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College of Engineering

BEHAVIOR OF STRESSES AND DEFORMATIONS FOR SOIL SURROUNDING TBM TUNNEL BY FINITE ELEMENT SIMULATION

A Thesis Submitted to the Council of the College of Engineering, University of Diyala in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering

by

Halah Hashim Mohammed

Supervised by

Assist. Prof. Dr. Waad A. Zakaria

Assist. Prof. Dr. Qasim A. Mahdi

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ (١)

الْحَمْدُ لِلَّهِ رَبِّ الْعَالَمِينَ (٢) الرَّحْمَنِ

الرَّحِيمِ (٣) مَالِكِ يَوْمِ الدِّينِ (٤) إِيَّاكَ

نَعْبُدُ وَإِيَّاكَ نَسْتَعِينُ (٥) اهْدِنَا الصِّرَاطَ

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غَيْرِ الْمَغْضُوبِ عَلَيْهِمْ وَلَا الضَّالِّينَ (٧)

صدق الله العظيم

سورة الفاتحة

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We certify that we have read the thesis entitled **(Behavior of Stresses and Deformations for Soil Surrounding TBM Tunnel by Finite Element Simulation)** and we have examined the student **(Halah Hashim Mohammed)** in its content and what is related with it, and in our opinion it is adequate as a thesis for the Degree of Master of Science in Civil Engineering.

Examination Committee	Signature
Assist. Prof. Dr. Waad A. Zakaria (Supervisor)	**……………….**
Assist. Prof. Dr. Qasim A. Mahdi (Co-Supervisor)	**……………….**
Assist. Prof. Dr. Mohammed Y. Fattah (Chairman)	**..……………..**
Assist. Prof. Dr. Safa Hussain Abid Awn (Member)	**........…………**
Assist. Prof. Dr. Hassan Obaid Abbas (Member)	**……………….**

Prof. Dr.Hafeth Ibrahim Naji …………….. (Head of Department)

The thesis was ratified at the Council of College of Engineering/ University of Diyala.

Signature: ....

Name: Prof. Dr. Abdul Monem Abbas Karim

Dean of College of Engineering/ University of Diyala.

Date:

CERTIFICATION

We certify that the thesis entitled **“Behavior of Stresses and Deformations for Soil Surrounding TBM Tunnel by Finite Element Simulation”** was prepared by **“Halah Hashim Mohammed”** under my supervision at the Department of Civil Engineering-College of Engineering-Diyala University in a partial fulfillment of the Requirements for the Degree of **Master of Science in Civil Engineering.**

Signature:

Supervisor: Assist. Prof. Dr. Waad A. Zakaria

Date:

Signature:

Co-Supervisor: Assist. Prof. Dr. Qasim A. Mahdi

Date:

In view of the available recommendation, I forward this thesis for debate by the examining committee.

Signature:

Name: Assist. Prof. Dr. Hafeth Ibrahim Naji

Chairman of the Department of Civil Engineering.

Date:

Dedication

I Wish to Dedicate My Thesis to The Light of My Eyes My Beloved Parents (My Mother and Father) ……………

Halah Hashim Mohammed

2018

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ABSTRACT

The increasing investment for the underground space such as the construction of the tunneling will part of the infrastructure development and exploitation of this space which becomes fundamental base in the development of large cities. In an urban environment, the tunneling induced ground loss is an essential matter to estimate ground movement during the excavation process. Therefore, an attempt has been made to study the settlement and behavior of stresses through tunnels construction by tunnel boring machine method (TBM)and their influences on the adjacent structures.

In this research study is carried out to predict of the behavior of the stresses and ground movement effect of applying a tunnel boring machine during the excavation process. A numerical model is built and developed to a tunnel project within the governorate of Diyala. For this purpose, two profiles of soil investigations are brought the first from Al-Shareef Al-Jadeed bridge project and second for new buildings of Diyala University project.

The main objective of this research is to study the behavior of stresses and determine the settlement in the area of study using a finite element method and to assess and the determination of extent the impact of a distance to move the mechanism of the drilling and advance into the soil. The model is run as three dimensional in both drained to sandy soil and undrained of clay soil of states with applied Mohr-Coulomb model.

Results are presented in terms of stress-depth curves. Those stresses are the vertical and horizontal, total and effective in addition to the pore water pressure. The changes in state of stresses compared to the in-site soil are put into consideration. Three vertical sections are chosen to study the TBM tunneling effects on surrounding soil. The first section (x=0) runs through center of the tunnel. Second section is located near lateral edge of the tunnel, while the third section is chosen more or less far

from the tunnel edge. The advance of TBM is reflected by stages through one to five. It is believed that the mentioned details of the analysis will provide full vision of stress change in the soil profile. The strains induced by the boring process are presented in different and simple methods. These methods reflected the soil movement and surface settlement of soil. The deflected shape of the tunnel is shown as well. Through running an axi-symmetric FE analysis, calculation results revealed mat large changes in stresses take place in zones of soil near the tunnel boundaries. In other words, the close-near by soil is mostly affected by tunneling. These stress changes reduce as proceeded farther away from tunnel horizontally and seams to reach a to negligible values for distances above 12m away tunnel edge.

All changes in the state of stress compared to the in-site soil depend on soil profile in site. The FE results also revealed that soil change in stress is more pronounced in the zone above tunnel than under it. It is believed that surrounding confinement plays a major role to that. The deflected soil shape shows that there is a vertical depression in the tunnel associated with lateral bulge. Maximum surface settlement recoded is 20mm in the upper soil region over tunnel which belongs the Al-Shareef Al-Jadeed bridge project and level off as gelling away horizontally from tunnel center.

Upon proceeding with drilling, soil movement vectors seem to run towards the tunnel. As in the case of stresses, it is maximum in zones near tunnel. And last but not least, this study provides soil engineering a good guide and through understanding how to avoid places of heavy engineering facilities upon passing by TBM tunnel near or under these structures. Every soil site has its own profile and should run a full FE analysis but the general trend of behavior is through to the same.

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C_c	Compression index
C_s	Swelling index
C_u	Undrained cohesion
C_v	Coefficient of consolidation
DS	Disturbed Sample
e_o	Initial void ratio
G_s	Specific Gravity
LL	Liquid limit
M_v	Coefficient of volume change
N.P	Non-Plastic
OCR	Over consolidation ratio
PI	Plasticity index
PL	Plastic limit
Q_u	Unconfined Compressive Strength
SPT	Standard Penetration test
S.S	Standard Penetration test Samples
US	Undisturbed Samples
UU	Unconsolidated undrained triaxial test
P_o	Effective overburden pressure
P_c	Reconsolidation stress
Ø	Angle of internal friction
W_c	Natural moisture content
γ_t	Total unit weight
γ_{wet}	Wet Unit Weight
γ_{dry}	Dry unit weight
MC	Mohr-Coulomb Model
CY	Strain-Hardening Model
LE	Linear Elastic Model

CHAPTER ONE
INTRODUCTION

1.1 Introduction

The growth of many cities has resulted in the need for exploitation of underground space. As urban cities space become more limited, the construction of structures such as tunnels is more efficient in infrastructure development and fundamental in the development of large cities. The first underground railway line was opened in1863 London. After that over 100 cities worldwide were carried out underground transport systems and over 50% of them had subjected to development or expansion **(Hellawell et al., 2001)**.

Tunnels usually are structures passing underground. The benefits of tunnels are improving connections and shorten lifelines between countries. There are many cross-sections commonly adopted for tunnels, such as circular sections, elliptical, and rectangular or box type tunnels. Tunnel can be drilled in all types of soil varying from the loose ground, such as sand, gravel, clay up to hardest rock **(Rasheed, 2006)**.

The excavation indicates the removal of soil within certain specified limits, or for building purposes. The necessity of constructions for such structures in urban areas has led to the need for a safe and efficient method for the deep excavations without severely influencing the adjacent structures.

In recent years the excavation methods in soft soil have improved after tunnels have become economically more attractive in the urban environment **(Obaid, 2001)**. For example, the tunnel boring machine method (TBM) have been widely utilized in tunnel construction, especially in soft ground where the most important purpose is to minimize the soil deformation, as shown in Figure (1.1)

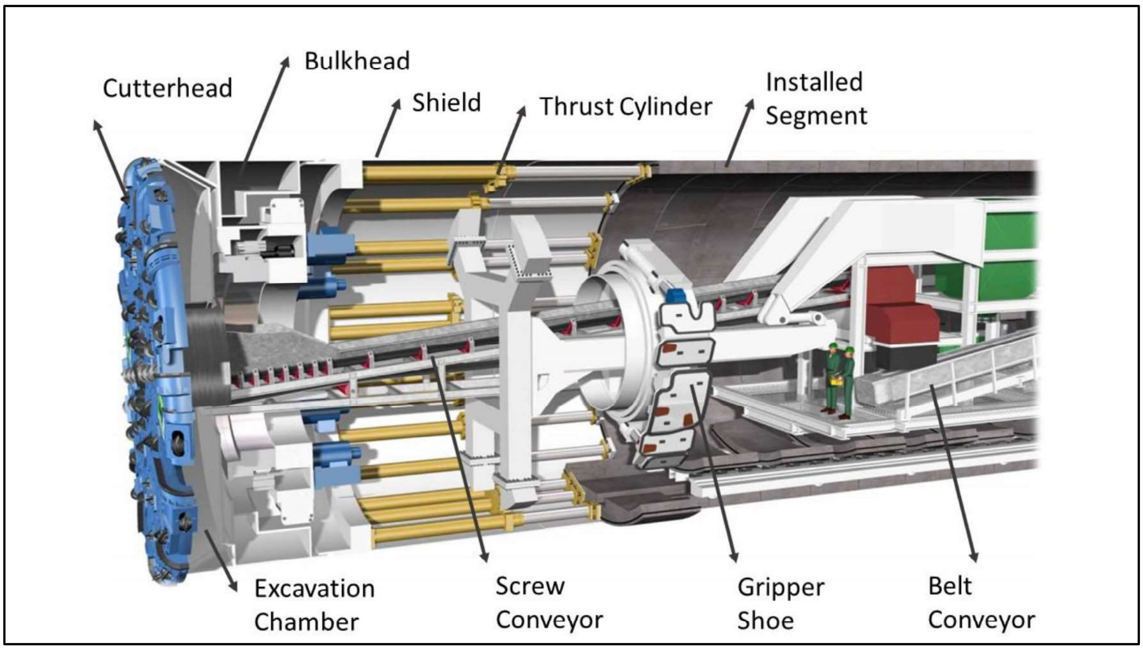

Figure (1.1): Tunnel boring machine elements **(Obaid, 2001)**.

The tunnel boring machine can be with a cross-section of the circular and rectangular shapes. The advantage of excavation methods of tunnels and the increasing need to avoid any disturbance at the surface through excavations **(Dimitrios Kolymbas, 2005)**.

When underground space or a large span tunnel is drilled, there will be a disturbance in-situ stress field which induces movements of soil and then leads to the surface settlement. Surface deformation may cause serious damage to adjacent buildings. Tunnel construction and design require the use of appropriate technologies at all stages of a tunnel project with selecting a suitable excavation method **(Sharifzadeh, et al,2013)**.

Ground movement of surface caused by the tunnel construction methods is an important matter in urban areas due to the excessive deformations which can trigger possible damage to surrounding roads and adjacent structures **(Yahya and Abdullah, 2014)**.

The amount surface settlement may differ according to different construction methods used for different cross-sections of the tunnel which leads to different settlements. As a result, the construction methods have an important influence on the ground surface settlements **(Sharifzadeh, et al., 2013)**.

The stresses and the ground movement in surrounding soil induced by drilling tunneling depend not only on the soil mass properties and the stresses, but depend also on the type and stiffness of the lining of a tunnel **(Brown, et al., 1983)**.

1.1 The Problem Statement of Research

Apart from the analysis and construction of tunnel and its interaction with the ground which becomes operation too complex as a result of the dependence of this interaction on the construction technology. In addition to a complex sequence of operations for different excavation methods, especially tunnel boring mechanie (TBM), such as excavation, front support, shield advancement, grouting of the annular void, along with the shield and grout consolidation, the determination of settlements in the surface is very significant in tunneling.

However, in geotechnical engineering, these deformations can be predicted with accuracy, apart from the appreciation of soil stability where large deformations of either excavation can lead to undesirable consequences such as damage to adjacent structures.

In order to predict the reliably of deformations and distribution of stresses using a numerical method, the finite element method (FEM) analysis has become a popular tool which can simulate construction stages for tunneling.

1.2 The Objectives of the Research

This study concentrates on the behavior of the stresses and settlement through the construction of the tunnel using tunnel boring machine with its advance into the different soil layers. The main aims of the study are:

1. To build the numerical model using the finite element method of the tunnel model under constructed buildings and simulate of the constructed stages by the (TBM).
2. To calculate and analyze the behavior of settlement and stress of the upper part of soil and down part of the soil for tunneling in addition to the soil around the face of the tunneling.
3. To predict the settlement of adjacent areas and determine safe areas during the advance of the TBM up to the final phase of the tunnel construction.

1.4. Methodology

To achieve the objects of this study, a research methodology is developed using the finite element method by model building for predicting the behavior of stresses and settlement during construction stages of the tunnel considering the various area of work necessary to perform and obtain the results. This methodology is summarized as follows:

1. A comprehensive review of the previous studies to identify the models which should be used to simulate ground movement induce by tunneling through simulation of the tunnel boring machine operations and the important parameters for the work of this simulation.
2. Data collection which are utilized to construct the model by using finite element method.
3. Data obtained to match with the conditions of the study area and requirements of the model.
4. Simulating method of the tunnel construction. As a result of this simulation, the settlement of the adjacent structures can be predicted that induced by the tunnel and determine safe zones.
5. Analysis for input parameters of the numerical model.

1.5 Thesis Layout

The scope of this thesis consists of five chapters. Chapter one presents a general introduction and information about tunnel, excavation machines, and the target of the present study.

Chapter two covers a brief review of the available literature related to the tunnels, different excavation tunneling methods. This includes the properties, advantages, and disadvantages of each method of drilling methods, in addition to the use of each method.

This chapter also presents a review about previous studies that deal with the effect excavation machine on the adjacent soil during drilling and review about methods to predict the behavior of stresses and settlement of soil.

Chapter three presents the methodology of the numerical model for tunneling constructed stages and procedures for building model. This chapter also shows the data of the investigation of field and laboratory for area limited.

Chapter four includes the presentation of test results and their discussions while chapter five reviews a summary of the main conclusions and recommendations for future work.