

Accepted Manuscript

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Javad Ghorbani, David W. Airey, Abbas El-Zein



PII: S0045-7825(18)30125-7
DOI: <https://doi.org/10.1016/j.cma.2018.03.008>
Reference: CMA 11814

To appear in: *Comput. Methods Appl. Mech. Engrg.*

Received date : 3 October 2017

Revised date : 2 March 2018

Accepted date : 3 March 2018

Please cite this article as: J. Ghorbani, D.W. Airey, A. El-Zein, Numerical framework for considering the dependency of SWCCs on volume changes and their hysteretic responses in modelling elasto-plastic response of unsaturated soils., *Comput. Methods Appl. Mech. Engrg.* (2018), <https://doi.org/10.1016/j.cma.2018.03.008>

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Numerical framework for considering the dependency of SWCCs on volume changes and their hysteretic responses in modelling elasto-plastic response of unsaturated soils.

Javad Ghorbani^{1*}, David W Airey¹, Abbas El-Zein¹

1) School of Civil Engineering, The University of Sydney, NSW 2006, Australia.

Abstract

This paper provides the mathematical framework for the continuum numerical modelling of dynamic and static problems of geomaterials when unsaturated in iso-thermal environments with chemically passive phases and immiscible flows. As the Soil Water Characteristic Curve (SWCC) plays a vital role in the response of unsaturated soils, the main attention in the presented framework is to include the full hysteretic response of the SWCC and its dependency on volume change; features which have been often ignored in the analyses of unsaturated soils.

As incorporation of these feature into the analysis of unsaturated soils brings additional complexities into the theoretical framework and the procedure of numerical implementation, the primary motivation of this study is to highlight these complexities and their associated numerical problems; and to propose a robust numerical framework by which simulations of unsaturated geomaterials at large scale can be facilitated.

First, the procedure of modelling the elasto-plastic response of partially saturated soil, where the dependency of the SWCC on volume changes is considered in the analysis, is investigated; and the corresponding finite element solution to solve boundary value problems is provided. Numerical examples are presented for validation and to demonstrate the effect of the SWCC dependency on volume changes.

Then, using the provided finite element approach, we illustrate the numerical problems which can arise from including the SWCC hysteretic behaviour when solving boundary value problems involving unsaturated soils. Then, a model to rectify these problems is provided. The introduced method yields an incremental nonlinear function which links the rate of saturation degree to the rate of porosity and the rate of suction. An integration scheme with automatic error control for updating the saturation degree during the analyses is introduced. Numerical examples are provided for validation and to demonstrate the capability of the proposed scheme in modelling hysteretic response of the SWCC.

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