), when two plates collide, an earthquake occurs. This typically occurs when subsurface rocks unexpectedly fracture along faults as a result of a sudden release of energy that causes ground shaking. When plates move, three things happen: the plates move apart, which is known as divergent boundary; the plates slide past one another, which is known as transform boundary; and finally, the plates collide, which is known as convergent boundary. Normal faulting, strike-slip earthquakes, and subduction earthquakes are all possible outcomes of plate movement.

Sabah has long been renowned in Malaysia as an earthquake-prone region, and it is one of the states that is more vulnerable to earthquake activity and is classified as a seismically active zone. Furthermore, Sabah is located near the most seismically active plate boundaries, which are the India-Australian Plate and the Eurasian Plate in the west and the Philippine Plate in the east (Tongkul, 2017). Several earthquakes with a magnitude of around 6 Richter scale have struck this state. Structures were moderately damaged by these earthquakes. It is reported that the earthquake was due to movement of the active fault which is the Lobou-lobou Fault in the district of Ranau.

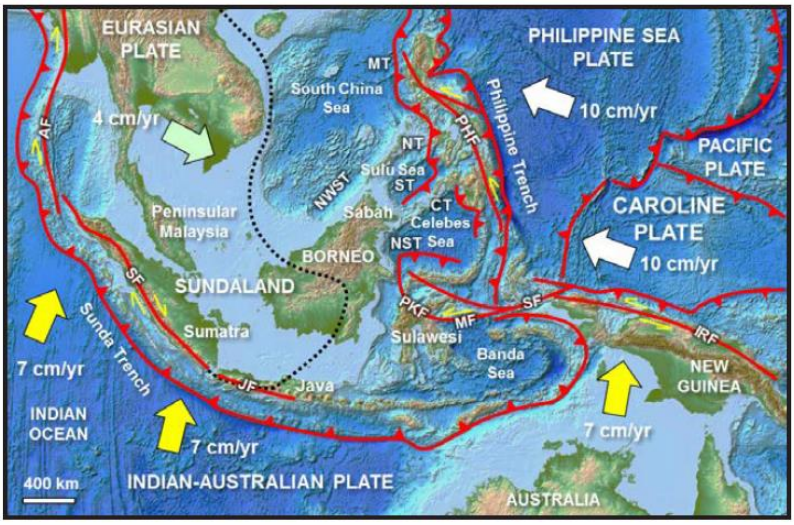

Figure 1.1 : The tectonic setting in Sabah

Source : Tongkul, 2017

The Eurasian plate, the Indian-Australian plate, and the Philippine Sea-Pacific plate, as indicated in the diagram above, all interact causing compression forces in Sabah (Idris, Solihin, Edmond, Murugiah, & Noh, 2021). At a rate of around 4 centimetres per year, the Eurasian plate is sliding south-eastward. The Indian-Australian Plate is migrating northward at around 7 centimetres per year, while the Philippine Sea-Pacific Plate is moving northward at roughly 10 centimetres per year. The plates are actually 1000 kilometres away from Sabah. However, the compressive force of tectonic movements can still be felt. According to the history of earthquakes in Sabah, four earthquakes with magnitudes of 6 or higher have been recorded: the 1923 Lahad Datu Earthquake, the 1951 Kudat earthquake, the 1976 Lahad Datu Earthquake, and the recent 2015 Ranau Earthquake (Tongkul, 2017).

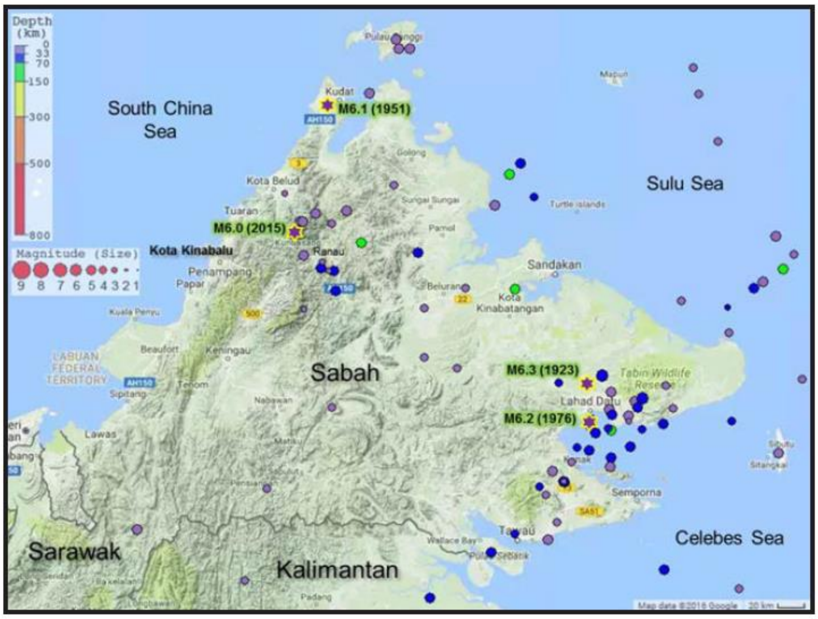

Figure 1.2 : Earthquake Distribution in Sabah between year 1973 to 2016

Source : Tongkul, 2017

It is obvious that significant physical damage levels of construction and partial or entire collapse of non-seismically designed or strengthened structures cause human and economic loss in medium and high seismic prone areas. Despite the fact that the seismicity of Sabah is much lower than that of other moderate seismicity zones, the risk of an earthquake should not be underestimated. Seismic risk is a result of three probabilistic components: hazard, exposure, and vulnerability, in that order (Ningthoujam & Nanda, 2018). The final element is especially important in the case of civil engineering structures, because strengthening methods serve to reduce the intrinsic susceptibility of buildings, lowering the seismic risk. Simple approaches to mitigate the effects of such catastrophic catastrophes that are scientifically confirmed while being understandable to non-technical people, owners, and decision-makers are required. As a result, this study suggested an approach for evaluating the seismic vulnerabilities of reinforced concrete buildings by using Rapid Visual Screening (RVS) approach, which included a few features.

1.2 Problem Statement

The recent magnitude-6.0 earthquake near Ranau, Sabah, on June 5, 2015, has highlighted the need for a seismic vulnerability assessment for the buildings in Sabah. Furthermore, while the recent earthquakes in Sabah were only of a low to moderate magnitude and were not particularly severe, they served as a warning that future earthquakes could cause major structural damage. The earthquake resulted in a number of negative outcomes, including structural damage and fatalities. Further, the inspection steps on buildings affected by earthquake are very few. The selection of suitable method is crucial and consist in analysing large stocks of buildings.

There have been several studies that explain the prospective effects of seismic loadings on buildings in Malaysia, but it is not taken into account in the Malaysian construction code. As a result, the seismic susceptibility of buildings must be examined in order to limit the risk to buildings and, ultimately, people. According to (Jainih & Harith, 2020), the majority of structures in Sabah, particularly in Kota Kinabalu, were designed and developed with non-seismic compatibility in mind. As a result, a seismic risk assessment must be completed in order to plan for potential structural retrofits in the event of future earthquakes.

In this research, a paradigm for assessing Sabah's reinforced concrete buildings' seismic vulnerability is presented. In the majority of prior studies, the findings of the possible damage to buildings in the study location are frequently given in a numerical or statistical form. In terms of this study, it will create a map with damage potential scores for chosen buildings in the research region. The Rapid Visual Screening (RVS) method was used in this study, and it is described as a qualitative evaluation procedure for identifying potentially hazardous structures.

1.3 Objectives of Study

The framework for seismic vulnerability assessment of reinforced concrete buildings in Sabah is presented in this study. The research approach is based on the following objectives:

i. To determine the typical building construction in Sabah;
ii. To determine the possibility for building damage and generate a map with each building's damage potential grade.

1.4 Scope of Study

The seismic risk evaluation of reinforced concrete buildings in seven districts in Sabah, namely Kota Kinabalu, Papar, Kudat, Ranau, Tawau, Semporna, and Lahad Datu, is part of the scope of work for this study. The Rapid Visual Screening Data Collection Form will be used to assess the seismic susceptibility of buildings. The FEMA-154 serves as a guideline for completing the form. The assessment of buildings in Sabah will result in the determination of the building's damage potential. A total of 443 buildings throughout Sabah will be used for this study, including 247 buildings in Kota Kinabalu, 7 buildings in Ranau, 13 buildings in Kudat, 13 buildings in Papar, 78 buildings in Tawau, 38 buildings in Semporna, and 47 buildings in Lahad Datu.

1.5 Significance of Study

This study contributes to a numerous advantage. Rapid visual screening results, particularly in Sabah, can be used for a range of applications that are an important aspect of the region's earthquake catastrophe risk management plan. Identifying the necessity for a building's further evaluation of its seismic susceptibility is one of the advantages. It also aids in the ranking of a district's seismic rehabilitation needs and simplifies the establishment of a seismic risk management plan for the districts involved. Furthermore, knowing the stage of seismic vulnerability of a building allows the community or person in charge to prepare post-earthquake building safety review measures. Finally, it has the potential to raise local citizens' knowledge of building seismic vulnerability.

1.6 Summary

According to current research, there have been a limited number of studies involving seismic risk assessment of buildings that covered the entire region of Sabah, despite the fact that the state is more seismically active than any other state in Malaysia. As a result, the goal of this research is to propose a framework for assessing building seismic performance, including generating a map with plotted structures based on the analysis that use the Rapid Visual Screening Procedure.

1.7 Project Outline

This research paper focused on the seismic vulnerability assessment based on the approach on Rapid Visual Screening. Chapter 1 in this study included the element of Background of Study, Problem Statement, Objective of Study, Scope of Work, Significance of Study and Summary. These elements acted as a guideline to complete the research

The preparatory research is covered in Chapter 2, and the main approach is a literature review. This chapter includes a review of previous journals and publications related to the research topic. Past research from 2017 to 2022 was viewed through several sites such as SpringerLink, ScienceDirect, ResearchGate, and others. All of these websites can be accessed using the UMS Database, which is supplied by the University Malaysia Sabah.

The framework for using RVS as a medium for analysing seismic performance of a building presented in Chapter 3. It comprised the variables that were taken into account when using the Rapid Visual Screening method. This chapter would go over the RVS method's flow in further detail. Additionally, the method of creating a map utilising the Geographic Informative System (QGIS) will be included.

The project's fourth chapter, which focused on identifying the different types of structures and their potential for destruction in the seven districts is presented. The damage potential grade for each building in the study area will also be shown on the map. The results are all summarised in Chapter 5, together with any limitations and suggestions for additional research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

A building's vulnerability in the case of an earthquake is frequently referred to as its damage potential. Vulnerability is described as "the ability to be damaged or injured." The majority of buildings in Sabah were found to be non-engineered and built without earthquake-resistant technology (Mansor, Siang, Ahwang, Saadun, & Dumatin, 2017). It is vital to investigate the susceptibility of building assets in such a seismically active environment.

The absence of clear rules in the form of provision codes is not the sole cause of this situation; another factor is the technical and professional community's lack of readiness to implement strengthening measures through quality control and specialised craft. In a conceptual sense, vulnerability, exposure, and hazard are the three probabilistic components that make up seismic risk (Ferreira, Rodrigues, & Vicente, 2020). The process of identifying a building's vulnerability entails a lengthy analysis. Seismic vulnerability assessment is an undeniably difficult technique, and only a few buildings can normally be assessed. As a result, a quick and reliable method for quickly assessing building vulnerability is essential, allowing more complicated evaluation techniques to be limited to the most critical structures. Rapid Visual Screening, a fieldwork-based strategy, had been found to be effective (Ghafar et al., 2015).

2.2 Typical building construction in Sabah

The type of construction is one of the most important aspects in measuring a building's seismic resistance. A structure is an obvious combination of building types in distinct plan directions or across the building's height. According to FEMA P-154, there were fifteen different types of structures. For each of these fifteen model building types, a Basic Structural Hazard Score had been generated, indicating the likelihood of building collapse if the building is subjected to the maximum assessed seismic ground motion for the area. Building types are classified based on the major structural material used in the structure as well as the sort of lateral force resisting system used.

According to the table below, there are two types of wood frame buildings: light wood frame (W1) and large wood frame (W2). There were five different types of steel buildings: Steel-framed structures with a masonry infill wall that is not reinforced (S1), steel-framed structures with braces (S2), buildings made of light metal (S3), Buildings with a concrete shear wall are made of steel frames (S4), and last but not least steel frame structures with a masonry infill wall that is not reinforced (S5). Moment-resisting concrete frame buildings (C1), Buildings with concrete shear walls (C2), Unreinforced masonry infill walls in concrete frame structures (C3), Concrete structures with a tilt (PC1), and Precast concrete frame buildings (PC2) are the fifth concrete building types. Buildings made of reinforced masonry with flexible floor and roof diaphragms (RM1), Reinforced masonry structures with stiff floor and roof diaphragms (RM2), and Buildings with non-reinforced masonry bearing walls (URM) were the three types of reinforced masonry buildings.