CONSTITUTIVE RELATIONS FOR UNSATURATED FLOW IN A FRACTURE NETWORK

H.H. Liu and G.S. Bodvarsson

Contact: H.H. Liu, 510/486-6452, hhliu@lbl.gov

RESEARCH OBJECTIVES

A commonly used approach for modeling water flow in unsaturated fractured rocks is the continuum approach, in which the constitutive relation models originally developed for porous media have often been borrowed to represent constitutive relations for the fracture continuum. While these models have been successfully used for soils and other porous media, their usefulness and limitations have not been investigated for the fracture continuum. The objective of this study is to present an evaluation of the commonly used van Genuchten and Brooks-Corey models and to develop improved constitutive relation models based on the evaluation results.

APPROACH

Because it is generally difficult to directly measure constitutive relations for a fracture network in the field, we have determined these relations from numerical simulations of steady-state unsaturated flow in two-dimensional fracture networks (Figure 1). In these simulations, a fracture network is considered as an effective porous medium. The rock matrix is treated as being impermeable for purpose of focusing on the fracture continuum. The fracture networks consist of vertical and horizontal fractures with different hydraulic properties.

ACCOMPLISHMENTS

It was found that the van Genuchten model could reasonably well match the simulated water retention curves except for high saturations, but both the van Genuchten and Brooks-Corey models generally underestimate relative permeability values except at low saturations. We propose a new relative permeability-saturation relation for the fracture continuum by modifying the Brooks-Corey relation. The combination of this new relation and the van Genuchten capillary pressure-saturation relation can represent the simulated curves and may provide an improved set of constitutive relations for the fracture continuum. However, this study is mainly based on the numerical experiment results and further investigation based on relevant field observations are needed.

SIGNIFICANCE OF FINDINGS

The constitutive relations are a key element of the unsaturated flow model based on the continuum approach. The accuracy of modeling results is largely determined by the accuracy of these constitutive relations that characterize flow processes at a subgrid-scale. The use of the constitutive relations developed for porous media for describing unsaturated flow in subgrid-scale fracture networks may not be valid, because the geometry of a fracture network is considerably different than the pore geometry in a

porous medium. Moreover, unsaturated flow behavior in a fracture network, which is mainly determined by the gravity, is not necessarily the same as that in porous medium. This study represents an effort to deal with this important issue.

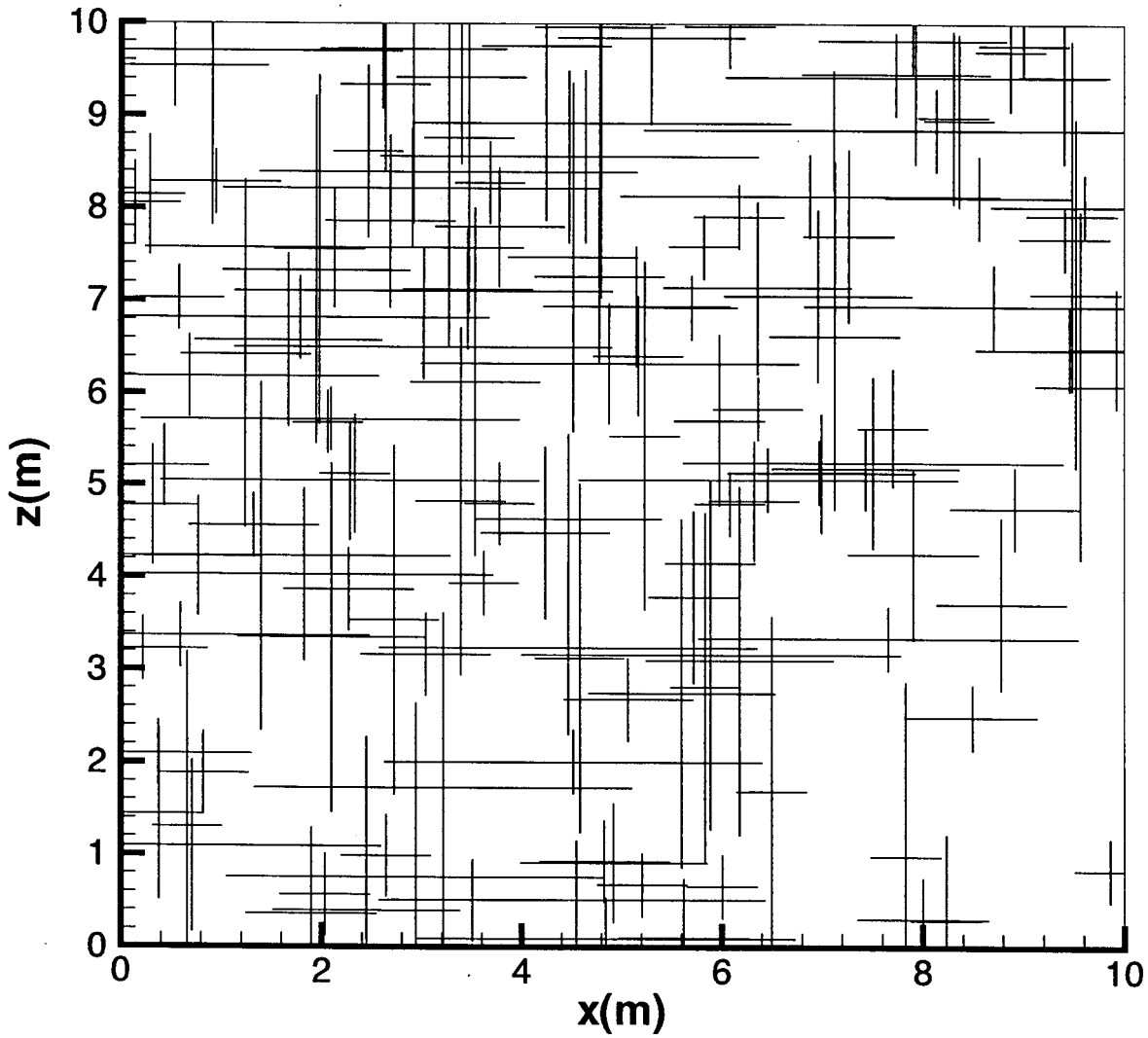
RELATED PUBLICATIONS

Liu, H.H. and G.S. Bodvarsson, Constitutive relations for unsaturated flow in a fracture network, Journal of Hydrology (in press).

ACKNOWLEDGEMENTS

This work was supported by the Director, Office of Civilian Radioactive WasteManagement, U.S. Department of Energy, through Memorandum Purchase Order EA9013MC5X between Bechtel SAIC Company, LLC and the Ernest Orlando Lawrence Berkeley National Laboratory (Berkeley Lab). The support is provided to Berkeley Lab through the U.S. Department of Energy Contract No. DE-AC03-76SF00098.

(Figure 1 Computationally generated fracture networks with the scanline density of 2.2 (fracture/m).)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