Potency of Soybean Crude Urease on Enzyme-induced Carbonate Precipitation (EICP) as Soil-Improvement Technique

Keywords: Carbonate precipitation, Urease enzyme, Soybean, Soil improvement

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Introduction

The enzyme-induced carbonate precipitation (EICP) technique has become one of the innovative and potential techniques for soil improvement. In this technique, a mixed solution composed of reagents and the urease enzyme, which produces calcite, is utilized as the grouting material. Recently, alternative materials such as soybean to the urease enzyme have been examined by several researchers to resolve the cost issue of using the urease enzyme [1]. Despite the great potential the, no comparative study between commercial enzyme and crude enzyme extracted from soybean powder can be found in the literature. Thus, the main objective of this study is to investigate the potency of EICP using soybean powder for sandy soil improvement through several experiments. To examine the efficacy of EICP using soybean powder, the amounts of calcium carbonate precipitation were measured and compared with EICP using purified urease through tube tests. In addition, a mineralogical analysis of the precipitated materials acquired from the tube tests were conducted through XRD. The reinforcing effect was also investigated by conducting unconfined compressive strength (UCS) tests. Finally, by combining the evaluations of the microstructural analyses and the reinforcing effects, the improvement mechanisms of the treated samples were thoroughly investigated.

Methods

Urea, $CaCl_2$, soybean powder, and distilled water were used to produce the grouting solution The urea and $CaCl_2$ were obtained from Kanto Chemicals Co. Inc., Japan. As an alternative material to purified commercial urease enzyme, soybean crude urease was extracted from soybean powder (Gasol Soybean Flour 200 gr) purchased from PT. Gasol Organik, South Jakarta, Indonesia. In addition, a purified commercial urease (16040-1210, Junsei Chemical, Tokyo, Japan) was used for comparison purposes. Keisha sand number 4 was obtained from Kitanihon Sangyo Co. Ltd, Japan and used for the soil samples. The specific dry density, D_{50}, uniformity coefficient (Cu), and coefficient of gradation (Cc) were 2.63 g/cm3, 0.755 mm, 1.3, and 0.96, respectively.

20 g/L concentration of soybean crude urease was chosen based on previous experiment [2]. For the preparation, 20 mL of the urease solution (both purified commercial enzyme and soybean crude urease) was mixed with 20 mL of the testing solution containing 1 M of urea and 1 M of calcium chloride, and then cured for 1, 3 5, 7, 14, and 21 days at room temperature. After each specified curing time, the precipitated material was oven-dried at 80°C for 24 hours. The evolution of the evolution of the calcium carbonate's mass and mineralogy over time was measured and analysed

The reinforcing effect of the EICP-treated samples using the soybean crude urease was compared with that of the EICP-treated samples using the purified commercial enzyme urease The experimental preparation procedure developed by Putra et al. [3] was adopted for reinforcing test. Under curing times of 7 and 14 days, the UCS strength of treated soils was examined, and the improvement mechanisms were investigated through SEM analysis.

Results and Discussion

The evolution of the precipitated mass and the increasing rate, defined as the percentage of increasing mass between the targeted curing time sample and the one day-cured sample, for each curing time, are depicted in Figure 1. The results appear to be similar, but the characteristic trends between them are different. In the early period of the curing time, the increase rate for the EICP-commercial enzyme mass is greater than that for the EICP-soybean urease. It is seen that the EICP-commercial enzyme solution takes about 7 days to produce the maximum number of precipitated materials, while the EICP-soybean urease solution takes about 14 days to reach the steady state. These results imply that the soybean crude urease requires a longer time to generate precipitated materials than the commercial enzyme urease.

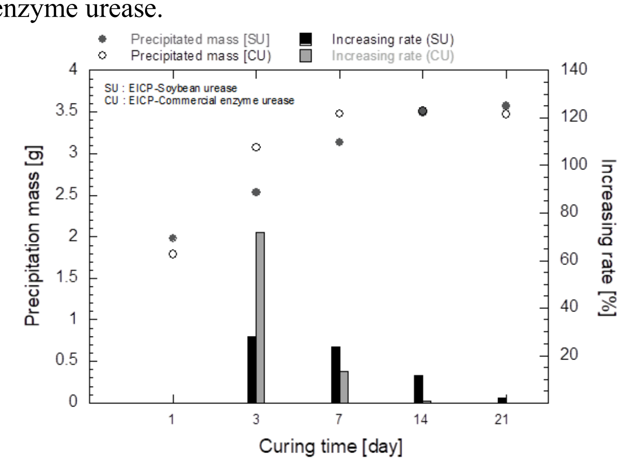
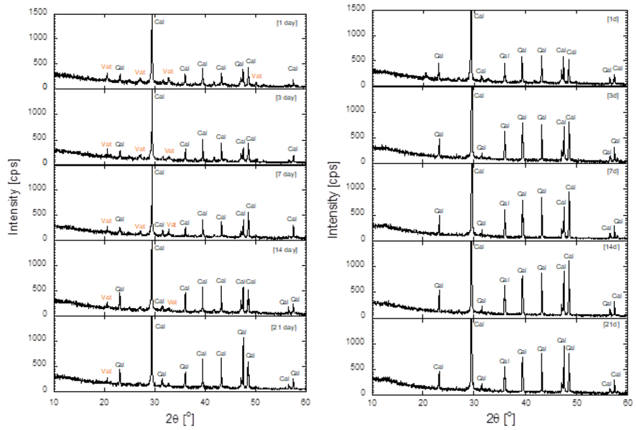


Fig 1. Evolution of precipitation mass and increasing rate with curing time

The XRD analysis results of both the EICP-soybean urease and the EICP-purified urease are depicted in Figure 2. The peak intensities of calcite, which is the most stable polymorph of calcium carbonate, are clearly observed in both the EICP-soybean urease and the EICP-purified urease. In addition, it is also confirmed from the EICP-soybean urease that vaterite, which is the least stable polymorph of the calcium carbonate, is precipitated. Moreover, it should be noticed that the peak intensities of vaterite decrease with the increasing curing time. Therefore, the decrease may indicate a phase change of the calcium carbonate from vaterite to calcite.



(a) (b)

Fig 2. Comparison XRD patterns of precipitation materials: (a) EICP-soybean urease and (b) EICP-commercial enzyme

The curing duration had no influence on the UCS evolution of the EICP-commercial enzyme samples, while it exerted a significant effect on that of the EICP-soybean urease samples. As no more calcium carbonate formed in the EICP-commercial enzyme samples after seven days, there was no increase in the strength of the EICP-commercial enzyme samples. On the other hand, increasing the curing duration may have caused the formation of more $CaCO_3$ in the EICP-soybean urease samples and resulted in the higher UCS values of the 14-day samples.

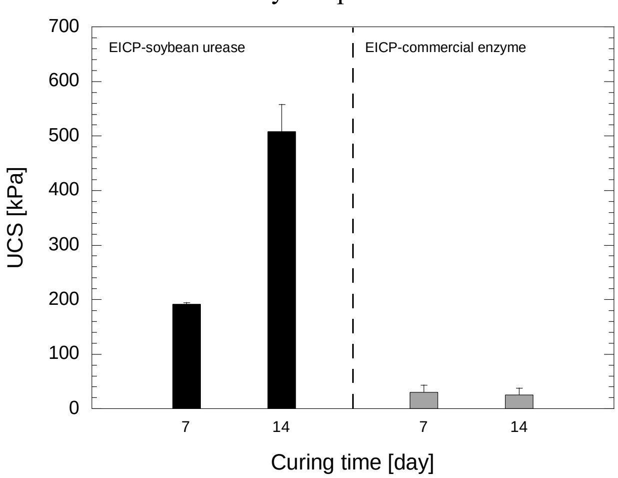


Fig 3. UCS test results of treated samples

The SEM images of soil samples treated by the EICP-soybean urease show the precipitation of spherical vaterite and rhombohedral calcite on the sand particle surfaces. On the other hand, the SEM images of the soil samples treated with the EICP-commercial enzyme show the precipitation of rhombohedral calcite distributed over the sand particle surfaces. It was observed in the SEM images that, when the EICP-soybean urease solution was added to the soil samples, relatively large calcite crystals appeared that had formed mainly at the grain-to-grain contacts.

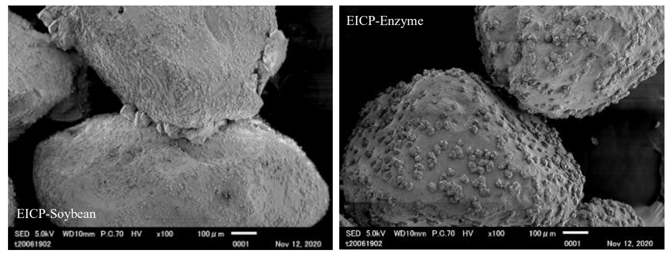


Fig 4. Comparison SEM images of treated samples

Conclusion

The potency of soybean crude urease in carbonate precipitation was evaluated. In the tube tests, vaterite precipitation was mostly observed when employing the soybean crude urease. Prolonging the curing duration was seen to possibly result in a decrease in vaterite content and to bring about the formation of more stable calcite. The UCS test series showed that the strength of the treated sample using EICP-soybean urease samples were much higher than those of the EICP-commercial enzyme samples. This should be attributed to the $CaCO_3$ precipitation concentrated at the grain-to-grain contacts. All the test results lead to the conclusion that soybean powder is a material showing great potential as a replacement for commercially purified enzyme urease in the carbonate precipitation of soil-improvement techniques.

References

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