Modeling of Biocalcification in Non-Saturated Conditions

B. Courcelles[1], C. Raymond-Poirier[1]

[1]École Polytechnique de Montréal, Montréal, QC, Canada

Abstract

In the context of increasing demographic pressures around the world, soil improvement techniques constitute viable alternatives to expensive foundations. Among these techniques, the biocalcification of granular soils appears as a promising alternative relying on the formation of calcium carbonates.

The process is relatively basic and energy efficient, as based on the metabolic activity of the Sporosarcina pasteurii bacteria. After injection of nutrients, salts and urea, the enzymatic activity results in the precipitation of calcium carbonates which provides a cohesion and densifies the granular medium. This method aims to increasing the bearing capacity and reducing the problem of liquefaction or erosion of granular soils.

Initially developed in saturated conditions, the biocalcification influences geomechanical and hydraulic parameters of soils such as stiffness, shear strength, hydraulic conductivity, etc. (Dejong et al., 2010). As a result of several years of research, these usual conditions led to several modeling approaches in terms of bacteria migration (van Wijngaarden et al., 2012) or variable permeability (van Wijngaarden et al., 2009, 2011). Nevertheless, last developments of injection in unsaturated conditions lack of efficient models in terms of transport in an evolving medium. Cheng et al. (2013) proposed a new injection method relying on surface percolation as well as a simple mathematical model that illustrated the dependency between the cementation depth, the infiltration rate and the in situ urease activity.

The proposed paper aims to present a multiphysics model including bacteria and nutrients transport, as well as variable porosity and permeability. This model mainly relies on the Richard's equation for infiltration in non-saturated granular media and considers variable permeability as a result of calcium carbonates precipitation and the variation of the water content. Based on the finite elements method, this highly non-linear model involves Chemical Reaction Engineering and Subsurface Flow Modules of COMSOL Multiphysics® software. As a results of the simulations, this model helps to design the biocalcification in non-saturated conditions, mainly observed in river banks or dikes subject to erosion.

Reference

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Figures used in the abstract

Figure 1

Figure 2

Figure 3

Figure 4