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Investigation on Rubber Isolator as Earthquake Resistance System for Single Storey Building in Seremban, Negeri Sembilan.

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Abstract

The title of this final year project is investigation on rubber isolator as earthquake resistance system for single storey building in Seremban, Negeri Sembilan. The main purpose of this research as it needs to find out the behavior of rubber isolator of the house as an earthquake resistance. And from those behaviors of the rubber isolator, these behaviors can be tested through experimental analysis and finite element analysis. In this research, there are 3 samples are tested. The dimensions of 3 samples are 100mm*100mm*40mm, 200mm*200mm*40mm and 300mm*300mm*40mm. Most earthquakes occur along the fault lines when the plates slide past each other or collide against each other. The effects of earthquake which is harmful for human being such as landslides or hillslides, tsunamis, fires, floods caused by the collapse of dam walls, falling electricity lines, damage of man-made structure, liquefaction, spill of hazardous chemicals, radioactivity from damaged nuclear power plants and etc. By installing the base isolator, it can resist the horizontal load and vertical load which the loads come from earthquake. This is the main purpose to research in this title.

1.0: Introduction

1.1 Introduction

An earthquake is a vibration of the ground caused by the slippage or rupture of a fault within the Earth's crust. Most earthquakes occur along the fault lines when the plates slide past each other or collide against each other. If the ground is shaking by itself, it is not dangerous at all. But the damage of other issues will be hazardous for human. There are some earthquake effects which is harmful for human being such as landslides or hillslides, tsunamis, fires, floods caused by the collapse of dam walls, falling electricity lines, damage of man-made structure, liquefaction, spill of hazardous chemicals, radioactivity from damaged nuclear power plants and etc.

Actually 3 million earthquakes take place in every year, most of the incidents happened unnoticed by human being. Earthquakes normally lasting a few seconds, but it can be big disaster for human; it can cause the death of hundreds or thousands of lives, injured, damage of building or big damage economical to the earthquake area.

However, we can reduce the damage of structures or number of deaths by installing rubber isolator in foundation. In earthquake resistance system, rubber isolator is being as resistance for earthquake. In this project, a single storey building is being installed a rubber isolator as an earthquake resistance system in Seremban. Due to the earthquake happened area is getting closer to Malaysia, Malaysia is starting to build building with rubber isolator to resist in coming earthquake. Rubber isolator is an effective way to reduce effects of the earthquake to the building. The combination between rubber and steel are effectively to reduce absorb the earthquake energy and damage effects to the building due to the earthquake happens.

1.2 Background of Study

An earthquake is the result of a sudden release of energy in the Earth's crust that creates seismic waves. During an earthquake, the ground surface moves in all directions. The most destructive effects on structures are horizontally movement to the building. Due to the building is designed vertical gravity load, the horizontal movement to the building will be a seriously effect. Rubber isolator is an earthquake resistance system for the building. It is a passive control method to protect the building from the seismic effect. The rubber isolator is installed in the foundation of the building to resist the earthquake energy and it is to prevent destruction of the building due to the earthquake motion. Earthquake motion is a horizontal earthquake wave to the building. Rubber isolator consists of alternating rubber layers and steel plates. Both are bonded together to give vertical rigidity and horizontal flexibility. For the purpose of vertical rigidity, it is to support the load of the structure whereas horizontal flexibility is to reduce the destructive force into gentle manner. This is the main purpose for installing rubber isolator for a structure to prevent damage when earthquake happens.

1.3 Objective

- To investigate the behavior of rubber isolator of the house as an earthquake resistance.
- To compare the result between experimental analysis with finite element analysis

1.4 Problem Statement

The purpose of investigate on rubber isolator as earthquake resistance system for single storey building in Seremban, Malaysia as the region of earthquake is getting nearer to Malaysia. In order to prevent the destructive of building, injured or death, this study is going to apply the buildings in Malaysia. This is to ensure people in Malaysia are getting ready when the earthquake comes. Rubber isolator is being installed in foundation. Rubber isolator is giving vertical rigidity and horizontal flexibility. When the earthquake comes, the rubber isolator will protect the building from destructive and injured or death.

1.5 Scope of Work

This report is about the investigation of rubber isolator as earthquake resistance system for Single Storey Building in Seremban, Negeri Sembilan. In this investigation, the behavior of the rubber isolator will be investigated by using experimental test method or finite element analysis. This both tests will carry out to measure in compression, shear and displacement.

Work scope includes:

- The preparation of material
- Laboratory testing
- Finite element analysis
- Comparison and Analysis
- Conclusion and Recommendation

1.6 Thesis Organization

Chapter 1 – Introduction

- From this chapter, I have to figure out the title of this topic, after that, I need to contribute introduction, background of study, objective and problem statement.

Chapter 2 – Literature Review

- From this chapter, I have to find out the some literature review discusses from published information like journals, books, internet or etc. Literature review is a simple summary from the sources. But normally it is combining summary and synthesis.

Chapter 3 – Methodology

- In methodology, I need to collect data which are relevant to my topics. Research is necessary as it includes the concepts and theories of my title. In methodology, I need to show that I understand the underlay.

Chapter 4 – Result

- From this chapter, it will be shown that I have designed a storey house and rubber isolator, research, laboratory experiment and etc.

Chapter 5 – Conclusion

- In this chapter, a conclusion will be written due to the 4 chapters above. Resources and appendix will be given in this chapter.

2.0: Literature Review

2.1 Introduction

Earthquakes are essentially vibrations of the earth's crust caused by subterranean ground faults. The tectonic plates will still to get stuck due to friction at the edge although they are moving slowly. Most of the earthquakes occur when the plates collide or past each other along the fault lines. When the earthquake release the energy to the earth's crust, it means that the stress overcome the friction on the edge. So we can feel the shaking.

The shock waves that sent out by earthquake are powerful enough to opening big cracks in the ground, thrusting up cliffs and alter the surface of the Earth. Earthquake can cause great damage to man-made structures, landslides, tsunami and volcanic eruptions.

2.2 The effects of Earthquakes to living things

The powerful of earthquake is a big disaster. The energy released from the earthquake is powerful. It is like 10,000 times more stronger than the first atomic bomb. The side-effects of the earthquake can be:

a) Ground Shaking

Seismic waves causes the shaking of the ground, the most destructive damage will be in the surface waves which near epicenter during an earthquake. The earthquake intensity of the ground shaking is depending on the duration and intensity of the earthquake. These are normally general to the size of the earthquake. And the distance will be influence the ground shaking. If the distance between the epicentre is far apart, the intensity of the earthquake will be decreased. The condition of the geology can be effect too.

b) Landslides

Earthquake can lead to landslides, rock slides and slump. From the real story happened, those landslide are more powerful damage than earthquake. As an example, a housing area in Alaska was destructed by sudden landslide when earthquake caused.

c) Damage to man-made structures

Earthquake will be a great destructive to man-made structure like road, bridges, dam and structure. The ground motion is depending on some types of construction which built the structure. As an example, the destructive to steel and wood will be less this is because both materials are flexibility. For masonry structures and concrete are much more brittle if compare to wood and steel. This is because there are susceptible to damage and collapse. "Earthquake don't kill people, collapsed do" (Jo da Silva 2013) This quote is from seismologists who trust that the cause of most death is man-made building and construction damaging during earthquake.

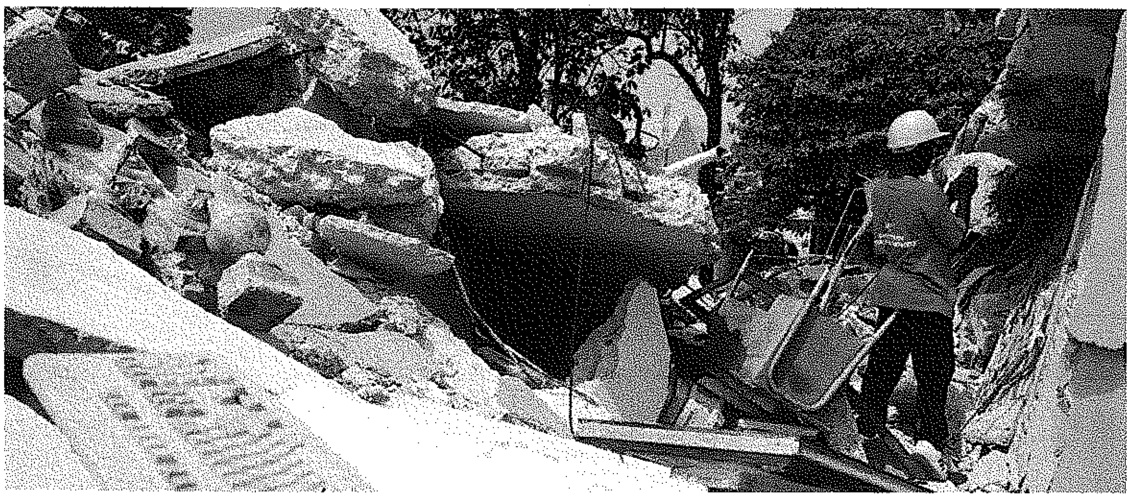

Figure 2.1 : Earthquake in Haiti 2010

Figure 2.2 : Seismic shaking and related dangers

The photo was shown that the extremely dangerous by earthquake shaking to people in the public on the street after an earthquake. The picture is shown that completely destroyed of buildings, electric signage and windows crash and collapses on the street.

d) Fires

Fire is one of the normal side effects of earthquake. As it often started with broken electrical and gas lines. Gases are set free as gas lines broken and start to spark. In order to complicate the situation, the water supply is broken and no water to put out the fire. As an example in 1906, earthquake hit San Francisco and caused 90% of damage by fire.

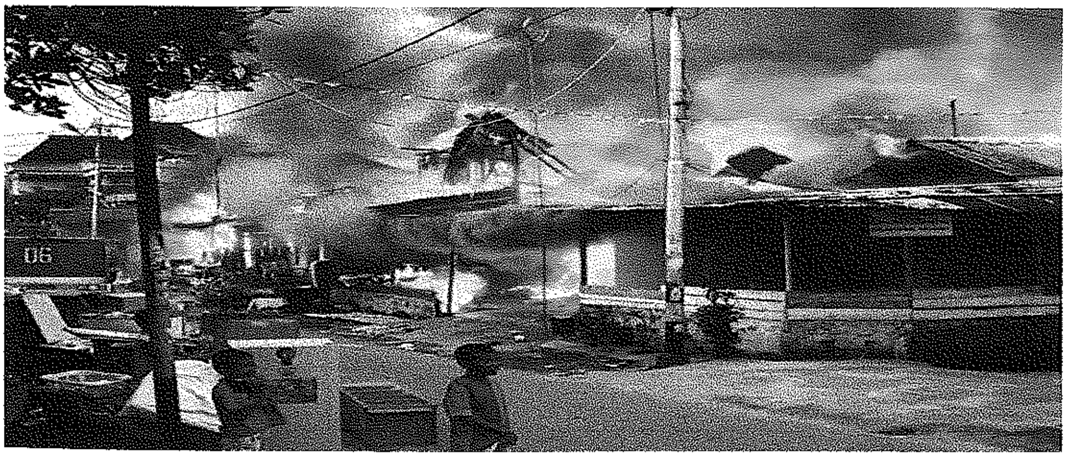

Figure 2.3: Fires started by broken gas line

e) Spill of hazardous chemicals

The ground movement or shaking of earthquake can causes the chemical products which are stored in the warehouse or under household to sink and spill. And eventually potentially mix. Silent killers are produced when the chemical reaction and it can cause serious injury. There are some ways to cause the hazardous chemicals to go in living things' body. The most common way is inhalation through nose. Absorb the chemical products by eyes and skin. Indigestion through mistakenly injection can be penetrating through the skin like the glass of chemical products falling or punch through the skin. There are some ways to avoid getting hazardous chemicals to body. We must always assume the spilled chemicals are dangerous and toxic. And we cannot immediately go nearer the spilled chemicals due to the products may be dangerous to our bodies. And must close all the room where the spilled chemicals. Apart from that, we must mark the outside the room with a signboard with "Spilled Chemicals Inside – Be Caution", this is to ensure people no step in accidentally. Inform the people the spill of hazardous chemicals.

Figure 2.4: Spill of hazardous chemicals in Japan 2011

f) Radioactivity from nuclear power plants

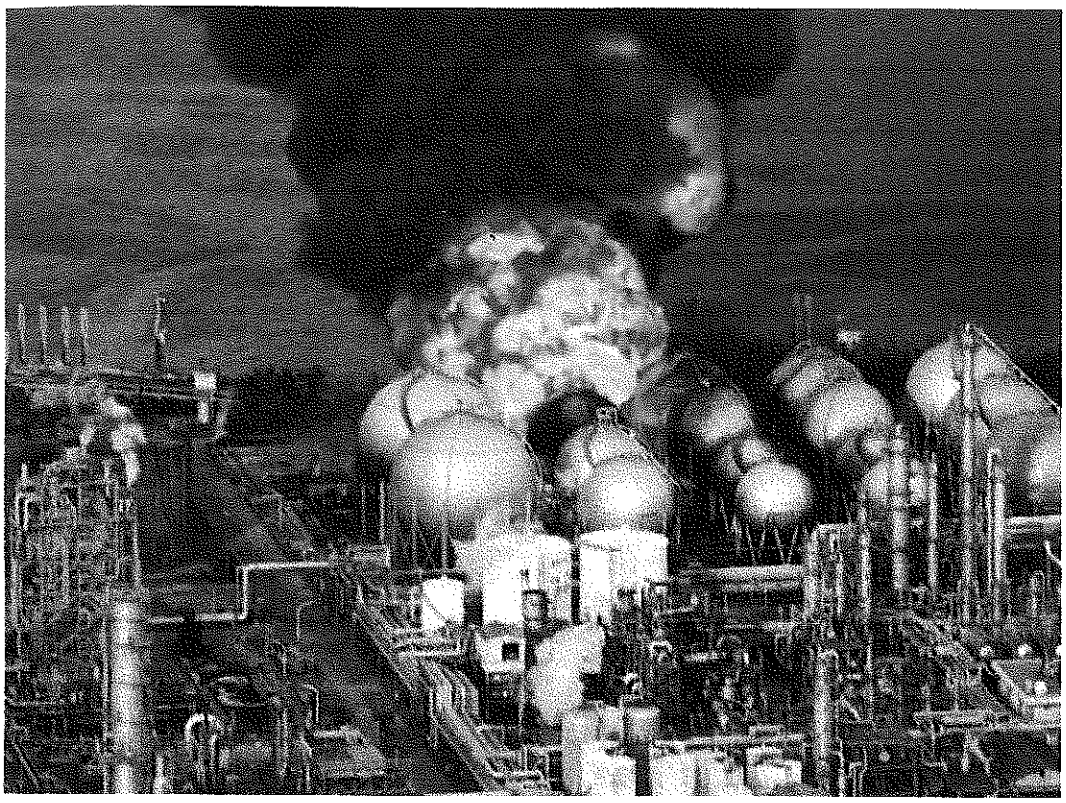

Figure 2.5: Fukushima Daiichi nuclear disaster - 11 March 2011

The size or magnitude of earthquakes is investigated by calculating the amplitude of the seismic waves which is recorded on a seismograph. The distance of the seismograph from the earthquake can be determined too. Those energies are converted into a formula which measure magnitude of the earthquake and the energy of the earthquake. In the reseach are shown that magnitude 6.0 earthquakes can release about 30 times more energy than magnitude 5.0 earthquakes. And when magnitude 7.0 earthquake hit, it can release about 900 times (30x30) more energy than a magnitude 5.0. A magnitude 8.6 earthquake releases energy equivalent to about 10 000 atomic bombs. If the nuclear power plants are destroyed when the earthquake hit, the area of the nuclear plant cannot be stayed anymore.

g) Liquefaction in water-laden sediments

Liquefaction occurred during moderate to powerful earthquake. The combination of groundwater, soil and sand during seismic shaking will form liquefaction. This process is just like quicksand happened. When liquefaction happens under the building, the foundation will sink and the building might collapse. The soil will be hardened and again the water will be settled more deeply in the ground after the earthquake has passed. The liquefaction of the area will be serious when sandy soil and groundwater are closer to the surface. Building will sink into the ground if liquefaction occurs.

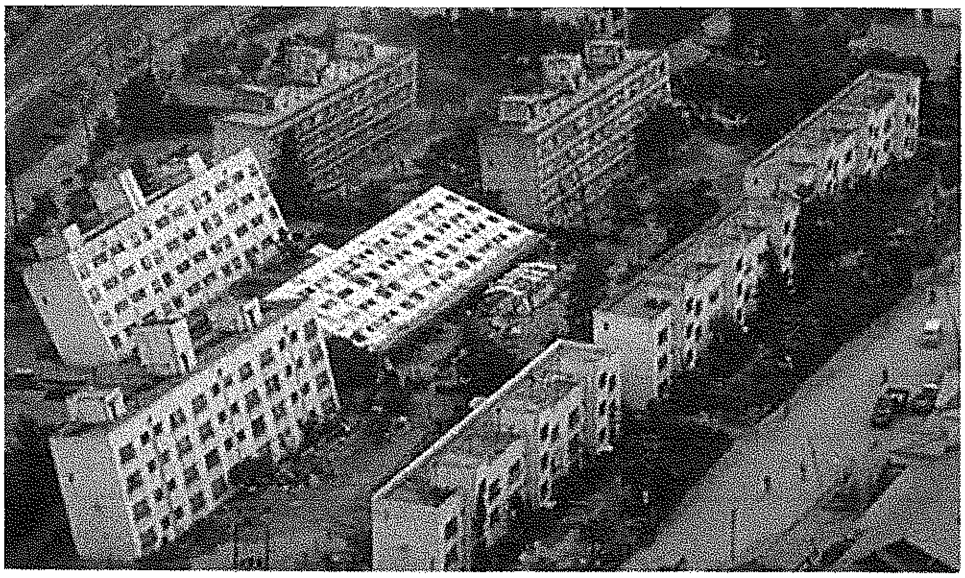

Figure 2.6: Liquefaction led the buildings collapsed

h) Flooding

Flooding caused due to several ways during earthquake. During earthquake, dam fails, broken main pipes or earthquake-generated tsunamis can cause serious flooding. When an earthquake breaks a dam and the water pass along the river and the water from reservoir or river can flood the area, swap away the houses or drowning people.

Figure 2.7: Flooding during earthquake

i) Injuries and death

During earthquake, injuries and death happened on human. This is not only for human; it is for living things like animals and plants. Earthquake can cause injuries and death to human due to building collapse, things collapse and crimping on human until he cannot moves, road cracks and etc. Those situations can cause living things injured and death. When 26th December 2004, Malaysia was affected by the Indian Ocean Earthquake. 68 persons found death during the incident.

Figure 2.8: People suffered after an earthquake

j) Tsunamis

Tsunamis is the one of the most dangerous effect when earthquake. Tsunamis give a large and strong giant waves that causes big floods for living things and non-living things. The tsunamis can shoot up to 100 feet high. Tsunamis occurred when the sea faulting of ocean floor send seismic shocks through the sea water and create big waves of low amplitude and long period. The moving of the tsunamis is about 500-700 mph.

Figure 2.9: Tsunami occurred when earthquake hit Japan 2011

Figure 2.10: Tsunami occurred when earthquake hit Japan 2011

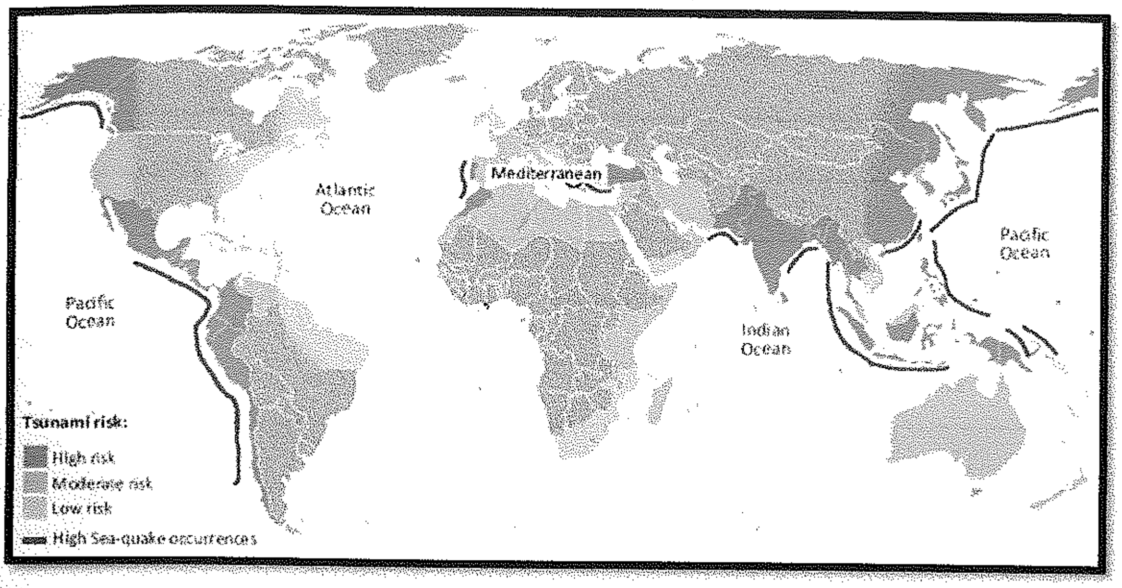

Figure 2.11: Tsunami risk by countries are shown above

2.3 Earthquake magnitude measure

2.3.1 Richter Scale

The first widely used method to measure the magnitude of earthquake is Richter scale. This Richter scale was developed by Charles F. Richter in 1934. Richter scale is used when the formula is based on amplitude of the biggest wave. The waves were recorded by seismometer. The Richter scale is famous for calculating the magnitude of earthquakes. The logarithm of the amplitude of the largest wave is proportional to the magnitude when earthquake. For an example, a record of magnitude 7, the disturbance with ground motion is 10 times larger when record of magnitude 6.

The table below shown the effects of the earthquakes and the frequency of earthquakes based on Richter scale.

Richter Scale

Magnitude	Description	What it feels like	Frequency
Less than 2.0	Micro	Normally only recorded by seismographs. Most people cannot feel them.	Millions per year.
2.0–2.9	Minor	A few people feel them. No building damage.	Over 1 million per year.
3.0–3.9	Minor	Some people feel them. Objects inside can be seen shaking.	Over 100,000 per year.
4.0–4.9	Light	Most people feel it. Indoor objects shake or fall to floor.	10,000 to 15,000 per year.
5.0–5.9	Moderate	Can damage or destroy buildings not designed to withstand earthquakes. Everyone feels it.	1,000 to 1,500 per year.
6.0–6.9	Strong	Wide spread shaking far from epicenter. Damages buildings.	100 to 150 per year.
7.0–7.9	Major	Wide spread damage in most areas.	10 to 20 per year.
8.0–8.9	Great	Wide spread damage in large areas.	About 1 per year.
9.0–9.9	Great	Severe damage to most buildings.	1 per 5-50 years.
10.0 or over	Massive	Never Recorded.	Never recorded.

Table 2.1: Richter scale

2.3.2 Mercalli Scale

Mercalli scale is another method to calculate the magnitude of the earthquake which is developed by Giuseppe Mercalli in 1902. Mercalli scale is used to estimate the intensity of the earthquake which is observed by people who experienced the earthquake. The Mercalli scale is not considered as scientific method as Richter scale this is because people may exaggerate for the earthquake of what they see. And it is hard to find two witnesses agree what had happened as everyone will voice out different matters. The amount of damage due to earthquake cannot be used in Mercalli scale.

Mercalli scale

Magnitude	Earthquake Effects
2.5 or less	Usually not felt, but can be recorded by seismograph
2.5 to 5.4	Often felt, but only causes minor damage.
5.5 to 6.0	Slight damage to buildings and other structures.
6.1 to 6.9	May cause a lot of damage in very populated areas.
7.0 to 7.9	Major earthquake. Serious damage.
8.0 or greater	Great earthquake. Can totally destroy communities near the epicenter

Table 2.2: Mercalli Scale

Source: Based on U.S. Geological Survey documents

Earthquake Magnitude Categories

Earthquakes are classified into categories. The range is from minor to major, this is depending on their magnitude.

Class	Magnitude
Great	8 or more
Major	7 - 7.9
Strong	6 - 6.9
Moderate	5 - 5.9
Light	4 - 4.9
Minor	3 -3.9

Table 2.3: Earthquake Magnitude Classes

Source: Based on U.S. Geological Survey documents

2.3.4 Earthquake Acceleration

Earthquake waves consist of both ways which are horizontal and vertical direction. Acceleration and velocity are calculated in the length of fault, the distance between fault and station.

The latter can have big influence on the ground acceleration and wave form. This is very important to know the about the changes in the subsurface below the station. And it is following the values of ground acceleration show result of changing even within a small area. This is especially for medium to large magnitude earthquakes. And it is interpolating the values is difficult. When we are away from the fault, the acceleration of the earthquake will decrease. From the measuring of PGA, the only one consideration is horizontal ground movements.

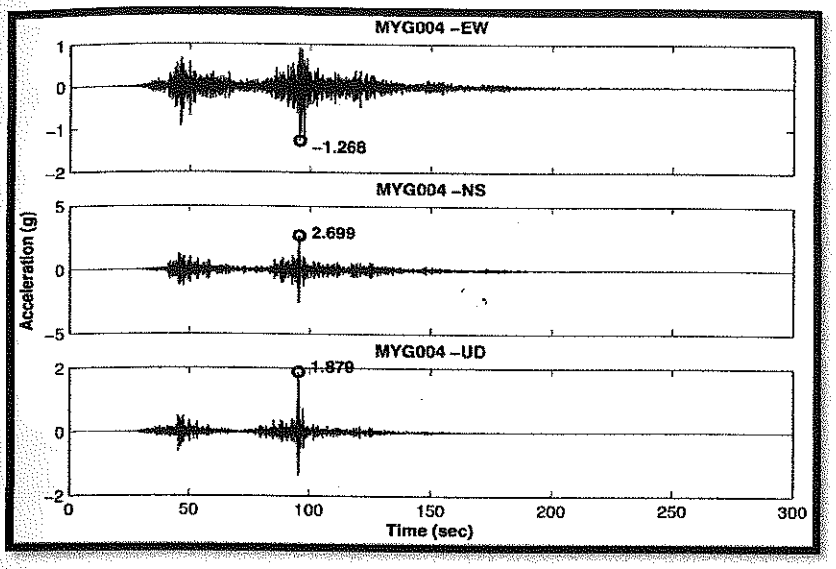

Figure 2.12: Earthquake acceleration histogram- Japan Earthquake 2011

Source: Saburoh Midorikiwa research

2.3.5 Earthquake Duration

The duration of an earthquake is considered related to its magnitude but it is not perfectly making sense. There are two kinds of methods to measure the duration of the earthquake. First is to measure the length of the time which makes the fault to rupture. Another method is the length of time shaking, as an example that person says: I felt the earthquake shake about 15seconds". This is just a voice statement. The duration of fault rupture is measured by how long it takes to slip. Another one is to measure the time to take to rupture along the fault. (USGS- science for a changing world)

Several important contributions to the description of the duration of strong earthquake ground motion. For example, Esteva and Rosenblueth describe the duration, s(sec) of an equivalent ground motion with uniform intensity per unit time by

$$S=0.02 \exp(0.74M)+0.3\Delta$$

where M is earthquake magnitude and Δ(km) is the source-to-station distance.

2.4 Earthquake zones

2.4.1 Earthquake zones in the world

An earthquake occurred when the ground shaking by a sudden slip on a fault. The outer layer of the earth pushes the stress to the sides of the fault together. Stress occurred and the rocks sudden slip when earthquake hit. And it is releasing energy in waves that send through the earth's crust. This is why we feel shake when earthquake. When earthquake occurs, it means that the plate grind collide against each other. The greatest earthquakes in the world occur when along the subduction zones. This is the meeting point between two tectonic plates. There are a few examples of earthquake occurred around the world. When December 2004, magnitude 9.2 earthquake was sit subduction zone off the coast of Sumatra, Indonesia. This is the strongest earthquake in recent history in this world. This earthquake also was bringing along the tsunami, more than 200000 people were killed in 14 countries including Malaysia. The magnitude 7.8 earthquake hit on San Francisco. It was ensuing fire killed 3000 people and influence the large areas of the city. In 1556, magnitude 7.8 earthquake hit China, 830000 people were killed. In the history of earthquake, there some terrible earthquake occurred and took many lives away. In 1960, the strongest earthquake in the world occurred in Chile among the record. With magnitude 9.5 earthquake, it was more than 4000 people killed. In 2011, earthquake occurred in Japan which along the subduction zones. With magnitude 9.0 earthquake, the earthquake was bringing along the tsunami. From all the record, all the magnitude is according to Richter Scale.

Figure 2.13: Earthquake and Tsunami happened in Japan 2011.

Sources : https://www.google.com.my/searchearthquakeinjapan2011

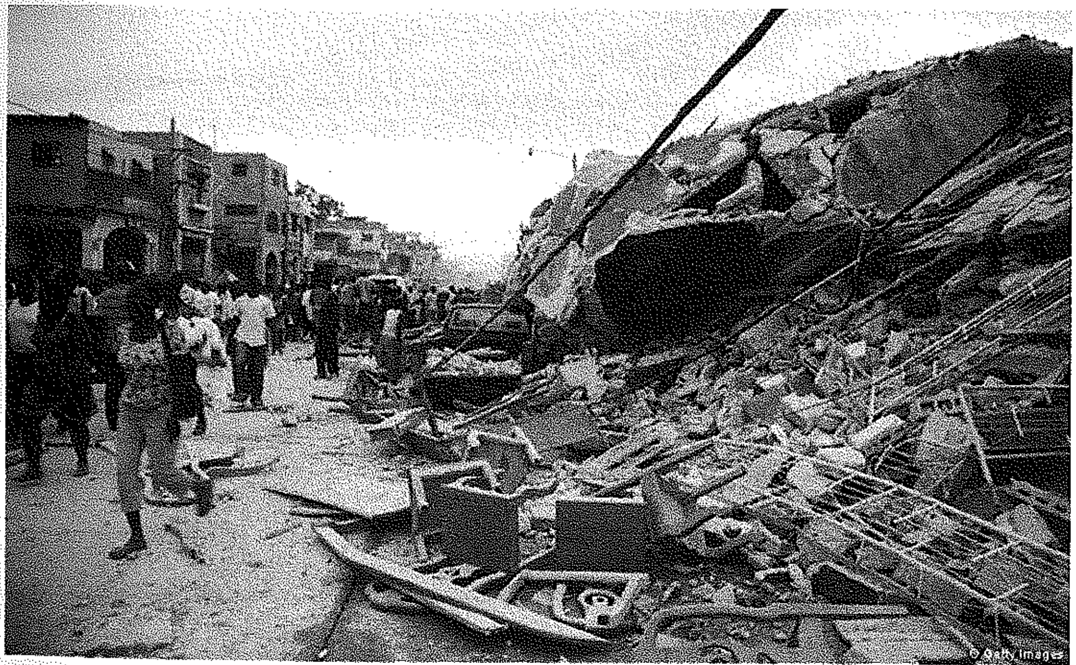

Figure 2.14: Earthquake strike on Haiti 2010.

Sources : https://www.google.com.my/searchearthquakeinhaiti2010

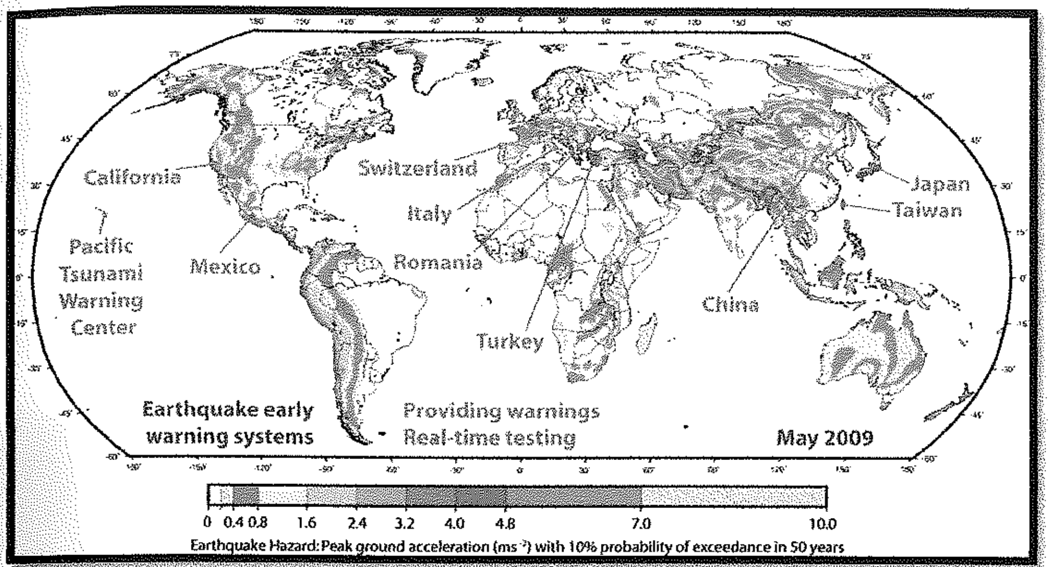

Figure 2.15: Earthquake zones around the world

Source: https://www.google.com.my/searchearthquakemonitoringinworld

2.4.2 Earthquake zones in Malaysia

Although Malaysians may feel that the country is not prone to earthquakes, experts believe otherwise. Malaysia is located beside two neighbors, Indonesia and the Philippines, which have seen violent episodes of seismological activities in the past few years. Australian, Eurasian and Philippine plates are moving around and pushing towards Malaysia even though Malaysia is located on the Sunda plate with stable condition. According to the researcher Azlan, the earthquake which occurred in Aceh in 2004 is disturbing the plates which nearby plates. This means that the plate is moving closer to the Sumatran fault line. He found out that the plate shift a few centimeters to the west. This was recorded after the earthquake happened. Now Malaysia is more nearer to epicenter. This also means that when the earthquake hit surrounding of Malaysia, the pressure that we feel will be greater. (Azlan, UTM's Structural Earthquake Engineering Research).

So far, Malaysia has only encountered strong vibrations and aftershocks after its neighbors were hit by strong earthquakes. Meteorological Department has detected 8 earthquakes in east Malaysia which are Sarawak and Sabah in 2012. According to Richter Scale, the magnitude is between 2 to 4.5 magnitude. The areas in Sabah which affected were Tambunan, Kota Marudu, Kudat, Beluran, Kunak and Keningau. The area in Sarawak was in Belaga. "Earthquake, in Malaysia cannot be ignored" (a seismology expert, Dr Mohd Rosaidi Che Abas, 54)

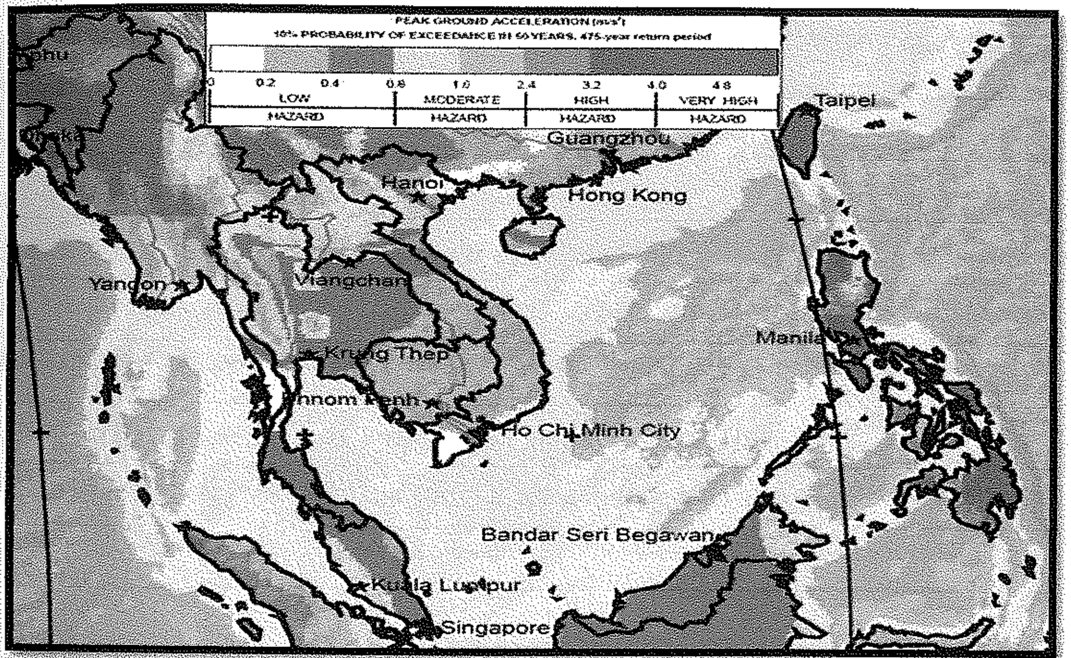

Figure 2.16: Earthquake zones around Malaysia

Source: Malaysian Meteorological Service

2.5 Earthquake Effect to low rise building

Compare to high rise building, low rise building will be collapsed when great earthquake hit. Due to low rise building are designed less flexible compare to high rise, so it will be easier to collapse. So when strong and rapid shaking occurs, low rise structures cannot cope with the high frequency and more likely to collapse. (Mohd Zamli Ramli, researcher of Engineering Seismology and Earthquake Research Group) . Low rise structure is not designed to sway during earthquake and most likely it will collapse. When the earthquake happened, low rise building which is not earthquake proof have more danger of collapsing because it is not flexible, which makes it brittle. When the height of the building decreases, the low rise building will get more effect when earthquake hit. This means that the radiation damping increase when earthquake and it also mean that the natural period of the building is short. Most of the low rise buildings consist of secondary structural members. All these members mostly are not counted in structural design. When the rocking motion and elastic deformation increase, the large radiation will be decreased when in sway motion. (Nubuo Fukuwa and Jun Tobita, Japan Seismologist)

A 6.3-magnitude earthquake ripped through a remote, mountainous area of China's Yunnan province. People death in this disaster is estimated about 400 persons. It has been estimated 42000 homes were damaged and 12000 of them being completely destroyed.

Figure 2.17: Most of the low rise building collapse after earthquake in Yun Nam 2014.

Source: BBC News

2.6 Earthquake Base Isolator

Base isolators are used to install to the building structures. The advantage of base isolator is a passive control technique when the earthquake hit. This technique is used to protect the building from destroy when the earthquake hit. Base isolator can be used to resist the seismic waves. Base isolators need enough horizontal flexibility in lateral motion when the earthquake hit. This means that it can extend the natural period of the building and away from destructive in earthquake situation. And it also needs enough vertical rigidity to withstand the gravitational load. Another advantage of installing base isolator is to reduce the acceleration when the earthquake hit. With base isolator of the building, the building only needs to undergo a small scale of movement when earthquake come. This can reduce the percentage of collapse from earthquake. From the Figure 2.18, the figure shows the movement of the base isolator. In Figure 2.19, it shown that the base isolator has large flexibility when earthquake. This means that the destructive of the building can be reduced.

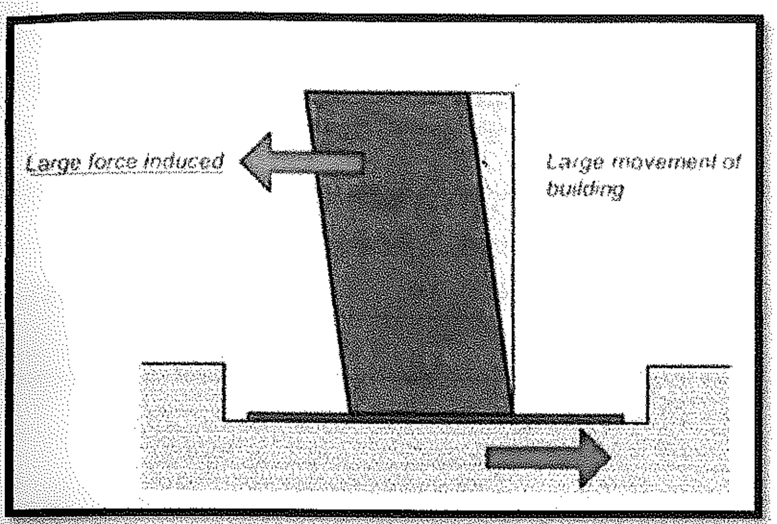

Figure 2.18: Building resting directly on ground

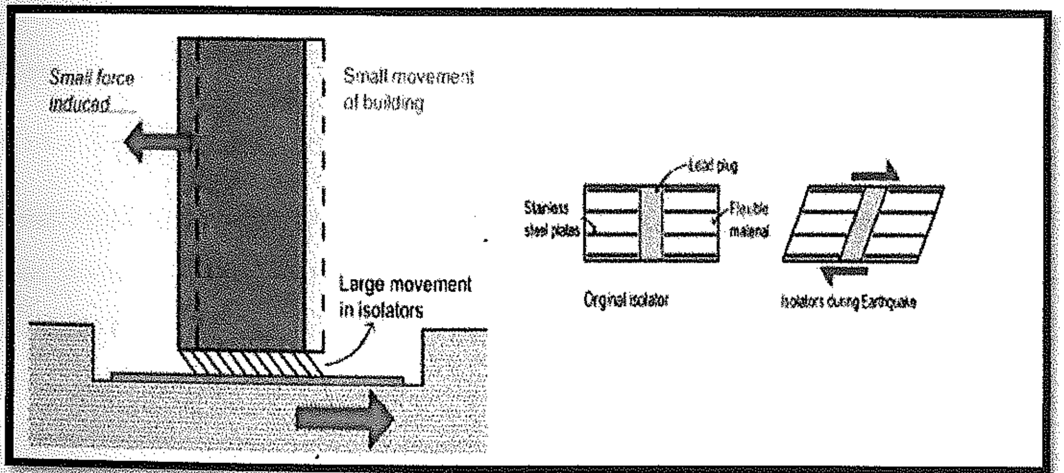

Figure 2.19: Building base isolated with rubber isolator.

2.6.1 Various Type of Base Isolator

2.6.1.1 Elastomeric bearings

Base isolators are widely used in nowadays. This is because due to the advantages of installing base isolator into the building. The materials that made up elastomer are natural rubber or neoprene. Inside the isolator, the steel plates and rubber are as one unit, it is just like a sandwich. Elastomeric bearing will compress the vertical load from the top and resist horizontal movement and give lateral shear movement. These bearing pads are most friendly user among the construction of buildings and large span of bridge.

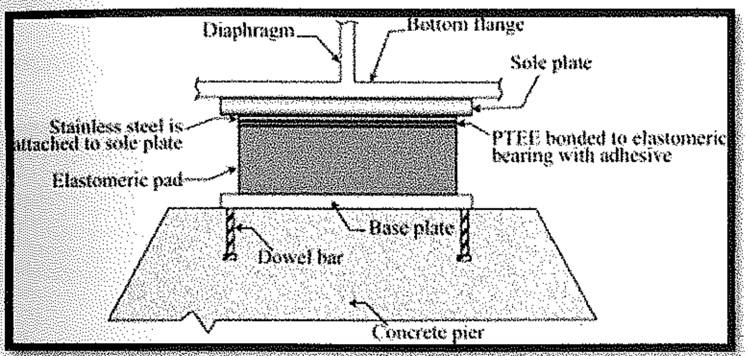

Figure 2.20: Elastomeric bearings

2.6.1.2 Lead Rubber Bearing

Lead rubber bearing, LRB is a type of base isolation which can stand a heavy damping. It was invented by William Robinson, a New Zealander. Base isolation devices, is often considered a valuable source of suppressing vibrations thus enhancing a building's seismic performance. The bearing is made of rubber with a lead core. It was a uniaxial test in which the bearing was also under a full structure load. Many building and bridges are protected with lead dampers or lead and rubber bearing.