Postdoc Position

Durability of microbial-induced calcite precipitation

Study of reactive flows in 2D model systems and in 3D soil columns using X-ray nano-tomography

Motivation, context

Microbial-induced calcite precipitation (MICP) is a process increasingly used to reinforce structures and soils, and appears to be a relevant alternative to conventional techniques based on the injection of manufactured materials, being more environmentally friendly and consuming less energy. Indeed, it reinforces the bond contacts between grains after injection of bacteria that accelerate the natural process of calcium carbonate precipitation ($CaCO_3$). A striking example is that a non-cohesive sand can be turned into a highly cohesive medium. Since the recent proof of concept made by Whiffin [1] and Mitchell and Santamarina [2], studies have demonstrated that calcite precipitation induced by bacteria activity is effective at large scale [3], and has a broad spectrum of applications, including internal erosion of hydraulic structures, liquefaction of soils during earthquake, landslides, or crack closure. Studies have focused on the effect of the process parameters : bacteria concentration [4], calcium concentration, pH, temperature, and water saturation of the media [5] on the calcite distribution in pores and on the mechanical properties of the improved media [6], [7]. Moreover, our teams have recently demonstrated the importance of the microstructure at the contact scale on the mechanical behaviour [8]–[11].

Nevertheless, for engineering applications, the assessment of the durability of the reinforcement process by MCIP is a concern. In particular, it is important to be able to predict how evolve the mechanical properties of a reinforced medium when it is submitted to acid conditions, which will cause the dissolution of calcite [12] and weakening of the structure.

Post doc program

The goal of this project is to characterize the evolution of the microstructure in reinforced media in real time, when exposed to an aggressive environment. In particular, a focus will be made on the contact surface area and the crystal morphology evolution through time.

The post-doc will have to develop experiments in 2D model porous media to characterize the dissolution process with a relevant instrumentation including high-resolution imaging. Then, the dissolution conditions used in the 2D experiments will be transposed in 3D soil columns to perform time-lapse 4D nano-tomography imaging experiments using the high spatial and temporal resolution available at synchrotron facilities (ESRF).

The expected results are a better understanding of processes associated to the decrease in mechanical properties induced by calcite dissolution.

Location and practical aspects

The successful applicant will be hosted by the laboratory 3SR (Grenoble) in the “CoMHet” team. He/she will work under the supervision of Antoine Naillon and Catherine Noiriel (laboratory Géosciences Environnement Toulouse), and in collaboration with Christian Geindreau and Fabrice Emeriault.

The position is a 1-year contract with the opportunity to have some extended months.

The post-doc will start as soon as possible, from January 2023.

The gross salary will be around 2919 €/month depending on the experience of the applicant, equivalent to a net salary of around 2346 €/month.

Qualifications of the applicant

A PhD with a strong background in fluid mechanics especially reactive transport in porous media, coupling phenomena, experimental work with micro-model system and image analysis is expected. However, profiles within the fields of geochemistry will be considered with interest.
Motivation for the design of original and advanced experimental testing is required.

Applications

Interested candidates should send their CV and cover letter to antoine.naillon@univ-grenoble-alpes.fr. Deadline for the application: 7th of December 2022 but the applications will be treated as they arise.

[1] V. S. Whiffin, "Microbial CaCO3 Precipitation for the Production of Biocement," Murdoch University, Perth,WA, 2004.

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[3] Z. Wang, N. Zhang, G. Cai, Y. Jin, N. Ding, and D. Shen, "Review of ground improvement using microbial induced carbonate precipitation (MICP)," Marine Georesources and Geotechnology, vol. 35, no. 8, pp. 1135–1146, 2017.

[4] J. Chu, V. Ivanov, M. Naeimi, V. Stabnikov, and H. L. Liu, "Optimization of calcium-based bioclogging and biocementation of sand," Acta Geotechnica, vol. 9, no. 2, pp. 277–285, 2014.

[5] L. Cheng, R. Cord-Ruwisch, and M. A. Shahin, "Cementation of sand soil by microbially induced calcite precipitation at various degrees of saturation," Canadian Geotechnical Journal, vol. 50, no. 1, pp. 81–90, 2013.

[6] D. Mujah, M. A. Shahin, and L. Cheng, "State-of-the-Art Review of Biocementation by Microbially Induced Calcite Precipitation (MICP) for Soil Stabilization," Geomicrobiology Journal, vol. 34, no. 6, pp. 524–537, 2017.

[7] D. J. Tobler, M. O. Cuthbert, and V. R. Phoenix, "Transport of Sporosarcina pasteurii in sandstone and its significance for subsurface engineering technologies," Applied Geochemistry, vol. 42, pp. 38–44, 2014.

[8] A. Dadda et al., "Characterization of microstructural and physical properties changes in biocemented sand using 3D X-ray microtomography," Acta Geotechnica, vol. 12, no. 5, pp. 955–970, 2017.

[9] A. Dadda, C. Geindreau, F. Emeriault, S. Rolland, A. Esnault-Filet, and A. Garandet, "Characterization of contact properties in biocemented sand using 3D X-ray micro-tomography," Acta Geotechnica, vol. 4, pp. 1–13, 2018.

[10] A. Dadda, C. Geindreau, F. Emeriault, A. Esnault Filet, and A. Garandet, "Influence of the microstructural properties of biocemented sand on its mechanical behavior," International Journal for Numerical and Analytical Methods in Geomechanics, vol. 43, no. 2, pp. 568–577, 2019.

[11] M. Sarkis, M. Abbas, A. Naillon, and F. Emeriault, "Computers and Geotechnics D . E . M . modeling of biocemented sand : Influence of the cohesive contact surface area distribution and the percentage of cohesive contacts," Computers and Geotechnics, vol. 149, no. June, p. 104860, 2022.

[12] C. Geindreau et al., "Mechanical and Microstructural Changes of Biocemented Sand Subjected to an Acid Solution," International Journal of Geomechanics, vol. 22, no. 3, 2022.