Effect of Magnesium as Substitute Material in Enzyme-Mediated Calcite Precipitation for Soil-Improvement Technique

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The optimization of enzyme-mediated calcite precipitation was evaluated as a soil-improvement technique. In our previous works, purified urease was utilized to bio-catalyze the hydrolysis of urea, which causes the supplied Ca$^{2+}$ to precipitate with CO$_2$–3CO$_3^{2-}$ as calcium carbonate. In the present work, magnesium chloride was newly added to the injecting solutions to delay the reaction rate and to enhance the amount of carbonate precipitation. Soil specimens were prepared in PVC cylinders and treated with concentration-controlled solutions composed of urea, urease, calcium, and magnesium chloride. The mechanical properties of the treated soil specimens were examined through unconfined compressive strength (UCS) tests. A precipitation ratio of the carbonate up to 90% of the maximum theoretical precipitation was achieved by adding a small amount of magnesium chloride. Adding magnesium chloride as a delaying agent was indeed found to reduce the reaction rate of the precipitation, which may increase the volume of the treated soil if used in real fields because of the slower precipitation rate and the resulting higher injectivity. A mineralogical analysis revealed that magnesium chloride decreases the crystal size of the precipitated materials and that another carbonate of aragonite is newly formed. Mechanical test results indicated that carbonate precipitates within the soils and brings about a significant improvement in strength. A maximum UCS of 0.6 MPa was obtained from the treated samples.
This study evaluates the potential of improving an insitu calcite grouting technique. The grout is composed of an equimolar solution of urea–CaCl$_2$ and an enzyme named urease. We examine the distribution of the grout materials and precipitated calcite within sand columns with a diameter of 5 cm and a height of 100 cm. In the first series of experiments, the concentration distributions of the individual grout materials (i.e., urea, CaCl$_2$ and urease) within the sand specimen are evaluated. In the second series of experiments, an enzyme-reagent mixed solution (i.e., grout) is injected into the sand columns to evaluate the distribution of calcite. Sand samples...
are collected from various vertical locations within the treated columns and the amount of precipitated calcite is evaluated. Furthermore, attempts are made to achieve the uniform distribution of the injected grout and hence uniform calcite distribution throughout the specimen. The results show that a uniform distribution of the grout materials up to a distance of 1 m from the inlet is achievable. It is also observed that a relatively uniform distribution of calcite is achievable as long as the rate of calcite precipitation is well controlled.

Keywords: Soil improvement; Grout; Precipitation; CaCO3; Reaction rate

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