PERFORMANCE AND BEHAVIOR OF FOUR STOREY SCHOOL BUILDING REINFORCED CONCRETE STRUCTURE UNDER ACHEH AND BUKIT TINGGI EARTHQUAKE LOADING

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NURNAJAT NADIRA BINTI ABDUL RAHMAN

Thesis submitted in fulfillment of the requirements
for the award of the
Bachelor Degree in Civil Engineering

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In dedication to my family,

For making me who I am,

And my friends for supporting me all the wat

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ABSTRACT

A lot of building in Malaysia is not design according to code that specifies seismic provision since Malaysia is located away from active seismic fault zones. Unfortunately, several tremors comes from neighbouring country especially Indonesia have expose local existing structure to a risk which may not withstand the earthquake load. This research is done to study the seismic behaviour of four storey reinforced concrete building due to Aceh and Bukit TInggi earthquake. Since reinforce concrete structures are widely used in this country, the behaviour of this types of structure is observed to model and analyses the reinforced concrete structure subjected to different earthquake loads using SAP 2000 program and also to determine the best mode shape of free vibration analysis. Besides that, this research also to study the behaviour of four storey RC structure that is subjected to different earthquake loading and to determine the performance of RC structure during earthquake force. All the data of earthquake load were taken from Malaysia Meteorological Department (MMD). Eurocode 8 that considering seismic provision were used for response spectrum analysis. From the analysis, the vulnerability of reinforced concrete structure and dynamic characteristic can be obtain and used for design a safer structure.

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ABSTRAK

Kebanayakan bangunan di Malaysia direka tidak mengikut kod rekaan yang mengambil kira risiko seismic terhadap sesebuah bangunan. Hal ini kerana, Negara Malaysia terletak di dalam zon selamat dan jauh daripada zon aktif seismic. Malangya, beberapa gegaran dapat dirasai di beberapa kawasan disebabkan oleh bencana gempa bumi di Negara-negara berdekatan terutamanya Indonesia. Ianya, telah memberi risiko dan mendedahkan bangunan tempatan yang sedia ada kepada bahaya. Kajian ini dijalankan untuk mengkaji tindakbalas bangunan konkrit tetulang bangunan sekolah empat tingkat terhadap gegaran gempa dari Acheh dan Bukit Tinggi. Disebabkan bangunan jenis tetulang besi banyak digunakan di Malaysia, kajian terhadap tindakbalas bangunan dilakukan dan analisis tertakluk kepada beban gempa bumi yang berbeza mengunakan program SAP2000. Maklumat data gempa bumi diperoleh daripada Jabatan Meterologi Malaysia (MMD). Eurocode 8 yang mengambil kira beban seismic digunakan kan untuk analisis reaksi spectrum. Hasil daripada analisis tersebut, kelemahan dan ciri-ciri dinamik bangun konkrit tetulang dapat digunakan untuk reka bentuk bangunan yang lebih selamat pada masa akan dating.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

U1	Move in x-direction
U2	Move in y-direction
d	Depth
u	Perimeter
Z	Lever arm
Ø	Diameter
θ	Angle
fck	Concrete strength

LIST OF ABBREVIATIONS

2D	Two dimensional
3D	Three dimensional
RC	Reinforced Concrete
DL	Dead Load
LL	Live Load
WL	Wind Load
BKT TINGGI	Bukit Tinggi
RSA	Response Spectrum Analysis
SAP	Structural Analysis & Design Program

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Malaysia is located somewhat far away from active seismic fault zone. In any case, it is clear that this region is encompassed with high seismicity zone at east, south and west part as shown in figure below

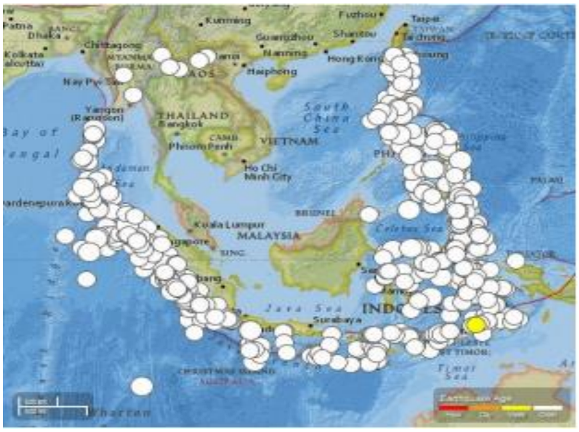


Figure 1.1 Earthquake event
Source: Zuli (2016)

This is related with the subduction between the Eurasian plate and Indo-Australian plate at the south and west part, likewise the subduction between Philippines and Eurasian plate at the east region. Before Malaysian step in the 21st century, all civilians are totally not aware of the earthquake hazard. They might only heard about incident catastrophic 1996 Kobe that happened in Japan and also in Turkey which is the 1999 Koacaeli earthquake, then they just showing sympathy to the all victims involved. The next following few days, they overlooked about the disaster incident and proceed their daily life as usual without worrying about dangers ahead. However, on December 2004, the world was shocked by a large earthquake which occurred at the west of Aceh, in Sumatera Indonesia, had turn into a reminder to all Malaysian as they felt the shaking or vibration at their home. The tremor with magnitude of 9.0 which causes an appalling Indian Ocean tsunami with a very high tidal that shore of a few nations in Asian district.

In Peninsular Malaysia, a sum of 76 people have been accounted killed and a lot of properties and belonging was destroyed when the tsunami strikes along the northwest coastal areas of Kedah, Perak, Perlis and Penang. Then the tsunami had been felt in Malaysia due to seismic tremors with the size magnitude of 8.6 which happened on 2005 March 28 in Nias and 2012 April 11 in Aceh, Sumatera Indonesia. (Adiyanto,2014)

1.2 PROBLEM STATEMENT

Malaysia is not included in active seismic fault zone, a lot of structures in Malaysia had been design according to BS8110 which is not considering any seismic provision. After encountered several tremors that comes from neighbouring nations, Malaysian begin to make a judgement on the probity of existing structures in Malaysia to resist the earthquake effect. It have been reported that a lot of buildings in Peninsular Malaysia still in a good performance and minimum 50% of selected buildings is known to felt or experience the concrete deterioration issue due to the vibration during earthquake. (Abas, 2001)

In a real earthquake situation, the first vibration is always subsequent by other vibration. This is the natural behaviour of earthquake and may arise not many hours after the previous one, and may occur constantly to a few days. In engineering view, it also known as repeated earthquake or multi event earthquake. Thus, during a huge earthquake event, structures are imposed to the action of tremors load more than one. The structure may exposed to the minor to medium damage after experiencing the first quake resulting in strength and stiffness degradation of the global system. If these structures are not repaired, they are expected to having worst damage that lead to collapse. Therefore, this research study will examines the resistance of earthquake and the performance of reinforced concrete building. The reinforced concrete structure modelling analysis was using the SAP2000 software.

1.3 RESEARCH OBJECTIVE

The main objectives for this research are:

i. To determine the vulnerability of existing four storey reinforced concrete building under earthquake loading.
ii. To compare the force produce in the reinforced concrete building under Acheh and Bukit Tinggi earthquake load.
iii. To study dynamic characteristic of reinforced concrete building under different types of loading.

1.4 SCOPE OF STUDY

In this research, the earthquake performance and behaviour of RC building will be investigated. The scopes of study for this research are:

i. The case study of this research is around the area of Acheh, Indonesia and their effect to reinforced concrete structure in Malaysia.
ii. The type of structure used is double storey building.
iii. Analyse the data provided from Malaysia Meteorology Department (MMD)
iv. The software that will be used for this research is analysis SAP2000

1.5 RESEARCH SIGNIFICANCE

The significance of this research is to analyse the earthquake motion of the ground due to Acheh, Indonesia earthquake for assessment of reinforced concrete building in Malaysia. Other purpose of this research study is to know vulnerability of existing critical structure in Malaysia when subjected to loading and also to know the dynamic of the structure. Many lives could be saved if the structures in Malaysia consider the safety factor of earthquake effect by design it to withstand the vibration from the seismic waves. (Arnaldo, 2001)

CHAPTER 2

LITERATURE REVIEW

2.1 EARTHQUAKE

Earthquake is one of the most dangerous natural disasters that usually happen in a few regions. Lately a huge earthquake has attack West Sumatra and has caused a severe damage. Earthquake is normally caused when the underground rock breaks suddenly along a fault. This abrupt is release of energy that causes the seismic waves. It makes the underground layer produce a movement or shaking. When the two plates or two blocks of rock are collides each other, they are not smoothly slide and the rocks are actually pushing forcing each other until the it reach the highest pressure and finally breaks and produce an earthquake. The underground phenomenon will constantly moving until they stuck again and the cycle repeated.

In other words, earthquake is a massive vibration of the ground begun by the abrupt movement of a large section called tectonic plates of the outermost crust of earth rock. The edges of the plates are distinct by the fractures or fault lines. A lot of earthquake appear along the fault lines when the plate colliding against each other.

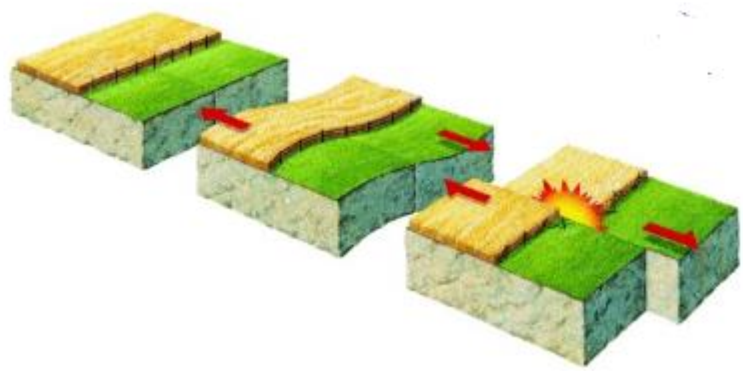


Figure 2.1 Crustal Stress

Source: British Geological Survey, Natural Environment Research Council)

The change of masses carry the sudden waves that might be strong enough to change the surface of the earth, sink up the cliffs, produce a huge cracks on the ground. It also can cause a terrible damages such as collapsing a building or structures, exterminate the power and gas lines, tsunamis, eruption of volcanic and landslides.

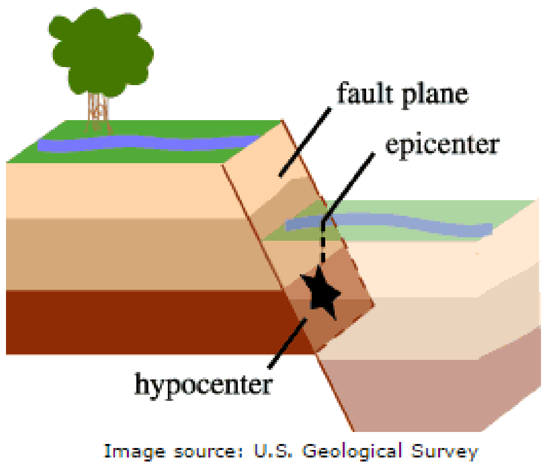


Figure 2.2 Location of earth surface

Sources: U. S. Geological Survey

An earthquake begun from a place and then will transmit in all direction through the fault plates. The underground point in earth is known as focus which release the energy and it will act as the area on one side of fault that move with the rocks on another side of the fault plates. The top of the earth layer that lies athwart above the focus is called epicentre. This is an earthquake phenomenon may cause the serious damages and defect up to 200km of its radius from the epicentre. (Wald, 2016)

For the local affect towards earthquake, West Malaysia is considered as a seismically safe or stable area. Eventhough there is no earthquake has begun or arising from our area, the flooding incidence in Kenyir Dam, Terengganu between year 1984-1987 has produce a seismic activity. Despite that, Malaysia is free from the risk of an earthquake due to west Malaysia is still categorized as vulnerable because of the location lies near to the Sumatran subduction zone or Sumatran fault. Massive earthquake that comes from this zone has created a somewhat round motion over the west part of Malaysia. For the east Malaysia, they are classifies as moderate active seismic. Some location has faced the earthquake at local origin with quite high magnitude up to 5.8 scalar ritcher.

2.2 SEISMIC WAVE

Earth or other planetary body can be express as an elastic object since it supports the circulation of traveling waves. A phenomenon like an earthquake at any location on earth will generate energetic waves known as seismic waves. The crust of the earth as a solid object will carry waves called body waves and the surface waves. This seismic waves are the energy that arise from the abrupt of breaking rock within the earth or explosion. They travels along the earth and recorded on seismograph.

Seismic waves consist of three types of waves and they all activate in different ways. The main types of waves are:

i. Body waves

ii. Surface waves

iii. Rayleigh waves

The body wave travel through the inner earth of earth, they occur before the surface waves discharge by an earthquake. These waves usually in a higher frequency compared to surface waves. While surface waves travel only through the crust and have a lower frequency than body waves. It is easily perceive on a seismogram as a result. This waves arise after body waves and responsible for the destruction and damage associated with earthquake. The strength of surface wave are lower in deeper earthquake

2.2.1 Body Waves

Body wave is an interior move of the waves and consist of two types of waves which is:

i. Primary waves (P waves)

ii. Secondary waves (S waves)

P waves or primary waves is the quickest types of seismic waves and it is the first waves to reach at a seismic station where the speed is twice of S waves. It can moves through any types of fluid and solid rocks such as water or liquid layer of earth. P waves pull and push through the solid rocks just like the sound waves that went through the air. The waves are longitudinal in nature which is a compressional waves. The particles of P waves move in the same order or direction with the energy travels are called ‘direction of the wave propagation. (Bachmann, 2002)

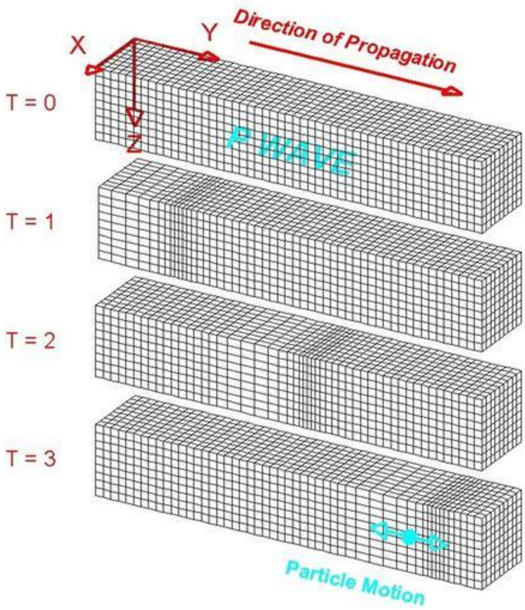


Figure 2.3 This cube model represented a P wave particle which travels through a medium of compression and dilation

Source: Lawrence Braile, 2000-2006

The second category of body waves is S waves or called secondary waves are the waves that transverse in nature which is shear waves. After an earthquake strikes, S waves will reach at the seismic station after the P waves and change the ground perpendicular to propagation direction. S waves does not travel through fluid such as liquid or gases because it does not support shear stress but can only travel through solid rock. The rock particles of S waves move side to side or up and down perpendicular to direction of the traveling waves. (Bachmann, 2002)

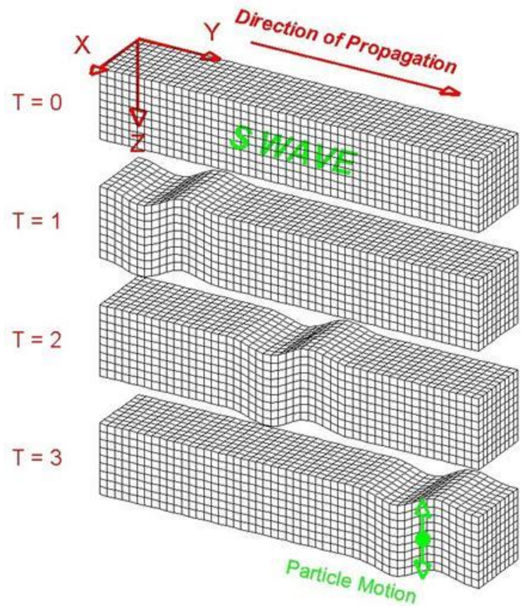


Figure 2.4 This cube model represented a S wave particle which travels through a medium

Source: Lawrence Braile, 2000-2006

2.2.2 Surface Waves

Surface waves are the waves that travel along the surface of the earth and it can be classified in the form of mechanical surface waves. This type of waves moves more slowly compared to seismic body waves. Surface waves travel only through the crust and easily notable as a result on seismogram.

Love wave is the first kind of surface waves. Bound to the surface of the crust, it make an entirely horizontal motion and exist only when the presence of semi-infinite medium top by an upper layer of thickness. (Bachmann, 2002)

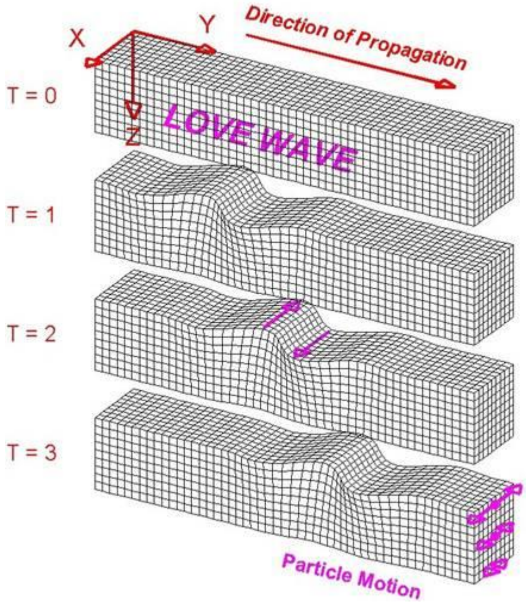


Figure 2.5 This cube model represented a S wave particle which travels through a medium

Source: Lawrence Braile, 2000-2006)

2.2.3 Rayleigh Waves

Rayleigh waves which are also known as ground rolls, are one of the surface waves that moves in motion as ripples which similar to the waves on the surface of water. Due to the waves rolls, it move the land or ground side to side and up and down same direction with moving waves. Major of the concussion felt from earthquake due to this type of waves, which might be larger than other waves. The Rayleigh waves are slower than body waves and its velocity is depend on their wavelength and frequency.

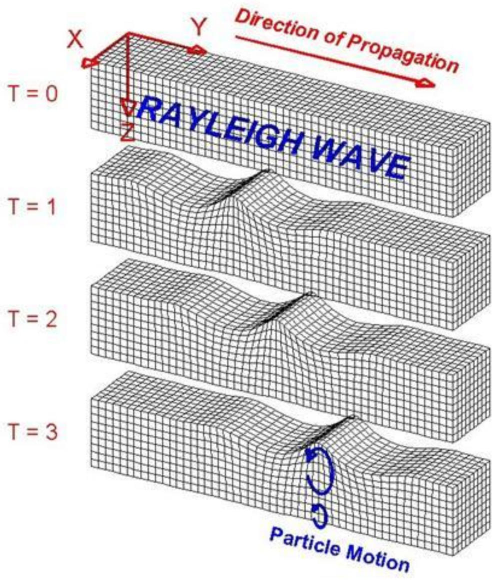


Figure 2.6 This cube model represented a S wave particle which travels through a medium

Source: Lawrence Braile, 2000-2006

2.3 MEASURING EARTHQUAKE

2.3.1 Seismographs

Seismographs are the machinery that is used record and detect the measurement of an earthquake. Seismologist used seismograph as their tool of principles to study seismic waves. This instrument is very sensitive because it can detect record and measure the ground motion or vibration and also their intensities during earthquake. The seismograph is used to measure:-

i. Magnitude: to know the size of an earthquake

ii. Location: to know where the earthquake occur

iii. Depth: to know how deep the earthquake

Normally, the instrument consists of a mass hook up to the fixed base. When the earthquake strikes, the mass doesn't moves due to inertia but the base are moving because the base motion with respect to the mass usually convert into an electrical voltage. The voltage of an electrical is recorded in magnetic tape, paper or other medium and the record is proportional to the seismometer mass relative motion to the earth, but it can be converted into a record of the complete motion of the ground.

A seismograph consists of a simple pendulum. When the ground moves and shakes the frame and base move together with the vibration but the inertia make pendulum remain on its place. The displacement of the pendulum records the changes over time the record of the out tracing of the event known as seismogram. The pen below the weight marked a zigzag on the moving rotating drum or paper whenever an earthquake event is detected. The seismogram (the paper) is detached and replaced to help the seismologist to know the epicenter, focus, time and types of faulting that formed earthquake also know the amount of energy released.

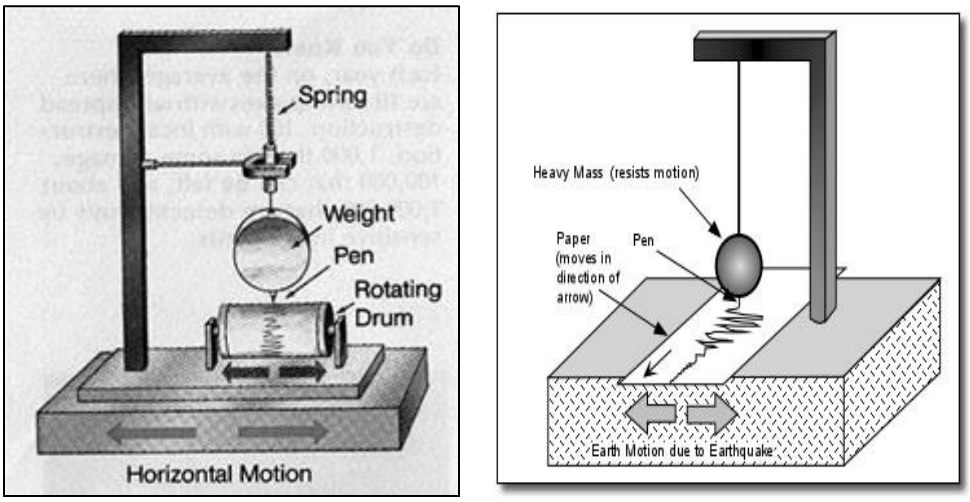


Figure 2.7 A seismograph used to measure the ground motion
Source: U. S. Geological Survey,2016

2.4 EARTHQUAKE MAGNITUDE

There are many ways of determining the magnitude of an earthquake. The first commonly used method was the Ritcher scale developed on 1934. The formula used is based on amplitude of the biggest wave recorded on the exact type of the seismometer and the distance between the seismometer and the earthquake. The phase of an earthquake can be different from event which are almost cannot be detects even when using a practical devices.

The amplitude or height of the biggest recorded wave of an earthquake event at an exact distance is called the Richter magnitude. Using a Richter scale, each form of magnitude is 10 times more accelerated than the previous one, which means that it is 10 times faster than a one and a three is one hundred times bigger. Despite of that, while it is accurate to say that an increasing in 1 in the Richter magnitude there is a decimal increase in amplitude of wave, it is wrong to say increasing of 1 in Richter magnitude shows a decimal increase in the size of the earthquake as it is usually incorrect. A better determination of the size of an earthquake is the total of energy released by an earthquake, which is relevant to the Richter scale by using the following equation:

$$\text{Log } E = 11.8 + 1.5\,M \qquad 2.1$$

Log is the logarithm to the base 10 and M is the Richter magnitude and E is the energy released in ergs.

Table 2.1 Earthquake severity-Ritcher scale

Ritcher Magnitude	Earthquake effects
0-2	**Not felt by people**
2.3	**Felt little by people**
3-4	**Ceiling lights swing**
4-5	**Walls crack**
5-6	**Furniture moves**
6-7	**Some building collapse**
7-8	**Many building destroyed**

8-Up	**Total destruction of buildings, brides and road**

A depth is one of the important factors in influencing the earthquake severity. We know that earthquakes can arise with various depths in the Earth's solid core. Increasing in the earthquake depth, will cause the more powerful quake, but it is also less to reach the surface. That is the reason why the shallow earthquakes are more dangerous and more common, because the shallow the earthquake, a lot of damage to the surface structures it can cause.

2.5 REINFORCED CONCRETE FOUR STOREY BUILDING STRUCTURE

Reinforced concrete structures are one of the most demands in structure system. Many contractor or developer in Malaysia are using reinforces concrete structure system for their project but there are many cases where they design the structure just because of the design ideas without considering the safety of seismic factor. Usually the seismic or earthquake consideration of the building would not be the primary focus because it might be disturbing the unique design of the structure.

The issues when designing an earthquake resistant of a reinforces concrete buildings such as the design of structure for many loading condition is one of the deformation in structure preliminary design and provide the detailing and proportioning of the members also their connections.

However, the structural behaviour during recent earthquakes has shown a strong basis for dealing with the problem in a more rational way. The refinements in design approach can be expect as more information is collected on earthquakes and on the response of the particular structural configurations to an earthquake type of loadings. As for the design of other loading conditions, the design is commonly focuses on the area in structure where experience and analysis indicate are to be subjected to the most serious demands. The special emphasis is focused on region where the failure can affect the stability and integrity of a similar portion of the structures.

In designing a structure against earthquakes is to make sure that the structure has the ability to resist the movement and loads caused by an earthquake, avoiding irreparable damage and collapse. Various types of building are classify into different levels of importance which the seismic design is concerned. Office building and residential are consider as medium priority, means that the members of basic structural are considered acceptable and expected. However, the resistance of the building consideration against lateral loads, limit lateral sway, the code of practice and acceleration. Usually, a building acceleration is due to wind load which last longer than earthquake loads. Therefore, it has said that a building that has been analysed for acceleration due to wind load will satisfy the acceleration limit in controlling earthquake.

2.6 SAP2000 PROGRAM

SAP can be classified as an art of analytical and structural program for designing and analysing of civil structures. This software feature is very sophisticated, advanced, versatile with the consumer with the interface operated by design tools which is very fast and perfect for construction models for engineer to finish up the complex projects.

SAP is the program that gives the understanding of the model forms using structure member that characterize the physical reality. After that, the complex models can be generated and appropriate with dominant that formed in templates. The integrated code character will be automatic produce a wind, wave and seismic loads with inclusive automatic steel and also the design standard. SAP also allows the analytical techniques with step by step with non-linear analyses that would be non-linear or static of time history dynamic analysis.

From an unsophisticated small 2D static frame analysis transforms to a great complex 3D nonlinear dynamic analysis. The software of SAP 2000 is the simplest, most helpful, practical solution for the design and structural analysis.

Figure 2.8 SAP 2000 Program Version 15

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Methodology is the organized or systematic theoretical analysis of the application of method and steps involved in this research. Other definition of methodology is the analysis of procedures in this research and it is needed to be shown to explain how the project or research is being carried out until finish.

However, this chapter will give the methodology on how this research obtains the data collection and its analysis. Plus, it will also include the further details of research procedure and method used to fullfill the objective of the study. In this research, the software used is ESTEEM and SAP2000. In order to ensure this project is successful, the scheduling and planning are as follows:

3.1.1 Research Planning

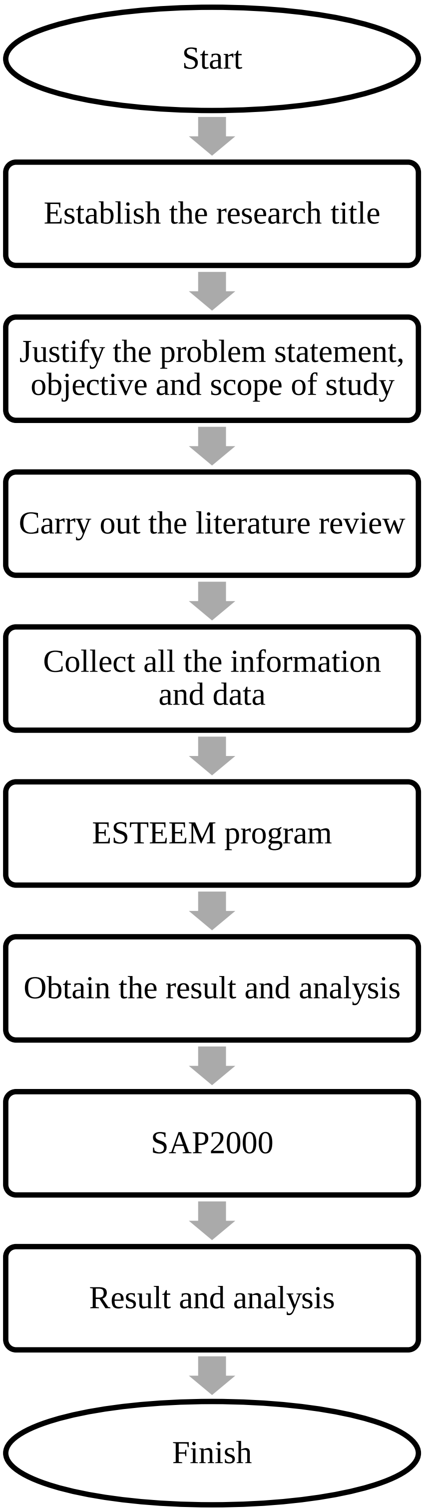


Figure 3.1 Flowchart of research planning

3.2 LITERATURE REVIEW

In this phase, all the data, studies, facts and information that related to this research are being collected. The collecting data process is concentrate on the main topics of this project as follows:-

1. Earthquake
2. Seismic wave
3. Measuring Earthquake
4. Earthquake Magnitude
5. Reinforced Concrete Structure Drawings
6. ESTEEM Software
7. SAP2000 Program

3.3 INFORMATION AND DATA COLLECTION

In this stage, in ensuring the research is run smoothly, the further data and information for the analysis and modelling work need to be carry out. The data and information that required are as below:-

1. Drawing of the reinforced concrete structure
2. Material and types of the structure
3. Loading carried by the structure
4. Data of the earthquake from Malaysia Meteorological Department (MMD)

3.3.1 Reinforced Concrete School Building Structure

For this research, one structure have been chosen which is 4 storey school building and the loads is includes column, beam and slab. The load of walls is ignored for this analysis.

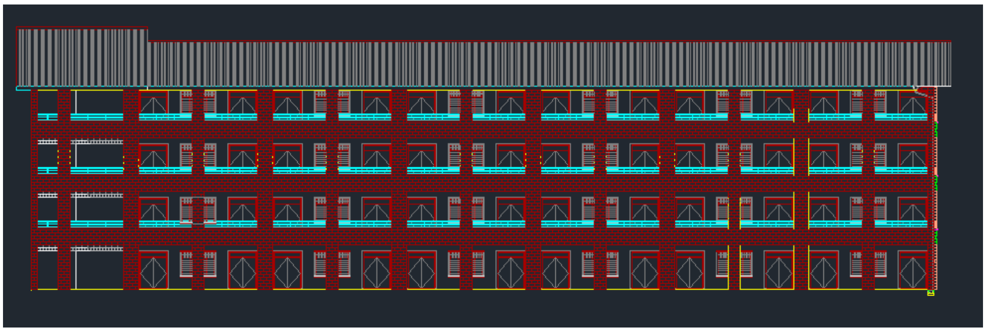


Figure 3.2 AutoCAD Drawing of front view School Building
Source: Autocad drawing of four storey school building

Figure 3.3 AutoCAD Drawing of top floor view
Source: Autocad drawing of four storey school building

3.4 SAP2000 PROGRAM

SAP2000 is a software use for analysis and design of the structural and earthquake engineering. This software feature are very sophisticated, versatile and advance for user with the interface operated by the design tools which is very fast and perfect construction models for engineer to solve the most complex projects.

SAP2000 is one of the most ideal tools and gadget for a great experience in modelling and designing a structural system. The advanced analysis options, designoptimization procedures, integrated modelling templates, customizable manufacturing reports of correspondent, code-based loading assignments, and coordinate beyond a powerful platform to generate SAP2000 is u useful software for studying and practicing professionals.

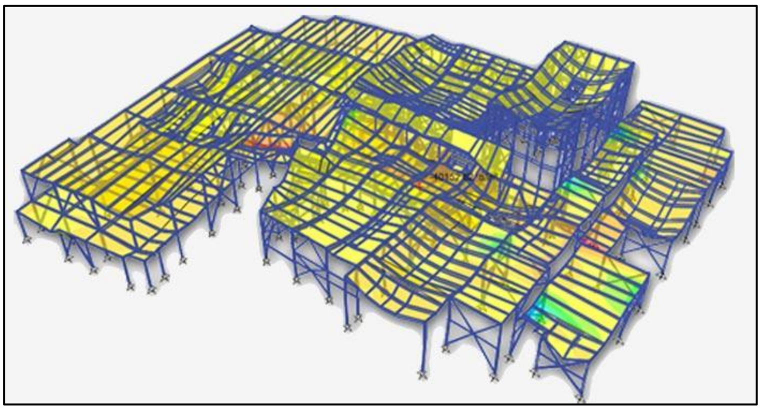


Figure 3.4 Modelling using SAP2000
Source: Steel-Concrete, ETABS

This software will generate and apply winds loads and seismic based on different international and domestic codes. It also contains a practical and mature moving load generator that will allow user to control the moving loads to lanes on frame and shell element.

3.4.1 Modelling

SAP2000 is used in modelling a typical double storey RC building. These are the step in modelling the RC building:-

i. Determine the type of the model of structure to be use

ii. Know the material used

iii. Detailed the section frame properties

iv. Determine the load pattern

v. Define the response of the spectrum function

vi. Define the load case and load combination

vii. Draw the building based on the properties

viii. Define the joint restraint

ix. Run the analysis of the load case

x. Analyses the result from the graph and table attained

3.4.2 Steps in SAP2000 Software

Step 1 : Define types of the model to be analyse

The unit for the analysis which is ‘kN, m, C’ is selected and by referring to the drawing of AutoCAD of four storey RC Building is used as a model. Then, the 3D Frames are selected as template and all the detailing from AutoCAD is inserted for the analysis. The coordinate/grid system data is defined by using the dimension referring to drawing.

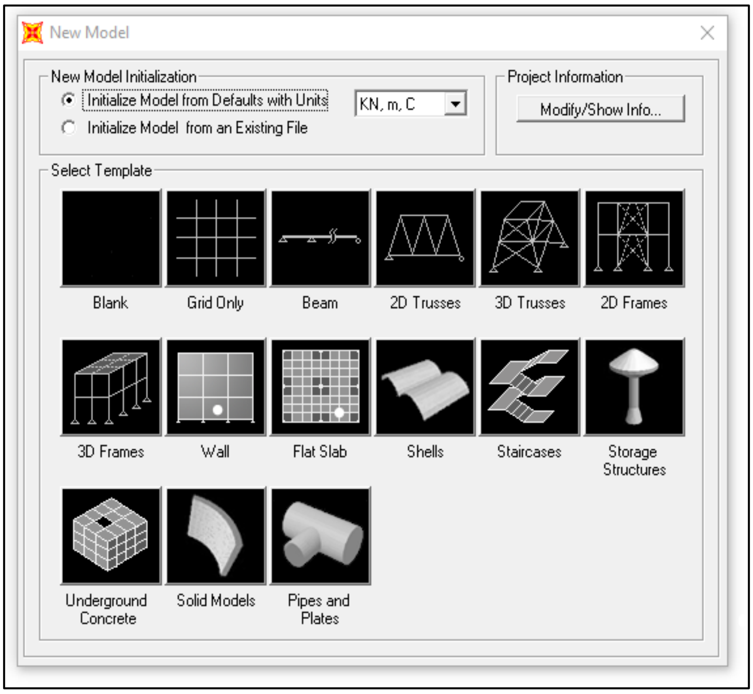


Figure 3.5 Define grid of system data

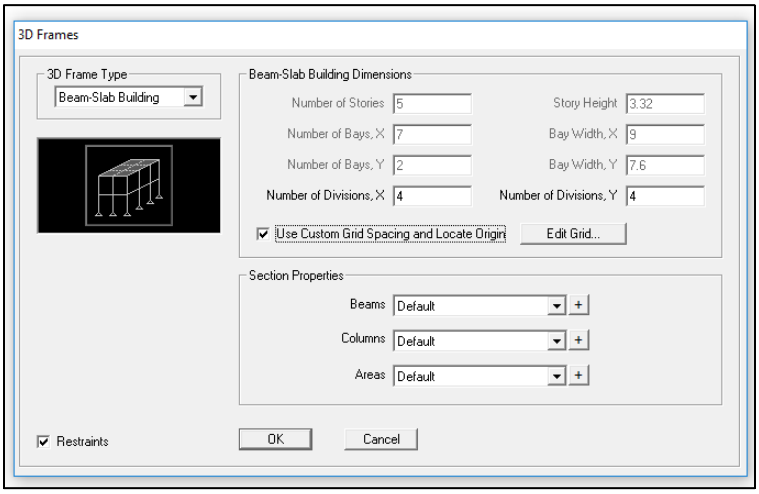


Figure 3.6 Geometry value of the structure

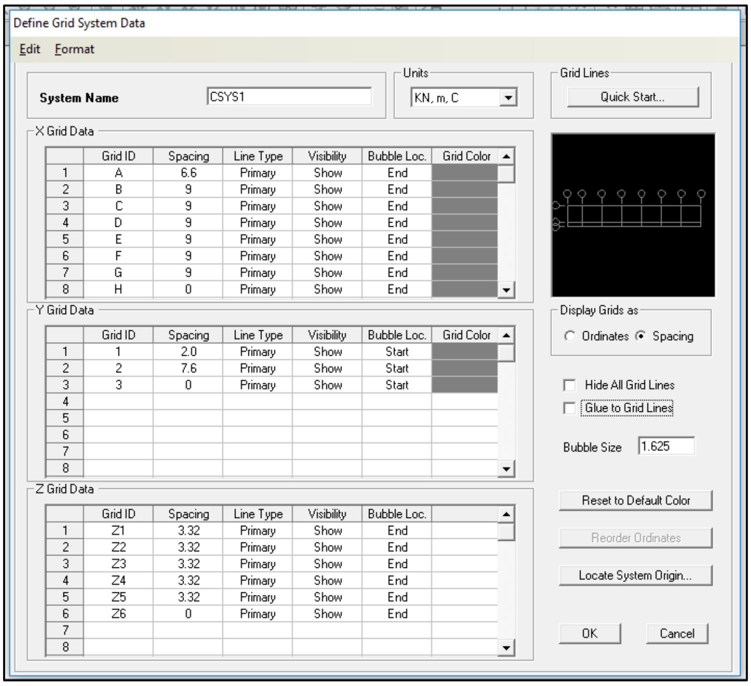


Figure 3.7 Grid Data System

Step 2 : Adding restrain at joint

All the joint is selected and restrain is added at all joint.

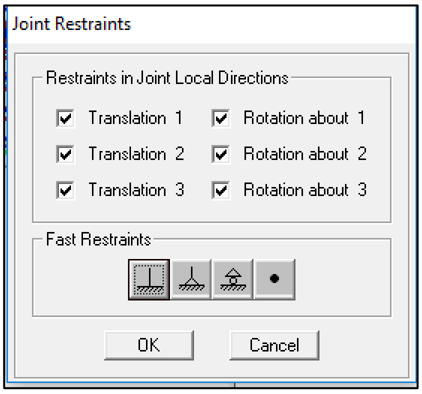


Figure 3.8 Restraints at the base condition

Step 3 : Addition of material and member of the structure

Two concrete frame section which rectangular beam and column are defined by selecting frame section in the menu bar. Then, the 'add new property' is selected and concrete rectangular beam and column was set to the strength C30.

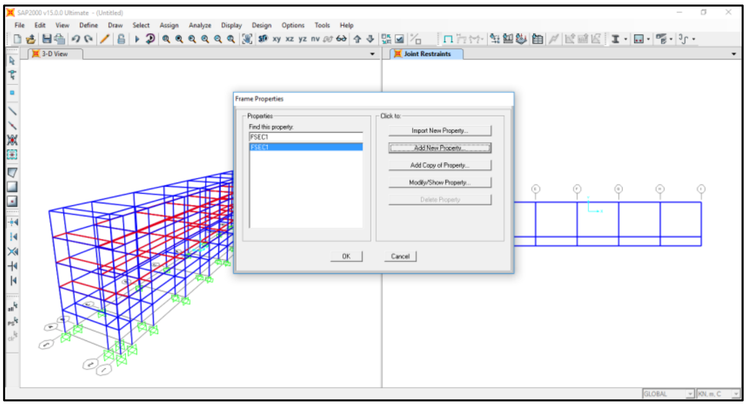


Figure 3.9 Frame section definition properties

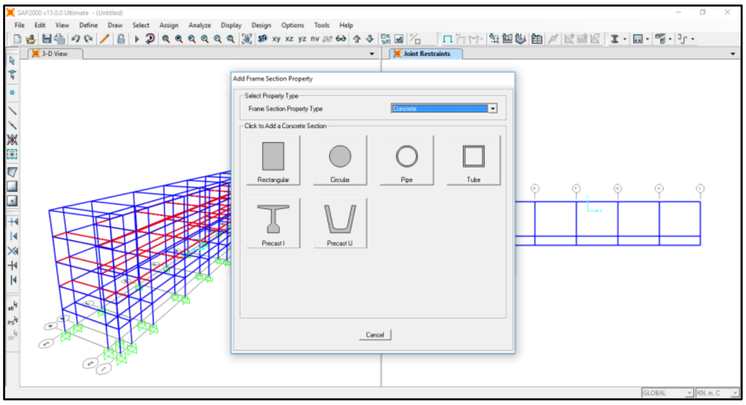


Figure 3.10 Add frame section property

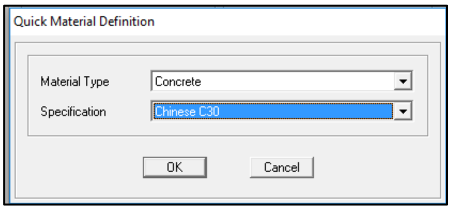


Figure 3.11 Quick material definition

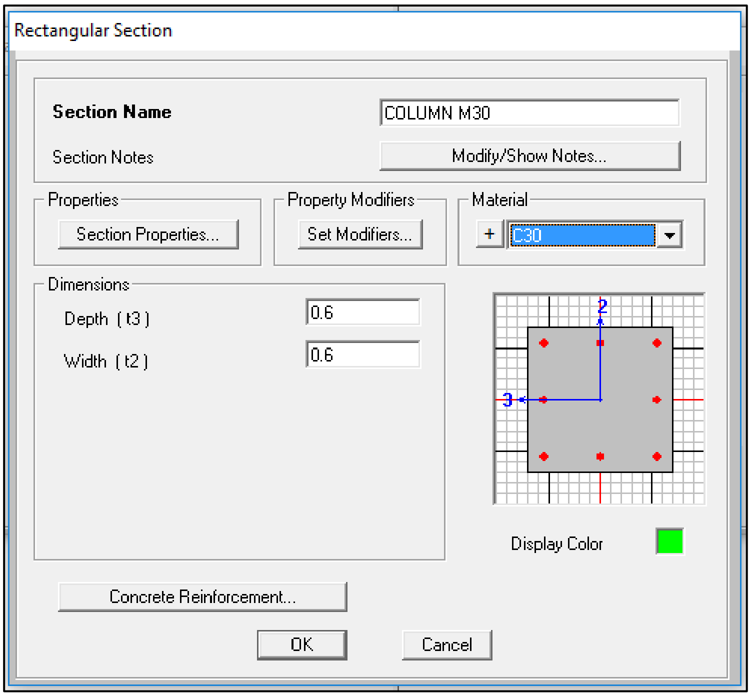


Figure 3.12 Section name and size of section

Step 4 : Defining the area sections of the model

Area of section for the slab area and material are under the section properties is selected and the area was assigned.

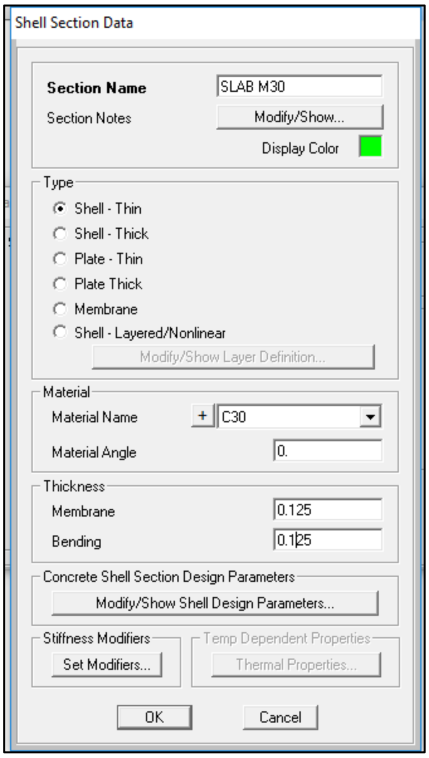


Figure 3.13 Shell section data

Step 5 : Assign all the material to the member

The properties for all beam, column and slab are assigned by selecting the related member of section.

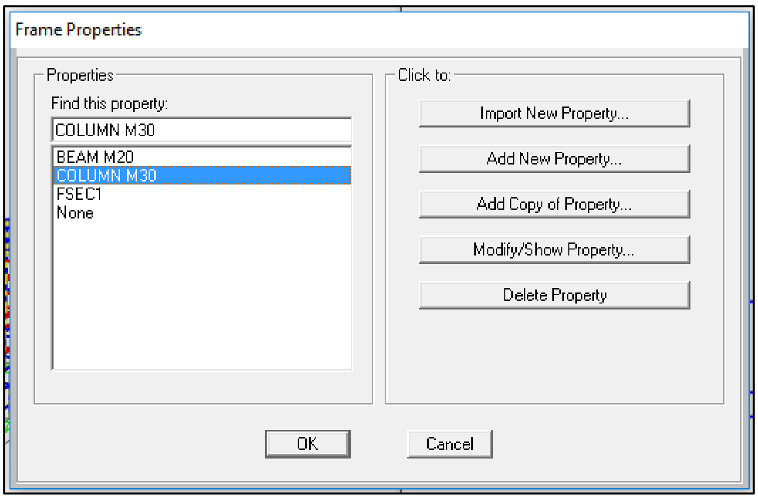


Figure 3.14 Frame properties for column

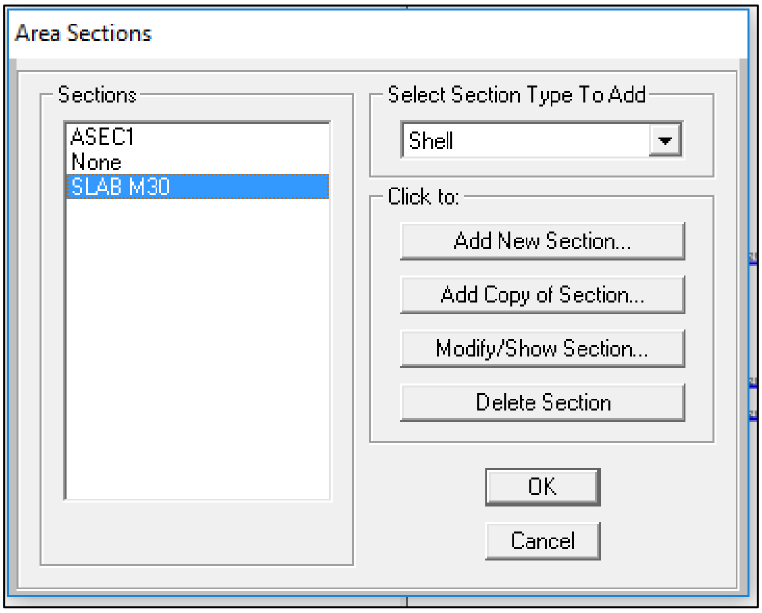


Figure 3.15 Assign of area section of slab

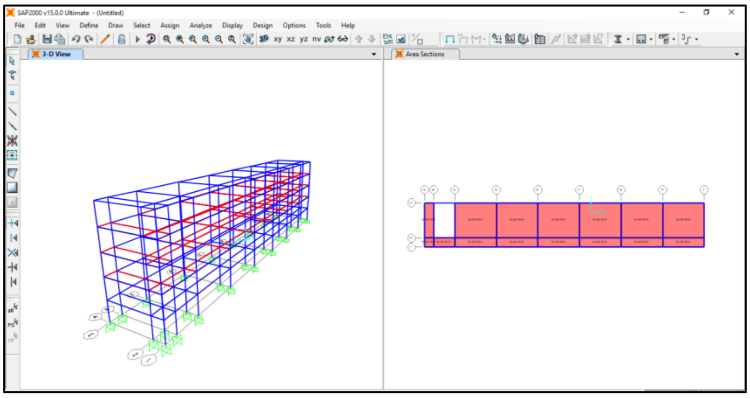


Figure 3.16 Structure layout produced in SAP2000 (2D and 3D)

Step 6 : Setting the function for the analysis

The function included for this analysis is Response Spectrum and Time History Analysis. Therefore, the raw data from Acheh and Bukit Tinggi which were taken from Malaysia Meteorology Department (MMD) is assigned for the analysis.

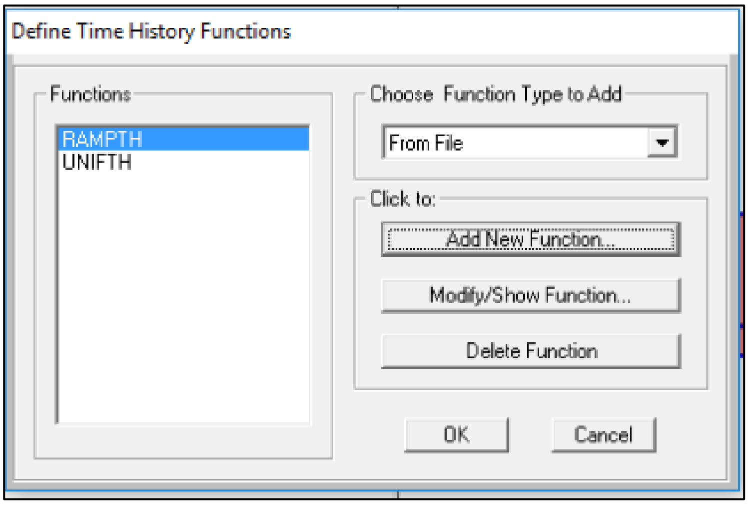


Figure 3.17 Define Time History Functions

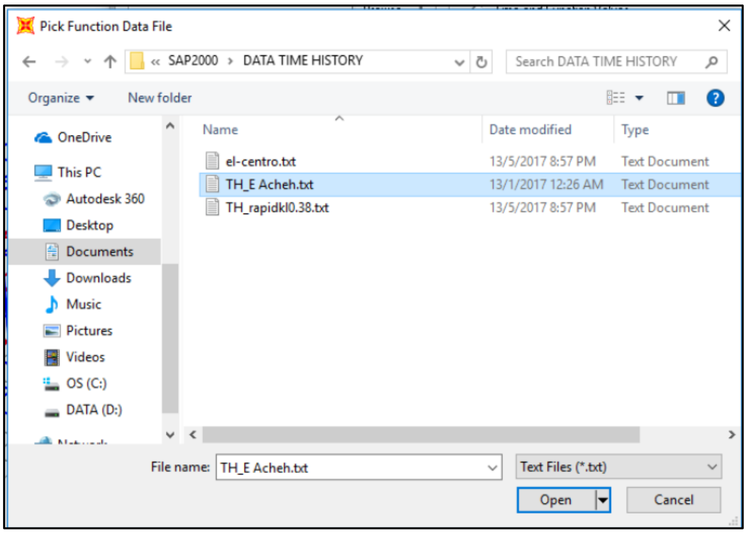


Figure 3.18 Data taken from file

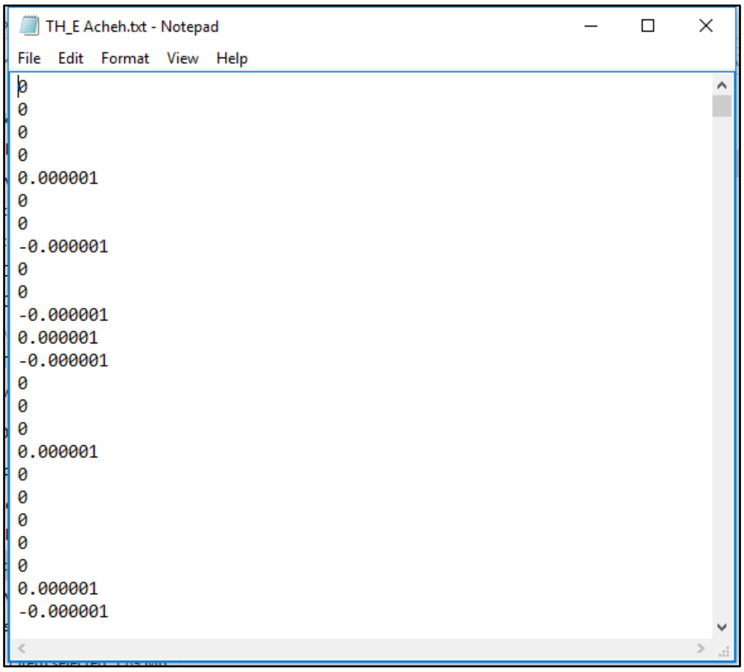


Figure 3.19 Raw Data of earthquake from MMD

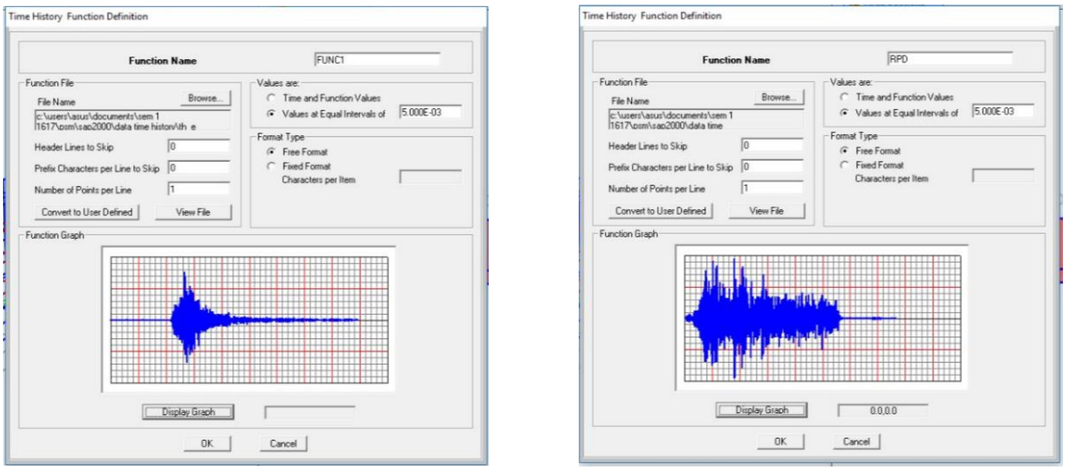


Figure 3.20 Time history function of Acheh and Bukit Tinggi

For response spectrum function, Eurocode 8 is selected and damping ratio are set to 0.05.

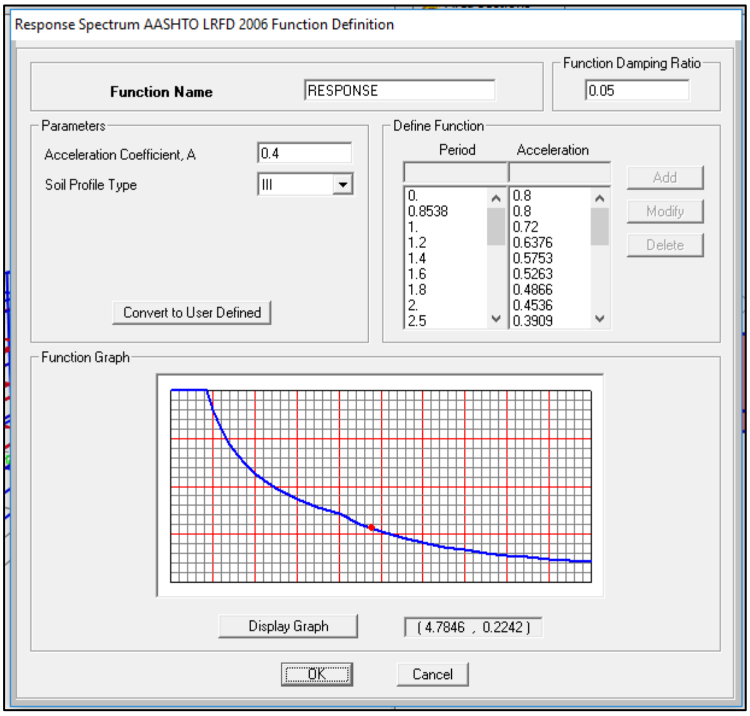


Figure 3.21 Response Spectrum Function

Step 7 : Defining all load patterns

The load cases such as dead load, live load, quake load and wind load is created for the structure with accordance to Eurocode 8.

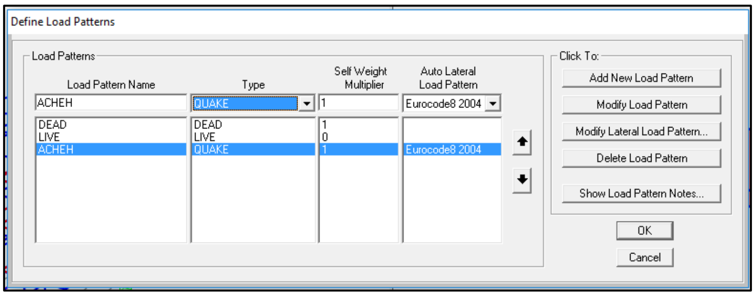


Figure 3.22 Load patterns

Step 8 : Defining the load cases

The response spectrum in U1 and U2 direction and the scale factor is set for all load.

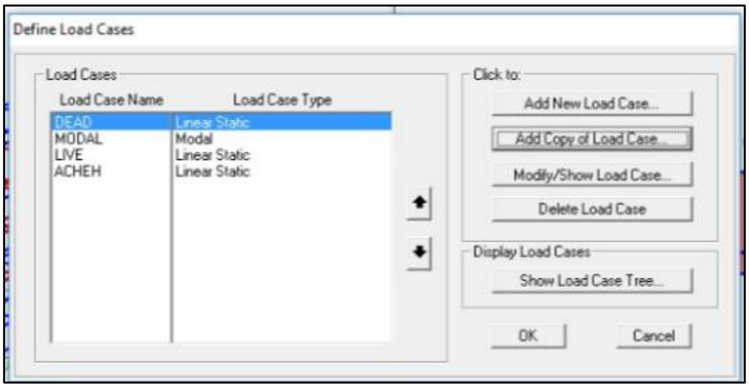


Figure 3.23 Define load cases

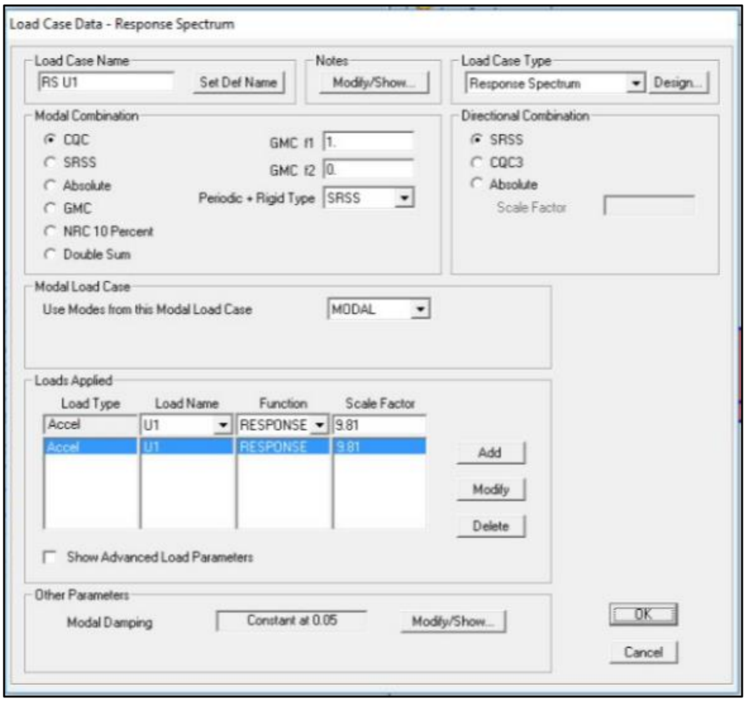


Figure 3.24 Response Spectrum Load Case

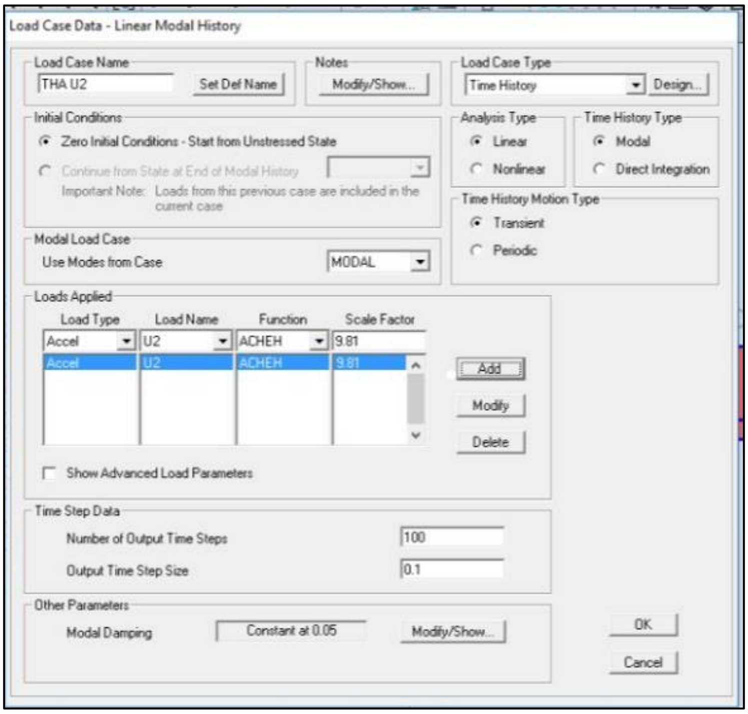


Figure 3.25 Time History Load Case

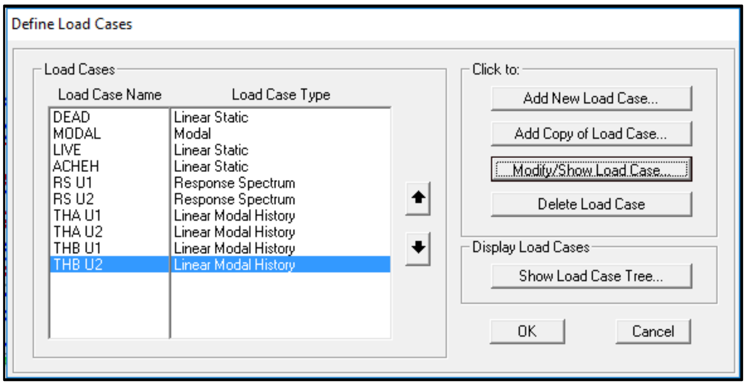


Figure 3.26 Completed Load Cases for analysis

Step 9 : Define Load Combination

For this school building, there are three load cases included which are:

- Dead load and live load
- Dead load, live load, wind load and Acheh earthquake load
- Dead load, live load, wind load and Bukit Tinggi earthquake load

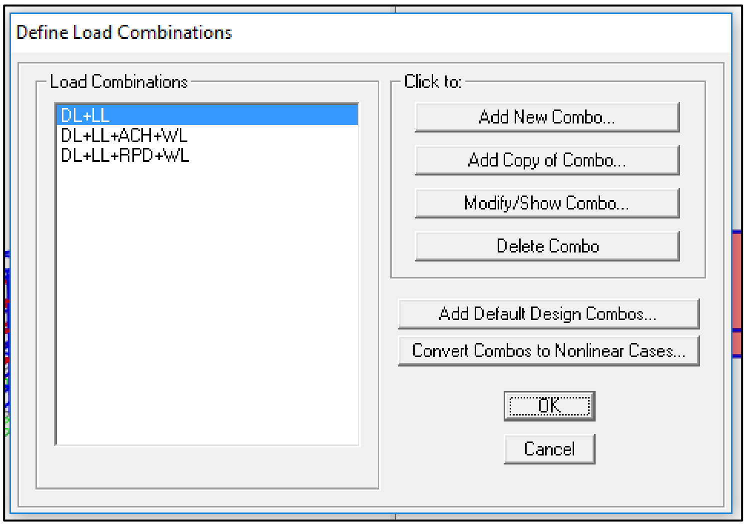


Figure 3.27 Load Combination

Step 10: Analysing the model

The analysis is run for three different analyses. The modal load case is selected and analysis is run. The results of analysis will be discussed in Chapter 4.

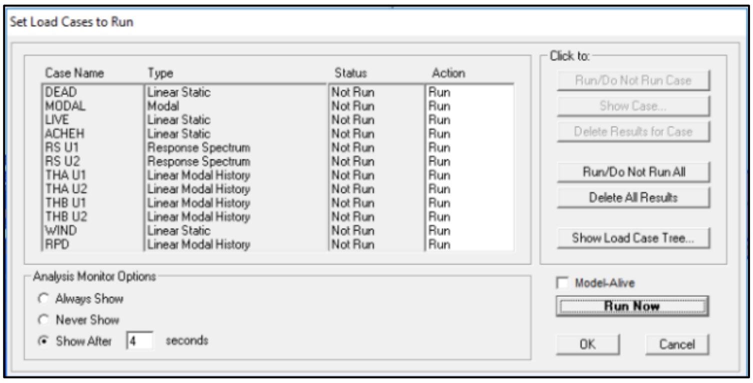


Figure 3.28 Running the analysis

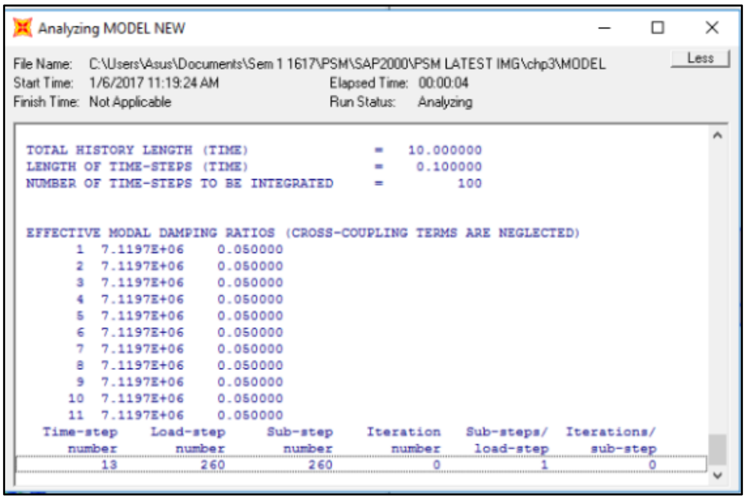


Figure 3.29 Analysing model

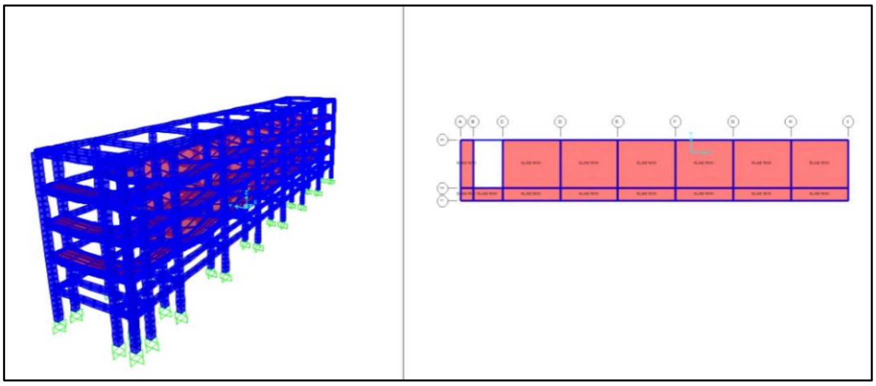


Figure 3.30 Structure of the ran analysis

Step 11: Display result and output table

All the result of diagram and details can be obtained from the SAP2000 and the result can be obtained in the form of table. The analysis and display of the critical member for each load case are obtained. The analysis compares the bending moment, torsion, shear stress, displacement and acceleration for different earthquake loading.

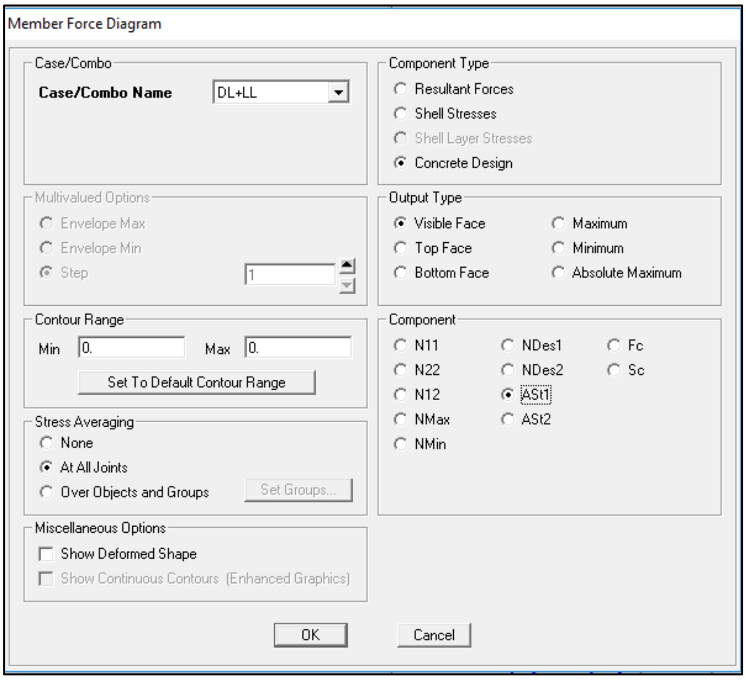


Figure 3.31 Member force diagram

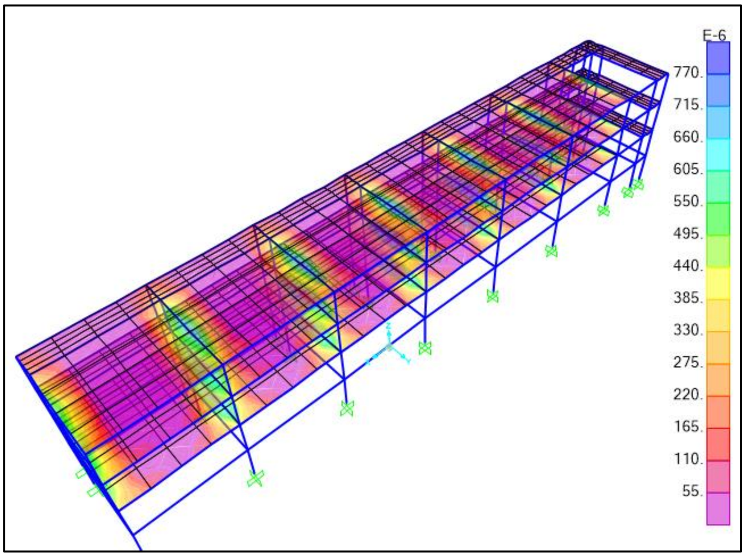


Figure 3.32 Member force mode

Joint Displacements

File View Format-Filter-Sort Select Options

Units: As Noted   Joint Displacements

Joint Text	OutputCase Text	CaseType Text	StepType Text	U1 m	U2 m	U3 m	R1 Radians	R2 Radians
1	DL+LL	Combination		0	0	0	0	0
1	ıL+LL+ACH+W	Combination	Max	0	0	0	0	0
1	ıL+LL+ACH+W	Combination	Min	0	0	0	0	0
1	ıL+LL+RPD+W	Combination	Max	0	0	0	0	0
1	ıL+LL+RPD+W	Combination	Min	0	0	0	0	0
2	DL+LL	Combination		-0.000063	0.00014	-0.000171	-0.00008	0.000015
2	ıL+LL+ACH+W	Combination	Max	-0.000078	0.000154	-0.00022	-0.000093	0.000019
2	ıL+LL+ACH+W	Combination	Min	-0.000078	0.000154	-0.00022	-0.000093	0.000019
2	ıL+LL+RPD+W	Combination	Max	0.0001	0.000219	-0.000169	-0.000063	0.000049
2	ıL+LL+RPD+W	Combination	Min	-0.000202	0.000075	-0.000198	-0.000099	-0.000012
3	DL+LL	Combination		-0.000045	0.000417	-0.000302	-0.000133	0.000044
3	ıL+LL+ACH+W	Combination	Max	-0.000057	0.000468	-0.000388	-0.000158	0.000054
3	ıL+LL+ACH+W	Combination	Min	-0.000057	0.000468	-0.000388	-0.000158	0.000054
3	ıL+LL+RPD+W	Combination	Max	0.00029	0.000598	-0.000298	-0.000113	0.000082
3	ıL+LL+RPD+W	Combination	Min	-0.000324	0.000252	-0.00035	-0.000152	0.000007409
4	DL+LL	Combination		-0.000032	0.000792	-0.000386	-0.000171	0.000054
4	ıL+LL+ACH+W	Combination	Max	-0.000046	0.000903	-0.000496	-0.000204	0.000065
4	ıL+LL+ACH+W	Combination	Min	-0.000046	0.000902	-0.000496	-0.000204	0.000065
4	ıL+LL+RPD+W	Combination	Max	0.000399	0.001042	-0.000381	-0.000151	0.000096
4	ıL+LL+RPD+W	Combination	Min	-0.000495	0.000521	-0.000447	-0.000184	0.000012

Record: 1 of 4545   Add Tables...   Done

Figure 3.33 Force of displacement

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter will represent the result and discussion seismic analysis of a four storey school building using the data of Acheh and Bukit Tinggi earthquake. The analysis of SAP2000 for the building is due to the surrounding seismic in Malaysia and the analysis of earthquake for the structure is considering Euro Code 8.

4.2 CHARACTERISTICS OF FOUR STOREY BUILDING

For this types of structure, it have different amount, size, type of beam and column. In this research, characteristic that being used is continuous concrete beam and the size of 300 mm x 600mm. The characteristic this concrete single storey building is the size of column size which are 600 mm x 600mm. Other than that, the characteristic this four storey concrete building contain of slab thickness of 125 mm.

4.3 ANALYSIS OF FOUR STOREY CONCRETE SCHOOL BUILDING

By using SAP200, the analysis consists of few types of load used for the school building structure which are dead load, live load, and also earthquake load. These are the sets of combination load cases are carried out in this analysis, which are:

i. Modal Analysis (Free Vibration Analysis)

ii. Dead load + Live load

iii. Dead Load + Live Load + Acheh Earthquake + Wind

iv. Dead Load + Live Load + Bukit Tinggi Earthquake + Wind

4.3.1 Free Vibration Analysis (Modal Analysis)

The free vibration analysis or also known as modal analysis is the analysis of the structure in motion movement and without any support motion or external forces. The structure which is four storey building will be moved away from the original position due to the modal analysis.

From the free vibration analysis, the 12 mode-shape of the school building will obtained the natural period which include the natural frequency, displacement and joint. Each mode of RC building will produce different of the natural frequency, natural period, eigenvalue and also the circle frequency. The figure below shown 12 mode shape of the building:

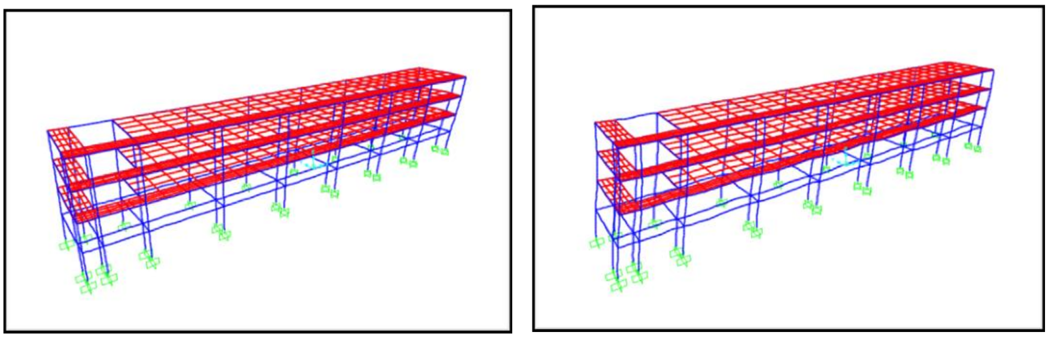


Figure 4.1 Mode shape 1 with period of 0.46635 and Mode shape 2 with period of 0.43678

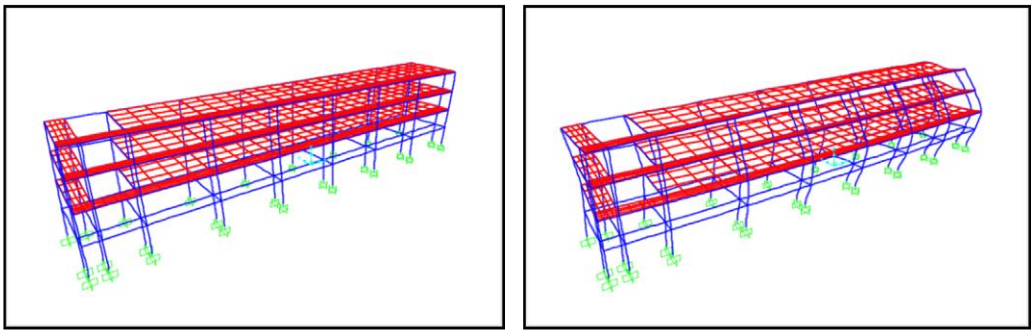


Figure 4.2 Mode shape 3 with period of 0.37340 and Mode shape 4 with period of 0.14240

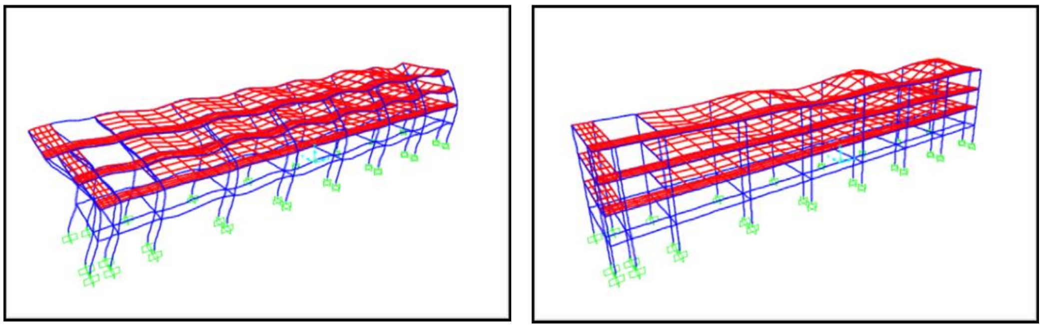


Figure 4.3 Mode shape 5 with period of 0.13440 and Mode shape 6 with period of 0.13031

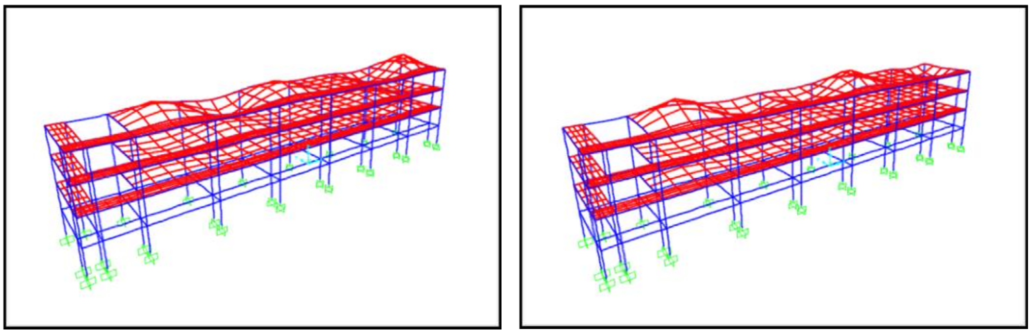


Figure 4.4 Mode shape 7 with period of 0.12784 and Mode shape 8 with period of 0.12498

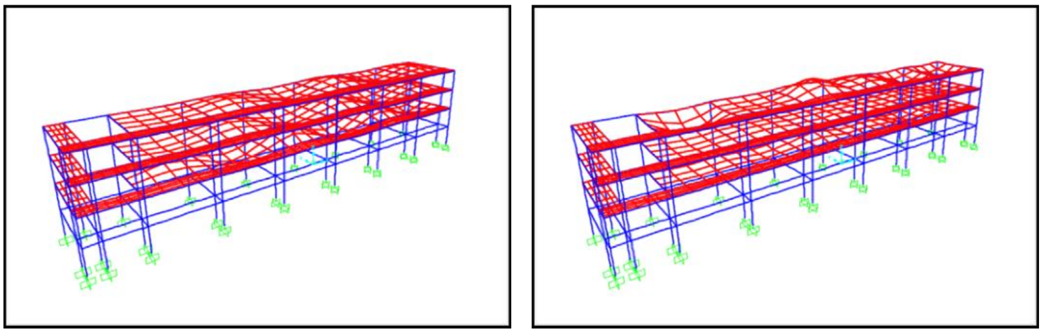


Figure 4.5 Mode shape 9 with period of 0.12453 and Mode shape 10 with period of 0.12305

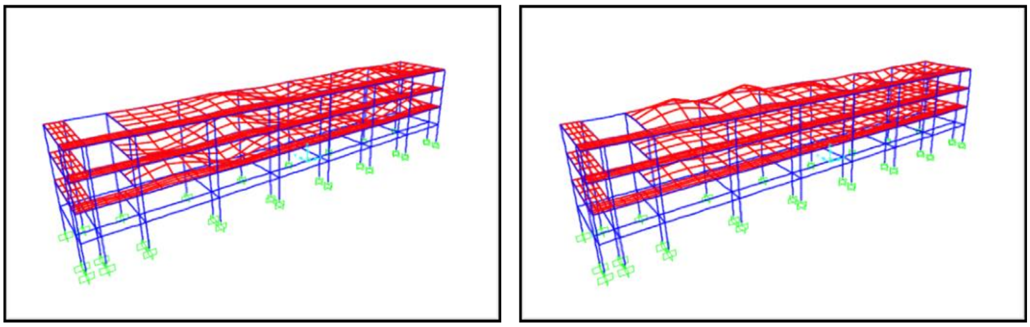
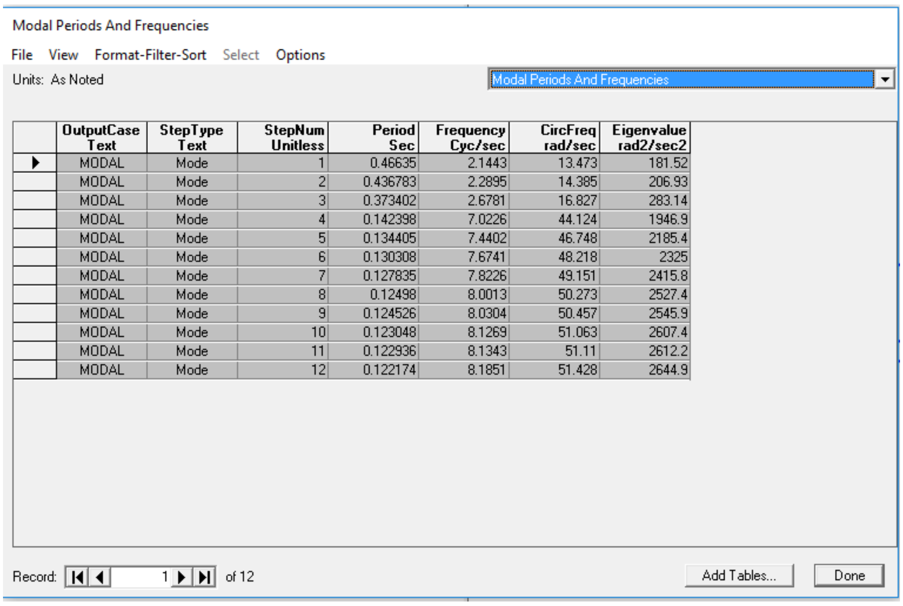


Figure 4.6 Mode shape 11 with period of 0.12294 and Mode shape 12 with period of 0.12217

After modal analysis is run, all the modal periods and frequency has been shown below:


Modal Periods And Frequencies

File View Format-Filter-Sort Select Options

Units: As Noted

Modal Periods And Frequencies

OutputCase Text	StepType Text	StepNum Unitless	Period Sec	Frequency Cyc/sec	CircFreq rad/sec	Eigenvalue rad2/sec2
MODAL	Mode	1	0.46635	2.1443	13.473	181.52
MODAL	Mode	2	0.436783	2.2895	14.385	206.93
MODAL	Mode	3	0.373402	2.6781	16.827	283.14
MODAL	Mode	4	0.142398	7.0226	44.124	1946.9
MODAL	Mode	5	0.134405	7.4402	46.748	2185.4
MODAL	Mode	6	0.130308	7.6741	48.218	2325
MODAL	Mode	7	0.127835	7.8226	49.151	2415.8
MODAL	Mode	8	0.12498	8.0013	50.273	2527.4
MODAL	Mode	9	0.124526	8.0304	50.457	2545.9
MODAL	Mode	10	0.123048	8.1269	51.063	2607.4
MODAL	Mode	11	0.122936	8.1343	51.11	2612.2
MODAL	Mode	12	0.122174	8.1851	51.428	2644.9

Record: 1 of 12

Add Tables... Done

Figure 4.7 Result from analysis of modal

Table 4.1 Tabulated period and frequency of modal analysis

Mode	Period (s)	Frequency (cyc/s)
1	**0.466**	**2.144**
2	**0.436**	**2.300**
3	**0.373**	**2.678**
4	**0.142**	**7.023**
5	**0.134**	**7.440**
6	**0.130**	**7.674**
7	**0.127**	**7.822**
8	**0.125**	**8.001**
9	**0.125**	**8.030**
10	**0.123**	**8.127**
11	**0.123**	**8.134**
12	**0.123**	**8.185**

From modal analysis, Mode shape 1 have the highest time period which is 0.46635 sec and the natural of frequency is 2.1443/sec, Mode shape 2 have the second highest time period which is 0.436783 sec and the natural of frequency is 2.2895 and Mode shape 3 have the third highest time period which is 0.373402 sec and the natural frequency is 2.6781/sec.

This result shown that the first three of the mode shape is the best among twelve mode shape because the highest of period and the lowest of frequency. Frequency also can be calculated by using the formula:

$$\text{Frequency} = \frac{1}{period} \qquad 4.1$$

Mode shape 1 produced period of 0.46635 sec. Frequency can be calculated by:

$$\text{Frequency} = \frac{1}{0.46635} = 2.1443/sec$$

4.3.2 Dead Load and Live Load

The combination of dead load and live load is the analysis used to obtain the maximum strength and loading situation without considering earthquake load. The dead load represent the permanent load on the structure while live load is the moving or imposed load of the structure. For the analysis, the critical members have been selected each for beam and column to analysing the result of axial load, shear force, moment, torsion and deflection. The section of beam 2/H-I (beam 172) and column 2/I (column 104 of top floor) for the analysis is shown in figure 4.8 and figure 4.9.

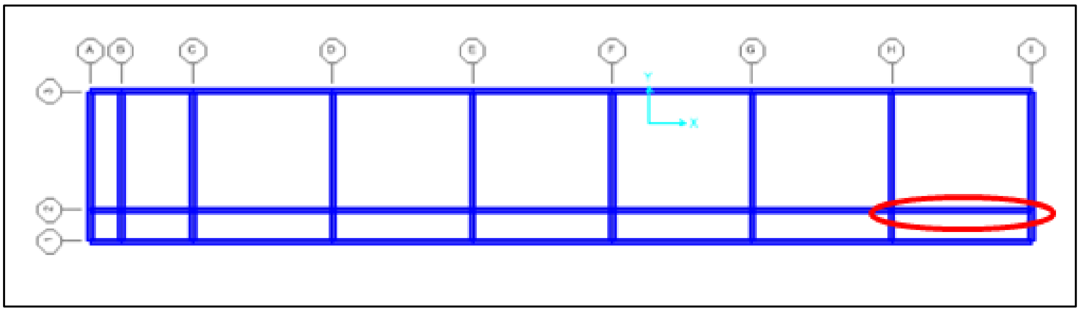


Figure 4.8 Critical beam used for analysis

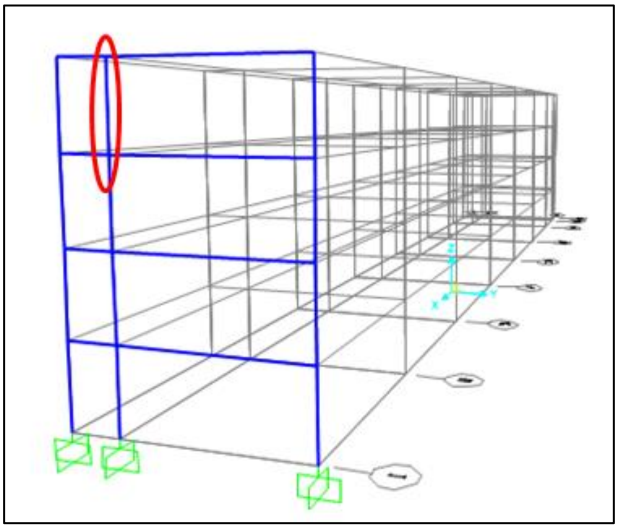


Figure 4.9 Selected critical column use for analysis

For the combination of dead load and live load, beam 172 having the maximum moment of 514.09 kNm and the maximum shear force is 289.38 kN. The deflection for this beam section is 7.47 mm, axial load of 91.35 kN, stress of 21319.07 kN/m^2 and torsion of 57.97 kNm.

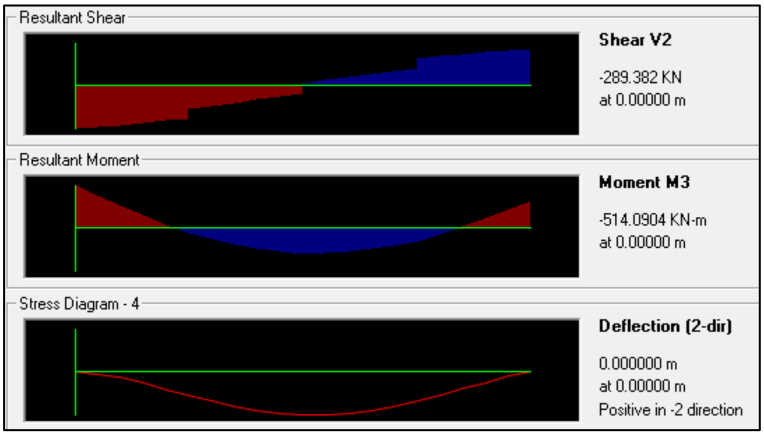


Figure 4.10 Result of shear, moment and deflection for beam 172

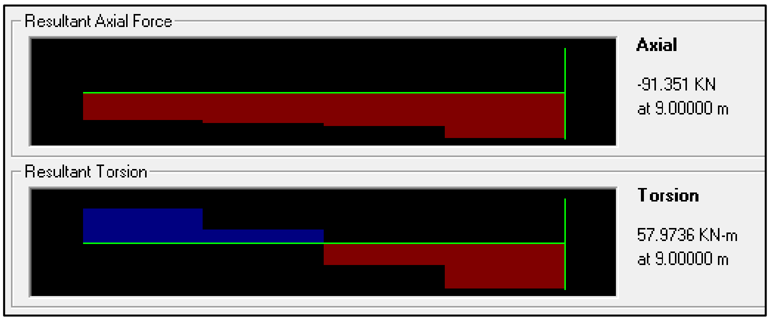


Figure 4.11 Result of axial force and torsion for beam 172

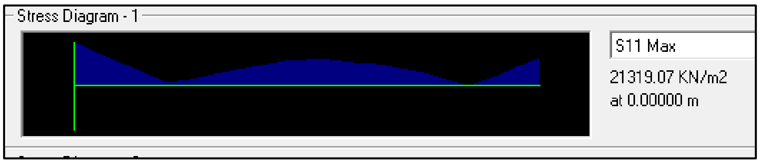


Figure 4.12 Result of stress for beam 172

While for column 104 the maximum moment is 357.96 kNm and maximum shear force is 189.31 kN. The deflection for this section is 0.40 mm, axial load of 592.78 kN, stress of 23503.12 kN/m^2 and torsion of 0.1291 kNm

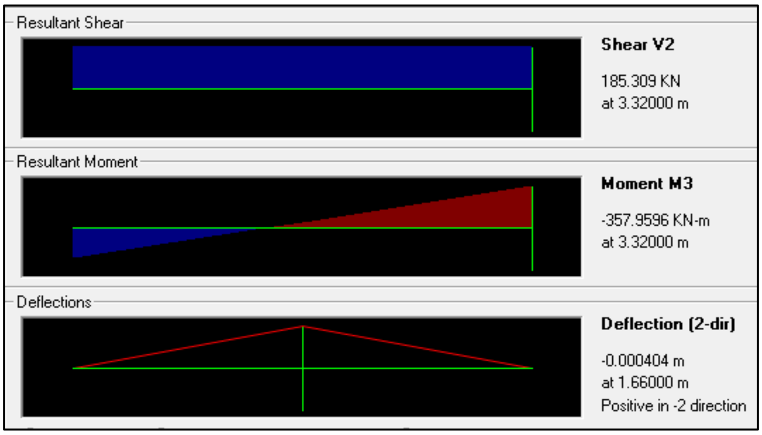


Figure 4.13 Result of shear, moment and deflection for column 104

Figure 4.14 Result of axial force and torsion for column 104

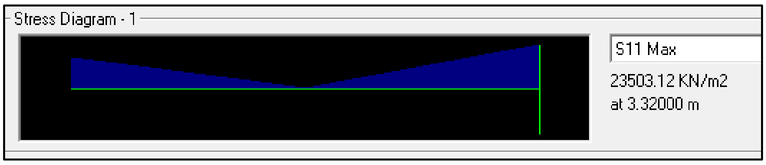


Figure 4.15 Result of stress for column 104

4.3.3 Dead Load and Live Load, Wind Load and Earthquake Load (Acheh)

The combination of dead load, live load and Acheh earthquake load is the analysis used to obtain the maximum strength and loading situation by considering earthquake load. The dead load represents the permanent load on the structure while live load is the moving or imposed load of the structure and the data of Acheh earthquake was taken from MMD.

For this cases beam 172 having the maximum moment of 608.12 kNm and the maximum shear force is 342.61 kN. The axial load of 108.93 kN, stress of 25217.22 kN/m^2 and torsion of 72.19 kNm

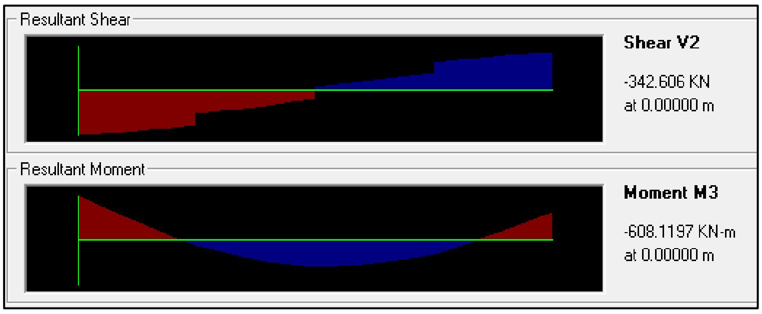


Figure 4.16 Result of shear and moment for beam 172

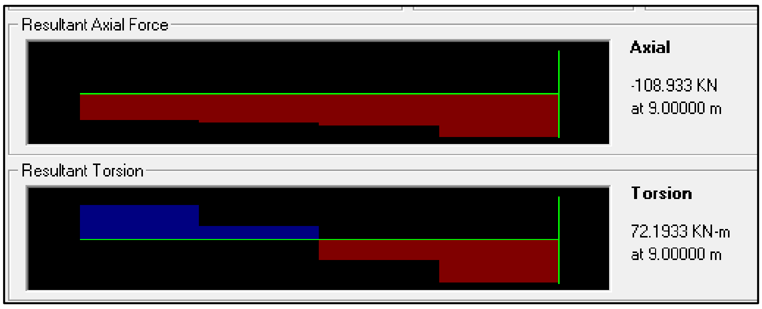


Figure 4.17 Result of axial force and torsion for beam 172

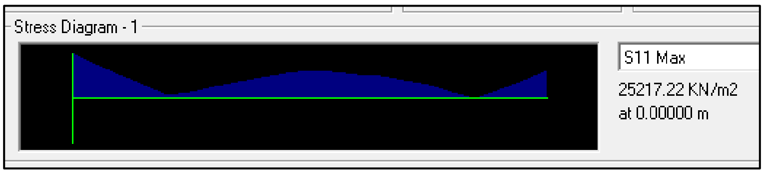


Figure 4.18 Result of stress for beam 172

While for column 104 the maximum moment is 426.97 kNm and maximum shear force is 221.05 kN. The deflection for this section is 0.913 mm, axial load of 716.77 kN, stress of 28192.21 kN/m^2 and torsion of 0.1598 kNm

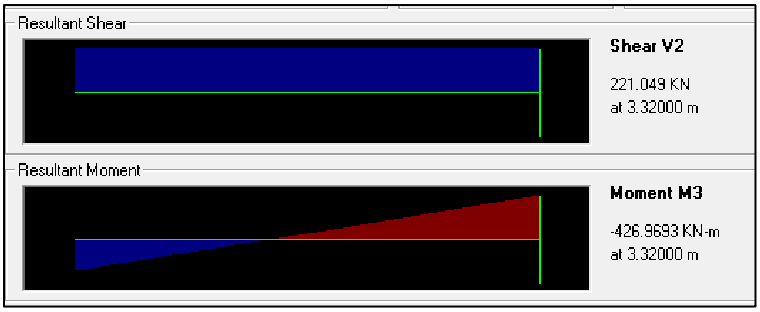


Figure 4.19 Result of shear, moment and deflection for column 104

Figure 4.20 Result of axial force and torsion for column 104

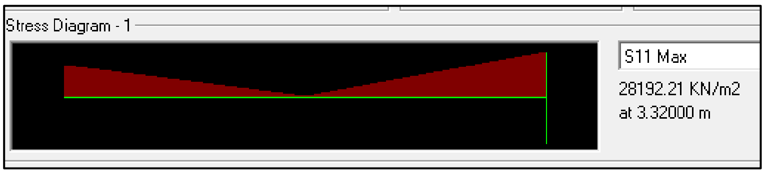


Figure 4.21 Result of stress for column 104

4.3.4 Dead Load and Live Load, Wind Load and Earthquake Load (Bkt Tinggi)

The combination of dead load, live load and Bukit Tinggi earthquake load is the analysis used to obtain the maximum strength and loading situation by considering earthquake load. The dead load represents the permanent load on the structure while live load is the moving or imposed load of the structure and the data of Bukit Tinggi earthquake was taken from MMD.

For this cases beam 172 having the maximum moment of 284.56 kNm and the maximum shear force is 503.05 kN. The axial load of 90.09 kN, stress of 21166.56 kN/m2 and torsion of 60.56 kNm

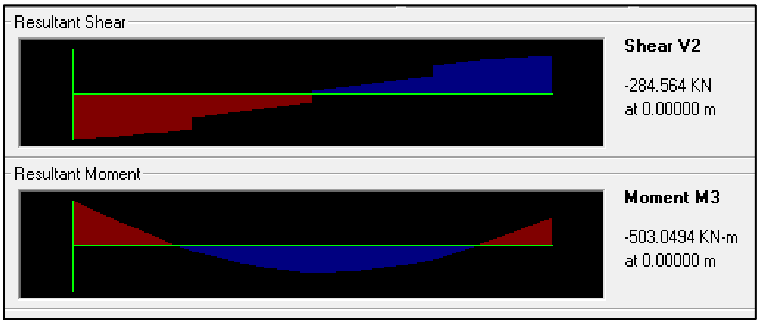


Figure 4.22 Result of shear and moment for beam 172

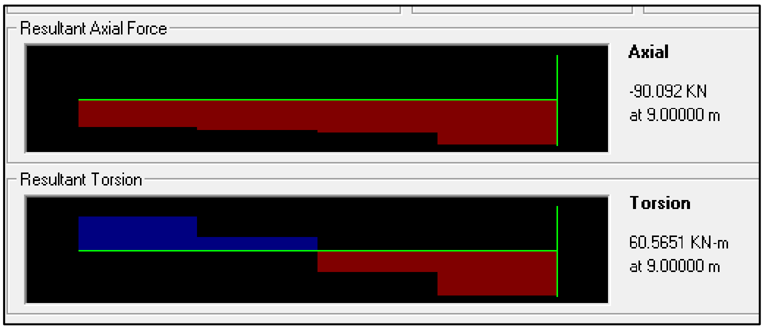


Figure 4.23 Result of axial force and torsion for beam 172

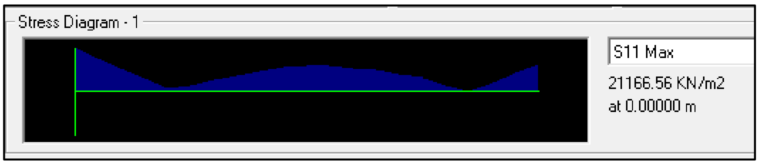


Figure 4.24 Result of stress for beam 172

While for column 104 the maximum moment is 351.72 kNm and maximum shear force is 186.20 kN. The deflection for this section is 1.221 mm, axial load of 716.77 kN, stress of 23878.65 kN/m^2 and torsion of 0.1598 kNm

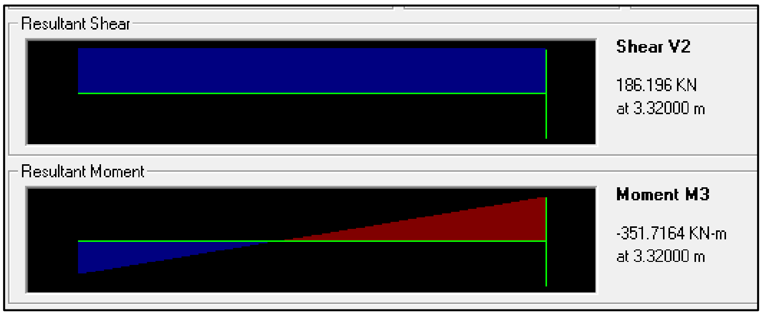


Figure 4.25 Result of shear, moment and deflection for column 104

Figure 4.26 Result of axial force and torsion for column 104

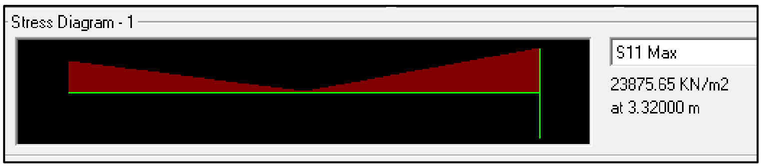


Figure 4.27 Result of stress for column 104

4.3.5 Comparison of Structure Capacity and Resistance

In the design of any structure, the comparison between the used member capacity should be compare with the resistance to ensure the safety of the structure. A comparison between shear and torsion moment resistance capacity is made by a manual calculation. Ratio of the comparison must be less than 1 to indicate the durability of a building structure. The result of comparison between the manual calculation and result from software was tabulated in Table 4.2 to table 4.4 for shear comparison. The calculation for shear and moment resistance is provided in Appendix.

EC2 : 04 Part 1 Expression 6.30 : Torsion

$$\frac{T_{Ed}}{T_{Rd,max}} \leq 1.0 \qquad 4.2$$

EC2 : 04 Part 1 Expression 6.9 : Column

$$\frac{V_{Ed}}{V_{Rd,max}} \leq 1.0 \qquad 4.3$$

Table 4.2: Comparison of RC structure torsion maximum resistance for Beam 172

Load Combinations	TEd (kNm)	TRd,max (kNm)	$\frac{T_{Ed}}{T_{Rd,max}}$
DL + LL	**57.97**	**77.15**	**0.75**
DL + LL + WL + ACHEH	**72.19**	**77.15**	**0.94**
DL + LL + WL + BKT TINGGI	**60.57**	**77.15**	**0.79**

Table 4.3: Comparison of RC structure shear maximum resistance for Beam 172

Load Combinations	V_{Ed} (kN)	$V_{Rd,max}$ (kN)	$\frac{V_{Ed}}{V_{Rd,max}}$
DL + LL	289.32	679.0	0.43
DL + LL + WL + ACHEH	342.62	679.0	0.50
DL + LL + WL + BKT TINGGI	284.56	679.0	0.42

Table 4.4: Comparison of RC structure torsion maximum resistance for Column 104

Load Combinations	T_{Ed} (kNm)	$T_{Rd,max}$ (kNm)	$\frac{T_{Ed}}{T_{Rd,max}}$
DL + LL	0.129	125.7	0.001
DL + LL + WL + ACHEH	0.160	125.7	0.001
DL + LL + WL + BKT TINGGI	0.196	125.7	0.002

Table 4.5: Comparison of RC structure shear maximum resistance for Column 104

Load Combinations	V_{Ed} (kN)	$V_{Rd,max}$ (kN)	$\frac{V_{Ed}}{V_{Rd,max}}$
DL + LL	**185.31**	**767.51**	**0.24**
DL + LL + WL + ACHEH	**426.97**	**767.51**	**0.56**
DL + LL + WL + BUKIT TINGGI	**351.72**	**767.51**	**0.46**

4.4 VIRTUALWORK DIAGRAM

As to achieve the most efficient control over the lateral displacement in SAP2000, virtual work diagrams can be used as an aid to determine which elements should be stiffened. The virtual work diagrams for RC school building structure are illustrated in Figure 4.28 – Figure 4.33.

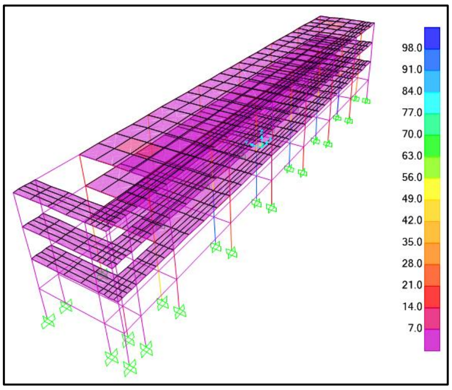


Figure 4.28 Forces: Dead, Displacement: Dead

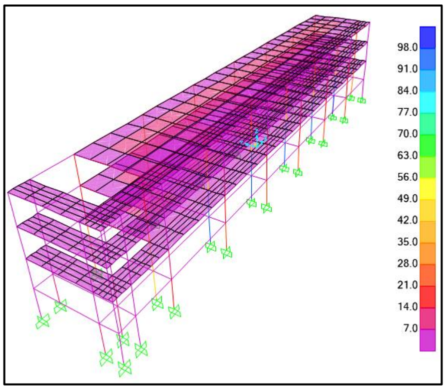


Figure 4.29 Forces: Dead, Displacement: Live

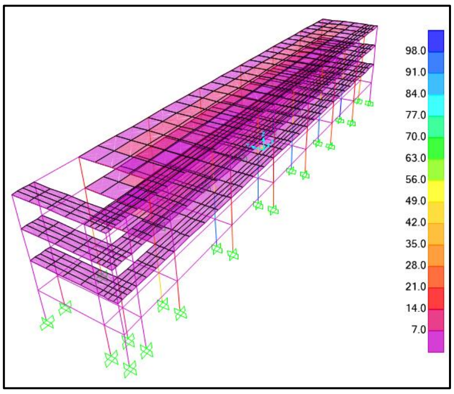


Figure 4.30 Forces: Dead, Displacement: Wind

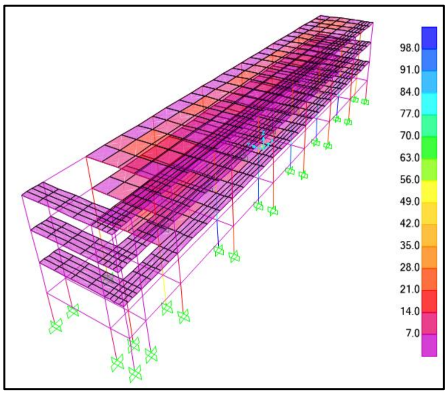


Figure 4.31 Forces: Live, Displacement: Live

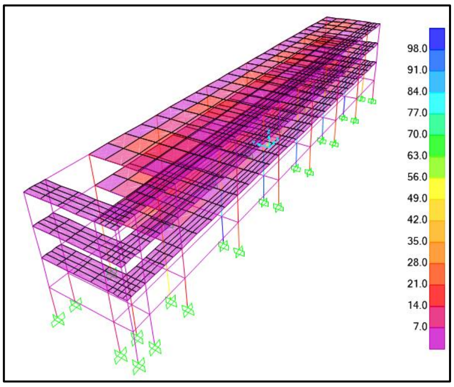


Figure 4.32 Forces: Live, Displacement: Wind

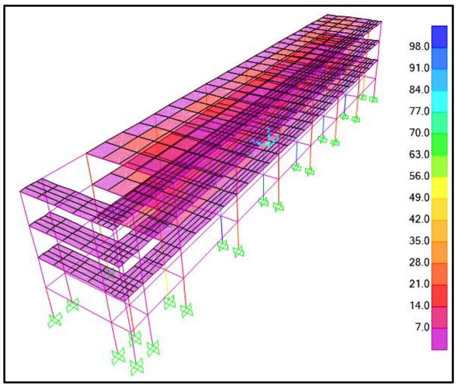


Figure 4.33 Forces: Wind, Displacement: Wind

4.5 TIME HISTORY ANALYSIS

Time history analysis give a nonlinear or linear evaluation structural dynamic response under loading that according to the specified function of time (Onrej, 2014). In this analysis, there are two scale factor used to define a time-history load case which are load pattern and acceleration. When a load pattern has been set for load type, the scale factor is times by the values of time-history function to give a unit-less terms. For the acceleration, after a load type is set, the value of time-history is multiplied with scale factor to give the desired acceleration in the current unit.

The time-history for this analysis is the combination of two load cases which are Acheh and Bukit Tinggi earthquake load. Five critical joint were selected to see the acceleration and displacement for both earthquake in x and y direction. The results are illustrated in the form of bar chart below.

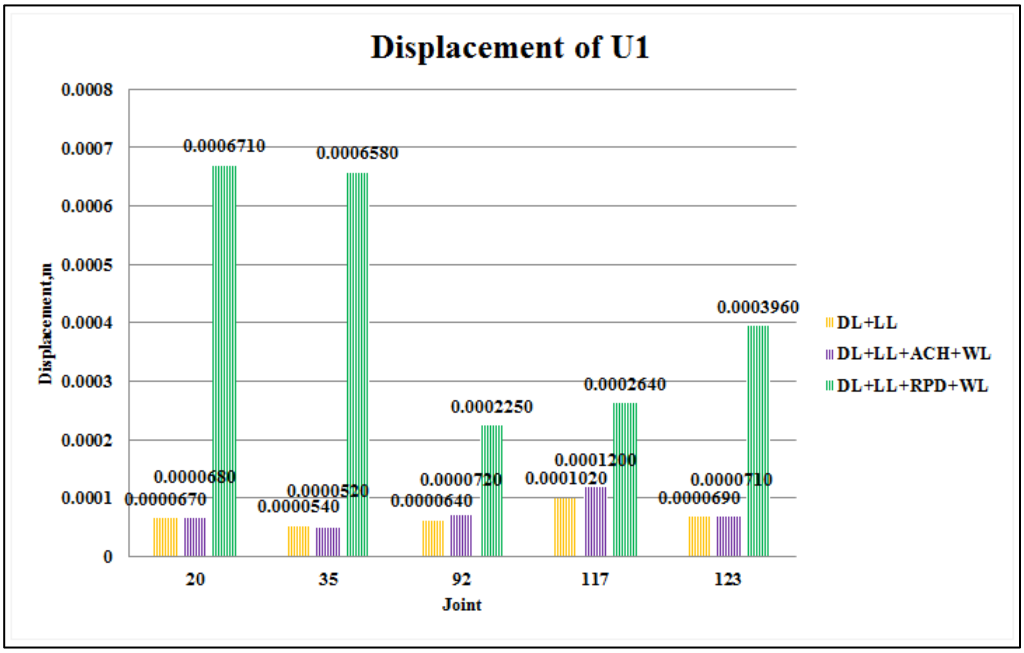


Figure 4.34 Maximum joint displacement in x direction

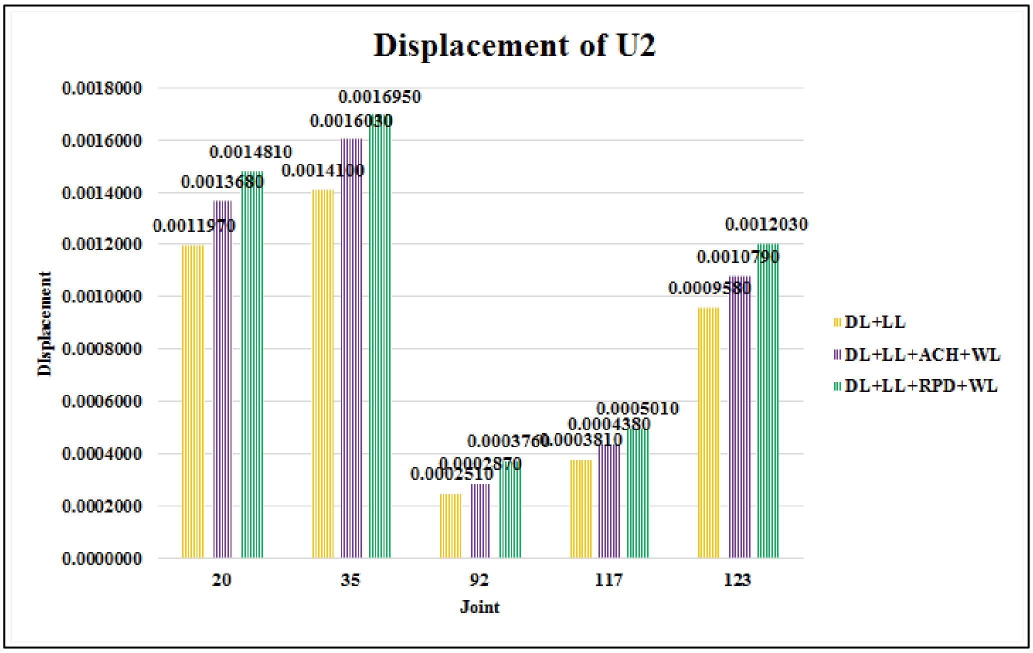


Figure 4.35 Maximum joint displacement in y direction

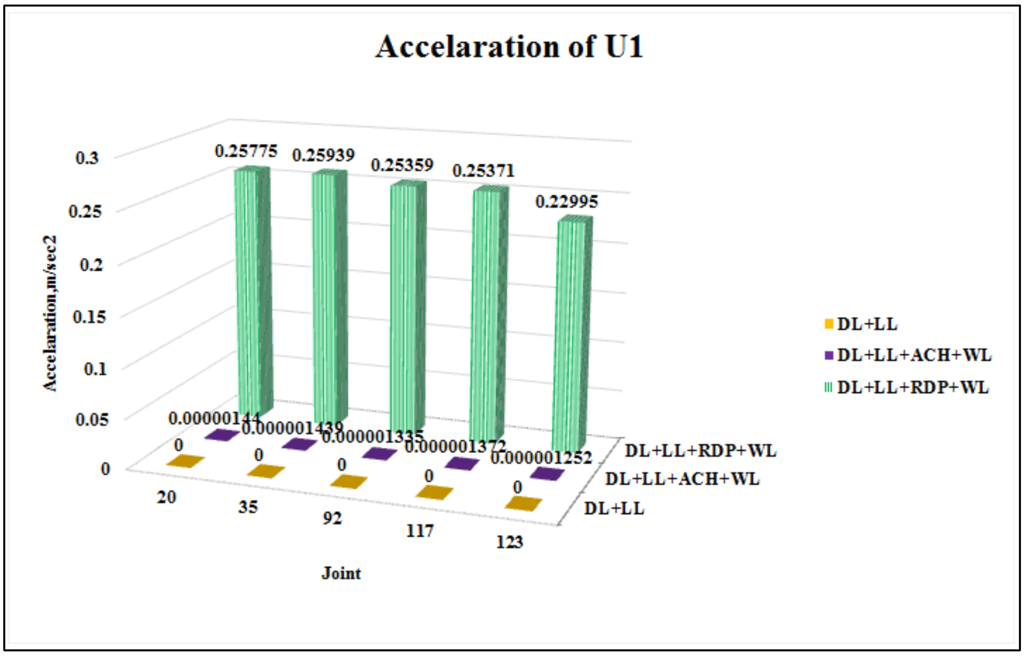


Figure 4.36 Maximum joint acceleration in x direction

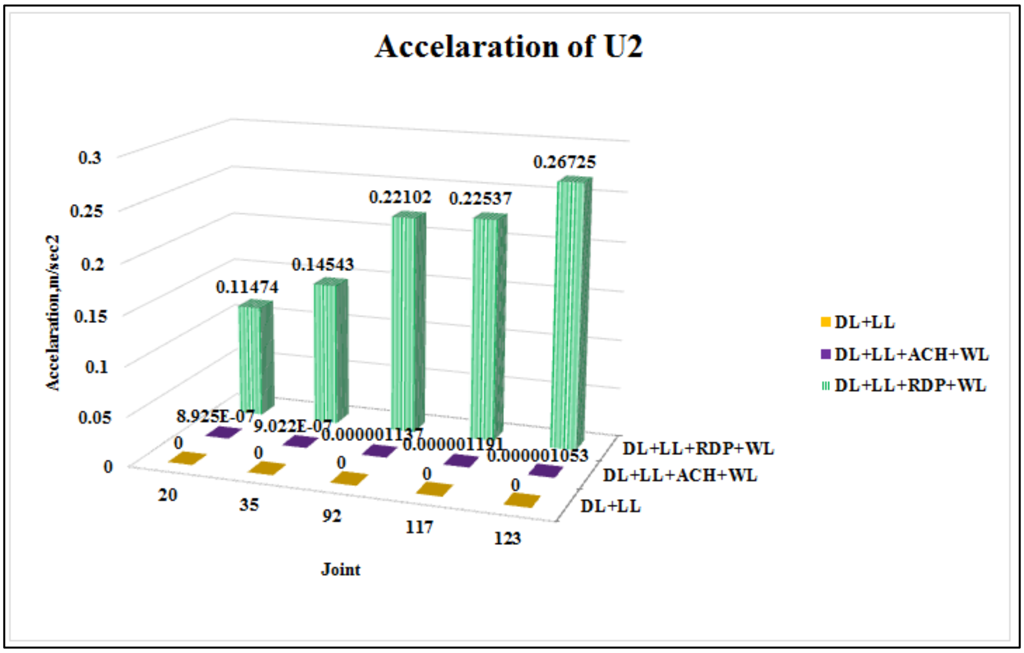


Figure 4.37 Maximum joint acceleration in y direction

From the bar chart, the letter 'U' represents the displacement or acceleration for the structure after thee data of time history being inserted while 1 is for x-axis and 2 is y-axis. The highest displacement for U1 is obtained from joint 20 which is 0.671mm and for acceleration is 0.2594 m/sec^2 at joint 35. While, for U2, the highest displacement obtained is at joint 35 with the value of 1.695mm and the acceleration is 0.2673 m/sec^2 at joint 123. All the highest value is obtained from load cases with Bukit Tinggi earthquake data. This is due to force produce by the near location of seismic force.

4.6 RESPONSE SPECTRUM ANALYSIS (RSA)

Response-spectrum analysis (RSA) can be said as a linear-dynamic statistical analysis method which measures the contribution from each natural mode of vibration as to indicate the likely maximum seismic response of an essentially elastic structure. Besides, RSA is simply a plot of the peak or steady-state response in the terms of displacement, velocity or acceleration of a series of oscillators of varying natural frequency which are forced into motion by the same vibration in the function of structural period for a given time history and level of damping.

Below is the response spectrum analysis for x and y direction in term of time period. The 4 storey concrete building RSA shown in 5 specs which are:

i. Spectral Displacements

ii. Spectral Velocities

iii. Pseudo Spectral Velocities

iv. Spectral Accelerations

v. Pseudo Spectral Acceleration

4.6.1 Time Period

Joint 123 was used to run the analysis for the time period. Figure 4.34 until Figure 4.43 shows the peak response of structure in direction x and direction y which is subjected to Acheh earthquake loading. The response was selected for damping 0%, 20% and 50%. Table 4.44 and 4.45 shows the maximum peak of RSA for x and y direction respectively.

X Direction

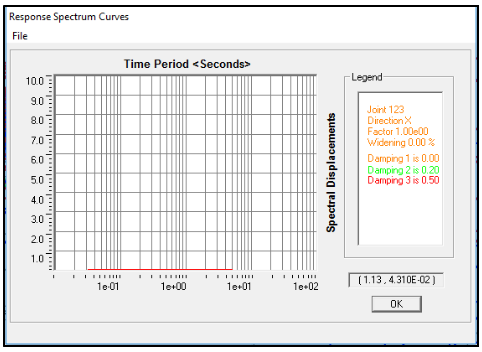


Figure 4.38 Spectral displacement in x direction

Y Direction

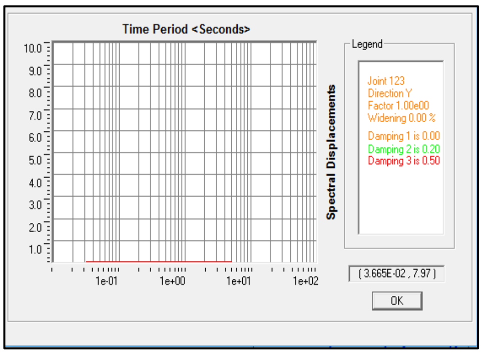


Figure 4.39 Spectral displacement in y direction

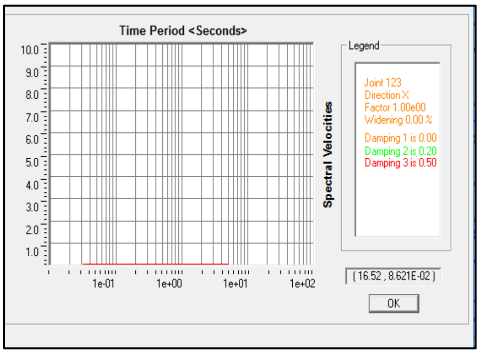


Figure 4.40 Spectral velocities in x direction

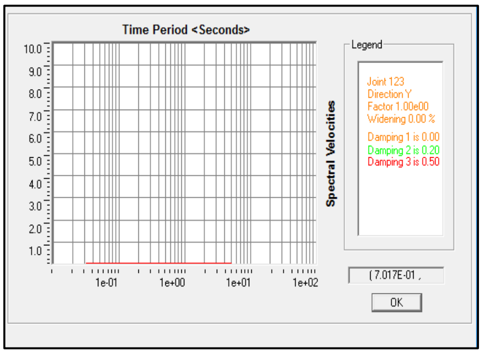


Figure 4.41 Spectral velocities in y direction

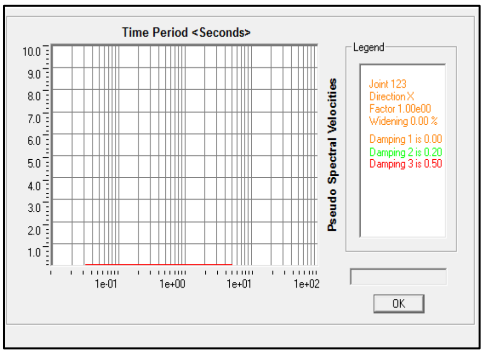


Figure 4.42 Pseudo spectral velocities in x direction

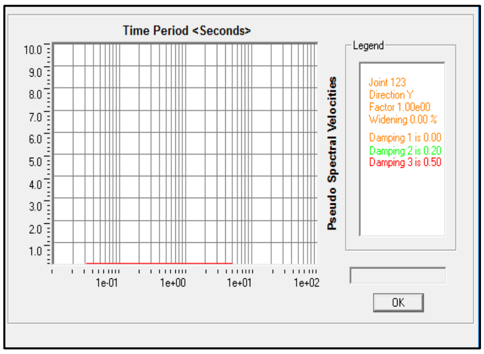


Figure 4.43 Pseudo spectral velocities in y direction

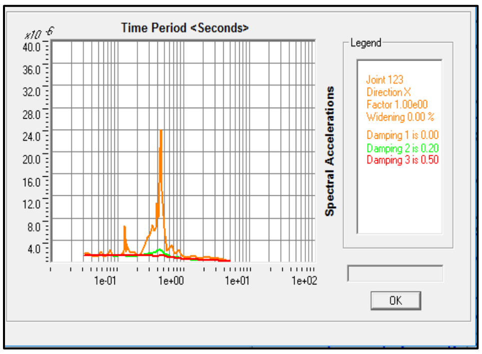


Figure 4.44 Spectral acceleration in x direction

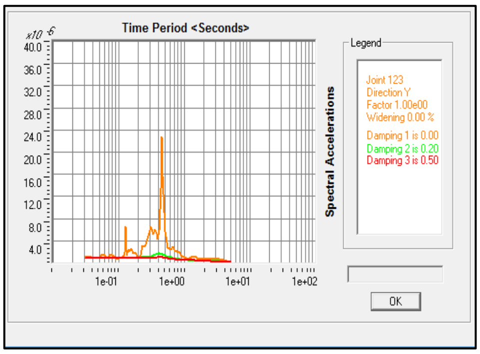


Figure 4.45 Spectral acceleration in y direction

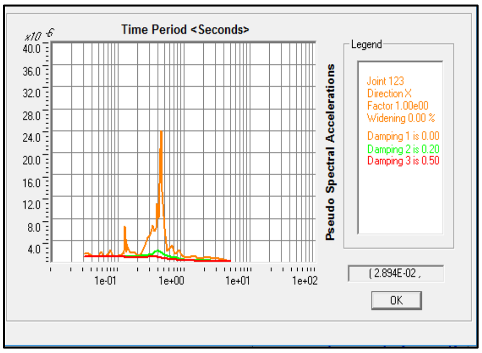


Figure 4.46 Pseudo spectral acceleration in x direction

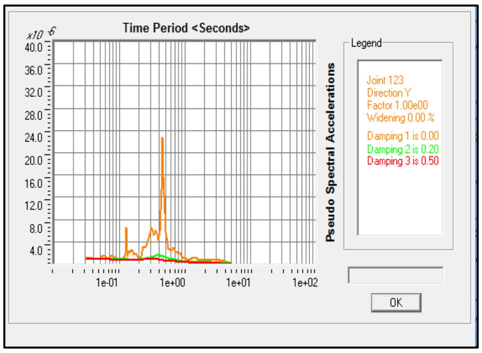


Figure 4.47 Pseudo spectral acceleration in y direction

Table 4.6 Peak response spectrum for Acheh excitation in x direction (Time Period)

	Peak response		
RSA/Damping	**0**	**0.2**	**0.5**
SD (m)	$\mathbf{1.84 \times 10^{-7}}$	$\mathbf{7.37 \times 10^{-8}}$	$\mathbf{5.52 \times 10^{-8}}$
SV (m/s)	$\mathbf{6.39 \times 10^{-7}}$	$\mathbf{2.08 \times 10^{-7}}$	$\mathbf{1.60 \times 10^{-7}}$
PSV (m/s)	$\mathbf{1.73 \times 10^{-6}}$	$\mathbf{1.37 \times 10^{-7}}$	$\mathbf{8.29 \times 10^{-8}}$
SA (m/s^2)	$\mathbf{2.39 \times 10^{-6}}$	$\mathbf{2.24 \times 10^{-6}}$	$\mathbf{1.21 \times 10^{-6}}$
PSA (m/s^2)	$\mathbf{2.39 \times 10^{-5}}$	$\mathbf{2.11 \times 10^{-6}}$	$\mathbf{1.09 \times 10^{-6}}$

Table 4.7 Peak response spectrum for Acheh excitation in y direction (Time Period)

	Peak response		
RSA/Damping	**0**	**0.1**	**0.5**
SD (m)	1.82×10^{-7}	7.24×10^{-8}	5.41×10^{-8}
SV (m/s)	1.64×10^{-6}	1.61×10^{-7}	1.09×10^{-7}
PSV (m/s)	1.64×10^{-6}	1.23×10^{-7}	7.32×10^{-8}
SA (m/s^2)	2.27×10^{-5}	1.67×10^{-6}	9.11×10^{-7}
PSA (m/s^2)	2.27×10^{-5}	1.56×10^{-6}	8.35×10^{-7}

Joint 123 was used to run the analysis for the time period. Figure 4.34 until Figure 4.43 show the peak response of structure in direction x and direction y that are subjected to Bukit Tinggi earthquake loading. The response was selected for damping 0%, 20% and 50%. Table 4.52 and 4.57 shows the maximum peak of RSA for x and y direction respectively.

X Direction

Y Direction

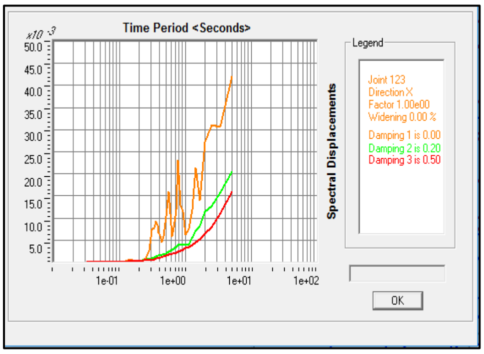


Figure 4.48 Spectral displacement in x direction

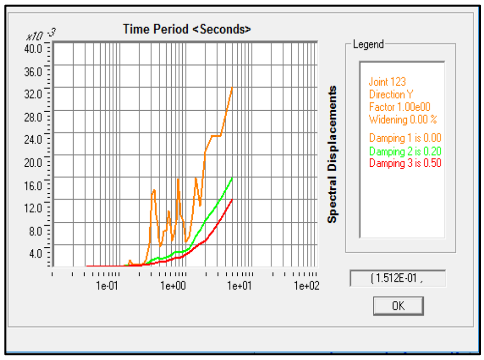


Figure 4.49 Spectral displacement in y direction

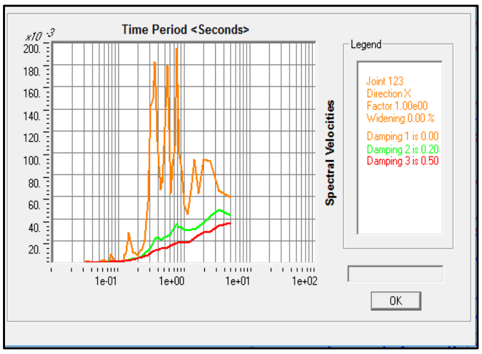


Figure 4.50 Spectral velocities in x direction

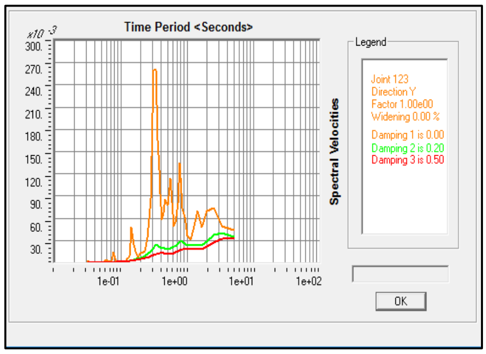


Figure 4.51 Spectral velocities in y direction

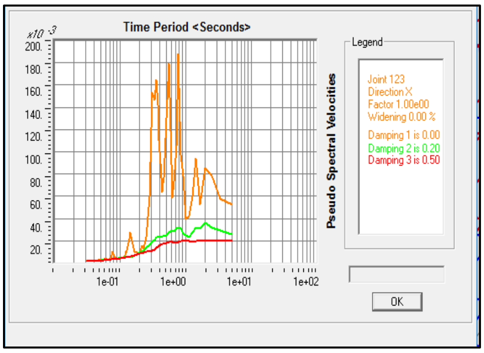


Figure 4.52 Pseudo spectral velocities in x direction

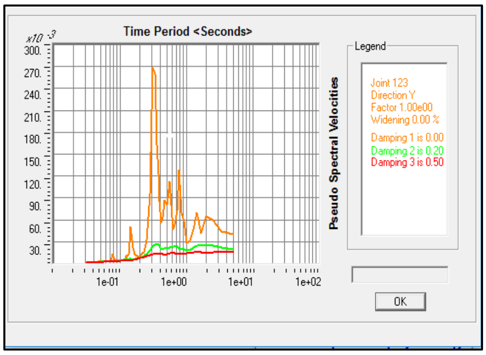


Figure 4.53 Pseudo spectral velocities in y direction

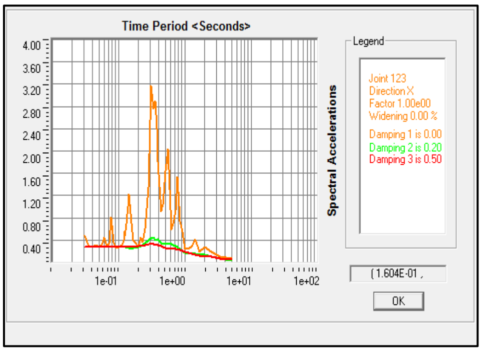


Figure 4.54 Spectral acceleration in x direction

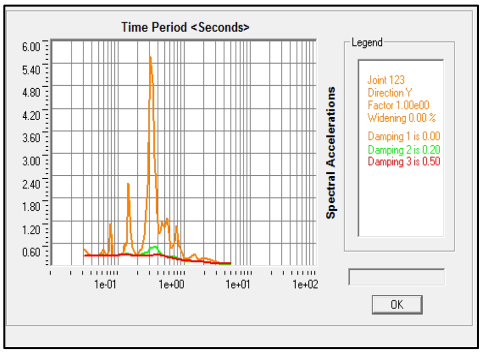


Figure 4.55 Spectral acceleration in y direction

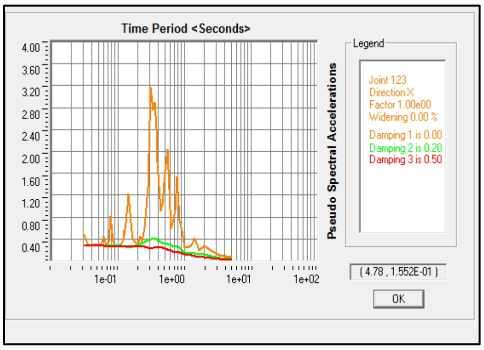


Figure 4.56 Pseudo spectral acceleration in x direction

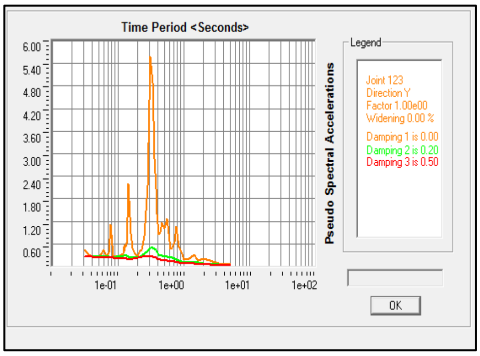


Figure 4.57 Pseudo spectral acceleration in y direction

Table 4.8 Peak response spectrum for Bukit Tinggi excitation in x direction (Time Period)

	Peak response		
RSA/Damping	**0**	**0.1**	**0.5**
SD (m)	4.20×10^{-2}	2.05×10^{-2}	7.99×10^{-3}
SV (m/s)	1.95×10^{-1}	4.79×10^{-2}	3.65×10^{-2}
PSV (m/s)	1.89×10^{-1}	3.61×10^{-2}	2.06×10^{-2}
SA (m/s^2)	3.18×10^{0}	4.36×10^{-1}	3.24×10^{-1}
PSA (m/s^2)	3.18×10^{0}	4.05×10^{-1}	2.73×10^{-1}

Table 4.9 Peak response spectrum for Bukit Tinggi excitation in y direction (Time Period)

	Peak response		
RSA/Damping	**0**	**0.1**	**0.5**
SD (m)	3.20×10^{-2}	1.59×10^{-2}	1.21×10^{-2}
SV (m/s)	2.60×10^{-1}	3.46×10^{-2}	3.18×10^{-2}
PSV (m/s)	1.63×10^{-1}	2.70×10^{-2}	1.58×10^{-2}
SA (m/s^2)	5.58×10^{0}	5.03×10^{-1}	2.79×10^{-2}
PSA (m/s^2)	5.58×10^{0}	4.96×10^{-1}	2.62×10^{-1}

4.6.2 Frequency

Joint 123 was used to run the analysis for the frequency. Figure 4.34 until Figure 4.43 show the peak response of structure in direction x and direction y that are subjected to Acheh earthquake loading. The response was selected for damping 0%, 20% and 50%. Table 4.64 and 4.67 shows the maximum peak of RSA for x and y direction respectively.

X Direction | Y Direction

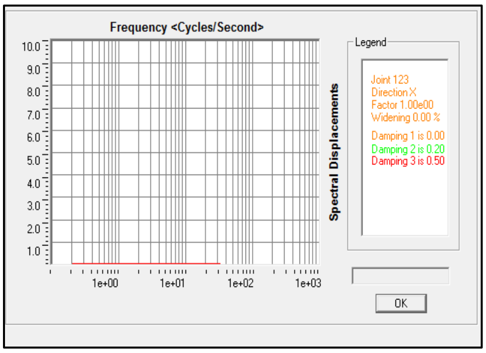


Figure 4.58 Spectral displacement in x direction

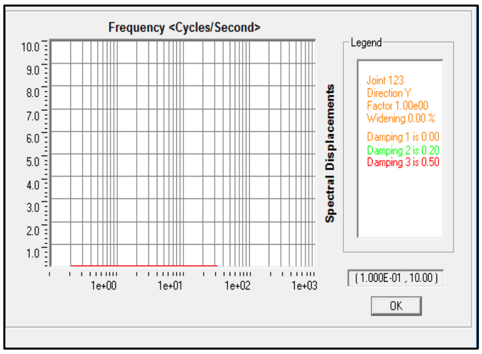


Figure 4.59 Spectral displacement in y direction

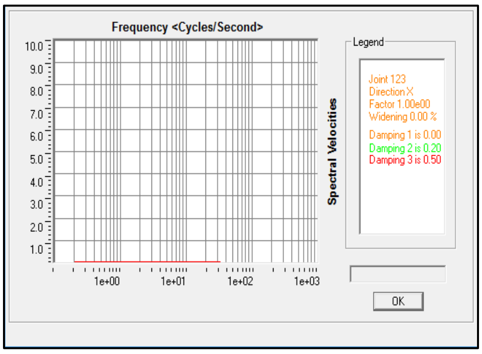


Figure 4.60 Spectral velocities in x direction

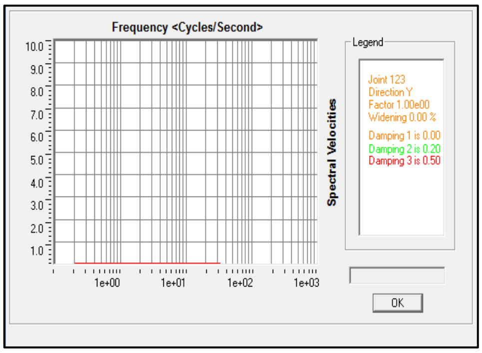


Figure 4.61 Spectral velocities in y direction

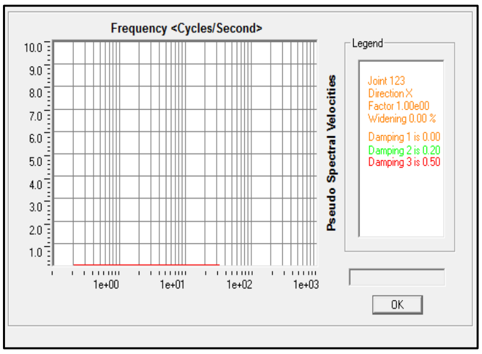


Figure 4.62 Pseudo spectral velocities in x direction

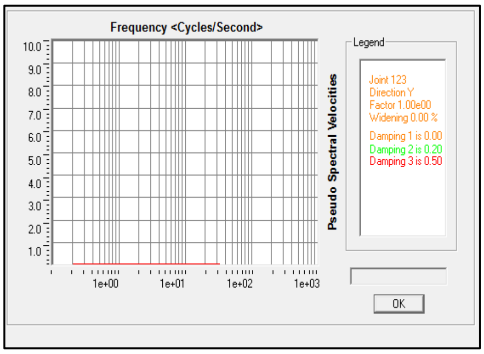


Figure 4.63 Pseudo spectral velocities in y direction

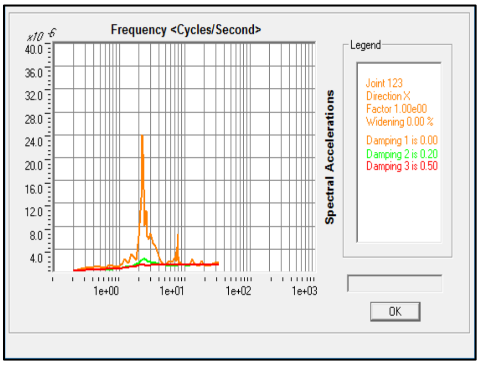


Figure 4.64 Spectral acceleration in x direction

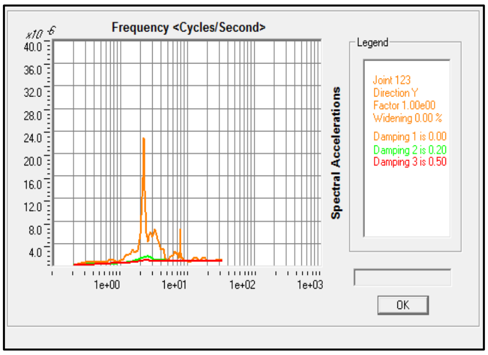


Figure 4.65 Spectral acceleration in y direction

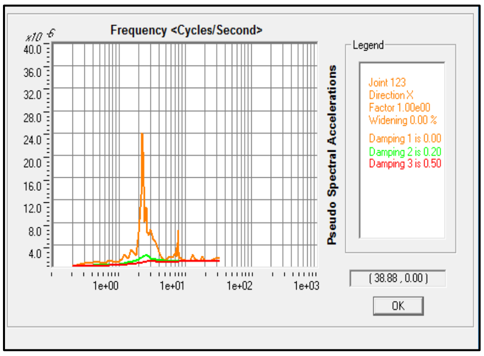


Figure 4.66 Pseudo spectral acceleration in x direction

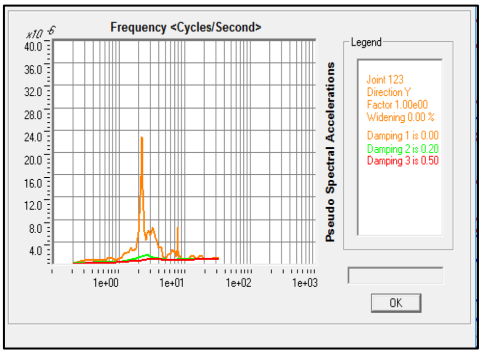


Figure 4.67 Pseudo spectral acceleration in y direction

Table 4.8 Peak response spectrum for Acheh excitation in x direction (Frequency)

	Peak response		
RSA/Damping	**0**	**0.1**	**0.5**
SD (m)	1.84×10^{-7}	7.37×10^{-8}	5.52×10^{-8}
SV (m/s)	1.76×10^{-6}	2.08×10^{-7}	1.60×10^{-7}
PSV (m/s)	9.54×10^{-7}	1.37×10^{-7}	8.29×10^{-8}
SA (m/s^2)	2.39×10^{-5}	2.24×10^{-6}	1.20×10^{-6}
PSA (m/s^2)	2.39×10^{-5}	2.11×10^{-6}	1.09×10^{-6}

Table 4.9 Peak response spectrum for Acheh excitation in y direction (Frequency)

	Peak response		
RSA/Damping	**0**	**0.1**	**0.5**
SD (m)	1.82×10^{-7}	7.24×10^{-8}	5.41×10^{-8}
SV (m/s)	1.64×10^{-6}	1.61×10^{-7}	1.09×10^{-7}
PSV (m/s)	1.64×10^{-6}	1.23×10^{-7}	7.32×10^{-8}
SA (m/s^2)	6.61×10^{-6}	1.67×10^{-6}	9.82×10^{-7}
PSA (m/s^2)	2.27×10^{-5}	1.56×10^{-6}	8.67×10^{-7}

Joint 123 was used to run the analysis for the frequency. Figure 4.34 until Figure 4.43 show the peak response of structure in direction x and direction y that are subjected to Bukit Tinggi earthquake loading. The response was selected for damping 0%, 20% and 50%. Table 4.70 and 4.77 shows the maximum peak of RSA for x and y direction respectively.

X Direction

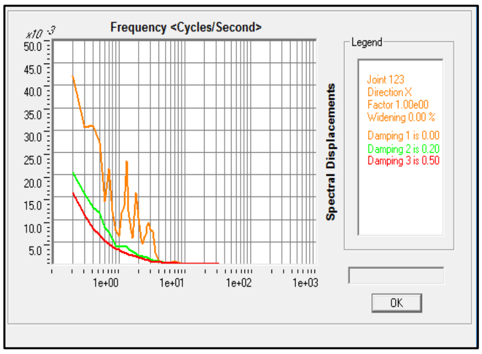


Figure 4.68 Spectral displacement in x direction

Y Direction

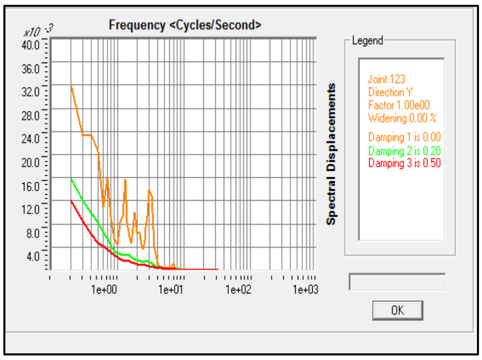


Figure 4.69 Spectral displacement in y direction

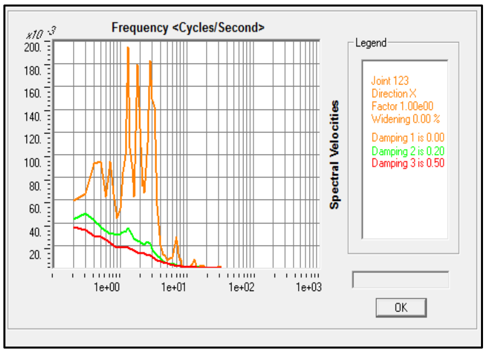


Figure 4.70 Spectral velocities in x direction

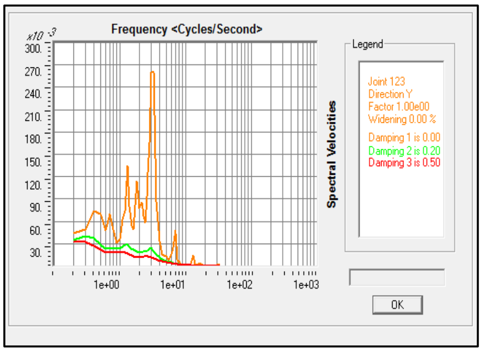


Figure 4.71 Spectral velocities in y direction

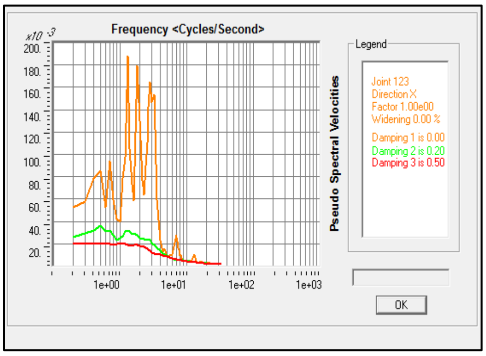


Figure 4.72 Pseudo spectral velocities in x direction

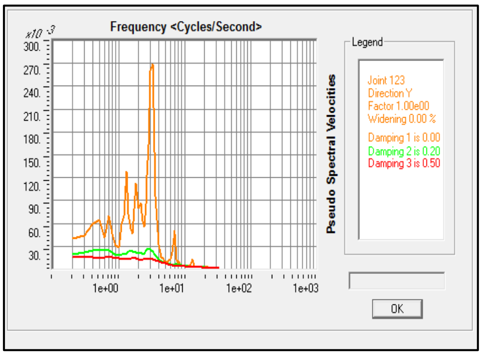


Figure 4.73 Pseudo spectral velocities in y direction

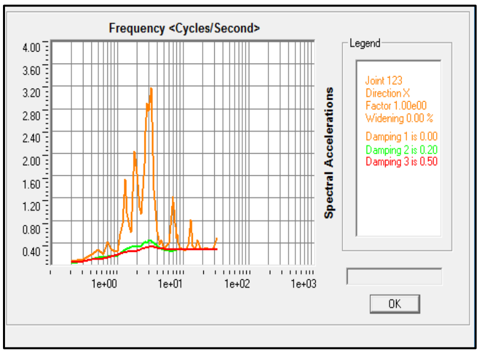


Figure 4.74 Spectral acceleration in x direction

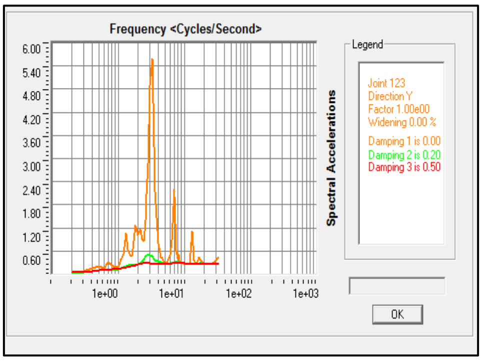


Figure 4.75 Spectral acceleration in y direction

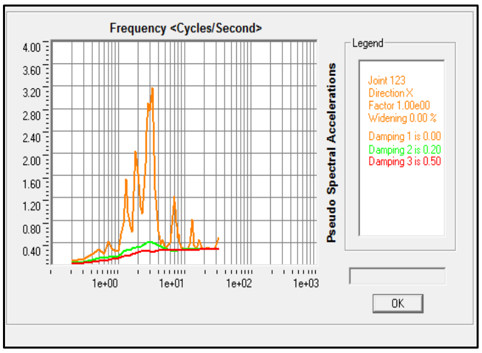


Figure 4.76 Pseudo spectral acceleration in x direction

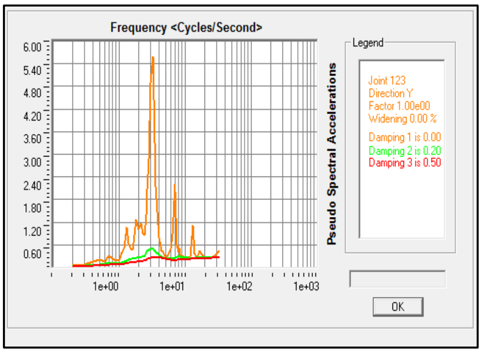


Figure 4.77 Pseudo spectral acceleration in y direction

Table 4.10 Peak response spectrum for Bukit Tinngi excitation in x direction (Frequency)

	Peak response		
RSA/Damping	**0**	**0.1**	**0.5**
SD (m)	4.20×10^{-2}	2.05×10^{-6}	1.59×10^{-2}
SV (m/s)	1.95×10^{-1}	4.79×10^{-2}	3.65×10^{-2}
PSV (m/s)	1.87×10^{-1}	3.61×10^{-2}	2.0×10^{-2}
SA (m/s^2)	3.18×10^{0}	4.41×10^{-1}	3.24×10^{-1}
PSA (m/s^2)	3.18×10^{0}	4.05×10^{-1}	2.73×10^{-1}

Table 4.11 Peak response spectrum for Bukit Tinggi excitation in y direction (Frequency)

	Peak response		
RSA/Damping	**0**	**0.1**	**0.5**
SD (m)	3.20×10^{-2}	1.59×10^{-2}	1.21×10^{-2}
SV (m/s)	2.60×10^{-1}	4.05×10^{-2}	3.18×10^{-2}
PSV (m/s)	2.69×10^{-1}	2.70×10^{-2}	1.59×10^{-2}
SA (m/s^2)	5.58×10^{0}	5.03×10^{-1}	2.79×10^{-1}
PSA (m/s^2)	5.58×10^{-1}	4.96×10^{-1}	2.62×10^{-1}

4.7 SUMMARY OF THE ANALYSIS

The seismic forces distribution usually not consider in the design of concrete building in Malaysia. Besides, the material qualities, element detailing and the different modelling design of concrete structure also can influence the existing building.

As a rule, whenever the building is considering the seismic factor, it is highly influences the seismic reaction of the generic reinforced concrete structure.

4.7.1 Time Period

When a structure is subjected to a dynamic action, it develops a vibratory motion in the building due to its elastic mass and properties. That vibration is similar to the vibration of a violin string, which is consists of a fundamental tone and the additional contribution of various harmonics. Similarly, the vibration of a building consists of a fundamental mode of vibration and the additional contribution of various modes, which vibrates at higher frequencies. On the basis of time period the building may be classified as Rigid ($T < 0.3$ sec), Semi-Rigid (0.3 sec $< T <$ 1 sec), and Flexible Structure ($T > 1$). Fundamental period of vibration can be determined by the empirical formula as shown before.

Table 4.12 Analysis of concrete building design

Mode Shape	Frequency (Cyc/sec)	Time Period (sec)	Structure classification
1	2.1443	0.46635	SEMI-RIGID
2	2.2895	0.43678	SEMI-RIGID
3	2.6281	0.373402	SEMI-RIGID
4	7.0226	0.14240	RIGID
5	7.4402	0.13441	RIGID

6	7.6741	0.13031	RIGID
7	7.8226	0.127835	RIGID
8	8.0013	0.124526	RIGID
9	8.0304	0.12453	RIGID
10	8.1269	0.12305	RIGID
11	8.1343	0.12294	RIGID
12	8.1851	0.12217	RIGID

4.7.2 Result of Load Combination

For the analysis, the critical member were chosen because it will be the first to affect if there is an earthquake event. All the results of maximum shear, moment, torsion, deflection and stress of a critical which are column 104 and beam 172 are shown the table 4.13.

Table 4.13 Maximum result of beam 172 subjected under different load combination

Load Combination	**DL + LL**	**DL + LL + WL + ACHEH**	**DL + LL + WL + BUKIT TINGGI**
Moment (kNm)	514.09	608.12	503.05
Shear (kN)	289.32	342.62	284.56
Axial Force (kN)	91.35	108.93	90.09
Torsion (kNm)	57.97	72.19	60.57
Deflection (mm)	7.47	7.99	8.04
Stress (kN/m^2)	21319.07	25217.22	21166.56
$V_{Ed}/V_{Rd,max}$	0.43	0.50	0.42
$T_{Ed}/T_{Rd,max}$	0.75	0.94	0.79

Table 4.14 Maximum result of column 104 subjected under different load combination

Load Combination	DL + LL	DL + LL + WL + ACHEH	DL + LL + WL + BUKIT TINGGI
Moment (kNm)	767.51	426.97	351.72
Shear (kN)	125.7	221.05	186.2
Axial Force (kN)	357.96	716.77	592.62
Torsion (kNm)	185.31	0.160	0.1960
Deflection (mm)	0.404	0.913	1.221
Stress (kN/m^2)	10861	28192.21	23875.65
$V_{Ed}/V_{Rd,max}$	0.24	0.56	046
$T_{Ed}/T_{Rd,max}$	0.001	0.001	0.002

4.7.3 Time History

After the analysis have been done using two different earthquake loading, the maximum displacement and acceleration were obtained and tabulated in table ***. Based on the result, the Bukit Tinggi shows a huge different of acceleration which is larger from Acheh excitation at the same of displacement.

Table 4.15 Maximum displacement and acceleration under different earthquake excitation

Earthquake Excitation	Acheh		Bukit Tinggi	
Direction	**U1**	**U2**	**U1**	**U2**
Displacement (mm)	0.12	1.603	0.671	1.70
Acceleration (mm/sec^2)	1.44×10^{-3}	1.91×10^{-3}	259.39	267.25

4.7.4 Response Spectrum Analysis (RSA)

Table 4.16 represent the maximum value of displacement and acceleration of 0% damping arise on critical joint when it was subjected to a different earthquake load. Based on the result, Bukit Tinggi earthquake load produce larger displacement and acceleration compared to Acheh earthquake load.

Table 4.16 Maximum displacement and acceleration of 0% damping under different excitation

	Acheh		**Bukit Tinggi**	
	Period	**Frequency**	**Period**	**Frequency**
SD (m)	1.84×10^{-7}	1.84×10^{-7}	4.20×10^{-2}	4.2×10^{-2}
SA (m/s^2)	2.27×10^{-5}	2.39×10^{-5}	5.58	5.58
PSA (m/s^2)	2.39×10^{-5}	2.39×10^{-5}	5.58	3.18

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The analysis indicates the necessity for us to control the damage that may be caused by an earthquake. The design of structure without considering seismic may expose the structure to collapse or crack. Through the result and discussion of the analysis, the time history analysis consume shows the huge difference when the seismic load is applied.

For a building to remain safe during earthquake shaking, columns (which receive forces from beams) should be stronger than beams, and foundations (which receive forces from columns) columns & foundations should not fail so that beams can safely transfer forces to columns and should be stronger than columns.

5.1.1 Vulnerability of Existing Building Under an Earthquake Loading

By using SAP2000, the analysis of the structure under two earthquake loading which are from Acheh and Bukit Tinggi excitation have been done. The result of the analysis have shown that beam 172 and column 104 is one the critical member of the structure.

5.1.2 The Force Produce in the RC Building under Acheh and Bukit Tinggi Earthquake Load

Under Acheh earthquake excitation, the maximum shear for beam and column are 342.62 kN and 221.05kN respectively. While under Bukit tinggi earthquake excitation, the maximum shear is 284.56 kN and 186.2 kN. For the torsion, the maximum value for beam and column under Acheh earthquake loading are 72.19 kNm and 0.16 kNm. While under Bukit tinggi earthquake excitation, the maximum torsion is 60.57 kNm and 0.196 kNm. Both ratio of shear and torsion design versus the resistance are below than 1.0. Even though, the values were relatively below to 1.0, but the structure still exposed to the risk when it encounter earthquake excitation.

5.1.3 Dynamic Characteristics of RC building under Different Types of Loading

For this research, the dynamic characteristic are refer to the displacement and acceleration. The dynamic will produce different values with under different earthquake load. In this analysis, the highest acceleration occur during Bukit Tinggi excitation which is equal to 0.2592 m/s^2 and it is due to the force produce by the near location of seismic force.

5.2 RECOMMENDATIONS

For the future study, engineers need to design a building in Malaysia by considering the earthquake. This is because nowadays, the earthquake had happened in Malaysia but in small scale as Malaysia is nearest to the major tectonic plates on the Earth's surface. Even it is in small scale, it is still can make the building collapse especially when the structure is not laterally design with the earthquake effects. But this is not showing that the engineer can consider that there will be no earthquake in

Malaysia. So, in future, all building structure to design with considering the earthquake load.

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APPENDIX A1
CALCULATION OF MAXIMUM RESISTANCE FOR BEAM

Beam size = 400 mm × 600 mm

EC 2 : 04 Part 1 Clause 6.3.1 and Clause 6.3.2

Section Width, = 400 mm

Effective depth, d = 515 mm

Beam area, A = 400 × 600 = 240 000 mm^2

Beam perimeter, u = 2 × (400 + 600) = 2000 mm

Thickness of section $= \frac{A}{u} = \frac{240\,000}{2000}$ = 120 mm

Area within centreline, Ak = (b – t) × (h – t) = (400 – 120) × (600 – 120)

= 96 000mm^2

Perimeter of centreline, uk = 2(b + h – 2t) = 2(400 – 2(120)) = 1520 mm

Inner lever arm, z = 0.9 d = 0.9(515) = 463.5 mm

Shear Stress due to Loading, vss $= \frac{V \times 1000}{b\,z}$

$= \frac{289.38 \times 1000}{(400)(463.5)}$ = 1.56 N/mm^2

EC 2 : 04 Part 1 Expression 6.6

Strength Reduction Factor for Torsion and Shear, v = 0.6 × (1 – fck/250)

$= 0.6 \times (1 - \frac{30}{250}) = 0.528$

fcd $= \frac{fck}{1.5} = \frac{30}{1.5}$ = 20 N/mm^2

use θ = 22°

EC2 : 04 Part 1 Expression 6.30

Maximum Torsion Moment Resistance, $T_{Rd,max}$

$T_{Rd,max}$ = 2(v)(fcd)(Ak)(t)(sin θ . cos θ) / 10^6

= 2(0.528)(20)(96000)(120)(sin 22)(cos 22) × 10^{-6}

= 104.5 kNm/m

EC2 : 04 Part 1 Expression 6.9

Maximum Shear Resistance, $V_{Rd,Max}$

$$= b \times z \times v \times \frac{fcd}{\cot\theta + \tan\theta} \times 10^{-3}$$

$$= 400 \times 463.5 \times 0.528 \times \frac{20}{\cot\theta + \tan\theta} \times 10^{-3} = 679kN$$

EC2 : 04 Part 1 Expression 6.9

Maximum Shear Stress Allowed, $v_{Rd,Max}$

$$= v \times fcd / (\cot\theta + \tan\theta)$$

$$= 0.528 \times 20 / (\cot 22 + \tan 22) = 3.67\ N/mm^2 \geq vss$$

Therefore, checking for maximum shear stress allowed passed!

APPENDIX A2
CALCULATION OF MAXIMUM RESISTANCE FOR COLUMN

Column size	= 500 mm × 500 mm
Ø bar	= 20 mm
Ø link	= 10 mm
Spacing	= 175 mm

Shear and Torsion Calculation in z-z axis

Section width, Bx	= 500 mm
Section height, Hx	= 500 mm
Section effective depth, dx	= 465 mm

EC 2 : 04 Part 1 Clause 6.3.1 and Clause 6.3.2

Column area, A	= 500 × 500 = 250 000 mm^2
Column perimeter, u	= 2 × (500 + 500) = 1500 mm
Thickness of section	$= \frac{A}{u} = \frac{250\,000}{1500}$ = 166.67 mm
Area within centreline, Ak	= (b – t) × (h – t) = (500 – 166.67) × (500 – 166.67)
	= 111108.89mm^2
Perimeter of centreline, uk	= 2(b + h – 2t) = 2(500 – 2(166.67)) = 1333.32 mm

EC 2 : 04 Part 1 Expression 6.6

Strength Reduction Factor for Torsion and Shear, v = 0.6 × (1 – fck/250)

$= 0.6 \times (1 - \frac{30}{250}) = 0.528$

fcd	$= \frac{fck}{1.5} = \frac{30}{1.5}$ = 20 N/mm^2
use θ	= 22°

EC2 : 04 Part 1 Expression 6.30

Maximum Torsion Moment Resistance, $T_{Rd,max}$

$T_{Rd,max} = 2(v)(fcd)(Ak)(t)(\sin\theta \,.\, \cos\theta) / 10^6$

$= 2(0.528)(20)(111108.89)(166.67)(\sin 22)(\cos 22) \times 10^{-6} = 125.7$ kNm/m

EC2 : 04 Part 1 Expression 6.9

Maximum Shear Resistance, $V_{Rd,Max}$

$V_{Rd,Max}$ $= b \times z \times v \times \frac{fcd}{\cot\theta + \tan\theta} \times 10^{-3}$

$= 500 \times 0.9 \times 463.5 \times 0.528 \times \frac{20}{\cot\theta + \tan\theta} \times 10^{-3} = 767.51$ kN

EC2 : 04 Part 1 Expression 6.9

hear Stress due to Loading, vss $= \frac{V \times 1000}{b\ z} = \frac{125 \times 1000}{(500)(0.9)(465)}$

$= 0.09$ N/mm^2

Maximum Shear Stress Allowed, $v_{Rd,Max}$

$v_{Rd,Max}$ $= v \times fcd / (b \times z)$

$= 0.528 \times 20 / (500 \times 465) = 3.3$ N/mm$^2 \geq$ vss

Therefore, checking for maximum shear stress allowed passed!