Ain Shams University
Faculty of Engineering
Department of Structural Engineering

3D Analysis of Settlement Trough Induced by Tunnelling

A THESIS
Submitted in Partial Fulfillment for the Requirements of the Degree of
MASTER OF SCIENCE IN CIVIL ENGINEERING

Submitted by

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Thesis : **3D analysis of settlement trough induced by tunnelling.**
Degree : Master of science in civil engineering **(Structural)**.

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STATEMENT

This thesis is submitted to Ain Shams University for the degree of M.Sc. in Civil Engineering (Structural).

The work included in this thesis was carried out by the author at the Department of Structural Engineering, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

No part of this thesis has been submitted for a degree or a qualification at any other University or Institution.

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ABSTRACT OF M.Sc. THESIS

Ashraf Ahmed Reda Mohamed El-Shamy,

3D analysis of settlement trough induced by tunnelling,

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In some cities, tunnels are located at shallow depth under densely populated zones through soils or soft rocks and their construction may have unfavourable effects on existing facilities and structures. Therefore, it is highly essential to evaluate in detail the expected ground settlement hazards before starting the tunnel construction.

In order to make sufficient assessment of settlement hazard, many factors should be considered in the calculations. For instance, tunnel depth and diameter, construction methods and details, 3D effect of tunnel construction, initial state of stress and the stress-strain behaviour of the surrounding soil. Due to high complexity of this issue, many investigations were made, and are still needed, on this topic by researchers all over the world.

3D numerical modelling should be used to simulate the construction of the tunnels as tunnel construction is a three-dimensional process. Also, 3D modelling is important to ensure proper analysis of ground surface settlement, and stress-strain situation in the soil and the lining. During tunnel construction, large number of processes takes place such as the details of segmental concrete lining, the applied face pressure, shield overcutting and the grout pressure. All these processes can be taken into consideration by performing a three-dimensional (3D) finite element model of a mechanized tunnelling (using TBMs).

In the past, many researchers studied the constitutive model effect on the calculated soil displacement but a few of them who clarified its effect on the tunnel behaviour. Many of them concluded that the settlement trough resulted from using simple constitutive models is shallower and wider than the one observed experimentally. Some of their studies indicated that using an elasto-plastic constitutive model containing strain hardening is very important in numerical modelling. By using these models, many of the basic characteristics of soil behaviour are taken into consideration such as the dependency of the modulus of stiffness on the state of stresses in soil and the changes in its value according to the different phases like unloading, reloading and primary loading.

El-Nahhas and El-Mossallamy (2009) illustrated that utilizing the small strains constitutive model can improve the prediction of differential settlement above tunnels in 2D analysis. Therefore, the double hardening soil model (DHS-Model) and the hardening soil model under small strains (HSSS-Model) are adopted in the present research.

Through this thesis, 2D and 3D modelling of tunnel construction are conducted using PLAXIS software to assess ground settlement associated with the construction of a section of the Greater Cairo Metro. The results of the numerical modelling of the case study are verified by comparing them with the compiled field measurements during tunnelling activities.

KEYWORDS: Tunnel, T.B.M., Constitutive Model, Hardening Soil, Ground Surface Settlement, 3D Numerical Modelling, Finite-Element Method

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SUMMARY OF M.Sc. THESIS

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After a short review of the previous related research studies, the main goal of this research is to develop a three-dimensional model that can capture the different aspects of soft ground pressurized shielded tunnelling. Also, a main target for the 3D numerical modelling is to show the constitutive model effect on the ground surface settlement due to tunnelling by adopting DHS-Model and HSSS-Model in the present research. To achieve these goals, 2D and 3D modelling of tunnel construction were conducted using PLAXIS software to assess ground settlement associated with the construction of a section of the Greater Cairo Metro. Results of the numerical modelling of the case study are verified by comparing them with the compiled field measurements during tunnelling activities.

The thesis consists of six chapters. The contents of each chapter are briefed as follows:

Chapter (1) gives an introduction to this thesis; it discusses the importance, the scope and the main objectives of the thesis.

Chapter (2) presents different methods for constructing underground tunnels. It discusses the main differences between open face tunnelling and closed face tunnelling. It describes the mechanism of conventional tunnelling, tunnel boring machine without shield and the principles of both open face and closed face shield tunnelling. Different tunnelling projects in Egypt are listed.

Chapter (3) contains a literature review of common elementary computational methods utilized for the estimation of ground deformations induced by tunnelling. Also, this chapter presents the empirical methods for the assessment of transverse surface and subsurface settlement troughs, horizontal surface displacement and longitudinal surface settlement trough.

Chapter (4) presents a brief discussion about the finite element method including analysis steps sequence and the different types of the elements used in analysis. Also, different constitutive soil models are highlighted. In addition, the constitutive soil models used in this thesis are briefly discussed.

Chapter (5) focuses on 2D and 3D analysis of the shielded tunnelling construction of Greater Cairo Metro–Line2. Results are verified by comparing the calculated deformations with the compiled field measurements during tunnelling activities. Effect of the utilized MC-Model, DHS-Model and HSSS-Model on the calculated stresses and deformations in 2D and 3D analyses are discussed.

Chapter (6) presents a summary of this thesis along with different concluding points of the considered case study. Finally, recommendations for further studies are pointed out.

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