POLYTECHNIQUE MONTRÉAL

WORLD-CLASS ENGINEERING

Modeling of Biocalcification in Non-Saturated Conditions

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Introduction

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.

State of the art

The process is based on the metabolic activity of *Sporosarcina pasteurii*. After the 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.

Figure 1.

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).

Cheng et al. (2013) proposed a new injection method relying on surface percolation and the present model aims to simulate laboratory tests and to verify the homogeneity of treatments.

Computational Methods

Including bacteria and nutrients transport, the model mainly relies on the Richard's equation for infiltration in non-saturated granular media (Eq1) and the classical dispersive, diffusive, convective and reactive-transport equation. (Eq2)

$$(C + S_e S)\frac{\partial H_p}{\partial t} + \nabla \cdot \left(-K\nabla\left(H_p + D\right)\right) = 0 \qquad \text{(Eq1)}$$

$$\frac{\partial}{\partial t}(\theta c) + u \cdot \nabla c + \nabla \cdot [-\theta D_L \nabla c] = \qquad R_L \qquad \text{(Eq2)}$$

Results

The numerical model was applied to a cylinder of 2'' in diameter and 4'' high. The percolation was performed from the center of the top surface and represented as a constant hydraulic charge. The results of the simulations are provided on Figure 3, which represents the evolution of the calcium content after 24h (a), 48h (b), 72h (c) and 96h (d) in axial symmetry. This calcium is considered as an immobile specie after its formation.

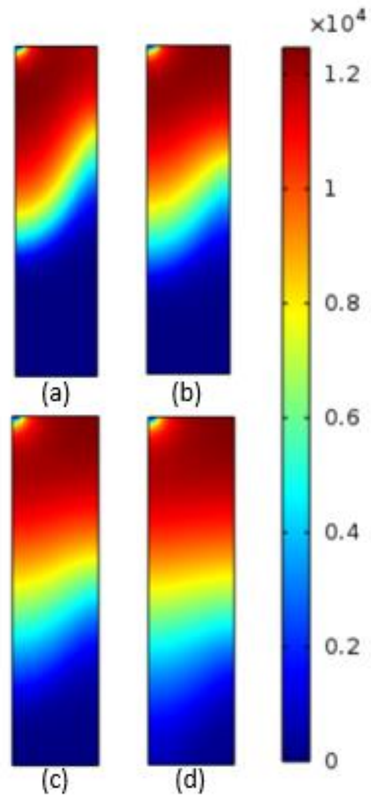

Figure 3.
Calcium content

Conclusions

The simulations confirmed the homogeneity of treatment as observed during our laboratory tests after preparation (Figure 1, background) or unconfined compression tests (Figure 2, background). These simulations were mandatory to adapt the laboratory step and prevent numerous variations of flowrate, concentration, etc...

References

1. DeJong, Mortensen, Martinez, Nelson, Bio-mediated soil improvement, Ecological Engineering, 36, pp197-210 (2010)
2. Cheng, Cord-Ruwisch, Shahin, Cementation of sand soil by microbially induced calcite precipitation at various degrees of saturation, Canadian Geotechnical Journal, 50, pp81-90 (2013)

Figure 2.