EFFECT OF SOIL TYPE AND LEVEL OF SEISMICITY ON SEISMIC DESIGN OF REINFORCED CONCRETE SCHOOL BUILDING

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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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EFFECT OF SOIL TYPE AND LEVEL OF SEISMICITY ON SEISMIC DESIGN OF REINFORCED CONCRETE SCHOOL BUILDING

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ABSTRAK

Pertimbangan seismik tidak diambil kira untuk reka bentuk dan pembinaan di Malaysia. Tetapi selepas insiden berlaku pada 5 Jun 2015, gempa bumi 6.0 magnitud telah berlaku di Ranau, Sabah, yang berlangsung selama 30 saat. Selepas kejadian itu, pihak berkuasa tempatan mula mempertimbangkan semula untuk melaksanakan reka bentuk seismik terutama bangunan sekolah. Di Malaysia, bangunan sekolah konkrit bertetulang (RC) akan menjadi tempat tumpuan perlindungan utama masyarakat apabila berlakunya bencana alam untuk kekal sehingga bencana berkuran. Oleh itu, ianya adalah sangat penting untuk memastikan reka bentuk bangunan sekolah RC pada masa akan datang dapat menampung beban dari gempa bumi, yang bermaksud bahawa bangunan sekolah RC tetap berfungsi walaupun setelah berlakunya gempa bumi. Objektif kajian ini adalah untuk menentukan kesan jenis tanah dan tahap seismicity pada jumlah pengukuhan keluli. Penggunaan model untuk kajian ini adalah empat tingkat bangunan sekolah RC yang reka bentuk berdasarkan Eurocode 8. Terdapat sejumlah sepuluh model dengan berbeza jenis tanah dan tahap seismicity. Kemudian, analisis dilakukan kepada semua model dengan menggunakan Designer Struktur Tekla untuk memperoleh kedu-dua objektif tersebut. Maklumat berdasarkan jumlah keluli yang diperlukan boleh didapati dari analisis. Ia diwakili dengan menggunakan graf Spektrum Respon Reka Bentuk dan jadual-jadual yang mengandungi maklumat seperti momen lentur. Berdasarkan hasilnya, peratusan yang berbeza daripada berat pengukuhan keluli yang diperlukan untuk reka bentuk bukan seismik yang menimbulkan Jenis Tanah meningkat 38%, 92% dan 131% untuk Tanah Jenis A, Tanah Jenis C dan Tanah Jenis E, masing-masing. Oleh itu, dapat disimpulkan bahawa model yang dibina pada Tanah Jenis E memerlukan jumlah pengukuhan keluli yang tinggi dalam setiap 1m³ konkrit. Walaupun bagi magnitud PGA yang berlainan, keputusan menunjukkan bahawa perbezaan peratusan pengukuhan keluli yang diperlukan berbanding dengan reka bentuk bukan seismik untuk rasuk dan lajur seluruh bangunan telah meningkat daripada 13%, 66% dan 131% untuk PGA bersamaan dengan 0.04g, 0.07g dan 0.10g masing-masing. Oleh itu, dapat disimpulkan bahawa model yang dibina di atas PGA 0.10g diperlukan jumlah tetulang keluli yang tinggi dalam setiap 1m³ konkrit. Oleh itu, jenis tanah dan tahap seismicity perlu diambil kira untuk reka bentuk kerana pembolehubah ini mempengaruhi jumlah keluli yang digunakan.
Seismic considerations are not taken into account for design and construction in Malaysia. but after the incident happened on 5th June 2015, earthquake of 6.0 magnitudes had struck in Ranau, Sabah, which lasted for 30 seconds. After the incident happened, the local authority starts to reconsider to implement the seismic design especially school building. In Malaysia, reinforced concrete (RC) school buildings will be the main focus of the community's protection when there is a catastrophic disaster to remain until the disaster is reduced. Therefore, it is very important to ensure that RC school building design in the future will be able to accommodate the burden of the earthquake, which means that the RC school building will work even after the earthquake. The objective of the study is to determine the effect of different Soil Type and effect of Level of Seismicity on the amount of steel reinforcement. The model use for the study is four-storey RC school building which is design based on Eurocode 8. There are total of ten models with different Soil Type and Level of Seismicity. Then, the analysis is conducted to all of the models by using Tekla Structural Designer to obtain both of the objectives. The information based on the amount of steel required is provided from the analysis. It is represented by using Design Response Spectrum graph and tabulated tables that contained information like bending moment. Based on the results, the percentage different of weight of steel reinforcement required for non-seismic design which considering Soil Type is increased 38%, 92% and 131% for Soil Type A, Soil Type C and Soil Type E, respectively. Thus, it can be concluded that model built on Soil Type E required high amount of steel reinforcement per 1m³ concrete. While for different magnitude of PGA, 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 13%, 66% and 131% for PGA equals to 0.04g, 0.07g, and 0.10g respectively. Thus, it can be concluded that model built on PGA of 0.10g required high amount of steel reinforcement per 1m³ concrete Therefore, Soil Type and Level of Seismicity should be taken into consideration for design since these variables influence the amount of steel used.
TABLE OF CONTENT

DECLARATION

TITLE PAGE

ACKNOWLEDGEMENTS   i

ABSTRAK    ii

ABSTRACT     iii

TABLE OF CONTENT     iv

LIST OF TABLES    viii

LIST OF FIGURES    ix

LIST OF SYMBOLS   xi

LIST OF ABBREVIATIONS   xii

CHAPTER 1 INTRODUCTION   1

1.1 Background   1

1.2 Problem Statement   4

1.3 Main Objectives   5

1.4 Scope of Work   6

CHAPTER 2 LITERATURE REVIEW    7

2.1 Introduction 7

2.2 Earthquakes effect on school building 7

2.3 Ductility 10

2.4 Ground Motion 10

2.5 Reviews from past studies 11
2.6 Summary

CHAPTER 3 METHODOLOGY

3.1 Introduction
3.2 Flowchart of Research Methodology
3.3 Phase 1: Model Generation
3.4 Phase 2: Seismic Design & Analysis
   3.4.1 Computation of Load
      3.4.1.1 Dead Load for Beam
      3.4.1.2 Dead Load for Slab
      3.4.1.3 Imposed Load for Slab
      3.4.1.4 Imposed Load for Roof
   3.4.2 Type of soil
   3.4.3 Ductility Class
   3.4.4 Seismic Base Shear Force, \( F_b \)
   3.4.5 Lateral Load
   3.4.6 Design Response Spectrum
   3.4.7 Design Ground Acceleration
   3.4.8 Beam Design
   3.4.9 Column Design
3.5 Phase 3: Taking Off

CHAPTER 4 RESULTS AND DISCUSSION

4.1 Introduction
4.2 Design Response Spectrum Graph and Base Shear Force, \( F_b \)
4.3 Influence of Soil Type and Level of Seismicity on concrete volume 37
4.4 Influence of Soil Type on Amount of Steel Reinforcement 39
  4.4.1 Influence of Soil Type on Amount of Steel Reinforcement for Beam 40
  4.4.2 Influence of Soil Type on Amount of Steel Reinforcement for Column 41
  4.4.3 Influence of Soil Type on Amount of Steel Reinforcement for Beam and Column (Overall) 42
4.5 Influence of Level of Seismicity on Amount of Steel Reinforcement 44
  4.5.1 Influence of Level of Seismicity on Amount of Steel Reinforcement for Beam 44
  4.5.2 Influence of Level of Seismicity on Amount of Steel Reinforcement for Column 45
  4.5.3 Influence of Level of Seismicity on Amount of Steel Reinforcement for Beam and Column (Overall) 47
4.6 Total weight of Steel Reinforcement per 1m$^3$ concrete normalised to non-seismic model 48
  4.6.1 Total weight of Steel Reinforcement per 1m$^3$ concrete normalised to non-seismic model for Soil Type A 48
  4.6.2 Total weight of Steel Reinforcement per 1m$^3$ concrete normalised to non-seismic model for Soil Type C 49
  4.6.3 Total weight of Steel Reinforcement per 1m$^3$ concrete normalised to non-seismic model for Soil Type E 50
4.7 Estimation of Total Cost of Material 51
  4.7.1 Estimation of Total Cost of Material for Soil Type A 51
  4.7.2 Estimation of Total Cost of Material for Soil Type C 53
  4.7.3 Estimation of Total Cost of Material for Soil Type E 54

CHAPTER 5 CONCLUSION 57
5.1 Conclusion 57
5.2 Future Recommendation 58
REFERENCES 59
APPENDIX A PENINSULAR, SABAH AND SARAWAK SEISMIC HAZARD MAP 61
APPENDIX B DESIGN RESPONSE SPECTRUM 63
APPENDIX C POSITION OF SELECTED BEAM AND COLUMN 64
APPENDIX D INFLUENCE OF SOIL TYPE 65
APPENDIX E INFLUENCE OF LEVEL OF SEISMICITY 68
# LIST OF TABLES

| Table 3.1 | Cross section of Structural Member | 17 |
| Table 3.2 | Weight of materials (Mc Kenzie, 2004) | 19 |
| Table 3.3 | Total Dead Load on Slabs | 20 |
| Table 3.4 | Categories of Use (Eurocode 1, 2002) | 21 |
| Table 3.5 | Imposed Loads on Floors, Balconies and Stairs in Buildings (Eurocode 1, 2002) | 22 |
| Table 3.6 | Categorization of Roofs (Eurocode 1, 2002) | 23 |
| Table 3.7 | Imposed Load on Roofs for Category H (Eurocode 1, 2002) | 23 |
| Table 3.8 | Design concepts, structural ductility classes and upper limit of reference values of the behavior factors (Eurocode 8, 2004) | 24 |
| Table 3.9 | Values of the parameters describing the recommended Type 1 elastic response spectra | 27 |
| Table 3.10 | Importance classes and importance factor for buildings (Eurocode 8, 2004) | 28 |
| Table 3.11 | All models of the RC school building | 30 |
| Table 4.1 | Design Response Spectrum, $S_d(T_1)$ and Base Shear Force, $F_b$ for every model | 37 |
| Table 4.2 | Bending Moment, $M_{Ed}$ and area of steel, $A_{s,req}$ for reinforcement for Beam C of $a_{gR} = 0.10g$ influenced by Soil Type | 40 |
| Table 4.3 | Bending Moment, $M_{Ed}$ and area of steel, $A_{s,req}$ for reinforcement for Column C of $a_{gR} = 0.10g$ influenced by Soil Type | 42 |
| Table 4.4 | Bending Moment, $M_{Ed}$ and area of steel, $A_{s,req}$ for reinforcement for Beam C of $a_{gR} = 0.10g$ influenced by Level of Seismicity | 45 |
| Table 4.5 | Bending Moment, $M_{Ed}$ and area of steel, $A_{s,req}$ for reinforcement for Column C of $a_{gR} = 0.10g$ influenced by Level of Seismicity | 46 |
# LIST OF FIGURES

| Figure 1.1 | A diagram of earth's layers | 1 |
| Figure 1.2 | Location of Malaysia on the Sunda Plate and the seismic sources around it (modified from Loi et al., 2016). The subduction lines, fault lines | 3 |
| Figure 1.3 | Modified Mercalli Scale mapping for East Malaysia (MMD, 2009) | 5 |
| Figure 2.1 | Level of Shaking Movement during Earthquake | 8 |
| Figure 2.2 | Tectonic plates and fault zones of the Caribbean. Port-au-Prince is the red star | 9 |
| Figure 2.3 | Types of fault | 11 |
| Figure 3.1 | Flowchart of seismic design and analysis | 17 |
| Figure 3.2 | Plan View of RC School Building | 18 |
| Figure 3.3 | Side view of RC school building frame generated in Tekla structural software | 18 |
| Figure 3.4 | Seismic hazard map on Peninsular Malaysia (MOSTI, 2009) | 29 |
| Figure 3.5 | Seismic hazard map on Eastern Malaysia (Adnan et al., 2008) | 29 |
| Figure 3.6 | 3D model of the building generated from Tekla structural software | 30 |
| Figure 3.7 | Flow chart of beam design according to Eurocode 8 (Adiyanto, 2016) | 31 |
| Figure 3.8 | Flow chart of column design to Eurocode 8 (Adiyanto, 2016) | 32 |
| Figure 4.1 | Design response spectrum for Soil type E with different magnitude of PGA | 36 |
| Figure 4.2 | Concrete volume for Beam | 38 |
| Figure 4.3 | Concrete volume for Column | 38 |
| Figure 4.4 | Concrete volume for Beam and Column (Overall) | 39 |
| Figure 4.5 | Total amount of steel required for 1m³ of concrete of beam influenced by Soil Type | 40 |
| Figure 4.6 | Total amount of steel reinforcement for 1m³ of concrete of column influenced by Soil Type | 41 |
| Figure 4.7 | Total amount of steel reinforcement for 1m³ of concrete of Beam and Column (Overall) influenced by Soil Type | 43 |
| Figure 4.8 | Total amount of steel required for 1m³ of concrete of beam influenced by Level of Seismicity | 44 |
| Figure 4.9 | Total amount of steel reinforcement for 1m³ of concrete of column influenced by Level of Seismicity | 46 |
| Figure 4.10 | Total amount of steel reinforcement for 1m³ of concrete of Beam and Column (Overall) influenced by Level of Seismicity | 47 |
| Figure 4.11 | Total weight of Steel Reinforcement per 1m³ concrete normalised to non-seismic model for Soil Type A | 49 |
Figure 4.12  Total weight of Steel Reinforcement per 1m³ concrete normalised to non-seismic model for Soil Type C  50
Figure 4.13  Total weight of Steel Reinforcement per 1m³ concrete normalised to non-seismic model for Soil Type E  51
Figure 4.14  Total Cost of concrete volume for whole building for Soil Type A  52
Figure 4.15  Total cost for steel for whole building for Soil Type A  52
Figure 4.16  Total Cost of concrete volume for whole building for Soil Type C  53
Figure 4.17  Total cost for steel for whole building for Soil Type C  54
Figure 4.18  Total Cost of concrete volume for whole building for Soil Type E  55
Figure 4.19  Total cost for steel for whole building for Soil Type E  55
### LIST OF SYMBOLS

- $a_g$ Design ground acceleration
- $a_{gr}$ Reference peak ground acceleration
- $A_{s,prov}$ Total area of steel provided
- $A_{s,req}$ Total area of steel required
- $F_b$ Base shear force
- $f_{cd}$ Design value of concrete compressive strength
- $f_{cu}$ Characteristic cylinder strength of concrete
- $F_i$ Lateral load on storey
- $f_y$ Yield strength of reinforcement
- $g$ Acceleration due to gravity, m/s$^2$
- $G_k$ Dead load
- $H$ Storey height
- $M$ Bending moment
- $m$ Mass of structure
- $M_{Rb}$ Design moment resistance of beam
- $M_{Re}$ Design moment resistance of column
- $M_w$ Magnitude of earthquake intensity
- $N$ Number of storey
- $q$ Behaviour factor
- $Q_k$ Live load
- $S$ Soil factor
- $S_d(T_1)$ Ordinate of the design spectrum at period
- $T_i$ Fundamental period of vibration
- $T_a$ Lower limit of the period of the constant spectral acceleration
- $T_c$ Lower limit of the period of the constant spectral acceleration
- $T_o$ Beginning of the constant displacement response range of the spectrum
- $V$ Beginning of the constant displacement response range of the spectrum
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS</td>
<td>British Standard</td>
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<tr>
<td>DCH</td>
<td>Ductility Class High</td>
</tr>
<tr>
<td>DCL</td>
<td>Ductility Class Low</td>
</tr>
<tr>
<td>DCM</td>
<td>Ductility Class Medium</td>
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<tr>
<td>IDR</td>
<td>Interstorey Drift Ratio</td>
</tr>
<tr>
<td>JKR</td>
<td>Jabatan Kerja Raya</td>
</tr>
<tr>
<td>PGA</td>
<td>Peak Ground Acceleration</td>
</tr>
<tr>
<td>RC</td>
<td>Reinforced Concrete</td>
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</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1 Background

An earthquake is a phenomenon that is difficult to expect when it will happen. This phenomena happens because of the powerful shaking from the earth's surface. This shaking was caused by movement in the outermost layers of the earth. Figure 1.1 shows the earth’s layer which is made of four basic layers which are super-heated core and its thin outer layer the crust, nearly solid bulk mantle, the liquid outer core and solid inner core. Earthquakes are caused by shifts in the outermost layers of earth a region called the lithosphere. An earthquake results from the sudden release of energy stored in the lithosphere by the continuous motion of plates. Litosphere is an uncontinuos piece that wraps around the whole earth. It was actually made up of giant puzzle pieces called tectonic plates.

![Figure 1.1 A diagram of earth's layers](image)
In Malaysia, the major natural processes that affect its landscapes are flooding, landslides and earthquakes. However, the study on plate tectonics and earthquakes in Malaysia is minimal as the effects are still within the safe zone when compared to the other processes, and countries such as Nepal and Indonesia (Gill et al., 2015). Tectonic plates are constantly shifting as they drift around on the viscous, or slowly flowing, mantle layer below. This non-stop shifting or movements causes stress on earth’s crust. When at one point the stresses get too large, it leads to cracks called faults, releasing elastic strain energy stored in the surrounding crust, which then radiates from the fault rupture in the form of seismic waves (Elghazouli, 2009).

Peninsular Malaysia covers an area about 0.3 million km2 at the southern tip of mainland Asia and is connected by land to Thailand to the north while separated from Singapore by Johor Strait to the south and from Sumatra of Indonesia by Malacca Strait to the west. Borneo, which contains the states of Sabah and Sarawak, is located east of Peninsular Malaysia and is separated by South China Sea.

The location of Malaysia is one of the countries that are safe from earthquake as it is located at the equator of the globe which are far away from the active seismic fault zone. Moreover, Malaysia part of the complex Eurasian and Indo-Australian plate tectonics which is located on southern edge of the Eurasian Plate which is known as Sunda Plate as shown in Figure 1.2. As the earthquake happened in Southern Philippine and Sumatera, it triggered several active faults that possible for Malaysia to experienced earthquake. However, as the previous recorded earthquake that occurred in the neighbouring countries such as Thailand and Indonesia, Malaysia is occasionally subjected to tremors. Seismic design for high-rise buildings, bridges and others structure has not been practiced in Malaysia, although Malaysia experiences minor to moderate earthquakes across the country (Ramli et al., 2017). Seismicity within the Sunda Plate has been historically low with progressive collision with the Eurasian Plate relatively slow.
During the earthquake, when the seismic waves reach the earth’s surfaces it will shake all the structures on the ground to be unstable due to the sudden force resulted from the movement and ground motion caused by earthquake and can lead to destruction. The vibrations caused by the movement of the plates bring bad impacts to the earth surface. Based on our daily life, we can see clearly people may lost their sources of income while wild life lost their habitat. Meanwhile, man-made structures like buildings, bridges, roads and slopes will be affected by this natural disaster. This situation also may contributes to lots of injury and fatality, lost of property, fire, flooding, and the most affliction is it can induce tsunami.

In a conclusion, every structural building is able to withstand seismic action and safe to use. This is a safe step to avoid injuries and fatality caused by earthquake strike. Therefore, the future design of buildings as well as the inspection and assessment of existing buildings shall be designed according by referring to seismic provision code such as Eurocode 8 (2004).
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