TUNNEL INDUCED GROUND MOVEMENT

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DEDICATION

This thesis is dedicated to my mother, Sarimah Binti Kamarudin and my father, Ismail Bin Mohd Ali, who taught me the value of love, compassion, honesty, and wisdom. To my beloved husband, Mohamad Amir Fikri Bin Mohamad Saeffee, who constantly showers me with love and determination. Finally, to my siblings and friends for their never-ending support.

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ABSTRACT

A tunnel construction facing high risk and being a major concern in the construction of underground structure especially for their stability and settlement. This dissertation study on the influence of various jack forces magnitude to the soil-tunnel reaction especially on the tunnel lining behavior and induced ground settlement at various depth above the tunnel crown. In addition, this research also discuss on the tunnel's global behavior in order to support the surrounding load. A series of soil-tunnel modelling were carried out using ABAQUS as a finite element method (FEM) software. A stand-alone ring method together with all-in-once method was used in this study to simulate the Singapore MRT Circle Line 3 (CCL3). Based on the results obtained and the assessment made in this study, it can be concluded that jack forces of 5 Mpa, 10 MPa,15 Mpa and 20 Mpa shows not significant ground settlement. The soil settlement at various depth show different ground settlement. One of the significant output from this study is one able to manage effectively the tunnel-soil reaction without significant or critical deformation and allow the tunnel to be used in stable and safe condition with deeper understanding of the jack force variations.

ABSTRAK

Pembinaan terowong menghadapi risiko tinggi dan menjadi perhatian utama dalam pembinaan struktur bawah tanah terutama untuk kestabilan dan penempatannya. Kajian disertasi ini mengenai pengaruh pelbagai kekuatan kekuatan jack terhadap reaksi terowong tanah terutama pada tingkah laku lapisan terowong dan penempatan tanah yang disebabkan pada berbagai kedalaman di atas mahkota terowong. Di samping itu, penyelidikan ini juga membincangkan tingkah laku global terowong untuk menyokong beban di sekitarnya. Rangkaian pemodelan terowong tanah dilakukan dengan menggunakan ABAQUS sebagai perisian kaedah elemen (FEM). Kaedah cincin berdiri sendiri dan kaedah all-in-sekali digunakan dalam kajian ini untuk mensimulasikan Singapore MRT Circle Line 3 (CCL3). Berdasarkan hasil yang diperoleh dan penilaian yang dibuat dalam kajian ini, dapat disimpulkan bahawa kekuatan jack 5 Mpa, 10 MPa, 15 Mpa dan 20 Mpa menunjukkan penyelesaian tanah yang tidak signifikan. Penempatan tanah pada pelbagai kedalaman menunjukkan penempatan tanah yang berbeza. Salah satu hasil yang signifikan dari kajian ini adalah yang dapat menguruskan reaksi terowong-tanah dengan berkesan tanpa ubah bentuk yang ketara atau kritikal dan membolehkan terowong digunakan dalam keadaan stabil dan selamat dengan pemahaman yang lebih mendalam mengenai variasi kekuatan jack.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

UTM	-	Universiti Teknologi Malaysia
CCL3	-	Circle Line 3
TBM	-	Tunnel Boring Machine
EPB	-	Earth Pressure Balance
FEM	-	Finite Element Method
3D	-	Three Dimensional
FE	-	Finite Element

LIST OF SYMBOLS

i	-	Horizontal distance from tunnel centre line to inflection point
S	-	Ground surface settlement
x	-	Distance from the tunnel centre line
V_L	-	Ground Loss

CHAPTER 1

INTRODUCTION

1.1 Background

Because of the rapid growth in Malaysia, tunnels and substructures are now successfully constructed and in high demand. Moreover, the construction of underground structures such as tunnels will meet the increasing demand for solutions that are affordable, effective, healthy and environmentally sustainable. Tunnel or underground construction basically can give many advantages especially when there is limit of space on the ground surface. Underground tunnel construction can actually have impact on what is already underneath and surrounding it. It is really critical to understand tunnel design from the preliminary stage to the end of the life cycle of the tunnel.

In order to evaluate any possible hazards to occur, overall stability and settlement of the tunnel and surrounding structure or equipment, especially during tunnel construction, must be closely controlled with accurate estimate and reading level. Theoretically, settlement in tunnel construction can come from short term as well as long term settlement. The application and interpretation of accurate or reasonable parameters in tunnel construction is crucial at the initial design stage for the success of a tunnel project. All the parameter must carefully adopt and interpreted in order to design and build a successful tunnel project.

The tunnel design concerns on the size and shape, lining thickness to be used, the jack forces value to use during the installation of tunnel liner and all of them must be sufficient to serve their specific functions (Zhao, 2017). Proper design and methodology in tunneling works require reasonable parameter or value estimation in order to study reflective ground interaction especially during tunneling activities to avoid or minimize any disaster to occur in future. Nowadays, there are several methods to explore to build tunnels according to the suitability of the soil as well as the surrounding conditions for a successful tunnel project in Malaysia. In designing and constructing a tunnel, tunnel designers should consider the effect of the tunnel construction especially during the preliminary design stage so that the designated tunnel can perform well after constructed and safe to use.

Many factors need to take into consideration when designing a tunnel project such as the geological formation especially at the location of tunnel will be bored, water table conditions, size and shape, logistics to help and support the tunnel excavation during construction, risk management particularly during tunnel construction, consideration of costs and time, restriction of ground surface disruptions and several other considerations. Issues in tunnel stability and settlement getting a lot of attention by the tunnel designers and cause significant studies done by many researchers in the world. There are various techniques and methods to construct underground structure especially tunnel have been proposed depending on many factors to determine and study the tunnel stability especially on the ground settlement and soil interaction behavior. These techniques can generally be limit equilibrium, numerical modelling, and empirical methods, and etc. Consequently, modelling has been a choice for many researchers in the world to deal with the effects of tunnel construction and one of the medium to carry out parametric study for tunnel construction especially during preliminary of tunnel design stage.

1.2 Problem Statement

Stability and settlement are the threats that will be faced when designing the tunnel. For geotechnical and structural designer of tunnel project, it is very crucial to ensure the stability of the tunnel particularly during construction period. The geotechnical and structural designer of the tunnel need to ensure the tunnel-soil interaction especially on the ground settlement are within the tolerance limit. Tunnel-soil interactions are interrelated and therefore any movement or change made in one of these parameter can have an effect on the other.

Acceptable estimation of the jacking force to be applied to the tunnel lining is very crucial and important, which controls the design of pipe segments and the efficiency of a pipe jacking tunnel project (Shou and Jiang, 2010). Theoretically, by over applying jack forces during the tunnel construction, it might lead to further disruptions to the underlying soil, in particular to the stability of the soil around the construction of the tunnel, which may lead to further complications and disasters. In conclusion, the study on the ground movement and soil-tunnel interaction is very crucial in tunnel project.

1.3 Objectives of the Study

The aim of this research is to evaluate and understand the ground settlement as well as the ground behavior by using ABAQUS which is finite element software due to tunneling activities. Objectives of the research are listed as follow:

1) To determine the soil-tunnel reaction based on variation of jack forces
   a. Surface settlement through
   b. Longitudinal settlement

2) To develop relationship between different soil depth from existing ground with soil settlement
   a. Surface settlement through
   b. Longitudinal settlement

1.4 Research Scope and Limitation

The study of this project is based on past case study of Singapore Circle Line Stage 3 (C852), Singapore Interchange Station, Singapore which have been carried out by other researcher. Below is the scope of this study which consists of the following:

(a) ABAQUS as finite element software were used to model of the tunnel and soil in this study

(b) 0.275 m thickness of tunnel lining have been assign for this study

(c) Various jack forces of 5 MPa, 10 MPa, 15 MPa and 20 MPa have been assigned to the tunnel lining as parametric study in this study.

(d) Various depth of 2.5m, 6m, 14m and 16m based on different layer of soil have been selected from the existing ground as parametric study in this research

(e) Analysis of ground settlement in longitudinal and transverse based on various jack forces applied to the tunnel lining and also soil depth will be discussed and presented in chapter 4 and chapter 5

1.5 Significance of the Study

This research is important to study and understand the soil tunnel reaction especially when the value of jack forces increase. Behavior of soil-tunnel reaction are very important information for designer and researcher in order to prevent a global disaster such as the collapse of the tunnel or nearby building due to significant ground settlement. Therefore, by carrying out this study on the tunnel induced ground movement, the value of the horizontal and vertical soil movements were expected to be affected due to tunnel construction. Ideally, by applying the appropriate jack forces, it will help to be cost-effective and speed up the construction time as higher pressure requires greater power to generate the high pressure..

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