FINITE ELEMENT ANALYSIS WITH SEISMIC RESPONSE ON RC-BUILDING'S SIMPLIFIED MODELLING

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FAKULTI KEJURUTERAAN
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ABSTRACT

Most of the reinforced concrete buildings in Malaysia are designed and built without seismic design as Malaysia is located far from the active plate boundaries until Ranau earthquake in 2015. Malaysia government had released Malaysia National Annex to Eurocode 8 in 2017 and the buildings should be designed and built according to the specification stated in this annex. The lack of attention and seismic design in reinforced concrete building as well as limited information and design performance of reinforced concrete building become the challenges in implementing seismic design and investigating the capability of Malaysian buildings toward seismic load. This paper aims to evaluate damage analysis and the location of potential weakness in the reinforced concrete buildings under different seismic intensities (0.05g, 0.10g, 0.15g and 0.20g) and reactions through SAP2000. Finite Element Model of four storey reinforced concrete buildings in Ranau, Sabah was modelled in analysing the earthquake damage to the building through pushover analysis and time history analysis with different PGA. The results show that the initial design of the concrete column is insufficient in providing the reinforcement and retrofitting is recommended for the safety of structure. All the hinges form within life safety (LS) level and the seismic performance of the modelling building is considered safe as the plastic connector is below immediate occupancy (IO) level.

ABSTRAK

ANALISIS UNSUR TERHINGGA DENGAN RESPON SEISMI PADA PEMODELAN MUDAH BANGUNAN RC

Kebanyakan bangunan konkrit bertetulang di Malaysia direka bentuk dan dibina tanpa reka bentuk seismik kerana Malaysia terletak jauh dari sempadan plat aktif sehingga gempa bumi Ranau pada tahun 2015. Kerajaan Malaysia telah mengeluarkan Lampiran Kebangsaan Malaysia kepada Eurocode 8 pada tahun 2017 dan bangunan tersebut harus direka bentuk dan dibina mengikut spesifikasi yang dinyatakan dalam lampiran ini. Kekurangan perhatian dan reka bentuk seismik dalam bangunan konkrit bertetulang serta maklumat terhad dan prestasi reka bentuk bangunan konkrit tetulang menjadi cabaran dalam melaksanakan reka bentuk seismik dan menyiasat keupayaan bangunan Malaysia terhadap beban seismik. Kertas kerja ini bertujuan untuk menilai analisis kerosakan dan lokasi potensi kelemahan dalam bangunan konkrit bertetulang di bawah intensiti (0.05g, 0.10g, 0.15g dan 0.20g) dan tindak balas seismik yang berbeza melalui SAP2000. Model Unsur Terhingga bagi bangunan konkrit bertetulang empat tingkat di Ranau, Sabah telah dimodelkan dalam menganalisis kerosakan gempa bumi pada bangunan itu melalui analisis pushover dan analisis sejarah masa dengan PGA yang berbeza. Keputusan menunjukkan bahawa reka bentuk awal tiang konkrit tidak mencukupi dalam menyediakan tetulang dan pengubahsuaian disyorkan untuk keselamatan struktur. Semua engsel terbentuk dalam tahap keselamatan hayat (LS) dan prestasi seismik bangunan pemodelan dianggap selamat kerana penyambung plastik berada di bawah paras penghunian segera (IO).

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°C	-	Celsius
°F	-	Fahrenheit
E	-	Modulus of Elasticity
E_{cm}	-	The Secant Modulus of Elasticity
f_t	-	Tensile strength
$f_{y,max}$	-	Maximum actual yield strength
f_{yk}	-	Yield Strength
ε_{uk} or f_t / f_{yk}	-	Ductility

LIST OF ABBREVIATIONS

CST	-	Constant Strain Triangle
EC8	-	Eurocode 8
EQx	-	Seismic Load in x-direction
ERSG	-	Electrical Resistance Strain Gauge
FE	-	Finite Element
FEA	-	Finite Element Analysis
FEM	-	Finite Element Method
Gk	-	Dead load
LST	-	Linear Strain Triangle
LVDT	-	Linearly Variable Displacement Transducers
NA	-	National Annex
Qk	-	Live Load
QST	-	Quadratic Strain Triangle
RC	-	Reinforced Concrete
PGA	-	Peak Ground Acceleration

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CHAPTER 1

INTRODUCTION

1.1 Background

Earthquake as the most destructive natural hazard can cause catastrophic damage and large amount of loss of life and property every year around the globe. Despite its distance from the active plate boundaries along the Sunda Trench and Philippine Trench, Malaysia is also affected by regional and local earthquakes. As indicated in Figure 1.1, several major earthquakes from west Sumatra, Indonesia, have been felt in Peninsular Malaysia. From 2010 through 2020, the USGS seismic data reports about 3000 earthquakes in and around Malaysia with a magnitude greater than 5.0 Mw. Although the regional earthquakes will only cause minor damage, they are still a source of concern, particularly for high-rise buildings.

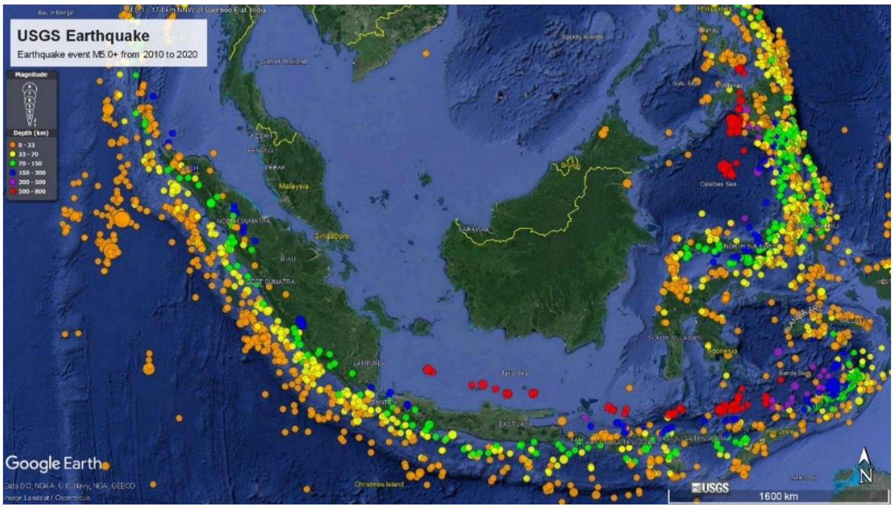

Figure 1.1 : Distribution of Regional and Local Earthquake (Magnitude ≥5.0Mw) Surrounding Malaysia

Source : USGS Earthquake Database (2021)

Seismic activity that culminates in an earthquake can produce two different types of seismic waves: body and surface waves. Primary waves, also known as P-waves, and secondary waves, also known as S-waves, travel through the interior layers of the earth, whilst surface waves, also known as Love (L) and Rayleigh (R) waves, travel through the outer layers of the crust (Yön et al., 2017). Body waves generate surface waves, which travel parallel to the ground surface and undercut numerous layer boundaries, resulting in considerable displacement. The types of seismic waves are shown in Figure 1.2.

Peninsular Malaysia had experienced tremors with two major significant earthquakes occurred in Sumatra in 2004 and 2005. A tsunami was triggered by the M9.1 earthquake in Aceh in 2004 and resulting with drastic and deadly effect including the beaches in Penang, Langkawi Island and Kuala Muda in Kedah. The Institution of Engineers, Malaysia (IEM) prepared and accepted a position paper on earthquake issues for mitigation policy and guidelines on earthquake safety aspects for the Malaysian government to review and accept (IEM, 2008). Several short- and long-term measures are recommended to address the potential risks caused by earthquake activity. On June 2015, Ranau earthquake occurred in Ranau town, Sabah and caused fatalities and structural damages to the reinforced concrete (RC) buildings. Cracks have been recorded in residential, commercial, resort, and hotel buildings, as well as religious places of worship and emergency structures. Brick wall shear failure cracks, cracks in columns and beams, roof collapse, failure of supporting columns or tilt, concrete spalling, and smashed windows were among the most common damages documented following the Ranau earthquake (Mansor et al., 2017). The Malaysian National Annex (NA) of Eurocode 8 was published in late 2017 and became Malaysia's first national code of practise for seismic design of buildings (EC8).

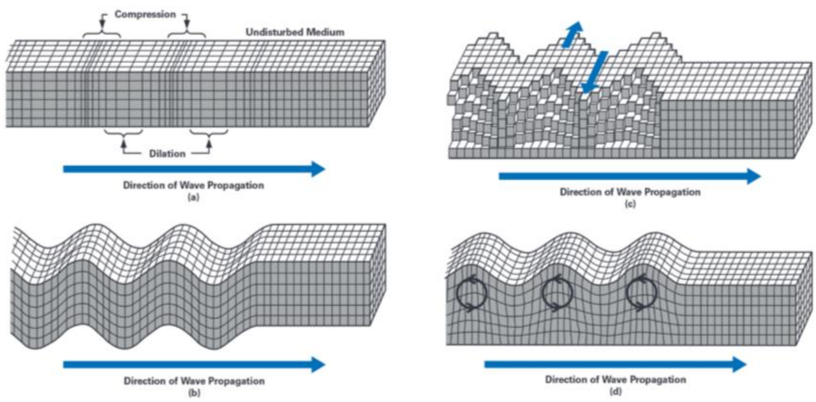

Figure 1.2 : Types of Seismic Waves (a) P-Waves (b) S-Waves (c) L Waves (d) R Waves

Source : Olivadoti (2001)

An existing RC school in Castelluccio Valmaggiore was the subject of research by Ruggieri et al (Province of Foggia, Puglia, Southern Italy). In their investigation, the outcomes of linear analysis were assessed by comparison with those of a model in which the flexibility of a slab was reproduced using a more sophisticated technique known as the "strut model" (Ruggieri et al., 2018). To create a realistic FE model that could simulate the actual structural behaviour of an RC-MRF building using ETABS, Abdel Raheem et al. conducted a thorough examination of various modelling methodologies ranging from basic to more sophisticated. The results of this study help quantify the accuracy of a simplified numerical modelling of structural components subjected to seismic excitation to predict structural response as well as the effects of FE modelling refinement level on seismic design requirements. They demonstrate that how the slab and beam floor system is modelled has a significant impact on the overall response of the building (Abdel Raheem et al., 2018). Zhang et al. used ABAQUS 3D finite element analysis to compare the seismic centrifuge tests and used a hyperbolic-hysteretic soil constitutive model to simulate the soft kaolin clay to explore the behaviour of pile groups in this material. Seismic centrifuge testing was supplemented by a 3D finite element modelling approach employing a hyperbolic-hysteretic soil constitutive model, resulting in high comparability between centrifuge test and numerical calculated findings (Zhang et al., 2017). Using ETABS nonlinear time history dynamic analysis and a suitable earthquake record for Malaysia (PGA = 0.15g), Abbood et al. conducted a study on the impact of structural linkages on seismic responses for a connected building system. The findings suggested that the link was more effective in strengthening the system and decreasing responses when installed at the last two top levels, where it may dramatically influence the structural responses (Abbood et al., 2018).

1.2 Problem Statement

The lack of seismic design in RC-building in Malaysia is due to Malaysia is not located in earthquake zone and seldom suffer to direct and indirect earthquake shockwave. Seismic occurrences of moderate size of magnitude 5 to 6 occurred in Malaysia in the 1990s in sparsely populated areas of Sabah, such as M5.3 in 1996 near Ranau, M6.2 and M5.7 in 1976 and 1994 near Lahad Datu. These early events did not draw significant attention due to the sparse population in the affected areas and a smaller number of engineered building structure. In addition, the information and design for the seismic performance of RC-building is limited as the magnitude of earthquake may beyond the expected performance. Working group 1 (WG1) for drafting Malaysia NA to EC8 acknowledged the challenges of dealing with seismic risks in a low-to-moderate seismicity region due to lack of seismic hazard assessment in Malaysia. The capability of Malaysian buildings due to earthquake loading is under investigation to predict the seismic performance of the buildings under mega magnitude.

As a result, earthquakes must be taken into account throughout the design phase, and their behaviour must be examined to determine their consequences in order to guarantee structural integrity and safety. The current building that is situated in an area with a high seismic risk should go through a seismic analysis to identify any potential structural weaknesses and take appropriate action to address them.

1.3 Objective of Study

The main objectives of this study are:

1) To evaluate damage analysis of RC-buildings under different seismic intensities (0.05g, 0.10g, 0.15g, and 0.20g)
2) To determine the location of potential weakness in the RC-buildings due to seismic reaction through SAP2000

1.4 Scopes of Study

The study includes finite element analysis with seismic response on reinforced concrete buildings' simplified modelling by using SAP2000. The building will be modelled based on the *Malaysia National Annex to Eurocode 8* (2017). SMK Ranau is selected for modelling to perform the analysis for the earthquake damage to the buildings through pushover analysis and time history analysis under four PGA (0.05g, 0.10g, 0.15g and 0.20g).