Preface

Readers of one of our previous works, *Constitutive Modeling of Soils and Rocks*, may recall a fleeting reference to Professor Jean Biarez.

The present book, adapted and updated from the original French edition, pays tribute to the man and his work. It faithfully reproduces the spirit in which the 10 chapters were conceived although the content of the introductory chapter has been modified for the sake of explaining, as fully as possible, the historical context of Jean Biarez's status in modern soil mechanics.

We are aware that, on the international stage of geomechanics, Jean Biarez's role as a pioneer may not be fully appreciated because he does not occupy a large place in the literature. Unfortunately, his characteristic perfectionism and anxiety about committing tentative results and ideas to paper prevented him from publishing more.

Hence, to set the record straight for now and for posterity, we have decided to risk what Jean Biarez himself was so wary of doing throughout his long career – that is, to publish our work in progress in his honor, conscious that one day this work may be enriched or contradicted by further research.

Professor Jean Biarez (1927-2006) played an important role in creating a school of soil mechanics in France, a fact that has never been specifically acknowledged. Shortly after his death, a group of his students from France and around the world gathered for a day in Paris for what was to be a lively scientific colloquium. Out of this event, a book was published in 2010 by the majority of the participants who in their capacities as academic researchers and engineering experts aspire to transmit Professor Biarez's vision of soil mechanics. The originality of Biarez's approach consisted of a double objective:

– to understand the basic mechanisms that govern the interactions among soil constituents in order to improve the engineer's scientific knowledge of terrain behavior;

– to introduce scientific discoveries into the field of engineering by introducing rational methods into civil and mechanical engineering.

The scope and organization of the original book, and its version in English, faithfully adhere to the spirit of Biarez's vision of soil mechanics.

The first half of the book treats the behavior of soils at the scale of their different constituents and analyzes the organization of these constituents as if they were the motor of the material's mechanical behavior. In the second half, soil behavior is studied at the scale of the representative elementary volume, that is, at the level of the soil sample. Here we encounter the approach introduced by Biarez that was to link the discontinuous medium formed by grains to an equivalent continuous medium. He demonstrated that this linkage could be conceived by connecting the representative parameters of the grains to the parameters of the constitutive laws of the equivalent continuous medium. These representative parameters can then be categorized into two groups:

– first, the mechanical properties of the grains and the contact laws;

– second, the geometrical conditions of the arrangement and the confinement of the grains.

This methodological approach has met with good results within the framework of quantifying the large deformation behavior in sands and remolded clays, a quantification that has permitted us to define a standard or reference behavior from the parameters of the nature of the soils.

Several mechanisms belonging to granular materials have been studied at different scales: geometric anisotropy from contact orientations and the orientation of contact forces as well as the equilibrium of local assemblies that are the cause of plastic mechanisms within granular materials. These mechanisms, which were studied experimentally by Biarez, are approached in this book by analytical and numerical means, the latter drawing from recent developments in discrete element mechanics. Several chapters also refer to grain breakage, a very prevalent phenomenon in granular materials, where we find another scale effect linked to the size of the constituents and to their evolution during the course of mechanical loading. As shown by Biarez, this phenomenon tends to modify the properties of the grain assembly. Grain breakage is discussed and taken into account in the calculation of construction projects, particularly in large rockfill dams.

Another phenomenon under discussion concerns the effect of water presence in soils. With water effect, the behavior of the equivalent continuous medium becomes dependent upon both the solid grain behavior and the behavior of the fluid and the solid–fluid interaction at the interfaces. This aspect is broached by studying the interactions and by discussing the notion of effective stress in non-saturated soils. An analysis of capillary forces at the grain scale shows that it is possible to devise a concept of effective stress that allows the behaviors of dry and partially saturated materials in the elastic domain at small deformation amplitudes to be joined and for a criterion of maximal resistance to be defined, whatever the degree of saturation may be. Another example of water effect can be found in coarse granular materials where compressibility increases during the saturation phase.

Based on Biarez's conceptual framework, referred to as the passage from the discontinuous to the continuous medium, we have found it possible to construct constitutive models for the equivalent continuous medium from the intergranular properties and the geometry of the grain assemblies. The approaches that homogenize granular assembly behaviors generally consider the granular medium as an ensemble of tangential planes consisting of contact points between particles all in interaction with each other. Therefore, the moment has come to describe a contact law along these planes and to develop the homogenization operators that permit all the contacts at the scale of the continuous medium to be integrated. The homogenization approaches to granular assembly behaviors were developed in the first place to evaluate the elastic characteristics. An extended version of plastic behavior is presented in this book. The benefit of this type of approach is that it enables us to integrate the different physical mechanisms that appear at the scale of intergranular contacts naturally enough.

Landslides were of particular interest to Biarez and for this reason he developed calculation methods based on the plastic equilibrium. Recent studies have shown that material instability can emerge within a soil mass before the plastic criterion is reached. The phenomenon of material instabilities arises when the second-order work vanishes by annulling itself, in accordance with Hill's studies on this subject. An analysis of the conditions of how second-order work annuls itself is made with the help of incremental non-linear or piecewise-linear laws. This analysis shows the existence of an instability cone gathering within itself all the unstable directions. An application has been made concerning the numerical simulation of a natural landslide with the help of a hydro-mechanical model for non-saturated soil. The results obtained show how potentially unstable zones develop during soil saturation.

Biarez's work was a precursor concerning the use of the finite element codes for modeling construction projects. Spurred on by his enthusiasm, his co-workers at the *Ecole Centrale de Paris* developed the numerical code GEFDyn. The capacities of this calculation code are quite evident in the modeling of such projects as retaining

walls, deep foundations and embankment dams. What this code manifested was the quality of the numerical predictions through the capacity of the particular constitutive model chosen to reproduce the rheology of the soil as well as the choice of parameters retained for any given soil. The latter was always seen as primordial in the eyes of Biarez, which led him in the last years of his life to collate a considerable collection of data from laboratory and *in situ* tests on a stock of very diverse soils. The results from these tests allowed him to propose a methodology in which the reference behaviors could construct a general framework, enriched thereafter by a comprehension of the geological history of the soil layers studied. This strategy of identifying the soil is discussed and illustrated by the impact it has on the calculation results of construction projects.

The principal preoccupation of Jean Biarez was always to place the comprehension of soil behavior at the service of engineers and to develop operational methods for facilitating and improving the quality of engineering constructions. As a staunch advocate of the observational method, he urged others to believe in the necessity of sounding out or "auscultating" existing constructions. In France, he was one of the first to work on dynamic soil behavior, to be applied primarily to testing the stability of nuclear power plants and dams under seismic loading, a subject of crucial concern for EDF (*Electricité de France*), a major public utilities firm for which Biarez not only worked as an engineering expert but remained attached to throughout his entire career.

The last chapter of this book evokes Biarez's approach at both the fundamental level concerning soil behavior and at the applied level concerning his attempt to diagnose the reasons for accidents and collapses. One of his tasks as an engineering expert was to evaluate the seismic stability of embankment dams. Given the types of accidents studied, a methodology is presented here for evaluating seismic risk, particularly the most dangerous one among them, known as liquefaction.

The chapter that opens the book contains a brief biography of Jean Biarez's professional career and recalls the contribution he made as a pioneer to the field of geomechanics in France as researcher and teacher just after the Second World War up to a more contemporary era, where the scientific contribution of his students started to become recognized internationally. The reader is invited to discover the role of a man whose vision has so far informed and inspired two generations of researchers, teachers and engineers. The progress obtained in geomechanical research can be attributed in no small part to his influence, especially since the creation of new research organizations in Europe, such as GRECO *Géomatériaux* and ALERT *Geomaterials*.

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