Chapter 1

INTRODUCTION

1.1. BACKGROUND

Structures such as walls, anchors, and braces are often used to support deep excavations, especially in urban areas, since the space available for construction is often very limited. Performance of deep excavation support systems is related to both stability and deformation. Ground deformations around excavations can damage buildings, streets, and utilities. Therefore, understanding and being able to predict the performance of deep excavations is an important issue for geotechnical engineers.

The task of predicting the performance of deep excavations is challenging, because many factors influence the performance of deep excavations. Soil conditions, groundwater conditions, and the stiffness of the support system are three that are always important, and experience shows that construction details and quality of workmanship can be equally as important in particular cases.

There are many published case histories of deep excavations. Peck's 1969 State of the Art Report for the Seventh International Conference on Soil Mechanics and Foundation Engineering was the first comprehensive review, and a few others have followed. There is a continuing need for a review and analysis of recent published data on excavation support system performance. This was one objective of the study presented in this dissertation.

Finite element analysis is often used to predict the performance of deep excavations. Many researchers have used finite element analysis to study the factors that control their performance. Analysis of deep excavations is one of the intended applications for SAGE, a finite element program. SAGE was created at Virginia Tech by Clark Morrison (1995) under the supervision of Professors J.M. Duncan and George M. Filz for analyzing soil-structure interaction problems.

A second objective of this study was to apply SAGE to a complex modern deep excavation. This would permit evaluation of the effectiveness and performance of the program, while providing an opportunity to learn about the behavior of deep excavations. The excavation for the Dam Number 2 Hydroelectric Project near Dumas, Arkansas was selected for examination. Figure 1.1 shows an aerial view of the completed excavation. The Arkansas Electric Cooperative Corporation (http://www.aecc.com), which owns the project, and the design firm for the project, Benham Holway Power Group, provided information about the design, construction, and performance of the project. The hydroelectric plant is scheduled to begin operating in the fall of 1998.

The first version of SAGE, developed by Morrison (1995), was only applicable to uncoupled soil deformation problems (i.e. only completely drained or undrained soil behavior could be modeled). A third objective of this research study was to modify SAGE for analysis of problems involving partial drainage, or consolidation. Biot (1941) was the first to publish the theory of three-dimensional consolidation, which is based on coupling soil deformation with pore fluid flow. This theory is well accepted in the field of geomechanics and numerous authors including Sandhu and Wilson (1961), Christian and Boehmer (1970), Hwang et al. (1971), and Zienkiewicz and Taylor (1991) have presented finite element formulations for Biot's theory. The implementation of Biot consolidation into SAGE during the course of this research study is based on the work of these researchers.

Figure 1.1. Aerial photo of Dam Number 2 excavation.

The implementation of Biot consolidation was only one of several changes made to SAGE during this study. The goal of these changes was to increase the usefulness of the program for analyzing soil-structure interaction problems. One of these changes was to extend SAGE to solve axisymmetric problems in addition to plane strain problems. Methods for establishing pore pressures and simulating water loads caused by steady state seepage or changes in piezometric level during uncoupled analyses were also implemented.

1.2. ORGANIZATION

The remaining chapters in this dissertation describe the work performed to enhance the capabilities of SAGE and the research on deep excavation support systems.

In Chapter 2, a review of literature on support systems for deep excavations in soil is presented. Lessons learned from the publications reviewed about factors that influence the performance of deep excavations are presented. Recent published experiences with deep excavations are also summarized. A comparison is made of maximum wall and ground movements from recent deep excavations to data published by Goldberg et al. (1976).

The implementation of Biot consolidation into SAGE is described in Chapter 3, and Appendix A contains the derivation of the formulation. The details of the computer implementation are discussed in Appendix B. Three example problems demonstrating the analysis of consolidation problems with SAGE are presented in Chapter 3. The analytical solutions to these example problems are given in Appendix C.

In Chapter 4, the extension of SAGE to axisymmetric conditions and the others changes made to SAGE during this research are described.

In Chapter 5, design and construction of the deep excavation support system for the Dam Number 2 Project is described. The project was extensively instrumented and the results of the monitoring program are presented. The soil and site conditions for the project are given in Chapter 6.

SAGE analyses of the Dam Number 2 excavation are presented in Chapter 7. The development of the finite element model is described, and the results of the analyses performed are presented and discussed.

Chapter 8 contains a summary of this dissertation and conclusions drawn from the work performed. Recommendations for future study and future development of the program SAGE are given.

The user's guide for the version of SAGE developed during this study is given in Appendix D.