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Influence of organic additive on EICP technique for soil improvement

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Introduction

Enzyme Induced Carbonate Precipitation (EICP) is a biochemical technique for improving soil properties in which calcium carbonate is precipitated within the soil pores. Calcium carbonate precipitation improves the strength and the stiffness of soil by filling up the void of soil and restricting their movement. Application of powdered urease enzyme as bio-catalysis mixing with urea and calcium carbonate to produce calcite precipitation has been confirmed. Yasuhara et al. (2012), Neupane et al. (2013), Putra et al. (2015) used the powdered urease enzyme from jack bean and had been purified; calcite precipitation occurs after the chemical reaction between the urease enzyme mixing with urea and calcium chloride is induced in the soil. Although the calcium carbonate may improve the mechanical behavior of the soil when it precipitates on the surface of the soil particles by increasing inter-particle friction, the most significant impact on soil strength is induced when it precipitated at the particle on the contact point of the soil (Almajed *et al.*, 2019). The utilization of non-fat milk powder added to the basic EICP solution is reported to result in larger calcium carbonate crystals and a higher proportion of calcium carbonate precipitation at inter-particle contact points (Almajed *et al.*, 2019). In this experiment, the influence of adding dry milk as an organic additive material to the EICP solution was confirmed. The other organic material from soybeans powder was also conducted. The optimum amounts of urease enzyme and curing time were obtained. The unconfined compressive strength tests with three different treatment solutions for enhanced strength of the soil were examined.

Methods

Material

EICP treatment solution was prepared by dissolving urea, and $CaCl_2$, with claimed purify levels greater than 95.0%, was obtained from the Kanto Chemicals Co.Inc. Urease enzyme (Junsei Chemical, Tokyo, Japan), purified from the jack bean meal and with urease activity of 2360U/g, is used in the bio-catalytic dissociation of urea. The adding of an organic additive such as dry milk and soybeans powder to the treatment solution was examined in this work. Expected reaction to obtain precipitated carbonates ions.

$$CO(NH_2)_2 + 2H_2O \rightarrow 2NH_4^+ + CO_3^{2-} \quad (1)$$

$$CaCl \rightarrow Ca^{2+} + 2Cl^- \quad (2)$$

$$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3 \quad (3)$$

Precipitation test

Precipitation of calcite was evaluated directly in transparent test tubes. The ratio concentration of urea - $CaCl_2$ was fixed at 1M urea and 0.67M calcium chloride (Almajed et al., 2019). The amounts of urease enzyme varied from 1-3g/L. Urea-$CaCl_2$ solution and urease enzyme were mixed in total solution volume of 30mL. The evaluation of the precipitated amount was carried out every 24h until approximated the constant ratio to obtain the curing time. The precipitation of $CaCO_3$ takes place after several minutes, depending upon the solution concentration. After curing time (1-6 days), the solution was filtered with filter paper. The particle on the filter paper and tubes are dried to calculate the total amount of the calcite precipitated. The procedure of the precipitation test shows in **Figure 1**.

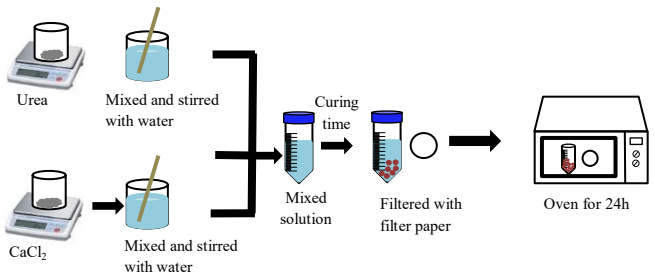

Figure 1. Procedures of test-tube experiment

PVC cylinder test

The optimal combination of the precipitation tests are utilized in the sand specimen, and the efficiency was evaluated. The PVC cylinder (5 cm in diameter and 10 cm in height) was used for preparing the sand specimen to examine the distribution of the precipitated material within the sand samples. Firstly, the dry silica sand was poured into the PVC cylinders to obtain a relative density of 50%. Secondly, the solutions are poured into the cylinders from the top.

The modified EICP solution by added organic additive material was conducted in this experiment. The treatment solution was mixed thoroughly with the organic additive material (dry milk, and soybeans) was fixed at 4g/L (Almajed et al., 2019). The specimen was treated with three different EICP solution. Solution 1 with no added organic additive material, solution 2 with added the dry milk, and solution 3 with added the soybeans as organic material. In this test, a single injection was applied. The PVC cylinder tests take five days, which should depend on the precipitation test results. After curing time, the specimens are removed from the PVC cylinder.

Results

The precipitation ratios with various amounts of urease enzyme and various curing times are evaluated in several transparent tubes. **Figure 1** shows the results of the precipitation ratio with various amounts of urease enzyme. The precipitation ratio at the different amount of urease (2g/L, and 3g/L) with a treatment solution 1:0.67 mol/L was more than 75%. Based on the results of precipitation tests, the urease enzyme concentration was selected at 2g/L for this experiment.

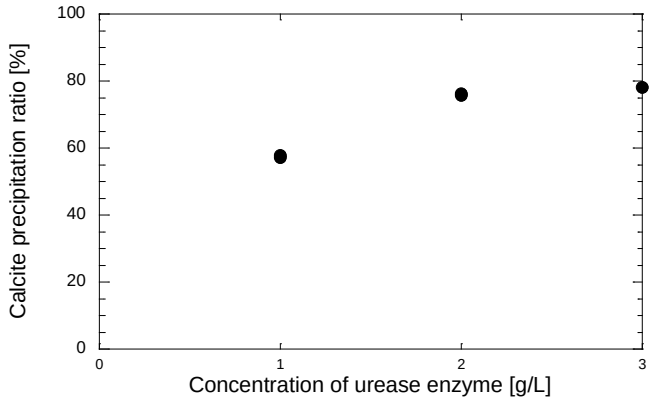

Figure 2. Precipitation ratio with various amounts of urease enzyme

Figure 3 shows the precipitation ratio with various curing times. The precipitation ratio of treatment solution 1:0.67 mol/L gradually increases until the curing time of 5 days. After that, it was approximately constant. Meanwhile, the precipitation of the treatment solution starts to appear on the fifth day, and it was approximately constant until six days. This may be attributed to the insufficient of the urease and hence the ureolytic activity for the higher concentration of urea.

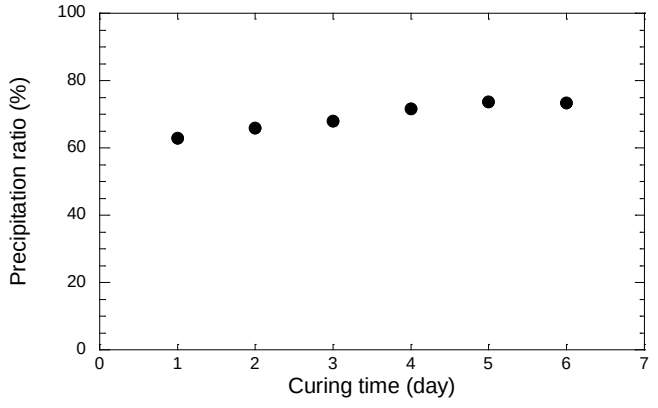

Figure 3. Precipitation ratio with various curing time

The results of soil treatment in terms of unconfined compressive strength using three different solutions were shown in **Figure 4**. The result shows that the specimens with added organic additive material have higher UCS strength than the specimens with basic EICP solution. The utilization of dry milk and soybeans powder has been confirmed to increase soil strength. The additional organic additive might affect the calcite precipitation formed; the calcite formation was not only on the surface of the soil but also in the contact point of soil (Almajed et al., 2019).

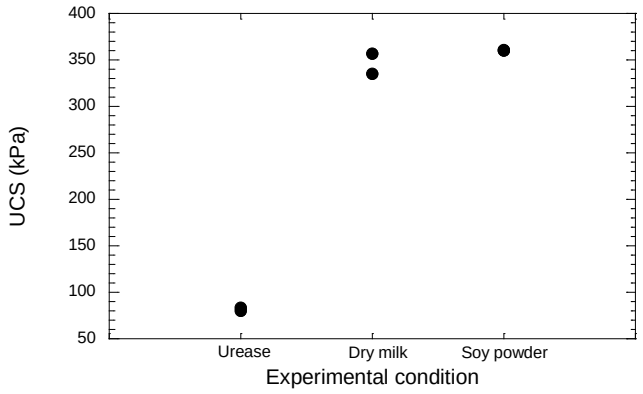

Figure 4. The relation between the UCS test with various treatment solution

Conclusion

This research examines the effect of the added organic material such as dry milk and soybeans powder for soil improvement using EICP technique. The precipitation ratio for various amounts of urease enzyme was evaluated. The results from the unconfined compressive strength tests showed the effect of the modified EICP technique. The UCS tests were confirmed that the specimens with modified EICP solution have more strength due to the added organic additive material. However, the further experiments for the effect of adding organic additive material in the EICP solution will be conducted, the SEM – EDX test for confirming the visualization of calcite precipitation will be reported in the near future.

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