Bio- and Chemo-Mechanical Processes in Geotechnical Engineering

Géotechnique Symposium in Print 2013

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Preface

Conventional geotechnical engineering theories do not provide a sufficient framework to fully address the new challenges that emerge due to the interactions between multi-physical phenomena. During the past two decades, advances in the study of unsaturated geo-materials including the non-isothermal conditions have been reported. A whole new framework for the characterization of the coupled thermo-hydro-mechanical processes has been set. However, the complexity of emerging energy and environmental geotechnical applications is increasing with the presence and development of chemical and biological processes. The evolution of these phenomena and their interaction with the different constituents of porous geo-materials unfold a vast new research domain, full of challenges. This is leading the global scientific interest towards new areas, far from the conventional and extensively explored ones.

The objective of this book is to present the recent developments in the study of the aforementioned phenomena and to provide readers with a handful material for addressing the uncharted chemo- and bio- mechanical couplings and their related geotechnical applications.

In recent years, substantial advances have been made in understanding the coupling between chemical and biological processes and mechanical and hydraulic behaviour in soils and rocks. At the same time, experimentation and modelling capabilities have progressed significantly, allowing effective design of geotechnical applications. The need for such analyses arises (for example) in chemical and biological soil improvement; nuclear, hazardous and municipal waste containment; petroleum and natural gas extraction; methane hydrate exploitation; carbon dioxide sequestration; and the assessment of pavement durability.

In such areas, instances of complexity and interaction are many, mainly because of the coexistence of several constituents and phases, their interactions, their reactivity, and their often non-linear behaviour. Flow involves water and gas, including the transport of chemical species and bacteria. Geomaterial deformation depends not only on classical effective stress, suction and temperature, but also on the history of chemical and bacterial activity in the material. Experimental observations are often difficult to carry out, and laboratory and in situ tests are costly challenges. An understanding of the material behaviour to be observed requires the control or measurement of many different parameters. Modelling inevitably implies numerical analyses. Coupled transient analyses are in fact a characteristic feature

of this field; proper variables must be selected which can describe the behaviour of the geomaterials subjected to chemical and biological phenomena.

A challenge at hand is to quantitatively describe the reaction and transport processes that occur. In this case, more complex variables enter the field equations for the different phases since the addressed chemical and biological processes refer to solute species that can react with species either in the same or in another phase. Robust numerical techniques are therefore required in order to solve, with sufficient accuracy, the strongly coupled analytical systems. Hence, progress in coupled bio- and chemo-mechanical processes in geotechnical engineering requires advances in theoretical formulations, numerical analyses, constitutive modelling and laboratory techniques, as well as detailed examination of well-documented field cases. Another issue is the study of the micro-structure where these processes can be better investigated and interpreted in mathematical terms. The analysis at the micro-scale requires the use of testing apparatus previously employed in limited cases in testing procedures for geotechnical problems.

This book is based on the two special issues of *Géotechnique* (Volume 63 issues 3 and 4) that preceded the *Géotechnique* Symposium in Print that was held on 3rd June 2013 at the Institution of Civil Engineers (ICE) in London. The symposium offered scientists and engineers from all over the world the opportunity to learn, discuss and outline future developments in this fascinating and critically important area. To this same purpose, the content of the book is enriched with papers from subsequent issues of the journal.

A total number of twenty contributions are organized in three sections. The first two focus on couplings between chemical, biological and mechanical aspects for different geo-materials (clay, shale, bentonite and sand among others) while emphasis is laid on modelling. Experimental evidence is presented along with cases addressing these couplings for real applications such as the mitigation of the liquefaction potential of sands or the carbon dioxide sequestration in coal beds. Finally, the third section is devoted to an overview of the progress in this emerging field providing at the same time readers with an outline of future challenges and potential developments.

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May 2014

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