SEISMIC PERFORMANCE OF CANTILEVER RETAINING WALL UNDER DIFFERENT EARTHQUAKE LOADING

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ABSTRAK

Beberapa tahun kebelakangan ini, jumlah bangunan struktur yang rosak dan terjejas disebabkan oleh gempa bumi semakin meningkat di Malaysia terutamanya di Sabah. Kajian telah dijalankan dimana gegaran di Malaysia adalah disebabkan oleh gelombang seismik yang dihasilkan daripada gempa bumi yang berlaku di negara jiran atau gegaran gempa berskala kecil yang berlaku. Sebab kegagalan struktur adalah kerana reka bentuk yang tidak mencukupi oleh jurutera tanpa mengambil kira kesan seismik ketika merancang struktur. Oleh itu, jurutera perlu mengambil berat tentang kekurangan pertimbangan tentang reka bentuk seismik di Malaysia Standard prosedur yang boleh dilihat dari prestasi seismik dan kelemahan tembok penahan yang digunakan secara meluas di Malaysia. Struktur dinding penahan yang kebanyakannya digunakan untuk mengekalkan tekanan bebanan sisi yang sangat kritikal dan penting untuk menghalang tanah daripada runtuh dan terhakis yang juga memegang tanah yang memberi kekuatan kepada bangunan dan struktur ini mungkin akan berlaku kerosakan dan pergerakan akibat kesan seismik. Oleh itu, matlamat kertas ini adalah untuk mengkaji ciri-ciri dinamik dinding penahan dan menilai kapasiti rintangan struktur di bawah bebanan gempa yang berbeza. Oleh itu, dinding penahan disimulasikan oleh model dan dianalisis menggunakan perisian *Finite Element Modelling* oleh perisian SAP2000 di bawah pelbagai jenis analisis yang berbeza. Analisis yang diliputi di dalam kajian ini adalah analisis getaran bebas, analisis sejarah masa dan tindak balas analisis spektrum di bawah dua pemuatan gempa bumi yang berbeza. Pemuatan gempa bumi diperolehi dari Jabatan Meteorologi Malaysia yang merupakan gempa Acheh dan Elcentro yang digunapakai di dalam analisis untuk melakukan perbandingan dalam ciri dinamik dinding penahan. Daripada analisis dapat merumuskan bahawa, struktur tembok penahan umumnya mampu menahan seismisiti yang rendah dan besar dan juga dapat menghasilkan pemuatan gempa yang berpotensi yang berbeza.

ABSTRACT

During past recent years, the number of building structural damage affected by earthquake is increase in Malaysia especially in Sabah. The study was conducted because the tremors in Malaysia were due to the seismic wave generated from the earthquake that occurred in neighbouring countries or low scale earthquake that occured. The reason of failure the structure because of inadequate design by Engineer without considering seismic effect in while designing the structure. Hence, engineers need concerned in lack of consideration of seismic design in Malaysia Standard procedure which can be seen from the seismic performance and vulnerability of cantilever retaining wall that widely used in Malaysia. Retaining wall structures mostly used in retaining the lateral earth pressure that is critical and important to prevent soil from collapse and erode which also held the soil that give the strength to the building and this structure may occur damage and movement due to seismic effect. Therefore, this paper objective is to study the behaviour and dynamic characteristics of retaining wall and asses the resistance capacity of the structure under different earthquake loading. Hence, the cantilever retaining wall simulated by modelled and analysed using finite element seismic response by SAP2000 software under different type of analysis. The analysis that covered in this research is free vibration analysis, time history analysis and response spectrum analysis under two different earthquakes loading. The earthquake loading is obtained from Malaysia Meteorological Department which is Acheh and Elcentro earthquake that implemented in the analysis to do the comparison in dynamic characteristic of cantilever retaining wall. It can summarize that, the retaining wall structures generally capable of resisting low and major seismicity and also can yield potential different earthquake loading.

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LIST OF SYMBOLS

km	kilometer
cm/yr	centimetre per year
m/s^2	metre per square second
Hz	Hertz
M	Meter
Nm	Newton meter
Mm	Milimetre
N	Newton
m/s	Meter per second
m^2	Meter square
g	Gals
s	second
Kn/m^2	Kilonewton per meter square

LIST OF ABBREVIATIONS

3D	Three dimensional
DL	Dead load
LD	Live load
RSA	Response Spectrum Analysis
SAP	Structural Analysis & Design Program
EC	Euro code
P	Primary
S	Secondary
L	Love
R	Rayleigh

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Earthquake disaster rarely happen in Malaysia except in Sabah and Sarawak, but the small number of seismic waves still can be felt in certain places especially because Malaysia is the nearest country to the tectonic plate located along Indonesia. Earthquake cause by a large strain of energy to the earth crust that produce from the movement of two tectonic plates slipped and moved away or towards each other. This is associated with the subduction zones between the Indo-Australian plate and Eurasian plate at the west and south part, also the subduction zones between the Eurasian and Philippines plate at the east region (Adiyanto & Majid, 2014).

In 2004 an earthquake with magnitude Mw 9.0 occurred in Indian Ocean with an epicentre at west coast of northern Sumatra caused by a rupture along the fault between Burma Plate and the Indian plate which also generated a disastrous tsunami that struck the coast of several countries in Southeast Asia. According to (Adiyanto & Majid, 2014), a total of 76 persons have been reported killed and many properties had been destroyed when the tsunami hit along the northwest coastal areas of Perlis, Kedah, Penang, and to some part of Perak. In Malaysia the strongest earthquake struck at Ranau, according to (Majid, Adnan, Adiyanto, Ramli, & Ghuan, 2017) on June 5th 2015, a moderate earthquake with magnitude Mw5.9 as reported by Malaysian Meteorological Department was occurred in Sabah, Malaysia around 7:15 am local time. The impact of tremor can be felt through Kota Kinabalu, Kundasang, Kota Belud Ranau and Donggohgon. The magnitude of this earthquake falls into the moderate category which can cause property damage and based on the figure 1.1 below the number of the earthquake with moderate magnitude occur 200 times per year worldwide. It gives bad impact on the structures although the intensity and magnitude were not as bad in other countries. Figure 1.2 shown that the earthquake epicentre located approximately 15 km north of Ranau with 10-meter-deep of focal depth. This shown that Malaysia need to aware with the earthquake hazard and tremors that had been felt due to the nearest earthquake by implement new method in designing building structure by including seismic design.

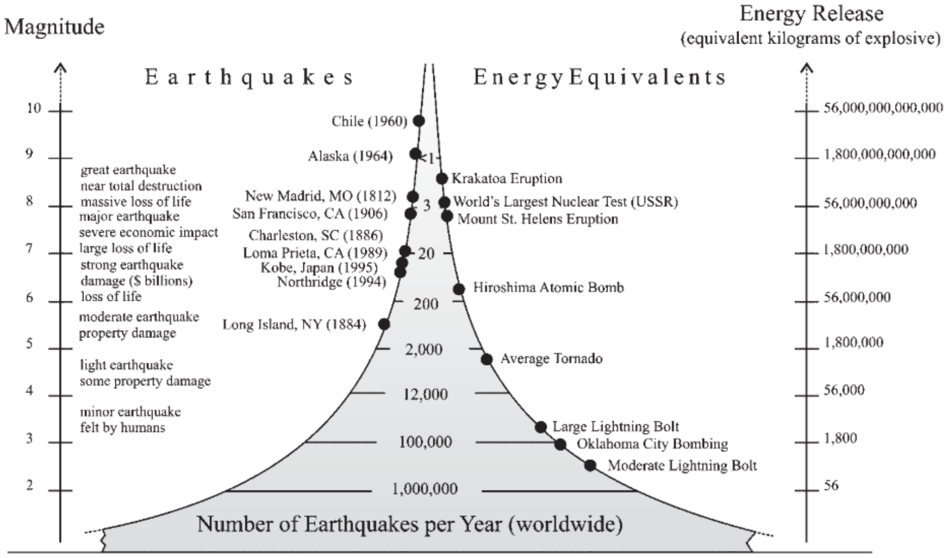
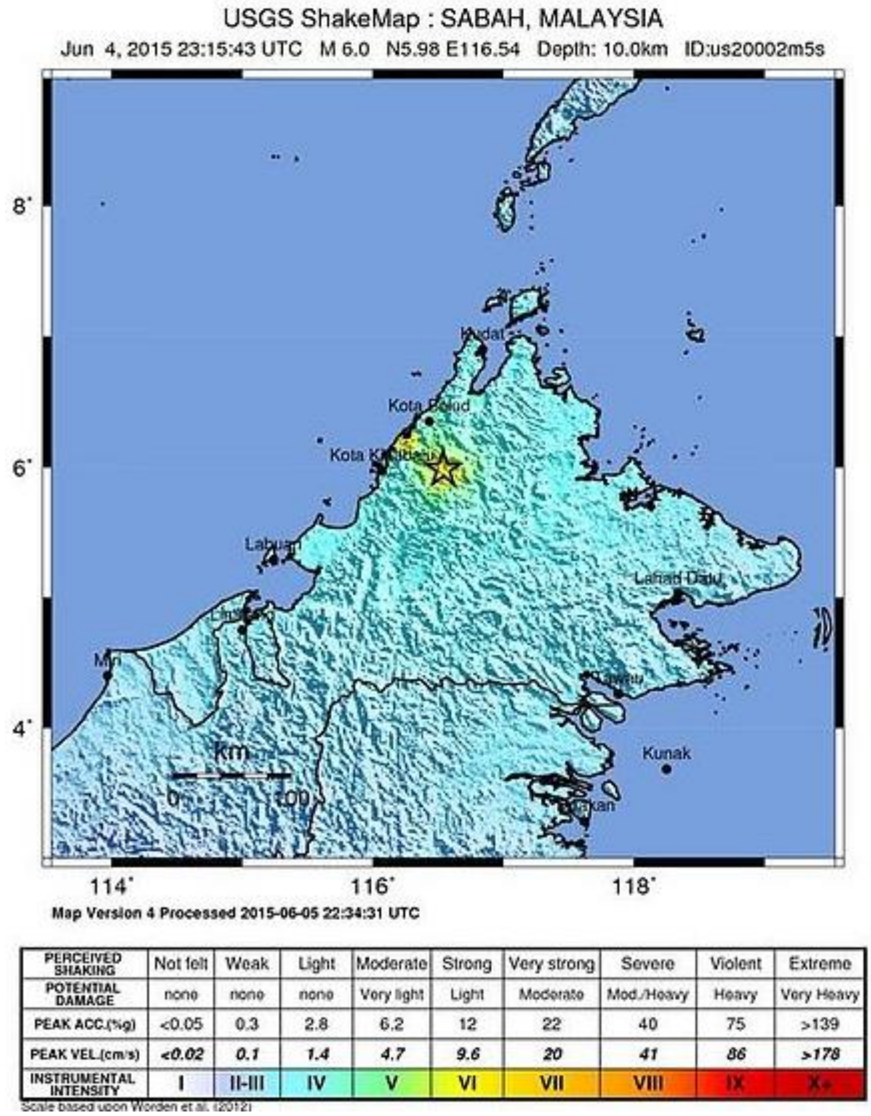


Figure 1.1 Correlation between magnitude and energy release



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	<0.02	0.1	1.4	4.7	9.6	20	41	86	>178
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 1.2 Epicentre of ranau earthquake.

(USGS,2016)

In Malaysia, there are a lot of development in hilly area either existed building and ongoing construction. Retaining wall widely used to retains soils behind it to prevent landslide that cause from erosion and cause failure of slope. Mostly retaining walls places at area of extra support required to prevent the soil from moving downhill with erosion. In modern development retaining walls used to create terraces provide usable land on slopes. These have been engineers challenge to provide the best design of retaining walls to provide safe structures.

1.2 PROBLEM STATEMENT

Malaysia are near to the country that surrounded by the ring of fire and the cyclonic wind that prone to natural disaster such as volcanic eruption, earthquakes and hurricanes. Fortunately, as shown in figure 1.3 Malaysia located between these cyclonic wind and circle of fire and the disaster not occur originally in Malaysia but by the effect of the earthquake from other countries. A few states may have inactive fault line and had been struck by small intensity earthquake as example latest news Ranau struck by 6.0 magnitude of earthquake which we can see the states very close to the ring of fire located in Indonesia and Philippines. Hence this shown Malaysia can feel the tremor from near earthquake as we already familiar with massive Aceh earthquake of 2004 cause tsunami in various countries including Malaysia.

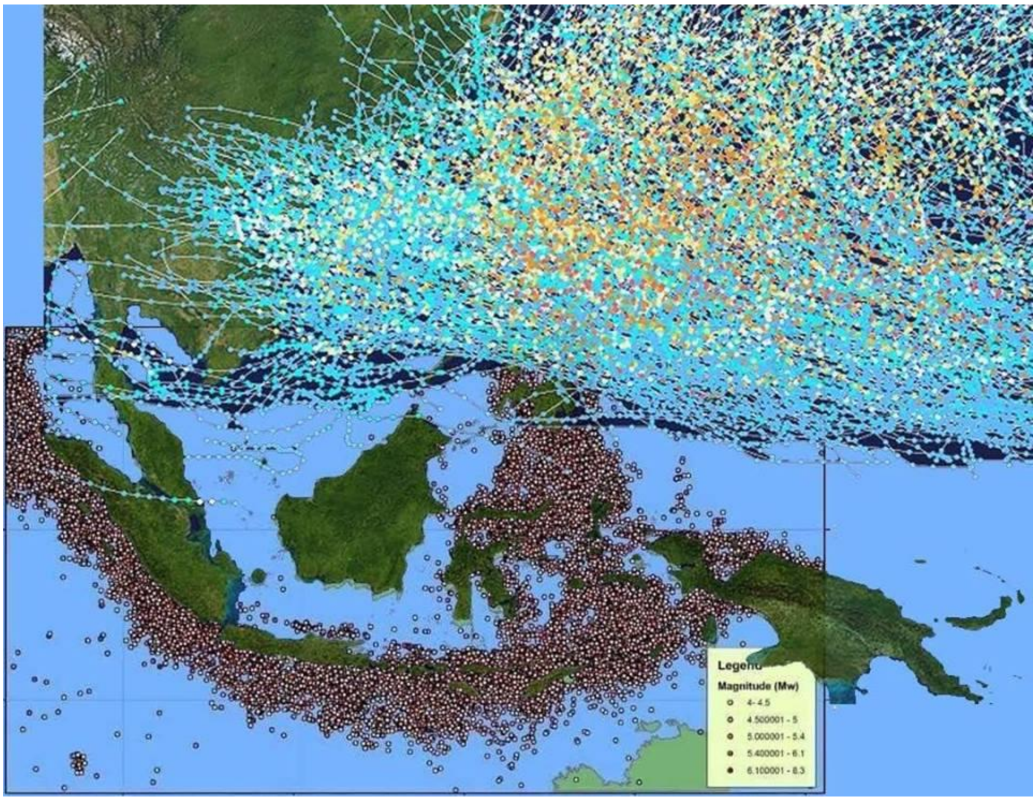


Figure 1.3 Ring of fire and cyclonic wind area

Source: https://cilisos.my/what-protects-malaysia-from-all-these-earthquakes-that-is-happening-in-indonesia/

The retaining wall design practices in Malaysia are focusing mostly on lateral force analysis but rarely include the seismic force effect. Therefore, the retaining walls safety level under earthquake loading cannot be ensured at the specific intensity of earthquake acceleration. Hence, this study was carried out to simulate the effect of earthquake loading to the existing retaining walls structure in Malaysia.

1.3 RESEARCH OBJECTIVES

The main objective of this research is to evaluate the seismic performance of cantilever retaining wall under different earthquake loading and come with other objectives shown below:

i. To determine vulnerability of existing critical retaining walls under earthquake loading.
ii. To assess the performance of the retaining walls under different type of loading.
iii. To study the dynamic characteristic of retaining wall under different type of loading.

1.4 SCOPE OF STUDY

In this research, earthquake loading effect to the retaining wall structure determined by modelling the structure using software. The area of the study conducted in Malaysia effected with Indonesia earthquake that affected retaining wall structure.

i. Type of structure limited to retaining wall.
ii. The case study of earthquake effect to retaining wall structure in Malaysia region due to Acheh and Elcentro earthquake.
iii. Resistance of retaining wall structure due to the earthquake loading.
iv. The software that used for modelling analysis of the retaining wall is SAP 2000 and Tekla.

1.5 SIGNIFICANCE OF STUDY

At the end of this research, we could determine the performance and behaviour of existing critical retaining wall structure from the effect of the earthquake loading from Acheh and Elcentro earthquake in Malaysia. The dynamic characteristics of wall could be determined when the simulation of the model is done. Based on the result from the simulation, it might be helpful by considering the seismic design in designing the retaining wall structures in Malaysia. Hence it can increase the safety factor of the retaining wall that can reduce damage, collapse and consequences disaster such as land slide. Besides, this study can enhance awareness to citizen especially expertise group in construction about earthquake effect to the structure which can provide safe structure to save many lives.

CHAPTER 2

LITERATURE REVIEW

2.1 EARTHQUAKE

2.1.1 Fundamental of Earthquake

Earthquake known as a disaster that can be feel from ground shaking cause from the sudden release of energy in the layer of earth called crust. The sources of the energy might originate from different sources such as volcanic eruption, manmade explosions, dislocations of the crust or the collapse of underground cavities such as karst or mines. The convection process that occur are because of pressure gradient and high temperature between core and the crust cause circulation process in the earth layers. Resulting from the circulation, hot molten lava splashes out and the cold rock mass fall into the Earth which will melts and become part of the mantle and will come out again someday. Convection currents within the earth's viscous mantle, powered by vast amounts of thermal energy radiating from the earth's core, generate forces sufficiently large to move the continents (Charleson, 2012). The tectonic plate can be analogy of chicken egg where the fragment of cracked shell moves and floating on fluid egg white and yolk. The movement of the tectonic plate are as fast as our fingernails grow with 50mm per year and figure 2.1 below show numbers of tectonic plates and their annual movement (mm) with the dots indicate positions of past earthquake. The theory of tectonic plates derives from the understanding of dynamic process called as tectonic plate movement or continental drift and sea floor spreading.

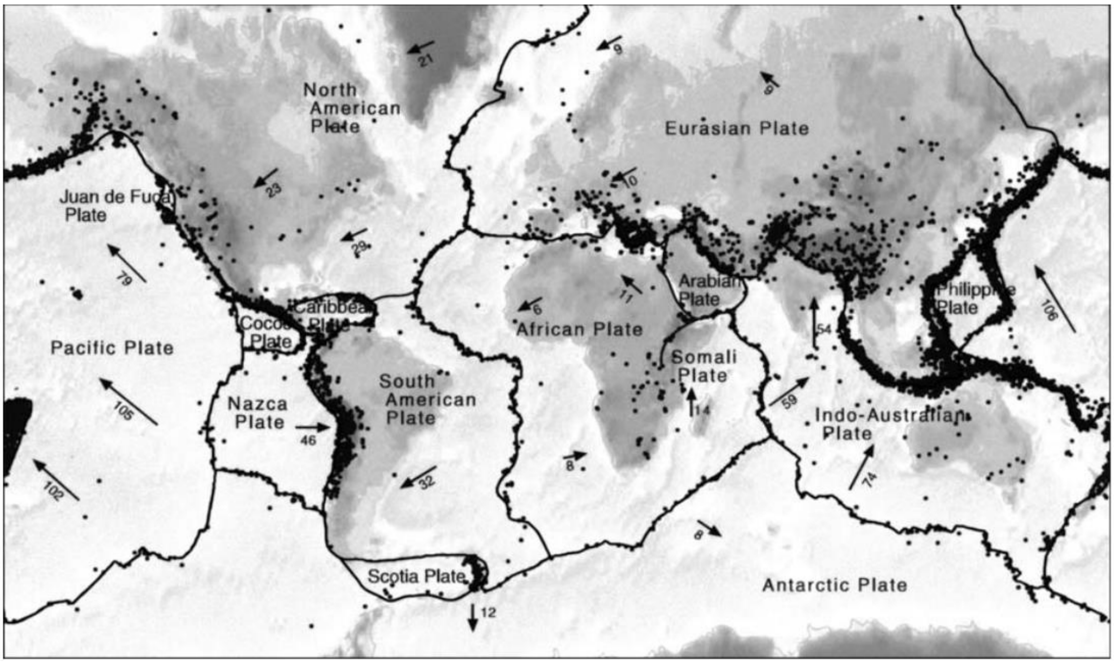


Figure 2. 1 Tectonic plates and their annual movement (mm). The dots indicate the position of past earthquakes.

Source: Seismic design for architects: Outwitting the quake (Charleson, 2012)

The subduction and slip process of tectonic plates cause rupture due to rock that absorb and store greater shear strains accumulate energy in the rock then release a sudden violent movement. There are seven major tectonic plate that cover 95% of the world's surface. There may have three types of movement under inter-plate interaction of the plates which is divergent, convergent and transform. Convergent interaction is when two plates move toward each other and collides, and mountains are formed. Sometimes two plates move away from each other and created rift which this called as divergent. In addition, in our study for those two interactions we called it as dip slip where one block moves vertically respect to each other that have two type of fault. Normal fault is when the footwall moves away from the hanging wall that cause by tension and the reverse fault is when the footwall moves toward the hanging wall that cause by compression. Moreover, transform interaction correlated with strike-slip fault where the two plates move horizontally with each other at different direction and velocity.

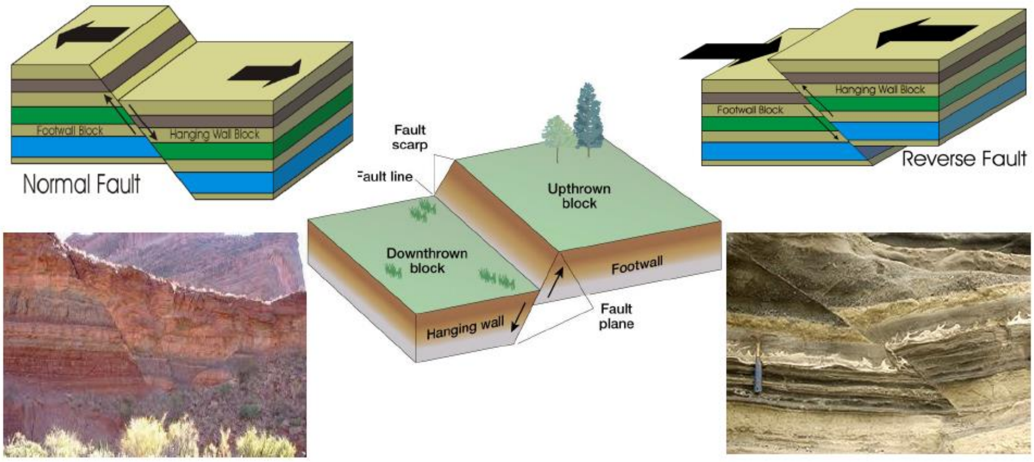


Figure 2. 2 Dip slip plate movement.

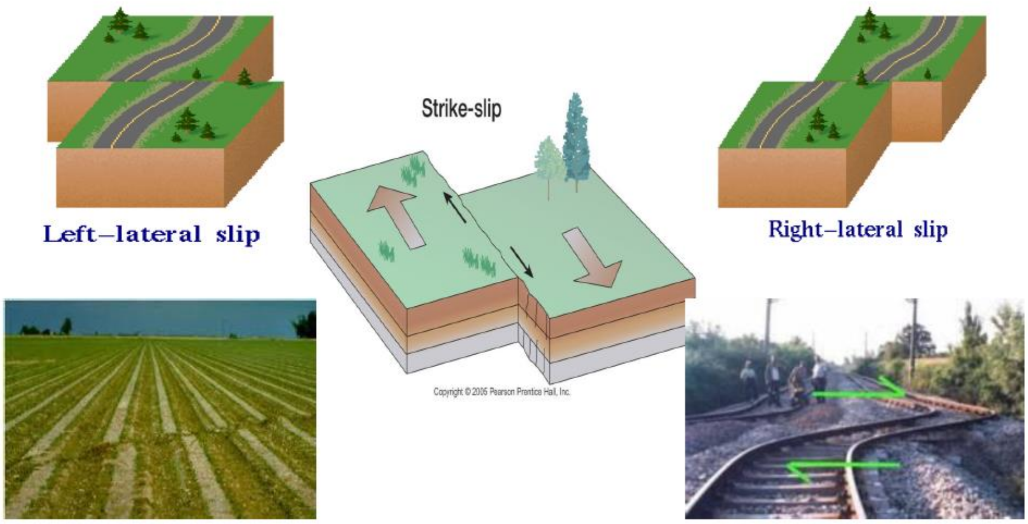


Figure 2. 3 Strike-slip plate movement.

The length and depth of the fault can be classified the earthquake and the intensity of the seismic wave to the point of interest. Focus is the point under the earth surface where rupture point of energy release to have originated. Fracture on the surface in the earth crust layer call as surface fault. Besides, the projection of the focus on the ground surface is the epicentre and the epicentral distance can be measure from it to the site of interest. Figure 2.4 below show the illustration of basic earthquake terminology.

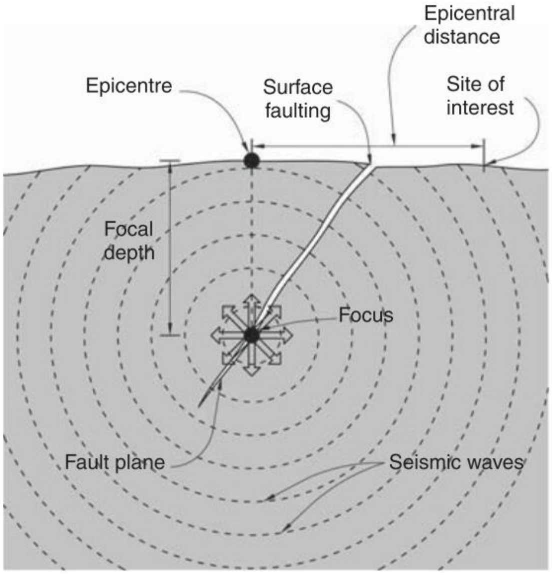


Figure 2. 4 Illustration of basic earthquake terminology.

Source: Seismic design for architects: Outwitting the quake (Charleson, 2012)

2.1.2 Seismic waves

Seismic waves are a form of energy that release during earthquake or explosion that travels through earth’s layer in all directions refracting and reflecting at each interface. There are two types of seismic waves which is body waves and surface waves. Waves that travel through ground surface of earth is called as surface waves while the waves that travel through the interior ground called as body waves. Moreover, body waves divided into two which is P-waves and S-waves while love waves and Rayleigh waves fall under surface waves category. Body waves arrive earlier than surface waves because body waves have higher frequency compared to surface waves. Even though the surface waves are easily distinguished on seismogram, mostly the destruction of structure are cause by them. The strength of the surface waves decreases proportionally with the depth of the earthquakes.

a) P-waves

P letter used as acronym for primary waves. Primary waves also known as compressional waves as the action of pushing and pulling they do that cause compressional and extensional strains in material particles along the direction of energy transmission. P wave can move through fluids and solid rock. P waves are the first signal from earthquake that detected by the seismograph as it travel faster than other seismic waves. P wave can be analogy as the big thunder clap that we had experienced in our life when the window glass rattle at the same time with the thunder clap. The windows rattle because the window glass was pushing by the sound waves similarly like the P waves that pull and push the rock.

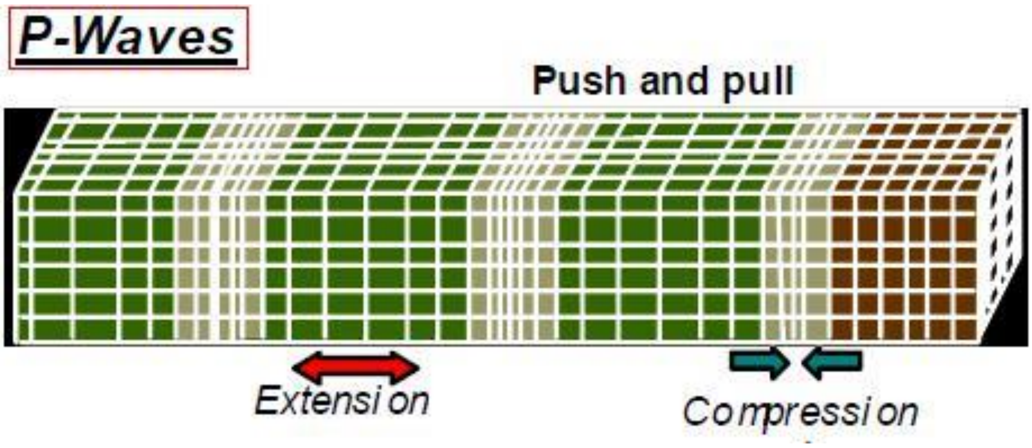


Figure 2. 5 Motion cause by P waves

b) S waves

Secondary wave under category of body wave which this wave is the second wave that we feel during an earthquake. This wave not move through any liquid but only move in solid rock medium. S wave cause the rock particle to move up and down or side to side perpendicular to the wave direction. The fact that name of secondary waves is come from the second wave that detected by seismogram during an earthquake.

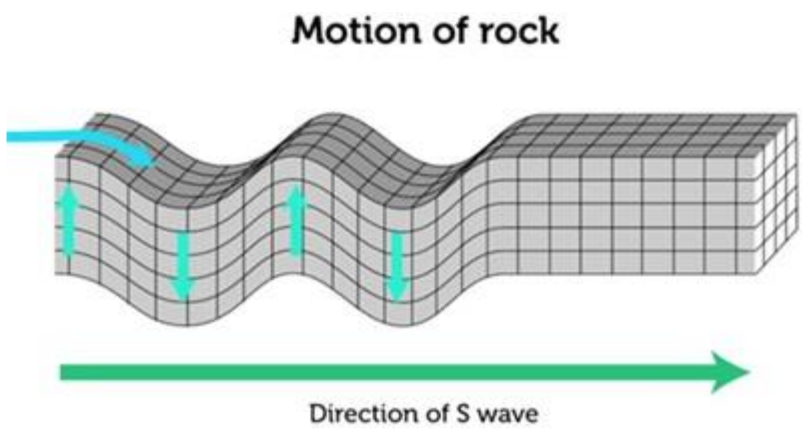


Figure 2. 6 Motion of rock cause by S wave.

c) Love waves

Love waves move from side to side and the fastest surface wave that produce horizontal motion during an earthquake. Love waves travel faster than Rayleigh waves with velocity of 2 to 4.4 km/sec.

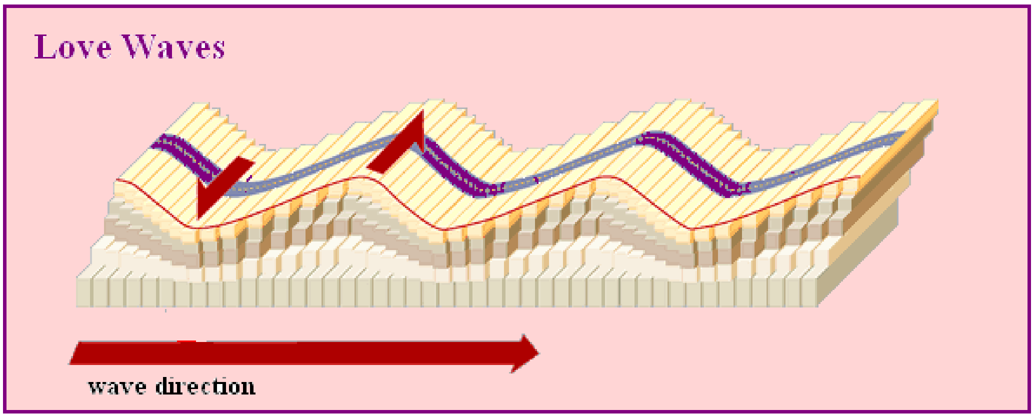


Figure 2. 7 Motion of particle cause by Love waves.

d) Rayleigh waves

This wave causes the ground to move side to side, and up and down in the same direction of wave moving which consequences of combination of P waves and S waves movement. Rayleigh wave can cause much larger shaking effect than the other waves. Wavelength of this wave have properties of dispersion which it will keep changing and the acceleration movement is not stable.

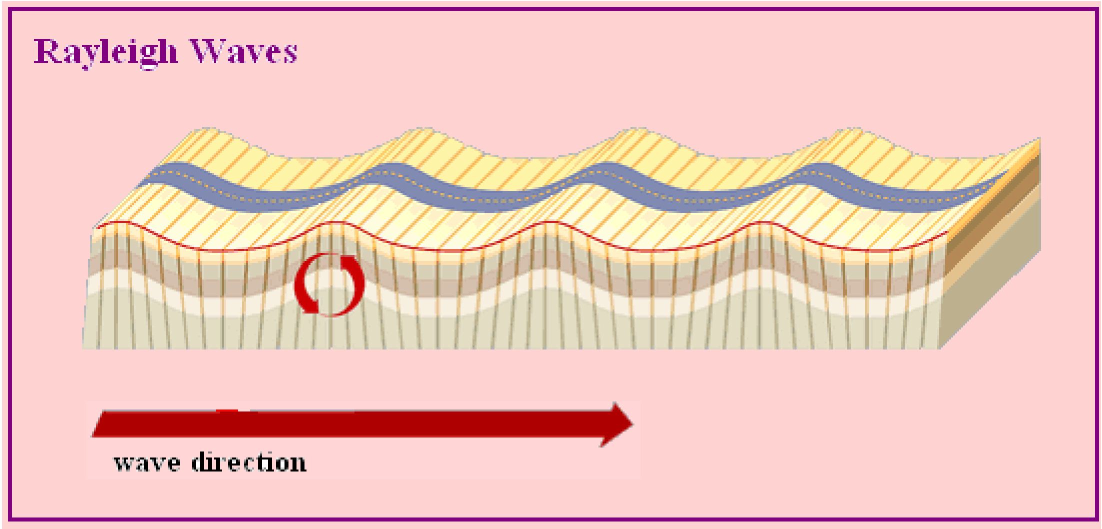


Figure 2. 8 Motion of particle cause by Rayleigh waves.

2.1.3 Measurement of Earthquake

2.1.3.1 Magnitude

The size of an earthquake is described in terms of magnitude, which is a measure of the amplitude of a seismic wave and is related to the amount of energy released during an earthquake (Baxter, 2000) . In 1930s Charles Richter introduced a magnitude scale that known nowadays as Richter scale which the objective to judge the size of shock by using seismograph that recorded the wave amplitude.

▼ 1.1 Partial summary of the Modified Mercalli Intensity (MMI) Scale

Intensity	Description
I to III	Not felt, except under special circumstances.
IV	Generally felt, but not causing damage.
V	Felt by nearly everyone. Some crockery broken or items overturned. Some cracked plaster.
VI	Felt by all. Some heavy furniture moved. Some fallen plaster or damaged chimneys.
VII	Negligible damage in well designed and constructed buildings through to considerable damage in construction of poor quality. Some chimneys broken.
VIII	Depending on the quality of design and construction, damage ranges from slight through to partial collapse. Chimneys, monuments and walls fall.
IX	Well designed structures damaged and permanently racked. Partial collapses and buildings shifted off their foundations.
X	Some well-built wooden structures destroyed along with most masonry and frame structures.
XI	Few, if any masonry structures remain standing.
XII	Most construction severely damaged or destroyed.

Figure 2. 9 Modified Mercalli Intensity scale

Source: Seismic design for architects: Outwitting the quake

Earthquakes have different magnitudes depending on method used to estimate the magnitude. Nowadays reporter love to use term Richter scale in reporting any earthquake news but any large earthquake that had been reported using Richter scale unlikely is an appropriate scale. The magnitude of earthquake events will be change as more data gets analysed. According to (Denton, 2004) , the devastating Dec 24^{th} 2004 event in Sumatra the original magnitude of Mw 9.0 was later recalculated to Mw 9.3 as more data was analysed.

2.1.3.2 Intensity

Intensity is a qualitative measure of the actual shaking at a location during an earthquake, and is assigned as Roman Capital Numerals (Murty, 2005). Intensity values show and reflect how we experienced the shaking and the degree of damage cause. There are two commonly used intensity scales which is Modified Mercalli Intensity (MMI) scale and the MSK scale. The scale range indicate from I with least perceptive to XII with most severe. The intensity and the severity of shaking is higher near the epicentre as the seismic waves diminishes when the point of interest distance farther from the epicentre. In seismic design the peak ground acceleration (PGA) is one of the ways on how to quantify the severity of ground shaking.

MMI	V	VI	VII	VIII	IX	X
PGA (g)	0.03-0.04	0.06-0.07	0.10-0.15	0.25-0.30	0.50-0.55	>0.60

Figure 2. 10 PGAs during shaking of different intensities

2.1.4 Ground motion records

Ground motion records from the real earthquake animated as propagation of energy waves. It divided into two part of earthquake field which is Far field earthquake and near field earthquake. The far field earthquake recorded reading distance is 50 km or more from the fault occur while near field earthquake recorded distance is less than 50km from fault. Besides, near field earthquake have forward, backward and flip directivity effect. The forward directivity effect can be defined and identified when the ground motion propagates toward the site with a velocity which closes to the shear wave velocity. Meanwhile, backward directivity is the ground motions where the wave propagates away from the site with longer duration and lower amplitude. Displacement of ground surface that cause by any ground motions is classified as fling step. Rupture mechanism strongly influence to tectonic deformation which is related with fling step.

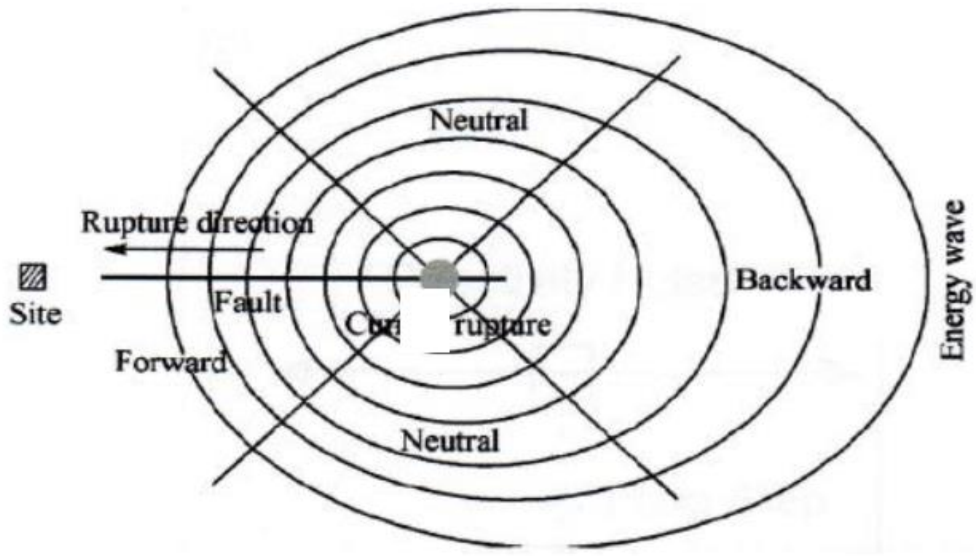


Figure 2. 11 Diagram of directivity of propagation of ground motion in Near field Earthquake.

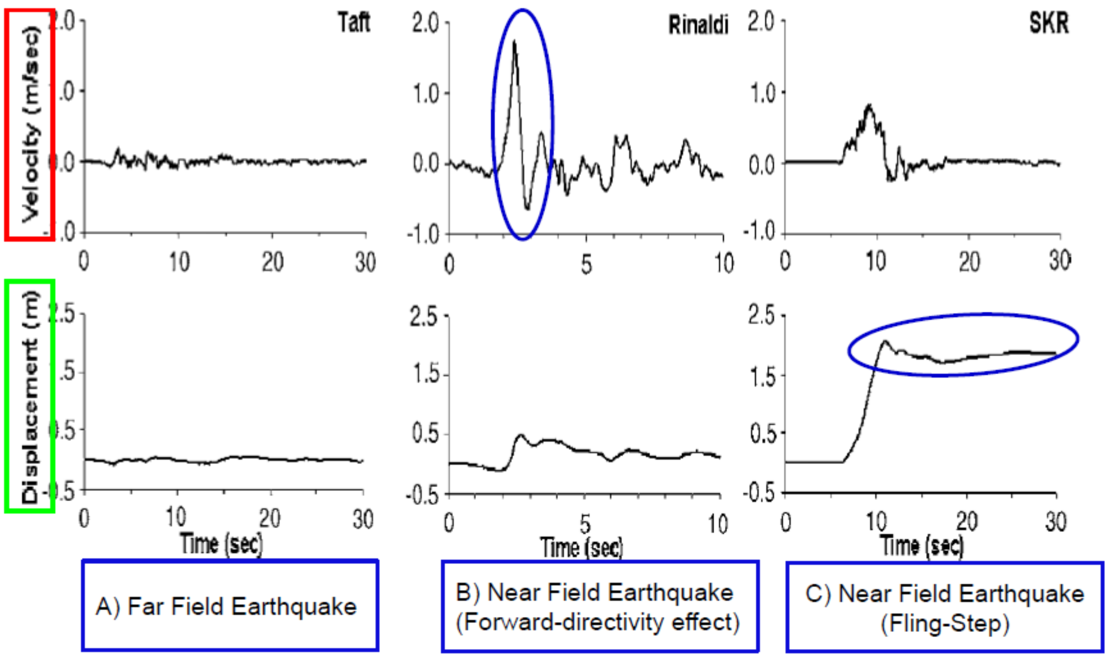


Figure 2. 12 Typical ground motion records from real earthquakes.

2.1.5 Seismic hazard map

Seismic hazard map shows the seismic intensity of region and associate with potential earthquakes area based on past fault and earthquakes. Hazard maps can be used as reference for development in mitigation, emergency response and for land use planning. The seismic hazard maps indicate diverse probabilities that are chosen to give a thought of the relative scope of danger. The bigger probabilities show the level of ground movement liable to cause issues. The littler probabilities indicate how impossible harming ground movements are in numerous spots. However, fundamentally the values picked mirror the latest history in earthquake designing. The map value is in form of reference peak ground acceleration, αgr and the unit are in gal, g. Below shown the seismic hazard map of Malaysia with a 10% probability of exceedance in 50 years (first edition,2017).

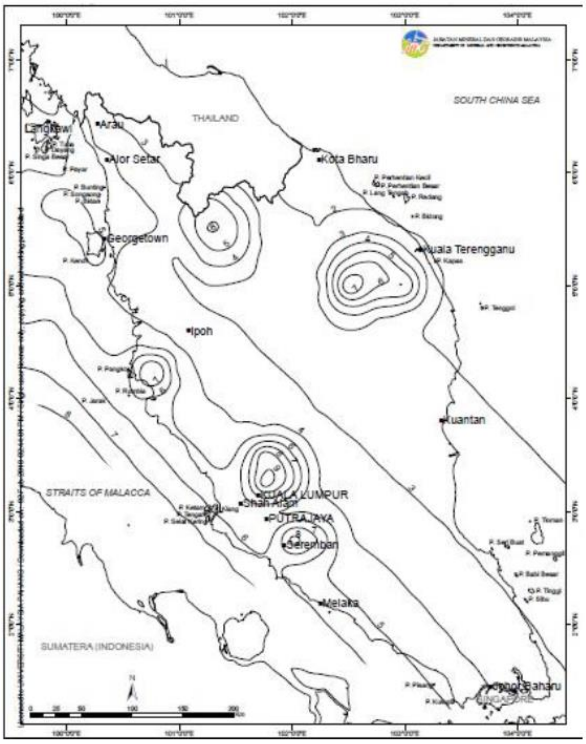


Figure 2. 13 Seismic hazard map of Peninsular Malaysia

Source

Source: Malaysia National Annex to Eurocode 8: Design of structures for earthquake resistance- Part 1: General rules, seismic actions and rules for buildings.

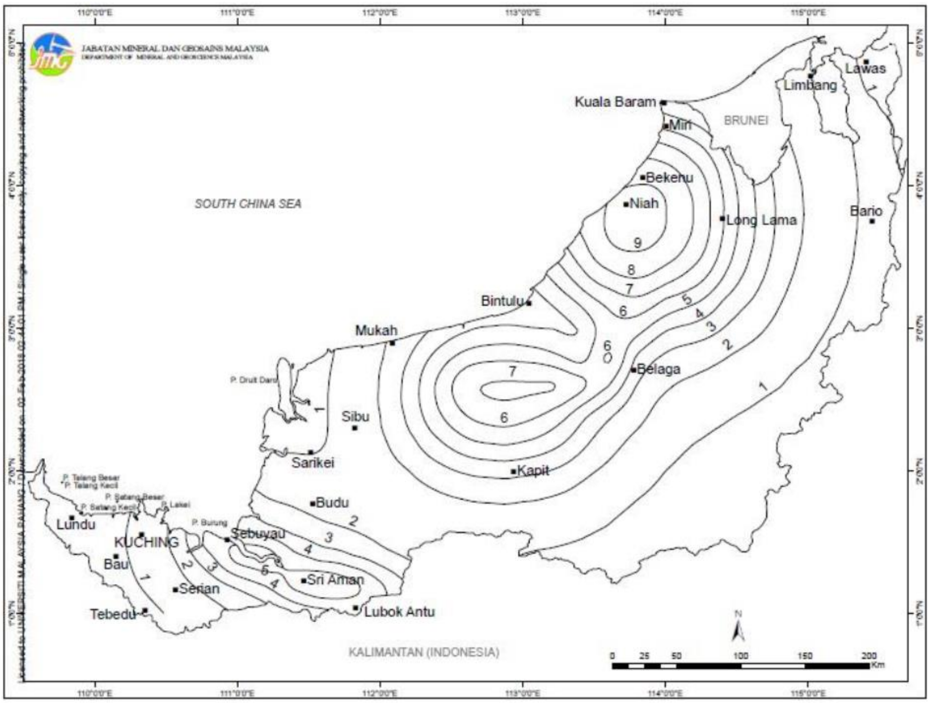


Figure 2. 14 Seismic hazard map of Sarawak.

Source: Malaysia National Annex to Eurocode 8: Design of structures for earthquake resistance- Part 1: General rules, seismic actions and rules for buildings.

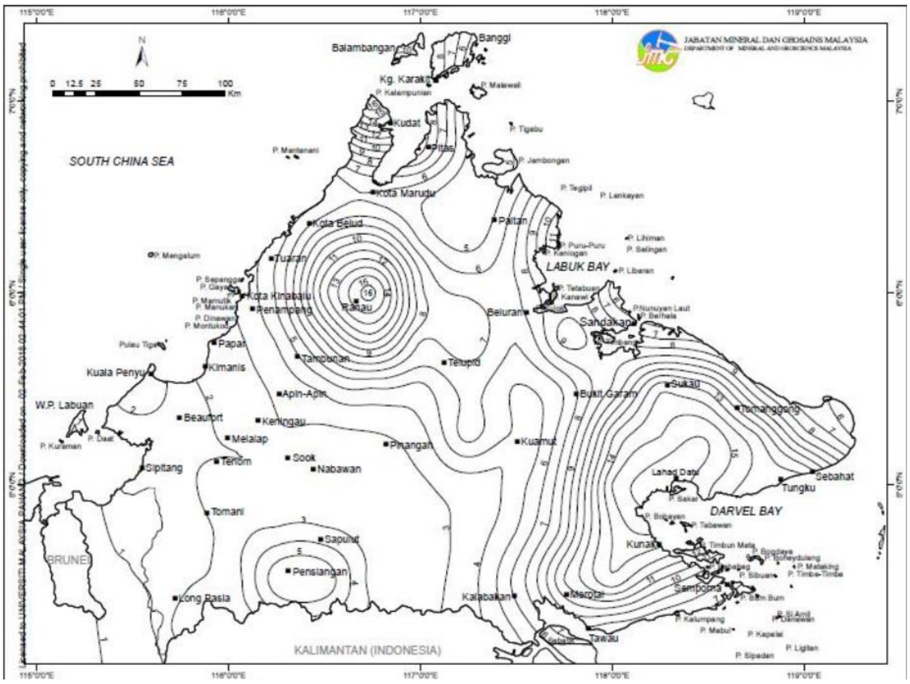


Figure 2. 15 Seismic hazard map of Sabah.

Source: Malaysia National Annex to Eurocode 8: Design of structures for earthquake resistance- Part 1: General rules, seismic actions and rules for buildings.

2.2 RETAINING WALL

Retaining walls is rigid walls structure used for supporting the soil mass prevent from erosion at different level of height. Retaining walls are structures intended to control soil to a slope that it would not normally keep to. They are utilized to bound soils between two distinct rises regularly in regions of terrain having unfortunate slopes or in zones where the scene should be formed seriously and designed for more particular purposes like slope cultivating or roadway bridges.

2.2.1 Gravity Retaining wall

Gravity dividers rely upon their mass to oppose weight from behind and may have a 'batter' setback to enhance soundness by reclining toward the held soil. For short landscaping walls, they are frequently produced using mortar less stone or segmental solid units as example brick units. Dry-stacked gravity walls are adaptable and don't require an unbending balance. Gravity holding dividers are substantially thicker in segment. Geometry of these dividers additionally assist them with maintaining the steadiness. Mass solid dividers are appropriate for held statures of up to 3 m. The cross-area state of the divider is influenced by security, the utilization of room before the divider, the required divider appearance and the strategy for development.

2.2.2 Cantilever Retaining Wall

Cantilever retaining walls are developed of reinforced concrete. They comprise of a generally thin stem and a base slab. The base is likewise partitioned into two sections, the heel and toe. The heel is the piece of the base under the backfill. The toe is the other piece of the base. Cantilever retaining wall are for the most part of reinforced concrete and work on the standards of use. Have significantly slenderer stem and use the heaviness of the backfill soil to give the greater part of the protection from sliding and toppling. These walls are named yielding as they allowed to turn about the foundation because of the lack. This is the most widely recognized sort of earth holding structure. The cantilever retaining wall developed of reinforced Portland-cement concrete (PCC) was the prevalent sort of inflexible retaining wall utilized from about the 1920s to the 1970s. Earth slopes and earth retaining structures are utilized to keep up two diverse ground surface elevations behind it and accomplish strength against failures. Gravity Retaining Wall can be built from solid, stone or even block brick work. Gravity retaining wall are considerably thicker in section. Geometry of these walls likewise assist them with maintaining the stability. Mass solid of walls are reasonable for retain soil of up to 3 m. The cross-section state of the walls is influenced by safety, the utilization of space in front of the wall, the required wall appearance and the technique for development.

2.2.3 Piling Retaining Wall

In area that have soft soil and tight space usually the sheet pile retaining walls will be used. The sheet pile that made of steel, vinyl or wood planks are driven into the soil using machinery. The depth of the material usually driven is 2/3 below the ground and 1/3 above ground but depending on the environment. Taller walls will need tie back anchor or dead load at certain distance behind the face of the wall that is tied to the wall by cable or rod. Interlocking sheet pile walls are used for many applications including cofferdams, basement walls, pits and marine structures.

2.2.4 Anchored Retaining Wall

Ground-anchored walls are thin concrete retaining walls that are permanently anchored to firm ground by grouted ties. The bar or strand ties are called permanent ground anchors or tiebacks. They generally are inserted into holes that are drilled or driven into the existing soil or rock behind the wall. High loads are expected to be catered by the walls and walls tend to slender proved that this type of wall is suitable.

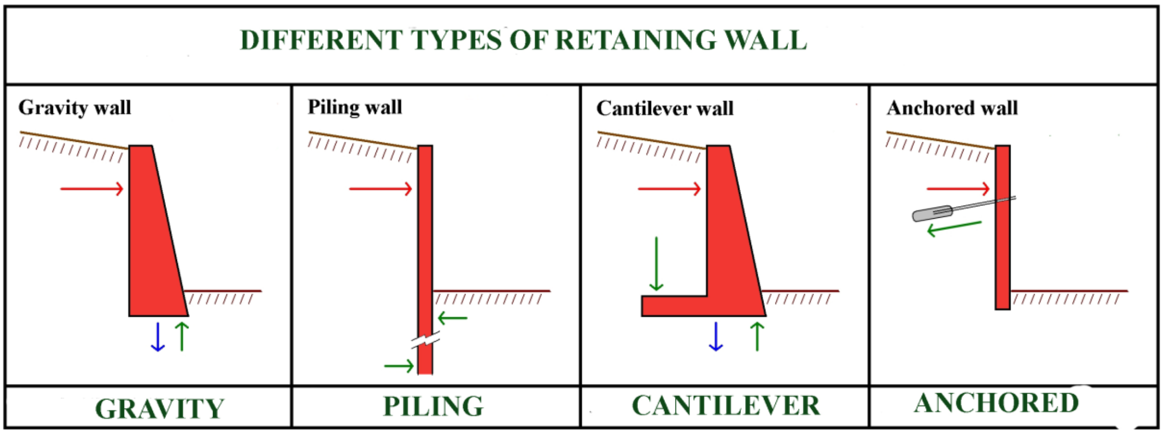


Figure 2. 16 Type of retaining walls.

Source: https://www.aboutcivil.org/retaining-wall-definition-types-uses-retaining-walls.html

2.3 SAP 2000

SAP2000 is general-purpose civil-engineering software ideal for the analysis and design of any type of structural system. Basic and advanced systems, ranging from 2D to 3D, of simple geometry to complex, may be modelled, analysed, designed, and optimized using a practical and intuitive object-based modelling environment that simplifies and streamlines the engineering process. An additional suite of advanced analysis features is available to users engaging state-of-the-art practice with nonlinear and dynamic consideration. Created by engineers for effective engineering, SAP2000 is the ideal software tool for users of any experience level, designing any structural system.

Integrated modeling templates, code-based loading assignments, advanced analysis options, design-optimization procedures, and customizable output reports all coordinate across a powerful platform to make SAP2000 especially useful for practicing professionals. Complex Models can be generated and meshed with powerful built in templates. Integrated design code features can automatically generate wind, wave, bridge, and seismic loads with comprehensive automatic steel and concrete design code checks per US, Canadian and international design standards.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 INTRODUCTION

In this research methodology part chapter is aiming to present the process of collecting data and information to achieve objective and making the decisions. There is variation of methods such as interview, surveys, journal, research techniques and simulation. In this research the methods of running software simulation to do the analysis have been chosen. The chosen software to be used to analyse the retaining wall structure is SAP2000 where it has specialty in analysing complex and basic structure where includes the seismic performance.

The steps of the research collection of data and analysing the will be review in this chapter. Data obtained from the Malaysian Meteorological Department of Acheh's earthquake is used for seismic analysis on the retaining walls structure. The data includes the time history and spectrum analysis of Acheh's earthquakes.

Reinforced concrete structure building is common in Malaysian construction scene or anywhere else in this world which have various of advantages to the users; for example, hospital building which provides patient treatment and shelters which is important and critical during disaster event occur. In addition, retaining walls is also a reinforced concrete structure that being used to hold and retain the soil form erode and sliding. Besides we can see retaining walls always being used at the perimeter of a project for example hospital which shown this structure is important to avoid failure of soil and causing consequences to other building around the area. Flexible and ductile structure can perform better when subjected to earthquake and one of it is steel structures; for example, steel bridge structure that we can see a lot around the world designed to connecting two places that separated by river, sea, lake or height of certain level. The vulnerability of these types of structures in Malaysia can be determined through this methodology. In fact, when the structures subjected to the earthquake loadings, the characteristics and dynamic characteristics of the structures can be determined.

The following planning and scheduling are arranged to ensure the research undergo smoothly and successfully. Below shown the chart and planning of how analysis going using software SAP200 in **Figure 3.1**.

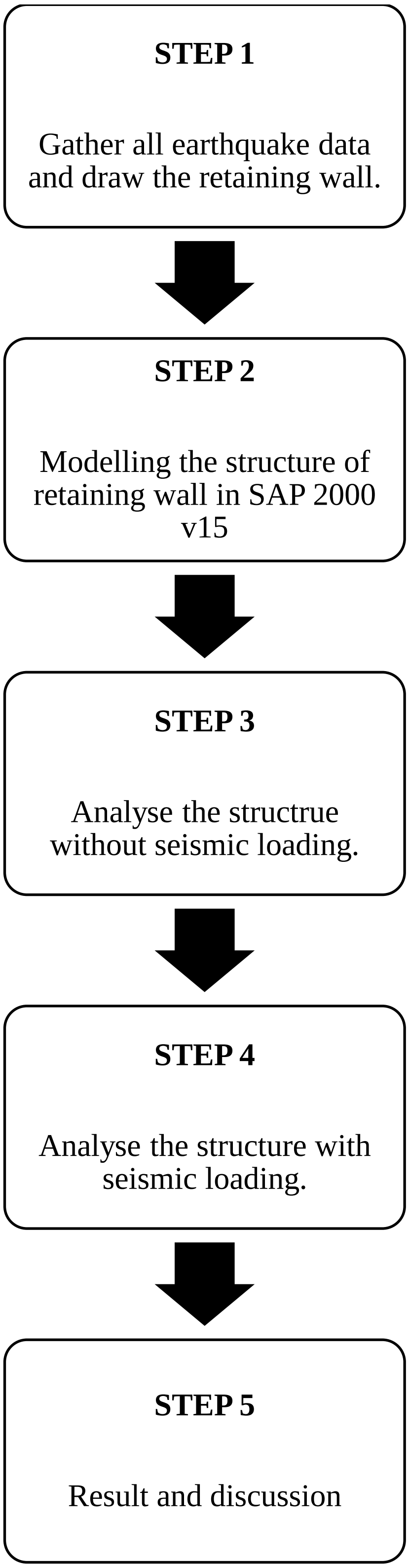


Figure 3. 1 Flow chart of methodology

3.2 GATHERING INFORMATION AND DATA

In this phase, to ensure the research study undergo smoothly, it is vital to obtain the information and data for modelling and analyzing the structure. The information and data needed are as follow:

i. Location of the case study of the retaining wall. The design used for the analysis was retaining wall design projects in Terengganu.
ii. Drawing of the retaining wall. The drawing contained detail of typical cross section such as height of wall, length of toe and heel of retaining wall, thickness and width of wall.
iii. Material used for the structure of retaining wall. For this analysis, the material used for the structure is reinforced concrete (RC).
iv. Earthquake data for seismic analysis. The earthquake data used in this research is from Acheh Earthquake that occurred in 2004 and Elcentro earthquake data. The data is acquired from the Malaysian Meteorological Department.

3.2.1 RETAINING WALL STRUCTURE

Various type of retaining wall structure exist and the type that had been used in this analysis is cantilever retaining wall structure. This cantilever retaining wall is existing structure that located in Terengganu **Figure 3.2** below shows the dimension and details of the typical cantilever retaining wall structure.

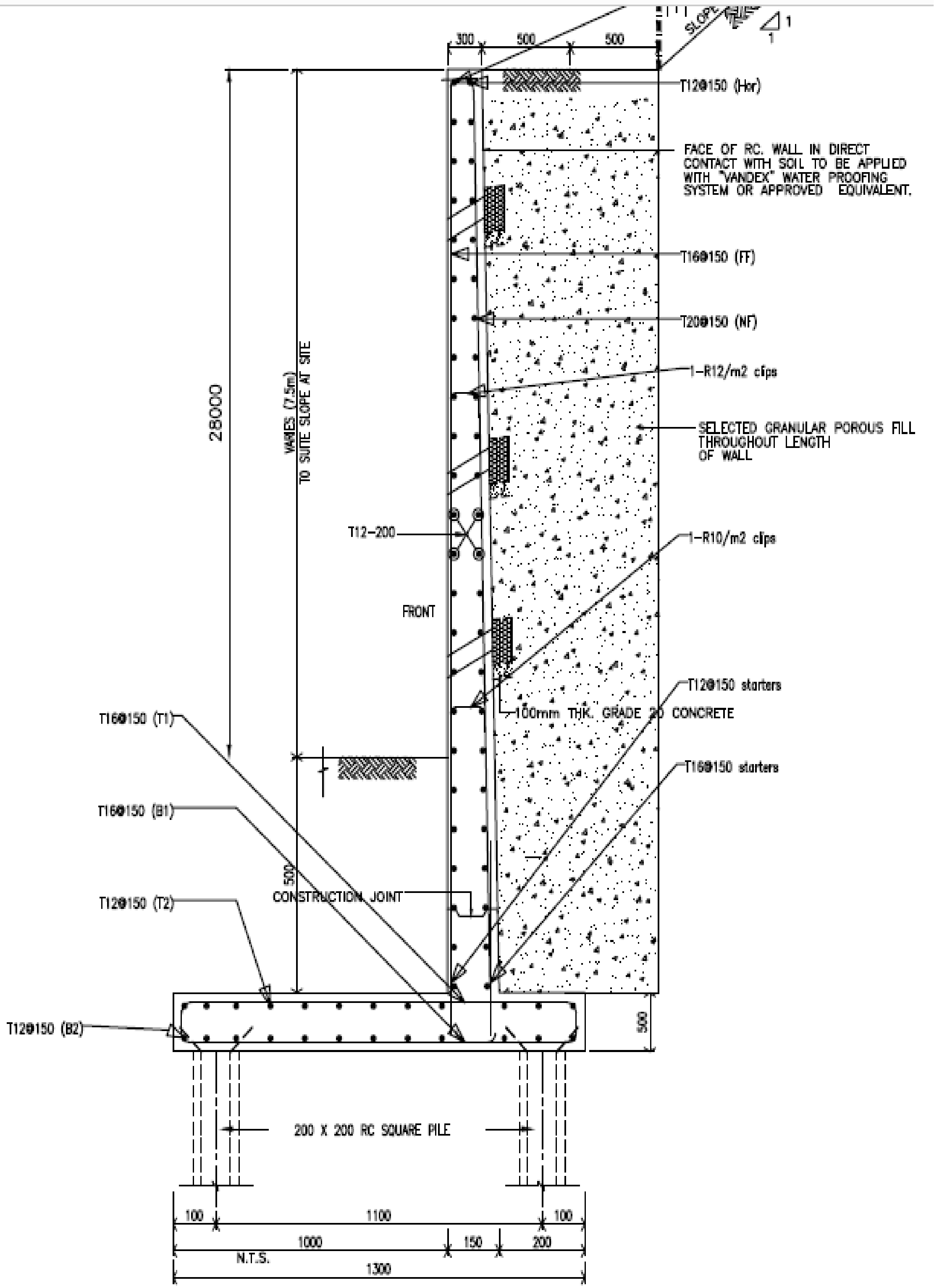


Figure 3. 2 Cross section of the Cantilever Retaining Wall.

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3.2.2 MATERIAL PROPERTIES

Usually and typically in Malaysia cantilever retaining wall made of reinforced concrete and work on principle of leverage. The main material of this wall will be Portland Cement Concrete (PCC) and will be reinforced with 10mm,12mm or 16mm in diameter of reinforced bar depending on the height of the wall.

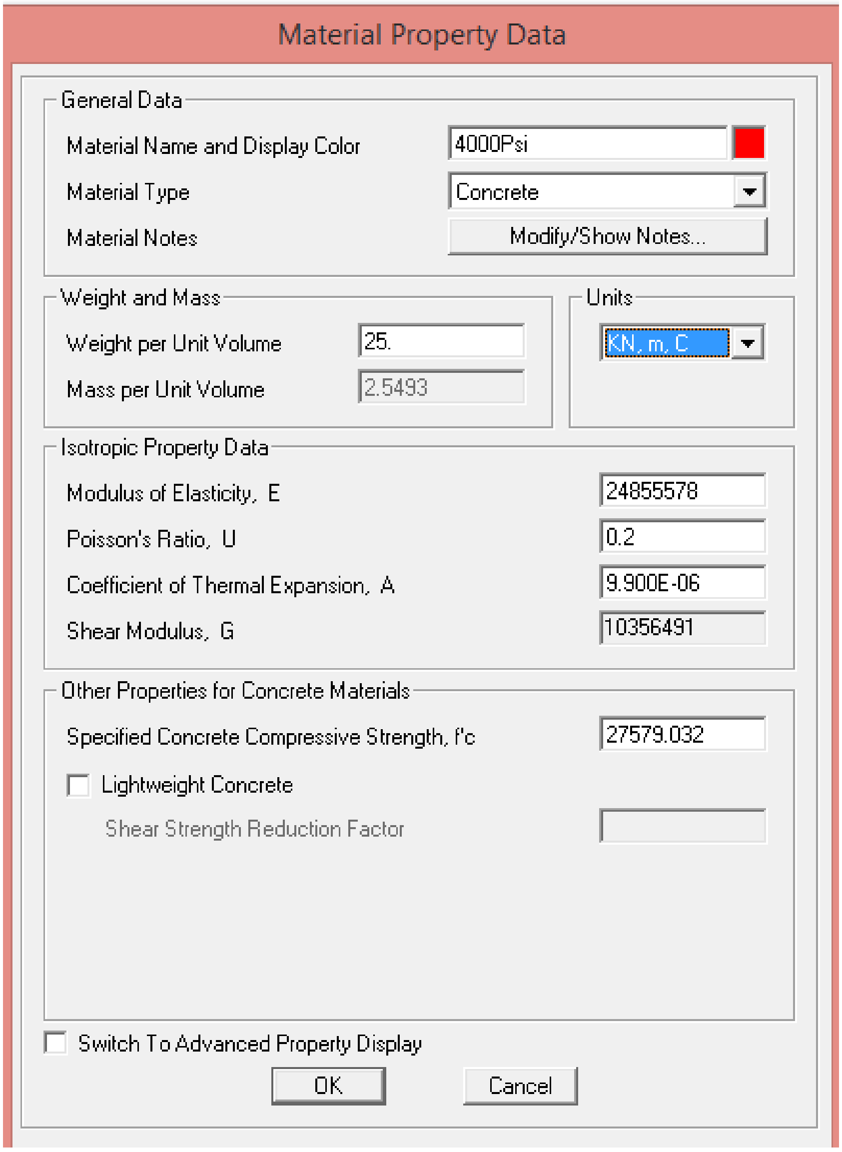


Figure 3. 3 Material property data

3.2.3 LOADING

Basic pressure load that need to be considered for the design is lateral earth pressure which is water pressure, static earth pressure, and pressure from the surcharge or due to live loads. In general, the resulting design pressure for earth retaining structures should not be less than the pressure due to fluid of unit weight $5kN/m^3$.

3.3 LOAD DESCRIPTION

3.3.1 LATERAL EARTH PRESSURE

Lateral earth pressures are analyzed for either "Active," "Passive" or "At-Rest" conditions. Active conditions exist when the retaining wall moves away from the soil it retains. Passive conditions exist when the retaining wall moves toward the soil it retains. At-Rest conditions exist when the wall is not moving away or toward the soil it retains.

Conditions for active, passive and at-rest pressures are usually determined by the structural engineer. Basically, at-rest pressures exist when the top of the wall is fixed from movement. Active and passive pressures are assumed when the top of the wall moves at least 1/10 of 1% of height of wall in the direction away from, and toward the soil it retains, respectively. Some theorize that at-rest pressures develop over time when a retaining wall is constructed for the active case.

Basic lateral earth pressure shall be assumed to be linearly proportional to the depth of earth and taken as: $P=k\gamma sz$, where:

p = basic lateral earth pressure (KSF)

k = coefficient of lateral earth pressure taken as, ko, for walls that do not deflect or move, or, ka, for walls that deflect or move sufficiently to reach minimum active conditions.

γs = unit weight of soil (KCF)

z = depth below the surface of earth at pressure surface (FT)

The resultant lateral earth loads due to the weight of the backfill shall be assumed to act at a height of (h\3) above the base of the wall, where h is the height of the pressure surface, measured from the surface of the ground to the base of the wall.

3.3.2 Earthquake Load

In determine the seismic load, data that been used in seismic analysis by software SAP2000 version 15 done with Eurocode 8, 2004 for response spectrum analysis. Time history analysis done with collected earthquake data of Acheh and El Centro event obtained from Pacific Earthquake Research Center and also analyzed through software SAP2000.

All the data was in notepad documented format which need to be transferred into other application which is Microsoft Excel for filtering the data and scattering plot of the graph of the event. The product from the graph was the maximum critical acceleration and compare the data easily. Figure 3.4 below showed the earthquake data that had been transferred into Microsoft excel and scattered the graph of time (s) versus Acceleration (g). The maximum values of acceleration obtained are 0.32g at 2.006 seconds.

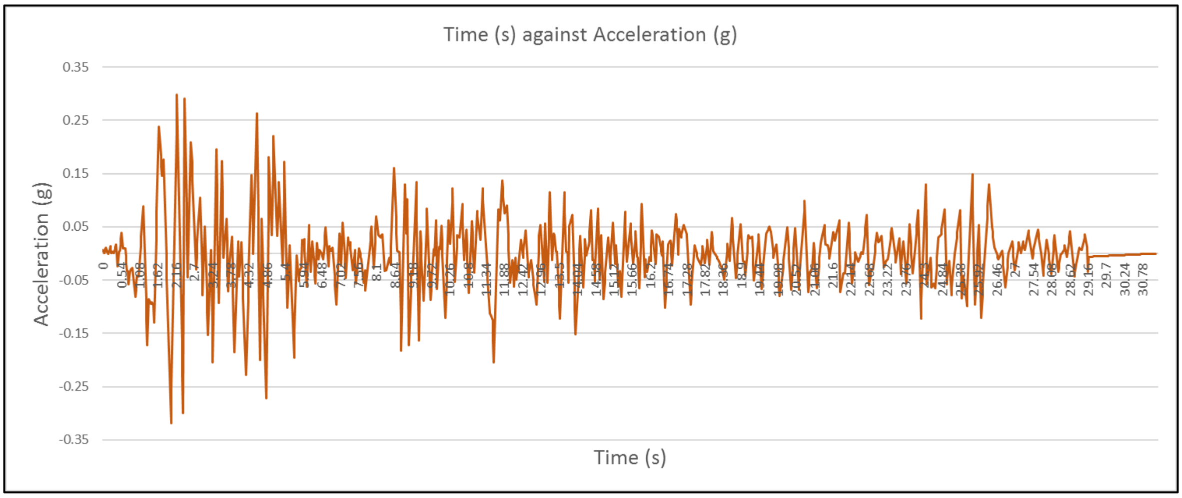


Figure 3. 4 Time (s) versus acceleration (g) graph.

3.4 ANALYSIS

SAP2000 software have been used to modelled and analyzed the cantilever retaining wall to get the result. The analysis that have been performed in this study were including the free vibration analysis, time history analysis, and response spectrum analysis. The load that have been used in the case study is dead load, live load, time history load, modal load and response spectrum load. There are a few load combination cases that were applied in this project study. The load combination is shown below:

i) Modal Free Vibration Analysis
ii) Live load + Dead load
iii) Live load + Dead load + Free vibration analysis
iv) Live load + Dead load + Free vibration analysis + seismic earthquake analysis

The result obtained from this study are as shown below:

i) Mode shape of cantilever retaining wall.
ii) Natural frequency and natural period of the cantilever retaining wall structure.
iii) Dynamic characteristic, displacement, velocity, acceleration of cantilever retaining wall joints under different earthquake loading.

3.5 SAP2000

The SAP name has been substitutable with progressive analytical ways since its introduction over thirty years alone. SAP2000 follows within the same tradition that includes a subtle, intuitive Associate in Nursing versatile interface steam-powered by an unmatched analysis engine and style tools for engineers functioning on transportation, industrial, structure, sports, and different facilities.

From its 3D object based mostly graphical modeling surroundings to the big variety of study and style choices utterly integrated across one powerful interface, SAP2000 has proved to be the foremost integrated, productive and sensible general-purpose structural program on the market these days. This intuitive interface permits you to form structural models apace and intuitively while not long learning curve delays. currently you'll be able to harness the ability of SAP2000 for all your analysis and style tasks, as well as little regular issues.

Complex Models are often generated and meshed with powerful inbuilt templates. Integrated style code options will mechanically generate wind, wave, bridge, and seismic masses with comprehensive automatic steel and concrete style code checks per United States, Canadian and international style standards.

Advanced analytical techniques provide in small stages massive deformation analysis, Eigen and Ritz analyses supported stiffness of nonlinear cases, curve cable analysis, material nonlinear analysis with fiber hinges, multi-layered nonlinear shell part, buckling analysis, progressive collapse analysis, energy ways for drift management, velocity-dependent dampers, base isolators, support physical property and nonlinear segmental construction analysis. nonlinear analyses are often static and/or time history, with choices for FNA nonlinear time history dynamic analysis and direct integration.

From a straightforward little 2D static frame analysis to an oversized advanced 3D nonlinear dynamic analysis, SAP2000 is that the best, most efficient resolution for your structural analysis and style wants.

3.6 STEP ANALYSIS IN SAP2000 SOFTWARE

In process obtained the result from this study, it's a must to follow the right procedure and steps in modelling and analyzed the retaining walls using SAP2000 software. Below shown the steps by steps in how to model and analyze using SAP2000.

Step 1: Define the model type.

The wall interface shown the template of the structure type that available and one of it was wall but for this study grid only template had been choosing to have freedom and easier to model the retaining wall. Choose the default unit for model which is KNm.

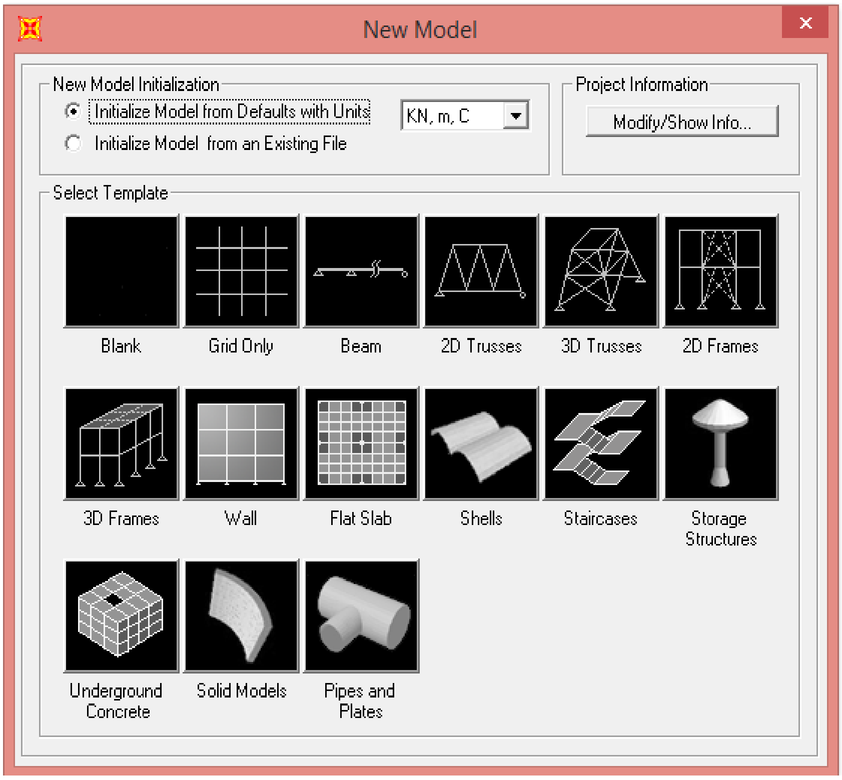


Figure 3. 5Select the structure model type

Step 2: Determine the 3D on the workspace

Insert all the grids to allocate the frame element accordingly to the drawing. Define the coordinate of the gridline by selecting “Define grid system data” template. Choose and start the project which is “KN, m, C”

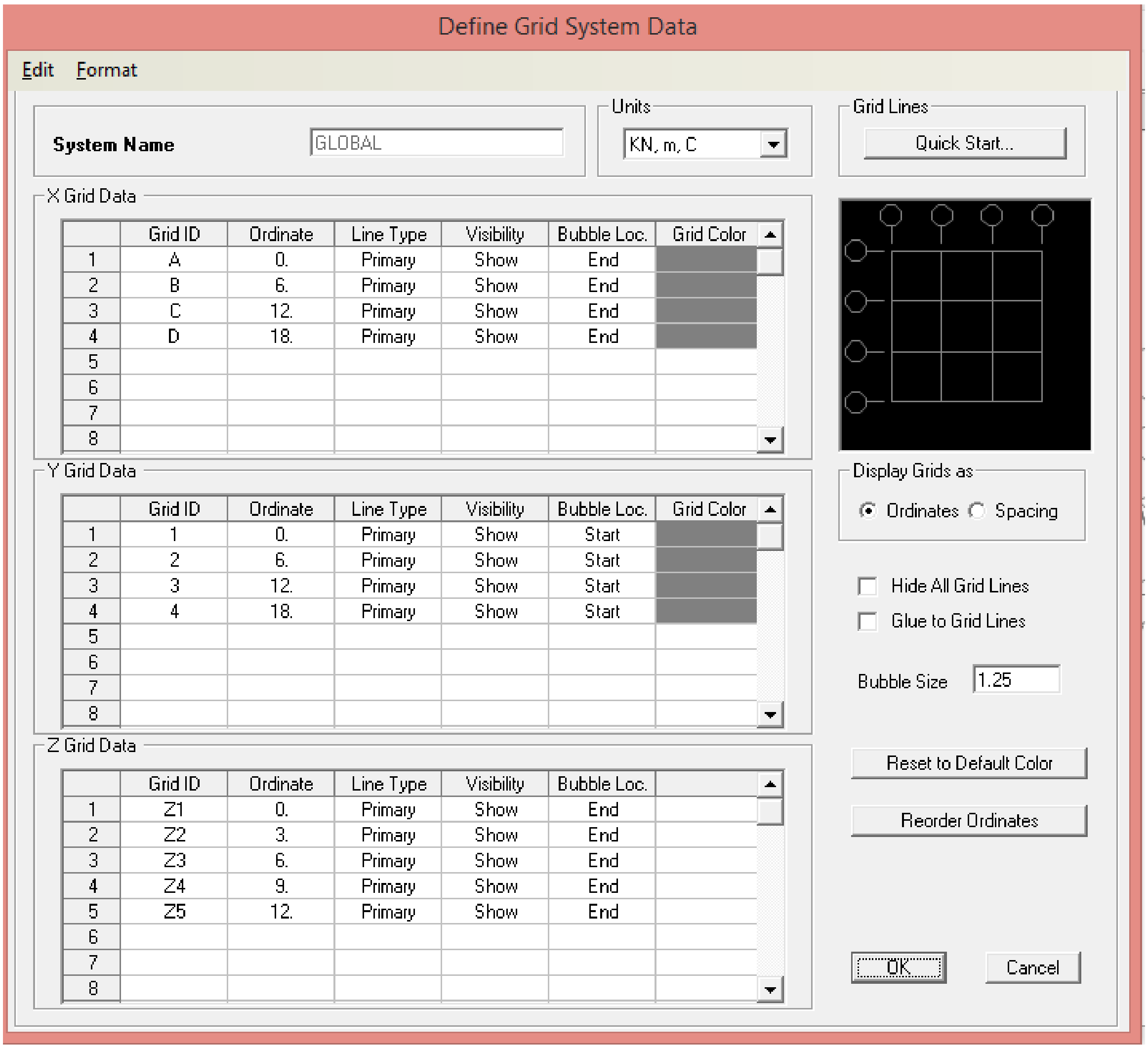


Figure 3. 6 Define grid system data.

Step 3: Define material and structural section properties

Define all type of materials and section properties which are presented in this cantilever retaining wall structure. Material type of structural steel has defined and used all along the study and together with its standard and material property data.

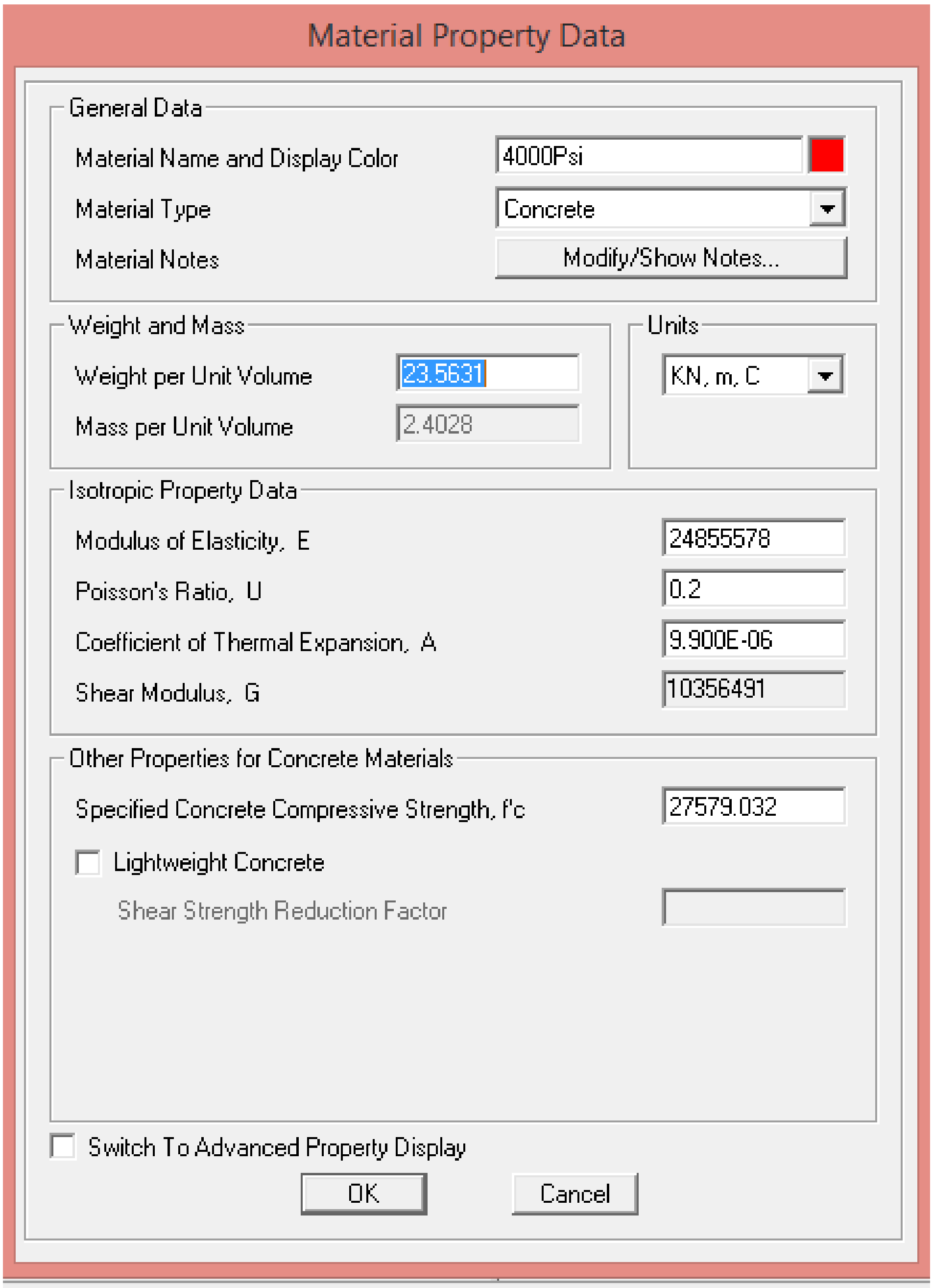


Figure 3. 7 Material properties of data

Step 4: Define area section of the model.

Assigned the section area of modelled cantilever retaining wall according to the architectural drawing. Choose restraint support as fixed at the base of the cantilever retaining wall.

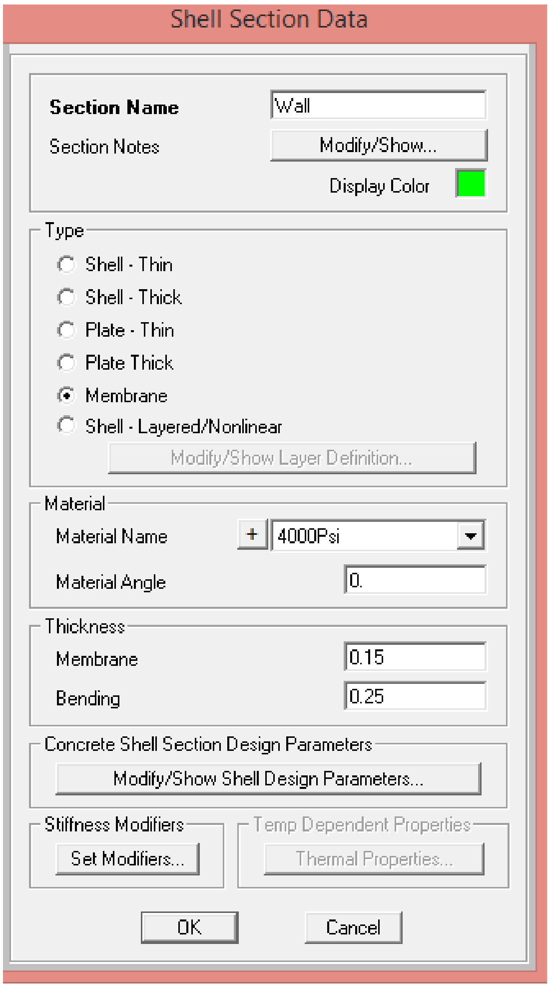


Figure 3. 8 Shell section material data.

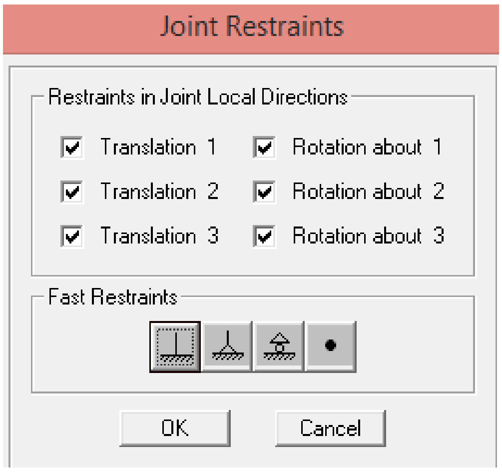


Figure 3. 9 Assign joint restraint

Step 5: Define load cases and load pattern

Define all the load cases for the retaining wall. The load consists of dead load, live load, earthquake load and modal.

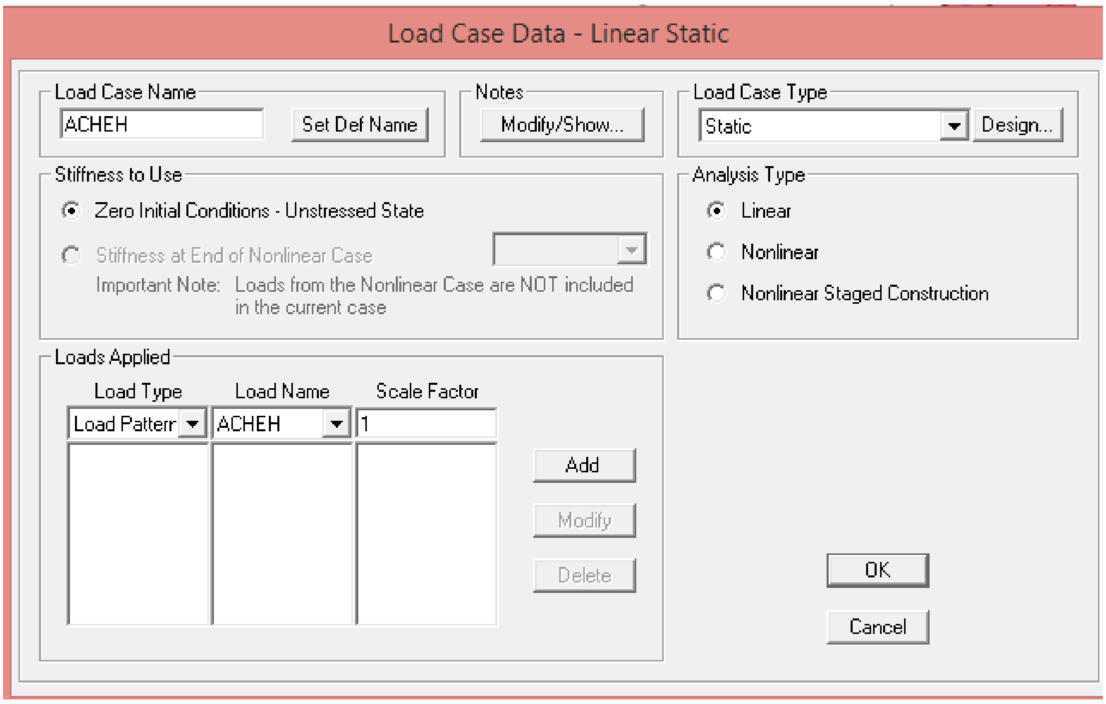


Figure 3. 10 Define load case data

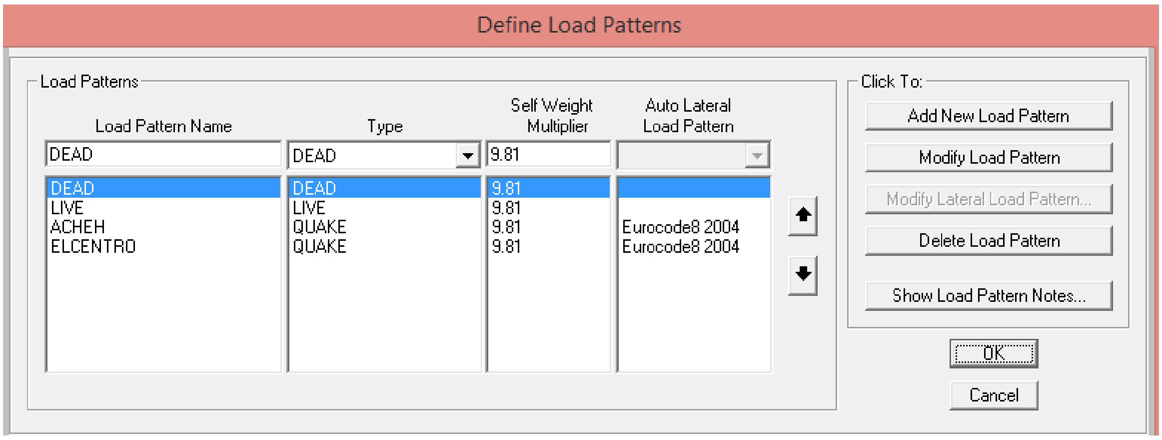


Figure 3. 11 Define the load patterns.

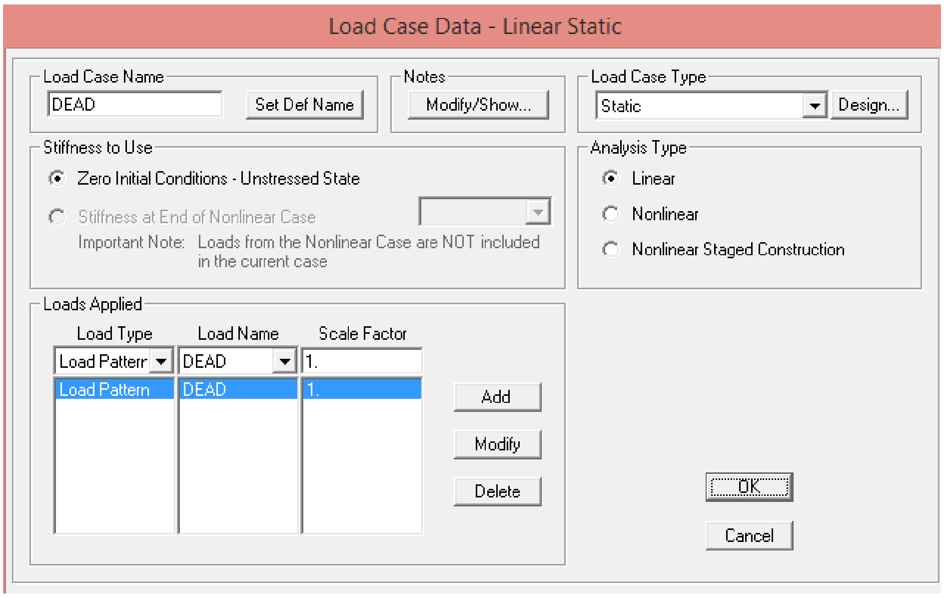


Figure 3. 12 Dead load case data

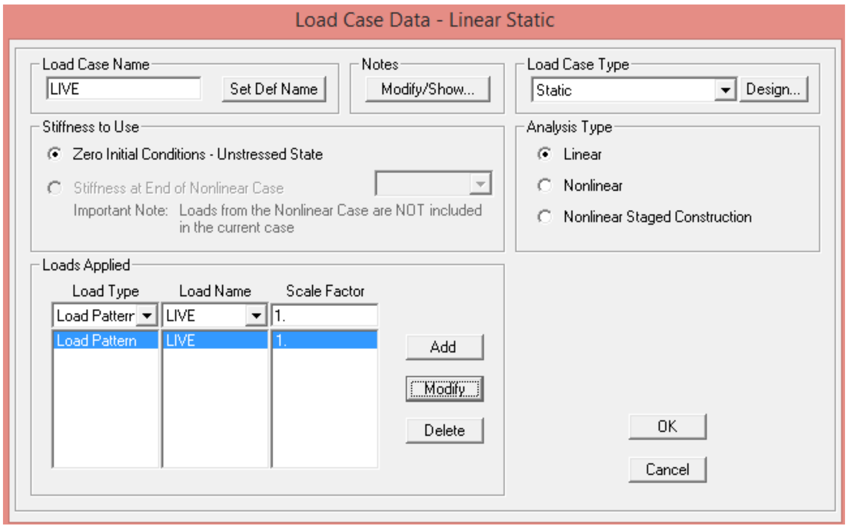


Figure 3. 13 Live load case data

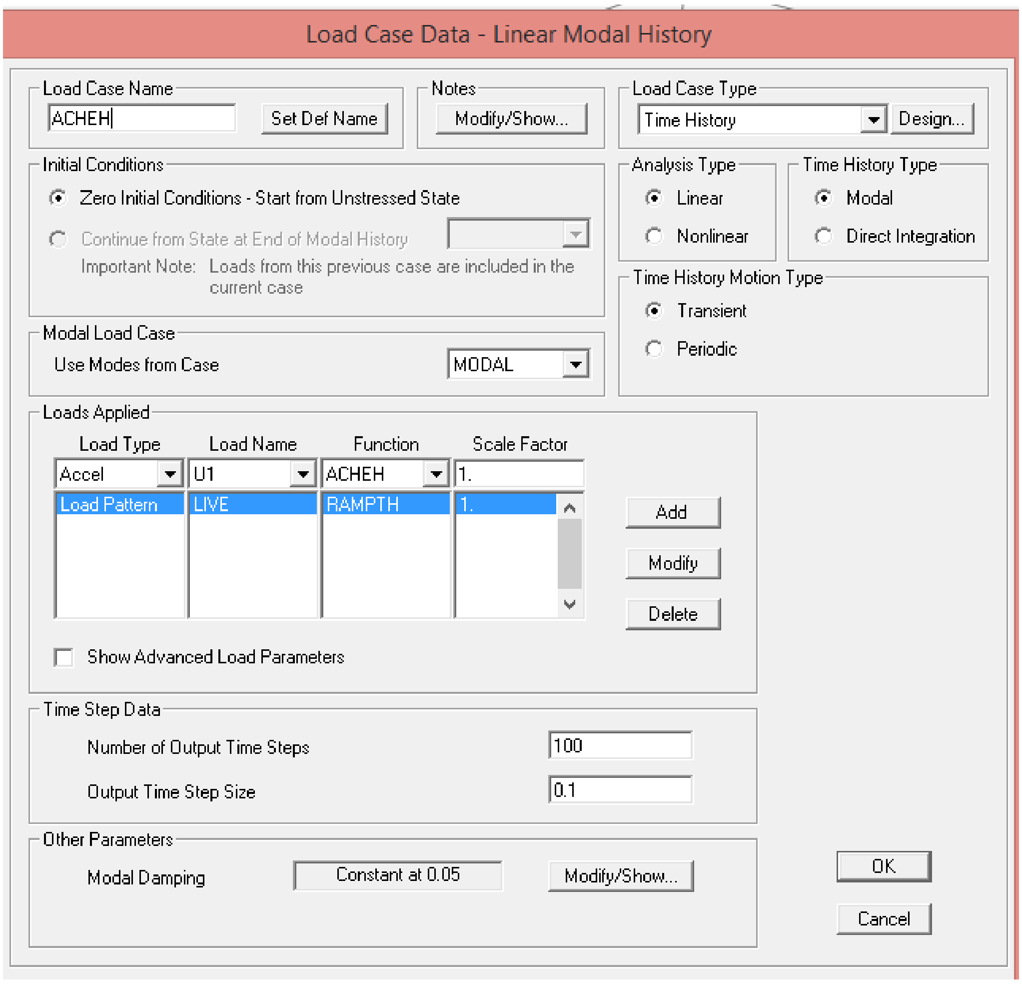


Figure 3. 14 Time history load case.

Step 6: Define functions of Time History and Response Spectrum

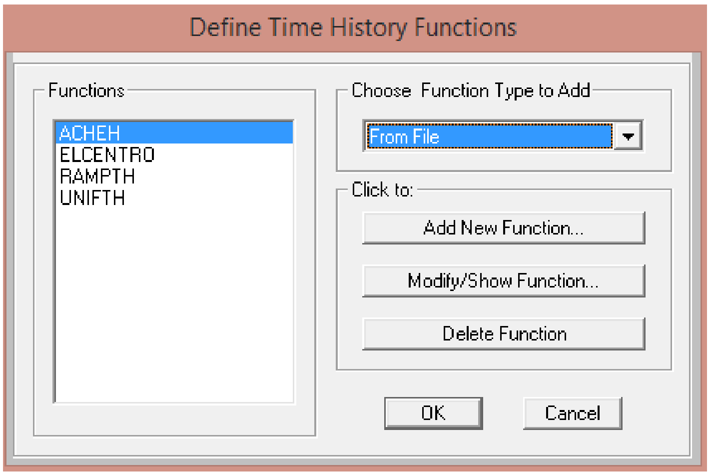


Figure 3. 15 Define Time History Function

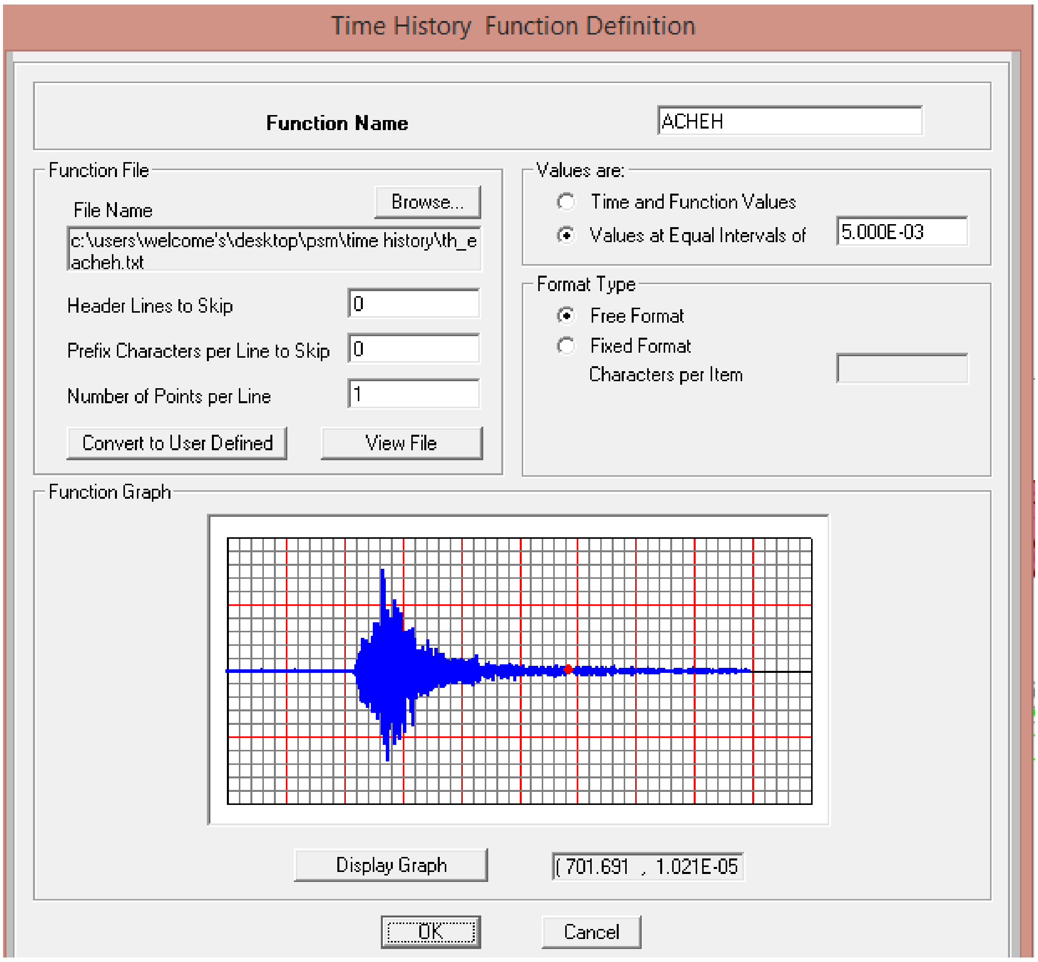


Figure 3. 16 Time History Function for Acheh

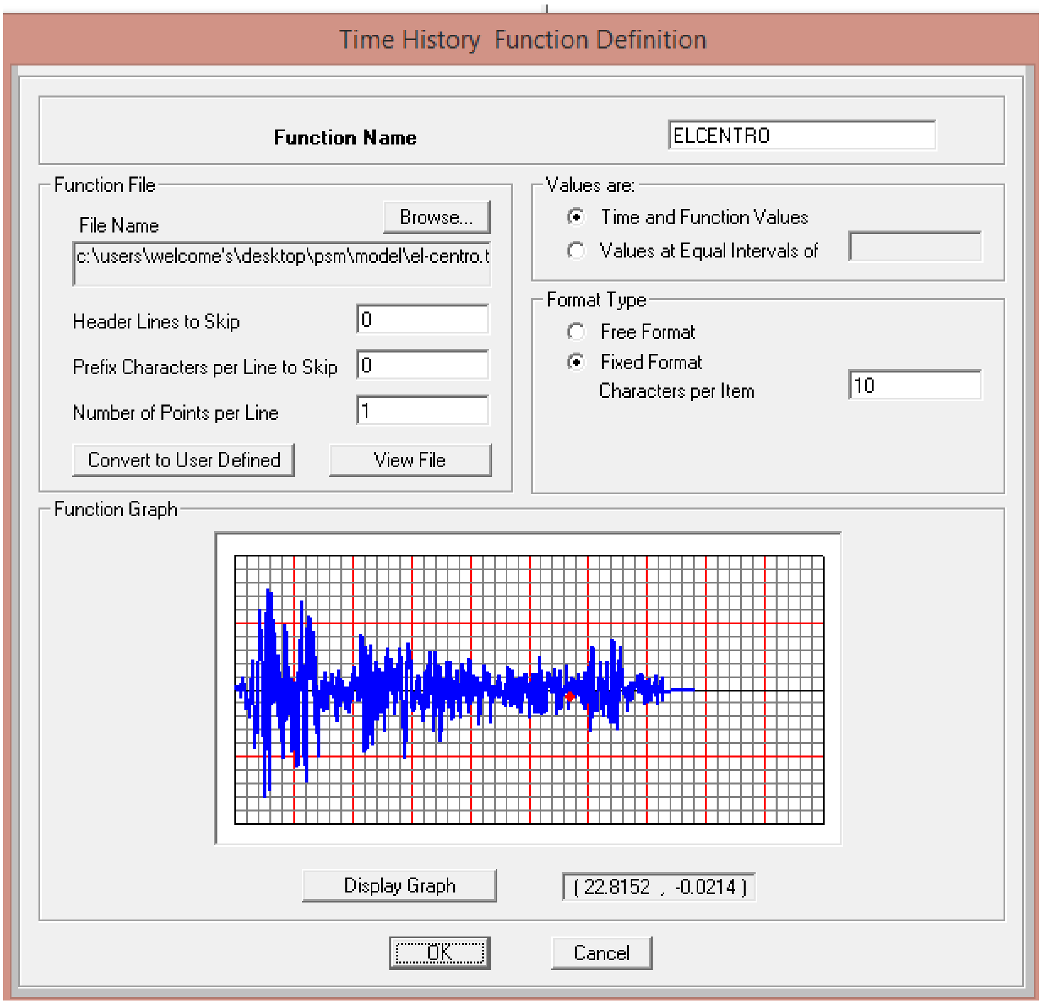


Figure 3. 17 Time History function for Elcentro

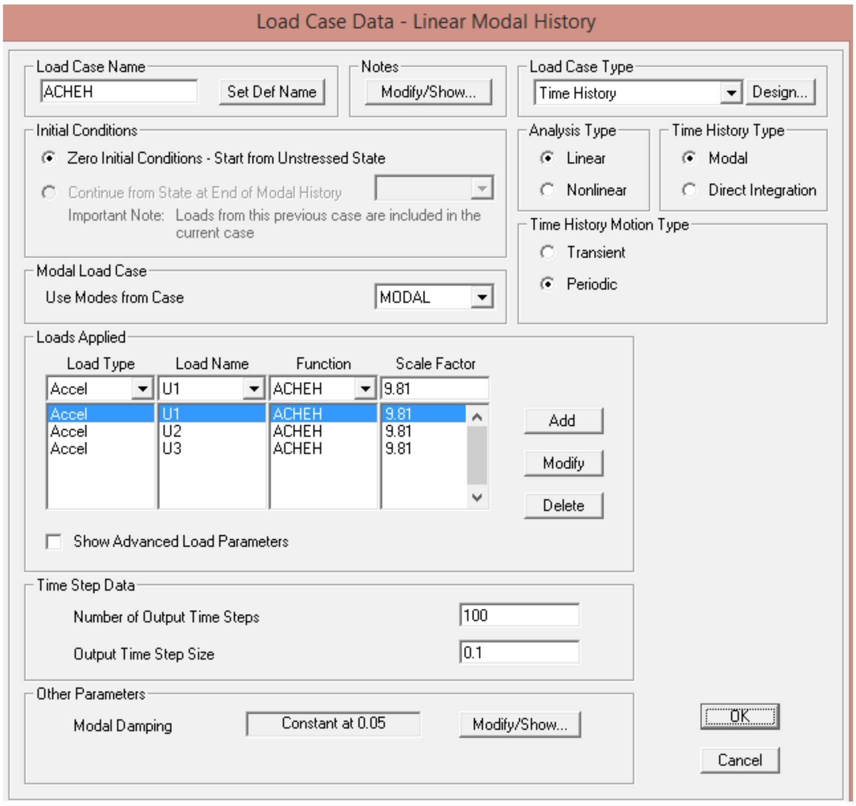


Figure 3. 18 Linear Modal History case data.

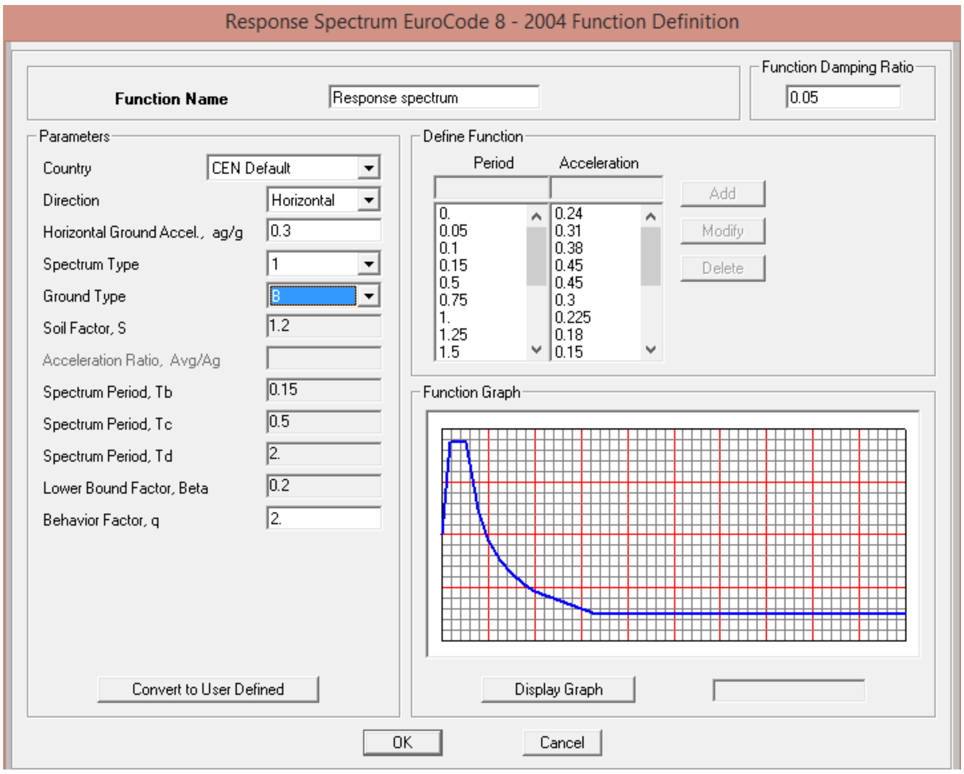


Figure 3. 19 Response spectrum Eurocode 8 function.

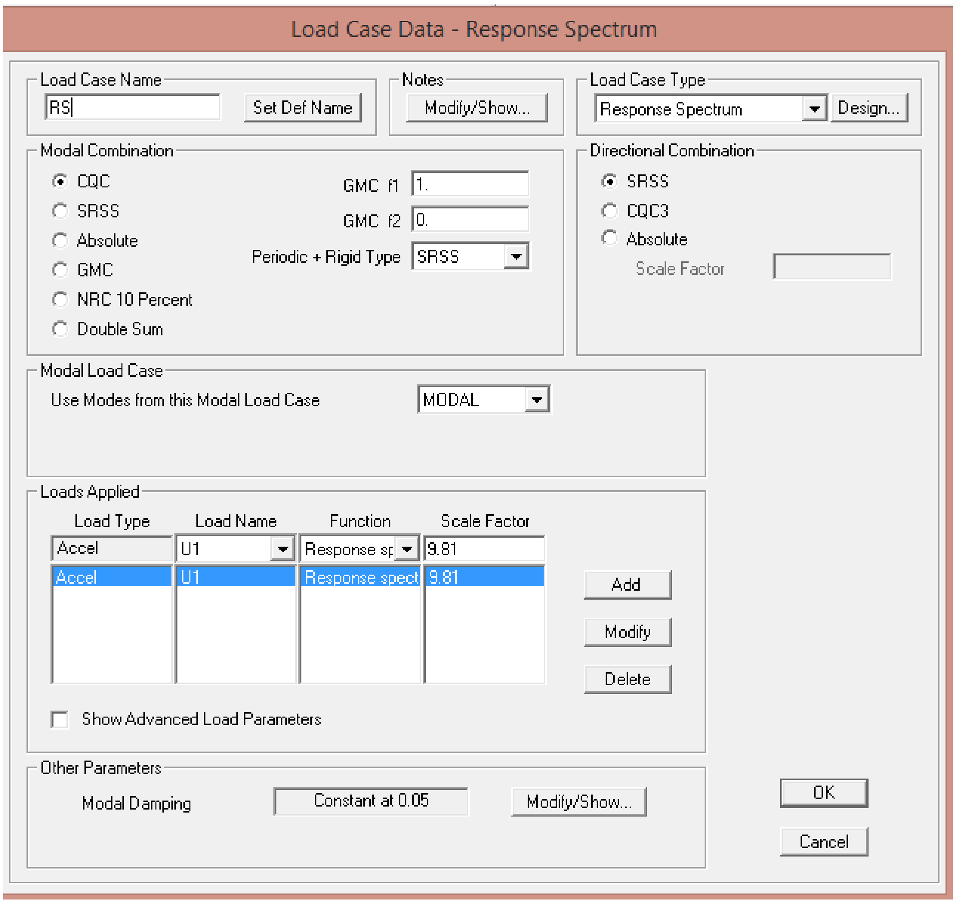


Figure 3. 20 Response spectrum load case data.

Step 7: Analysis the Model

Define the load combination will be used in the analysis as shown in figure 3.20. There are few load combinations which can be choose in set load case before running the analysis.

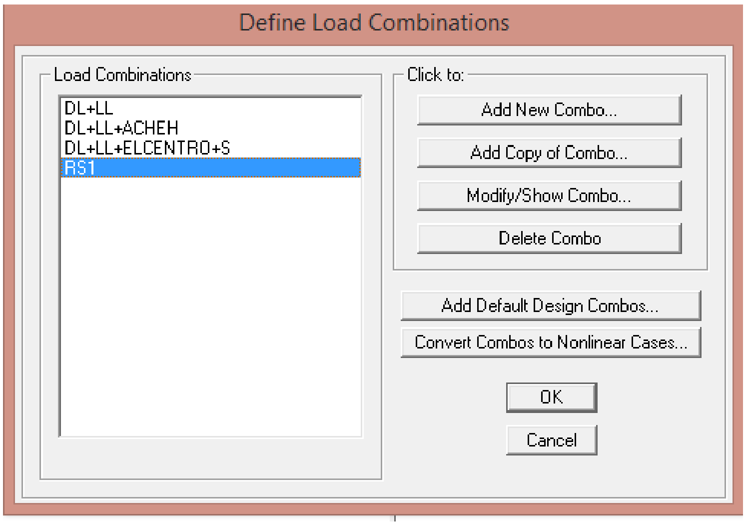


Figure 3. 21 Define load combination

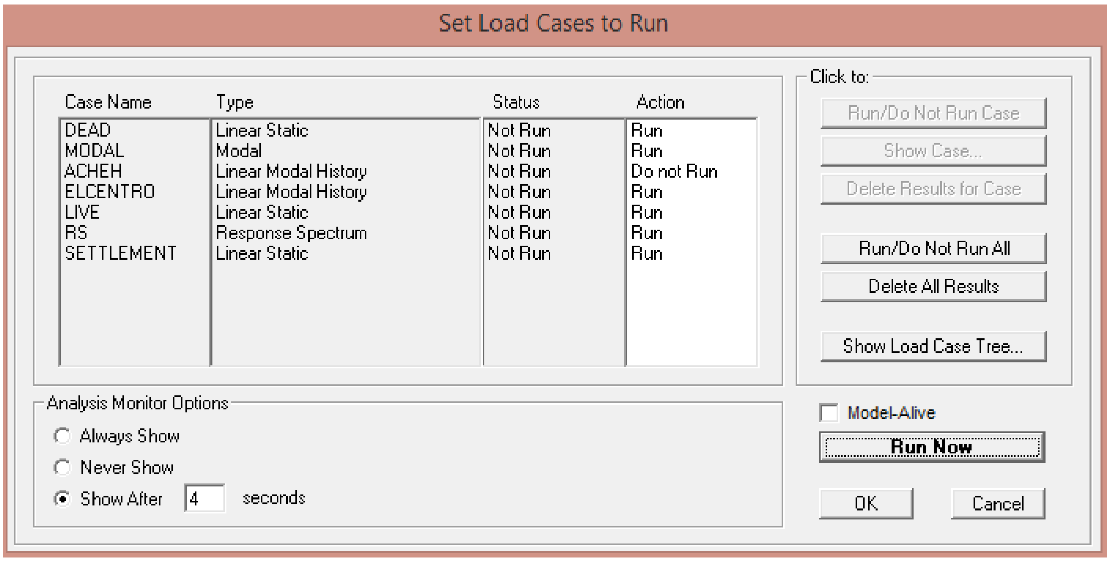
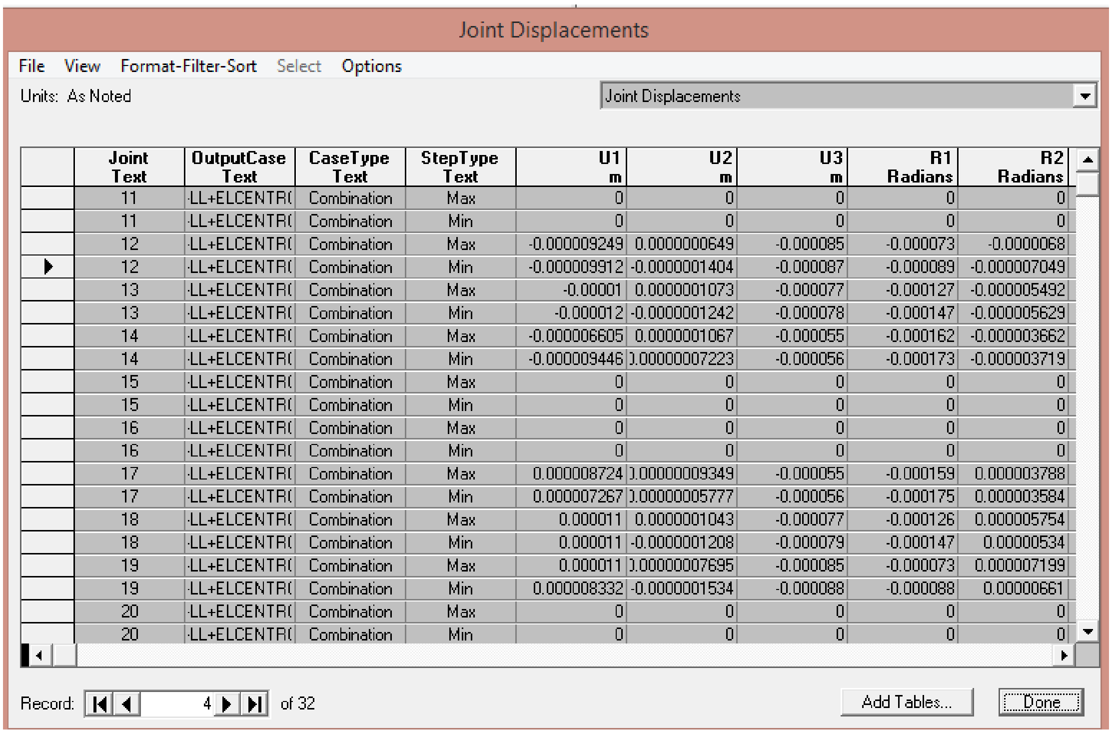


Figure 3. 22 Set load case to run.

Step 8: Display result and output table

After done the analysis, the result can be obtained from **Display** tab in the menu. The result obtained are showed in table as in figure below.



Joint Text	OutputCase Text	CaseType Text	StepType Text	U1 m	U2 m	U3 m	R1 Radians	R2 Radians
11	LL+ELCENTR(	Combination	Max	0	0	0	0	0
11	LL+ELCENTR(	Combination	Min	0	0	0	0	0
12	LL+ELCENTR(	Combination	Max	-0.000009249	0.0000000649	-0.000085	-0.000073	-0.0000068
12	LL+ELCENTR(	Combination	Min	-0.000009912	-0.0000001404	-0.000087	-0.000089	-0.000007049
13	LL+ELCENTR(	Combination	Max	-0.00001	0.0000001073	-0.000077	-0.000127	-0.000005492
13	LL+ELCENTR(	Combination	Min	-0.000012	-0.0000001242	-0.000078	-0.000147	-0.000005629
14	LL+ELCENTR(	Combination	Max	-0.000006605	0.0000001067	-0.000055	-0.000162	-0.000003662
14	LL+ELCENTR(	Combination	Min	-0.000009446	).00000007223	-0.000056	-0.000173	-0.000003719
15	LL+ELCENTR(	Combination	Max	0	0	0	0	0
15	LL+ELCENTR(	Combination	Min	0	0	0	0	0
16	LL+ELCENTR(	Combination	Max	0	0	0	0	0
16	LL+ELCENTR(	Combination	Min	0	0	0	0	0
17	LL+ELCENTR(	Combination	Max	0.000008724	).00000009349	-0.000055	-0.000159	0.000003788
17	LL+ELCENTR(	Combination	Min	0.000007267	).00000005777	-0.000056	-0.000175	0.000003584
18	LL+ELCENTR(	Combination	Max	0.000011	0.0000001043	-0.000077	-0.000126	0.000005754
18	LL+ELCENTR(	Combination	Min	0.000011	-0.0000001208	-0.000079	-0.000147	0.00000534
19	LL+ELCENTR(	Combination	Max	0.000011	).00000007695	-0.000085	-0.000073	0.000007199
19	LL+ELCENTR(	Combination	Min	0.000008332	-0.0000001534	-0.000088	-0.000088	0.00000661
20	LL+ELCENTR(	Combination	Max	0	0	0	0	0
20	LL+ELCENTR(	Combination	Min	0	0	0	0	0

Figure 3. 23 Result output table.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Summary of Cantilever Retaining Wall Analysis

The structure of cantilever retaining wall has been modelled by SAP2000 version 15. In early stage of the analysis, free vibration analysis has been performed where in this stage there is no including any loads on the structure but by the modal load of the structure. Next stage of analysis was the earthquake analysis such as Time history and Response spectrum which in this analysis there are few loads considered to be included. The loads that included during the earthquake analysis are dead loads, live loads, modal load, settlement load, time history load and response spectrum load. Several combinations of load cases were applied in this study as shown below.

i. Free vibration analysis (modal analysis)
ii. Dead load + Live load
iii. Dead load + Live load + Time history load
iv. Response Spectrum

Furthermore, the expected result obtain from this software analysis by SAP2000 are as:

i. Mode shape of cantilever retaining wall
ii. Natural period and natural frequency of the cantilever retaining wall structure.
iii. Joint displacement, acceleration, and velocity of cantilever retaining wall under different earthquake loading.

4.2 Cantilever retaining wall structure Modelling

The model of retaining wall structure has been performed by using SAP 2000 version 15 shown in figure 4.1. There are some assumptions and linear properties have been made and used to model the structure:

I. The location, size. Material and section used of the retaining wall structure are represented similarly as the actual structure.

II. The dimension and geometry details of the structure represented are same as drawing of the actual structure.

III. Structure was assumed to be fixed on the ground at certain joint throughout the modelling process.

IV. The ground motion of El Centro and Acheh earthquake were used.

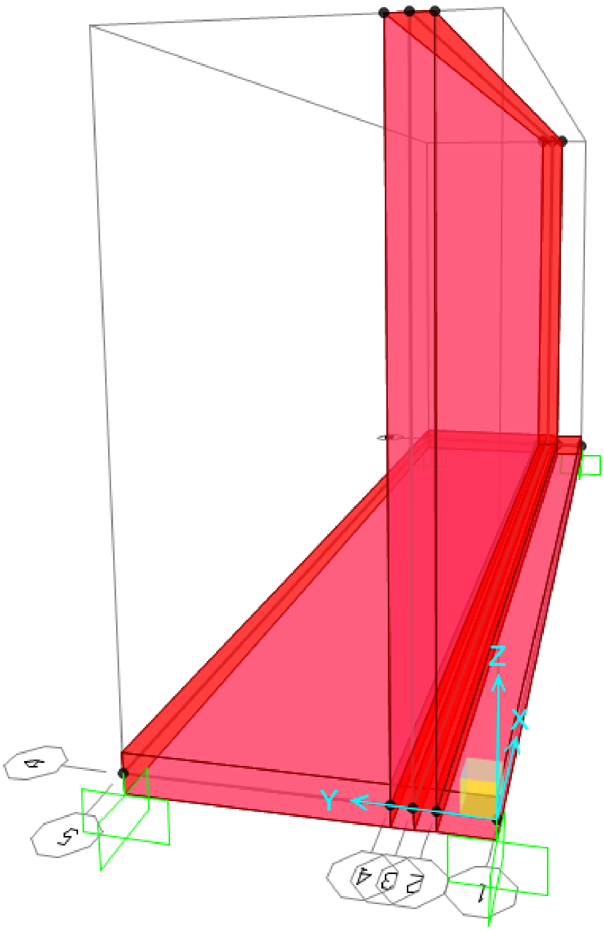


Figure 4. 1 3D model of the cantilever retaining wall.

4.3 Free Vibration analysis

Free vibration analysis or also known as modal analysis in SAP2000 is the analysis which carried out by only considered the modal itself without any external forces. The structure could move and vibrate freely, and its deformed shape will be presented.

In the analysis, the obtained number of the model number where show the mode shape and the natural frequency are twelve (12). Resulting from the analysis, the deformed shape of each has been tabulated in table 4.1 and the mode shape of the structure also will be shown later below. Usually the first three mode of the free vibration are the most critical and interest because of the largest contribution to the structures motion. The first three modes of vibration have the longest time period which make its most interest. Each of the mode shape of retaining wall produce different natural period and frequency which will have different deformed shape. All the twelve-mode shape will be presented later below.

Table 4.1 Natural period and frequency of modals

Mode	Natural Period, T (sec)	Natural Frequency, f (Hz)
1	0.0588	17.00818
2	0.0526	19.01252
3	0.00873	114.55798
4	0.00787	127.12232
5	0.00525	190.4757
6	0.00463	216.12361
7	0.0042	238.15698
8	0.00313	319.5753
9	0.00217	461.48287
10	0.00208	481.63923
11	0.00189	528.47776
12	0.00129	775.47571

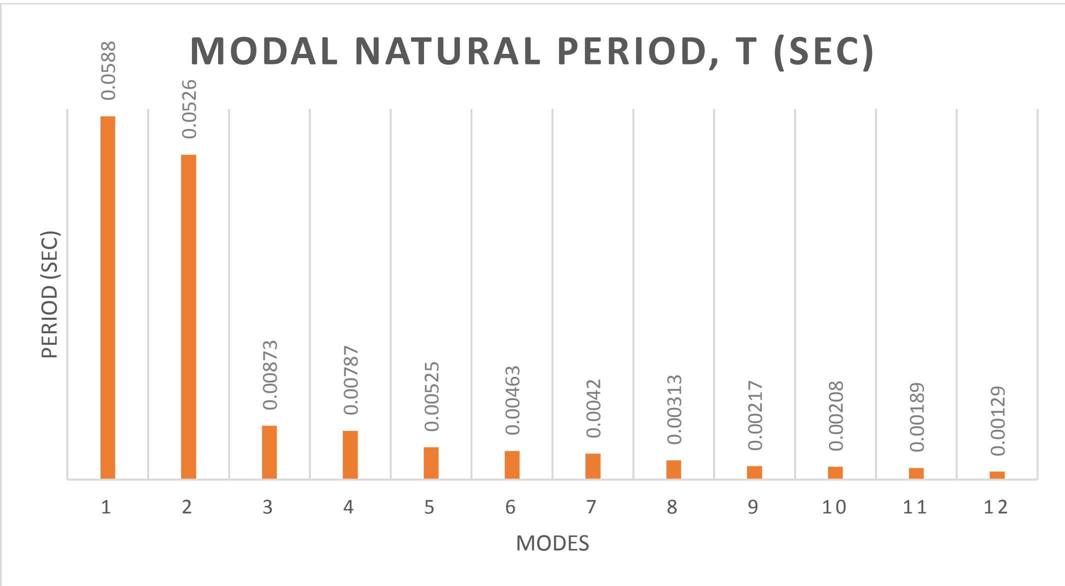


Figure 4. 2 Modals natural period, (sec).

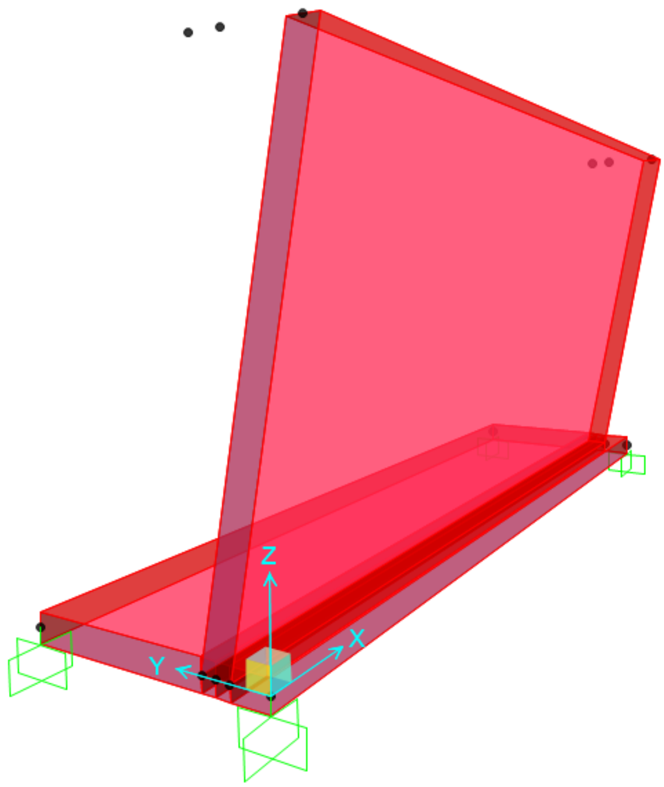


Figure 4. 3 Mode 1, T=0.05880, f=17.00818

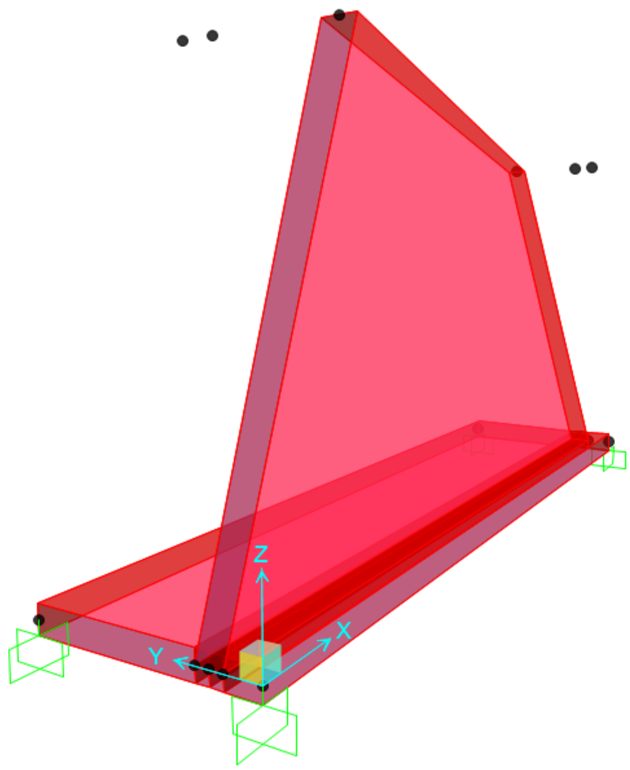


Figure 4. 4 Mode 2, T=0.05260, f=19.01252

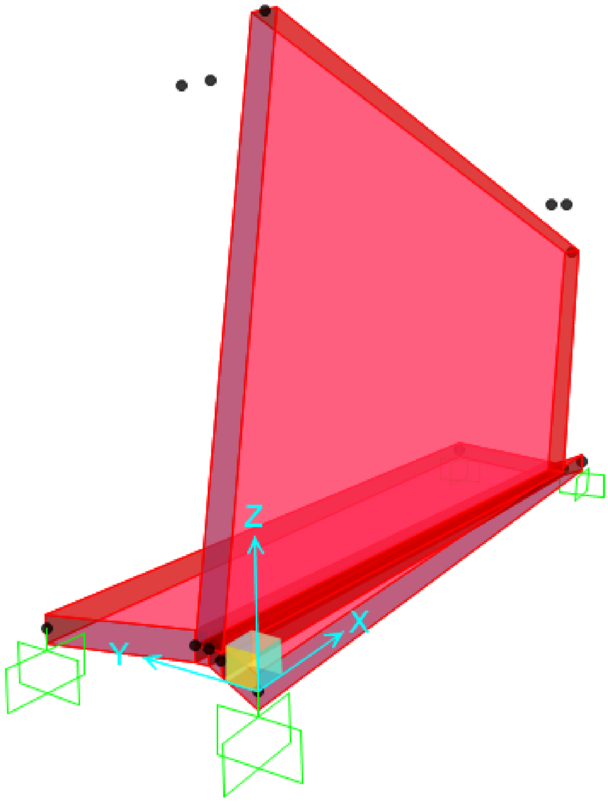


Figure 4. 5 Mode 3, T=0.00873, f=114.55798

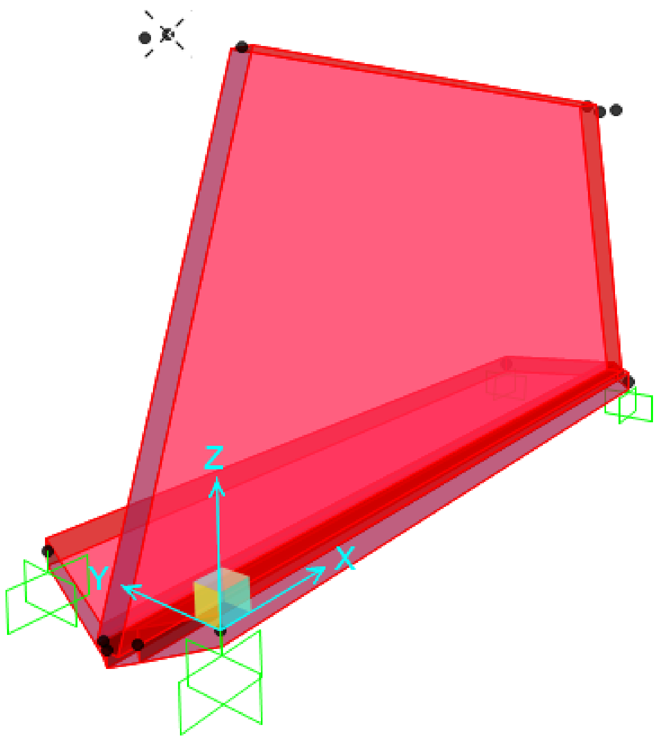


Figure 4. 6 Mode 4, T=0.00787, f=127.12232

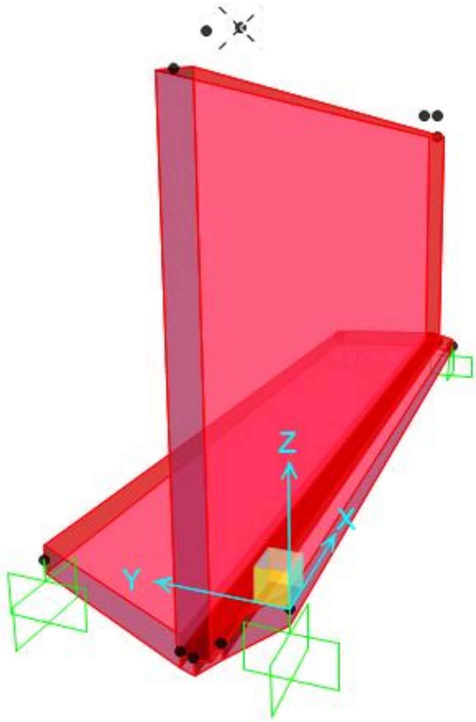


Figure 4. 7 Mode 5, T=0.00525, f=190.47570

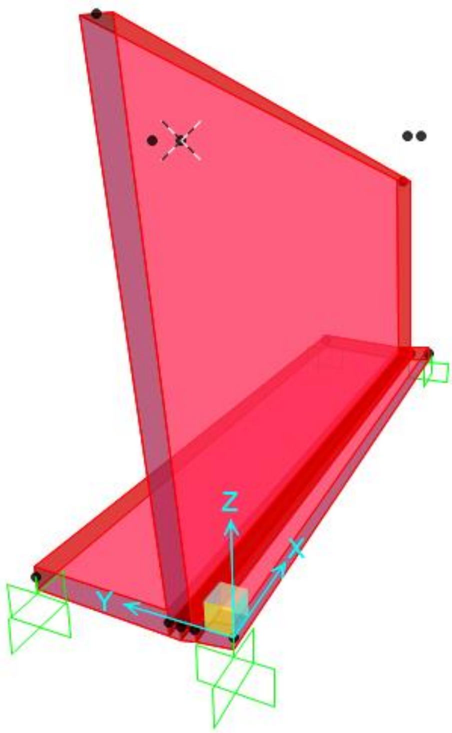


Figure 4. 8 Mode 6, T=0.00463, f= 216.12361

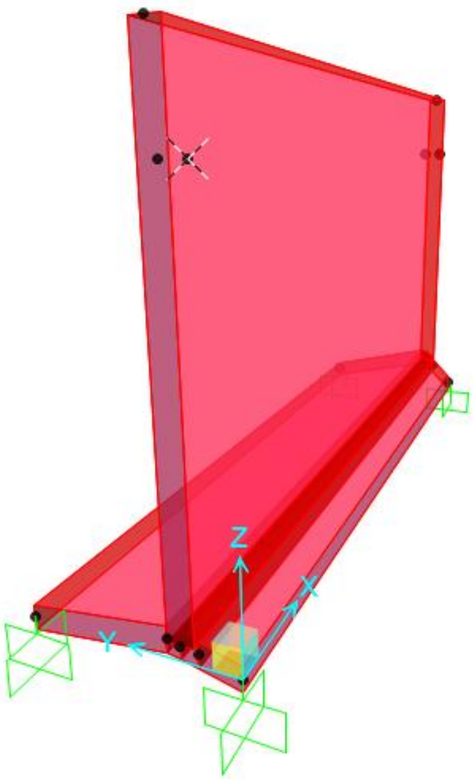


Figure 4. 9 Mode 7, T=0.00420, f=238.15698

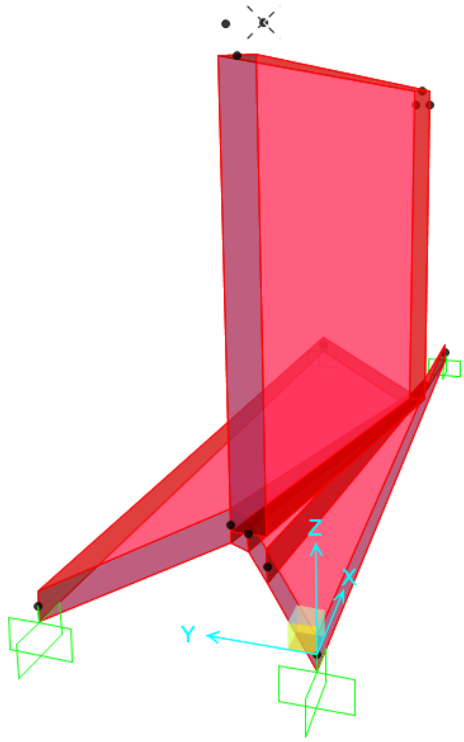


Figure 4. 10 Mode 8, T=0.00313, f=319.57530

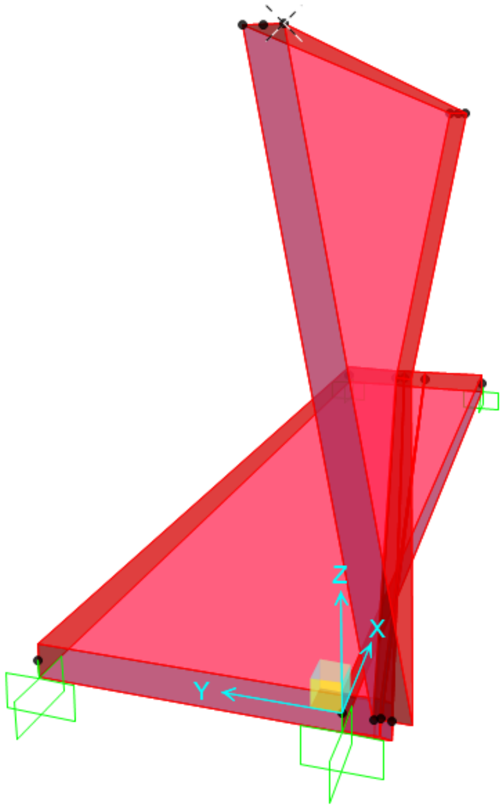


Figure 4. 11   Mode 9, T=0.00217, f=461.48287

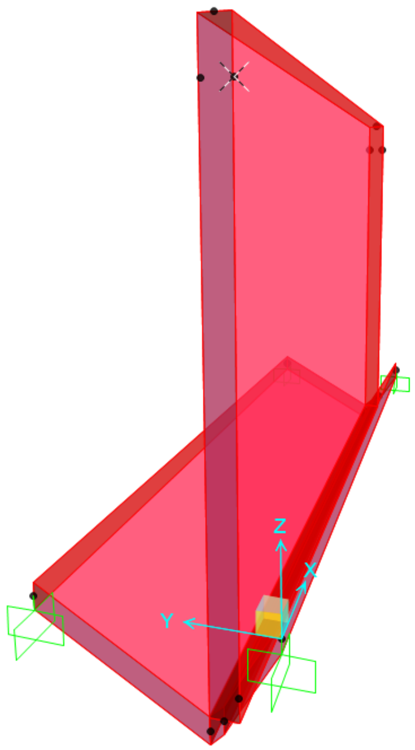


Figure 4. 12   Mode 10, T=0.00208, f=481.63923

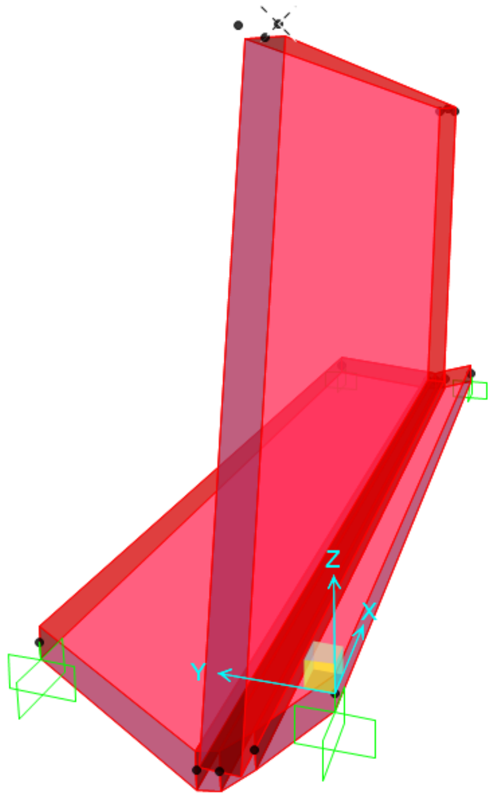


Figure 4. 13 Mode 11, T=0.00189, f=528.47776

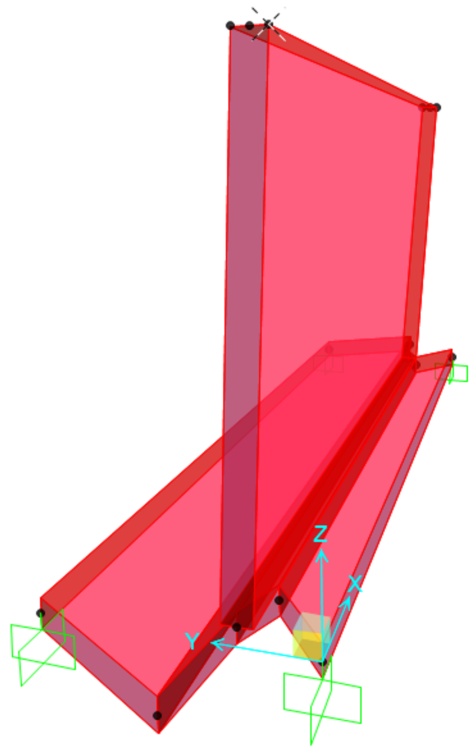


Figure 4. 14 Mode 12, T=0.00129, f=775.47571

4.4 Time History Analysis

Time history earthquake analysis has been performed on the cantilever retaining wall structure by referring to the ground motion of Acheh and Elcentro obtained from Malaysian Meteorological Department and PEER center. Acheh earthquake occurred on December 26,2004 at Indonesia with magnitude of 9.1 Richter Scale and El-Centro earthquake occurred on May,18, 1941, at Imperial Valley with magnitude 6.9 Richter scale or 0.32g of ground acceleration. Figure 4.15 and 4.16 shown below present plotted graph acceleration versus time of Acheh and El-centro earthquake.

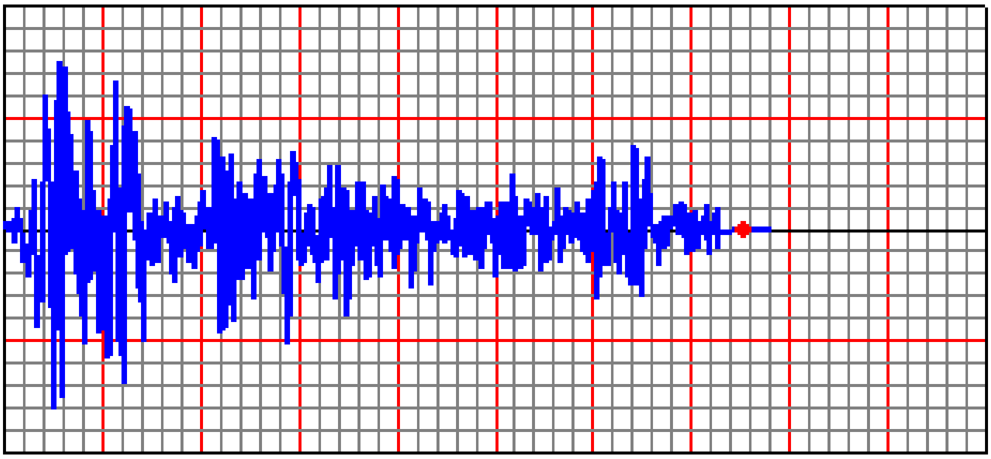


Figure 4. 15 Elcentro time history plotted graph.

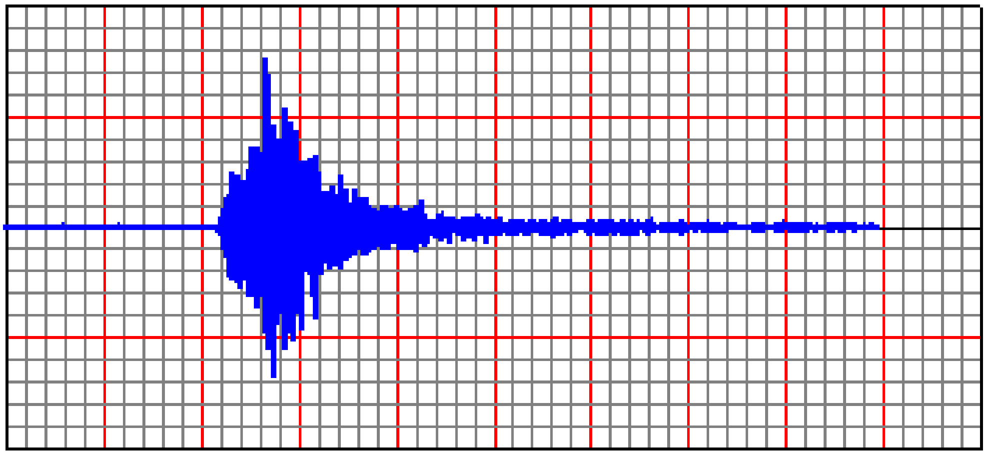


Figure 4. 16 Acheh time history plotted graph.

This analysis used to determine the dynamic response of the cantilever retaining wall structures under different earthquake loading and action of any general time dependent loads. The result obtained from this analysis are time varying displacements, velocities and accelerations of the cantilever retaining wall structure joint and shell in x, y and z direction under Acheh and Elcentro earthquake. The result between of the two time history are compared to see the difference cause by the earthquake to the structure. Based on the analysis result by software SAP 2000, the most critical part of the joint of the structure are joint 22 and 25. Besides the most affected is in y-direction because of the theoretically understanding of ground motion that move horizontally. The comparison of the result from time history analysis between Acheh and Elcentro are presented in table 4.2 until table 4.5 and graph plotted will be shown in figures later in this report. The table only represented the maximum response of three direction and the peak responses occur in y-direction. The maximum displacement found between Elcentro and Acheh are occurs in y-direction of joint 25 in Elcentro earthquake with value of 0.000574 m compared to Acheh with only 0.000341. Next, the maximum velocities occur in y-direction of joint 25 in Elcentro event with value of 0.2919 m/sec compared with 7.897E-07 m/sec in Acheh event. The maximum acceleration occurs in z-direction of joint 22 in Elcentro earthquake with value 2.928 m/sec^2 compared to Acheh earthquake with only 0.00001369 m/sec^2.

Table 4.2 Joint 25 dynamic response of Elcentro time history analysis.

Joint	Direction	Displacement, (m)		Velocities, (m/sec)		Acceleration (m/sec2)	
		Min	Max	Min	Max	Min	Max
25	x	0.000019	0.000026	-0.338	0.2893	-2.68523	2.9272
25	y	0.000096	0.000574	-0.3417	0.2919	-2.72532	2.8432
25	z	-0.00017	-0.000168	-0.338	0.2892	-2.68498	2.92758

Table 4.3 Joint 25 dynamic responses of Acheh time history analysis

Joint	Direction	Displacement, (m)		Velocities, (m/sec)		Acceleration (m/sec2)	
		Min	Max	Min	Max	Min	Max
25	x	0.000022	0.000022	-8.11E-07	7.94E-07	-0.000023	0.000014
25	y	0.000341	0.000341	-8.28E-07	7.90E-07	-0.000030	0.000023
25	z	-0.00017	-0.00017	-8.03E-07	7.84E-07	-0.000011	0.000018

Table 4.4 Joint 22 dynamic responses of Elcentro time history analysis

Joint	Direction	Displacement, (m)		Velocities, (m/sec)		Acceleration (m/sec2)	
		Min	Max	Min	Max	Min	Max
22	x	-0.000026	-0.000019	-0.338	0.2893	-2.68519	2.92728
22	y	0.000097	0.000573	-0.3417	0.2919	-2.72497	2.84374
22	z	-0.000172	-0.000168	-0.338	0.2893	-2.68501	2.92765

Table 4.5 Joint 22 dynamic responses of Acheh time history analysis

Joint	Direction	Displacement, (m)		Velocities, (m/sec)		Acceleration (m/sec2)	
		Min	Max	Min	Max	Min	Max
22	x	-0.000022	-0.000022	-8.10E-07	7.94E-07	-0.000020	0.000013
22	y	0.000341	0.000341	-8.28E-07	7.90E-07	-0.000030	0.000023
22	z	-0.00017	-0.00017	-8.11E-07	7.94E-07	-0.000022	0.000014

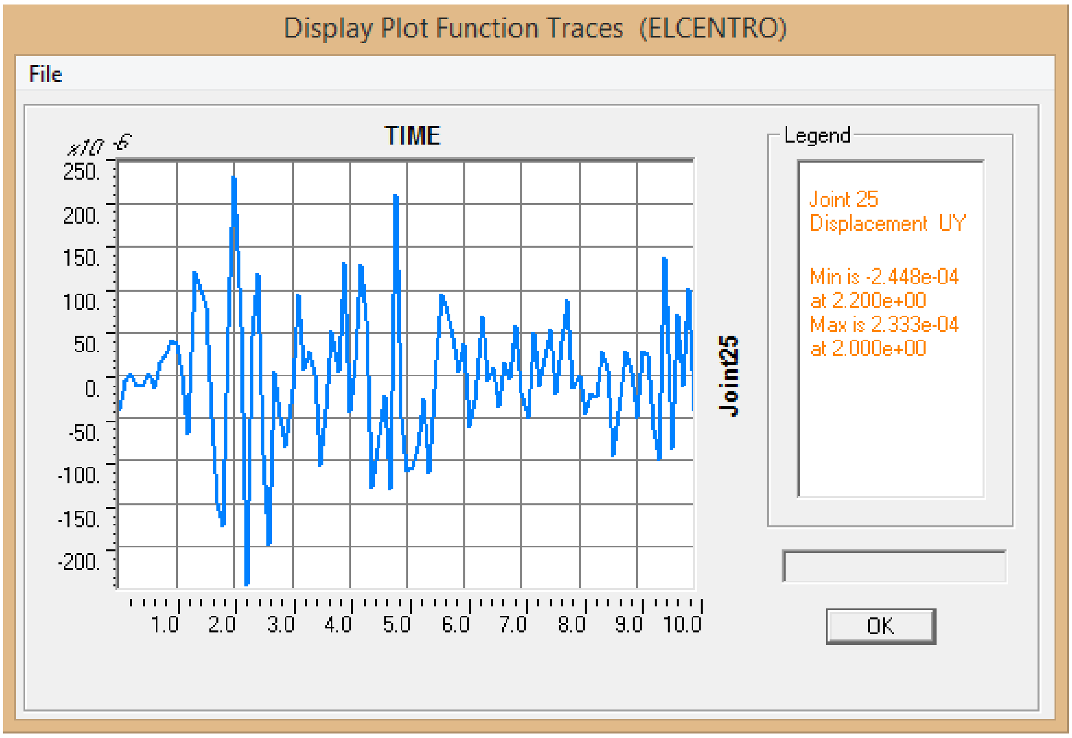


Figure 4. 17 Displacement joint 25, y-direction, Elcentro earthquake.

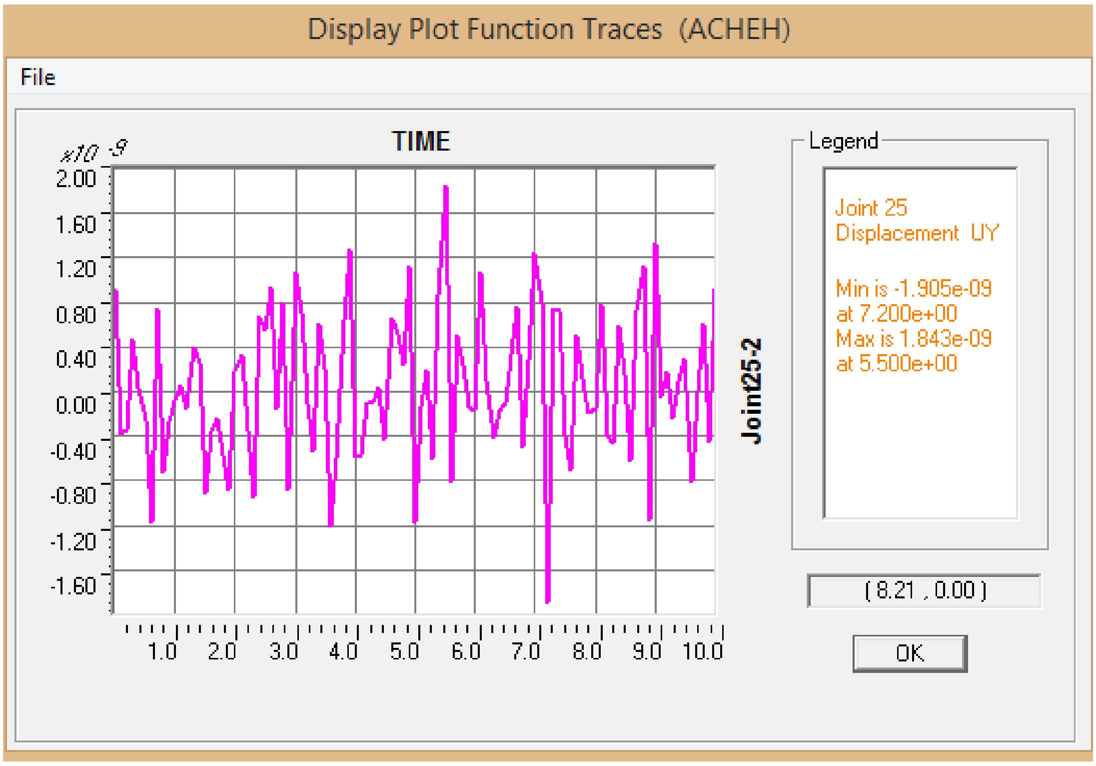


Figure 4. 18 Displacement joint 25, y-direction, Acheh earthquake.

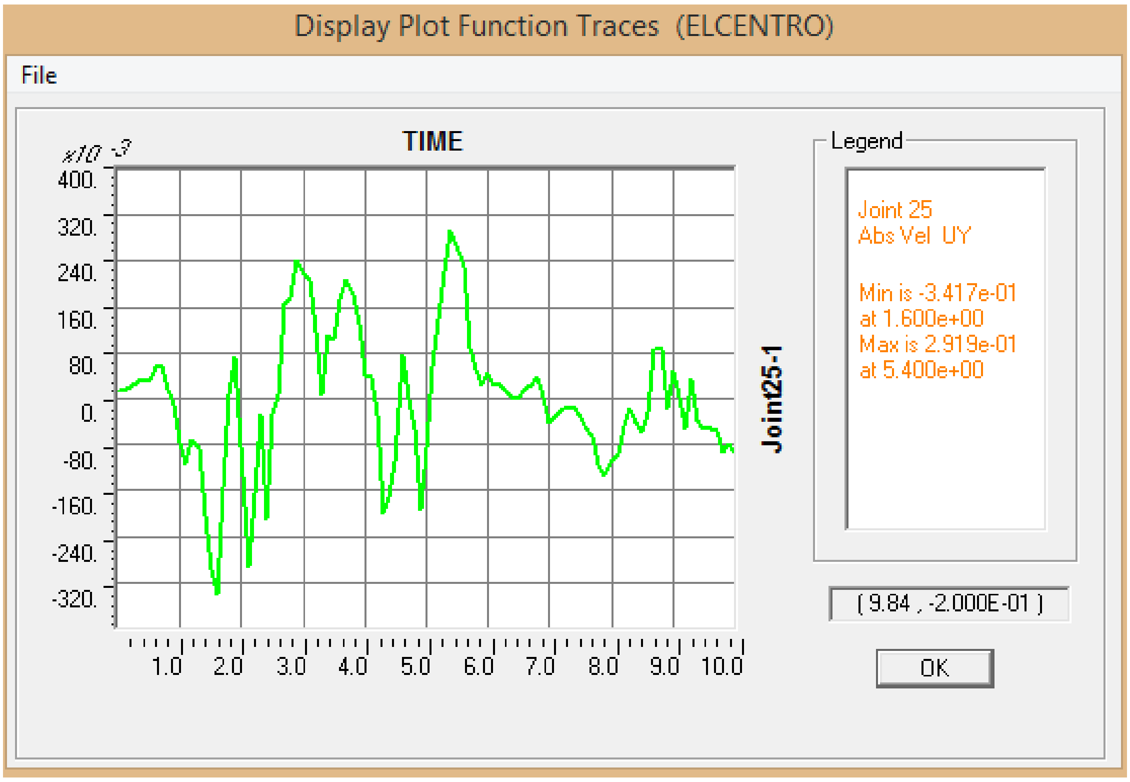


Figure 4. 19 Velocity joint 25, y-direction, Elcentro earthquake.

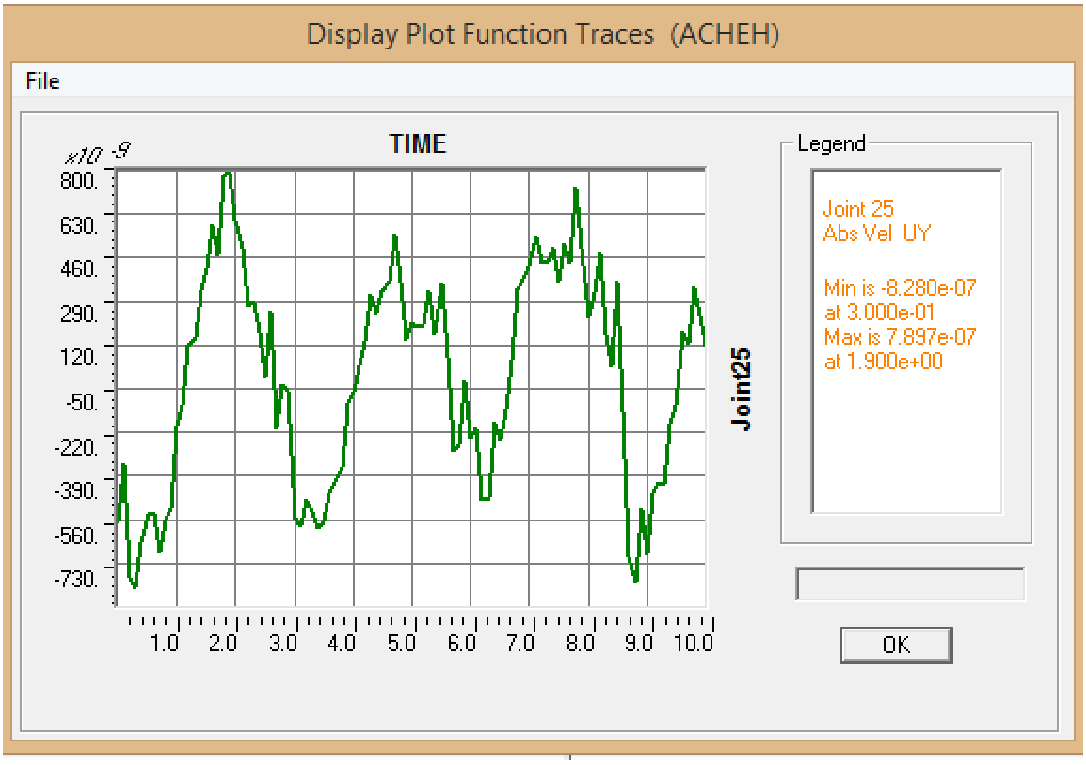


Figure 4. 20 Velocity joint 25, y-direction, Acheh earthquake.

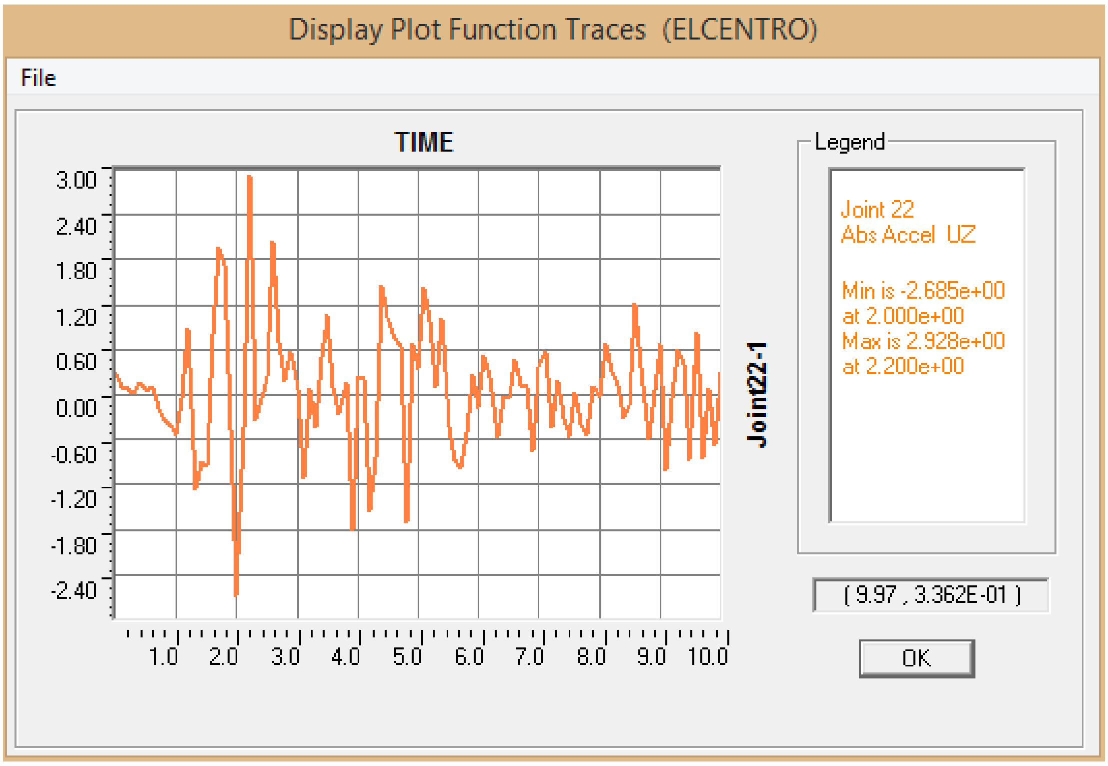


Figure 4. 21 Acceleration joint 22, z-direction, Elcentro earthquake.

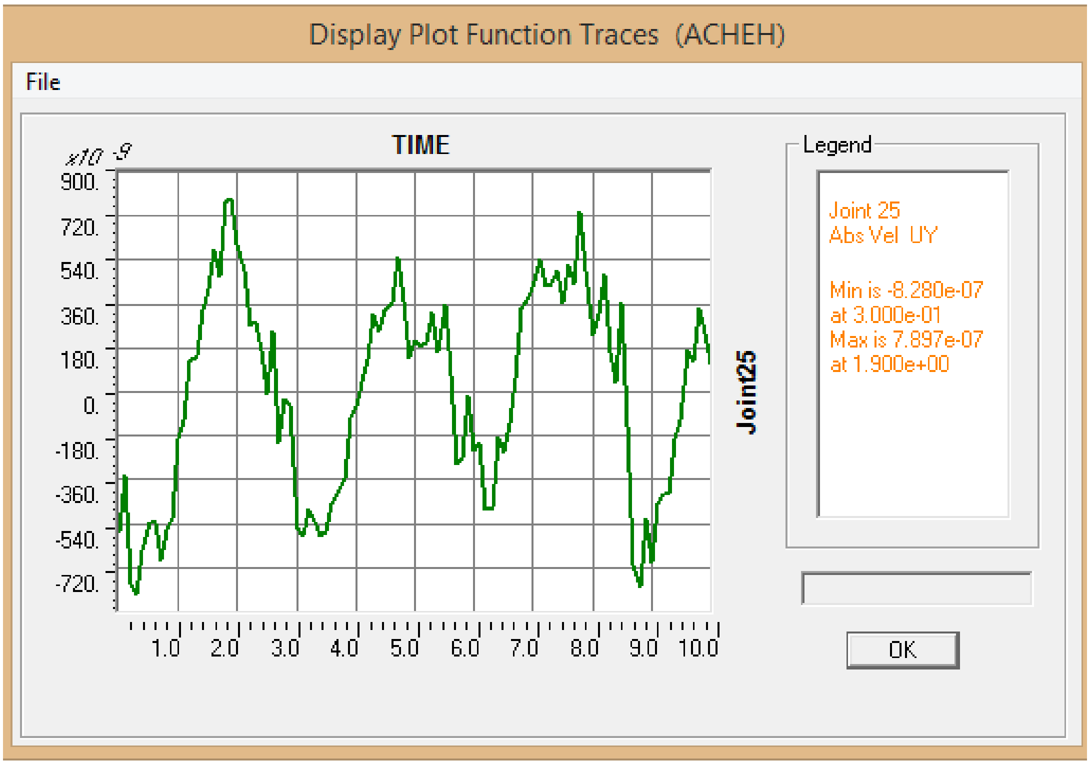


Figure 4. 22 Acceleration joint 22, z-direction, Acheh earthquake

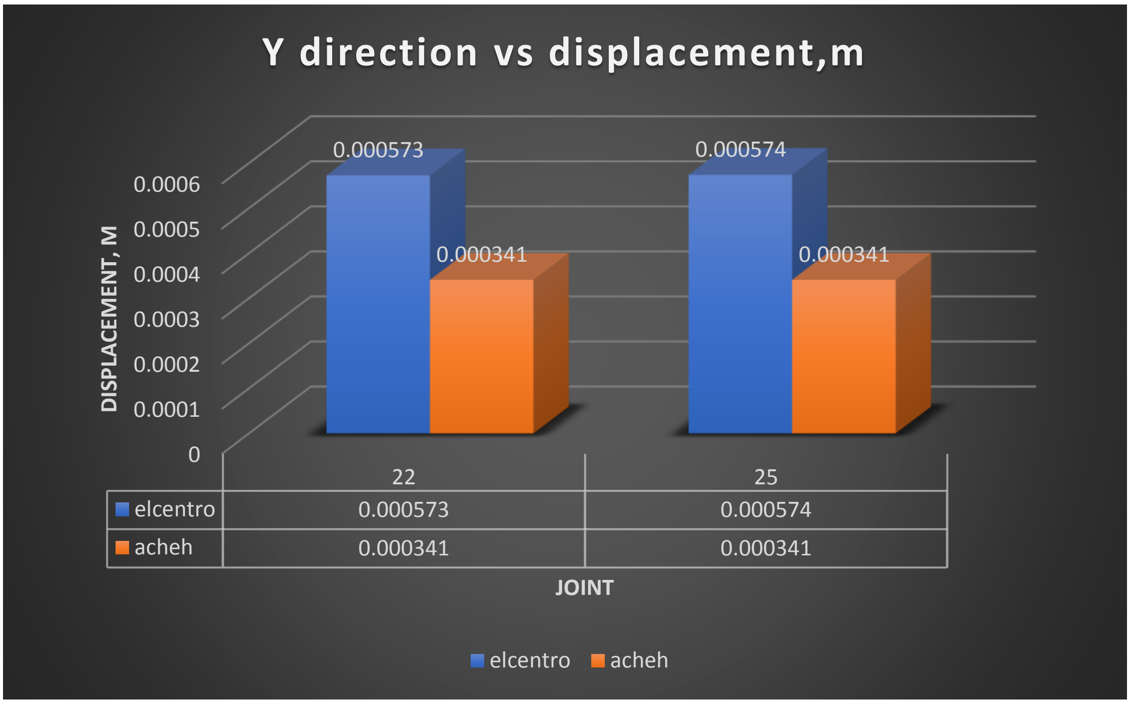


Figure 4. 23 Y direction vs Displacement, m.

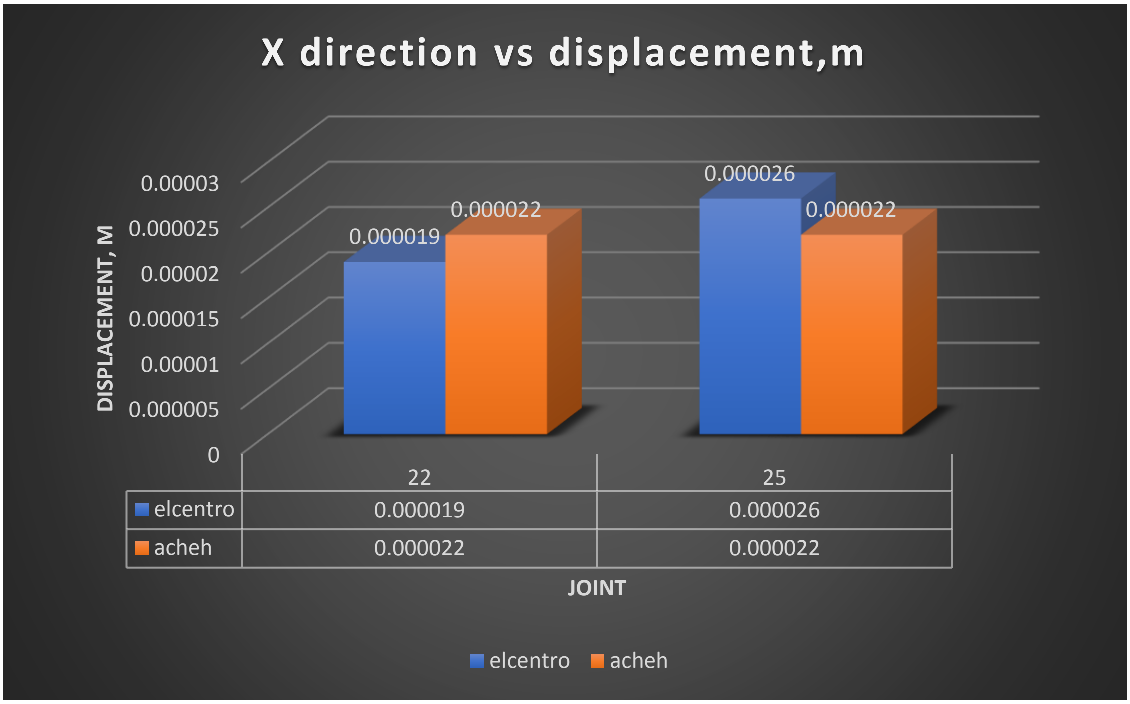


Figure 4. 24 X direction vs Displacement, m.

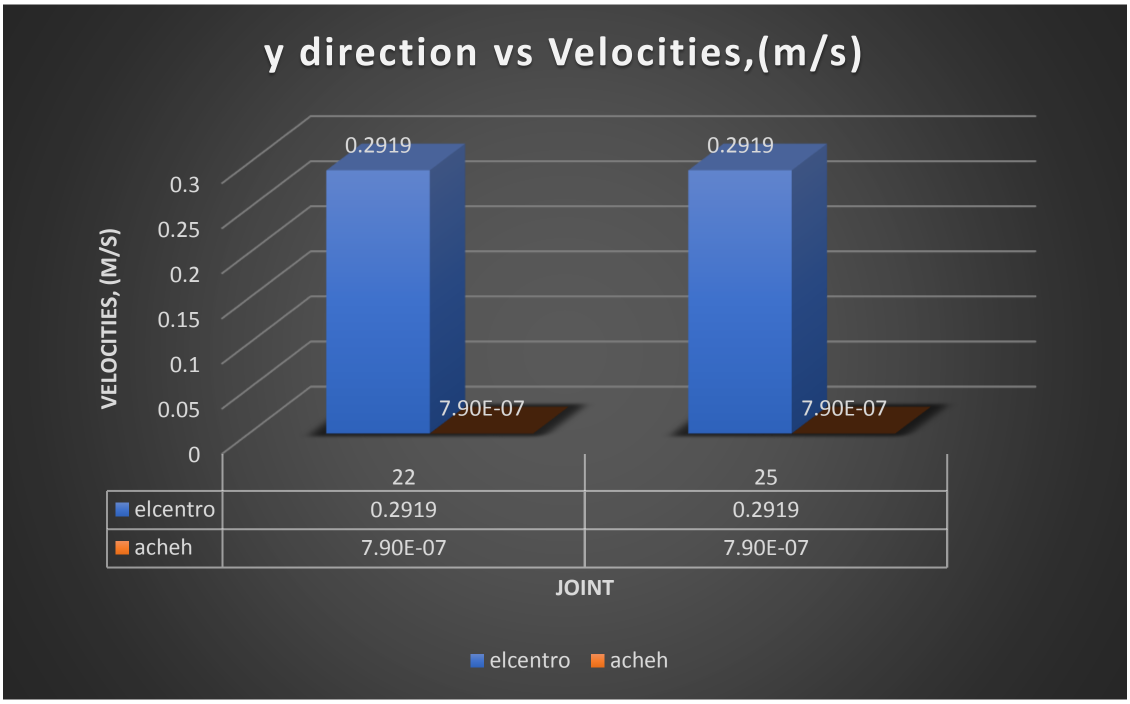


Figure 4. 25 Y direction vs Velocities, m/s.

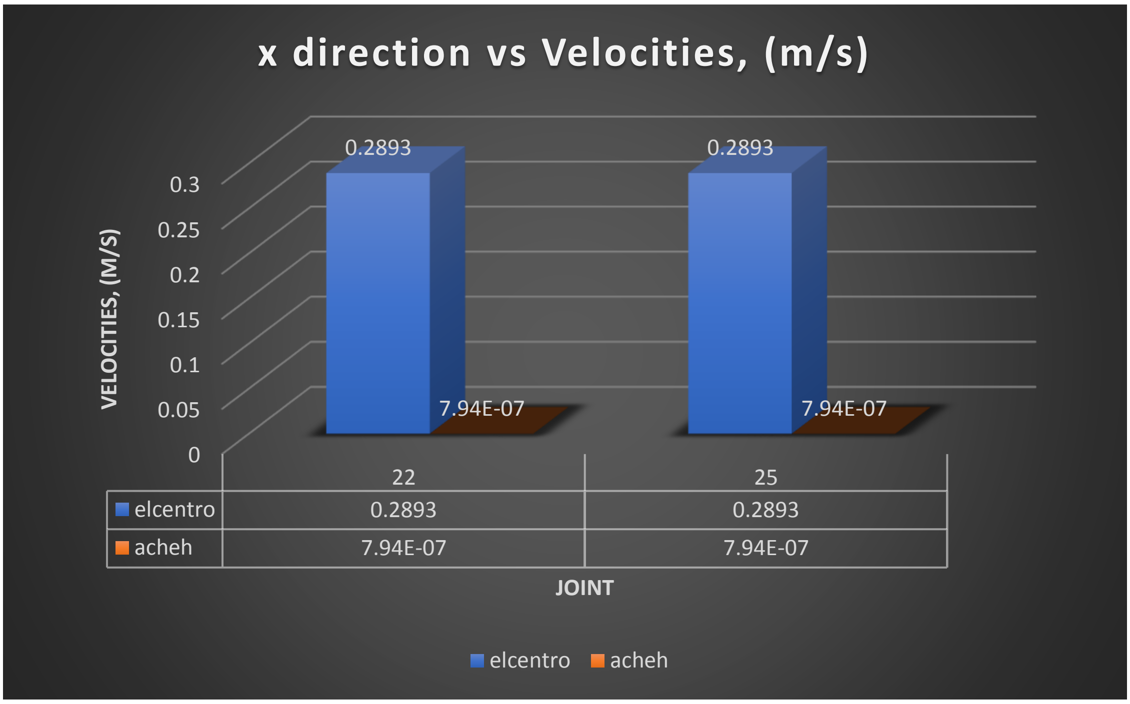


Figure 4. 26 X direction vs Velocities, m/s.

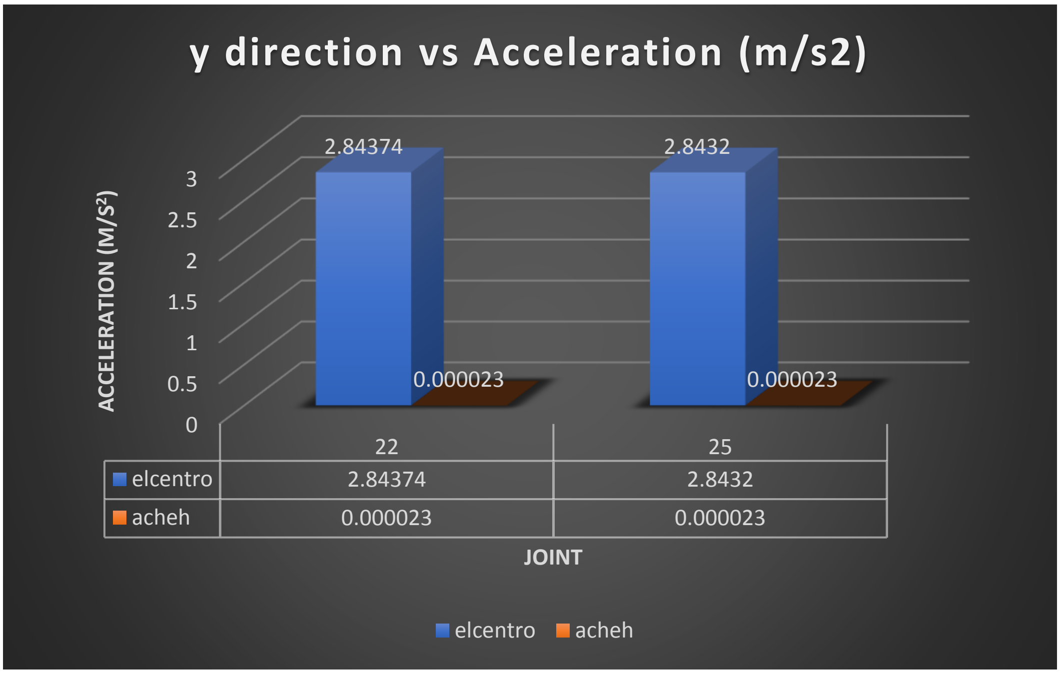


Figure 4. 27 Y direction vs Acceleration, m/s^2.

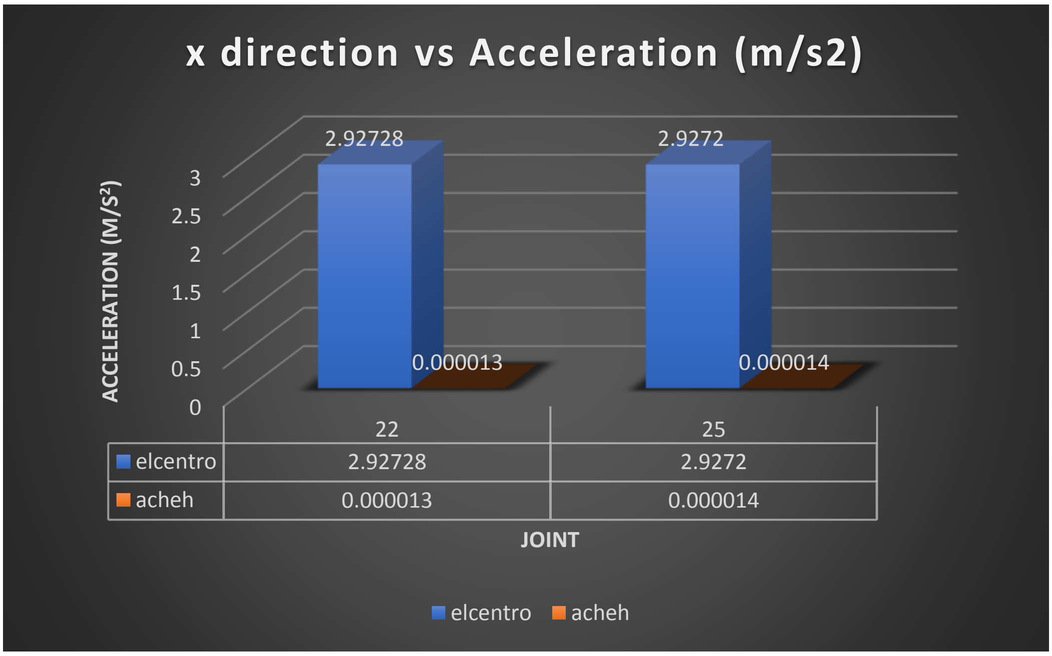


Figure 4. 28 X direction vs acceleration, m/s^2.

4.5 Response Spectrum Analysis

In order to demonstrate the maximum seismic response of the elastic structure, it is impossible to have the actual time history for each location if it is not existing and do not occur any earthquake previously. To solve all these difficulties and problem in having time history data, response spectrum analysis is the most famous method that had been used around the world in the seismic performance of structure. A response spectrum is a function of frequency or period, showing the peak response of a simple harmonic oscillator that is subjected to a transient event. The response spectrum is a function of the natural frequency of the oscillator and of its damping. Thus, it is not a direct representation of the frequency content of the excitation, but rather of the effect that the signal has on a postulated system with a single degree of freedom. Response-spectrum analysis provides insight into dynamic behavior by measuring pseudo-spectral acceleration, velocity, or displacement as a function of structural period for a given time history and level of damping. In using this analysis, it can produce design decision making because it relates dynamic performance of structure and the selection of structural type and design that can cater and endure the ground motion.

In each country practically there are response spectra envelope that create a smooth curve represent time period against acceleration (ground motion) depending and referring to the seismic hazard map which have their own value. Besides, the parameter such as damping, important factor, behavior factor, and soil factor of each location might be difference depend on the soil type and the structure. Response spectrum has been performed according to Eurocode 8 2004. In this study, the location of the retaining wall structure located at Terengganu and the value of the parameter assumed and depend on the seismic hazard map. The parameter value is as shown;

i) Horizontal ground acceleration = 0.04 g
ii) Spectrum type = 1
iii) Ground type = B
iv) Soil factor = 1.2

Response spectrum with 0%,2%,5%, and 10% damping ratio used in spectrum analysis at joint 25 are presented in Figure 4.29 that presented the maximum response of the structure due to the response spectrum in y-direction.

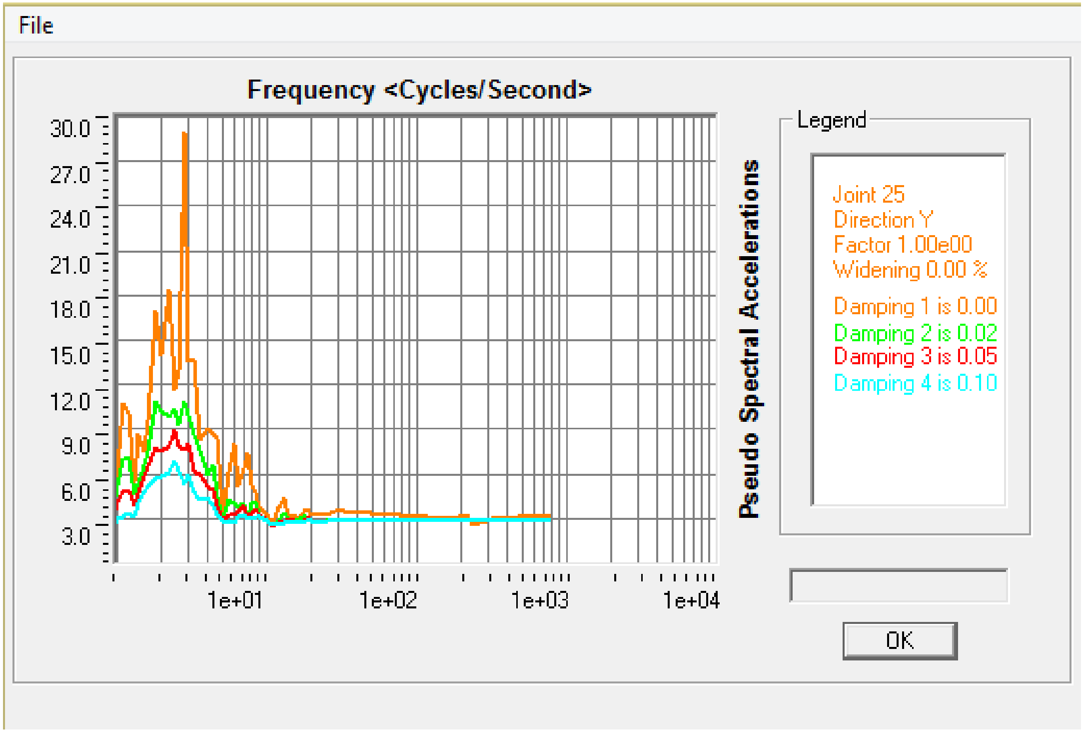


Figure 4. 29 Pseudo Spectral Acceleration Y-direction

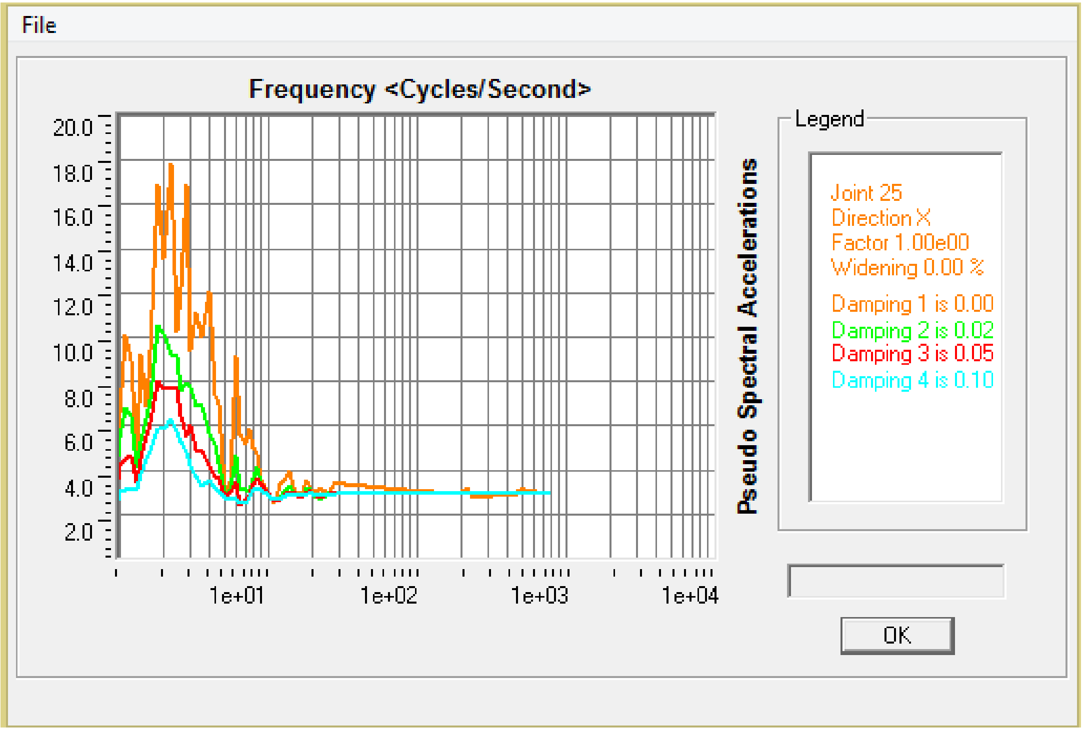


Figure 4. 30 Pseudo Spectral Acceleration X-direction

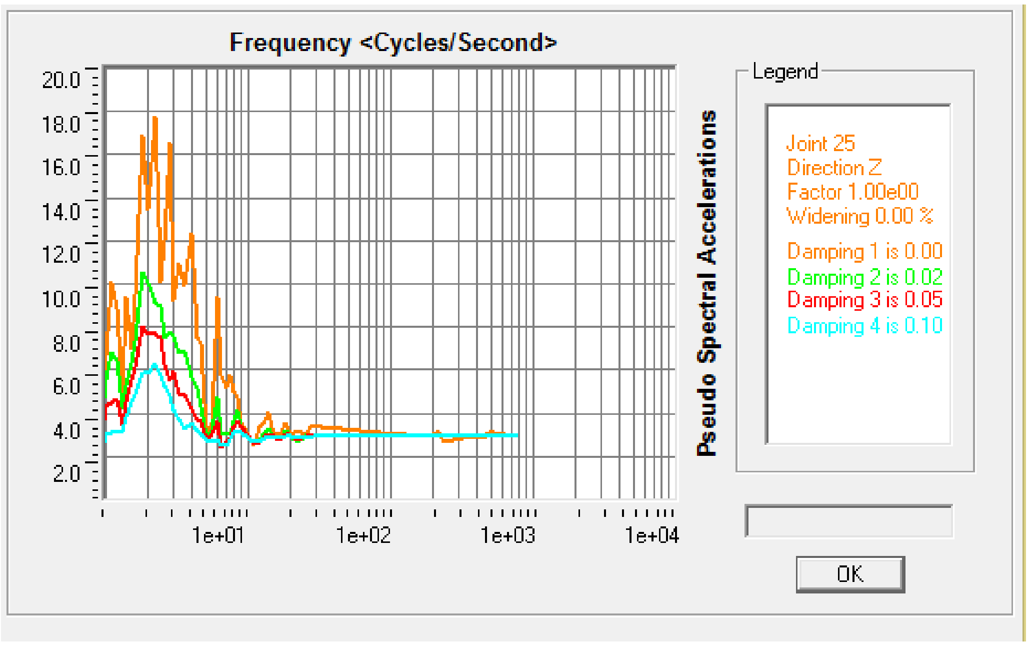


Figure 4. 31 Pseudo Spectral Acceleration Z-direction

Below shown the spectral displacement of Elcentro earthquake at joint 25 in x, y and z direction. Besides, the spectral displacement in Acheh earthquake cannot be display and seen because the value is too small.

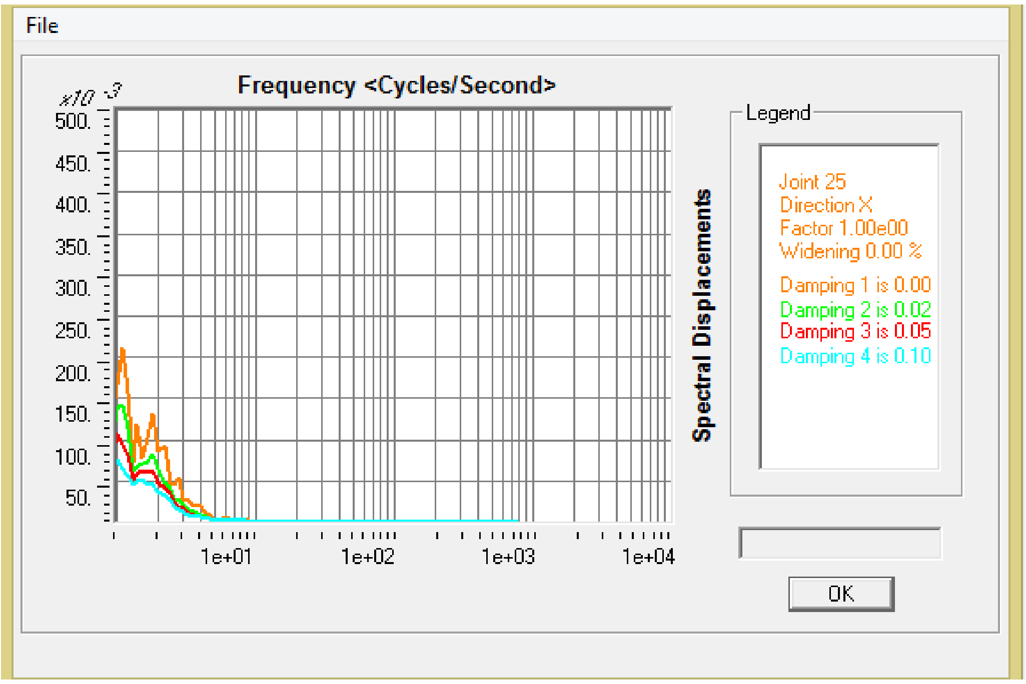


Figure 4. 32 Spectral Displacement X-direction

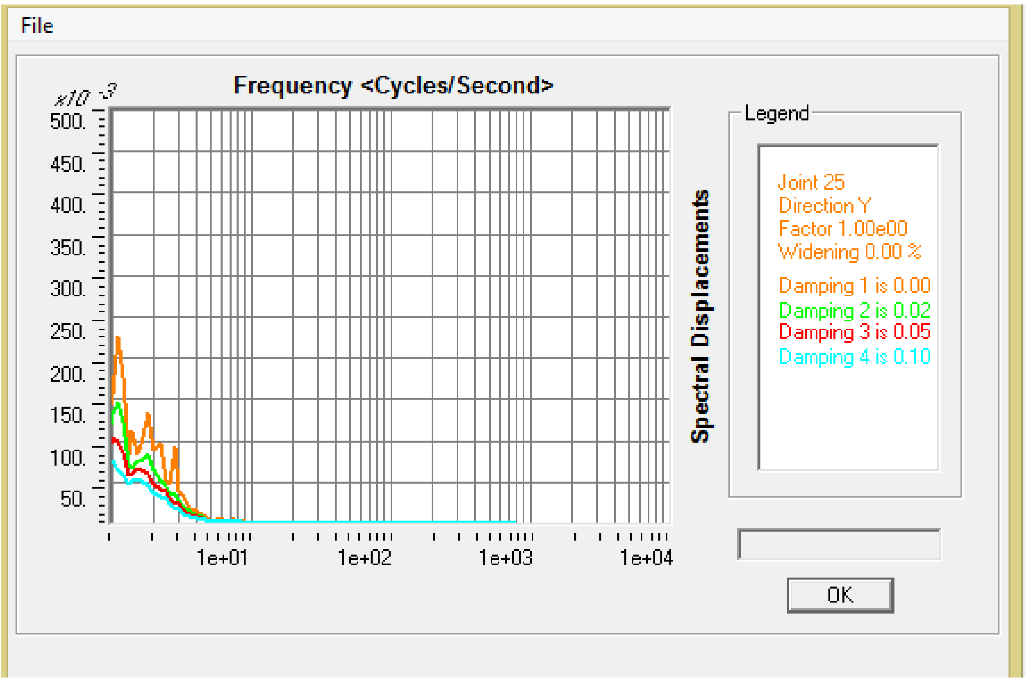


Figure 4. 33 Spectral Displacement Y-direction

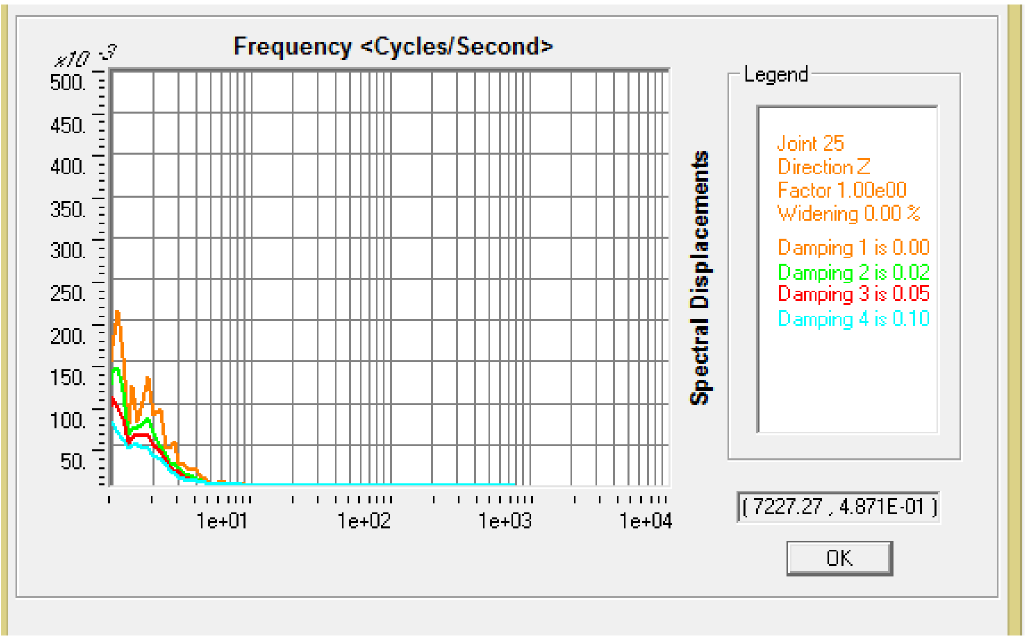


Figure 4. 34 Spectral Displacement Z-direction

Below shown the spectral velocities of Elcentro earthquake at joint 25 in x, y and z direction. Besides, the spectral velocity in Acheh earthquake cannot be display and seen because the value is too small.

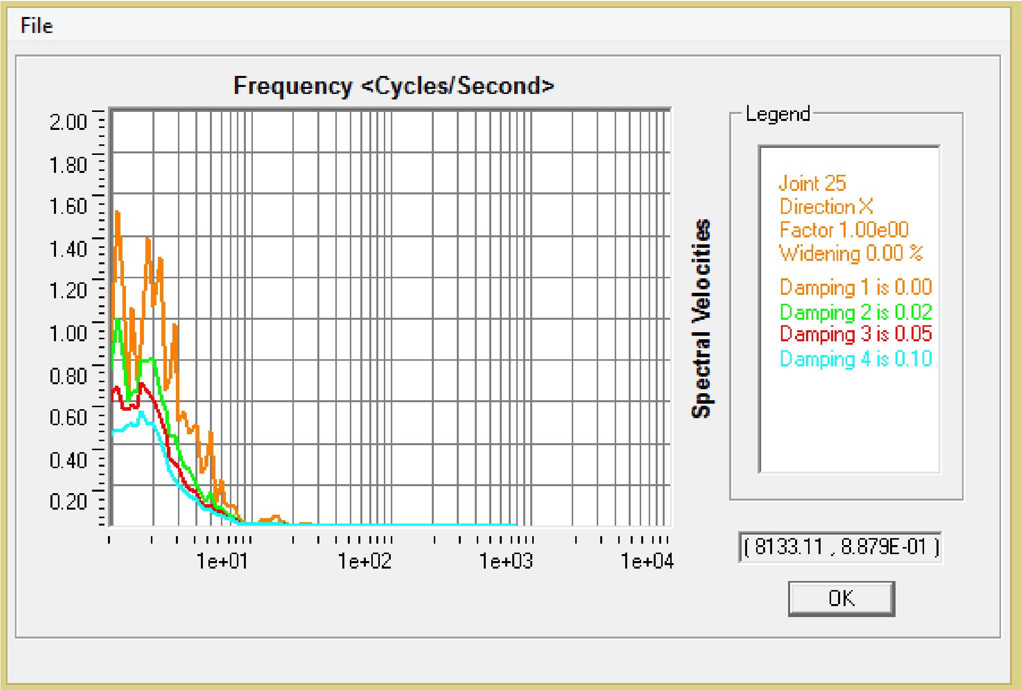


Figure 4. 35 Spectral velocities X-direction

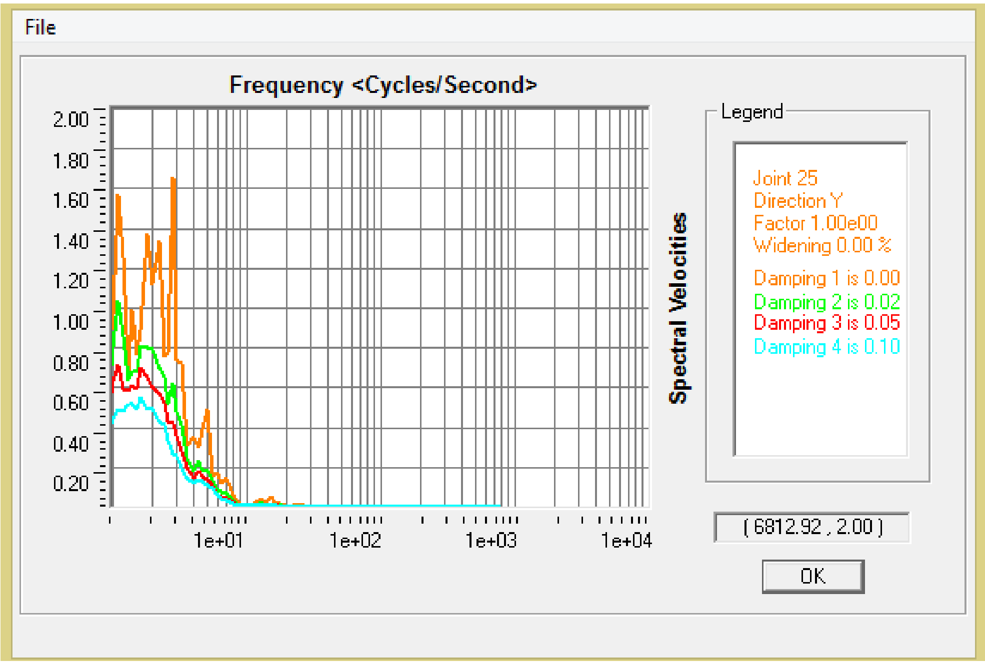


Figure 4. 36 Spectral velocities Y-direction

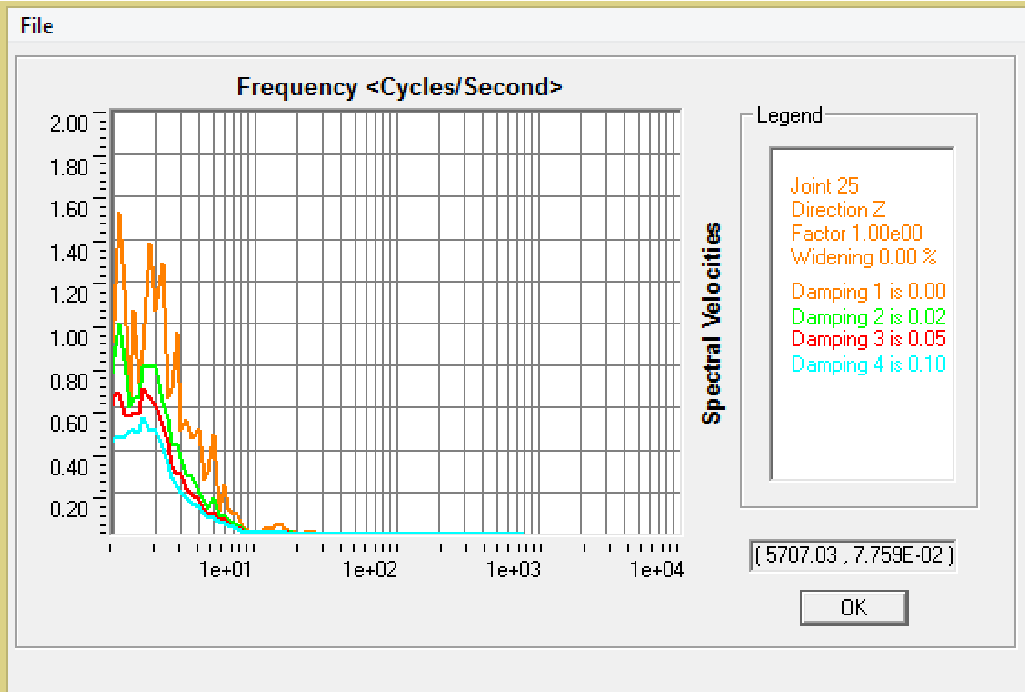


Figure 4. 37 Spectral velocities Z-direction

4.6 Linear Analysis

In this analysis, there are several load cases and combination that has been applied which the combination is dead load (DL), Live load (LL) and time history load (TH). Different time history has been used which is Acheh and Elcentro for comparison of maximum out of plane shearing stress (force per unit area) in the shell of cantilever retaining wall structure. The result from the load combination applied will be presented in diagram and table form.

Table 4.6 Maximum and minimum Shearing stress.

Load Combination	Shearing stress (kN/m^2)	
	Max	**Min**
DL+LL+TH(Elcentro)	196.461	-1214.078
DL+LL+TH(Acheh)	189.452	-1234.224
DL+LL	126.301	-822.816

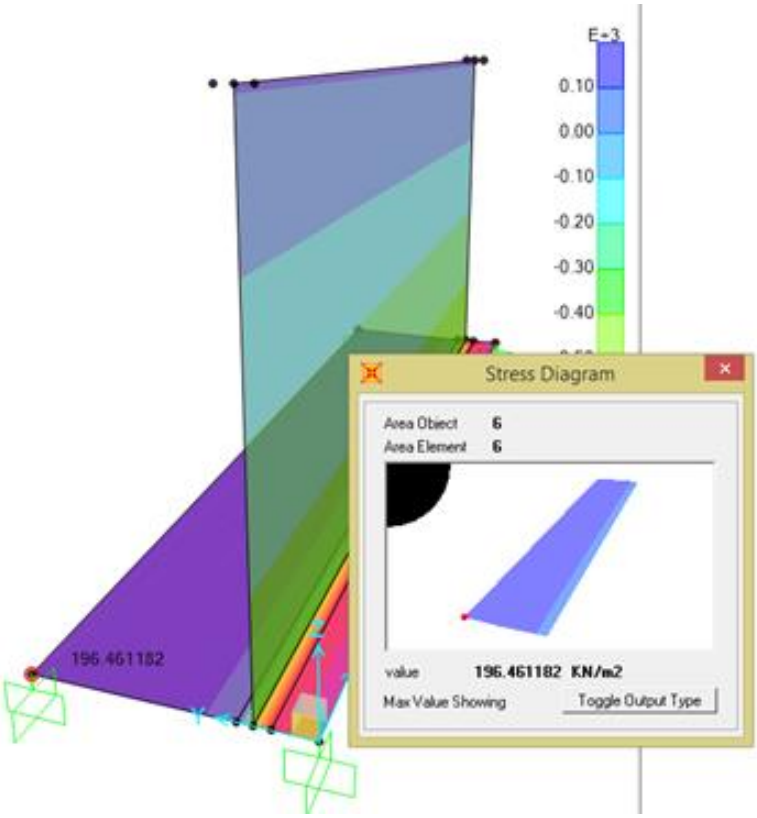


Figure 4. 38 Max Shearing Stress in Load Combination DL+LL+TH(Elcentro)

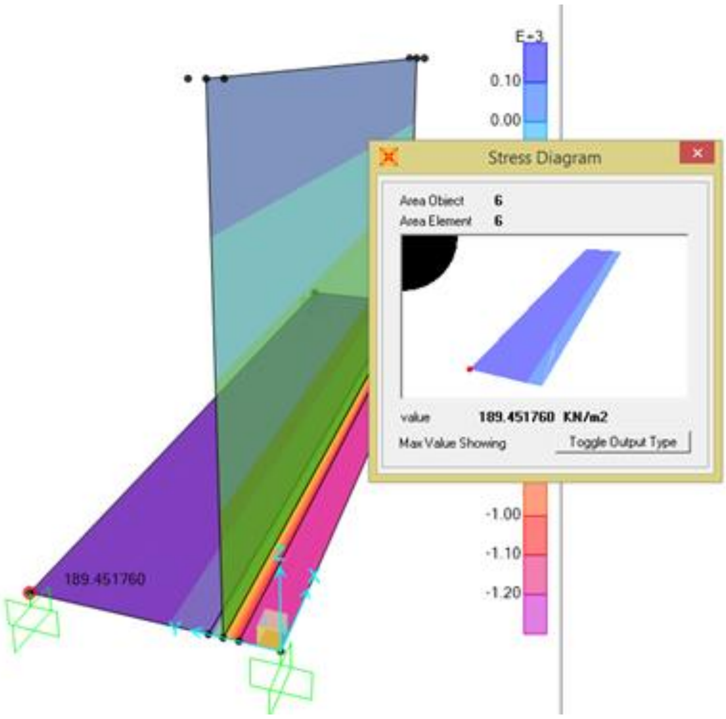


Figure 4. 39 Max Shearing Stress in Load Combination DL+LL+TH(Acheh)

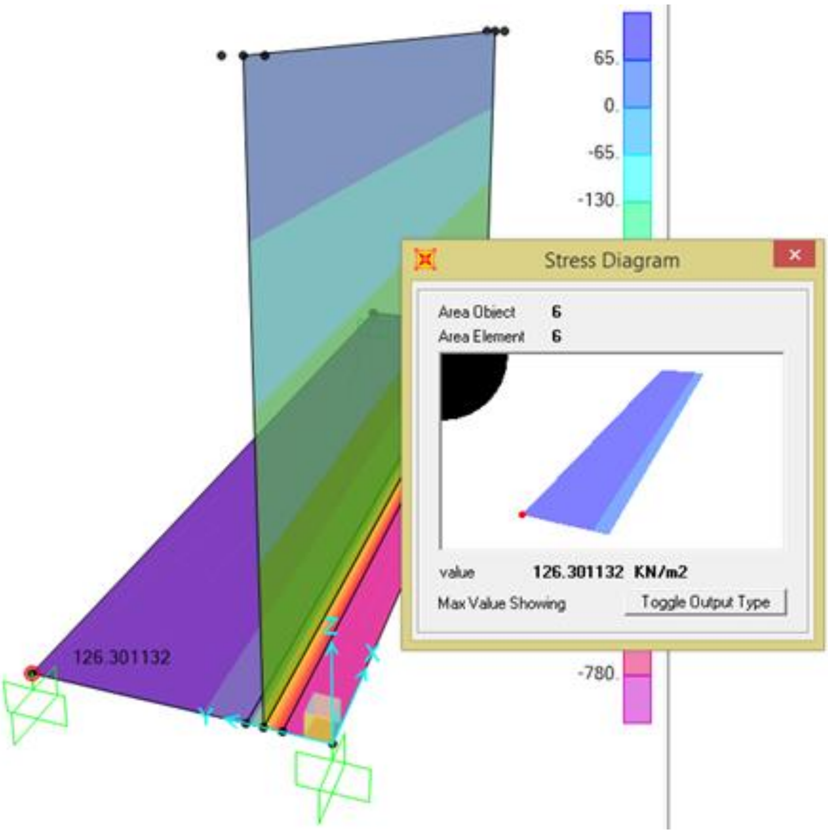


Figure 4. 40 Max Shearing Stress in Load Combination DL+LL.

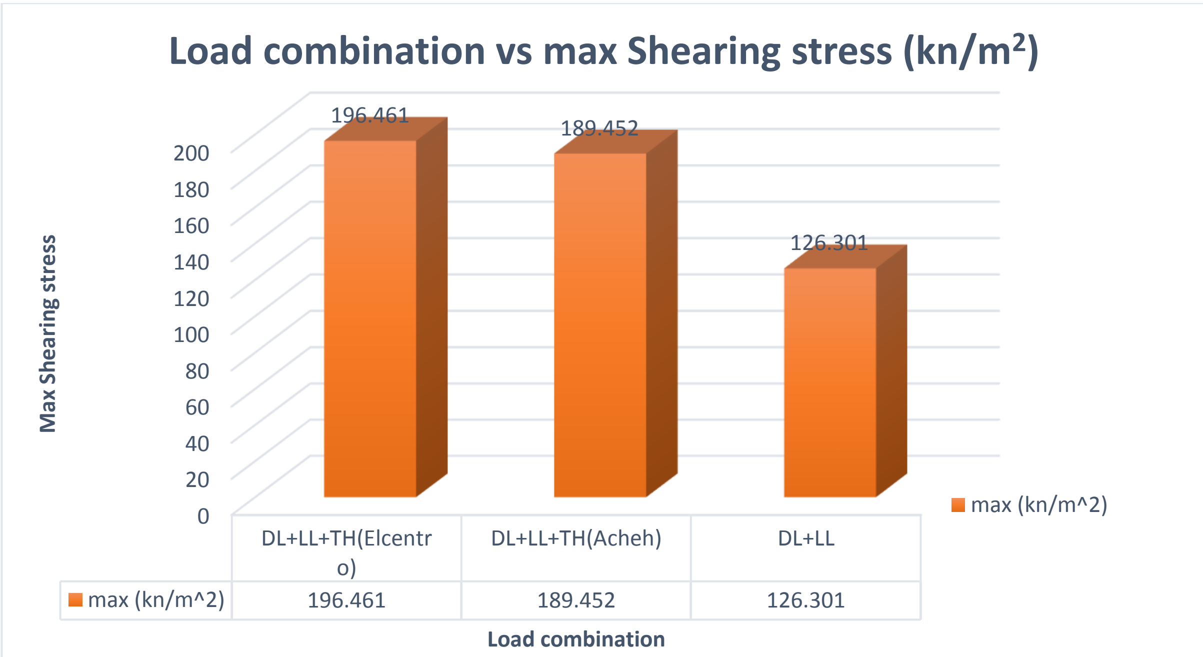


Figure 4. 41 The Comparison of Maximum Shearing stress.

Based on the result that have been determined and presented it shows that in Load combination DL+LL+TH(Elcentro) have the highest shearing stress with value of 196.461 kN/m^2 follow up with load combination DL+LL+TH(Acheh) with value of 189.452 kN/m^2 and lastly with lowest value with 126.301 kN/m^2 in load combination of DL+LL.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Even though in Malaysia there is no major earthquake occurred, but it already has speculation and study that Malaysia may prone to impact of major earthquake from near country. This study conducted are based on the real-life project of cantilever retaining wall project located in Terengganu to check the vulnerability of the retaining wall structure due to major and minor earthquake. Two different time history of earthquake was used which is Acheh earthquake as minor earthquake and Elcentro earthquake as major earthquake event. The structure has been modelled and analyzed using SAP2000 software. The objective of the research has been achieved when the result from the analysis shown the relevant result of performance of cantilever retaining wall.

Furthermore, the result obtained from the analysis of free vibration, time history and response spectrum are mode shape, natural period, natural frequency, displacement, acceleration and shear stress of the joint and element in structure under different load combination.

Regarding to the study of the project, the conclusion that can be made are:

i. The modelled and simulation of cantilever retaining wall structure presented not fulfil the actual structured due to the earlier assumption made on restraint at based condition and the joint connection of element of the cantilever retaining wall structure. The actual restraint of the wall is pile foundation where it assumed to be fixed in the model. In addition, the connection of the wall structure not designed following to specification of Eurocode 3.

ii. Resulting from the free vibration analysis, 12 mode shape with natural period and frequency was produced.

iii. The highest natural period produced in free vibration analysis was in mode shape 1 with 0.0588 sec where the most impact as mention before was in first three mode shape.

iv. The maximum shearing stress that occur at the most critical area is 198.461 kN/m^2 produced when applied the load combination of dead load, live load and time history of Elcentro earthquake.

v. From the time history analysis, the dynamic characteristic of cantilever retaining wall of parameter time versus velocity, acceleration and displacement, it shown that from the comparison between Elcentro earthquake and Acheh earthquake shown that all of three parameters produced from Elcentro earthquake have higher value compared to the Acheh earthquake.

5.2 Recommendation

In the future study, it is recommended to include the restraint and footing of the retaining wall in the study because of the ground motion of the soil and it have different type of soil. Besides, to increase the accuracy of the analysis of seismic performance, the data need and should be updated so that the intensity of earthquake included and reduce error. For improving the accuracy on the seismic response study, the researcher can also analyse the behaviour of material of the structure used when the earthquake approaches the structure. To have more comparison and desirable result for seismic performance evaluation about retaining wall, it is recommended to do the evaluation at different location because of the difference of soil type and other parameter. In addition, engineers in Malaysia or authorities that related to construction and design need to include the seismic design in any structure especially important building such as hospital, school, fire station, and others. This is important because of the seismic occur regularly near to our country and it might be felt also in Malaysia.

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