

# CHAPTER 1

## INTRODUCTION

### **1.1 Description of Soil-Bentonite Cutoff Walls**

A soil-bentonite cutoff wall is a type of subsurface vertical barrier constructed by back-filling a trench with a mixture of soil, bentonite, and water. The purpose of a soil-bentonite cutoff wall is to create a low permeability structure in the ground to contain or direct groundwater flow. Soil-bentonite cutoff walls have been used for contaminant containment, site dewatering, seepage control through embankment dams, and controlling landfill leachate (D'Appolonia 1980; USACE 1996).

Soil-bentonite cutoff walls are typically constructed using the slurry trench method. This involves excavating a narrow trench that is stabilized during construction by filling the trench with a slurry. The method is used to construct cement-bentonite cutoff walls and structural diaphragm walls as well as soil-bentonite cutoff walls. For a soil-bentonite slurry trench cutoff wall, the trench is excavated under a bentonite-water slurry. As the excavation proceeds along one end of the trench, the other end of the trench is backfilled with soil-bentonite. The soil-bentonite backfill consists of a mixture of soil, bentonite, and water. Typically, soils excavated from the trench are used but off-site soils can also be used. The bentonite and water typically comes from mixing bentonite-water slurry in with the soil, although sometimes additional dry bentonite is also blended in. The bentonite from the slurry combined with the natural fines of the soil creates a soil-bentonite backfill that has a low hydraulic conductivity.

Cutoff walls using the slurry trench method, which can include soil-bentonite cutoff walls and cement-bentonite cutoff walls, have become the most common type of subsurface vertical barrier (Evans 1991). Other types of subsurface vertical barriers include sheet pile walls, grouted cutoffs, soil-mix barriers, rolled fill cutoffs, vibrating beam walls, and composite walls. Soil-bentonite cutoff walls have gained popularity due to ease of

construction, economic competitiveness (Ryan 1985), and because they are favored at hazardous waste sites (USACE 1996). Use of soil-bentonite cutoff walls is expected to continue to grow in the future (Ryan 1985; Ressi de Cervia 1992; Millet et al. 1992).

## **1.2 Need for Information on Mechanical Behavior of Soil-Bentonite Cutoff Walls**

Although soil-bentonite cutoff walls are common, their mechanical behavior is not well understood. Specifically, there is a lack of information about the stress-strain behavior of soil-bentonite, the in situ state of stress in the soil-bentonite backfill, and deformations of the soil-bentonite cutoff wall and the adjacent ground. Current design procedures are primarily based on past experience with the goal of creating a low hydraulic conductivity barrier. Current design procedures cannot predict the final state of stress in the soil-bentonite or the deformations due to construction of the wall.

Although stress state and deformations are not typically primary design criteria for a cutoff wall, they do influence the cutoff wall's effectiveness. The final stress state in the completed wall is important because it directly influences the hydraulic conductivity of the cutoff (*Barrier* 1995), the susceptibility to hydraulic fracture, and the magnitude of deformations adjacent to the cutoff wall. Deformations adjacent to the cutoff wall can be significant and can cause damage to adjacent structures. One example of such damage occurred at a Raytheon Company site in Mountain View, California. Deformations due to construction of a soil-bentonite cutoff wall caused cracking to a building that was located 20 ft from the cutoff, and a large lawsuit resulted (Filz et al. 1999).

In order to improve analysis procedures and design practices, there is a need for greater understanding of the mechanical behavior of soil-bentonite cutoff walls.

## **1.3 Objectives and Scope of Research**

The objectives of this research are to provide information in the area of the mechanical behavior of soil-bentonite cutoff walls, including the following: stress-strain behavior of

soil-bentonite, in situ stress state of soil-bentonite backfill, and deformations of the soil-bentonite cutoff wall and the adjacent ground. Due to lack of such information, current design procedures do not adequately address the mechanical behavior of soil-bentonite cutoff walls. Specific objectives and the method of approach are described below.

1. Add to the current body of knowledge of soil-bentonite properties.

This objective was accomplished by first summarizing the current body of knowledge that exists in the literature and then executing a laboratory testing program on soil-bentonite. Conventional laboratory tests were performed on three soil-bentonite mixtures to characterize stress-strain properties of soil-bentonite.

2. Evaluate constitutive models and select a model to represent soil-bentonite.

This objective was accomplished by evaluating how different constitutive models match the laboratory test data. Three existing models, the hyperbolic model (Duncan and Chang 1970), the Cam Clay model (Roscoe and Schofield 1963), and the Modified Cam Clay model (Roscoe and Burland 1968), were first evaluated. These models provided a good prediction of the behavior of soil-bentonite under certain loading conditions, but poor predictions in other loading conditions. Two other models were then evaluated that are special cases of a more complicated model by Kutter and Sathialingam (1992). One of these models, referred to as the RS model, was chosen to best represent soil-bentonite and provided a good match of the soil-bentonite behavior in the laboratory tests. The RS model is a non-associative Modified Cam Clay type model that has parameters to change the yield surface and plastic potential surface into ellipses of varying shapes.

3. Model a soil-bentonite cutoff wall using finite elements.

This objective was accomplished using the computer program SAGE (Bentler et al. 1998), which is a finite element program with a coupled fluid flow and deformation formulation that was developed at Virginia Tech. The RS constitutive model was implemented into the finite element code and used to represent soil-bentonite. The following

construction sequences were simulated numerically: trench excavation under bentonite-water slurry, replacement of bentonite-water slurry with soil-bentonite backfill, and consolidation of the soil-bentonite backfill. The model was calibrated with a well-documented case history. There is good confidence in the prediction of deformations in adjacent ground, but there is lower confidence in the prediction of the final stress-state of the soil-bentonite and the settlement of the soil-bentonite in the trench. It is believed that the model over predicts the stresses in the consolidated soil-bentonite and the settlement in the trench.

4. Investigate the influence of several factors on the deformations in adjacent ground.

This objective was accomplished by performing a parametric study using the finite element model assuming sand sites of varying density and OCR. Deformations in adjacent ground were calculated for various soil conditions, soil-bentonite properties, and trench configurations. Conclusions are drawn regarding the importance of these factors on the deformations of the adjacent ground. In addition, a correlation was found between maximum calculated settlement in adjacent ground and factor of safety against trench stability during excavation.

#### **1.4 Overview of Report**

The rest of this report describes the research performed on the mechanical behavior of soil-bentonite cutoff walls for this research project. Chapter 2 describes the literature review of soil-bentonite cutoff walls with respect to mechanical behavior of the cutoff. Chapter 3 describes the laboratory testing program completed on soil-bentonite mixtures and presents the results of the tests. Chapter 4 describes the evaluation of constitutive models for soil-bentonite and selection of the RS model to represent the behavior of soil-bentonite. Chapter 5 describes the case history used to calibrate the finite element model. Chapter 6 describes the development and calibration of the finite element model used to simulate construction of a soil-bentonite cutoff wall. Chapter 7 presents the results of the

parametric study using the finite element model. Chapter 8 summarizes the results and conclusions of the research and presents recommendations for further research.

Corrections made to triaxial data from the laboratory testing program are described in Appendix A. Appendix B contains preliminary finite element analyses performed with SAGE, including verification of the RS model, analysis of arching in a soil-bentonite trench, and deformation of a thin 2-D element of soil-bentonite. The SAGE input data file for modeling the case history is given in Appendix C.