Mechanics of Unsaturated Porous Media

Ning Lu, F.ASCE
Professor, Dept. of Civil and Environmental Engineering, Colorado School of Mines, Golden, CO 80401 (corresponding author). Email: ninglu@mines.edu

Giuseppe Buscarnera, M.ASCE
Associate Professor, Dept. of Civil and Environmental Engineering, Northwestern Univ., Evanston, IL 60208. Email: g-buscarnera@northwestern.edu

DOI: 10.1061/(ASCE)EM.1943-7889.0001489


The last few decades witnessed a great surge in research activities in variably saturated porous media, particularly in the mechanical and hydrological behavior of earthen materials. This is in response to many emerging engineering applications, such as natural and engineered slope stability under rainfall conditions, municipal and high-level nuclear waste containments by clay barriers, geologic sequestration of CO₂, and wastewater injection in deep wells, among others. The underpinning of all these engineering problems is the mechanics of porous media. During the annual conference of the Engineering Mechanics Institute of ASCE in Stanford, California, in summer 2015, there were three minisymposia on mechanics of unsaturated porous media. A total of 22 presentations were given on various aspects of the mechanical behavior of porous media under variably saturated conditions. Because of the technical breadth and depth of the presentations that were presented by some of the most prominent researchers in the field, a special issue dedicated to the theme was determined to be the most beneficial outcome to expose a broader audience to the advances reported at the symposia. This special issue, cumulating the postsymposium effort, highlights 12 articles covering a range of topics with a common theme across these papers is the fundamental importance of effective stress concepts as a platform to understand deformation processes and coupled phenomena. Among these lines, the work of Mihalache and Buscarnera (2016), who tackled the challenging analysis of coupled fluid-deformation processes in near-instability conditions. For this purpose, the paper studies from a mathematical standpoint the link between the instability of unsaturated soils and the illposedness of coupled flow-deformation equations, thereby providing theoretical guidance to assess the robustness of simulations tools widely used for engineering applications. Coupled phenomena are also the focus of the work presented by Pedroso et al. (2017), who discussed the ever-growing richness of numerical tools for coupled analyses in unsaturated soils by recognizing their strategic role for the solution of a wide variety of engineering problems. For this purpose, the authors present a series of computational strategies able to efficiently handle processes ranging from dynamic effects to hydraulic hysteresis and transitions between states of saturation.

The special collection consists of another series of papers that are closely related to coupled solid-fluid interactions in unsaturated porous media. A common theme across these papers is the fundamental importance of effective stress concepts as a platform to understand deformation processes and coupled phenomena. Along these lines, the work of Duriez and Wan (2017) tackled the intuitive—yet not yet fully understood—connection between soil microstructure and unsaturated soil behavior. For this purpose, the authors used both analytical tools and discrete element methods to explore how the soil fabric influences the nature of stress interactions within granular soil samples in the pendular regime. The work by Pasha et al. (2017) addresses the fundamental link between pore structure and water retention processes by recognizing the role of volume change on the water retention behavior of deformable porous media. For this purpose, the authors present a new approach to evaluate the void ratio dependency of the water retention curve...
(WRC) solely on the basis of the WRC measured at a reference void ratio, thereby simplifying the characterization of couplings at the local material scale. The paper presented by Mašín (2017) offers new insights about the growing area of coupled process in porous materials by focusing on the complex feedback generated by multiple levels of porosity. Specifically, the paper explores thermohydromechanical couplings in expansive soils by taking into account separate effective stress definitions for each level of porosity. Finally, effective stress principles are at the core of the conclusive paper by Ma et al. (2016), who presented a constitutive model for unsaturated soils accounting for physicochemical effects through a new intergranular stress definition able to quantify the influence of the pore fluid chemistry in processes such as osmosis, capillarity, and adsorption.

In summary, we hope that this collection provides the reader with a fresh sample of the vibrant field of the current global research in Mechanics of Unsaturated Porous Media. Challenges in experimental techniques, analytical and computational methods, and constitutive modeling continue to be the frontier in academic research and engineering applications of mechanics of unsaturated porous media. We trust that this collection of papers will stimulate new scientific advances and continued growth in this area of engineering mechanics.

References


