SEISMIC VULNERABILITY ASSESEMENT OF SELECTED BUILDINGS IN KOTA KINABALU, SABAH

VILIANA JAINIH

FACULTY OF ENGINEERING
UNIVERSITY MALAYSIA SABAH

2020

SEISMIC VULNERABILITY ASSESMENT OF SELECTED BUILDINGS IN KOTA KINABALU, SABAH

VILIANA JAINIH

THESIS SUBMITTED IN FULFILLMENT FOR THE DEGREE OF MASTER IN ENGINEERING

FACULTY OF ENGINEERING
UNIVERSITY MALAYSIA SABAH
2020

UNIVERSITY MALAYSIA SABAH

BORANG PENGESAHAN STATUS TESIS

JUDUL : **SEISMIC VULNERABILITY ASSESMENT OF SELECTED BUILDINGS IN KOTA KINABALU, SABAH**

IJAZAH : **SARJANA KEJURUTERAAN**

BIDANG : **KEJURUTERAAN AWAM**

Saya **VILIANA JAINIH**, Sesi **2018-2020**, mengaku membenarkan tesi Sarjana ini disimpan di Perpustakaan Universiti Malaysia Sabah dengan syarat-syarat kegunaan seperti berikut:-

1. Tesis ini adalah hak milik Universiti Malaysia Sabah
2. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan tesis ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (/):

☐	SULIT	Menengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA1972)
☐	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☐	TIDAK TERHAD	

Disahkan Oleh,

VILIANA JAINIH
MK1811009T

(Tandatangan Perpustakawan)

Tarikh : 11 Dec 2020

(Dr. Noor Sheena Herayani Harith)
Penyelia

DECLARATION

I hereby declared that the work in this thesis is my own, except for the quotation, equation and all the summaries where each of them has been cited and mentioned appropriately with the sources.

11 December 2020

VILIANA JAINIH
MK1811009T

CERTIFICATION

NAME	**:**	**VILIANA JAINIH**
MATRIC NUMBER	**:**	**MK1811009T**
TITLE	**:**	**SEISMIC VULNERABILITY ASSESMENT OF SELECTED BUIDINGS IN KOTA KINABALU, SABAH**
DEGREE	**:**	**MASTER OF ENGINEERING**
FIELD	**:**	**CIVIL ENGINEERING**
DATE OF VIVA	**:**	**11 DECEMBER 2020**

CERTIFIED BY;

CO - SUPERVISORY Signature

1. **MAIN SUPERVISOR**
   Dr. Noor Sheena Herayani Harith

2. **CO- SUPERVISOR**
   Prof. Ir. Dr. Abdul Karim Bin Mirasa

ACKNOWLEDGEMENT

I am truly grateful to God for the good health, mind and well being throughout my master study that was necessary to complete this thesis. Here, I would like to take this opportunity to express my deepest gratitude to everyone who has supported and contributed in many ways towards the completion of this thesis. Indeed, with their endless support that this thesis was made possibly a success. I am sincerely thankful for their aspiring guidance, invaluably constructive criticism and advice throughout this research. First and foremost, I am really thankful to University Malaysia Sabah (UMS) for providing research grant UMSGreat (GU/2018) throughout this research. I would like to also express my sincere gratitude to mu supervisor, Dr. Noor Sheena Herayani Harith, for her valuable guidance, patience, continuous support and constructive feedbacks. Her sincere guidance helped me in all the time of research and writing of the thesis. Besides, I am also great full to the stuff of Faculty of Engineering (FKJ) for providing all the necessary facilities for this project.

Last and most importantly, I would like to thank my family for their wise counsel sympathetic ear as well as support; spiritually and verbally, during my entire degree of master. None of this would be possible without the love and strength by them throughout these years. Thank you.

Viliana Jainih
11 December 2020

ABSTARCT

June 5th 2015 incident in Ranau, Sabah has brought the attention of both local and international researchers due to the 6.0 magnitude of earthquake that hit the district. It was the most powerful earthquake ever recorded in Borneo for the past 120 years since 1900. The records of loses demonstrate the significant needs for seismic vulnerability assessment on the existing buildings in the effected state. The objective of this study is to investigate the building vulnerabilities in the capital city of Sabah, Kota Kinabalu. Then, to establish a performance level of the existing buildings. Case buildings include major government buildings and facilities, educational and institutional buildings, residential buildings, commercial as well as public buildings. The empirical vulnerability assessment involves 250 number of buildings evaluations by Rapid Visual Screening according to FEMA 154 (2002). Local ground motion data indicates that Sabah is a region with moderate seismicity level. Case buildings ranging from low-rise to high-rise were screened with Level 1 assessment form and categorized into two groups; hazardous and non-hazardous, based on the determined final value "cut-off value". 60.4% of the case buildings deem to be potentially seismically hazardous under local ground excitation. 38.54% of the building stock possesses limiting seismic performance criteria and put forward for further seismic vulnerability assessment. Second part of this study involves analytical vulnerability assessment by means of Nonlinear Static Analysis (Pushover Analysis) using Capacity Spectrum Method. 7 case buildings were modeled into engineering software and evaluated with the highest expected ground excitation magnitude at 0.17ag with 10% probability of exceedance (PE) and 50 years design time period with respect to 2,475 return periods. Considering elastic damping at $\beta_o = 5\%$, all case buildings are assumed to be Type B category. Analysis of building performance results show majority of the building stock give a linearly elastic response under the local seismic excitation. Structures without seismic code compliance were estimated to show early damage accumulation due to ground shaking.

Key words: seismic vulnerability, nonlinear static analysis, rapid visual screening, capacity demand

ABSTRAK

PENILAIAN KERENTANAN SEISMIK DI KOTA KINABALU, SABAH

Kejadian 5 Jun 2015 di Ranau, Sabah telah menarik perhatian para penyelidik tempatan dan antarabangsa disebabkan gempa berkekuatan 6.0 yang melanda daerah itu. Gempa tersebut adalah yang terkuat pernah dicatatkan di Borneo selama 120 tahun sejak tahun 1900. Rekod kehilangan menunjukkan keperluan penting untuk penilaian kerentanan gempa pada bangunan yang ada di negeri yang terjejas tersebut. Objektif kajian ini adalah untuk mengkaji kerentanan bangunan di ibu kota Sabah, Kota Kinabalu. Kemudian, untuk menentukan tahap prestasi bangunan yang ada. Bangunan kes meliputi bangunan dan kemudahan utama kerajaan, bangunan pendidikan dan institusi, bangunan kediaman, bangunan komersial dan awam. Penilaian kerentanan empirikal melibatkan 250 penilaian bangunan dengan Rapid Visual Screening menurut FEMA 154 (2002). Data gerakan tanah tempatan menunjukkan bahawa Sabah adalah wilayah dengan tahap gempa sederhana. Bangunan kes meliputi bangunan bertingkat rendah hingga bangunan bertingkat tinggi disaring dengan borang penilaian Tahap 1 dan dikategorikan kepada dua kumpulan; berbahaya dan tidak berbahaya dari segi seismik, berdasarkan nilai akhir yang ditentukan "nilai cut-off". 60.4% bangunan kes dianggap berpotensi berbahaya secara gempa akibat eksitasi tanah tempatan. 38.54% stok bangunan mempunyai kriteria prestasi seismik yang terhad dan dikemukakan untuk penilaian kerentanan seismik selanjutnya. Bahagian kedua kajian ini melibatkan penilaian kerentanan analitik dengan kaedah Analisis Statik Tidak Linear (Analisa Tolakan) menggunakan Kaedah Kapasiti Spektrum. 7 bangunan kes dimodelkan dalam perisian kejuruteraan dan dinilai dengan magnitud pengujaan tanah tempatan yang dijangkakan paling tinggi pada 0.17ag dengan kebarangkalian 10% dan jangka masa reka bentuk 50 tahun berkenaan dengan 2.475 tempoh pengembalian. Dengan mempertimbangkan redaman elastik pada $\beta_{\circ} = 5\%$*, semua bangunan kes dianggap sebagai kategori Jenis B. Analisis hasil prestasi bangunan menunjukkan sebahagian besar stok bangunan memberikan tindak balas anjal secara linear di bawah pengujaan seismik tempatan. Struktur tanpa pematuhan kod seismik dijangkakan menunjukkan pengumpulan kerosakan awal akibat gegaran tanah.*

Kata Kunci: kerentanan seismik, analisis statik tidak linear, pemeriksaan visual yang cepat, permintaan kapasiti

LIST OF CONTENTS

CHATER 2: LITERATURE REVIEW

CHATER 3: RESEARCH METHODOLOGY

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND SYMBOLS

MMD	-	Malaysian Meteorological Department
MOSTI	-	Ministry of Science, Technology and Innovation
NERC	-	Non-engineered Reinforced Concrete
RVS	-	Rapid Visual Screening
ERA	-	Earthquake Risk Assessment
IEM	-	Institute of Engineering Malaysia
FEM	-	Finite Element Method
SDOF	-	Single Degree of Freedom
MDOF	-	Multi Degree of Freedom
MDR	-	Mean Damage Ratio
SLS	-	Service Limit State
RC	-	Reinforced Concrete
PoA	-	Pushover Analysis
GIS	-	Geographical Information System
SI	-	Soil Investigation
PI	-	Plasticity Index
ADRS	-	Acceleration-Displacement Response Spectrum
PP	-	Performance Point
IO	-	Immediate Occupancy level
LS	-	Life Safety level
CP	-	Collapse Prevention level

T	-	Torsion
V	-	Shear
P	-	Axial force
NLSA	-	Nonlinear Static Analysis
S_{MIN}	-	Minimum score of Level 1 RVS building
S_{L1}	-	Final score of Level 1 RVS building
N_{SPT}	-	Number of Blows
$V_{s,30}$	-	30^{th} Penetration Blow
C_u	-	Coefficient of uniformity
G_k	-	Dead load
Q_k	-	Imposed load
V_b	-	Base shear
Δ_{rt}	-	Roof top displacement
μ	-	Ductility ratio
B_{eff}	-	Equivalent damping
T_{eq}	-	Equivalent period
U_N	-	Roof displacement
N_{th}	-	N Floor
f_{bs}	-	Base shear
$m *_1$	-	Effective modal mass for the fundamental vibration mode, $\emptyset_1$
N	-	Number of floors
U_N	-	Displacement at N_{th} floor

$\boldsymbol{\Gamma_1}$	-	Participation factor corresponding to fundamental mode, $\emptyset_1$
$\boldsymbol{m_i}$	-	Lump mass at i_{th} floor
$\emptyset_{i1}$	-	i_{th} floor element of the fundamental mode, $\emptyset_1$
T	-	Corresponding vibration period
$\boldsymbol{S_d}$	-	Spectral displacement ordinate of the elastic demand spectrum
$\boldsymbol{S_a}$	-	Spectral acceleration ordinate of the elastic demand spectrum
$\boldsymbol{T_B}$	-	Lower limits of constant spectral acceleration plateau
$\boldsymbol{T_C}$	-	Upper limits of constant spectral acceleration plateau
$\boldsymbol{T_D}$	-	Controlling periods for constant displacement plateau

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Overview

Scientifically, earthquakes are caused by faulting, a sudden lateral or vertical movement of rock along a rupture surface. Accumulated strain in the earth along faults is released, resulting in radiation of seismic energy and ground shaking. The area of the fault where the sudden rupture takes place is called the focus or hypocenter of the earthquake. The point on the Earth's surface directly above the focus is called the epicenter of the earthquake. Earthquakes can also be triggered by volcanic or magmatic activity as well as other sudden stress changes in the earth. Scientists and researchers have increasingly focused their attention beyond seismology and the physics of the earth's structure and interior, to look at real-time earthquake damage estimation. According to researches by Berckhemer (2002), it is possible to estimate the seismic hazard or how much an earthquake could potentially shake the ground in an area by looking at local seismicity, seismotectonics and from records of strong-motion accelerographs.

Being one of the most destructive natural hazards, earthquake had caused large destruction in terms of life and economic losses (both recorded and non-recorded). The risk posed by earthquakes gradually increases with the ever expending human populations. According to the data on reported deaths compiled by the EM-DAT International Disaster Database, records stating the average amount of loss of human life were 27,000 lives per annum since 1900. Data shows that the number of earthquakes causing significant human and economic loss has increased since 1970 (Guha-Sapir and Vos, 2011). The records of losses demonstrate significant needs to the societies of the effected countries for Earthquake Risk Assessment (ERA). For the recent decade, media coverage of global events has expanded widely as telecommunication across the world has been eased with the help of social media (sites and apps) like Facebook, Twitter, Instagram, Snapchat and others. Hence, data quality and coverage on natural disaster events have vastly improved. In this section, we look at some of the patterns and trends in the earthquake data since 1970s. An annual average of 21 earthquake disasters has been reported over the last 39 years; according to EM-DAT criteria. But over the last 9 years, this average has increased to 30 earthquakes per year. According to study from Doocy *et al.* (2013), there were a range of 314,634 to 412,599 deaths, 845,345 to 1,145,093 injuries and more than 61 million people affected by earthquakes, where mortality was the greatest in Asia from 1980 through 2009. However, the frequency of seismic shocks with significant human impact is suggested to be underestimated due to inconsistent reporting across data sources.

The three peak years for high numbers of earthquake disasters were 1990, 2003 and 2004. Most recently, the 24thApril 2015 7.8-magnitude earthquake that hit Lamjung, Nepal (also known as the Gorkha earthquake) caused large-scale of human and economic loss, killing almost 9,000 people and may have pushed an estimated 2.5-3.5 per cent of the population into poverty (ESCAP, 2015). Moreover, the 9.0 magnitude earthquake that struck Japan’s northeastern coast and Tōhoku region on March 11, 2011 has triggered a tsunami with catastrophic consequences with material damage estimated to be $300 billion according to CNN that measure up to the 9.1 magnitude earthquake that shook the seas near the coast of Sumatra on Dec. 26, 2004, which recorded more than 227,000 fatalities. China’s Sichuan7.9

magnitude earthquakes left 87,000 killed and 4.8 million rendered homeless 18,000 schools damaged with international aid reaching up to $137.5 billion. The 7.6 magnitude shock that felled swaths of the fast-growing state of Gujarat on January 26th, 2001 recorded at least 20,000 of casualties.

According to (IEM, 2005), there are three types of interactions that can cause earthquakes, namely divergent boundary, convergent boundary and transform boundary. In Sumatra, the types of plate boundary that cause earthquakes, posing direct vibration threat to Malaysia are of the last two types. The NEIC estimates several million earthquakes occur in the world each year. However, many go undetected as they hit remote areas or have very small magnitudes. Table 1.1 shows the frequency of earthquakes worldwide, according to magnitude and annual average. The data shown for earthquakes having magnitude of 8 or higher were obtained based on observations since 1900, while data shown for earthquakes having magnitude of 5 to 7.9 were obtained since 1990.

Table 1.1: Frequency of Earthquakes Occurrence Worldwide

Descriptor	Magnitude	Annual average
Great	8 or higher	1
Major	7–7.9	17
Strong	6–6.9	134
Moderate	5–5.9	1,319
Light	4–4.9	+/- 13,000
Minor	3–3.9	+/- 130,000
Very minor	2–2.9	+/- 1,300,000

Source: National Earthquake Information Center, U.S. Geological Survey