Preface

Clay is a commonly occurring porous material that is frequently used in engineering endeavors, but there are also other important porous materials, such as those used in some types of electrodes and as catalysts. Porous media should be examined giving due regard to both the physics and chemistry of the constituents. The purpose of this book is to present an approach that examines porous media from both these aspects, outlining a procedure that combines microscale (or even nanoscale) characteristics with macroscale behavior.

A fundamental outline of mechanics (or physics) and chemistry, including thermodynamics, is provided in Chap. 2, *Introduction to Continuum Mechanics*; Chap. 3, *Non-equilibrium Thermodynamics* and Chap. 4, *Virtual Work Equation, Variational Methods and Energy Principles*.

In Chap. 5, *Classical Theory of Diffusion and Seepage Problems in Porous Media* and Chap. 6, *Classical Theory of Consolidation for Saturated Porous Media* we review and re-organize the classical soil mechanics in terms of modern continuum mechanics; looking at the mass conservation law for a multi-component solution, we show that the diffusion field is strictly connected with the seepage field.

The central results for saturated porous media are given in the following chapters: In Chap. 7, *Introduction to Homogenization Analysis*, a one-dimensional (1D) elastic problem is used and the fundamental notion of the homogenization analysis (HA) is outlined, giving a unified procedure for treating a micro-inhomogeneous material, not only in the micro-domain but also in the macro-domain. In Chap. 8, *Homogenization Analysis and Permeability of Porous Media*, we use Stokes' equation, and then apply the HA scheme to obtain the seepage equation together with the HA-based Darcy's law. Using this procedure we can obtain the true velocity and pressure fields in the micro-domain. A relationship between the HA seepage theory and the conventional theory is discussed. Note that the distribution of water viscosity in the interlayer space between clay minerals is obtained using a molecular dynamics (MD) simulation. A diffusion problem in bentonite, including adsorption at the clay edges is discussed in Chap. 9, *Homogenization Analysis for Diffusion Problem in Porous Media*. The distribution of the diffusion coefficient in the micro-domain (i.e., the interlayer space between clay minerals) is calculated using MD, and the macroscale diffusivity obtained by HA is significantly similar to that obtained experimentally. The purpose of Chap. 10, *Long-term Consolidation of Bentonite and Homogenization Analysis of the Flow Field*, is to analyze the problem of secondary consolidation of bentonite, which is frequently observed in long-term experiments. This phenomenon was considered to be the result of time-dependent deformation such as creep of the solid skeleton of bentonite. However, we show that the secondary consolidation is caused by a non-homogeneous distribution of permeability, which occurs as a result of a change in the crystalline structure during the consolidation process. This result was verified by a series of X-ray diffraction analyses, that continuously measured the crystalline structure at each point of a bentonite specimen.

In the Appendices we outline the essential mathematics and classical thermodynamics, including some chemistry. The section on thermodynamics is referred to in Chap. 3.

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