# SEISMIC BEHAVIOUR OF LOW-DUCTILE MOMENT RESISTANCE FRAME UNDER FAR FIELD EARTHQUAKE EXCITATIONS CONSIDERING SOFT-STOREY PHENOMENON

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TO MY BELOVED PARENTS, FAMILY AND FRIENDS

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# ABSTRACT

Most of current Malaysian's structures have not been designed for designs did not consider seismic excitation effect. Since Malaysia's geography is far from earthquake prone region, the tremors, mostly non-lethal can be felt. The effects of seismic excitation on the stability and fragility of the building are now concerned by most researchers and engineers all over the world to mitigate structural damage and societal losses. This study focuses on the seismic performance of Reinforced Concrete (RC) Moment Resistance Frames (MRF) in Malaysia due to far field earthquake excitation, which has been designed to resist gravity and wind loads effects only. An ordinary building layout with different number of storeys (four, seven, and ten storeys) is selected in ways that represent the soft-storey phenomenon of RC building in Malaysia. Such structures have limited lateral load capacity to withstand against strong ground motion. Therefore, the outcomes of this study the vulnerability of typical RC, MRF structures in Malaysia motions and clarifies on the necessity of seismic retrofit for such structures.

# ABSTRAK

Kebanyakan bangunan sedia ada di Malaysia tidak mempertimbangkan kesan pengujaan seismik di dalam reka bentuk. Memandangkan keadaan geografi Malaysia yang agak jauh daripada kawasan yang sering dilanda gempa bumi, gegaran tanah yang kebanyakannya tidak membawa maut tetap dapat dirasai. Kesan daripada pengujaan seismik terhadap kestabilan dan keutuhan bangunan menjadi kebimbangan oleh kebanyakan penyelidik dan jurutera masa kini di seluruh dunia untuk mengurangkan kesan kerosakan struktur dan kerugian masyarakat. Kajian ini memberi tumpuan kepada prestasi konkrit bertetulang bagi struktur kerangka Momen Rintangan yang terdapat di Malaysia terhadap kesan seismik jarak jauh, yang dimana bangunan ini telahpun dibina tetapi direkabentuk hanya untuk kesan graviti dan tekanan angin sahaja. Pelan bangunan yang biasanya direkabentuk telah dipilih dengan jumlah tingkat yang berbeza (empat, tujuh, dan sepuluh tingkat) untuk mewakili tipikal bangunan konkrit bertetulang berfenomena tingkat lembut di Malaysia. Struktur ini mempunyai kapasiti beban sisi yang agak terhad untuk bertahan daripada gegaran bumi yang kuat. Oleh itu, hasil kajian ini menerangkan kelemahan prestasi konkrit bertetulang tipikal yang mewakili bangunan yang terdapat di Malaysia dan menjelaskan keperluan seismik retrofit untuk struktur tersebut.

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| | | |
|---|---|---|
| $\mu$ | - | Ductility |
| $\Delta$ | - | Deflection |
| CP | | Collapse Prevention |
| E | | Modulus Of Elasticity |
| F | - | Force |
| $F_u$ | - | Ultimate Capacity |
| $F_y$ | - | Yield Strength |
| I | | Importance factor |
| IO | | Immediate Occupancy |
| k | | Stiffness |
| LS | | Life Safety |
| MRF | - | Moment Resistance Frames |
| RC | - | Reinforced Concrete |
| PGA | | Peak Ground Acceleration |
| PGV | | Peak Ground Velocity |
| PGD | | Peak Ground Displacement |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Earthquake is one of the natural phenomenons that cause damages to structural and infra-structures. Huge amount of life and economic losses has been reported based on the previous earthquake phenomenon case. In 2011, according to analysis by Center for Disaster Management and Risk Reduction Technology (CEDIM), more than 20,000 people died, and almost 365 billion U.S dollar total economic losses have been report due to this natural hazard. According to Bertero and Bertero (2002), 7 billion U.S dollar in Lorna Prieta on 1989, 30 billion U.S dollar in Northridge on 1994, and 200 billion U.S dollar in Kobe on 1995 economic losses that have been report from previous year due to earthquake. Earthquake phenomenon is unpredictable and cannot be avoided. The number of losses will give an impact to the growth of the country to especially during the retrofit plan. However, structural damage and societal losses from the earthquake phenomenon can be mitigated if the structure or building able to withstand strong excitation.

Malaysia is located at the tectonically inactive Sunda shelf and situated between major boundaries of tectonic plates; Australia plate and Eurasian plate in the

west of Malaysia and Philippine Sea plate and Eurasian plate in the East of Malaysia. Figure 1.1 shown major earthquake hazards that happen surround Malaysia region since 1973 and tectonic plate boundaries. Even though the distance from the active seismic source is more than 300km away and Malaysia lies in a low-seismicity region, the tremor of earthquake from Sumatra island of Indonesia and the Philippine sometimes can be felt in Malaysia. Several tremors in Malaysia have been recorded; about 20 tremors at Kenyir Dam area since 1984, 13 tremors at Bukit Tinggi Pahang since 2007, Manjung and Jerantut Pahang, and other places (The Star Online, October 11th, 2009). The strongest tremor recorded is magnitude 5 on the Richter scale at Kenyir Dam area. Even though the tremors are considered low; the earthquake excitation from Indonesia and Philiphine could still affect Malaysia as happen in Mexico City on 1985 earthquake which had epicenter more than 350km away. Figure 1.2 shows the microzonation maps for 500 years return period of Malaysia.

In line with economic growth, number of construction and development in Malaysia are rapidly increasing. Early actions on protecting existing country's asset are concerned to mitigate number of losses on any situation.

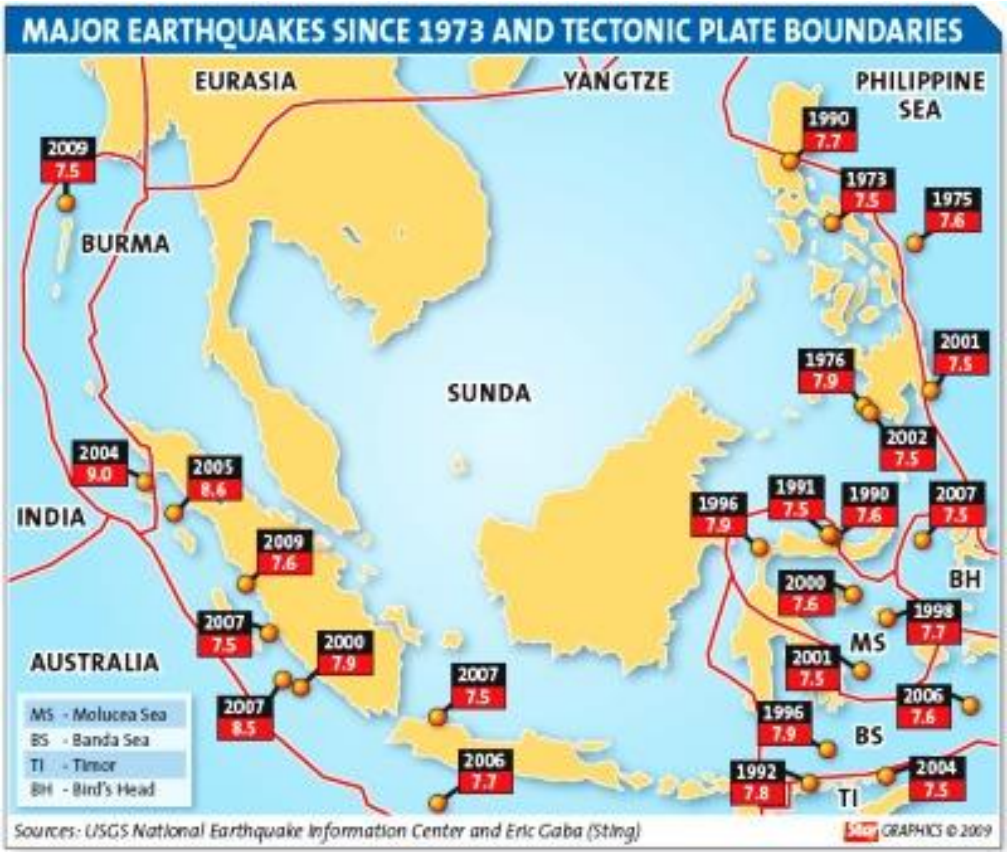


**Figure 1.1**: Major earthquakes surround Malaysia since 1973 and tectonic plate boundaries. (The Star Online, October 11th, 2009)

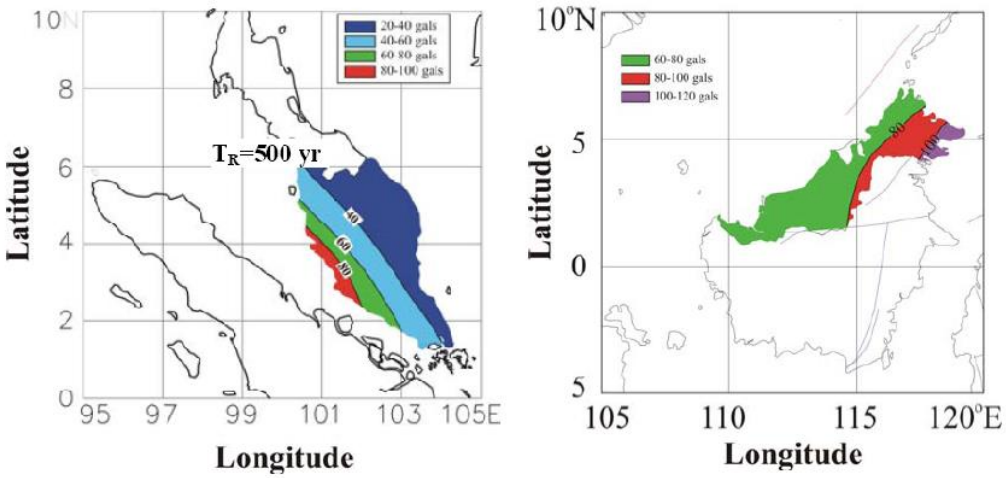


**Figure 1.2**: Seismic hazard maps for 500 years return period of Peninsular Malaysia (left) and East Malaysia (right). (Azlan et al, 2006)

## 1.2 Problem Statement

Most of current Malaysian's structures have not been designed for seismic load. Since Malaysia's geography is far to earthquake prone region, the tremors, mostly non-lethal can be felt. However, the effects of such seismic activities on the stability and safety of the building are now concerned by researchers and engineers. As Malaysia is one of developing country, structural damages and societal losses are concerned, it is a good practice if seismic excitation force is considered in the structural design. Even there is no serious structural damage report for the past decades due to far field ground motions and tremors, the stability of current Malaysia's building and its safety due to seismic excitation effect can be questioned.

This study focuses on the seismic performance of Reinforced Concrete (RC) Moment Resistance Frames (MRF) in Malaysia due to far field earthquake excitations, which has been designed to resist gravity and wind loads effects only. An ordinary structural building layout was selected in way that represents the soft-storey phenomenon of RC building in Malaysia. The gravity load designed MRF structures have limited lateral load resistance to withstand strong ground shaking. Therefore, the outcomes of this study can display the vulnerability of typical RC, MRF structure in Malaysia and clarifies on necessity of seismic retrofit for such structures.

## 1.3 Objectives of the Study

The main aim of the study is to evaluate seismic behavior of low-ductile RC moment resistance frame (MRF) structures under far field earthquake by considering soft-storey phenomenon that can commonly occurring in the Malaysia's buildings. In order to achieve this aim, specific objectives for this study are as follow:

1. To obtain the capacity curve of typical RC, MRF building in Malaysia and compare it with wind load demands.
2. To study the effect of infill panels on the ductility and lateral stiffness of typical RC MRF buildings in Malaysia.
3. To evaluate seismic performance of typical RC MRF in Malaysia under far-field earthquakes

## 1.4 Scope of the Study

This research only studies the effects of brickwall infill panels on the seismic behaviour of typical MRF in Malaysia and concrete wall structures are not included in the scope. Moreover, for seismic excitation, only far field earthquake will be considered. This is because of Malaysia's geographical condition. In addition, the focus of this study is only on reinforced concrete structures and steel structures will not be included.

## 1.5 Significance of the Study

Significant of this study is to get the seismic vulnerability of low-ductile MRF structure under far field earthquake excitation by considering soft-storey phenomenon which meets to Malaysia's MRF structure criteria. By the result of software analysis, the fragility of the structure due to the selection of ground motion from far field case will be evaluated. Therefore, the outcomes of this study illuminate the vulnerability of typical RC MRF structure in Malaysia and clarify on necessity of seismic retrofit for such structures.

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