PSZ 19:16 (Pind. 1/07)

UNIVERSITI TEKNOLOGI MALAYSIA

DECLARATION OF THESIS / UNDERGRADUATE PROJECT PAPER AND COPYRIGHT

Author's full name : CHRISTIE LANJING ANAK ENTIKA

Date of birth : 08TH JUNE 1986

Title : STRUCTURAL RESPONSE SPECTRA FOR DIFFERENT SOIL CONDITION UNDER EARTHQUAKE LOADING

Academic Session : 2011/2012-2

I declare that this thesis 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 Universiti Teknologi Malaysia reserves the right as follows:

1. The thesis is the property of Universiti Teknologi Malaysia.
2. The Library of Universiti Teknologi Malaysia 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 :

SIGNATURE	**SIGNATURE OF SUPERVISOR**
860608-52-5906	PROF DR. AZLAN ADNAN
(NEW IC NO. /PASSPORT NO.)	**NAME OF SUPERVISOR**
Date : 20th MAY 2011	Date : 20th MAY 2011

NOTES : * If the thesis is CONFIDENTAL or RESTRICTED, please attach with the letter from the organization with period and reasons for confidentiality or restriction.

"I declare that I have read through this project report and to my opinion this report is adequate in term of scope and quality for the purpose or awarding the degree of Master of Engineering (Civil-Structure)"

Signature : ....

Name of Supervisor : PROFESSOR DR. AZLAN ADNAN

Date :

STRUCTURAL RESPONSE SPECTRA FOR DIFFERENT SOIL CONDITION
UNDER EARTHQUAKE LOADING

CHRISTIE LANJING ANAK ENTIKA

A report in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Civil-Structure)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

MAY 2011

I declare that this report entitled "Structural Response Spectra for Different Soil Condition under Earthquake Loading" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is concurrently submitted in candidature of any other degree.

Signature : ....

Name of Supervisor : CHRISTIE LANJING AK ENTIKA

Date :

Dedicated To

Dear God, My beloved Mum and Dad, my sister and my two brothers, my dearest beloved best friend, and my beloved church members.

For the unfailing and unreserved love, support, care, concern and prayer in every moment of trials and triumphs, thank you for being there for me. I am more than blessed that all of you are there with me.

ACKNOWLEDGEMENT

I am heartily thankful to my supervisor, Professor Dr. Azlan Adnan, whose encouragement, supervision and support from the preliminary to the concluding level has enabled me to complete this master project. His guidance and constructive leading has thought me well and has been a meaningful experience to be able to undergo my master project under his supervision.

I am also truly thankful to the members of engineering Seismology and Earthquake Engineering Research (e-SEER) team: Mr. Ehsan Noroozinejad Farsangi, Ms. Reni Suryanita, Mr. Patrick Tiong Liq Yee, Mr. Mohd. Zamri Ramli and Mr. Meldi Suhatril for every guidance, advice and support given throughout the entire process of completing this master project.

I wish to express my warmest gratitude to my parents and siblings who have been faithfully giving their precious support throughout the bad and good times and to my dearest best friend for sharing my joy and pain at all time. I also wish to extend my sincere appreciation to my church members who have been all the while giving their faith in me as I go through trials in life and sharing their joy when I was blessed to experience triumph in life. All of your presence in those moments brought sunlight to my life. Thank you.

ABSTRACT

The extent or degree of damage due to earthquake depends very much on the response of ground and structure to earthquake loading. One of the main concerns with respect to ground response to earthquake loading is seismic wave amplification. Seismic wave amplification causes large accelerations to be transferred to structure especially when the resulting seismic wave frequencies match with the structures resonant frequencies. Such phenomenon may lead to catastrophic damages and lost. In this study, the aim is to produce structural response spectra for different soil condition under earthquake loading with the objectives to determine peak ground accelerations at the ground surface for three locations in Malaysia, to determine peak accelerations at the highest point of low rise, medium rise and high rise building and as well as to investigate amplifications of ground and structure accelerations. The ground condition of each location of interest is presented by one bore log data which are collected at site and in each location the response of three types of building are investigated. The soil and the building are model as soil structure model using finite element method. In each location, the response of ground and structure are being investigated by applying synthetic time histories according to the three selected locations respectively. At the end of this study, response spectra are produced for ground accelerations at bedrock, ground accelerations at ground surface and peak accelerations of the highest point of every type of building. From the response spectra, peak ground acceleration at ground surface and peak accelerations of the highest point of every type of building are determined and amplification has been investigated.

ABSTRAK

Tahap atau darjah kemusnahan akibat gempa bumi sangat bergantung kepada respon tanah dan struktur terhadap beban kenaan daripada gempa bumi. Salah satu daripada masalah utama yang berkaitan dengan respon tanah terhadap beban kenaan daripada gempa bumi adalah amplifikasi gelombang seismik. Amplifikasi gelombang seismik menyebabkan pecutan besar dipindahkan ke struktur terutamanya ketika frekuensi gelombang seismik yang dihasilkan adalah sama dengan frekuensi resonan struktur. Fenomena tersebut boleh menyebabkan kerosakan dan kehilangan yang teruk. Tujuan kajian ini dijalankan adalah untuk menghasilkan respon spektra struktur bagi keadaan tanah yang berbeza di bawah pembebanan gempa bumi dengan tujuan untuk menentukan pecutan tanah maksimum pada permukaan tanah di tiga lokasi di Malaysia, untuk menentukan pecutan puncak pada titik tertinggi pada bangunan yang rendah, sederhana tinggi and bangunan pencakar langit serta menyiasat amplifikasi pecutan tanah dan struktur. Keadaan tanah di setiap lokasi yang diplih diwakili oleh satu data bor log yang telah kumpulkan di lokasi dan di lokasi masing-masing respon kesemua tiga jenis bangunan diselidiki. Tanah dan bangunan bagi setiap lokasi dimodelkan sebagai model struktur tanah menggunakan kaedah ‘Finite Element’. Di setiap lokasi, respon tanah dan struktur yang diselidiki dengan mengenakan ‘synthetic time history’ pada setiap tiga lokasi yang dipilih. Pada akhir kajian ini, respon spectra dihasilkan untuk pecutan tanah di batuan dasar, pecutan tanah pada permukaan tanah dan pecutan puncak titik tertinggi dari setiap jenis bangunan. Daripada respon spectra yang dihasilkan, pecutan tanah puncak di permukaan tanah dan pecutan puncak titik tertinggi dari setiap jenis bangunan ditentukan dan amplifikasi telah dikaji.

TABLE OF CONTENT

LIST OF TABLES

LIST FIGURES

LIST OF SYMBOLS

N	=	Standard Penetration Test Number
V_s	=	Shear Wave Velocity
$\ddot{u}$	=	Accelerations
$\mathring{u}$	=	Velocity
u	=	Displacement
t	=	Time
γ	=	Shear Strain
H	=	Total thickness of soil layer
Z	=	Depth of interest
ξ	=	Damping Ratio
G	=	Shear Modulus
K	=	Wave Number
ρ	=	Soil Density
ω	=	Circular Frequency
A, B	=	Amplitude of Waves

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Background

Earthquake is one of nature’s greatest catastrophic threat to human kind, living creatures and as well as properties. Earthquakes have caused much destruction all around the world causing many were left homeless and lost their lives. The destructions nonetheless, come from almost entirely the result of earthquakes forces on civil engineering structures and ground that support them (Villaverde, 2009). Therefore, it is obvious that understanding the structural response with regard to different soil condition under earthquake loading is essential. Such understanding will be able to assist engineers to foresee the appropriate measures to be considered in their construction project and also developments required to improve structural design and structural safety evaluation.

1.2 Problem statement

Most of the time earthquakes are often caused by the slippage along a fault in the earth's crust (Frederick and Edward, 2003). When the fault ruptures in the earth's crust, the seismic waves will travel away from the source known as focus, in all direction to the ground surface. As they travel through different geologic materials the waves are reflected and refracted. Throughout the whole journey from the bedrock to the ground surface, the waves may experience amplification. Seismic wave amplification may cause large acceleration to be transferred to the structures especially when the resulting seismic wave frequencies match with the structure resonant frequencies. This phenomenon may result in catastrophic damages and lost. Thus, with respect to the possible risk of earthquake hazard, it is essential to be able to estimate the peak ground acceleration at the ground surface in order to produced appropriate response spectra for the purpose of structural design and structural safety evaluation.

1.3 Aim and Objective of study

The aim of this study is to produce structural response spectra for different soil condition in Malaysia under earthquake loading. The objectives of this study are as follow;

i. To determine peak ground accelerations at the ground surface for different ground condition in several locations in Malaysia (Johor, Kuala Lumpur and Penang) under earthquake loading.

ii. To determine peak accelerations at the top of building with respect to 3 different categories of building according to height namely; low-rise, medium rise and high rise building.

iii. To investigate amplification of ground and structural accelerations.

1.4 Scope and Limitation of Study

The scopes and limitations of the study are as follow:

i. This study will involve investigation of soil conditions at three locations in Malaysia namely; Penang, Kuala Lumpur and Johor.
ii. The ground condition in each investigated location will be represented using one bore log data only.
iii. This study will be using synthetic time history according to the respective locations investigated only which is obtain from previous study.
iv. The structural response spectra of building being identified are with respect to height only.

1.5 Brief Research Methodology

This study has been carried out according to the following steps and as shown in the flow chart;

a) *Stage 1: Identifying problem.*

Various problems are look into within the field of earthquake engineering and with regard to the critical needs, a problem is identified.

b) *Stage 2: Determining objective and scope of study*.

The scope of study was being considered so that the study will be appropriate and several objectives are being verified to ensure this study will have a proper and clear direction.

c) *Stage 3: Literatures and Data collection*

At this stage, the necessary information and data are collected. Parameters such as SPT N and thickness of soil layer are being process into a more organized data presentation. This is to simplify the modelling process.

d) *Stage 4: Ground response analysis*

One dimension wave propagation analyses are carried out using NERA program (a manual calculation using excels) once the data from the respective investigated areas are collected. At this stage the main goal is to obtain the peak ground accelerations.

e) *Stage 5: Modelling*

Different soil conditions are modelled base on borehole log data using PLAXIS and SAP 2000 computer program. In each soil conditions, it will be modelled along with building. Since there are 3 categories of building, therefore in one soil condition, there will be 3 models. At the bedrock, synthetic time histories according to the respective locations investigated are being applied.

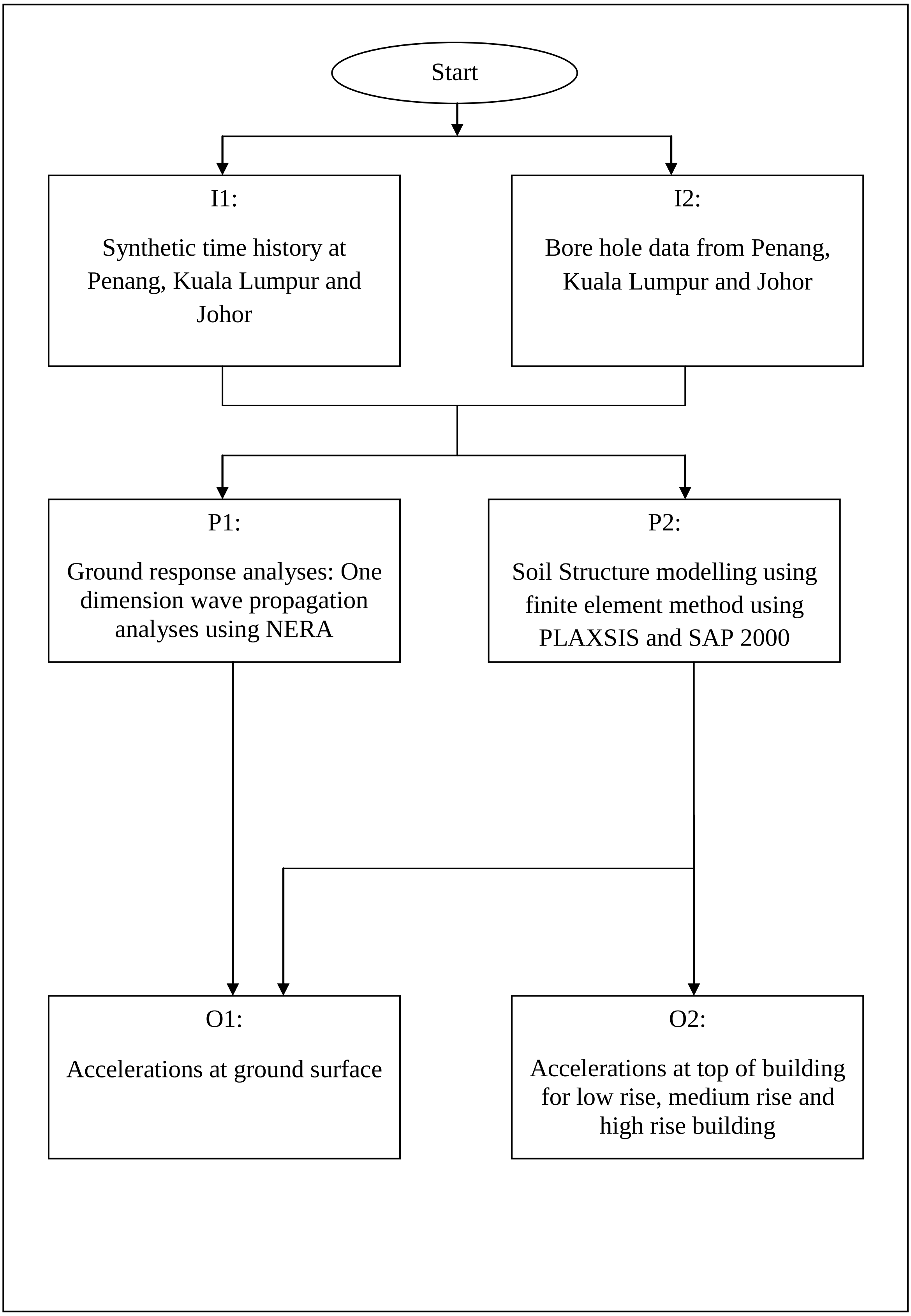

Figure 1.1: The flow of the study

CHAPTER 2

EARTHQUAKE

2.1 Introduction

An earthquake is a ground vibration due to the rapid release of energy (Frederick and Edward, 2003). The vibration produced causing the ground to be in motion where such ground motion generates complicated transient vibrations in structures. The response of a structure under earthquake loading is directly associated with the response of soil to ground shaking. Thus, the extent and degree of damage during an earthquake is mainly influence by the response of soil to ground vibrations. Therefore, it is vital to evaluate the response of soil due to ground vibration.

The evaluation of soil response due to ground vibration is known as site specific response analysis or soil amplification study. It is carried out in order to estimate the site dynamic response of a layered soil deposit. The site specific response analysis is the beginning point for most a seismic study and a solution to provide various parameters, mainly response spectra for structural design and safety evaluation. Response spectrum is compulsory to evaluate the dynamic forces induced in structures.

2.2 Seismic Impact in Peninsular Malaysia

Malaysia was said to be a country that is free from earthquake hazard and it is located at large stable region of earth layer (Mark Peterson, 2007). Nonetheless, in these few years, several earthquake events at the nearby region started to give an alarming impact to Malaysia especially at the Peninsular. Peninsular Malaysia was impacted at least by three earthquakes occurred in west coast of Sumatra (Jhonny, 2010).

The earthquake in Acheh, in the year 2004 has impacted the Peninsular Malaysia causing the northern part of Peninsular Malaysia suffered the greatest deformation compared to other places. In the year 2005, the Nias earthquake is another earthquake that impacted Peninsular Malaysia. The Middle West coast of Peninsular Malaysia deforms badly compared to other places and in the year 2007, Bengkulu earthquake in turn impacted the southern part of Peninsular Malaysia.

The global positioning system (GPS) measurement recently has shown that Peninsular Malaysia is no longer in the stable platform even it was believed that Peninsular Malaysia was located in the relative stable continent. This fact has been indicated by three minor earthquakes recorded at Bukit Tinggi, Jerantut and Kuala Pilah area in 2007, 2008 and 2009 with the magnitude of 2-3 on Richter scale (Jhonny, 2010).

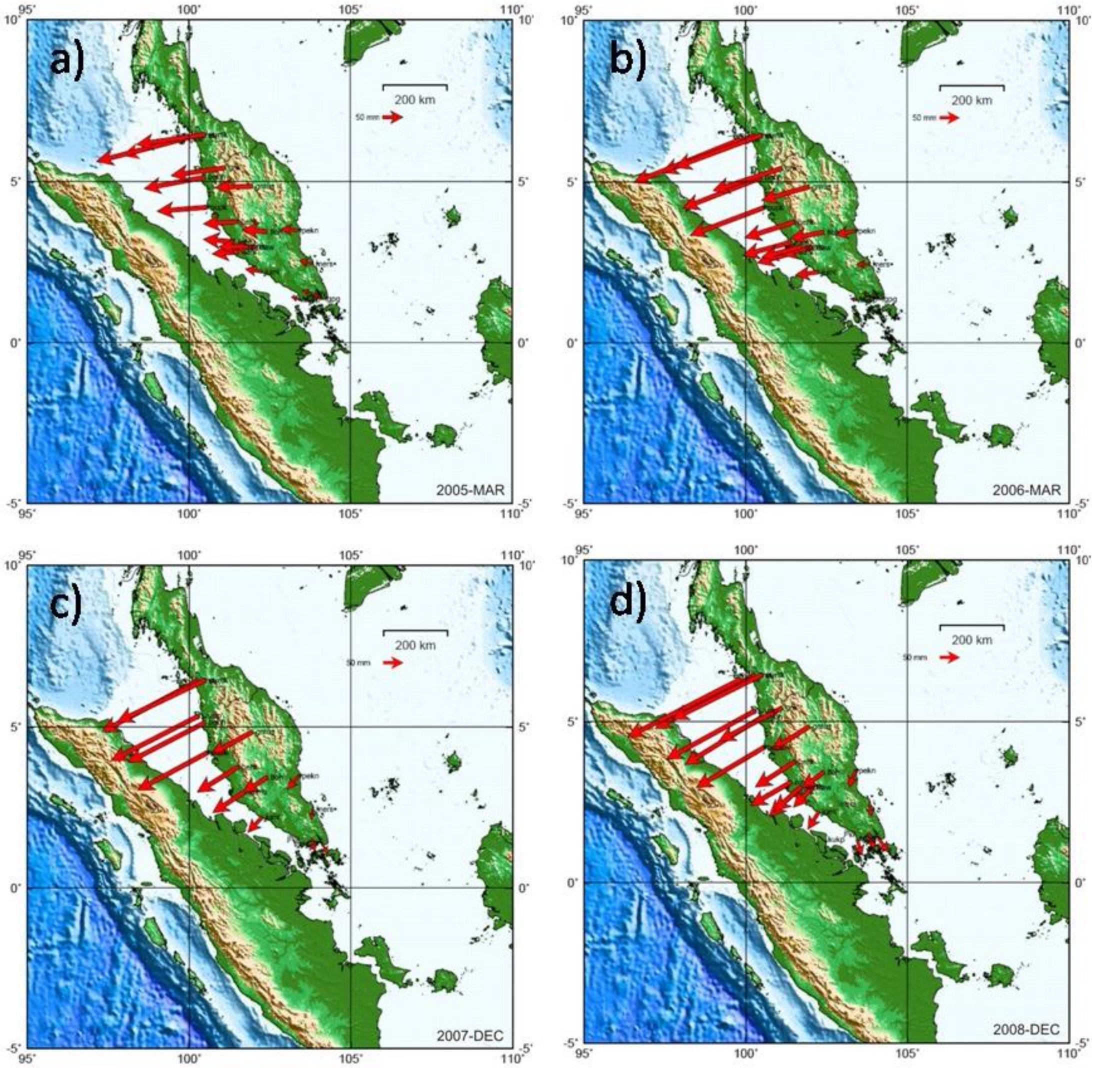

Figure 2.1: The displacement in Peninsular Malaysia due to Acheh earthquake (Jhonny, 2010)

2.3 Occurrence of Earthquakes

According to the tectonic earth theory, the earth's outer layer known as lithosphere constitute of approximately twelve hard tectonic plates (Tedesco et. al, 1999). These plates sit on a comparatively soft asthenosphere which is thought of to be molten rock. Thus, the lithosphere which is fairly rigid as the earth crust is floating above it. The large slabs on earth's crust are in continual slow motion where these mobile plates interact with neighbouring plates, straining and deforming the rocks. Basically, there are three types of plate interactions may occur which may give rise to three types of boundaries namely; convergent, divergent and transform boundaries. Each of plate interaction produces significant straining in crustal rocks.

The movement of the tectonic plates relative to one another both in direction and magnitude leads to accumulation of strain, both at the plate boundaries and inside the plates due to the shifting of the tectonic plates. When accumulated stress finally surpasses the strength of the rocks, fracture occurs and the earth snaps into the unstrained position. This phenomenon cause great energy release that creates shock waves. The shock waves then, propagate through the elastic medium and eventually reach the surface of the earth producing earthquake. Most of the earthquakes are produced due to slips at the faults or at the plate boundaries (Datta, 2010). Generally, earthquakes that occur along the boundaries of the tectonic plates which are known as intra-plate earthquakes are often recorded as large earthquakes. A chain reaction would take place in major earthquakes along the entire length of the slip.