Ministry of Higher Education
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College of Engineering

PERFORMANCE ANALYSIS FOR TUNNELING PROCESS IN ROCKS USING FINITE ELEMENT METHOD

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

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ (1)

الْحَمْدُ لِلَّهِ رَبِّ الْعَالَمِينَ (2) الرَّحْمَنِ الرَّحِيمِ

(3) مَالِكِ يَوْمِ الدِّينِ (4) إِيَّاكَ نَعْبُدُ وَإِيَّاكَ

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صِرَاطَ الَّذِينَ أَنْعَمْتَ عَلَيْهِمْ غَيْرِ الْمَغْضُوبِ

عَلَيْهِمْ وَلَا الضَّالِّينَ (7)

صدق الله العظيم

سورة الفاتحة

Dedication

I Wish to Dedicate My

Thesis to The Light of My Eyes

My Beloved Parents (My Mother

and Father)With All My Respect,

Love and Gratitude .....

Dhuha Hussien Ali

2020

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"In the name of Allah, the most beneficent, the most merciful". First praise be to "Allah" who gave me the strength and health to work and enable me to achieve this research

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Performance Analysis for Tunneling Process in Rocks Using Finite Element Method

by

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ABSTRACT

In this research study, The prediction of the stress behavior and the effect of ground motion for applying the tunneling machine during the drilling process. A numerical model was developed for a tunnel project in Sulaymaniyah Governorate. For this purpose, a file of site investigation has been used for the rocks, which is the Hassan Kanoush Dam Project.

The main objective of this study is to investigate the pressure behavior, stress ratio and determine settlement in the study area using the finite element method, and evaluate and determine the effect of a distance to move the drilling mechanism and progress to the rocks. The model is operated as three dimensional in drainage into clay stone rock and is filtered by using the applied Hoek-Brown model.

Results are shown in terms of depth of stress curves. Those total vertical and horizontal pressures. Changes in stress conditions compared to rocks at the site are taken into account. Three vertical sections are select to study the effects of the TBM tunnel on the surrounding rocks. The first section ($x = 0$) passes through the center of the tunnel. The second section is located near the side edge of the tunnel, while the third section is chosen approximately off the edge of the tunnel. It is believed that the details mentioned in the analysis will provide a complete view of the pressure change in the rock. The strains caused by a boring process are presented differently and simply. This method reflected the movement of the rocks

and the stability of the rock surface. The deflected shape of the tunnel is also shown. By performing an axial symmetric FE analysis, calculation results revealed significant pressure changes occurring in rock regions near the tunnel boundaries. In other words, proximity to rocks is mostly affected by the tunnel. The stress effect fades for both diameters for the side of tunnel(1.33-2)D, in the top of tunnel (0.167-0.5)D, and in the lower of tunnel(2.92-5)D. All changes in the state of stress compared to the in-site rock depend on rock profile in site. The highest surface settlement is observed immediately above the tunnel due to processes of TBM excavation which formed the first phase of the tunnel method. The behavior of surface settlement curve depends on the nature and shape of rock position layers. For other phases, the surface settlement is observed during tunnel construction phases, where it slowly decreases or converges when it is away from the drilling zone which established these TBM advancement phases since the distance is equal to 1.5 m. The maximum depression is recorded as the approximate top of the tunnel being 0.045 mm (diameter 6 m) and 0.16 mm (diameter 12 m).

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DS	Disturbed Sample
G_s	Specific Gravity
LL	Liquid limit
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
Ø	Angle of internal friction
γ	Total unit weight
γ_{wet}	Wet Unit Weight
HB	Hoek-Brown Model
LE	Linear Elastic Model
TBM	Tunnel Boring Machine
DBM	Drill and Blast Method

CHAPTER ONE

INTRODUCTION

1.1 Introduction

The tunnel is a structural, underground corridor. The first tunnel under the Euphrates river, which was 900 m long, was constructed in Babylon between 2180 and 2160 BC. Since then, passageways for water and people have been tunneled throughout the world using simple tools **(Souza, 1986).** Tunnels are a means of transport.

Because of the growth of many cities, underground spaces have been used, and since urban space has become more limited, building systems such as tunnels are more effective in the construction of infrastructure and are important in the development of large cities. In 1863, the first subway railway line opened in London. More than 100 cities around the world have subsequently introduced underground transport networks, and more than 50 percent of them have been built or extended **(Hell a well et al., 2001).**

The tunnels are typically underground transport systems, their advantages of improving connectivity and shortening the lifeline between countries. There are several cross-sections widely used for tunnels, such as circular sections elliptical, and rectangular tunnels. The tunnel can be excavated on all surfaces, ranging from sand, gravel and clay to the roughest rocks **(Rasheed, 2006).**

The excavation indicates removal of part of the ground within defined limits, or for building purposes. Construction criteria for these structures in urban areas have resulted in the need for a secure and efficient method for deep excavations without having a significant impact on neighboring structures.

The excavation methods changed in the last years after tunnels became economically more desirable in the urban setting **(Obaid, 2001).** For

example, the tunnel boring machine method (TBM) has been widely used in tunnel construction, particularly in soft ground where deformation is the most important purpose, as shown in Figure (1.1).

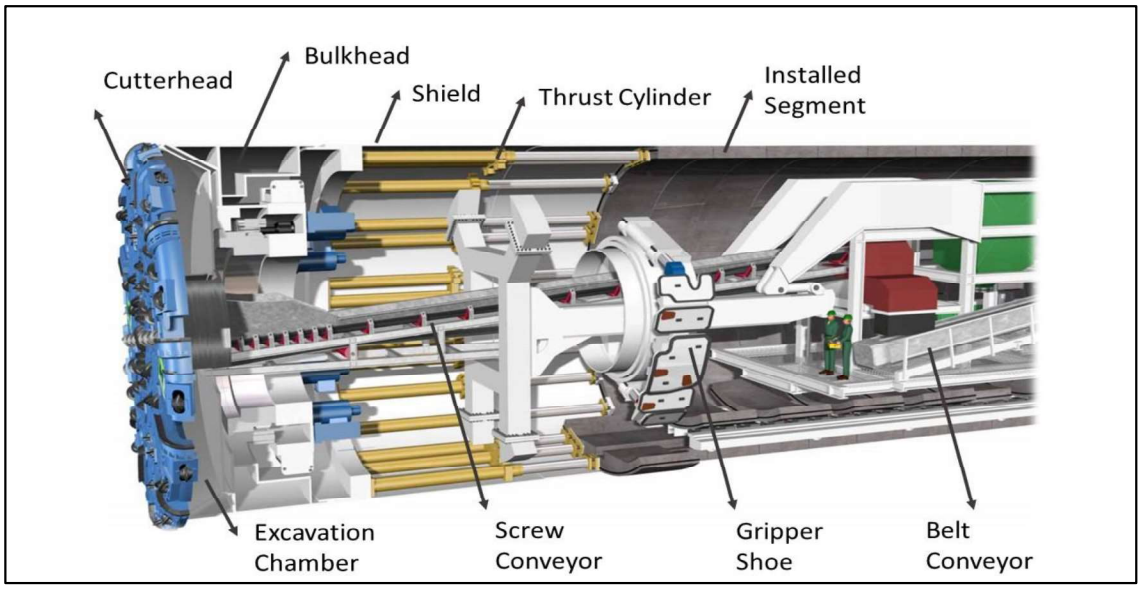

Figure (1.1): Tunnel boring machine elements **(Obaid, 2001)**.

The tunnel boring machine cross-section may have both round and rectangular shapes. Benefit from tunneling techniques, and the need to avoid surface disruption during excavation **(Dimitrios Kolymbas, 2005).**

Rock drilling appears to release pre-existing stresses and change the surrounding stress field which can contribute to flexible deformation; however, if the stresses are strong enough, the rocks deform inflexibly. The consequence of the subsequent process is rock breakage, which reduces the carrying ability of the rock mass **(Ewy and Cook, 1990).**

Methods of tunnel construction are a significant problem in urban areas due to ground surface movement that causes unnecessary deformations that can cause potential damage to nearby roads and neighboring structures **(Yahya and Abdullah, 2014).**

Depending on the various construction methods used in several various tunnel cross-sections, the amount of surface settlement can vary

which leads to different clusters. As a result, building techniques have a considerable effect on land surface settlement **(Sharifzadeh, et al., 2013).**

The stresses and ground movement in the rock caused by drilling tunneling depend not only on the properties of the rock mass and the stresses but also on the form and rigidity of a tunnel lining **(Brown, et al., 1983).**

1.2 The Problem Statement of Study

Regardless of the tunnel's study and design and its relationship with the ground, which is a rather complicated process because of the reliance of this relationship on building technology. In addition to a complex series of processes for various drilling methods, in particular, tunneling mechanics (TBM), such as excavation, front support, shield development, annular space fillers, along with shield and compact grout, the determination of surface settlements is very critical in tunneling.

However, these deformations can be predicted with precision in geotechnical engineering, irrespective of estimating the stability of the rocks where major deformations of any of the excavations can lead to undesirable consequences, such as damage to adjacent structures.

FEM has become a common tool that can simulate the construction of tunnel stages to predict the strength of deformations and distribute stresses using a numerical method.

1.3 The Objectives of the Study

This study focuses on the conduct of stresses and settlement by using tunnel boring machine with its advance into the rock layer by constructing a tunnel. The study's principal aims are:

1. Creating the numerical model using the tunnel model's finite element method and simulate the (TBM) built stages.

2. Calculating and analyzing the settlement and stress action of the upper part of the rock and down part of the rock for tunneling along with the rock around the tunneling face.
3. Predicting the settlement of neighboring areas and defining secure areas by advancing the TBM to the final tunnel construction process.

1.4. Methodology

A research methodology is developed to realize the objects of this study by using the finite element method by model building to predict the behavior of stresses and settlement during tunnel construction stages, considering the different areas of work necessary to perform and obtain the results. This methodology is summarized as follows:

1. The overall analysis of the earlier studies to define the models that should be used to simulate ground movement induced by tunneling by simulating the tunnel boring system operations and the essential parameters for the work of this simulation.
2. Use the finite element method to collect data that is used to construct the model.
3. The data acquired to fit the requirements of the study area and model.
4. Simulation of method of building tunnels. As a result of this simulation, it is possible to predict the localization of adjacent tunnel-induced structures and identify safe areas.
5. Analysis of numerical model input parameters.

1.5 Thesis Layout

There are five chapters to this study. Chapter one offers a general overview and knowledge about tunnels, excavation machines, and the purpose of this study.

Chapter two includes a brief overview of the tunnel-related literature available, various tunneling methods for excavation. It requires, besides the use of each tool, the properties, advantages, and disadvantages of each drilling process.

This chapter also presents a review of previous studies dealing with the effect of excavating machine on the adjacent rock during drilling, and reviews of methods for predicting stress behavior and rock settlement.

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

Chapter four consists of presenting results of finite element method (numerical analysis) and explanations while chapter five discusses a list of key findings and suggestions for future research.