Introduction

Compacted clay liners are the most common design feature for shielding the environment against the detrimental effects of leaching products from a waste disposal site. Their main function is to act as a low permeability layer, in this way minimizing the migration of contaminants from the disposal site to the surrounding subsoil and groundwater. The foundation of a safe barrier-design is adequate transport modelling. Most designs are based on simplified models, assuming simple advection and diffusion (or even only advection) in a rigid (non-deformable) soil-matrix.

The basic mathematical description of the contaminant flow phenomenon is the so-called advection-diffusion-reaction equation (ADRE) — a model which is widely used and thoroughly described in literature. New research focusses on extending this basic model, trying to grasp the complexity of the actual transport problem by taking into account phenomena as e.g. unsaturated flow, coupled flows (caused by thermal, chemical and/or electrical gradients), special chemical reactions (dissolution, precipitation, complexation, biodegradation, ...), deformations of the skeleton (non-linear consolidation, drying/shrinking, cracking,...), heterogeneity and more.

The work presented in this manuscript is part of a larger project aiming at a better understanding of the behaviour of liners systems of waste disposals. While the project looks in general at a whole number of aspects dealing with the behaviour of these hydraulic and contaminant barriers under a variety of conditions, like the ones listed in the previous paragraph, the main goal of this work is to propose and validate a more elaborate theoretical model able to correctly describe the behaviour of compacted saturated mineral liners with respect to contaminant migration in specific situations, like overburden and physico-chemical effects, leading to volume changes in the soil.

Basically, the two phenomena which are the main subjects of the research are *osmotically induced consolidation* and *osmotic consolidation.* Both phenomena have been termed after Barbour [Barbour 1986]. Osmotically induced consolidation results from a fluid flow developing in the soil material in response to osmotic gradients. Osmotic consolidation occurs when changing pore fluid concentrations produce a change in long-range attractive-repulsive forces between the clay particles, inducing a deformation on macroscopic scale.

The osmotic effects have been introduced following the approach described by Barbour. Their mathematical representations were incorporated in a series of coupled flow equations based on the well-known equations by Mitchell and Yeung. The complete description is obtained by combining the flow equations with the conservation laws for the fluid phase and the contaminant mass, leading to a system of parabolic differential equations. To allow for writing a non-linear small-strain consolidation formulation, the osmotic pressure was selected as a stress state variable, linking volume changes to the osmotic pressure through a constitutive relationship.

As a second step, numerical solutions have been obtained using the finite difference and the finite volume method, for boundary conditions relevant to both laboratory migration experiments and actual contaminant migration scenarios. A number of validation exercises have been performed to indicate that the model correctly predicts the expected behaviour.

Finally, as a part of the experimental stage of the research, several tests have been performed. The "standard" tests include batch tests, permeability tests, column tests and compression tests. For the measurement of material parameters governing the osmotic effects, a recently proposed testing method [Malusis, Shackelford and Olsen 2001] has been used.

The structure of this report falls into two pieces. The first holds three chapters dealing with the theoretical side of the problem. The initial chapter gives a quite extended overview of the main chemical, physical and mineralogical phenomena in clays. It acts as a reference for the second chapter, which contains the stepwise development of the mathematical expressions. The numerical formulation of this system of equations will be discussed in chapter 3.

The second part of the work, the experimental part, also contains three chapters in which we give a detailed description of the methodology and equipment of the different tests and finally an overview of the results and their analysis.