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Use of iron-based biogeotechnologies for soil improvement

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Abstract

In geotechnical engineering, conventional soil improvement techniques – including both mechanical and chemical stabilization methods – have potential drawbacks such as high cost, high energy consumption and sometimes negative environmental influences. However, the rapid development of biotechnology has provided opportunities for innovation in soil improvement methods. In recent years, a promising approach, the so-called microbial geo-technology, has been attempted. This study contributes to the development of biocement and its application to soil improvement. A new variation of biocement through the microbially induced iron salts precipitation was also studied. The iron-based biocement consists of UPB, ferrous and urea solution and the iron is produced by microbial activity through a reduction process. Experiments with ferrous cations provided by chemical reagents were also studied. The data on the sand biocemented with iron-based biocement have shown a reduction in the hydraulic conductivity of the sand from 10^{-4} m/s to 10^{-7} m/s. There is also an increase in the unconfined compressive strength (UCS) of 402 kPa when the precipitated iron to sand ratio is 6% (w/w). The precipitated iron hydroxide in the sand grains has been identified from the FESEM images.

Keywords: Iron-based, biocement, soil improvement, ferrous cations.

1. INTRODUCTION

Çabalar (2007) and Ivanov and Chu (2008) also reported that biocementation in sands can be facilitated by using an agent such as hydrous iron oxide. The iron salts precipitated can be considered a clogging and cementing compound called iron-based biocement. There are two reasons for the use of iron-based biocement. The first reason is annual production of thousands of tons of iron salts. The second is that natural sandstone often originates from sand saturated with ferric oxides or hydroxides (Pettijohn et al. 1987). Therefore, iron salts precipitation through iron-based biocementation could be a new method. Little work has been published on the mechanisms and potential applications of iron-based biocementation (Ivanov et al. 2009, Chu et al. 2011, Ivanov et al. 2012). In this study, calcium chloride used in the MICP process was replaced with ferrous sulfate for precipitation of iron salts as a biocementation method. In the present study, innovative biocement production by the addition of urea and ferrous sulfate solution after the application of UPB to sand samples was carried out and the possibility of increasing the shear strength of soil in the presence of ferrous cation was explored.

The objectives of the study presented in this chapter are as follows:

1) To examine iron-based biocement production using UPB, ferrous sulfate and urea solution.
2) To evaluate the effects of different iron-based biocements on the hydraulic conductivity of sand.

Similar to the precipitation of calcium carbonate in the presence of hydroxide and carbonate ions through MICP, iron salts can be precipitated based on the following Reactions:

$$2NH_4^+ + 2OH^- + FeSO_4.7H_2O + CO_2 \xrightarrow{Urease} FeCO_3 + 8H_2O + (NH_4)_2SO_4 \quad (1)$$

$$Fe + 3OH^- \rightarrow Fe(OH)_3 \quad (2)$$

In this method, UPB was applied before the solution of ferrous sulfate ($FeSO_4.7H_2O$, molecular weight of 278 g from SIGMA) and urea for the production of iron salts. 100 ml of intact bacterial suspension (*Bacillus sp.)* was used in the experiment.

Since the pH of ferrous sulfate and urea solution is acidic (3-4) and the activation of urease activity occurs in the basic phase (8-9.5), it was important to monitor the pH of the solution after mixing with UPB. Therefore, 30 ml of diluted or concentrated UPB was mixed with 30 ml of 7.5 mM ferrous sulfate and 15 mM urea solution. The highest pH for diluted UPB was measured in the basic phase (8) while, under the same conditions, the pH for concentrated UPB was neutral (7) after 12 hours. In addition, increasing the biomass