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SEISMIC BEHAVIOUR OF TUNNELS WITH DIFFERENT SOIL TYPES  
AND DEPTHS

KU SAFIRAH BINTI KU SULAIMAN

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

Faculty of Civil Engineering  
Universiti Teknologi Malaysia

APRIL 2010

I declare that this report entitled “Seismic Behaviour of Tunnels With Different Soil Types and Depths” 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.

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*Alhamdulillah...*

*Thousand of gratitude to the Almighty Allah for the countless mercy and for giving  
me the courage and strength all this while...*

*To my beloved family...*

*Ku Sulaiman B. Ku Hashim*

*Ku Fathiyyah Bt. Ku Ismail*

*Ku Muhammad Saufi B. Ku Sulaiman*

*Ku Shakirah Bt. Ku Sulaiman*

*Ku Ahmad Shahir B. Ku Sulaiman*

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## ABSTRACT

Effect of seismic wave towards the tunnel as underground structure could cause unforeseeable damages during earthquake event. The waves that transmitted through the soil medium would affect the behaviour of the tunnel depending on the soil properties. The scope of this study will focus on tunnel structures in Malaysia; namely the SMART Tunnel and RAPID Tunnel. The objective of this study is to investigate the performance of the said tunnels under seismic load with different soil layer types and depths. These tunnels were modelled using finite element method (FEM) under dynamic analysis approach. Time history analyses were performed with several peak ground acceleration values, ranging from 0.05g, 0.10g, 0.15g, 0.19g and 0.25g. From this study, it was revealed that different soil properties surrounding the tunnel would affect the seismic behaviour of underground tunnel significantly. Nevertheless, both tunnels are capable to resist the earthquake loading compared with the design capacity of the tunnels.

## ABSTRAK

Kesan gelombang sismik terhadap terowong terutamanya sebagai struktur bawah tanah boleh menyebabkan kesan kurang dilihat ketika gempa bumi berlaku. Namun, gelombang yang dipindahkan melalui medium tanah akan mempengaruhi kelakuan terowong yang bergantung terhadap sifat tanah. Kajian ini akan memfokuskan terowong di Malaysia iaitu terowong SMART dan RAPID. Tujuan kajian ini dijalankan adalah untuk mengenalpasti tahap kelakuan terowong yang berkenaan akibat gempa bumi dengan pelbagai kedalaman dan jenis tanah. Melalui analisis dinamik, terowong ini dimodelkan menggunakan kaedah teori unsur tak terhingga. Analisis 'Time History' dijalankan dengan mengenakan beberapa kekuatan gempa bumi iaitu dari 0.05g, 0.10g, 0.15g, 0.19g dan 0.25g. Hasil kajian menunjukkan sifat tanah yang berbeza dikeliling terowong mempengaruhi kelakuan terowong. Walaubagaimanapun, kedua-dua terowong berupaya menahan beban gempa bumi jika dibandingkan dengan kapasiti rekabentuk terowong.



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**LIST OF SYMBOLS**

$E$	=	Young Modulus
$V_s$	=	Shear wave velocity
$N$	=	Standard Penetration Test Number
$I_c$	=	Moment of inertia of tunnel lining section
$C_s$	=	Apparent velocity of S-wave propagation
$G_m$	=	Shear modulus of soil
$I$	=	Second Moment of Area
$M$	=	Maximum Moment Capacity
$S$	=	Maximum Shear Capacity
$\rho_m$	=	Density of medium
$g$	=	Gravity acceleration
$T$	=	Natural Period
$\gamma$	=	Soil unit weight
$r$	=	Radius of circular tunnel
$h$	=	Thickness of soil deposit
$A_c$	=	Cross sectional area of tunnel lining
$L$	=	Wavelength of ideal sinusoidal shear wave
$Q_{\max}$	=	Maximum axial force in tunnel cross section
$K_a$	=	Longitudinal spring coefficient of soil or rock medium

$K_t$  = Transverse spring coefficient of soil or rock medium

$\nu_m$  = Poisson's ratio of soil medium

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## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 General**

It is most common opinion that underground structure will safe during earthquake. This is because their responses to earthquake loading are less damage compare with surface structure. Underground structures are constrained by the surrounding medium (soil or rock). It is unlikely that they could move to any significant extent independently of the medium or be subjected to vibration amplification.(Wang,1993)

Nowadays, tunnelling in soft ground is become a common geotechnical activity for urban transportation or water management facilities in many large cities around the world. For this reason, the determination of the dynamic response of the tunnel in soil to seismic waves is important.

## **1.2 Earthquake Effect on Underground Structure**

Earthquake effects on underground structures can be grouped into two categories which is ground shaking and ground failure such as liquefaction, fault displacement and slope instability. Ground shaking refers to the deformation of the ground produce by seismic waves propagating through the earth's crust. The major factors influencing shaking damage include the shape, dimensions and depth of the structure , the properties of the surrounding soil or rock, the properties of the structure and the severity of the ground shaking (Dowding and Rozen, 1978)

## **1.3 Problem Statement**

Eventhough tunnel were considered as safest structure under earthquake loads but there has been increasing awareness of seismic hazards for underground structures (Merit,et al. 1985). This study is important to enhance awareness of seismic hazards of tunnel. Furthermore, this study could be a guideline in designing the tunnel that combines geotechnical and structural engineering point of view.

It is important to know the behaviour of the tunnel that embedded with different soil layer and depth because it reacts differently with earthquake loading. Therefore, this study are important as it will study the value of ground motion acceleration at the tunnel lining which will varies with different soil type and depth.

## **1.4 Objective of study**

The objectives of the study are:

1. To determine the ground accelerations of tunnel models under various type of intensity.
2. To investigated the capability resistant of the tunnel.



3. To identify the performance of the tunnel under various earthquake intensities.

## 1.5 Scope of study

In this study the scope can be divided into these following:

- i) This study will focus on tunnel structures in Malaysia which is SMART Tunnel and RAPID Tunnel
- ii) Modelling circular tunnel embedded in different soil layer and depths.
- iii) Modelling circular tunnel with spring connection in different soil layer and depths.
- iv) Modelling the tunnel with depth of 5m,10m,15m and 25m.
- v) Analyzing the tunnel with various earthquake intensities of 0.05g, 0.10g, 0.15g, 0.19g and 0.25g

## 1.6 Research Methodology

The methodology of the study are explained as follows with flowchart of methodology as shown in Figure 1.1:

*Stage 1: Clarification of the project on the objectives and scopes of the study*

This is to verify the feasibility of the study outcomes and planning of methodologies.

*Stage 2: Literatures, collecting data*

In this stage, data such as detailed drawing and soil investigation reports have been collect. Other parameter from the soil is required such as thickness of soil layer, SPT- Number, shear wave velocity and other control data that have to be identify.

*Stage 3: Modelling of structure*

Knowing the performance of tunnel structure under earthquake loading is essential to assume the structure behave accordingly to literature finding.

*Stage 4: Ground response analysis*

The analysis was carried out by using nonlinear one dimensional shear wave propagation analysis approach by using Nonlinear Earthquake Site Response Analysis (NERA) program. The ground response analysis was performed by propagating the strong motion data at the bedrock through each soil profile with the NERA program. Synthetic time history of Kuala Lumpur with various intensities of 0.05g, 0.10g, 0.15g, 0.19g and 0.25g were applied as input data

*Stage 5: Analysis of finite element modelling*

Finite element modelling using SAP2000 computer program are used to analyze the tunnel. Two cases of tunnel are model in linear and nonlinear analysis. Linear analysis is by modelling circular tunnel with spring connection in 4 type of subsoil model with depth of 5m, 10,15m and 25m from tunnel crown. For nonlinear analysis is by modelling circular tunnel in 4 type of subsoil model with depth of 5m, 10m, 15m and 25m from tunnel crown. Earthquake loading from synthetic time history of Kuala Lumpur were used with intensities of 0.05g, 0.10g, 0.15g, 0.19g and 0.25g.

*Stage 6: Performance Analysis*

The performance of tunnel had been study by looking at the displacement, normal stress and shear stress from the analysis. The result will be compared with the design capacity of the tunnel system.

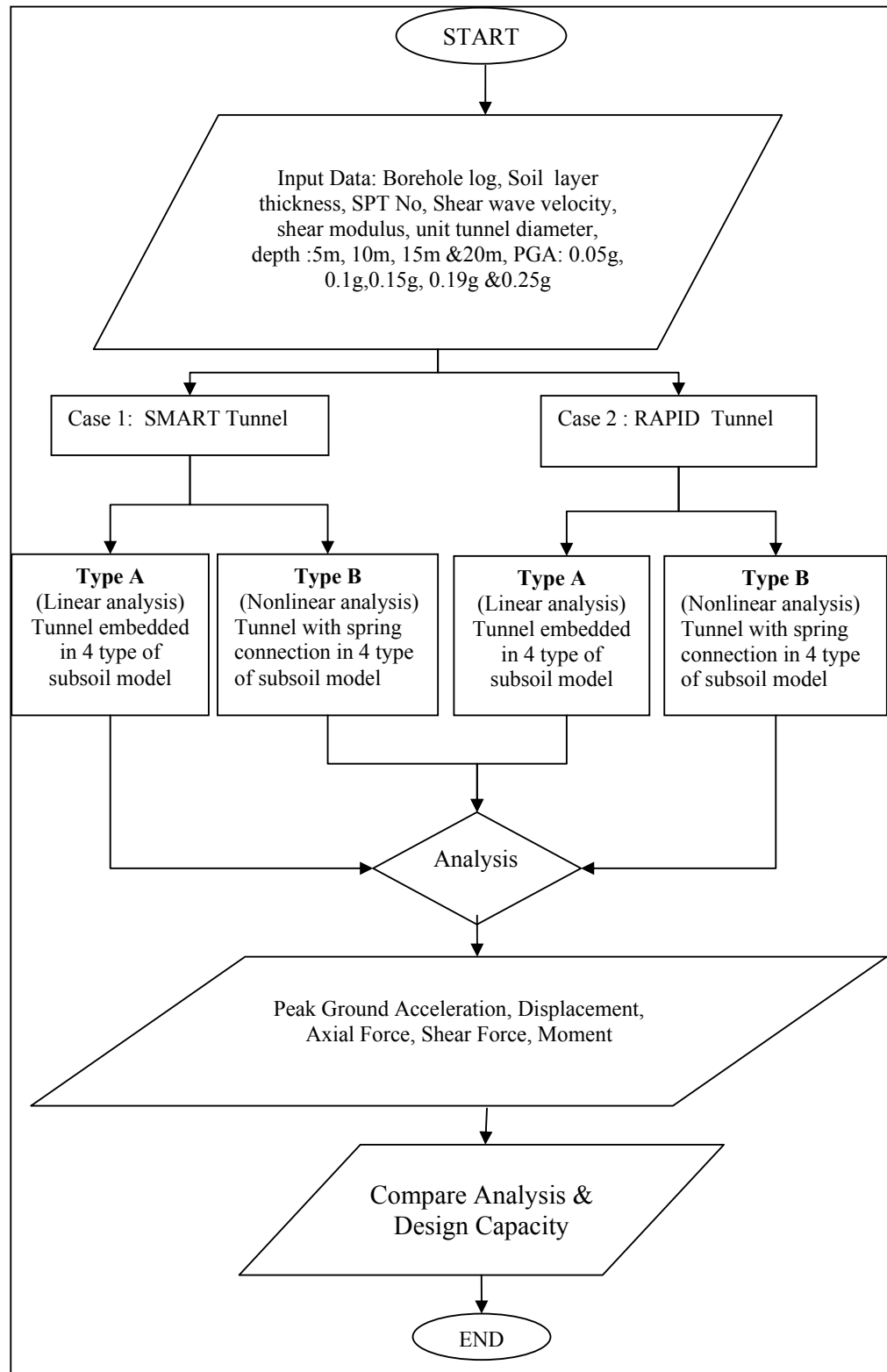


Figure 1.1 : Research Methodology Flowchart