# Modelling of biocementation in soils using chemo-hydro-mechanical coupled analysis.

**Summary**

Microbially induced calcite precipitation is a soil reinforcement technique where urease producing bacteria are used to produce calcium carbonate, precipitated after the hydrolysis of urea promoted by the enzyme urease present in the microorganisms (Eq. 1), in the presence of a calcium source (Eq. 2). This biocement clogs the soil pores and bonds its grains, causing an increase of the soil strength and stiffness and a decrease of its permeability. In the research proposed, a Finite Element model for soils will be defined in which fluid flow and ion transport by conduction and diffusion will be computed, incorporating a model for calcite precipitation as function of known treatment conditions and boundary conditions.

To analyse the precipitation process, a model of a two-phase porous medium, where each phase is composed of several species), will be developed. The solid phase is composed by soil particles, bacteria and calcite precipitated mineral, while the fluid phase contains water, urea and other dissolved species that are present in the biochemical reaction. A finite element formulation embodying water seepage, advective diffusion of species and soil deformation, will be developed to compute the generation of solid mass (the biocement), and numerical simulations are carried out under various conditions (e.g. different bacteria dosages, feeding frequency and composition). The modelling of the chemical reactions is divided in two main stages: the urea hydrolysis and the calcite precipitation (Eqs 1 and 2). Initially, the Michaelis-Menten type kinetics mathematical model is used to obtain the reaction rate for urea hydrolysis, ru (Eq. 3).

Once the urea molecule is breaked forming ammonia and carbonate ions, and there are available calcium ions on the medium, the precipitation of calcite occurs instantaneously. The results of the numerical simulations will be compared to results available in the literature obtained with models that only address diffusion couplings and where soil deformation is not accounted for. The existence of such model is important to promote this low carbon footprint technique as alternative to standard soil improvement techniques, being a valuable tool for design and a relevant contribution to current knowledge.

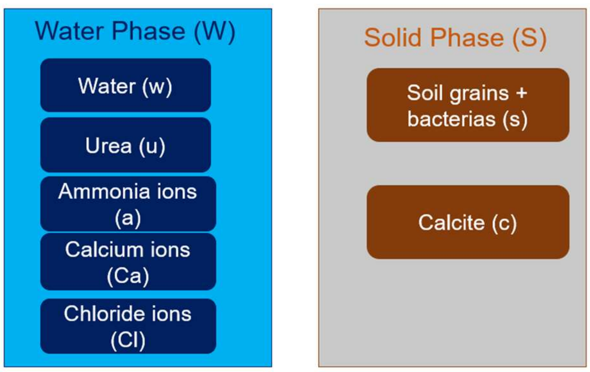
**Keywords**

Biocementation, model, chemo-hydro-mechanical coupled analysis, design, prediction, low carbon footprint technique.

$$CO(NH_2)_{2\,(aq.)} + 2H_2O_{(l)} \xrightarrow{bacteria} 2NH_4^+{}_{(aq.)} + CO_3^{2-}{}_{(aq.)} \quad [1]$$

$$Ca^{2+}_{(aq.)} + CO_3^{2-}{}_{(aq.)} \rightarrow CaCO_{3\,(s)} \quad [2]$$

$$r_u = v_{max}\frac{C_{uW}}{K_m + C_{uW}}\left(1 - \frac{t}{t_{max}}\right) \quad [3]$$




*Species present in the current numerical model.*

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