CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Cities are not sustainable without infrastructure, as increasing population pressures drive the need for more infrastructure while simultaneously leading to the consumption of more surface space, the best choice for much of this infrastructure will be a tunnel. In 1863 the first underground railway line was opened in London. Since then over 100 cities worldwide have implemented underground transport systems and over 50% of them are undergoing development or expansion (Hellawell et al., 2001). Tunnels can be significantly cheaper than the over-ground solutions when costs for acquiring land or moving utilities are considered.

Tunnel construction, particularly in soft ground conditions, can cause ground movements which have the potential to cause a restriction of services, and damage to surface or other subsurface structures. An increasingly significant portion of the cost of tunneling is due to protective measures required to reduce the risk of damage to these structures. A better understanding into the mechanisms that control the tunneling induced deformations could reduce costs and help avoid disputes and resolve claims.

General geotechnical conditions, and more particularly soil-structure interaction considerations, can have a significant impact on the choice of the horizontal and vertical alignment (Attewell et al., 1989). For example a more circuitous route or deeper tunnel may be required to avoid damage to structures or expensive protective measures may be required. If building damage assessment methods are overly conservative this could lead to more expensive tunneling or excessive and unnecessarily costly protective works. With more accurate and efficient methods of assessing tunnel-induced ground movements and the risk of associated building damage, such costs can be minimized and construction operation and contractual arrangements can be more easily made.

Investigating methods of assessing the impact of soft ground tunneling on buildings is thus the thrust of the research described in this thesis. In particular, this research is concerned with developing a settlement prediction/building damage assessment (SP/BDA) charts based on verified finite difference model results, these charts can improve the preliminary building damage risk assessment and mitigation plan.

1.2 RESEARCH OBJECTIVES

During and after tunnel construction, the surrounding buildings are subjected to different deformations and strains due to faces losses, shield losses, tail losses, and long term losses. These tunnel induced deformations and strains can cause damage to the surrounding buildings and other structures. Current prediction approaches are conservative and lead to unnecessary expenditure in the design and construction of protective measures, thus the objectives of the research described in this thesis are:

1. To have a better understanding into the mechanisms that control the tunneling induced building deformations.
2. Introducing a three dimensional elasto-plastic finite difference model to predict building damage due to tunnel construction taking into account the interaction between building stiffness, tunnel and the soil.
3. Verifying the proposed three dimensional finite difference model based on observed field measurements, and previous numerical analysis.
4. Studying the effect of: soil stiffness, building eccentricity, building length/width ratio, and building stiffness on building damage due to tunneling.
5. Refining the prediction of tunnel induced building damage by generating settlement prediction/building damage assessment charts. These charts can be incorporated in the current damage risk assessment and may reduce the number of buildings for which an expensive, detailed evaluation has to be performed.

1.3 THESIS LAYOUT

Chapter 2: A literature review presents a brief description of different constraints facing tunneling in soft ground and associated induced ground movement. The currently used design approaches for predicting tunnel induced soil movement; building damage prediction and building protection of such induced ground movement are discussed. Previous numerical studies which focus on tunnel-soil-structure interaction are presented; assumptions and limitations on each approach are briefly discussed.

Chapter 3: This chapter deals with the finite difference modeling of tunnel construction in soft soils. Brief descriptions of the finite difference method used in this thesis are introduced. Mathematical representations of the geotechnical problems and factors that may affect the accuracy of the finite difference modeling are discussed, including the influence of the tolerated equilibrium error, mesh dimensions, and mechanical force ratio value. Different aspects of geotechnical numerical modeling was discussed to assess tunnel-soil-building interaction such as soil initial stress state, excavation and construction sequence, soil material model behavior, and building stiffness.

Chapter 4: This chapter discusses the implementation of the numerical modeling procedures for this research project. It describes the soil geometrical modeling, its initial stress state, and its material behavior then a description of the tunnel construction including pre-support shotcrete, tunnel excavation and the installation of the final lining. A description of two case studies; A building behavior due to construction of Greater Cairo Metro Line 3, and Neptune House building due to construction of the Jubilee Line Extension Tunnel in London. For each of the two case studies; an overview of the site under consideration, a description of the observations made in the field, the aims and assumptions of the numerical model for that specific site, the results obtained and a comparison with the observations, and a discussion of the lessons learnt relevant to the verification of the numerical modeling procedures are introduced.

Chapter 5: This chapter describes the parametric study which carried out to investigate the effect of: soil stiffness, building eccentricity, building width/length ratio, and building stiffness on building damage due to tunneling, a brief description of the derivation of building deformation control parameters are also introduced.

Chapter 6: Based on the data derived from the parametric study, a preliminary settlement prediction/building damage assessment charts are introduced with a building damage assessment example to facilitate the use of these charts. Charts assumptions and limitations are briefly discussed with a detailed procedure of how to use them to predict building deformation control parameters and related damage category. A brief comparison between the prediction of building damage category using the proposed charts and the modification method proposed by Potts and Addenbrooke (1997) and amended by Franzius et al. (2006) are also introduced.

Chapter 7: This chapter contains concluding remarks, summarizing the main findings of the project. It draws together the experience gained in parametric study, and assesses how effective the proposed settlement prediction/building damage assessment charts had been. It considers how the actual project activities carried out varied from those originally planned and, and it contains recommendations for future research.