1D-modelling of microbially induced calcite precipitation for geotechnical applications

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Introduction

BioGrout is a soil strengthening technology in which *Sporosarcina Pasteurii,* urea and calcium chloride are injected in the subsurface. The bacteria degrade urea in the presence of calcium ions, resulting in calcium carbonate precipitation:

$CO(NH_2)_2 + 2H_2O \rightarrow CO_3^{2-} + 2NH_4^+$

$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3\downarrow$

The result is the strengthening of the treated material, with a restricted reduction of the permeability. The principles of the proposed process are fairly well known and on lab-scale, it is applied. The final objective, however, is application of the method on a large scale (field). Therefore, an engineering model is required capable of predicting the desired process variables to reach the requirements set by a contractor. The modelling is complex as it includes hydrological aspects (a.o. decreasing porosity due to precipitation and density flow), geochemical aspects and microbiological aspects. Therefore, a modular approach is chosen to model the proposed process using different modelling tools (Matlab, COMSOL Multiphysics, Excel and Geochemist's Workbench). This paper focuses on the predicted calcite profile in 1D-columns in comparison with experimental results. First, a calcite precipitation experiment in three sand-filled columns placed in series will be described. Subsequently, a description of a simplified model approach is presented. Experimental results and model results are compared and discussed. Finally, follow-up activities towards a more sophisticated model are discussed.

Methods:

Columns were constructed with Itterbeck sand (125-250 μm). The sand was packed under water and tamped in layers to a dry density of 1.73-1.74 g/cm^3. The height of the final sand packet was 16 cm. At each end of the column, a 1 cm layer of filter gravel (60 g) was packed in the same manner. Column dimensions were 6.53 cm (internal diameter) by 18 cm in length including filter material.

Cementation fluid (a solution of urea and calcium chloride in water) was injected from an inflow reservoir at a flow rate of 40 ml per hour and flowed through the column from top to bottom, to minimise disturbance of the sand packet. Ammonium samples were taken directly from the outflow tube from each individual column.

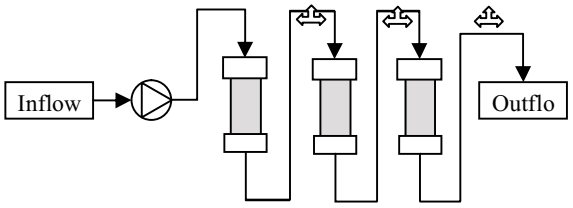

Fig. 1: Configuration for columns in series experiments. Sampling points (⇔) were located at inflow/outflow of each column to enable measurements within the series.

Fixation of bacteria in the columns was accomplished as follows:

One pore volume of bacteria was injected to fill the column, immediately followed by one pore volume of 0.05 M $CaCl_2$ for fixation of the bacteria. Continuous injection of urea/calcium fluid was then initiated.

A flow rate of 35 ml/min was used to inject the bacteria with a concentration of 0.05 M $CaCl_2$. General grouting conditions are given in table 1.