Evaluation of a New Injection Method for Biologically Improvement of Sandy Soils

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Received: 19 Nov 2016 Accepted: 17 June 2017

Extended Abstract

Paper pages (29-44)

Introduction

Microbial induced calcite precipitation (MICP) is one of the environment-friendly soil improvement methods that uses urease activity of the microorganisms to bound soil grains.

This method is based on three following steps:

1. Urea hydrolysis by urease activity of microorganisms and formation of ammonium and carbonate ions:

$$CO(NH_2)_2 + H_2O \xrightarrow{\text{urease}} 2NH_4^+ + CO_3^{2-} \quad (2)$$

2. The reaction between carbonate and calcium ions and formation of calcium carbonate:

$$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3 \quad (2)$$

3. Bonding the soil particles by calcium carbonate.

One of the main challenges in use of MICP for soil improvement is the selection of proper injection method. An efficient injection method should lead to the construction of a homogeneous specimen beside of less used materials. In this study, a new method based on the theory of convection of liquids, for injection of bacteria and cementation solution is introduced.

Specimens are made according to the new injection method and their strength and homogeneities are tested. The obtained results are compared with the specimens which are made based on common injection method. Eventually, the success of the proposed injection method is investigated.

Material and methods

Gram-positive microorganism Sporosarcina Pasteurii No. 1645 (DSM 33) is provided from Persian type culture collection (PTCC). To make sand columns, Poly Vinyl Chloride (PVC) tubes were used with an internal diameter of 5cm and length of 12cm. Molds were placed vertically and a scouring pad and approximately 1 cm gravel as a filter are placed at the bottom of the column. Then the column packed with pure silica (Table 1). Finally, a scouring pad and approximately 1 cm gravel as a filter are placed at top of the column and mold were closed with a threaded Polypropylene layer on top and bottom with a hole for injection of bacteria and cementation solutions.

Table 1. Sand properties used in this study

Soil Type	G_s	γ_d	e	D_{10}	D_{30}	D_{60}
Sw	2.6	1.84	41%	0.11 mm	0.43mm	0.85mm

In this study, a new multi-step method of injecting bacterial and cementation solutions is introduced. Injection of solutions is done after washing the sand column with distilled water. At the first step, 0.25 times of the void volume of soil, the bacterial solution is injected into the sand column. The bacteria allowed resting in the sand for 2 hours before the cementation solution was injected. After 2 hours, cementation solution is injected into the sand column by the amount of 0.25 times of pore volume of soil. The cementation solution consisted of 1.5 M urea and 3 M Calcium chloride. Again after 2 hours delay, bacterial solution and cementation solution are injected into sand column both by the amount of 0.25 times of pore volume of soil, same as aforementioned steps. In order to provide a comparison between the proposed injection methods of this study with conventional injection method, specimens are also made by the conventional method. In these specimens, bacterial solution and cementation solution are injected into the soil both by the amount of 1.5 times of pore volume of soil.

Results and discussion

To evaluate the homogeneity of the biologically improved sand specimens, the specimen is divided into 6 equal parts and the amount of

calcium carbonate in each part is measured. It is found that calcium carbonate crystals are formed more homogenous in parts of specimens which are improved by new injection method (Figure 1). While specimens improved with conventional injection method are not homogeneous. The new injection method used in this study is based on the theory of convection in cementation and bacterial solution. Since the specific gravity of used cementation solution (3M urea and 1.5M calcium chloride solution) is 1.120 gr/cm3 and the specific gravity of ammonium chloride (which is the result of reaction between ammonium and chloride ions) is 1.031 gr/cm3, therefore a convection flow occurs in cementation solution after urease reaction (reaction 1) because of difference in specific gravity of two mentioned solutions. This convection flow causes a sustainable contact between cementation and bacterial solution in entire height of specimen.

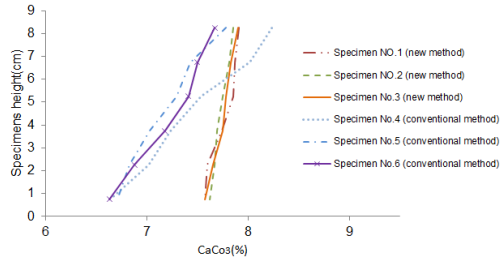

Figure 1. Amount of calcium carbonate deposition along improved specimens by new and conventional injection method

To examine the efficiency of newly suggested injection method in this study, uniaxial compressive strength test (UCS) is performed on biologically improved sand specimens. Figure 2 shows stress-strain curves of specimens. The peak strength of specimens with conventional injection method is about 0.6 MPa. While the peak strength of biologically improved specimens prepared by new injection method is about 1.6 MPa. The reason for this difference in the obtained results is that when the volume of bacterial solution is more than the pore volume of soil, a part of bacteria solution in the first step of injection is removed. Then with an injection of cementation solution, more amounts of bacteria removes from the specimen before efficient placement of bacteria between soil particles. However, in new

injection method the total volume of injection solutions (bacterial and cementation solutions) are equal to the pore volume of soil and this prevents the removal of bacteria from a porous medium.

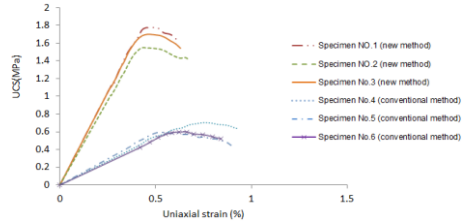

Figure 2. Uniaxial stress-uniaxial strain curves of biologically improved specimens

Conclusion

In this study, the feasibility of using a new injection method for biological soil improvement is investigated based on the theory of convection with the aim to decrease the volume of bacteria and cementation solution. In this method, the final volume of bacterial and cementation solutions are reached the soil void volume in 4 consecutive injection steps. Specimens are made to investigate the efficiency of the proposed injection method. Also, specimens are made base on conventional injection method to provide the comparing possibility. Studying the precipitated calcium carbonate along the specimens show more homogeneity in ones prepared by proposed injection method in comparison to the specimens made by the conventional method. The obtained results of UCS tests are also showed that specimens made by new injection method have the more uniaxial strength (1.6 MPa) while the conventional method specimens are presented the strength of 0.6 MPa. Eventually, the proposed injection method of this paper implies less amount of bacterial and cementation solutions in a proper and efficient manner to bond the soil particles which leads to specimens with more strength, stiffness and homogeneity.

Keywords: Biological improvement, Injection method, Uniaxial compressive strength, X-Ray analysis, SEM images.

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