UNIVERSITI MALAYSIA PAHANG

DECLARATION OF THESIS / UNDERGRADUATE PROJECT PAPER AND COPYRIGHT

Author's full name : **AHMAD LUTFI BIN MOHD YUSOF**

Date of birth : **17 JULY 1993**

Title : **SEISMIC PERFORMANCE OF CANTILEVER RETAINING WALL UNDER EARTHQUAKE LOADING**

Academic Session : **2016/2017**

I declare that this Final Year Project Report is classified as:

☐	**CONFIDENTIAL**	(Contains confidential information under the Official Secret Act 1972)*
☐	**RESTRICTED**	(Contains restricted information as specified by the organization where research was done)
√	**OPEN ACCESS**	I agree that my thesis to be published as online open access (full text)

I acknowledged that University Malaysia Pahang reserves the right as follows:

1. The Final Year Project Report is the property of University Malaysia Pahang.
2. The Library of University Malaysia Pahang has the right to make copies for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

______________________________	______________________________
(STUDENT'S SIGNATURE)	(SIGNATURE OF SUPERVISOR)
930717-06-5065	**IR SAFFUAN BIN WAN AHMAD**
(NEW IC NO. / PASSPORT NO.)	NAME OF SUPERVISOR
Date:	Date:

NOTES * If the Final Year Project Report is CONFIDENTIAL or RESTRICTED, please attach with the letter from the organization with period and reasons for condentially or restriction

SEISMIC PERFORMANCE OF CANTILEVER RETAINING WALL STRUCTURE UNDER EARTHQUAKE LOADING

AHMAD LUTFI BIN MOHD YUSOF

Thesis submitted in fulfillment of the requirement for award of the degree of

B.ENG (HONS.) CIVIL ENGINEERING

Faculty of Civil Engineering & Earth Resources

UNIVERSITI MALAYSIA PAHANG

DECEMBER 2016

SUPERVISOR'S DECLARATION

"I hereby declare that I have read this thesis and in
my opinion this thesis is sufficient in term of scope and
quality for the award of degree of Bachelor of Civil Engineering"

Signature	: ……………………………………
Name of Supervisor	: IR SAFFUAN BIN WAN AHMAD
Position	: SENIOR LECTURER
Date	:

STUDENT'S DECLARATION

"I declare that this thesis entitles *"Seismic Performance of Cantilever Retaining Wall Structure Under Earthquake Loading*" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not currently submitted in candidature of any other degree."

Signature : ……………………………………….

Name of Supervisor : AHMAD LUTFI BIN MOHD YUSOF

Date :

Dedicated to my parents,

For their loves and devotions,

Making me be who I am today.

ACKNOWLEDGEMENT

I would like to take this opportunity to thank my university which is University Malaysia Pahang for providing a good condition of facilities and equipment for me to complete this study.

I also want to express my sincere appreciation to my one and only supervisor, Ir Saffuan Bin Wan Ahmad, who has been very supportive in guiding and providing me informative discussion and recommendation throughout this study. His consistent encouragement and motivation allowed me to perform and unleash my capabilities during this study.

In addition, I would like to express my gratitude to my panel, Ms Norhaiza Binti Ghazali and Dr Cheng Hock Tian for their valuable suggestions and comments during my presentation and allowed me to improve my research outcome so that I can achieved the objectives of this study.

A special thanks to my friend, Rahamah Wati Binti Sulaeman, Nurul Atikha Binti Khariul Abidin and Norshakila Binti Abdul Wahab since they always share their precious knowledge and resources with me during completing this study.

Finall, I am also grateful to my parents, Mr Mohd Yusof Bin Abd Ghani and Mrs Norran Binti Ahmad and to all my siblings for their love and encouragement all the way with me in completing this study.

ABSTRACT

Retaining wall structures in Malaysia region are placing more emphasis on lateral earth pressure rather than seismic effect. However, Malaysia actually experienced tremors due to the earthquakes occurred in the neighbouring countries. Therefore, the main objective of this research is to study the behaviour of retaining wall structure under earthquake loading and to determine acceleration and displacement of retaining wall structure during earthquake. Hence, a finite element seismic response simulation of a retaining wall structure using SAP2000 has been presented.

Time history, response spectrum and free vibration analysis has been carried out and compared throughout this study. Generally, retaining wall structures in Malaysia region are capable of resisting low seismic activity based on the study. This is happen because the design of retaining wall structures for lateral earth pressure can provide sufficient resistance against potential low seismic effects.

ABSTRAK

Struktur tembok penahan di rantau Malaysia meletakkan lebih penekanan kepada tekanan bumi sisi dan bukannya kepada kesan seismik. Walau bagaimanapun, Malaysia sebenarnya mengalami gegaran daripada gempa bumi yang berlaku di negara-negara jiran. Oleh itu, objektif utama kajian ini adalah untuk mengkaji tingkah laku struktur dinding di bawah beban gempa bumi dan untuk menentukan pecutan dan anjakan struktur tembok penahan semasa gempa bumi.

Oleh itu, simulasi balas unsur seismik struktur tembok penahan menggunakan SAP2000 telah dibentangkan. Sejarah masa, spektrum tindak balas dan analisis getaran bebas telah dijalankan dan dibandingkan sepanjang kajian ini. Secara umumnya, struktur tembok penahan di rantau Malaysia mampu untuk menahan aktiviti seismik yang rendah berdasarkan kajian yang terdahulu. Ini berlaku kerana reka bentuk tembok penahan dinding untuk tekanan bumi sisi boleh memberikan ketahanan yang mencukupi terhadap beban seismik yang rendah.

TABLE OF CONTENT

CHAPTER 2 LITERATURE REVIEW

LIST OF FIGURES

LIST OF SYMBOLS

kN	Kilo Newton
kNm	Kilo Newton meter
mm	Millimeter
mm^2	Millimeter square

LIST OF ABBREVIATIONS

RC	Reinforced Concrete
EC2	EuroCode 2
EC8	EuroCode 8
3D	Three Dimension
2D	Two Dimension
C	Concrete

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

In Malaysia, there are several types of retaining wall that commonly used in construction. Retaining wall is mostly used in highway and dam construction. A retaining wall can be used to prevent soil from being wash away, through erosion. The wall will prevents rainwater from irrigation activities and washing away the soil. Landscaping a sloped garden poses a great challenge. The sloping causes lateral pressure that may lead to the movement of soil downwards. We need to build retaining wall which will redistribute and accommodate the lateral pressure and allow us to make landscape without the soil sliding downwards.

From USGS record, there are around 500, 000 earthquake occur each year. In Malaysia, there is no earthquake disaster occur except a few in Sabah and Sarawak with just a very small magnitude. Although there are just a few small magnitude earthquakes in Malaysia, the nearest country like Indonesia is the country that constantly experience earthquake. Since Indonesia is located in the eastern of Malaysia, he following chapter will discuss about how earthquake occur in Indonesia can affect retaining wall in East Coast of Malaysia.

1.2 PROBLEM STATEMENT

Malaysia is located beyond the seismically active zone, but it is still questionable whether the numerous cantilever retaining wall structures in Malaysia region shall be design to withstand an earthquake ground motion. In fact, parts of Sabah and Sarawak coastal area are very close to the seismically active area and have experience the tremors truly owing to the earthquakes occurred in the neighbouring countries. Sabah has experienced an earthquake with 6.0 magnitudes in 2015 that cause the peaks of Kinabalu Mountain to collapse.(USGS)

The current Malaysian retaining wall structural design practices focus more on lateral earth pressure analysis rather than seismic effect. We cannot ensure whether the retaining wall structure is safe at a specific level of earthquake acceleration. Therefore, the necessity of seismic design consideration for retaining wall structure in Malaysia due to surrounding earthquake should be determined.sec^2.

1.3 OBJECTIVES OF STUDY

The main objective of this research is to study the seismic performance of retaining wall structure due to earthquake while the sub objectives of this research are:

a) To study the behaviour of retaining wall structure under far field earthquake loading.
b) To determine the displacement and acceleration of retaining wall structure during earthquake.
c) To study the dynamic characteristics of retaining wall structure.

1.4 SCOPE OF STUDY

In the proposed study, the effect of retaining wall due to earthquake in Indonesia will be investigated. In this research, the study of the architecture drawing of a cantilever retaining wall will be done. The case study will be related to the Indonesia earthquake that affected the cantilever retaining wall in Malaysia. The modelling analysis of the retaining wall structure will use SAP2000. This research was recommended to test the typical retaining wall by using these analysis factors:

a) Free vibration analysis
b) Response spectrum earthquake analysis
c) Time history earthquake analysis

1.5 EXPECTED OUTCOME

The expected outcome of the analysis results will show the response of retaining wall structure under earthquake loading and all the outcome of the analysis will be done by using analysis software which is SAP2000.

1.6 SIGNIFICANT OF STUDY

The outcomes and findings of this research are to study and analyse the seismic performances of retaining wall structure under earthquake loading. It may be useful for seismic behaviour assessment of typical wall structure and can contribute to understanding the effect of accounting parameters of seismic performance of existing retaining wall structure. The analysis results obtained may be used to develop some earthquake design criteria to increase the safety factor of retaining wall structure to prevent the damage caused from earthquake.

CHAPTER 2

LITERATURE REVIEW

2.1 EARTHQUAKE

In general sense, the word earthquake is used to describe any seismic event whether caused by human or nature that generates seismic waves. According to geologist, before the existing of human, the earth has suffered earthquakes for millions years. An earthquake is the perceptible shaking of the surface of the earth, resulting from the sudden release of energy in the earth crust that creates seismic waves. It can be violent enough to toss people around and destroy a whole city. The seismic activity of an area refers to the frequency, type and size of earthquakes experienced over a period of time. Earthquakes are measured using observation from seismometers. Usually earthquake with smaller magnitude than five that reported by national seismological observatories are measured most on local magnitude scale, known as Richter scale. This scale can be divided into three parts which are weak for magnitude three and below, medium for magnitude between three and seven, and strong for magnitude that higher than seven. The largest earthquakes in historic time have been occurs in Valdivia, Chile with magnitude 9.5 on May 22 1960.

Strong earthquake potentially cause serious damage over larger areas depending on their depth. If the point of the earthquake is near to the surface, it will cause more damage to the structure on the surface. An earthquake's point of initial rupture is called its focus or hypocenter while epicenter is the point directly above the hypocenter at ground level. When the epicenter of large earthquake is located offshore, the seabed may be displaced sufficiently to cause tsunami. Earthquake can also trigger landslides and volcanic activity. There are two types of earthquake which are inter-plate earthquake and intra-plate earthquake. The inter-plate earthquake is the most common earthquake occurred in the world which it is occur along the plate boundaries. Meanwhile, the intra-plate earthquake occurs further from the boundaries.

2.2 SEISMIC WAVES

Seismology is the study of earthquakes and seismic waves that move through and around the earth. A seismologist is a scientist who studies earthquakes and seismic waves. Seismic wave's amplitudes decrease as travel distance increase, due to phenomena like geometrical spreading, scattering attenuation, and intrinsic attenuation. (Farrokhi, M. & Hamzehloo, H. J Seismol, 2015). There are several different kinds of seismic waves, and they all move in different pattern. Seismic waves can be divided into two main parts which are body waves and surface waves.

2.2.1 BODY WAVES

Body wave is a seismic wave that travels through the earth rather than across its surface. Body waves usually have smaller amplitudes and shorter wavelengths than surface waves and travel at higher speeds. Primary waves and secondary waves are body waves.

2.2.1.1 P-WAVES

P-Wave is one kind of body waves that also known as Primary Waves. This is the fastest kind of seismic waves and consequently the first to arrive at seismic station. P-Wave can move through both form of material, solid rock and fluids. It pushes and pulls the rock as it moves through just like sound waves push and pull the air.

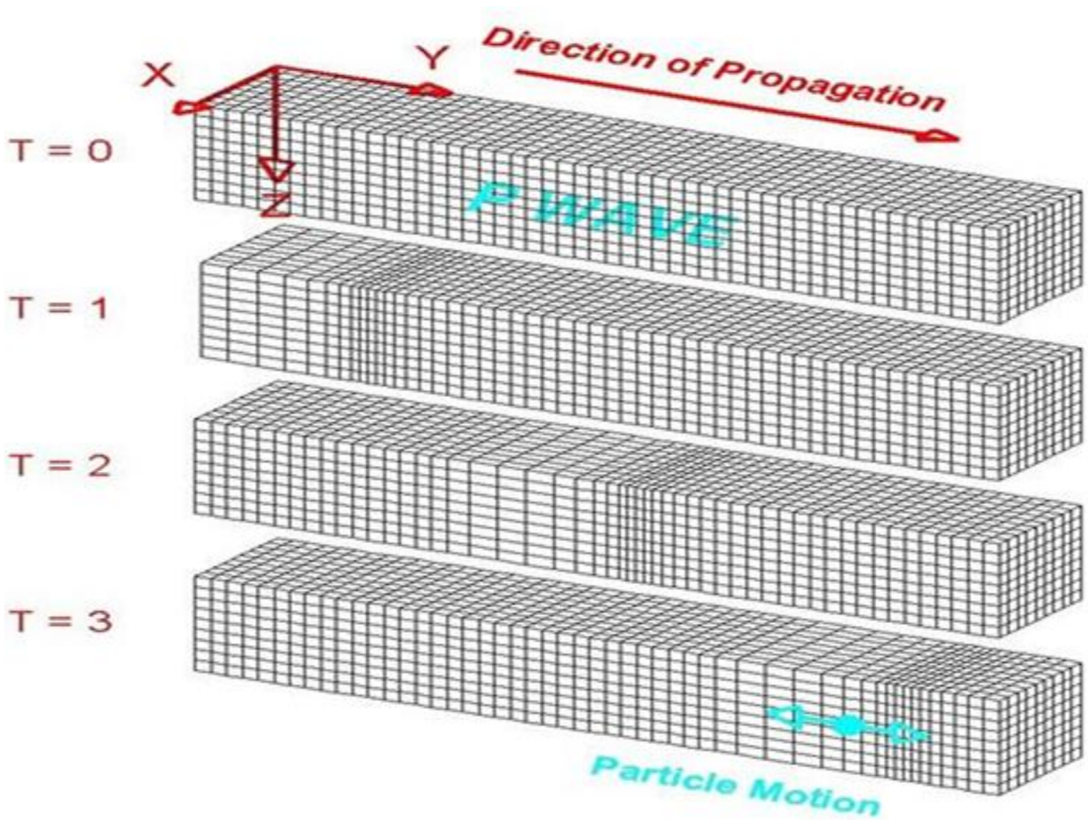


Figure 2.1: Direction of Propagation for P-Waves

2.2.1.2 S-WAVES

S-Wave is the second type of body waves that also known as Secondary Waves since it is the second wave you feel in an earthquake. S-Wave is slower than a P-Wave and only can move through solid rock. This property of S-Wave led seismologist to conclude that the earth’s outer core is a liquid. The S-Wave move rock particles up and down or side to side perpendicular to the direction that the wave is travelling in known as the direction of propagation.

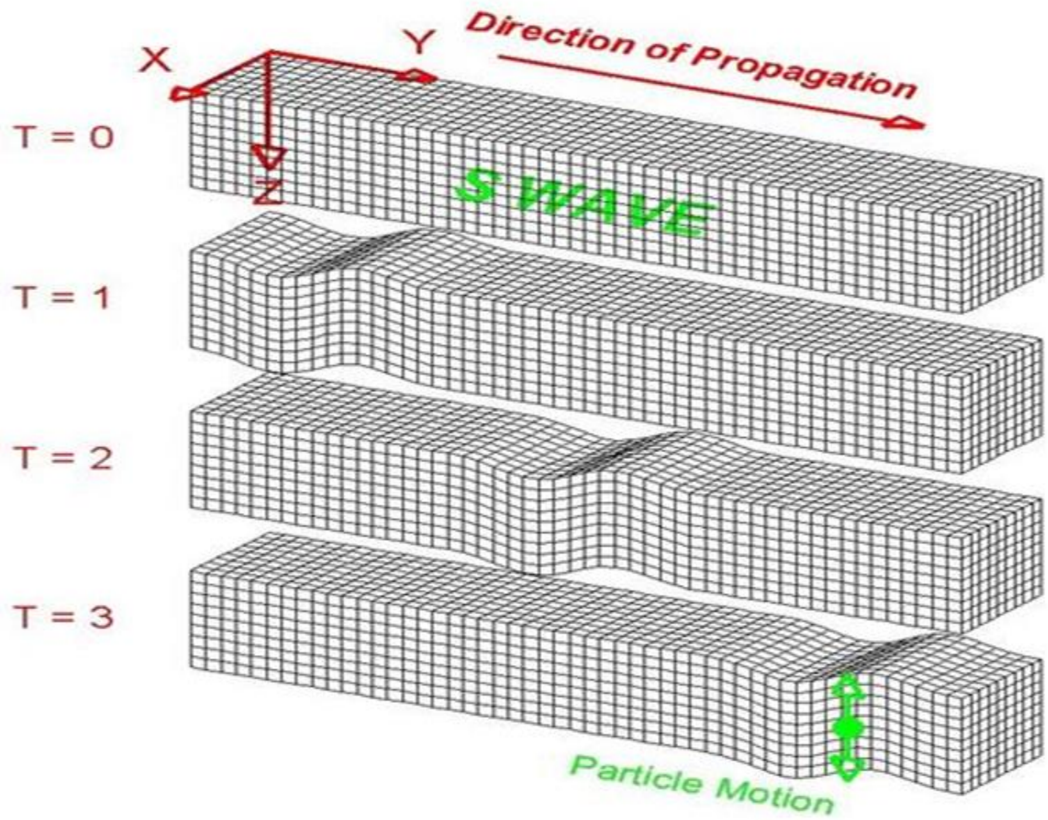


Figure 2.2: Direction of Propagation for S-Waves

2.2.2 SURFACE WAVES

Surface wave is a seismic wave that only travel through crust and have a lower frequency compare to body waves and it can be easily distinguished on a seismogram as a result. Although they arrive after body wave, it is surface wave that are almost entirely responsible for the damage and destruction associated with earthquakes. The strength and damage cause by surface wave are reduced if the hypocentre is deeper. Surface wave also can be divided into two categories of waves which are Love Wave and Rayleigh Wave.

2.2.2.1 LOVE WAVES

Love Wave are named after A.E.H love, a British mathematician who worked out the mathematical model for this kind of wave in 1911it is the fastest surface wave and moves the ground from side to side. Confined to the surface of the crust, Love Wave produces entirely horizontal motion.

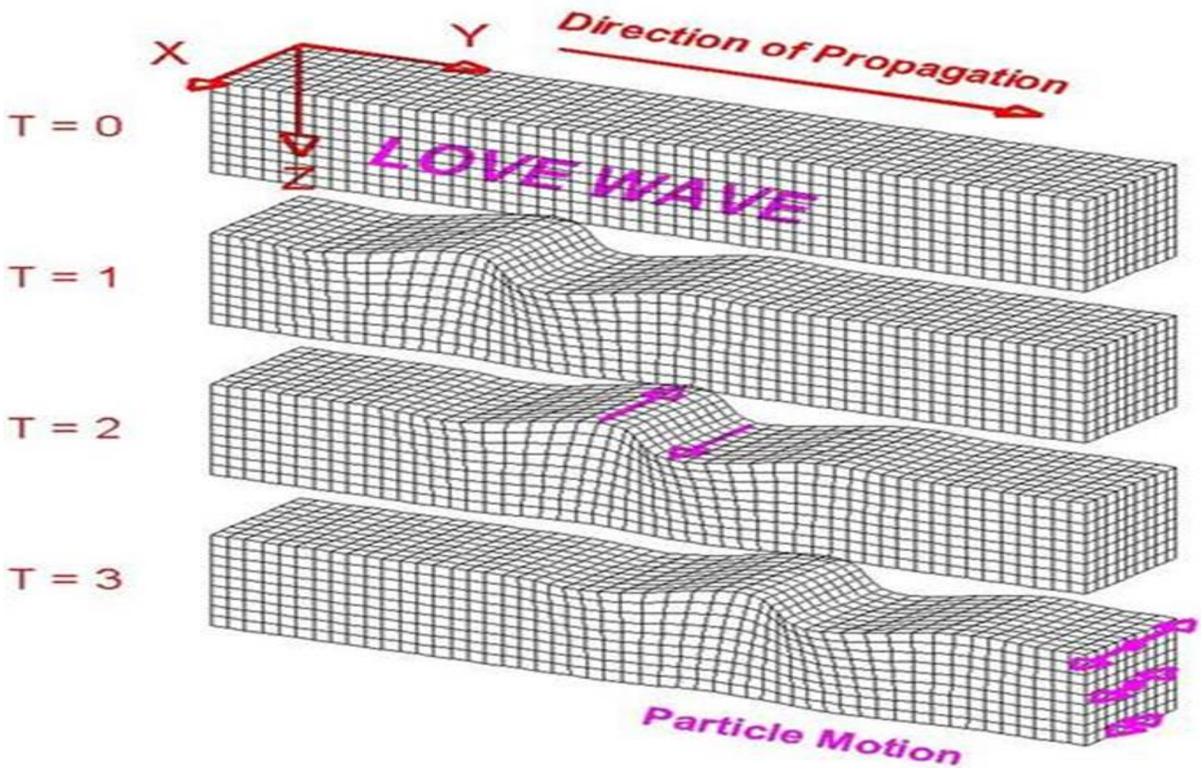


Figure 2.3: Direction of Propagation for Love Waves

2.2.2.2 RAYLEIGH WAVES

Rayleigh Wave is named after Lord Rayleigh who mathematically predicted the existence of this kind of wave in 1885. Rayleigh wave rolls along the ground just like a wave rolls across a lake or an ocean. Because it rolls, it move the ground up and down and side to side in the same direction that the wave is moving. Most of the shaking felt from an earthquake is due to the Rayleigh Wave which can be much larger than the other waves.

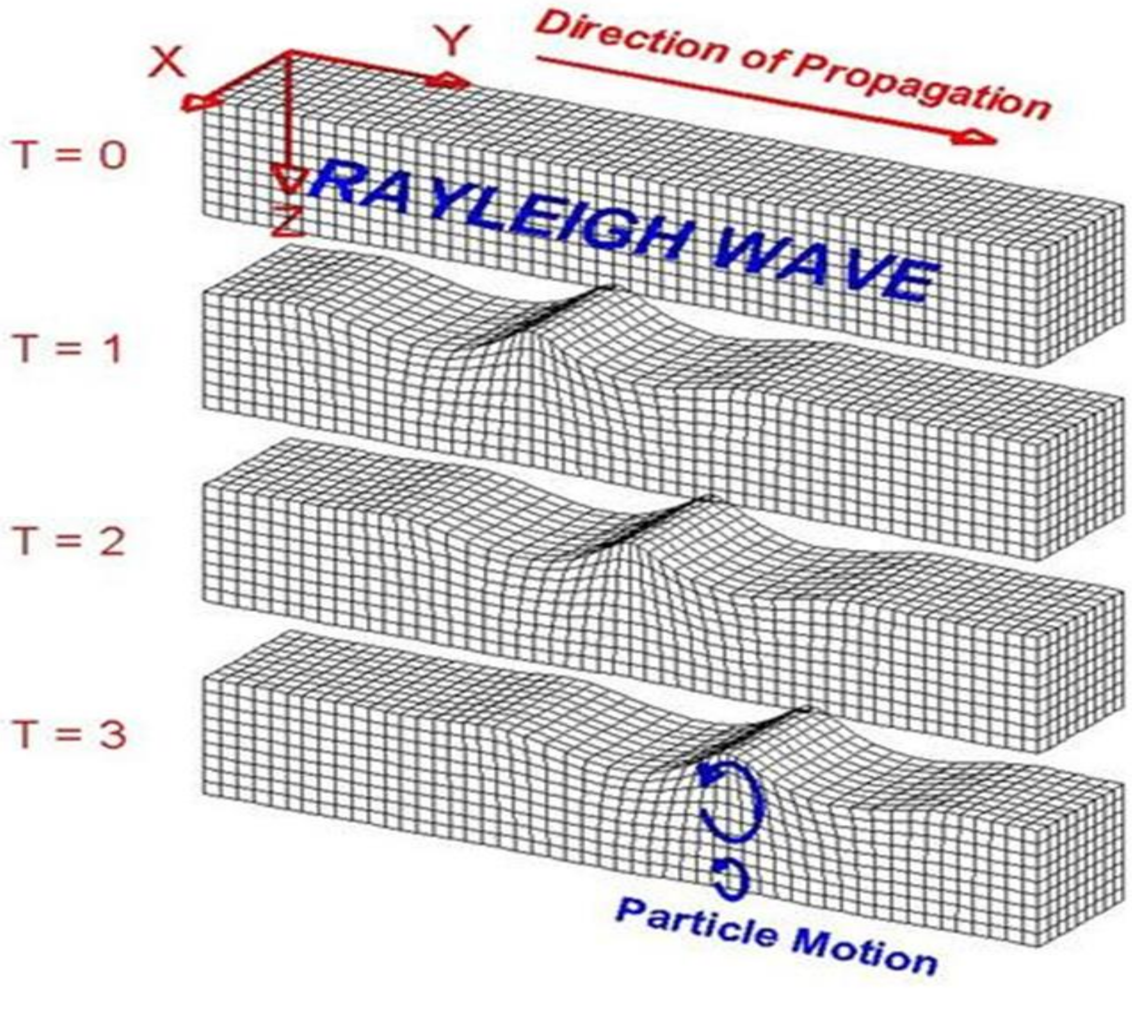


Figure 2.4: Direction of Propagation for Rayleigh Waves

2.3 CAUSE OF EARTHQUAKE

2.3.1 PLATE TECTONIC

The earth outer shell known as lithosphere is consisting the crust and uppermost mantle that divided into a patchwork of large tectonic. This tectonic plate is move very slow relatively to each other. There are seven to eight major plates and many minor plates in this world. Varying between 0 to 100mm per year, the movement of a plate is driven by convection in the underlying hot and viscous mantle.

The relative motion of the plates is horizontal. They can occur underwater or on land. Because of the friction, the plates cannot simply glide past each other. Rather, stress builds in both plate and when it exceeds the threshold of the rocks, the energy is released and causing an earthquake.

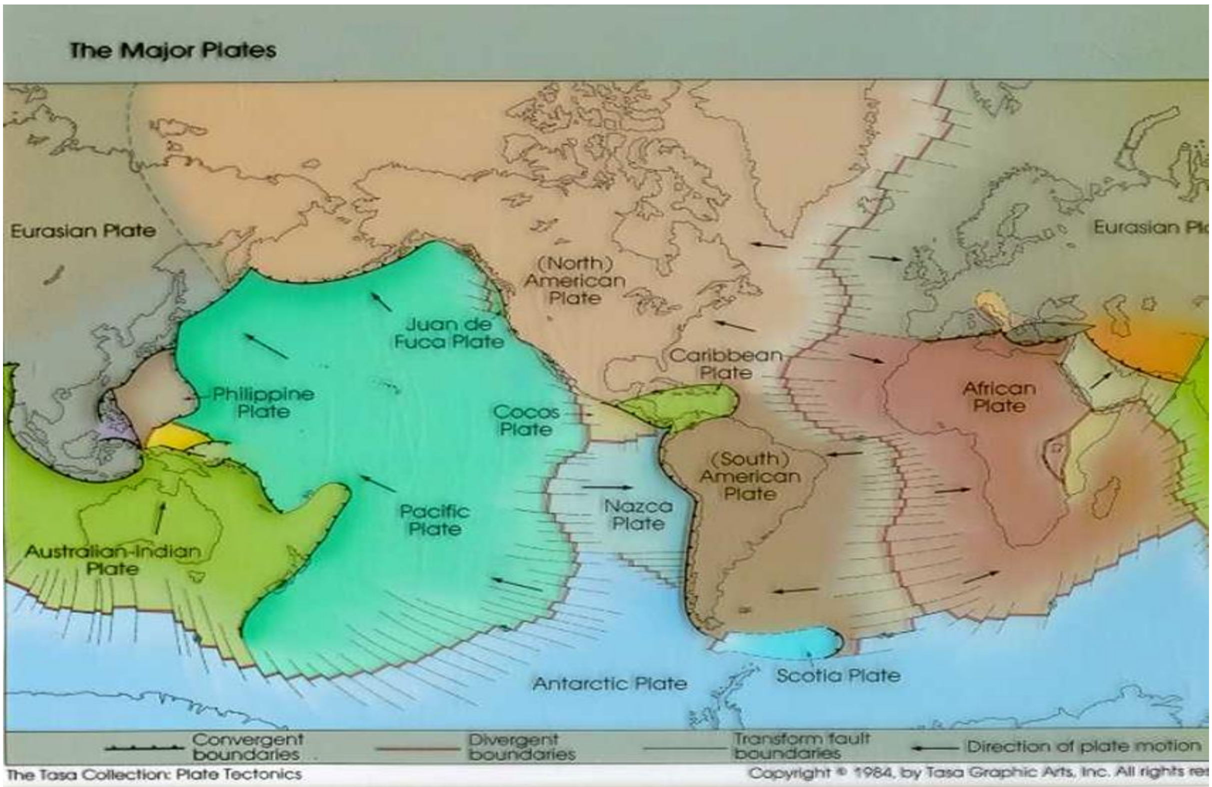


Figure 2.5: Major Plates

2.3.2 FAULT

Fault is a thin zone of crushed rock separating blocks of earth's crust. When an earthquake occurs on one of this fault, the rocks on one side of the fault slips with respect to the other. Faults can be centimetre to thousands of kilometre long. The fault surface can be vertical, horizontal or at the same angle to the surface of the earth. Faults can extend deep into the earth and may not extend up to the earth's surface.

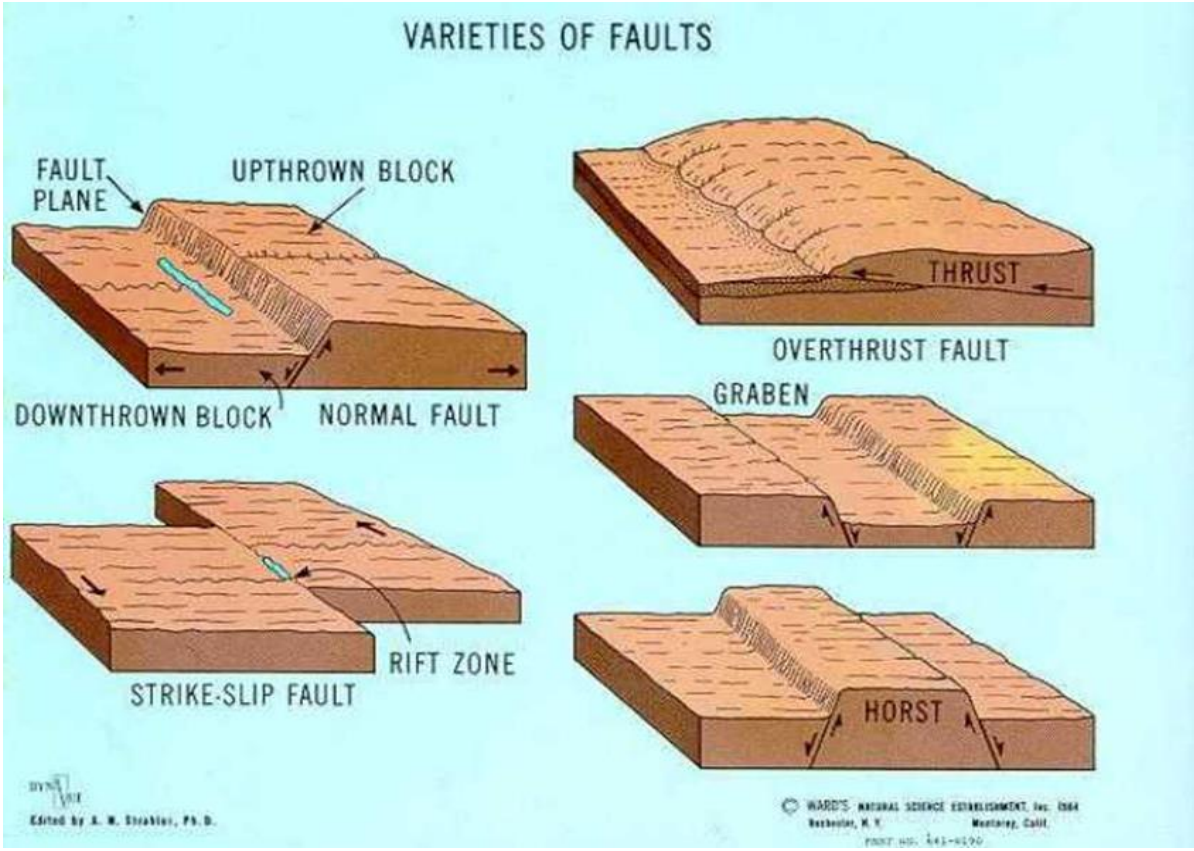


Figure 2.6: Varieties of Fault

2.4 EARTHQUAKE MEASUREMENT PARAMETERS

2.4.1 MAGNITUDE OF EARTHQUAKE

Magnitude is the maximum motion that record by a seismograph. Size of an earthquake is determined by the magnitude that recorded by seismograph. The higher the magnitude recorded by seismograph, the larger the earthquake. Earthquake magnitudes are most commonly measured using the Richter Scale (Kusky, 2008). In 1935, Charles F. Richter, a California seismologist has introduced the magnitude Richter scale. The magnitude scales are calculated using the zigzag trace on the seismograph.

Modified Mercalli Intensity Scale Compared to Richter Magnitude

MERCALLI INTENSITY	RICHTER MAGNITUDE	DESCRIPTION
I-II	< 2	Not felt by most people
III	3	Felt by some people indoors, especially on high floors
IV-V	4	Noticed by most people. Hanging objects swing, dishes rattle.
VI-VII	5	All people feel. Some building damage (esp. to masonry), waves on ponds.
VII-VIII	6	Difficult to stand, people scared or panicked. Difficult to steer cars. Moderate damage to buildings.
IX-X	7	Major damage, general panic of public. Most masonry and frame structures destroyed. Underground pipes broken. Large landslides.
XI-XII	8 and higher	Near total destruction

Figure 2.7: Modified Mercalli Intensity Scale Compared to Ritcher Magnitude

2.4.1.1 LOCAL MAGNITUDE SCALE, M_L

The first widely used method is Richter scale and also known as local magnitude scale, M_L. This scale was developed by Charles F. Richter in 1934. It used a formula based on amplitude of the largest wave recorded on a specific type of seismometer and the distance between the earthquake and the seismometer. This scale is specific to California earthquake.

2.4.1.2 SURFACE WAVES MAGNITUDE SCALE, M_S

Surface wave magnitude scale, (M_s) is one of the magnitude scales used in seismology to describe the size of an earthquake. It is based on measurements in Rayleigh surface waves that travel primarily along the uppermost layers of the earth. It was initially developed in 1950 by the same researchers who developed the local magnitude scale (M_L) in order to improve resolution on larger earthquakes. The successful development of the local magnitude scale encouraged Gutenberg and Richter to develop magnitude scales based on teleseismic observation of earthquakes.

2.4.1.3 MOMENT MAGNITUDE SCALE, M_W

Moment magnitude (Mw) was introduced in 1979 by Hanks and Kanamori and has since become the most commonly used method of describing the size of a micro seism. Moment magnitude measures the size of events in terms of how much energy is released. Specifically, moment magnitude relates to the amount of movement by rock (i.e. the distance of movement along a fault or fracture) and the area of the fault or fracture surface. Since moment magnitude can describe something physical about the event, calculated values can be easily compared to magnitude values for other events. The moment magnitude is also a more accurate scale for describing the size of events.

2.4.2 INTENSITY OF GROUND MOTION

The increase in the degree of surface shaking (intensity) for each unit increase of magnitude of a shallow crustal earthquake is unknown. Intensity is based on an earthquake's local accelerations and how long these persist. Intensity and magnitude thus both depend on many variables that include exactly how rock breaks and how energy travels from an earthquake to a receiver. These factors make it difficult for engineers and others who use earthquake intensity and magnitude data to evaluate the error bounds that may exist for their particular applications.

2.5 RETAINING WALL

Retaining wall is a structure that retains any material such as earth to prevent it from sliding or eroding away. It is designed so that it can resist the material pressure of the material that it is holding away.

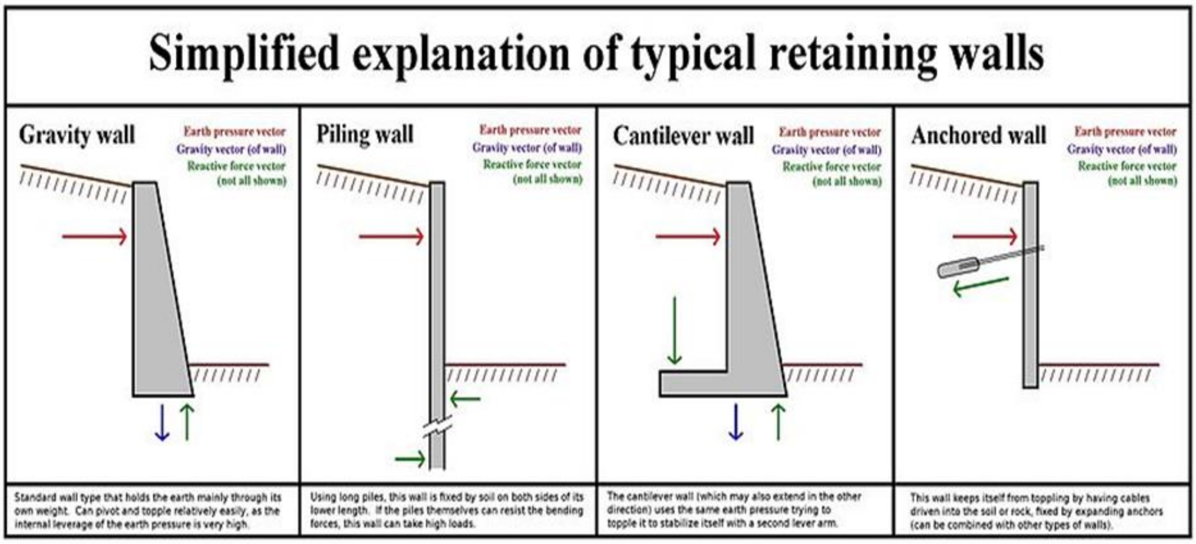


Figure 2.8: Type of Retaining Wall

2.5.1 CANTILEVER RETAINING WALL

Cantilever retaining walls are constructed of reinforced concrete. They consist of a relatively thin stem and a base slab. The base is also divided into two parts, the heel and toe. The heel is the part of the base under the backfill. The toe is the other part of the base. Cantilever wall are usually of reinforced concrete and work on the principles of leverage. Have much thinner stem, and utilize the weight of the backfill soil to provide most of the resistance to sliding and overturning. These walls are classified as yielding as they free to rotate about the foundation because of the lack This is the most common type of earth retaining structure. The cantilever retaining wall constructed of reinforced Portland-cement concrete (PCC) was the predominant type of rigid retaining wall used from about the 1920s to the 1970s. Earth slopes and earth retaining structures are used to maintain two different ground surface elevations.

2.5.2 GRAVITY RETAINING WALL

It is that type of retaining wall that relies on their huge weight to retain the material behind it and achieve stability against failures. Gravity retaining wall can be constructed from concrete, stone or even brick masonry. Gravity retaining walls are much thicker in section. Geometry of these walls also helps them to maintain the stability. Mass concrete walls are suitable for retained heights of up to 3 m. The cross section shape of the wall is affected by stability, the use of space in front of the wall, the required wall appearance and the method of construction.

2.5.3 PILING RETAINING WALL

Piling retaining walls can be either of a permanent or temporary nature. A wide variety of materials, steel, plastic or concrete, can be installed using percussion, hydraulic or vibratory hammers. Interlocking sheet pile walls are used for many applications including cofferdams, basement walls, pits and marine structures.

2.5.4 ANCHORED RETAINING WALL

An anchored retaining wall can be constructed in any of the aforementioned styles but also includes additional strength using cables or other stays anchored in the rock or soil behind it. Usually it is driven into the material with boring, anchors are then expanded at the end of the cable, either by mechanical means or often by injecting pressurized concrete, which expands to form a bulb in the soil. Technically complex, this method is very useful where high loads are expected, or where the wall itself has to be slender and would otherwise be too weak.

2.6 SAP2000

The SAP name has been synonymous with state-of-the-art analytical methods since its introduction over 30 years ago. SAP2000 follows in the same tradition featuring a very sophisticated, intuitive and versatile user interface powered by an unmatched analysis engine and design tools for engineers working on transportation, industrial, public works, sports, and other facilities.

From its 3D object based graphical modelling environment to the wide variety of analysis and design options completely integrated across one powerful user interface, SAP2000 has proven to be the most integrated, productive and practical general purpose structural program on the market today. This intuitive interface allows you to create structural models rapidly and intuitively without long learning curve delays. Now you can harness the power of SAP2000 for all of your analysis and design tasks, including small day-to-day problems.

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.

Advanced analytical techniques allow for step-by-step large deformation analysis, Eigen and Ritz analyses based on stiffness of nonlinear cases, catenary cable analysis, material nonlinear analysis with fibre hinges, multi-layered nonlinear shell element, buckling analysis, progressive collapse analysis, energy methods for drift control, velocity-dependent dampers, base isolators, support plasticity and nonlinear segmental construction analysis. Nonlinear analyses can be static and/or time history, with options for FNA nonlinear time history dynamic analysis and direct integration.

From a simple small 2D static frame analysis to a large complex 3D nonlinear dynamic analysis, SAP2000 is the easiest, most productive solution for your structural analysis and design needs.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 PLANNING OF STUDY

For the planning of the study, it was done in the first month of semester. The scope of the study and problem statement was decided along with research title. Cantilever retaining wall has been identified for the modelling and analyses using software SAP2000. During early stage of this study, time history earthquake data have been obtained from Malaysian Meteorology Department (MMD). The data then being used during this study to analyses the cantilever retaining wall structure model.

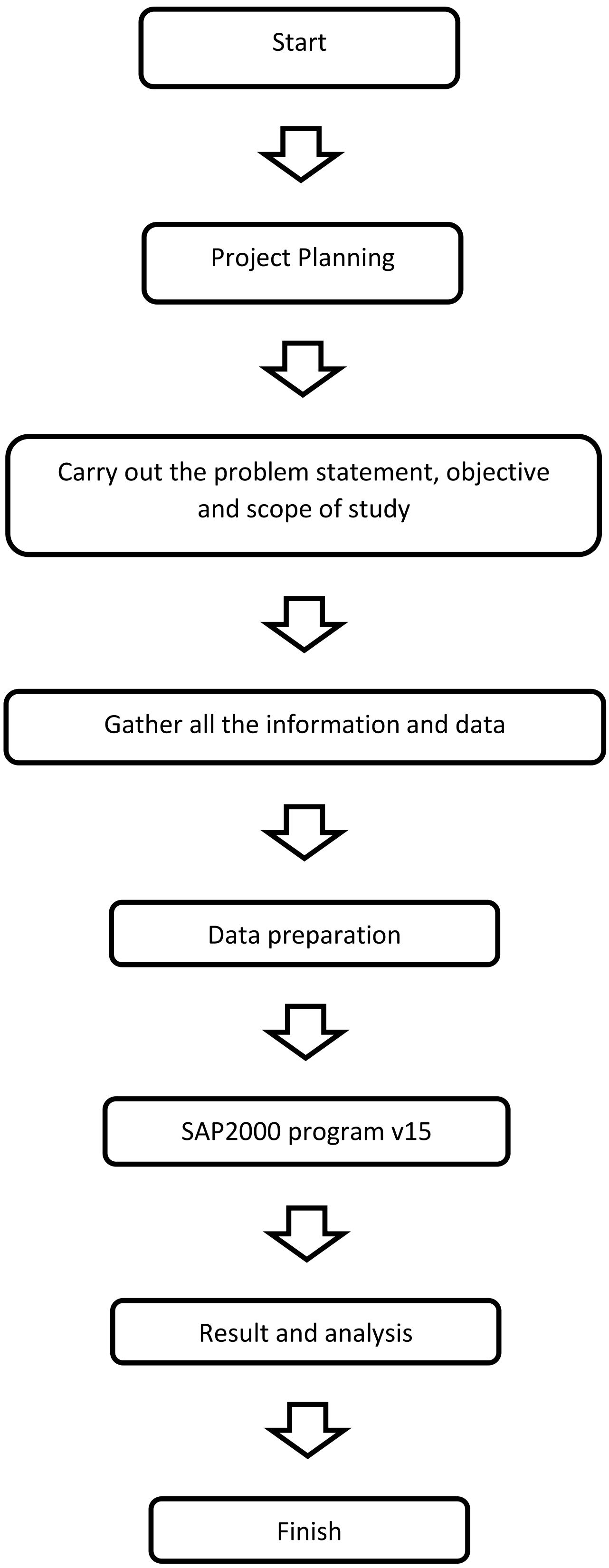


Figure 3.1: Flowchart of Study

3.2 INFORMATION AND DATA COLLECTION

During this phase, the important information and data for modelling and analysing the structure need to be obtained so that the research study will go smoothly. The information and data needed are as follow:

i. Location of the case study for the retaining wall structure
ii. Typical retaining wall use in East Coast Malaysia
iii. Material used for the retaining wall structure
iv. Earthquake data from Malaysia Meteorology Department (MMD)

3.2.1 RETAINING WALL STRUCTURE

The type of retaining wall structure used in this analysis is cantilever retaining wall structure. This cantilever retaining wall structure is the existing retaining wall structure that located in Pasir Gudang, Johor. Figure 3.2 shows the dimension of this cantilever retaining wall structure.

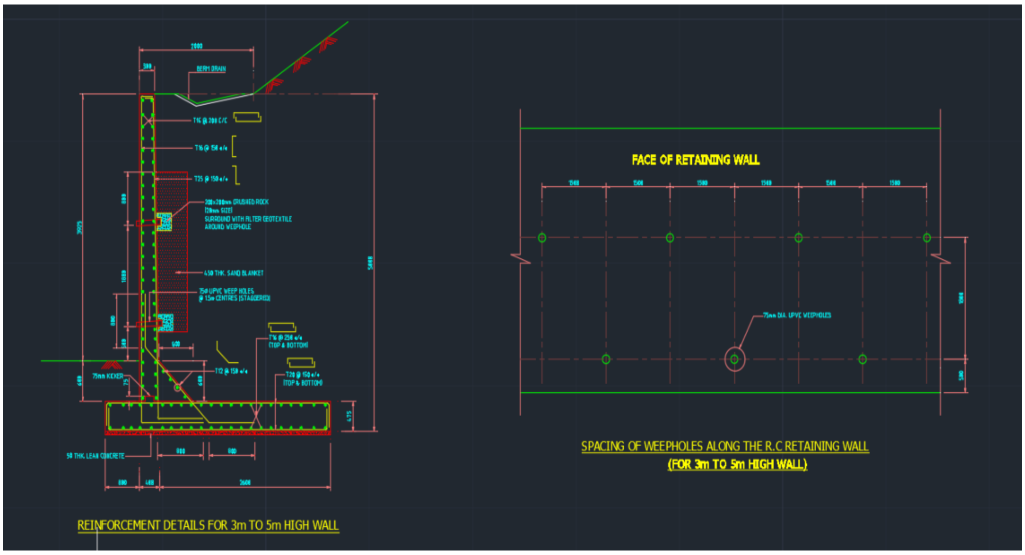


Figure 3.2: Dimension of the Cantilever Retaining Wall in unit millimetre

3.2.2 MATERIAL PROPERTIES

Cantilever retaining wall are usually made of reinforced concrete and work on principle of leverage. This wall will use Portland Cement Concrete (PCC) as the main material and will be reinforced with 12mm in diameter reinforced bar.

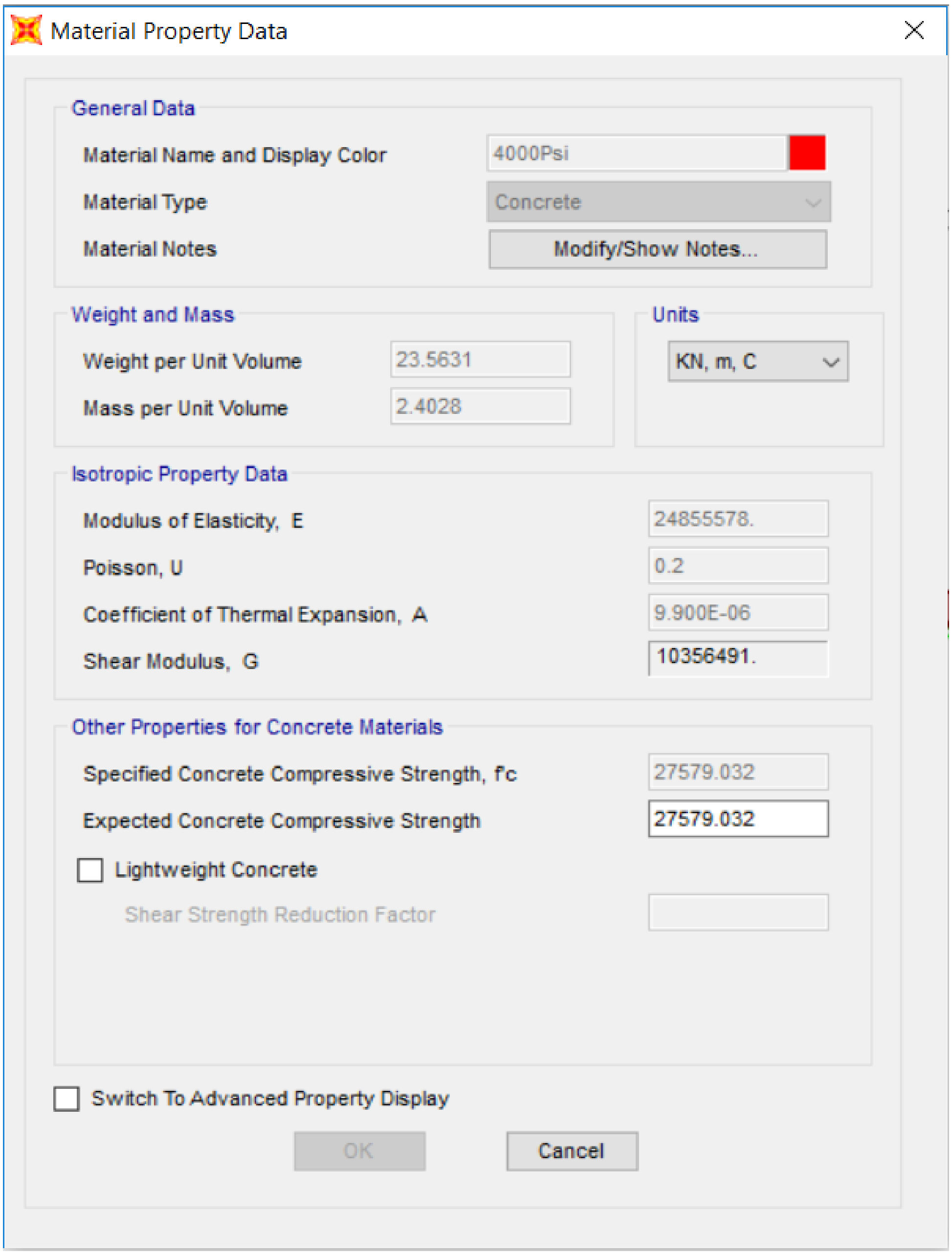


Figure 3.3: Material Property Data

3.2.3 LOADING

The basic pressure loading to be considered for the design is normal loading which include static earth pressure, water pressure and pressure due to live loads or surcharge. In general, the resulting design pressure for earth retaining structures should not be less than the pressure due to a fluid of unit weight 5 kN/m^3.

3.3 LOAD DESCRIPTION

3.3.1 LATERAL EARTH PRESSURE

Lateral earth pressures are analysed 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: $P=k\gamma_s z$, where:

p = basic lateral earth pressure (KSF)

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

γ_s = unit weight of soil (KCF)

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

The resultant lateral earth load 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 EARTQUAKE LOADING

3.4 ANALYSES

The cantilever retaining wall have been modelled and analysed using SAP2000 which is an integrated software for structural analysis and design. The free vibration analysis, time history analysis, and response spectrum analysis have been performed in this study. The loads that being considered in this study consist of dead load, live load, modal load, time history load and also response spectrum load. There are several combinations of load cases that were applied in this study. The load combination consists of:

i. Free Vibration Analysis
ii. Dead Load + Live Load
iii. Dead Load + live Load + Free Vibration Analysis

The result obtained from this study are as follows:

i. Mode shape of cantilever retaining wall
ii. Natural period and natural frequency of the cantilever retaining wall structure
iii. Displacement, acceleration and velocity of cantilever retaining wall joints under free far earthquake loading

3.5 SAP2000 COMPUTATIONAL PROGRAM

The SAP name has been synonymous with state-of-the-art analytical methods since its introduction over 30 years ago. SAP2000 follows in the same tradition featuring a very sophisticated, intuitive and versatile user interface powered by an unmatched analysis engine and design tools for engineers working on transportation, industrial, public works, sports, and other facilities.

From its 3D object based graphical modelling environment to the wide variety of analysis and design options completely integrated across one powerful user interface, SAP2000 has proven to be the most integrated, productive and practical general purpose structural program on the market today. This intuitive interface allows you to create structural models rapidly and intuitively without long learning curve delays. Now you can harness the power of SAP2000 for all of your analysis and design tasks, including small day-to-day problems.

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.

Advanced analytical techniques allow for step-by-step large deformation analysis, Eigen and Ritz analyses based on stiffness of nonlinear cases, catenary cable analysis, material nonlinear analysis with fibre hinges, multi-layered nonlinear shell element, buckling analysis, progressive collapse analysis, energy methods for drift control, velocity-dependent dampers, base isolators, support plasticity and nonlinear segmental construction analysis. Nonlinear analyses can be static and/or time history, with options for FNA nonlinear time history dynamic analysis and direct integration.

From a simple small 2D static frame analysis to a large complex 3D nonlinear dynamic analysis, SAP2000 is the easiest, most productive solution for your structural analysis and design needs.

3.5.1 CHECKLIS OF SAP2000 MODELING AND ANALYSIS

Modelling and analysis of cantilever retaining wall are done using SAP200 program. Checklist and step in modelling and analyse the cantilever retaining wall are as below:

i. Define the coordinate of grid systems for the model
ii. Define materials and structural section properties
iii. Determine area section of the model
iv. Determine the restrains at base condition
v. Define all load cases
vi. Define function of Time History and Response Spectrum
vii. Analyse the model
viii. Display result in output table
ix. Check for structural design

3.5.2 STEPS IN SAP2000 MODELING AND ANALYSIS

Step 1: Define the coordinates of grid line

First, we need to define our coordinate of the grid line which can be done by selecting the "Define Grid System Data" template. We also need to define the unit of this project which is "KN, m, C".

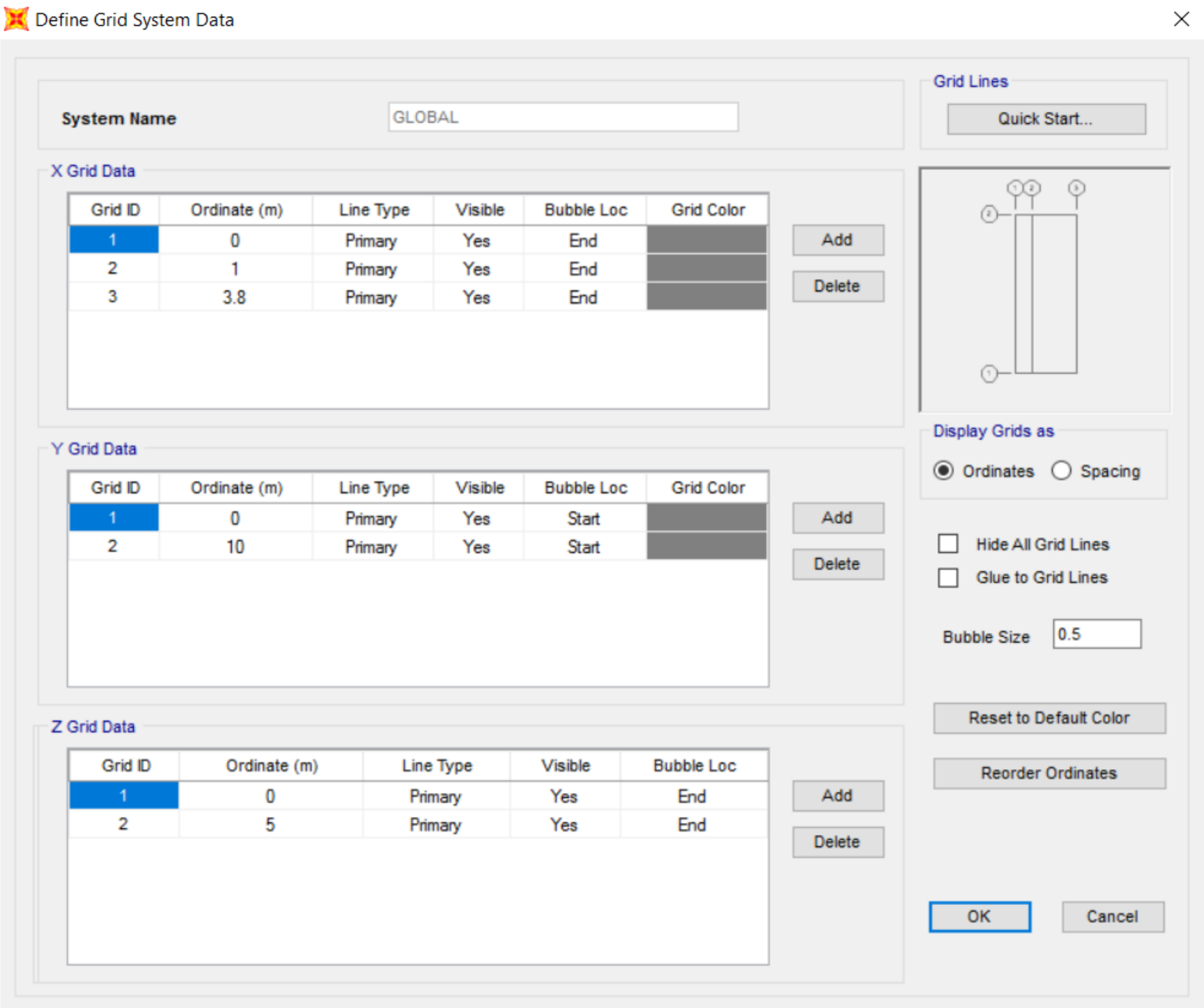


Figure 3.4: Define Grid System Data

Step 2: 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.

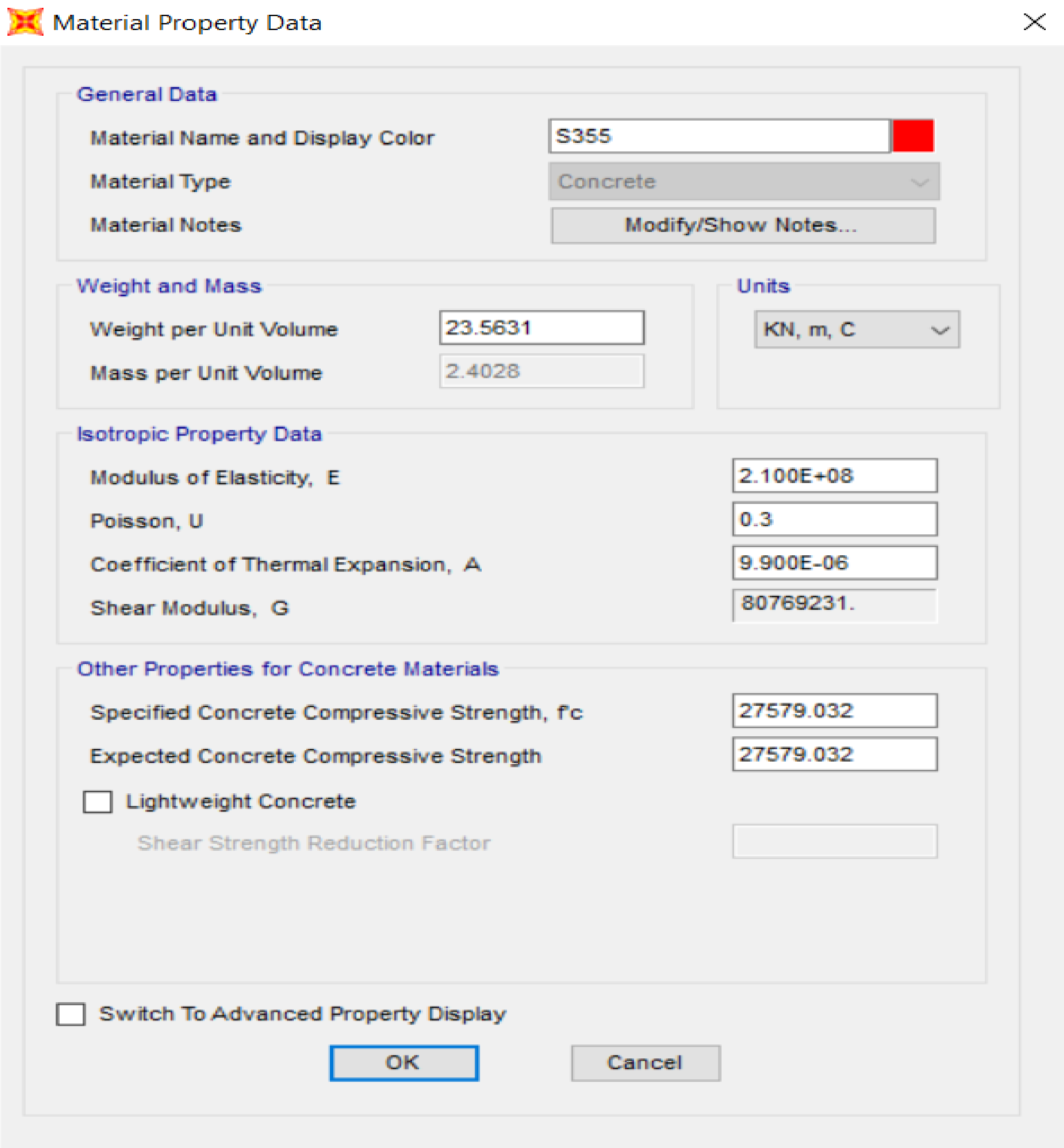


Figure 3.5: Material Properties of Data

Step 3: Define area section of the model

Modelled the cantilever retaining wall by assigning the section area according to the architectural drawing. Select fixed support as the restraints of the cantilever retaining wall at the base condition.

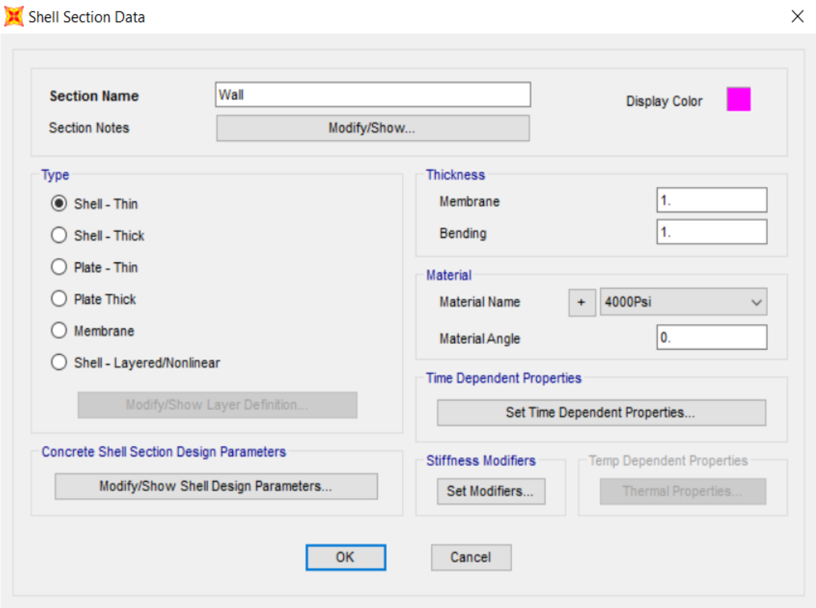


Figure 3.6: Shell Section Data

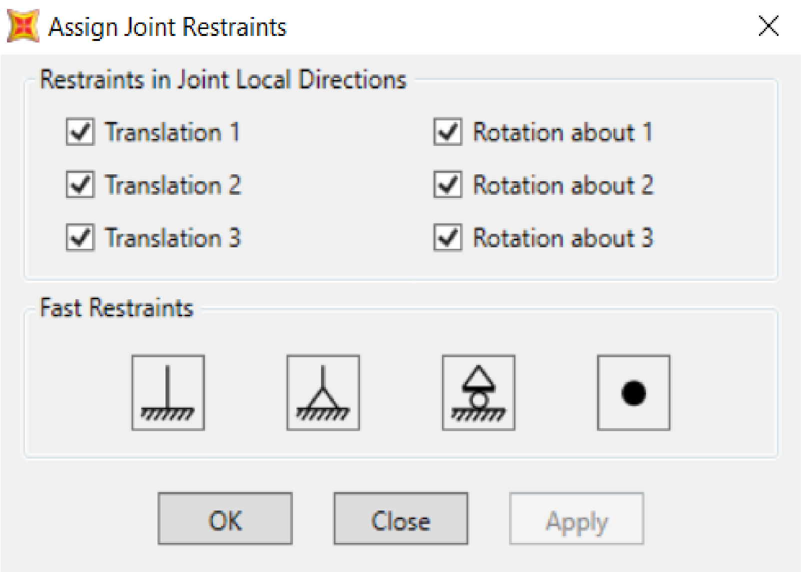


Figure 3.7: Assign joint Restraint

Step 4: Define load cases

Define all load cases for the cantilever retaining wall structure accordingly, the load cases consist of dead load, live load, modal and time history.

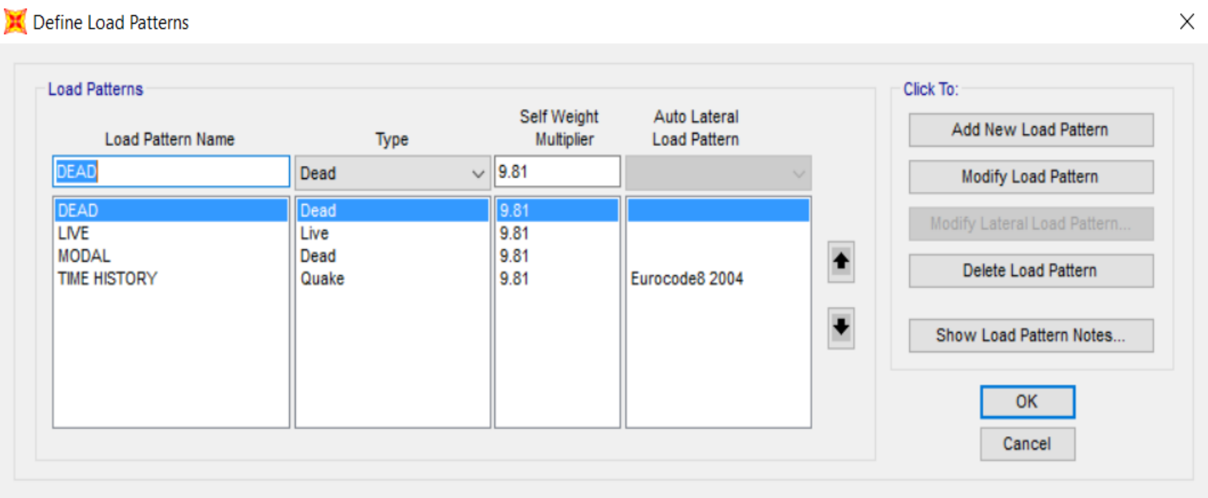


Figure 3.8: Define Load Patterns

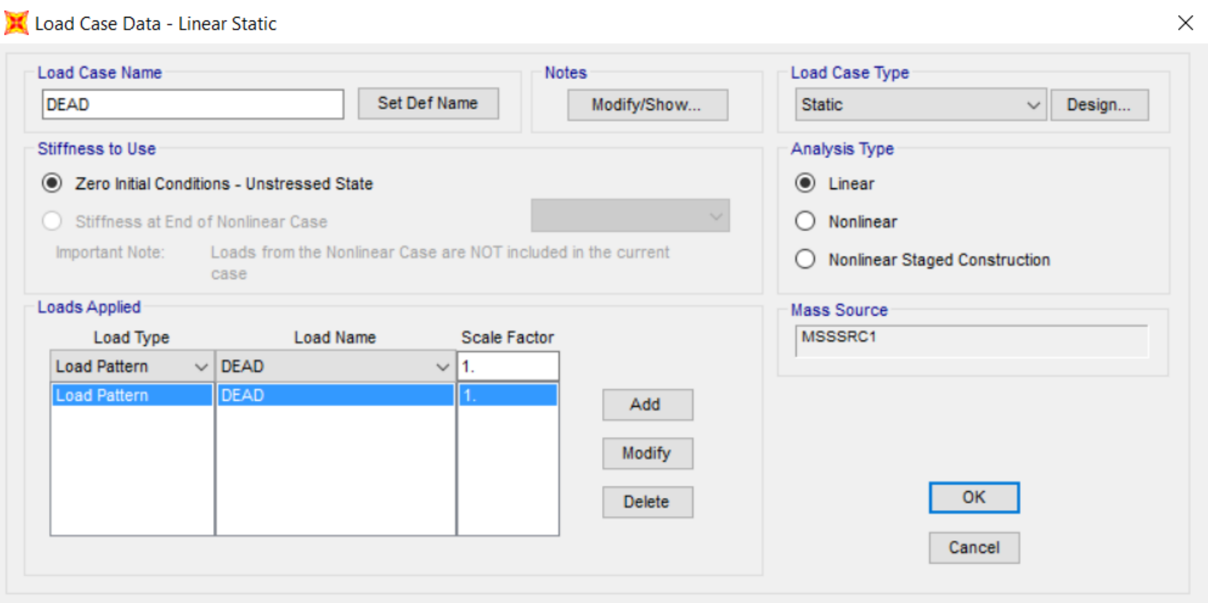


Figure 3.9: Dead Load Case Data

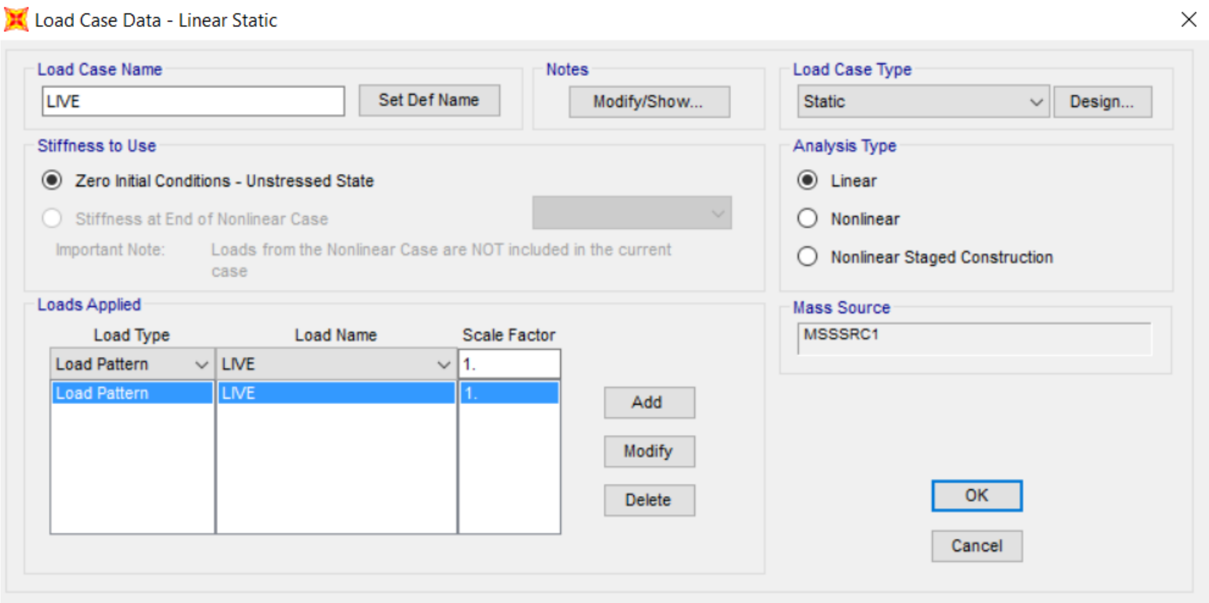


Figure 3.10: Live Load Case Data

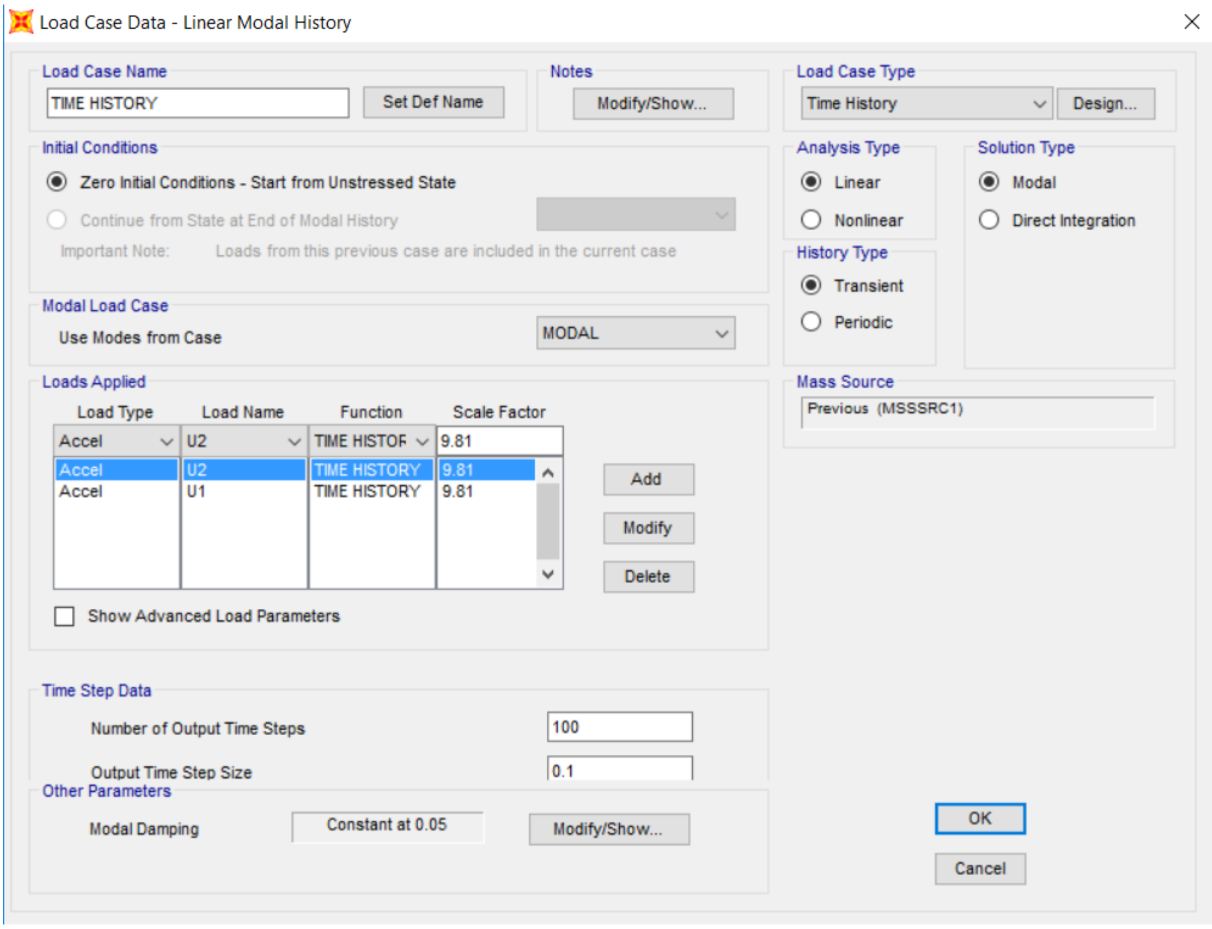


Figure 3.11: Time History Load Case Data

Step 5: Define functions of Time History and Response Spectrum

Function of Time History were defined by attached the seismic data from the MMD.

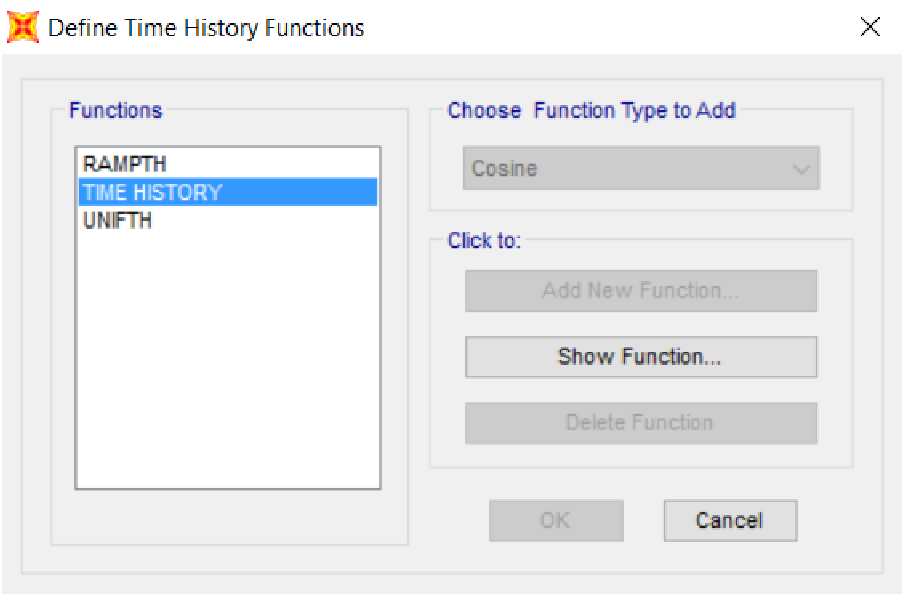


Figure 3.12: Time History Function

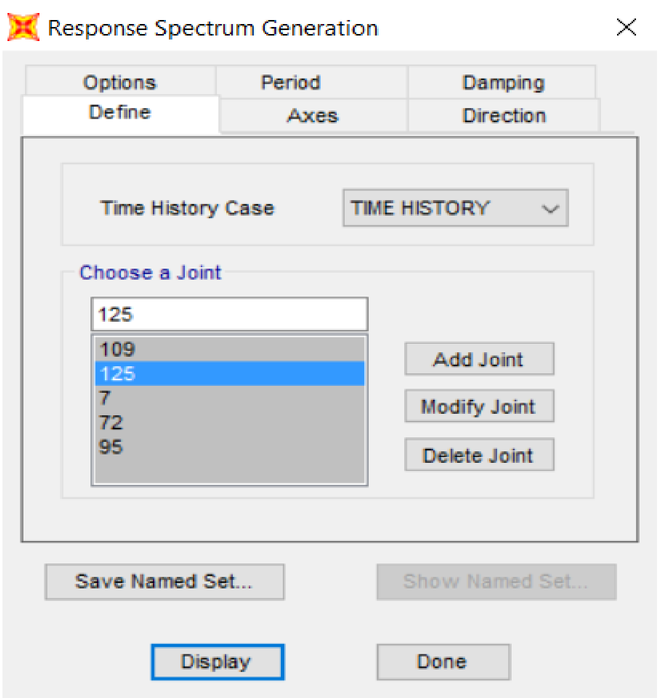


Figure 3.13: Response Spectrum Function

Step 6: Analysis of the model

There are several combinations of load cases data that was applied in this analysis which are consist of:

i. Free Vibration Analysis (FVA)

Select the modal load cases and run the analysis

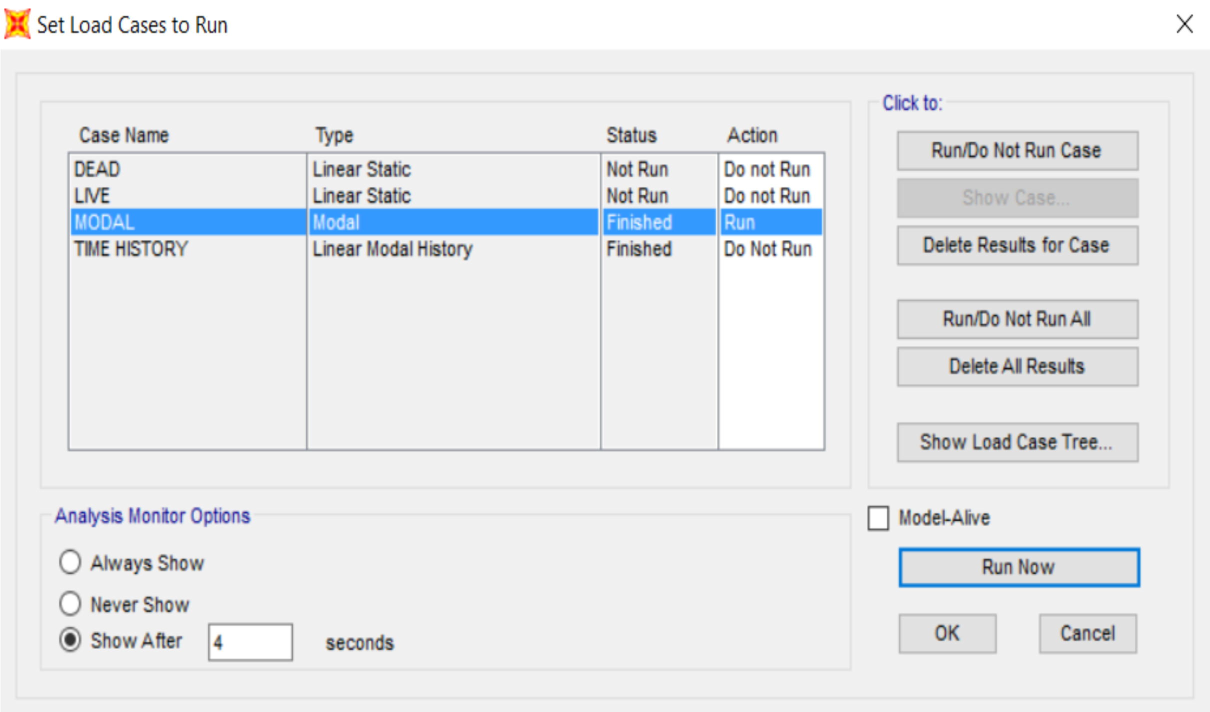


Figure 3.14: Modal load Cases

12 mode shapes, natural frequency and natural period of the cantilever retaining wall structures were determined through this analysis.

ii. Dead Load (DL) + Live Load (LL)

Select the dead load and live load cases and run the analysis.

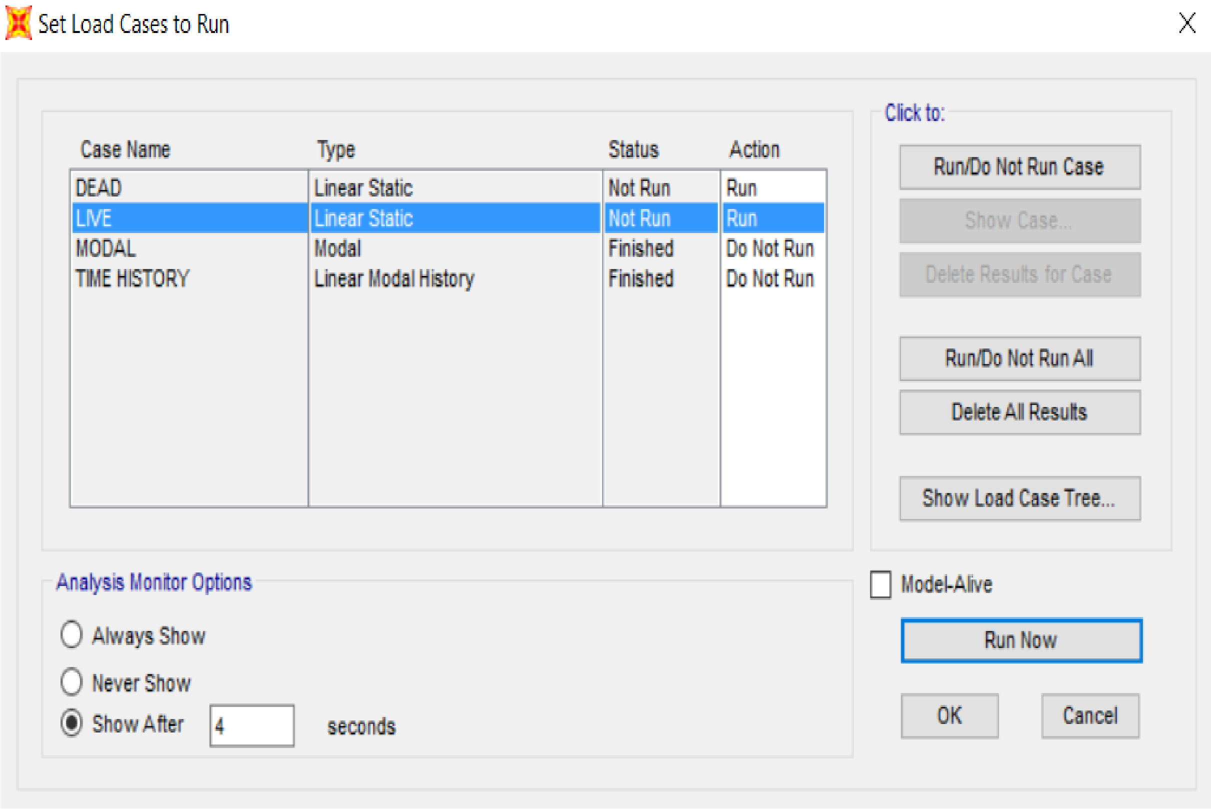


Figure 3.15: Dead Load + Live Load Cases

iii. Free Vibration Analysis (FVA) + Dead Load (DL) + Live Load (LL)

Select dead load, live load, and time history load and run the analysis.

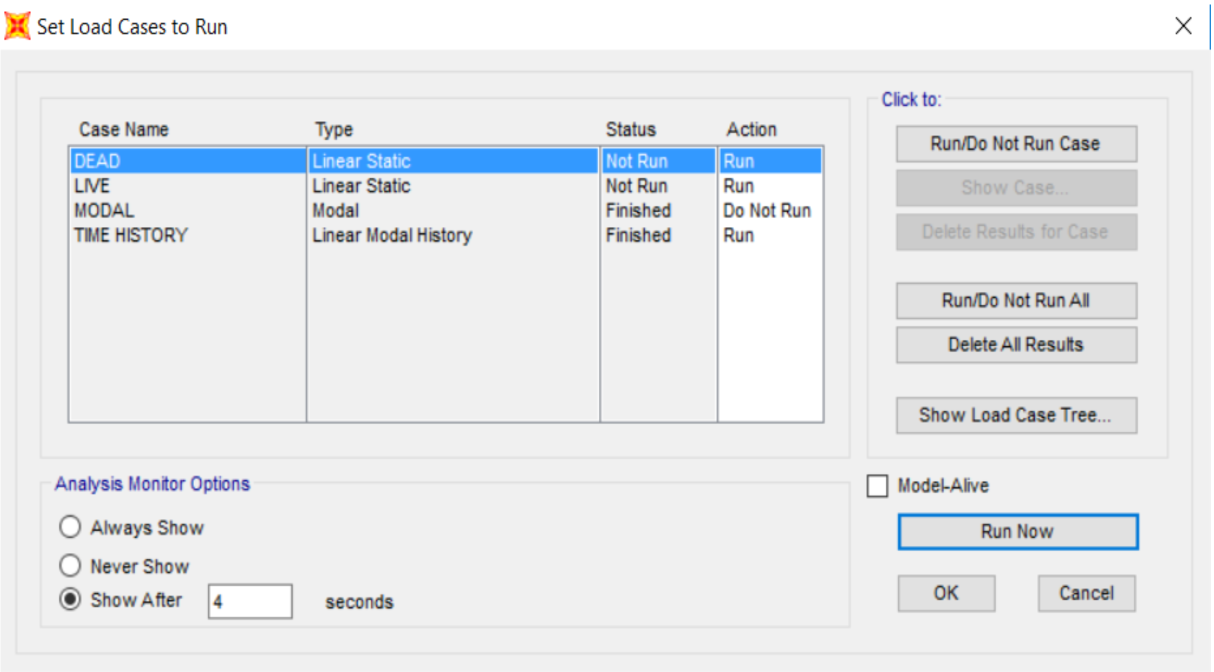


Figure 3.16: Dead Load + Live Load + Time History Load

After running the load cases analysis, acceleration and velocity of cantilever retaining wall based on joint number can be determined.

Step 7: Display result and output table

After performed all the analysis, the result obtained from this study are as follows:

i. 12 mode shapes of the cantilever retaining wall structure
ii. Natural period and natural frequency of the cantilever retaining wall structure
iii. Joint displacement, velocity and acceleration under combination of load cases

Assembled Joint Masses

File View Format-Filter-Sort Select Options

Units: As Noted
Filter:

Assembled Joint Masses

Joint Text	MassSource	U1 KN-s2/m	U2 KN-s2/m	U3 KN-s2/m	R1 KN-m-s2	R2 KN-m-s2	R3 KN-m-s2	CenterX m	CenterY m	CenterZ m
1	MSSSRC1	0.57	0.57	0.57	0	0	0	0	0	0
2	MSSSRC1	0.57	0.57	0.57	0	0	0	3.8	0	0
3	MSSSRC1	0.57	0.57	0.57	0	0	0	3.8	10	0
4	MSSSRC1	0.57	0.57	0.57	0	0	0	0	10	0
5	MSSSRC1	0.6	0.6	0.6	0	0	0	1	0	0
6	MSSSRC1	0.6	0.6	0.6	0	0	0	1	10	0
7	MSSSRC1	0.6	0.6	0.6	0	0	0	1	10	5
8	MSSSRC1	0.6	0.6	0.6	0	0	0	1	0	5
13	MSSSRC1	1.14	1.14	1.14	0	0	0	0.95	0	0
14	MSSSRC1	2.28	2.28	2.28	0	0	0	0.95	1	0
15	MSSSRC1	1.14	1.14	1.14	0	0	0	0	1	0
16	MSSSRC1	2.28	2.28	2.28	0	0	0	0.95	2	0
17	MSSSRC1	1.14	1.14	1.14	0	0	0	0	2	0
18	MSSSRC1	2.28	2.28	2.28	0	0	0	0.95	3	0
19	MSSSRC1	1.14	1.14	1.14	0	0	0	0	3	0
20	MSSSRC1	2.28	2.28	2.28	0	0	0	0.95	4	0

Record: << < 1 > >> of 124 Add Tables... Done

Figure 3.17: Result Output Table

CHAPTER 4

RESULT AND DISCUSSION

4.1 CANTILEVER RETAINING WALL STRUCTURE ANALYSIS

The cantilever retaining wall have been modelled and analysed using SAP2000 which is an integrated software for structural analysis and design. The free vibration analysis, time history analysis, and response spectrum analysis have been performed in this study. The loads that being considered in this study consist of dead load, live load, modal load, time history load and also response spectrum load. There are several combinations of load cases that were applied in this study. The load combination consists of:

iv. Free Vibration Analysis
v. Dead Load + Live Load
vi. Dead Load + live Load + Free Vibration Analysis

The result obtained from this study are as follows:

iv. Mode shape of cantilever retaining wall
v. Natural period and natural frequency of the cantilever retaining wall structure
vi. Displacement, acceleration and velocity of cantilever retaining wall joints under free far earthquake loading

4.2 CANTILEVER RETAINING WALL STRUCTURE MODELING

The cantilever retaining wall structure has been modelling using SAP2000, an integrated software for structural analysis and design. Figure 4.1 shows the 3D model for the cantilever retaining wall structure. This structure was modelled using the linear properties and the structure was assumed to be fixed on ground instead of footing throughout the modelling process.

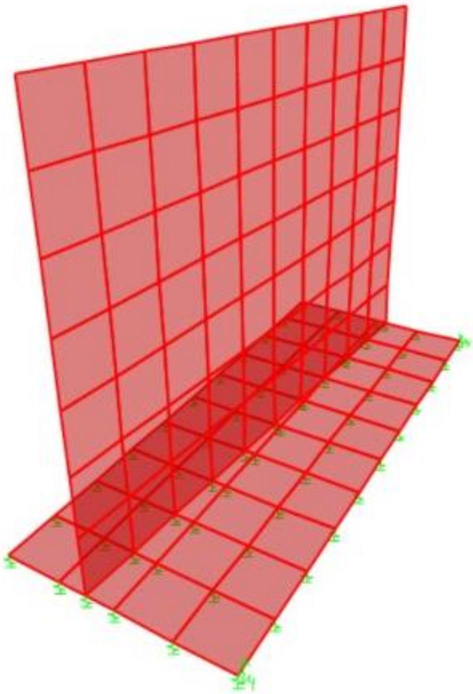
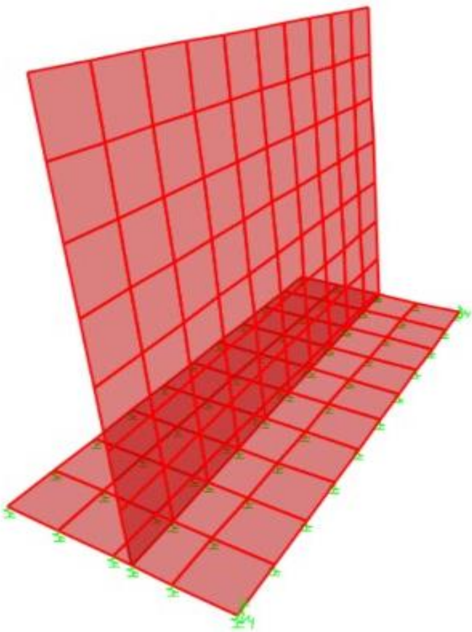
4.3 FREE VIBRATION ANALYSIS

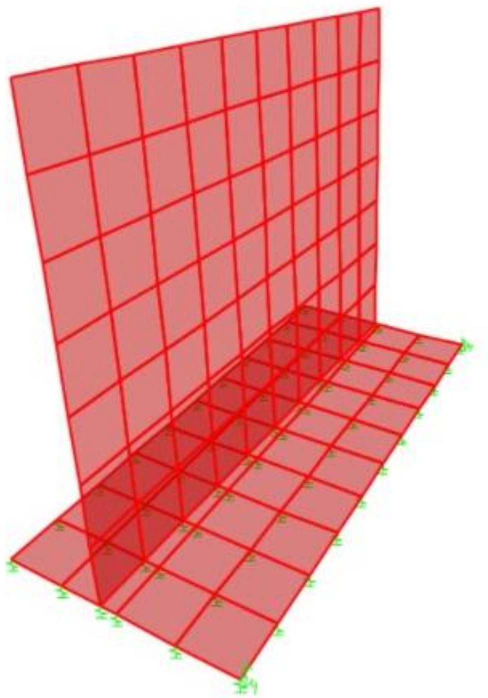
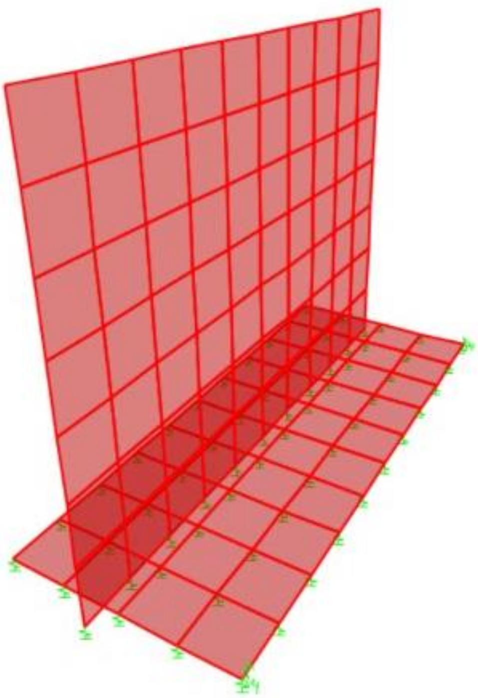
Modal analysis or also been call as free vibration analysis is the structure with the motion without any of external forces or support motion. The structure which is free standing landing staircase will be move away from its equilibrium position because of the modal analysis.

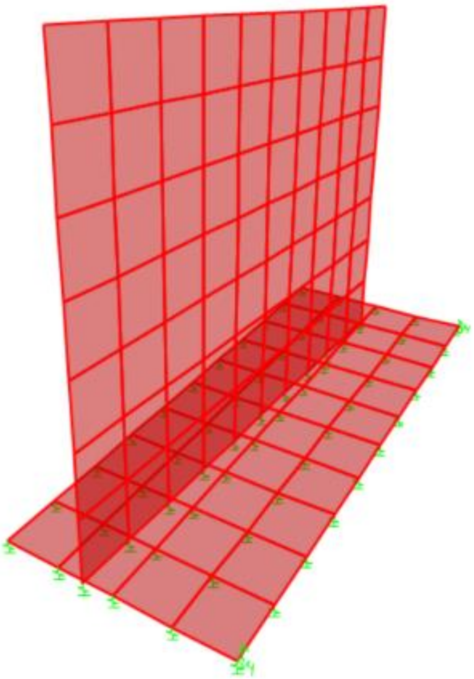
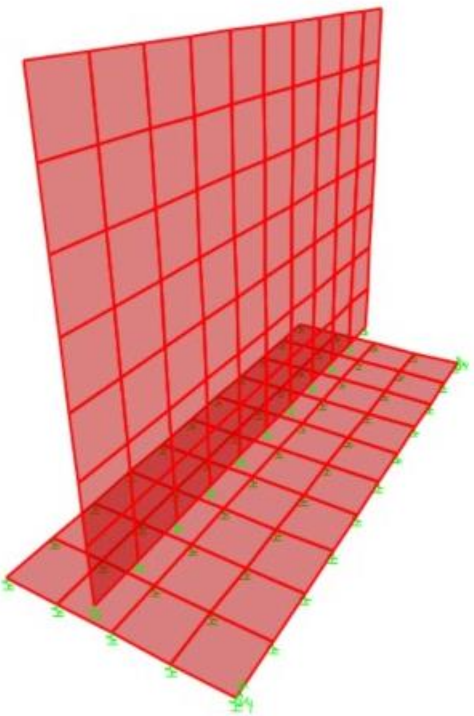
Any physical system like structure can be vibrating at any time. Naturally the vibration occurs because of the frequency. This is showing that earthquakes bring frequency to the earth and will making the ground vibrate. The modal shapes which will be vibrating which have been assumed are properties of the system and this can be decisive empirically by using Modal Analysis.

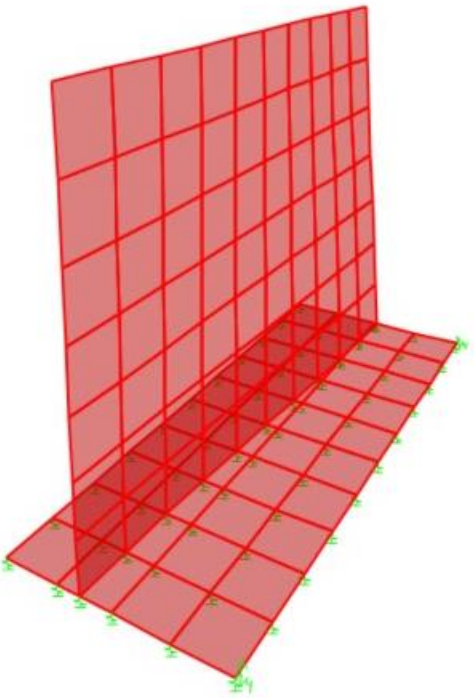
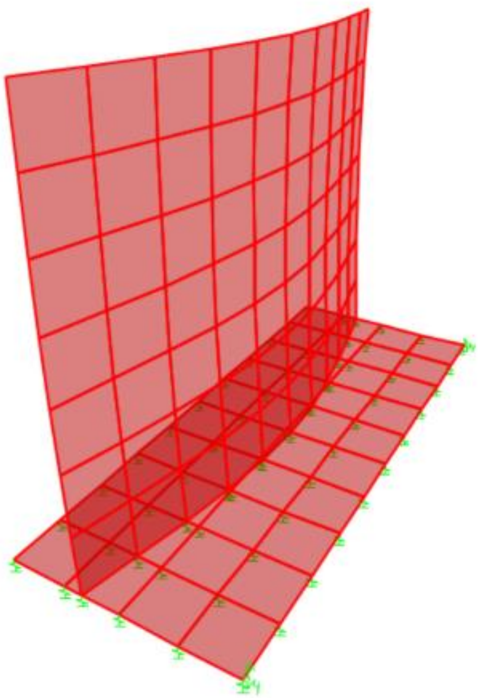
From the modal analysis or free vibration analysis, will obtain of the natural period, 12 mode shape of staircase, natural frequency, joint and lastly is displacement. Each of the mode shape of stairs produce different of the natural period, natural frequency, circle frequency and lastly is eigenvalue.

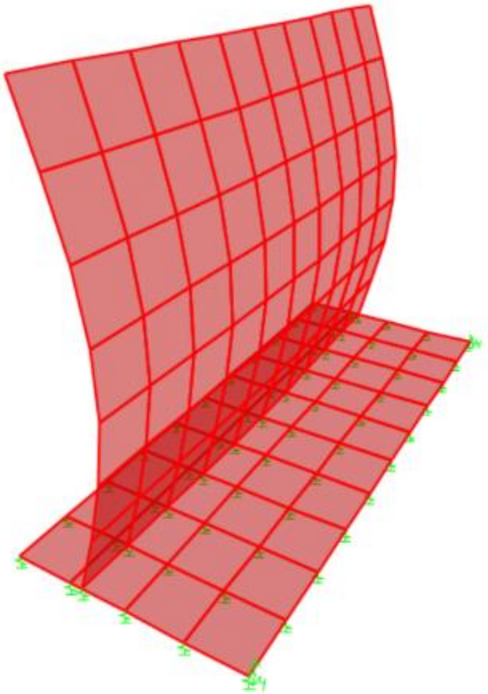
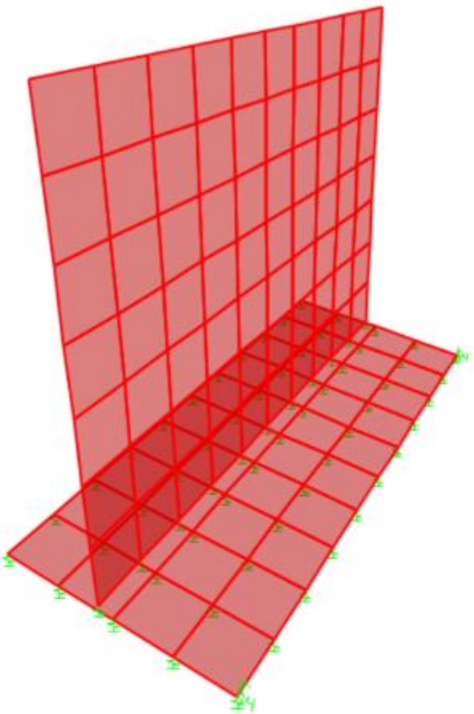
The table below shown 12 mode shape of staircase:

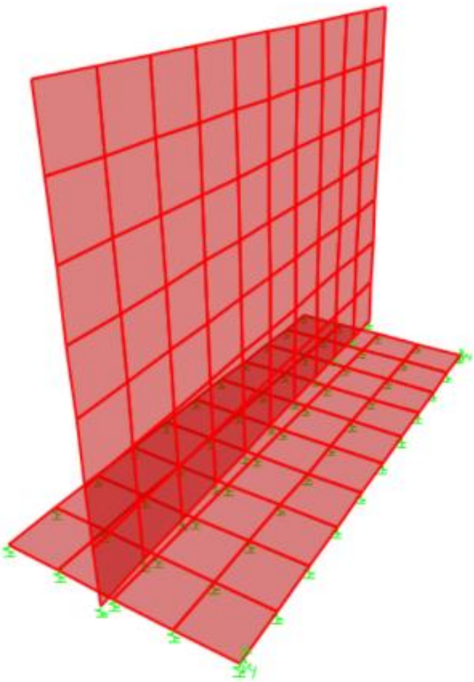
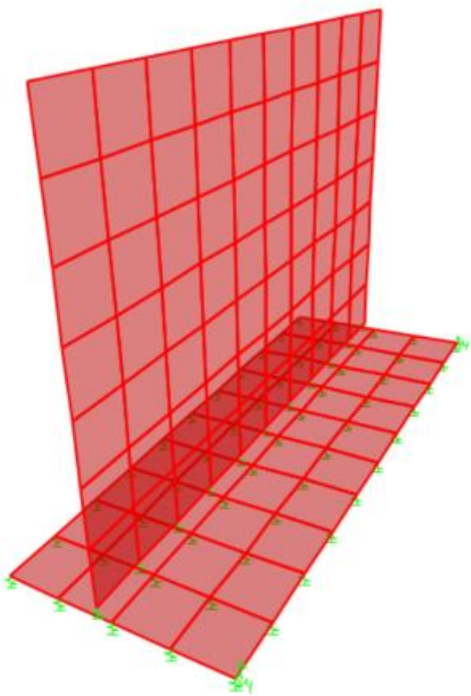
Mode	Natural Period, T (sec)	Frequency, f (Hz)	
1	0.04815	20.76	
2	0.03055	32.73	

Mode	Natural Period, T (sec)	Frequency, f (Hz)	
3	0.01635	61.15	
4	0.01160	86.21	

Mode	Natural Period, T (sec)	Frequency, f (Hz)	
5	0.00903	110.74	
6	0.00803	124.61	

Mode	Natural Period, T (sec)	Frequency, f (Hz)	
7	0.00712	140.39	
8	0.00646	154.89	

Mode	Natural Period, T (sec)	Frequency, f (Hz)	
9	0.00605	165.34	
10	0.00581	172.17	

Mode	Natural Period	Frequency	
11	0.00564	177.17	
12	0.00524	190.93	

4.4 TIME HISTORY EARTHQUAKE ANALYSIS

Time history analysis have been performed on the cantilever retaining wall structure by referring to the earthquake data obtained from Malaysian Meteorological Department. Figure below show the graph of time data versus acceleration data. The result obtain from this analysis is time history responses at all joints of the cantilever retaining wall.

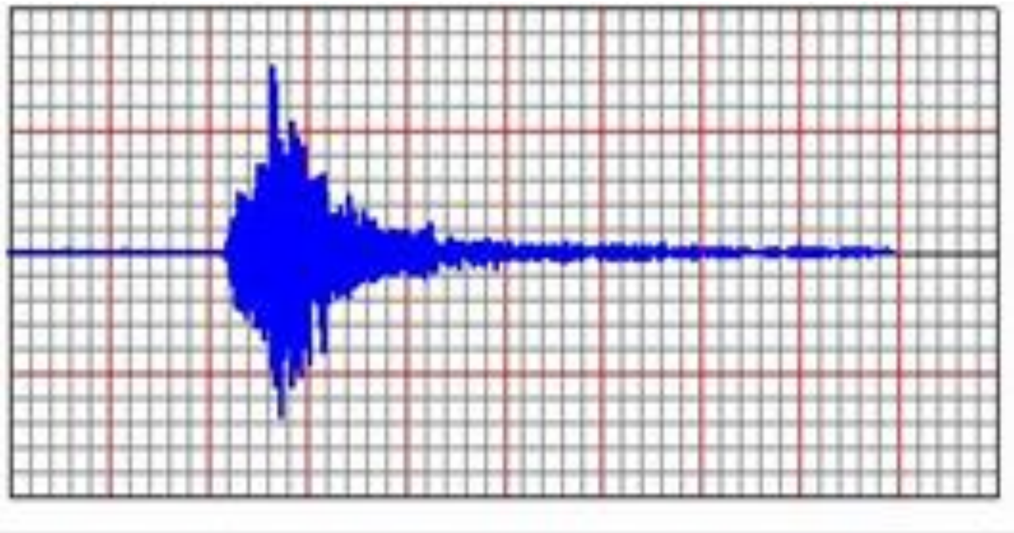


Figure 4.1: Graph of Time History Data

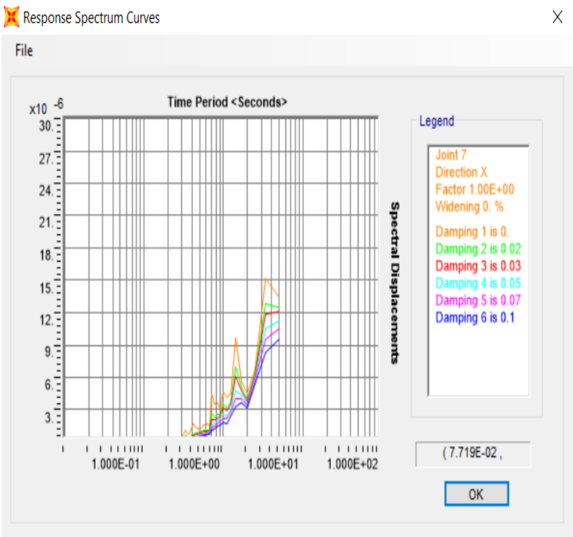
4.5 RESPONSE SPECTRUM ANALYSIS

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.

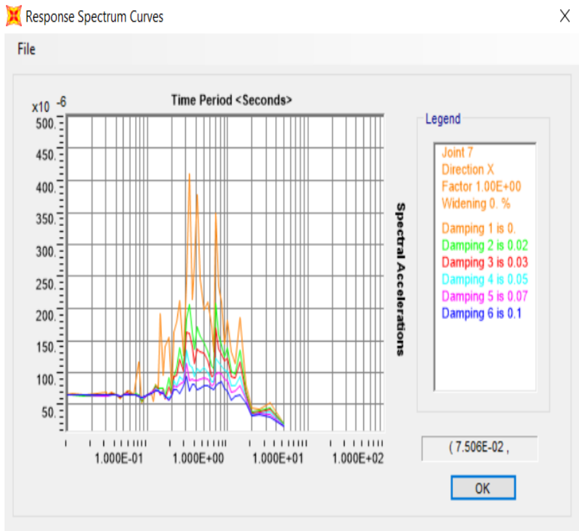
Below is the response spectrum analysis for x and y direction in term of time period. The staircase RSA shown in 5 specs which are:

1. Spectral Displacements
2. Spectral Velocities
3. Pseudo Spectral Velocities
4. Spectral Accelerations
5. Pseudo Spectral Acceleration

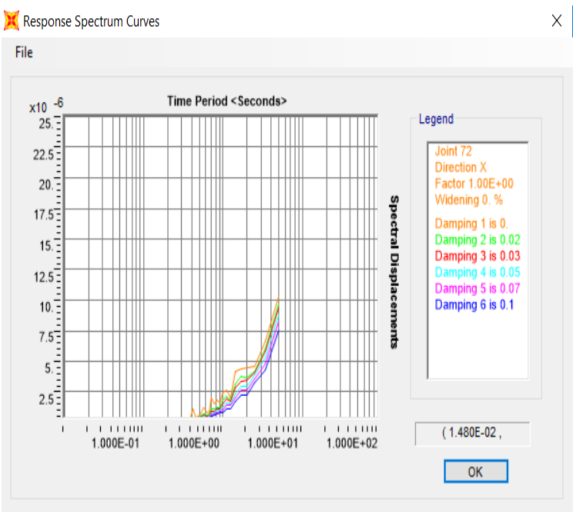
<table>
<tr><th>Displacement</th><th>Acceleration</th></tr>
<tr><td>Joint no. 7



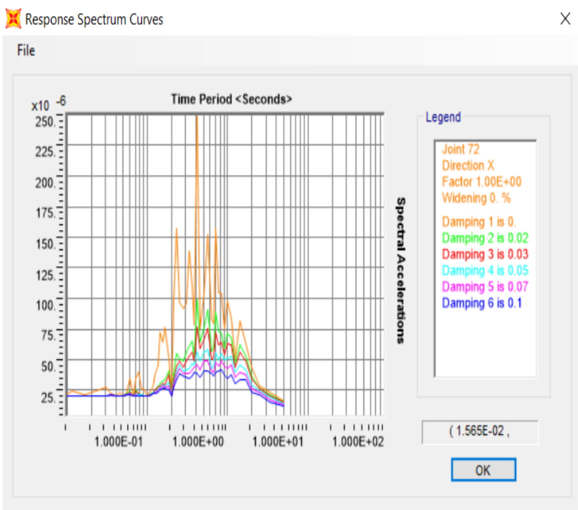
</td><td>Joint no. 7



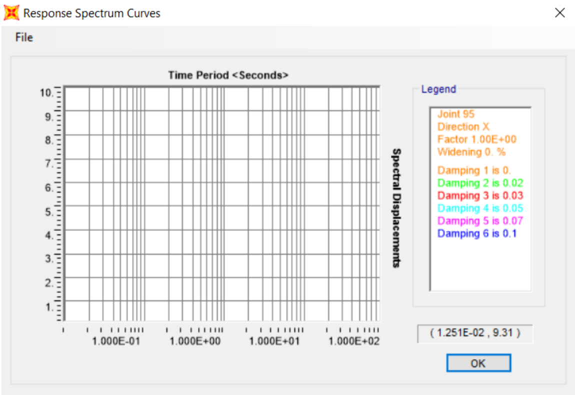
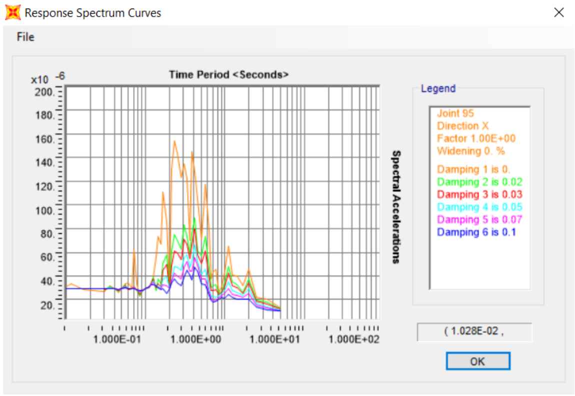
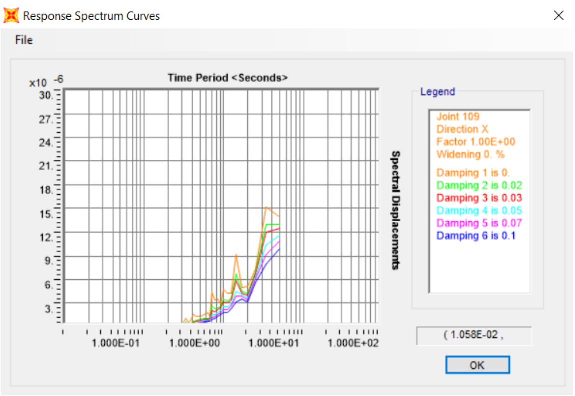
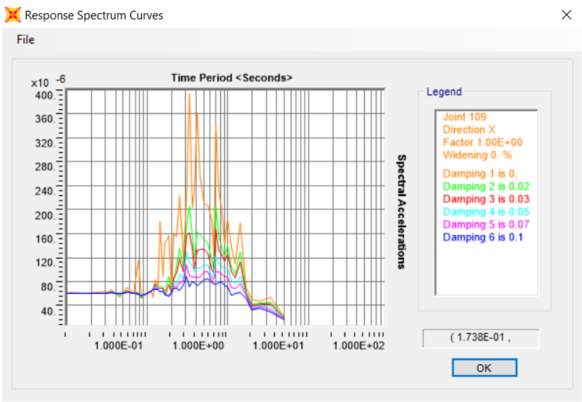
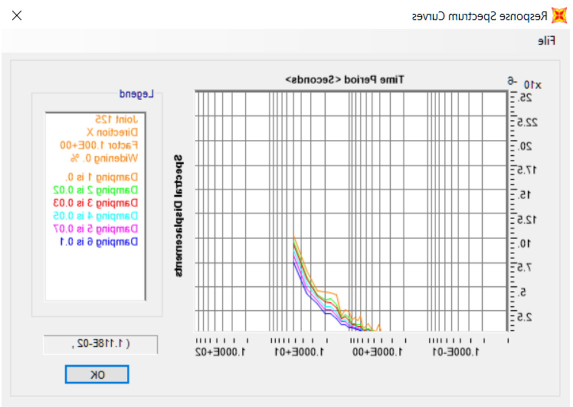
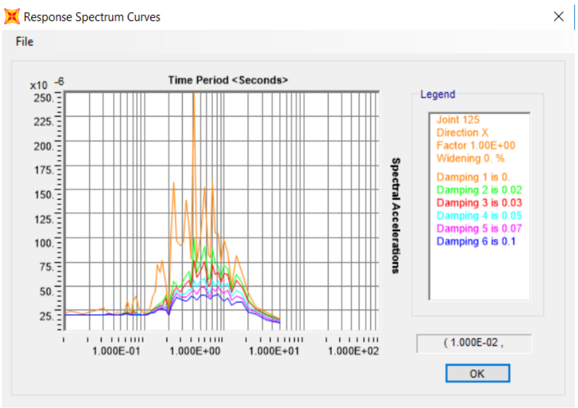
</td></tr>
<tr><td>Joint no. 72



</td><td>Joint no. 72



</td></tr>
</table>

Displacement	Acceleration
Joint no.95 	Joint no.95 
Joint no. 109 	Joint no. 109 
Joint no. 125 	Joint no. 125 

4.6 SUMMARY OF THE ANALYSIS

In the end of this study, the mode shape, displacement and velocity of the cantilever retaining wall structure have been determined. The mode shape result has been obtained from the free vibration analysis while displacement and velocity of cantilever retaining wall have been obtain from response spectrum analysis. All sections and joints passed the stress capacity check since the shape of the structure is rigid.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Based on the finding of the study, the conclusion that can be made consist of:

i. The simulation of the cantilever retaining wall structure model is not 100% represent the actual structure. This is due to the assumption made on the restraint at the based condition and the joint connection of the cantilever retaining wall structure. The restraint at base condition of the cantilever retaining wall structure is assumed to be fixed to the ground as a replacement for foundation. Moreover, the connection of the cantilever retaining wall structure was not designed according to the EuroCode3 design specification.

ii. The cantilever retaining wall is still can withstand the seismic response from Acheh as from the time period that analysed by SAP2000, it shows that the cantilever retaining wall is rigid. This is due to the distance from Acheh to Malaysia is far away since when the seismic travel to a long distance, the magnitude will become smaller.

iii. Modal analysis from the software SAP2000 produce 12 mode shape which each of the mode shape give different frequencies and natural period value. The modal analysis also shows that mode shape 1 is the best mode shape since it has highest value of natural period.

iv. The value for displacement and acceleration of the joint is different according to axis and the joint number.

5.2 RECOMMENDATIONS

For future study, the footing and the restraint of the cantilever retaining wall should be consider in the study. This is because the earthquake load transfer from the ground surface to the upper surface. It might have slightly different result if the footing and the restraint of the cantilever retaining wall is being consider in the study. Engineers also need to consider the seismic loading in when designing the cantilever retaining wall. Nowadays, Malaysia happens to be affected by the seismic event that occur in neighbouring countries regularly. Even Malaysia also have their own seismic activity. For example, an earthquake with magnitude of 5.9 that hits Ranau Sabah in 2015. Even though it occurs once in a moon light in Malaysia, we need to take precaution in this matter. So, engineers need to consider earthquake loading in designing cantilever retaining wall in future.

REFFERENCES

i. Aitken, G.H. (1982). Seismic Response of Retaining Walls, MS Thesis, University of Canterbury, Christchurch, New Zealand.

ii. Al-Atik, L. and Sitar, N. (2010), "Seismic Earth Pressures on Cantilever Retaining Structures," Journal of Geotechnical and Geoenvironmental Engineering, October, (136) 10,pp. 1324-1333.

iii. Clough, G.W. and Fragaszy, R.F. (1977). "A Study of Earth Loadings on Floodway Retaining Structures in the 1971 San Fernando Valley Earthquake," Proceedings of the Sixth World Conference on Earthquake Engineering, Vol. 3.

iv. Coulomb, CA. "Essai sur une application des regies des maximis et minimis a quelques problemes de statique relatifs a 1'architecture," Memoires de I'Academie Royale pres Divers Savants, Vol. 7, 1776.

v. Gazetas, G, Psarropoulos, PN, Anastasopoulos, I. and Gerolymos, N. (2004). "Seismic Behaviour of Flexible Retaining Systems Subjected to Short-Duration Moderately Strong Excitation," Soil Dynamics and Earthquake Engineering, (24), 537-550.

vi. Lew, M., Sitar, N., Al-Atik, L., Pourzanjani, M. and Hudson, M.B. (2010b). "Seismic Earth Pressures on Deep Building Basements." Structural Engineers Association of California, Proceedings of the Annual Convention, 2010.

vii. Mononobe, N, and Matsuo M. "On the Determination of Earth Pressures during Earthquakes," Proceedings, World Engineering Congress, Vol. 9, 179-187, 1929.

viii. Nazarian, H.N. and Hadjian, A.H. (1979). "Earthquake Induced Lateral Soil Pressures on Structures," Journal of Geotechnical Engineering Division, ASCE, (105) GT9: 1049-1066.

ix. Okabe S. "General Theory of Earth Pressure," Journal of the Japanese Society of Civil Engineers, Tokyo, Japan, Vol. 12 , No. 1, 1926. Prakash, S. and Basavanna, B.M. (1969). "Earth Pressure Distribution behind Retaining Wall during Earthquakes," Proceedings of the Fourth World Conference on Earthquake Engineering, Santiago, Chile.

x. Prakash, S. and Basavanna, B.M. (1969). "Earth Pressure Distribution behind Retaining Wall during Earthquakes," Proceedings of the Fourth World Conference on Earthquake Engineering, Santiago, Chile.

xi. Prakash, S. (1981). "Dynamic Earth Pressures," State of the Art Report – International Conference on Recent Advances on Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, Missouri, Vol. III, 993-1020.

xii. Rankine, W. "On the Stability of Loose Earth," Philosophical Transactions of the Royal Society of London, Vol. 147, 1857.