Faculty of Engineering

SEISMIC PERFORMANCE OF SHEAR WALL WITH DIFFERENT THICKNESS AND WIDTH FOR LOW RISE BUILDING

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Grade: ____________

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Final Year Project Report	√
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MUHAMMAD ‘IZZAT BIN ISHAK

This project is submitted in partial fulfilment of

the requirement for the degree of Bachelor of Engineering with Honours

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“Dedicated to my beloved family…”

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ABSTRACT

Earthquake is a natural phenomenon that result from the sudden energy released in the Earth's crust. Nowadays, Malaysia is no longer free from seismic hazard as few tremors recorded in recent year. The impact of earthquake on building have to take seriously especially for low rise building as the vibration resonate closer to shorter building. Therefore, the main purpose of this research is to study seismic performance of shear wall with different thickness and width for low rise building. The model of shear wall is analysed by using nonlinear static pushover analysis (POA) and nonlinear dynamic time history analysis (NLTHA). Both analysis is observed based on the maximum displacement and peak ground acceleration (PGA) at top of shear wall. In conclusion, increased thickness of shear wall are able to minimise the displacement. Besides, increased the width of shear wall in POA had improve the performance against earthquake. Meanwhile, increased the width of shear wall in NLTHA resulted the PGA value decreased.

ABSTRAK

Gempa bumi adalah satu fenomena semulajadi yang terhasil daripada tenaga yang dilepaskan daripada perut bumi. Pada masa kini, Malaysia tidak lagi terlepas daripada bahaya seismik setelah beberapa bacaan gempa direkodkan pada tahun-tahun kebelakangan ini. Implikasi dripada gempa bumi ini perlu dipandang serius terutamanya pada bangunan yang rendah kerana gegaran lebih dekat pada bagunan yang rendah. Oleh itu, antara tujuan utama kajian ini dijalankan adalah untuk mengkaji prestasi seismik dinding ricih dengan ketebalan dan lebar yang berbeza untuk bagunan rendah. Analisis terhadap model dinding dibuat dengan menggunakan Kaedah Pengendalian Statik Pushover Nonlinear (POA) dan Kaedah Masa Dinamik Nonlinear (NLTHA). Kedua-dua analysis ini dilihat dripada sudut anjakan maksimum dan Peak Ground Acceleration (PGA) pada bahagian penjuru atas dinding ricih. Konklusinya, peningkatan pada ketebalan dinding rincih mampu untuk mengurangkan anjakan maksimum. Selain itu, peningatan lebar pada dinding rincih dalam POA meningkatkan prestatinya terhadap gempa bumi. Sementara itu, peningkatan lebar pada dinding rincih dalam NLTHA menghasilkan nilai PGA yang menurun.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

An earthquake is a natural phenomenon that causes ground shaking by sudden energy released in the Earth's crust. The impact from this phenomenon is destruction of infrastructure such as building, road and others. The tremors of earthquake is because of collusion happens between the plate. There are many interrelationship of earthquake as demonstrated in Figure 1.1. The movement of the plate causes faults which can be divided into 4 categories which is normal fault, reverse fault, strike slip fault and oblique slip fault. Normal faults occurred from the compressive stress between plates and result the hanging wall move down relative to the footwall and vice versa for reverse fault. Meanwhile, strike flip fault occurred when the forces act in parallel but opposite direction and oblique slip faults occurred when the plate dip slip and strike slip movement.

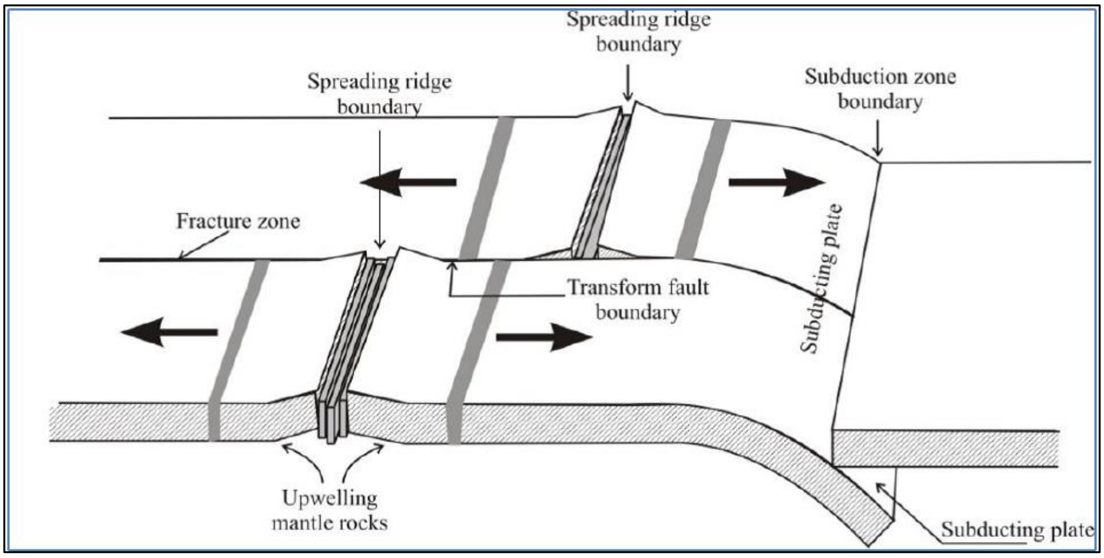

Figure 1.1: Interrelationship of plate boundaries

In general, Malaysia is classified as low – seismic activity country because of the strategic location on stable part of Sunda Plate. The seismic hazard within Sunda boundaries is in between low and medium seismic activity level and Peninsular Malaysia is classified as stable region (Manafizad, Pradhan, & Abdullahi, 2016). If the magnitude is compared between Peninsular and Sabah, the reading is slightly higher in Sabah as the location is closer to Indian-Australian Plate and Eurasian Plate as the plate is classified as active boundaries (Tongkul, 2017).

Malaysia is no longer free from seismic hazard. From the past record, there are a few places in Malaysia was effected through the disaster such as Penang, Kuala Lumpur, Bukit Tinggi and Sabah. On 2^{nd} November 2002, buildings in Penang showed some cracks because of tremors from Sumatera with magnitude 7.4 and 5.8 by the end of 2002 and early 2003. From the data analysis done, one to ten storey buildings in Penang and Kuala Lumpur were effected with maximum motion (Adnan, Hendriyawan, Marto, & Irsyam, 2005). Meanwhile in Sabah, an earthquake of magnitude 6 was recorded in 5 June 2015 as the largest reading in Malaysia. The town of Ranau and Kundasang was associated with a normal fault. Besides, earthquake also give some impact on building and some property are damage as shown in Figure 1.2 (a) and (b).

(a)

(b)

Figure 1.2 (a) and (b): Effect by Sabah Earthquake 2015

1.2 Research Problem

From the past history, Malaysia is no longer free from seismic hazard as Sabah recorded magnitude of 6 and the building shows some crack after the earthquake event. This is due to the construction of building in Malaysia are based on BS8110 standard which are not considering earthquake resistance. Since Malaysia had experience earthquake, some of building were starting to crack. This is because type of buildings in Malaysia are designed using BS8110 standard, which is not specify any seismic provision. The buildings were not able to withstand the rapid wave of earthquake and may collapse anytime with bigger magnitudes of earthquakes. Nowadays, the new modelling of structure are referring to Eurocode 8 (EC8) as the standard implement seismic design. Although Eurocode 8 had been introduce which considering earthquake resistance; however, the present standard's application is preliminary. Even though the design is only suggest to considering single earthquake in analyse, it helps to reduce hazard (Adiyanto & Majid, 2014). In the future, all building must be design with seismic provision as a safety purposes especially in Sabah. This is because the seismic activity in Sabah is active compared to peninsular of Malaysia.

There are many method were introduced to withstand earthquakes such as flexible foundation, damping, reinforce the building's structure and seismic invisibility cloak. Frame system is one of method used in other parts of the world against seismic event. In Malaysia, the frame system is also widely used in the present construction, In this system, the usage of steel as the main material can causes lateral deflection. Usually, the failure of this system at beam and column. From the case study on a frame building response to Northridge earthquake located in California, the critical damage appeared in the column of the fourth story which is at middle of the height of building (Browning, 2000). Besides, earthquake causing more damage to the low rise building compared to high rise building because of the vibration will resonate closer to the shorter building. From the previous studies, shear wall is one of the best method to be implement in the structure as the wall is good in transfer lateral and seismic forces. In many earthquake prone countries in the world such as Canada, Colombia, Chile, Romania and Turkey, concrete shear wall are constructed for medium to high rise building (Moroni M. O., 2011). This type of structure are able to increase strength and stiffness of the building against earthquake.

Moreover, many software are introduced method of design with considering seismic activity to the structure. SAP 2000 is the one of software that offers method for nonlinear static pushover analysis such as the capacity spectrum, the displacement coefficient and modal pushover analysis (Poluraju & Rao, 2011). The pushover analysis is to study post-yield behaviour of the building and required less data if compared with nonlinear response history analysis (Rana, Jin, & Zekioglu, 2004). In this study, nonlinear static pushover analysis and nonlinear dynamic time history analysis is done to study impact on the building against seismic event. The present engineers are not well versed with seismic design and have to expose themselves into the different seismic analysis using the Eurocode 8 seismic design as to minimise damage on the building when experience with earthquake event. Besides, research on seismic design must be conducted as the event may repeated in the future.

1.3 Research Significance

Nowadays, Malaysia have to start implement seismic design to minimise damage of the buildings. By exposing local engineers with Eurocode 8, they are able to understand further details of the building design to suite to the seismic requirements. . The seismic design is important as preparation of earthquake in the future may happens. The significance of study is to introduce shear wall component in the existing structure to evaluate the ability of shear wall to take up earthquake forces. This is because, most of the building in Malaysia are not consider seismic activity in the design In this research, the different thickness and width of shear wall with same seismic parameter is tested on the shear wall model to resists earthquake. The performance of the building are analysed through nonlinear static pushover analysis and nonlinear dynamic time history analysis by using SAP 2000 which is simple and quick.

1.4 Research Aim and Objectives

The main aim of this study is to analyse shear wall of low rise building design against earthquake in Malaysia based on non-linear seismic analysis

1. To model shear wall with different thickness and width.
2. To analyse the behaviour of shear wall with different thickness and width by using nonlinear static pushover analysis and nonlinear dynamic time history analysis.

1.5 Scope of Work

In this study, ten model of shear wall for low rise building is design by using SAP 2000. This software presence of seismic input for modelling and able to analyse the seismic performance of the structure. The same parameter is being used for all of the shear wall model. Each model is different in dimension of thickness and width. Five different thickness of shear wall which is 0.1mm, 0.15mm, 0.20mm, 0.25mm and 0.3mm is used in the research with two different width which 2.15m as minimum and 4.29 as maximum. The structure is analysed using nonlinear static pushover analysis and nonlinear dynamic time history analysis.

1.6 Summary

Chapter 1 of the thesis is introduction of research. It consist research background, research problem, research significant, objective and scope of work. This subtopic is provided as guide of the research.

Chapter 2 of the thesis is the literature review. This part including the review from the other research that had been done related to shear wall analysis. Besides, it also review alternative design included in shear wall to resist seismic event.

Chapter 3 of the thesis is the methodology. This chapter explained the parameter used and the process of the analysis is done. Besides, it also shows the step by step procedure of shear wall analysis in SAP 2000 software.

Chapter 4 of the thesis is the results and discussion. This chapter compiled the result of different analysis involved in the SAP 2000 software. The result is shown in form of graft and tables. Then, the result is compared and discussed in this chapter.

Chapter 5 of the thesis is conclusion and recommendations. This chapter summarize the overall of the thesis and recommendation for further improvement.

CHAPTER 2

LITERATURE REVIEW

2.1 General

Earthquake is one of disaster that happen around the world. The impact to the structure is high due to vibration of land and some building are start to crack and collapse. Turkey is the example of country that prone to have earthquake since 1992 Erzincan, 1999 Kocaeli, 1999 Duzce, 2003 Bingol and 2011 Van Earthquakes etc. The magnitude of 7.2 is recorded in 2011 Van Earthquake and give heavily damage to RC building. Two different RC building with existing shear wall is observed on seismic performance. Figure 2.1 shows building are start to crack and shows some failure on 2011 Van Earthquake. The other factor failure of building in resisting earthquake is because of having poor lateral and vertical reinforcement (Ozkul, Kurtbeyoglu, Borekci, Zengin, & Kocak, 2019). Thus, building are having low ductility and strength during Van Earthquake. The building must be design according to standard and addition on shear wall component may help the structure in resisting earthquake.

Figure 2.1: Crack on Building A and B in 2011 Van Earthquake

In Malaysia, earthquake also can be felt especially in Sabah. Magnitude of 6 is recorded in Ranau and the building is constructed based on BS 8110 which not include any seismic resistance. The earthquake causes some of structure shows some failure and no building collapse recorded due to magnitude is classified as low. A school building with four stories in Ranau area shows crack at column, column beam connection and wall. Figure 2.2 shows damage that had been observe of earthquake event occurred in 2015. Due to the heavy impact on the structure, it’s realise the engineer to implement seismic factor in the design to sustain from damage on the building. Thus, research on seismic resistance is done to evaluate the existing building in Malaysia.

Figure 2.2: Crack on Column and Wall at Ranau School

2.2 Shear Wall

Shear wall is a part of structural component which good in resist lateral and seismic forces. Slender wall are commonly used for high rise building and squat wall for low rise building. The cost to construct squat wall often more expensive for low to medium rise building compared to RC moment resisting frame (Moehle, Ghodsi, Hooper, Fields, & Gedhada, 2011). Shear wall is commonly use as the stiffness of the building is increased and stabilise the structure during earthquake. In addition, applying shear wall can reduce the displacement and story-drift of the structure (Tarigan, Manggala, & Sitorus, 2018). Turkey is known as one of the most prone area of earthquake event in the world. From the previous study, they determine the failure of the structure are causes by large displacement under earthquake. Shear wall is one of the best option of structural system that resist lateral load (Ozkul et al., 2019). In this section, behaviour of shear wall is observe in term of diagonal strut and thickness.

2.2.1 Effectiveness of Diagonal Strut

Shear wall for low rise building or squat wall are tend to have high inherent flexure strength compare with shear strength. Flexure yielding mechanism for aspect ratio h_w/l_w is difficult to achieve as less than approximately 1. Besides, diagonal strut are more to be considered to resist lateral forces in low rise building (Moehle et al., 2011). Hence, the detail of design of shear wall in low rise building is more complicated compared to high rise building. Basically, the design are begins shear design, shear friction checking and combined flexure and axial force. Figure 2.3 shows type of shear failure which known as shear yielding and shear sliding

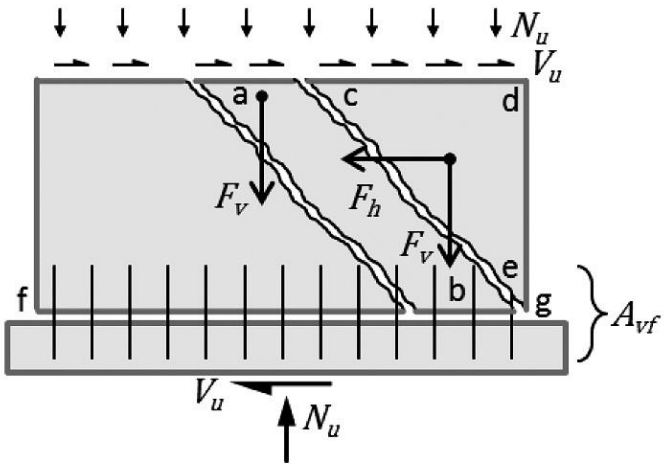

Figure 2.3: Shear Yielding and Shear Sliding in a Squat Wall

Another research on performance of inclined rebar is done by using single layer of web reinforcement. The web are arrange in low rise shear wall and about 7 from 16 specimens are having inclined rebar in shear wall and the thickness for all specimen is 140mm. By using shaking table method, dynamic performance and damage of shear wall are determined. Meanwhile, SAP 2000 is used for dynamic nonlinear analysis. From the result, they conclude that the shear are having excellent ductility with implementation of diagonal bar. The bar prevent from any diagonal crack as it can store more seismic capacity in the shear wall (Zhang, Zheng, Cao, Dong, & Li, 2019). Hence, diagonal bar are recommended in constructed for low rise shear wall. Figure 2.4 shows some example of shear wall with single layer of web reinforcement with different position of inclined bars.

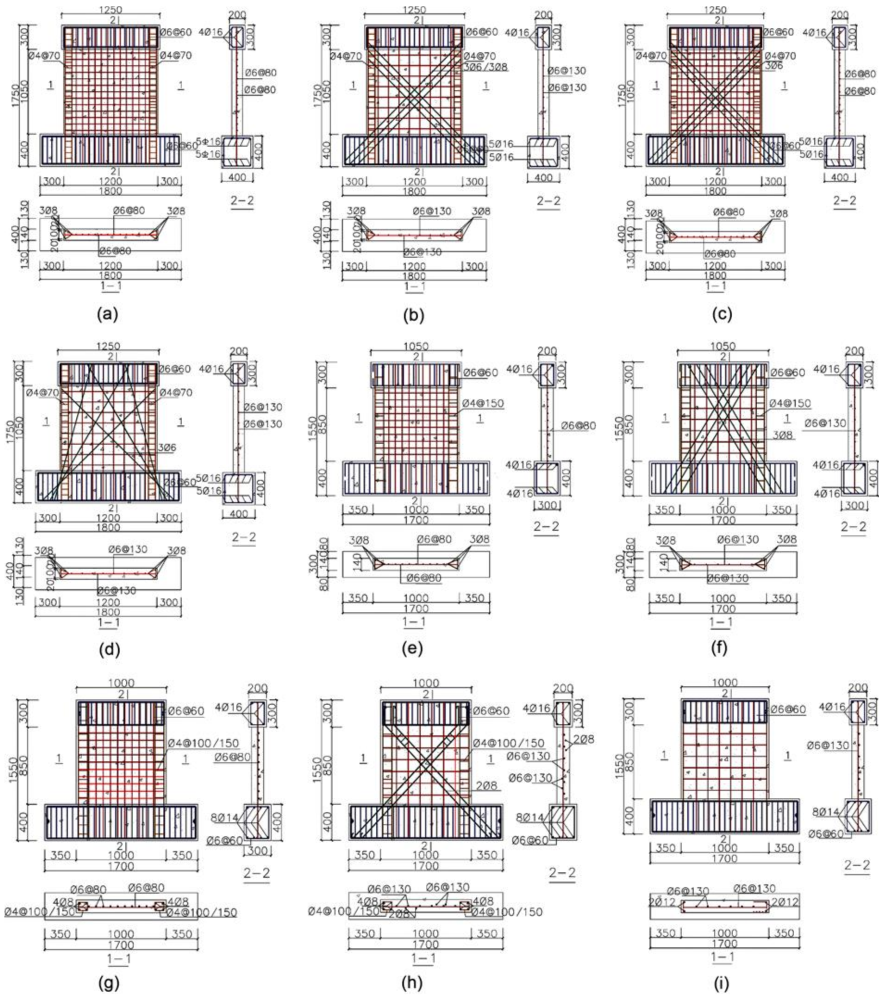

Figure 2.4: Concrete Shear Wall with Single Layer of Web Reinforcement with different position of Inclined Bar

2.2.2 Thickness of Shear Wall

Thickness of shear wall increase stiffness of the structure and gives significant effect on crack pattern, displacement, ductility and shear absorption. Thus, thick shear wall indicate more in strength and ductility against earthquake event (Khatami & Kheyroddin, 2011). In their research, four T flanged shear wall is used with same amount of volume with different thickness. When the thickness is decrease, the length of wing increase. From the analysis, dimension of the flange are not affected to the strength of the shear wall as all the sample start to crack at 232kN. As the thickness of the shear wall decrease, yielding forces is increase.

Moreover, another research on shear wall effect with changes of thickness and height is done for 24 story building in zone III Aurangabad. Five models for five different thickness of shear wall is analyse at level 4, 9, 14, 19 and 24 by using SAP 2000 and ETAB. The purpose of study is to determine story drift, story shear and deflection of the building under seismic forces. From the analysis, they conclude that increase of shear wall thickness will increase the stiffness of the building. Besides, increase the height and thickness of shear wall reduce the deflection (Shinde, 2016).

2.3 Nonlinear Static Pushover Analysis (PAO)

Pushover analysis is a static nonlinear analysis method to evaluate the performance of a structural system by estimate strength and the deformation demand (Keshava Murthy & L K, 2019). In the analysis of frame structure, the increasing magnitude of loading are able to detect weak link and failure of structure with a certain predefined pattern. The performance of the structure are presented by capacity curve which relationship between force and displacement. The graph can tell us the capacity limit of structure when the slope of deformation curve change and nonlinear behaviour are presented. In the other word, capacity curve represent ability of structure to perform during earthquake event. In their research, non-linear static pushover analysis of medium and high rise building are compared with introduce of soft stories in the higher building. From the result obtained, the higher structure are able to withstand higher base force and higher correspond of displacement produced compared to the medium building. Meanwhile, the soft stories causes the displacement and base shear increase as the hinge formation is decrease.

2.4 Nonlinear Dynamic Time History Analysis (NLTHA)

Time history analysis is one of dynamic analysis method which analyse dynamic response of a structure to a specific loading that may vary with time This analysis is important to represent inelastic respond characteristic to time dependent effect during earthquake event (Mohan, 2011). In the analysis, Peak Ground Acceleration (PGA) have to be considered as earthquake load intensities for the building. The performance level of the building is qualitative statement of damage which divided into minor, moderate, major and collapse level (Ismail, Adnan, & Ibrahim, 2011). Time history can be linear and nonlinear analysis. Thus, plastic hinges are assigned to the elements to achieve the nonlinearity (Ozkul et al., 2019).