Determination of Soil-Water Characteristic Curve Using Multifractal Soil Media and Pore Network Modeling

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Abstract

Prior knowledge of Soil Water Characteristic Curve (SWCC) is essential to evaluate mechanical behavior of unsaturated soils, that is to say, basic mechanical parameters of unsaturated soils have intrinsic dependency on the suction induced changes of water (wetting) phase inside soil. For instance, effective stress is closely related to volume and interfacial areas of water (wetting) phase inside an elementary representative volume of soil which can be computed using SWCC. In recent years, fractal mathematic is vastly employed by the researchers for modeling and estimation of SWCC. Almost all of the fractal models which have been presented to date are mono-fractal and they cannot be considered as good representatives of the real soil. In the current study, a multifractal soil modeling is used to estimate pore size distribution of the soil. Next, the obtained pore size distribution is employed to construct a pore network model, based on which SWCC is calculated. Such joint modeling can take the most advantage of fractal simulation of the real soil structure along with the physically meaningful modeling of the drainage in a pore network model.

Keywords: Fractal, Pore Network, Soil -Water Characteristic Curve, SWCC, Percolation Theory

1. INTRODUCTION

Soil-Water Characteristics Curve (SWCC) relates soil volumetric water content and its water potential. For the reason that direct measurement of this basic hydraulic property of unsaturated soils is time-consuming and expensive, many empirical and physico-empirical relationships for this curve have been presented throughout the literature. Such formulae for this curve usually involve constants which seem physically senseless. To improve physical understanding of those constants, fractal geometry has been employed. In almost all of the researches which has been presented to date, fractally made geometries does not exactly replicate the soil texture(being mono-fractal they can not essentially replicate reality) and does not provide the same properties, like porosity, as the real soil. Current fractal models usually assume mono-fractality of the soil grading within a broad range of scales. Based on recent studies of soil scientists, this assumption fails to correctly model all soil textures. In other words, in different ranges of scales soils show different fractal dimensions. This pattern can be mathematically captured using multifractals. As a matter of fact, the location of soil pores and grains in real nature can not be dictated by an exact mathematical relationship. Hence, it is not far from reality to construct the fractal model in a random manner.

Despite the proposed intentions of the researchers, to shed light into physical modeling of SWCC, they have developed fractally made models just to connect fractal dimension to some constants stated by the previous studies. Needless to say, fractals can provide a medium to simulate drainage and imbibition. Therefore, not only they can be tuned to match basic properties of the soil structure, but also they can act as an artificial laboratory to simulate time-consuming experiments such as pressure plate test. This is definitely what is expected from a physical modeling, not simply making some regressions to connect fractal dimension to some empirical constants. In this regard, another tool is required to couple with the fractal soil simulation which is percolation theory.

Percolation theory is one of the branches of mathematics, which has intensively been employed in fields like petroleum engineering. However, it has faced less attention in soil science and geotechnical engineering. Percolation theory which studies flow through pore networks can be considered as a good complement for fractal modeling.

This research, for the first time, presents a robust procedure to overcome aforementioned drawbacks. In this study, basic soil parameters are used to develop a fractal model of soil structure. After arriving at the most suitable fractal medium which is a random multifractal, the corresponding pore characteristics are implemented in a pore network to calculate SWCC. Finally, a comparison is made between results obtained from the proposed model and the real soil behavior. In the following sections of the paper, first drawbacks of