CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

After the analysis yields all results of the research problems and after some possible causes related to the monitoring equipment and performances are identified, some positive conclusions and recommendations are given in the following sections.

8.1 Conclusions

The 2D-FE analyses were carried out to back-simulate and to analyze the ground surface and subsurface displacements as well as bridge structure and building settlements. The study yields the following findings:

1.) Behaviors of ground surface and subsurface displacements are classified into three phases as deformation in front of shield face, deformation within the length of shield body when the cutting face has passed and the deformation behind the shield which consists of tail void deformation and subsequent settlement. The average tail void settlement for the tunnel in dense silty sand and hard silty clay layers is about 77% and 35%, respectively, of the total settlement measured after three months. In both cases, the average magnitude of settlement one week after the pass of the TBM reaches to 90% of the settlement after three months, which is considered as the final short-term settlement.

2.) Elasto-plastic failure criteria of Mohr Coulomb soil model can be satisfactorily used for back-simulation of the ground surface and subsurface movements caused by tunnel excavation.

3.) When EPB shield bores the tunnel in dense silty sand underneath the Klongtan bridge pile foundation and in hard silty clay layer beside the BTS's sky train pile foundation, the 2D-FE analyses yield similar results to the analysis of the field monitored data at the ground surface and subsurface settlements whereas the lateral displacement is not well simulated.

4.) The results yielded from the empirical method for surface settlements are also in agreement with those from the field monitored data and FE analyses.

5.) The surface settlement trough width, *i*, found in this research is between $0.24z_0$ and $0.35z_0$ for tunnel excavated in dense silty sand layer while this trough width increases to $0.46z_0$, which is wider, for the tunnel in hard silty clay.

This study confirms that the ratios of undrained soil stiffness over the undrained shear strength (E_u/S_u) are 240 and 480 for soft and stiff clays respectively, and the value for medium stiff clay is taken as the average of these two intervals. In addition, the drained stiffness E' (kN/m^2) = 2000.N_{60} for medium and dense silty sand layers has also been confirmed in this research study. Therefore, the proposed undrained elastic stiffness (E_u) for tunnel design in Bangkok can be determined from the undrained shear strength (S_u) based on the ratios of 240, 360 and 480 for soft, medium and stiff clayey soil respectively. Furthermore, the drained stiffness (E') of sandy soil can be estimated from the SPT test as 2000. N_{60}. Since the formulation of FEM program may not follow the unique concept, the suggested soil stiffness is restricted to the 2D PLAXIS program in which the Mohr Coulomb model is selected and the ground loss is simulated by tunnel contraction.

8.2 Recommendations

In order to improve the quality of geotechnical works in terms of academic research, which is the major sources for updating the knowledge of geotechnical engineers, the following recommendations are beneficial to future research:

a.) To get a realistic longitudinal deformation, the monitor should be frequently conducted when the shield face is moving within a distance about three times its length, i.e. 25 m, before and after the controlled section.

b.) Although the output might slightly vary from one to another, the different kind of soil models can be used and the analysis results have to be compared among them and with the real monitored data obtained from the field performance.

c.) If the deformation of tunnel wall has to be studied, the new invented devices such as the *Tunnel Deformation Meter* presented by Hashimoto et al. (2006) should be used since this monitoring system provides a qualitative data.

However, at least one reference point must be surveyed to get the new coordinates of its current position. Therefore the polar deformation of the tunnel wall could be correctly plotted.