STRUCTURAL RESPONSE SPECTRA FOR DIFFERENT SOIL CONDITION UNDER EARTHQUAKE LOADING

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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.

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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.

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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

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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.

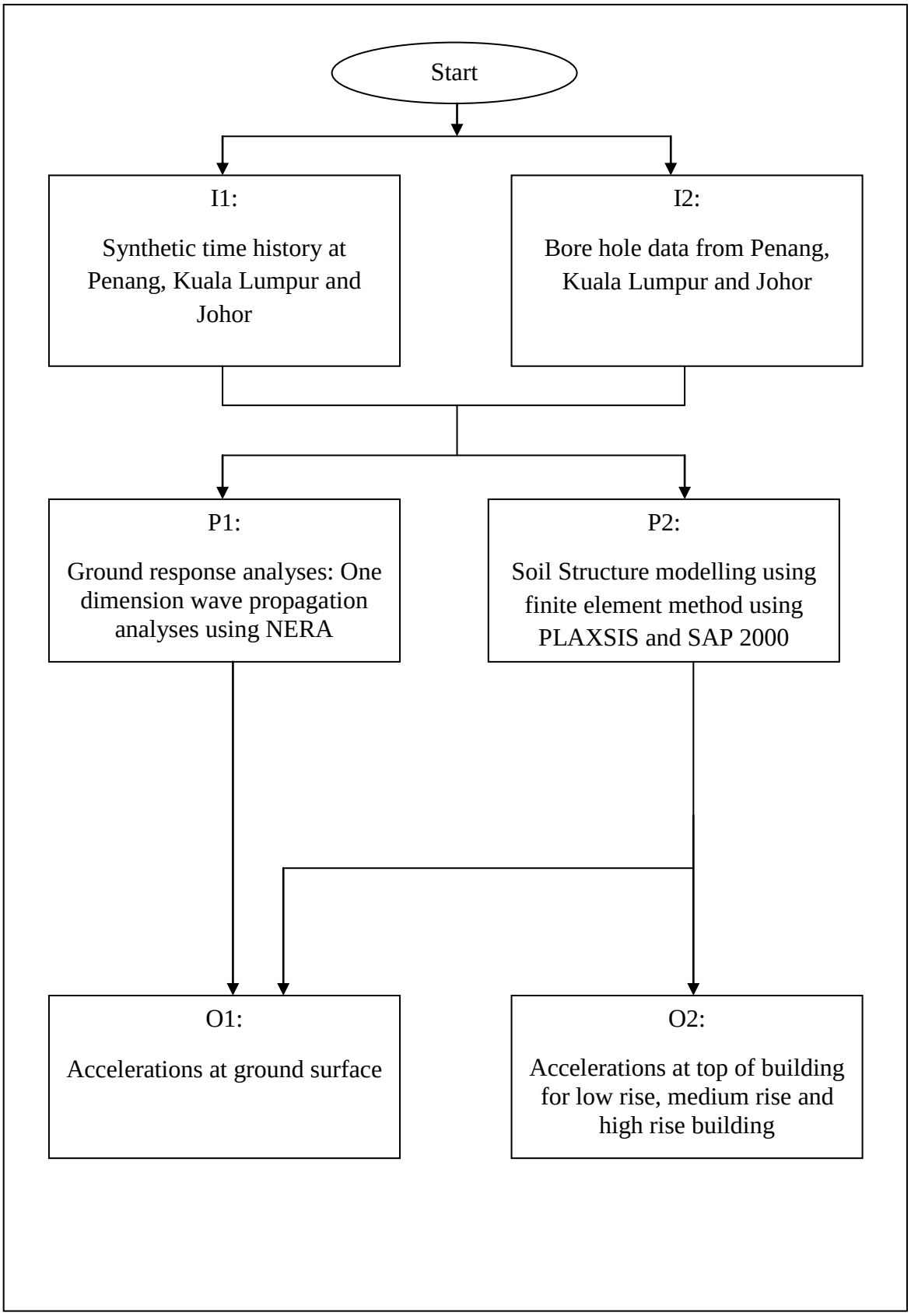

Figure 1.1: The flow of the study

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