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Investigation of Biogrout processes by numerical analysis at pore scale

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Biogrout is a soil improving process that aims to improve the strength of sandy soils. The process is based on microbially induced calcite precipitation (MICP). In this study the main process is based on denitrification facilitated by bacteria indigenous to the soil using substrates, which can be derived from pretreated waste streams containing calcium salts of fatty acids and calcium nitrate, making it a cost effective and environmentally friendly process. The goal of this research is to improve the understanding of the process by numerical analysis so that it may be improved and applied properly for varying applications, such as borehole stabilization, liquefaction prevention, levee fortification and mitigation of beach erosion. During the denitrification process there are many phases present in the pore space including a liquid phase containing solutes, crystals, bacteria forming biofilms and gas bubbles. Due to the amount of phases and their dynamic changes (multiphase flow with (non-linear) reactive transport), there are many interactions making the process very complex. To understand this complexity in the system, the interactions between these phases are studied in a reductionist approach, increasing the complexity of the system by one phase at a time. The model will initially include flow, solute transport, crystal nucleation and growth in 2D at pore scale. The flow will be described by Navier-Stokes equations. Initial study and simulations has revealed that describing crystal growth for this application on a fixed grid can introduce significant fundamental errors. Therefore a level set method will be employed to better describe the interface of developing crystals in between sand grains. Afterwards the model will be expanded to 3D to provide more realistic flow, nucleation and clogging behaviour at pore scale. Next biofilms and lastly gas bubbles may be added to the model. From the results of these pore scale models the behaviour of the system may be studied and eventually observations may be extrapolated to a larger continuum scale.