Preface to the English Edition

The French version of this book appeared in 2002 as part of the “Material Mechanics and Engineering” series. The objective of this book was to create as complete as possible a corpus of knowledge and methods in this field.

In designing this book on the mechanical behavior of soils and rocks, we gathered together a number of internationally known specialists, who each brought a significant contribution to the knowledge of the experimental behavior of these materials, as well as their constitutive modeling. Our goal was to cover as far as possible the theories at the basis of the different approaches of modeling, and also to address the most recent advances in the field.

In translating this book into English, we hope to make available to a wider scientific and engineering public the approaches and school of thought which have dominated the field of geomaterial mechanics in France over the past few decades. We have put together present-day knowledge of mechanical behavior and their theoretical bases in order to construct an original, analytical framework which, we hope, will give readers a useful guide for their own research. Most of the chapters have been updated in order to include the most recent findings on the respective topics.

Finally, we wish to dedicate this book to the memory of Professor Jean Biarez, who not only played a ground-breaking role in the history of soil mechanics in France, but remains a source of inspiration to many of us today.

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Preface to the French Edition

Soils and rocks possess a number of similar characteristics: both are highly heterogenous materials formed by natural grains. This alone gives them certain rheological features which distinguish them from other solid materials, such as a strongly non-linear character, a behavior which depends on the mean stress and shearing which induces volume variations, often dilatancy, which leads to unassociated plastic strains.

Soils and rocks can be studied at different scales. At the scale of one or several grains (from µm to cm), we can examine the discrete phenomena which govern the interactions between grains. They can be described using micro-mechanical models or analyzed in order to better understand the material behavior at a larger scale, typically the size of the material specimen: this approach corresponds to passing from a discontinuous to an equivalent continuous medium. Even though the size of the latter can vary, it has to be "sufficiently large" (typically from 1 cm to 1 dm) compared to the size of the material discontinuities in order to be representative of the equivalent continuous medium, whose behavior can be modeled by using certain concepts of continuous medium mechanics which ignore the notion of scaling in its basic equations.

However, some phenomena, such as the development of defects or cracks within the material specimen, are located at an intermediary scale, called the "meso" scale. It is thus necessary, in a constitutive model for continuous medium, to use scaling techniques in order to take into account these intermediary scales. This approach, still recent but potentially strong, can also be adapted to change the scale from the material specimen to the *in situ* soil or rock masses in geotechnical work modeling.

The constitutive models developed to describe the mechanical behaviors at the macroscopic scale can be roughly classified into two categories: those adapted to the behavior of "ductile" materials and those adapted to the behavior of "fragile" materials. The first category corresponds mainly to sandy or clayey soils, but also to soft rocks subjected to high confining stresses. The second category corresponds mainly to hard rocks, but also to certain soft rocks and highly overconsolidated clays subjected to small confining stresses. In ductile materials, the non-linear behavior is essentially due to irreversible grain displacements, which leads to a more or less significant hardening and to a pore volume change which induces volume changes at the scale of the specimen. In fragile materials, the non-linear behavior is due to the development of cracks, whose size may vary and whose direction depends on the principal stress directions.

In order to model ductile behaviors, plasticity (elastoplasticity or viscoplasticity) has shown to be an operational framework and the large majority of the constitutive models for soils and certain soft rocks belong to this category. However, for non-cohesive soils in particular, the difficulty of characterizing an elastic domain, determining the plastic mechanisms (potential and yield surface) experimentally, has led to the development of specific constitutive models, whose structure can be defined as incrementally non-linear.

In order to model fragile behaviors, the damage mechanics framework has been used to propose constitutive models adapted to describing irreversible phenomena linked to the deterioration of certain physical properties. In particular, they can take into account a large amount of rock properties: irreversible strains, dilatancy, induced anisotropy, hysteresis loop during loading-unloading due to opening and closing of mesocracks and frictional mechanisms along closed mesocracks.

In intermediary materials, the non-linear behavior can be due to microstructural changes, associating damage and hardening phenomena. Models coupling plasticity and damage have been developed to take into account this type of behavior.

After a general presentation of the constitutive models and their internal structures, each chapter will give a brief description of the different approaches mentioned above by focusing on a given class of materials. The first three chapters are devoted to the elastoplasticity theory applied to soils and soft sedimentary rocks. An alternative approach is then presented by means of the so-called incrementally non-linear models. The time-effect in clayey soils is analyzed in the framework of viscoplasticity. The behavior of hard rocks is then studied in Chapters 8 and 9, through the use of the damage theory at different scales. The modeling of the poromechanical behavior is also introduced in order to take into account the hydromechanical coupling in saturated porous rocks.

As the validity of any given model lies in its capacity to reproduce the observed material characteristics, the authors have placed the experimental data, obtained mainly from laboratory testing on intact soil and rock samples, under special consideration. The final chapter is devoted to parameter identification procedures. This is an important topic when dealing with natural materials because, each site being different from another, accurate parameter identification is essential for the quality of geotechnical work calculations, which is the final goal of this modeling approach.

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