CHAPTER I

INTRODUCTION

1.1 Motivation and Background

As the problems of floods and transportation in many parts of the world have been seriously increasing for many years, some countries have taken several measures to solve these problems. One of the most acceptable solutions is a use of an available subsurface space for tunnel constructions, since these structures can be served either for subway transportation, water supply, or flood diversion.

The tunnel construction by using the cut-and cover techniques in urban areas invades the social lives of the people who are living along the construction route as well. One of the strongest impacts of these techniques on people in their vicinity is traffic congestion. In addition, these techniques usually cause the excessive ground surface movements. In order to eliminate or to reduce such problems, the tunnel boring machines (TBMs) has been invented. The most well known TBM has been used in the Southeast Asian region, especially in Thailand, is Earth Pressure Balance (EPB) shield machine. The use of EPB for soft ground tunneling is a relatively new but it is very efficient because it uses high technology developed for civil engineering works. This EPB machine enhances the availability of underground space through soft-soil tunneling, which is heavily in demand especially in such a crowded metropolis as Bangkok. The machine is possibly adjusted to be used in complicated geological conditions, for example clay, silty clay, clayey and silty sand soils below the water table where engineers previously found it difficult for tunnel construction.

The tunnel constructed using an EPB machine seems to minimize the volume of ground loss and provide a perfect appearance of the permanent structure; however, the machine operators and workers must have enough competency and knowledge relative to this work. Moreover, the prediction of ground and structural movements induced by the tunnel excavation should be accurately given in order to protect the surrounding environment and accommodate daily activities on the ground surface.

The latter could be fulfilled based on the experiences and back-analyses of the case studies from the previous tunneling projects as well as the considerations used in the analysis model.

For the past several decades, the approximate (empirical and analytical) methods have been extensively used for estimating the ground movements responding to the tunnel excavations as well as determining the internal forces of concrete lining. Nevertheless, the use of these methods seems to be difficult for the tunnel constructed in such extreme conditions as urban areas with heterogeneous soil conditions and water bearing soils presented and also with different underground obstructions for example pile foundations. To facilitate these problems, many Finite Element Method (FEM) and Finite Difference Method (FDM) programs have been developed with the window base. In the elastic or elasto-plastic analysis, the soil stiffness (E or G) and poisson's ratio (ν) play an important role in predicting the movements of the ground surface and subsurface as well as the structures in the analysis model.

Regarding the soil stiffness, it is used as a base parameter for designing a tunnel. Mair (1993) has proposed a wide range of shear modulus (G) obtained in the interval of shear strain between 0.1 and 1%. In order to simplify the way for selecting soil stiffness, the designers have linked this parameter to the shear strength with a constant number according to their work experiences on a specific area such as Prinzl and Davies (2006) used FDM with the undrained soil stiffness $E_u = 225c_u$ and $E_u = 400c_u$ for soft and stiff clays respectively to design the tunnel in Bangkok (North Contract of MRTA subways). However, to avoid the unrealistic heave in the area underneath the tunnel, the unloading elastic modulus $E_{ur} = 375c_u$ and $E_{ur} = 800c_u$ were applied to this area for soft and stiff clays respectively. However, Teparaksa (1999) and Teparaksa and Heidengren (1999) proposed the value $E_u = 240S_u$ and E_u=$480S_u$ for soft and stiff clay, respectively, to predict the ground displacement due to EPB shield tunneling in Bangkok without distinction the loading and unloading areas. In addition, Teparaksa (2005a) used the value of drained modulus $E'(\text{kN/m}^2) = 2000.N_{60}$ (N_{60} is the SPT N-value at 60% Energy Ratio) for silty sand to design a tunnel boring in Bangkok subsoils.

1.2 Statement of the Problem

The study of ground surface and subsurface movement behaviors is remained the questions for tunnel researchers, especially for the tunnel bored in the densely populated urban area where the several obstructions are usually found along the tunneling route. Several researchers have conducted studies on tunnel construction in order to provide a better prediction related to these issues such as Peck (1969) proposed a normal contribution curve to predict the transverse settlement profile based on the field monitoring. Vereuijt and Booker (1996) proposed an analytical solution, which is an extension of a method suggested by Sagaseta (1987), for a tunnel in a homogeneous elastic half-plane to predict the ground surface and subsurface movements caused by a uniform radial ground loss. However, this analytical solution was modified by Loganathan and Poulos (1998) by redefining the equivalent ground loss parameters with respect to the gap parameter in order to predict the ground movements around the tunnel in clays.

The geological and existing conditions along the tunnel route vary depending on regions, and the empirical method of Peck (1969) is limited to such various conditions. The analytical solutions are currently proposed and based on only a few case studies for the tunnel in clays. In addition, the surface loads as well as their structures were not taken into account for the prediction.

The understanding of ground movement behaviors leads to a minimization of their displacement as well as the excessive settlements of the structures located above the tunneling route. Based on the studies of tunnel excavation and back-analyses of the case studies from the previous tunneling projects located in the same region using FE analysis program, this minimization could be achieved. Therefore, this research intends to study the behaviors of ground surface and subsurface deformations and to do a back analysis based on the FE program in order to help designers to make an accurate prediction as well as to make the most effective tunnel in Bangkok, which can last for a long time.

1.3 Research Objectives

This thesis is limited to the description of only three aspects as follows:

1.) The behaviors of ground surface, subsurface and structural movements in response to the EPB shield machine tunneling in Bangkok subsoils for Saensaep-Latphrao Phrakhanong Flood Diversion Tunnel project.

2.) The use of the Mohr Coulomb soil model to back-analyze the ground surface and subsurface displacements due to EPB tunneling based on the results of field performance in various conditions such as driving beneath the bridge foundations, service roads, and through the underground obstructions. To achieve this objective, the two-dimensional (2D) Finite Element Method (FEM) program will be carried out.

3.) The confirmation of the design assumptions, which are resulted from the second objective, and the new approach and appropriate parameters in design of segmental linings will be proposed.

1.4 Research Scope

The scope of this study is limited to the behaviors of ground surface and subsurface movements as well as the structural settlements of Bangkok subsoils: silty sand and silty clay from tunneling work of the Saensaep-Latphrao Phrakhanong Flood Diversion Tunnel project. Two different locations along the tunneling route where the most comprehensive monitoring system for this project was implemented are selected for this study: one is Klongtan Bridge area where the tunnel was bored in dense silty sand and the other is BTS-Sukhumvit area where the tunnel was bored in hard silty clay layer. Based on FEM program, the back analyses and simulation are carried out to obtain the appropriate design parameter of Young's modulus. The different steps of calculation were performed based on 2D-FEM program to simulate the 3D advancement of the tunnel, and the elasto-plastic failure criteria of Mohr Coulomb soil model was used in this research.

1.5 Strength of the Study

The strength of this study is the consistent agreement of FE-simulation results with field monitored data for tunnel located in dense silty sand and hard silty clay layers, where different types of surface and underground obstructions were present. These results could be achieved due to the adequate dimension of the model to be analyzed, the generated mesh and especially the selected elastic modulus for each soil layer. Therefore, these can be applied as a practical guideline for the designers to follow in order to obtain a more accurate prediction of ground and structural movements as well as a safe, efficient, and economical tunnel construction in Bangkok.

1.6 Layout of the Thesis

The thesis is divided into eight chapters. The first chapter gives an overview of the whole study while chapter two reveals different types of tunnel boring machines and the methods of tunnel construction related to each machine are also briefly described. However, the EPB shield tunneling method used in the project of this research is explained in detail in the last section of the chapter. Chapter three provides an overview of the geological conditions of Bangkok soil, an introduction of the subsoil profile along the tunnel route of the current tunneling project and the special characteristics of the underground water. In chapter four, several causes of ground movements due to tunnel excavation are mentioned. In addition, this chapter also provides a comprehensive overview of some empirical and analytical solutions, which are well known for estimating the ground surface and subsurface settlements induced by tunnel excavation. A short introduction to different ways of finite element simulation of tunnel excavation is given as well. Chapter five introduces the selected locations for this research, highlights the different obstructions and gives a detail of specification of the EPB shield machine used in the project. Additionally, the various monitoring systems and monitoring methods are also given. Chapter six presents an overview of the PLAXIS program and the specific options of the implementation of the program for the analysis in this research. The analysis method used in this study is described in the final section of the chapter.

Chapter seven contains the results of the research and some discussions regarding to the obtained results while chapter eight is the summary of the findings and some recommendations for future works.