COST COMPARISON OF SEISMIC DESIGN FOR REINFORCED CONCRETE BUILDING UNDER RANAU EARTHQUAKE

NOR AMELIA BINTI ADHA

SCHOOL OF CIVIL ENGINEERING
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By

NOR AMELIA BINTI ADHA

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Name of Student: NOR AMELIA BINTI ADHA

I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

Signature: Approved by:

_____ _____

(Signature of Supervisor)

Date : Name of Supervisor :

Date :

Approved by:

_____

(Signature of Examiner)

Name of Examiner :

Date :

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ABSTRAK

Sempadan plat aktif boleh menyebabkan gempa bumi pada lokasi yang berhampirannya termasuk Malaysia. Pada 5 Jun 2015, gempa bumi telah berlaku di Ranau, Sabah dengan magnitud 6.0 skala Richter. Kerosakan serius pada bangunan tertentu telah berlaku akibat daripada kesan gempa bumi ini. Oleh itu, jurutera struktur memerlukan penyelesaian untuk mengatasi masalah ini daripada berlaku lagi. Anggaran kos bagi bangunan reka bentuk seismik adalah penting bagi jurutera untuk menganalisis dan mendapat pemahaman yang lebih baik tentangnya. Justeru itu, anggaran kos kepada sektor pembinaan kos sebagai persediaan awal untuk pelancaran *Malaysia Annex* untuk Piawai Malaysia dalam masa terdekat. Kajian ini memberi tumpuan kepada perbandingan kos antara reka bentuk seismik dan bukan seismik untuk tiga, enam dan sembilan tingkat dengan bangunan seragam dan tidak seragam. Analisis telah dijalankan dengan menggunakan perisian SAP 2000 dan direka bentuk berdasarkan Eurocode 2 untuk rasuk dan tiang. Keputusan menunjukkan bahawa bangunan reka bentuk seismik mempunyai kos yang paling tinggi dalam tan tetulang dan isipadu konkrit berbanding reka bentuk bukan seismik. Jumlah kos bangunan tiga tingkat yang mengalami beban seismik untuk bangunan seragam adalah 7.9 % lebih tinggi berbanding dengan reka bentuk bangunan bukan seismik. Jumlah kos bangunan tiga tingkat yang mengalami beban seismik untuk bangunan tidak seragam adalah 21.9% lebih tinggi berbanding dengan reka bentuk bangunan bukan seismik. Seterusnya, jumlah kos bangunan enam tingkat di yang mengalami beban seismik untuk bangunan seragam adalah 43.2 % lebih tinggi berbanding dengan reka bentuk bangunan bukan seismik. Jumlah kos bangunan enam tingkat di yang mengalami beban seismik untuk bangunan tidak seragam adalah 46.9 % lebih tinggi berbanding dengan reka bentuk bangunan bukan seismik. Selain itu, jumlah kos bangunan sembilan tingkat

yang mengalami beban seismik untuk bangunan seragam adalah 13.1 % lebih tinggi berbanding dengan reka bentuk bangunan bukan seismik. Jumlah kos bangunan sembilan tingkat yang mengalami beban seismik untuk bangunan tidak seragam adalah 43.2 % lebih tinggi berbanding dengan reka bentuk bangunan bukan seismik.

ABSTRACT

Active plate boundaries can cause an earthquake to its nearest location including Malaysia. On 5th June 2015, an earthquake has occurred at Ranau, Sabah with magnitude of 6.0 Richter scale. Serious damages on certain building had occurred by the impact of this earthquake. Thus, structural engineers need solution to overcome this problem from happening again. The cost estimate for superstructure under seismic loading is important for engineers to analyze and have a better understanding on costing. Therefore, the cost estimation is important for Malaysia as preliminary information for construction player in preparation of the launch of Malaysia Annex to Standard Malaysia. This study focuses on comparison of cost between seismic and non-seismic design for three, six and nine storey with regular and irregular buildings. The analyses were carried out by using SAP 2000 software and calculated the beam and column design based on Eurocode 2. Results show that seismic design building has the higher cost in steel tonnage and concrete volume compared to the non-seismic design. The total cost of three storey under seismic design for regular building is 7.9 % higher compared to the non-seismic design building. The total cost of three storey under seismic design for irregular building is 21.9 % higher compared to the non-seismic design building. Next, the total cost of six storey under seismic design for regular building is 43.2 % higher compared to the non-seismic design building. The total cost of six storey under seismic design for irregular building is 46.9 % higher compared to the non-seismic design building. Besides that, the total cost of nine storey under seismic design for regular building is 13.1 % higher compared to the non-seismic design building. The total cost of nine storey under seismic design for irregular building is 43.2 % higher compared to the non-seismic design building.

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LIST OF ABBREVIATIONS

fck	Concrete Compression Strength
fyk	Stregth of Steel
Gk	Dead Load
Qk	Live Load
q	Behaviour Factor
Fb	Base Shear Force
m	Masses
Fi	Lateral Forces
T_1	Fundamental Period of Vibration

CHAPTER 1

INTRODUCTION

1.1 Background

Location of Malaysia is close to two seismically active plate boundaries which is the inter-plate boundary between the Indo-Australian and Eurasian Plate on west and the inter-plate boundary between the Eurasian and Philippines sea plates on east. Major earthquake events occur from this plate boundaries is still felt even though Malaysia is considered safe from earthquake. Peninsular and East Malaysia has experienced local earthquake such as at Bukit Tinggi (Pahang), Miri (Sarawak) and Ranau (Sabah). On 5th June 2015, earthquake measuring magnitude of 6.0 richter scale struck Ranau, Sabah and caused serious damages on structures. Due to Ranau earthquake, structural engineer are alarmed with the possible earthquake threat in Malaysia especially in Ranau, Sabah.

The cost estimation is important for Malaysia as preliminary information for construction player in preparing for the launch of Malaysia Annex (Lam et al 2016). The loading characteristics such as gravity and lateral loads also influence the structural cost as most buildings were designed without considering lateral load especially seismic. Thus, the structural cost of the superstructure would influence based on the difference type of loading which is seismic loading and non-seismic loading. Figure 1.1 and Figure 1.2 show the damages building occurred at Ranau, Sabah.

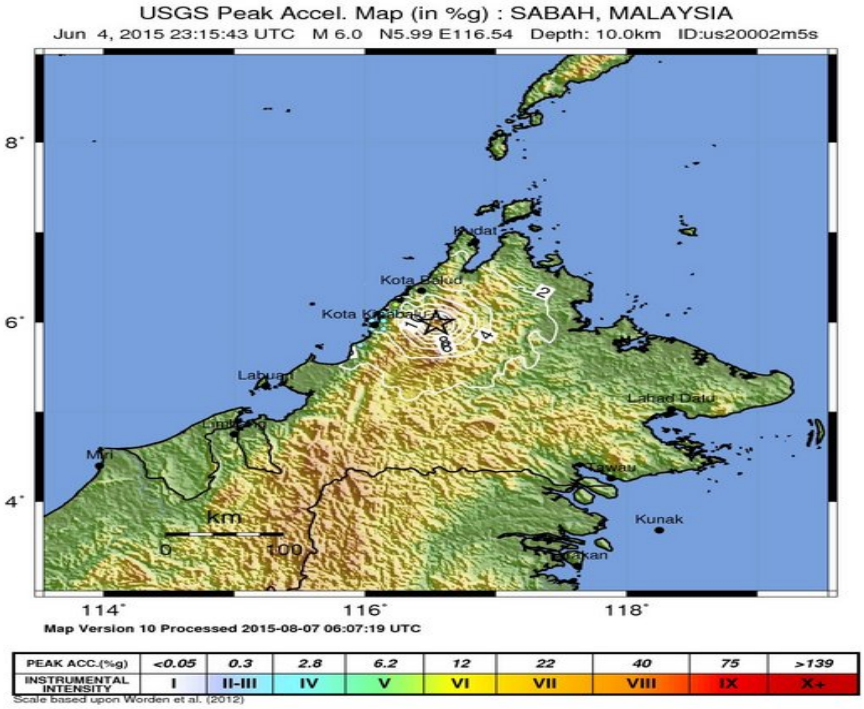

Figure 1.1 : Ranau earthquake on 5th June, 2015

(U. S. Geological Survey, 2015)

Figure 1.2 : The crack at the bottom of column at Hospital Ranau

1.2 Problem Statement

In Malaysia, many buildings are constructed without considering seismic loading due to lack of awareness on recent earthquake threat. Nowadays, earthquake and its effects are concerned by the government and public on the seismic costing and its resistant especially on existing and newly buildings. Therefore, comprehensive earthquake resistance cost of building are needed for the cost management studies as to focus on the issue of cost implications on seismic resistance in buildings. Thus, cost comparison is important to ensure a better understanding on seismic resistance as preparation for the establishment of the Malaysia Annex in Eurocode 8. Therefore, this study is to carried out the costing by considering gravity and lateral (earthquake) loads to the structures.

1.3 Objectives

The objective of this project are :

1. The main objective for this study is to compare the structural cost of superstructure with and without earthquake loading in term of steel tonnage and concrete volume of the of reinforced concrete buildings.

1.4 Scope of work

The following are the scope of work for this study:

i. Frames designed with gravity and earthquake loading according to Eurocode 8 and 2.

ii. Model is designed by using SAP 2000 software according to the Eurocode 2 and Eurocode 8.

iii. Soil type (B) which is very dense sand according to the Eurocode 8.

iv. Costing of superstructure based on Standard Method of Measurement (SMM).

v. The original model followed Hatzigeorgiou and Liolios (2010) in term of building configuration and design prospect.

CHAPTER 2

LITERATURE REVIEW

2.1 Past Earthquake Events

An earthquake magnitude of 6.7 occurred in Bingol, Turkey and caused 5617 buildings collapsed, 3509 had moderate damages and 3618 had light damages were reported. About 878 casualties were reported from this earthquake. This incident happened due to usage of poor material quality and quantity, poor in curing of concrete and designing the building without considering earthquake loading in building. The estimation of direct economic loss in the building stocks is approximately 250 million US dollars according to Dogangun (2004).

The earthquake struck in Lorca, Spain with magnitude of 4.5 causes structure become weak under first tremor. Nine people were death and 324 were injured. The failure of building is due to unawareness of actual seismic hazard, lenient prescription of design codes and lack of fulfilment of regulations and poor construction practices. The estimated losses of insured building in Spain earthquake cost about 332.5 millions of Euros (Valcarcel et al., 2012).

On 17th January 1994, Northridge earthquake magnitude of 6.4 hit the Los Angeles metropolitan area. This earthquake produced highest peak ground acceleration which is 1.8 g. From this earthquake, the estimate of damage is more than $20 billion and 57 people were deaths. Figure 2.1 shows building collapsed as result of the Northridge earthquake.