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APPLIED MICROMECHANICS OF POROUS MATERIALS

EDITED BY

LUC DORMIEUX
ECOLE NATIONALE DES PONTS ET CHAUSSEES,
CHAMPS SUR MARNE, FRANCE

FRANZ-JOSEF ULM
MASSACHUSETTS INSTITUTE OF TECHNOLOGY,
CAMBRIDGE MA, U.S.A.

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PREFACE

All natural composite materials (soils, rocks, woods, hard and soft tissues, etc.) and many engineered composites (concrete, bioengineered tissues, etc.) are multiphase and multiscale material systems. The multiphase composition of such materials is permanently evolving over various scales of time and length, creating in the course of this process the most heterogeneous class of materials in existence, with heterogeneities that manifest themselves from the nanoscale to the macroscale. The most prominent heterogeneity of such natural composite materials is the porosity, ie. the space left in between the different solid phases at various scales, ranging from interlayer spaces in between minerals filled by a few water molecules, to the macropore space in between microstructural units of the material in the micrometer to millimeter range. This porosity is the key to understanding and prediction of macroscopic material behavior, ranging from diffusive or advective transport properties to stiffness, strength and deformation behavior.

The specific nature of the mechanical behavior of multiphase porous materials was early on recognized in the groundbreaking works of M.A. Biot and K. Terzaghi, who developed the macroscopic basis of what is now known as 'Poromechanics'. Ever since, poromechanics has entered a large number of engineering applications ranging from civil and environmental engineering to petroleum engineering and more recently biomechanical engineering. In the 1970's, a breakthrough was achieved with pioneering works that relate macroscopic laws to microstructural properties. Furthermore, as new experimental techniques such as nanoindentation, now provide an unprecedented access to micromechanical properties and morphologies of materials, it becomes possible to trace these features from the nanoscale to the macroscale of day-to-day engineering applications, and predict transport properties, stiffness, strength and deformation behaviors within a consistent framework of 'Micromechanics of Porous Media'. The focus of this course which took place in July 2004, was to review fundamentals and applications of this rapidly emerging discipline of Applied Mechanics and Engineering Science.

This book assembles the lecture notes on 'Applied micromechanics of porous materials'. It is composed of three parts: (I) Transport properties of porous media; (II) Microporomechanics; (III) Materials Applications. Part I and II introduces the two fundamental homogenization theories of micromechanics of porous media, namely asymptotic expansion techniques and linear and nonlinear mean-field theories based on the concept of a representative elementary volume (Part II). The first is illustrated for the upscaling of fluid mass transport phenomena through the pore space that involve both advection and diffusion, and allows for a rigorous derivation of the permeability and tortuosity tensor. Linear and nonlinear mean-field theories are most effective for upscaling of the elastic and inelastic solid response of porous materials, which is illustrated for cracked porous media and for plastic deformation of saturated *porous materials. Finally, the combination of microporomechanics theory with advanced experimental micromechanical techniques (incl. Nanoindentation, Atomic Force Microscopy and Environmental Scanning Electron Microscopy) is illustrated in Part III of these lecture notes, and is applied to the multiscale investigation of the poroelastic properties of cement-based materials, shales and bones.*

From the onset, the course was designed as a well-balanced blend of theory and hands-on application of microporomechanics to a large range of porous materials in the linear and nonlinear regimes. Intended for a first course in 'micromechanics of porous media' for graduate students, researchers and engineers working at the forefront of Engineering Mechanics and Materials Science, we trust that these lecture notes be a source of imagination.

Luc Dormieux
Franz-Josef Ulm

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