Modeling of Soil Carbonation for sustainable soil subgrade stabilization.

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Abstract

Soil Carbonation is an alternative method to chemically stabilize subgrade materials by inducing cementation on the soil matrix. The approach is similar to conventional soil chemical stabilization in that additives are mixed into the soil, but soil carbonation involves the introduction of carbon dioxide gas to stimulate a reaction and precipitate carbonate minerals that bind the soil increasing its strength and stiffness. A defining feature of the method is that carbon is sequestered, substantially reducing the carbon footprint associated with producing chemical additives compared to conventional techniques. The rate of carbonation and binder formation is governed largely by the reaction kinetics and mobility of gas in the soil matrix. Investigating carbon dioxide gas flow on limed treated soils while it is consumed during the reaction is significantly challenging because of the coupled physicochemical nature of the reaction, 2D and 3D flow regimes, and changing soil state conditions (e.g., saturation, void ratio). Motivated by the need to establish methods that can be used to evaluate potential implementation schemes (i.e., methods that enable the introduction of carbon dioxide) a numerical framework is proposed herein to address the challenges mentioned. Mass conservation principles and the advection-diffusion equation were applied to simulate the flow of carbon dioxide gas through the porous media, reaction kinetics, and the associated rate of binder formation. The governing systems of partial differential equations were solved using the finite element method and the predicted spatial and temporal changes in binder content are compared with observations from 1D elemental carbonation experiments performed on lime-mixed silt with changing flow rates, lime content, compaction, and saturation. The results demonstrate that the proposed numerical formulation is capable of capturing the physics of gas flow and reaction kinetics associated with the rate of binder formation and can be useful to predict soil carbonation in large-scale implementations.

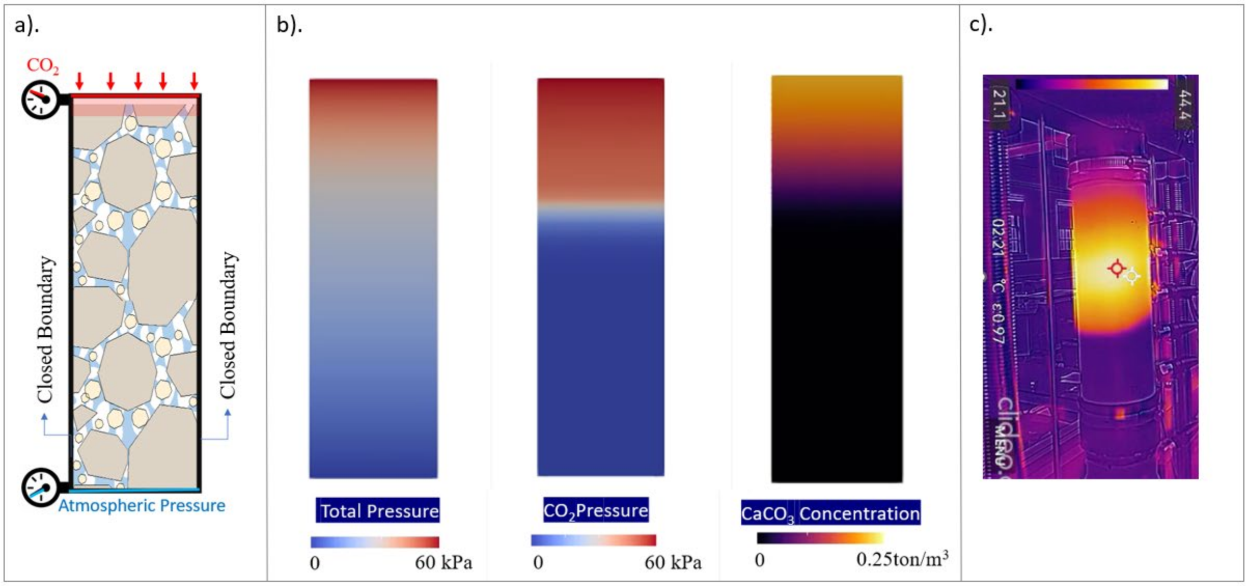

Fig 1. One-dimensional soil carbonation demonstration. a). scheme of a column of soil mixed with lime, CO_2 is introduced at the top, and the bottom of the column is open to the atmosphere. b). Finite Element Analysis simulation results, the CO_2 pressure front is advancing on the system generating the binder ($CaCO_3$). c). Thermal camera registration of one-dimensional carbonation reaction in the laboratory, increase in temperature is due to the reaction.

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