Soil-Water Characteristic Curve prediction by Gene Expression Programming

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Abstract

Soil–water characteristic curve is one of the most important parts of any model that describes unsaturated soil behavior as it explains the variation of soil suction with changes in water content. In this research, gene expression programming is employed as an artificial intelligence method for modelling of this curve. Gene expression programming can operate on large quantities of data in order to capture nonlinear and complex relationships between variables of the system. Inputs of the model are the initial void ratio, initial gravimetric water content, logarithm of suction normalized with respect to atmospheric air pressure, clay content, and silt content. The model output is the gravimetric water content corresponding to the assigned input suction. The results illustrate that the advantages of the proposed approach are highlighted.

Keywords: Unsaturated soil, Soil–water characteristic curve, Pressure plate test, Gene expression programming

1. INTRODUCTION

Soil-water characteristic curve (SWCC) has huge importance in unsaturated soil behavior such as shear strength, volume change, diffusivity and absorption, as well as most of soil properties such as specific heat, permeability and thermal conductivity which can be also related to the soil-water characteristic curve [1]. This curve can be depicted as a continuous function describing the water storage capacity of a soil as it is subjected to various suctions. SWCC contains significant information respecting the amount of water contained in the pores at various suctions of soil and the pore size distribution corresponding to the stress state in the soil [2].

SWCCs are affected by various factors such as the pore shape and pore size distribution, the particle size distribution, the specific surface area, the chemo-physical properties of the soil phases, the soil density and the temperature. The effects of pores and particles are studied in many researches (e.g., [3,4]).The effect of temperature on SWCC is studied by relatively limited researchers (e.g., [5,6]). Grant and Salehzadeh [6] incorporated the thermal effects into van Genuchten's equation [7] to obtain a temperature-dependent SWCC equation. Recently, Zhou et al. [8] presents an approach to modelling the effect of temperature on SWCC of deformable soils.

Several empirical methods have been proposed for predicting the SWCC of a particular soil in the literature that can be classified into five groups as follows:

1. Fitting type equations for the SWCC. In this group of equations a simple mathematical equation is fitted to the experimental data, and the unknown parameters are determined [7, 9].
2. Water contents at different suctions are correlated to specific soil properties such as D_{10} (sieve size for 10% passing) and porosity. This process generally requires a regression analysis followed by a curve fitting procedure [10,11].
3. Correlating parameters of an analytical equation with basic soil properties such as grain size distribution and dry density, using a regression analysis [12,13].
4. Physico-empirical modelling of SWCC. This approach converts the grain size distribution into a pore size distribution, which is in turn related to a distribution of water content and associated pore pressure [14–16].