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A Two-dimensional Bio-chemo-hydro-mechanical Model for In-situ Stabilization of Soils using Biochemical Processes

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Ground improvement techniques involving chemical additives are often energy-intensive and unsustainable due to the environmental distress caused by them. Sustainable biocementation processes such as microbially induced calcite precipitation (MICP) can overcome the drawbacks of traditional ground improvement techniques[1]. Capturing the underlying coupled mechanisms in the biocementation process requires the knowledge of diverse fields of bio-chemo-hydro-mechanics. Modeling such a complex phenomenon is imperative for the successful implementation of the stabilization technique in the field. The existing coupled models on biocementation are chiefly intended to validate the observed behavior of laboratory-scale biocemented specimens[1]. This scenario demands the need to develop a coupled bio-chemo-hydro-mechanical (BCHM) model for field simulations. The BCHM model was developed with finite element and backward Euler finite difference approximations in space and time. The Galerkin weak formulations are derived for the mass balance equations of the coupled model. The advective-governed transport phenomena are accommodated with the Petrov-Galerkin formulation. An overall kinetically controlled reactive model is implemented to reproduce the urea hydrolysis and associated chemical kinetics[1]. The reduced permeability of the biocemented soil is accounted in terms of its effective porosity, using the modified Kozney-Carman equation[2]. The fixed point iteration method is implemented for bio-chemo-hydraulics to deal with the nonlinearity in the balance equations. The mechanical constitutive response of biocemented soil is simulated using a micromechanical framework. The von Mises and Drucker-Prager plasticity models were adopted for the biocement and soil particle phases, respectively[3]. The integration of plasticity models was carried out using a return mapping algorithm[3]. The Newton Raphson scheme is considered for the finite element implementation of elastoplastic models. The fully coupled nonlinear finite element problem is solved in a staggered approach using the developed MATLAB routine. The contour plots of biomass and chemical concentrations and precipitated calcite content are generated. The iso error maps are acquired for the inspection of the error behavior of the integration algorithm. The considered elastoplastic models predicted improvement in mechanical strength of biocemented specimen. A complete bio-chemo-hydro-mechanical behavior of the two-dimensional geometry is captured.

REFERENCES

[1] Wang, X. and Nackenhorst, U. A coupled bio-chemo-hydraulic model to predict porosity and permeability reduction during microbially induced calcite precipitation. *Adv. Water Resour.* (2020) **140**: 103563.

[2] Koponen, A., Kataja, M. and Timonen, J. Permeability and effective porosity of porous media. *Phys. Rev. E* (1997) **56(3)**: 3319-3325.

[3] Abdulla, A.A. and Kiousis, P.D. Behavior of cemented sands—II. Modelling. *Int. J. Numer. Anal. Methods Geomech.* (1997) **21(8)**: 549-568.