Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 54(9) (2022) 659-662
DOI: 10.22060/ceej.2022.18917.6997

Improvement and stabilization of soft and loose fine-grained soils by Microbial Induced Calcite Precipitation (MICP) method (Case study: fine-grained soil of Kermanshah Faculty of Agriculture)

S. Karami[1], J. Khazaei[1*], M. Sharifipour[1], R. Sharifi[2]

[1]Department of Civil Engineering, Razi University, Kermanshah, Iran¬
[2]Department of Plant Protection Engineering, Razi University, Kermanshah, Iran¬

ABSTRACT: The process of biomineralization as a method of biological soil improvement refers to a set of biochemical reactions in which the sediment formed by bacteria causes the grains of soil to graft and thus improve its properties. In each of the previous researches in the field of biomineralization, one of the methods of mixing, adsorption and injection have been used to add cementation solution to the soil and so far, no comparison has been made on these methods. What is very important in the biomineralization process as a soil remediation method and in fact, one of the most important challenges of this method is the uniform penetration of the biocementation solution and, consequently the proportional distribution of sediments formed in the soil matrix. In the present study, after optimizing the precipitation conditions, the effect of the sample-making method on the biological improvement of Kermanshah clay fine-grained soil with two bacteria Bacillus megaterium and Lysinibacillus boronitolerans was studied. The results show that the method of sample making (in terms of adding biocementation solutions) has a significant effect on the improvement of the compressive strength of samples. The maximum improvement of soil compressive strength (up to 2.68) occurred for Bacillus megaterium in the adsorption method. In general, the addition of solution to the soil by adsorption method has been more effective in the proper placement of sediment between soil grains than the mixing and injection method. It has been more effective and in fact the solutions have been allowed to move between the soil grains to the corners where the grains join, thus resulting in the formation of effective sediment at the grains joint. Also, biological stabilization of the consolidation test sample reduced the soil void ratio change from 0.584 to 0.354 and the compression index from 0.077 to 0.038. The addition of biocementation solutions to the sample of atterberg limits test sample reduced the plasticity index from 26 to 19.

Review History:

Received: Aug. 26, 2020
Revised: Sep. 28, 2021
Accepted: Dec. 17, 2021
Available Online: Feb. 21, 2022

Keywords:

Biological Soil improvement
Microbial induced calcite precipitation
unconfined compression strength
Soil plasticity and Environmental geotechnics

1- Introduction

Microbial Induced Calcite Precipitation (MICP) method is a new and interdisciplinary method that is formed from the link between biotechnology and geotechnical engineering. In this method, during a series of chemical reactions in the presence of bacteria, calcium carbonate precipitate is formed between the soil particles.

MICP, by increasing soil strength and hardness can be used as a cost-effective soil improvement method.

Many environmental factors affect the efficiency of MICP process. These factors include temperature, the concentration of additives, humidity, pH, culture medium, water salinity, type of mineral and soil particle size, injection pressure, duration of treatment, etc.

What is significant in the biomineralization process as a soil remediation method which is in fact one of the most important challenges of this method, is the uniform penetration of the cementation reagent and consequently the proportional distribution of sediments in the volume of soil [1].

In the present study, after determining the optimal conditions of biocementation reaction according to the type of soil and selected bacteria, the importance of the method of making UCS samples was studied. This issue has not been studied in any of the previous studies.

2- Methodology

Soil

The soil used in this study was taken from the Faculty of Agriculture of Razi University located in the east of Kermanshah from a depth of approximately one meter above the ground. Based on the tests performed, this soil is mainly evaluated as fine-grained, soft and loose.

Microorganism

*Corresponding author’s email: j.khazaie@razi.ac.ir

Table 1. results of UCS test to investigate the effect of cementation reagent concentration

Strain (%)	Stress (kg/cm²)	Bacteria	Parameter under study: cementation reagent concentration
1.78	1.15	—	Control sample
2.29	1.8	B.m	0.25 M
1.52	1.38	B.124	
2.29	1.63	B.m	0. 5 M
1.78	1.55	B.124	
2.29	1.4	B.m	0.75 M
1.73	1.35	B.124	

Table 2. Results of UCS test to investigate the effect of the sample-making method

Strain (%)	Stress (kg/cm²)	Bacteria	Parameter under study: sample-making method
1.78	1.5	untreatment	mixing
2.29	1.8	B.m	
1.78	1.55	B.124	
2.29	1.07	untreatment	adsorption
2.23	2.87	B.m	
2.32	2.24	B.124	
2.29	1.11	untreatment	injection
2.01	1.73	B.m	
2.28	1.58	B.124	

In this study, two bacteria Bacillus megaterium (B.m) and Lysinibacillus boronitolerans (B.124) were used to compare the performance of efficient microorganisms in biological improvement.

Cementation reagent

The precipitating solution cementation reagent contains urea and water-soluble homolar calcium chloride. In this study, three concentrations of 0.25, 0.5 and 0.75 M were examined based on previous research in order to find the most appropriate concentration of urea-calcium chloride solution in relation to the selected bacteria and soil.

pH value of cementation reagent

The pH value of the additives as well as the pH value of the treated soil are the factors that control the biomineralization process. The pH value of the soil of the project site is equal to a constant value of 7, but the pH value of the cementation reagent will be used in two values of 7 and 9 to be able to compare the performance of bacteria in these two pHs and its relationship with the selected soil type.

Sample making method

In this study, different modes of adding biocementation solution including three methods of mixing, adsorption, and injection by pressure were studied to compare the differences in the effect of each method.

Unconfined Compressive Strength (UCS) was performed according to ASTM D2166 standard on cylindrical specimens with a diameter of 5.5 cm and a height of 11 cm.

In the mixing method, additives including bacterial suspension and urea-calcium chloride solution were added to the soil and mixed thoroughly, then the soil containing the necessary solutions to prepare a UCS test sample in the form of the prepared sample was kept in a zippered bag for the required time and then the UCS test was prepared.

In the adsorption method, first the soil with the desired density was pounded into the mold and then the necessary additives were added to the sample as adsorption. In the pressure injection method, after making the soil sample in the mold, additives were added to the soil with the pressure of 2 bars.

3- Results and discussion

3- 1- Investigation of the effect of cementation reagent concentration

The compressive strength of samples improved with cementation solution with different concentrations, can be seen in Table 1. According to this table, in all improved specimens, an increase in unconfined Compressive Strength occurred, but the magnitude of this increase varies with the concentration of the cementation reagent.

In biological improvement using B.124 bacteria, the greatest improvement in compressive strength is observed in the concentration of 0.5M of the cementation reagent. While the highest increase in resistance occurred with B.megaterium in the concentration of 0.25M cementation reagent. Previous studies investigating the effect of cementation reagent concentration on sandy soil improvement with B. megaterium reported the best MICP performance at 0.5M concentration of cementation reagent [2], this distinction indicates the effect of soil type and the reaction conditions on the function of the bacterium are known.

3- 2- Investigating the effect of sample making method

In order to evaluate the performance of sample making method, UCS tests were performed on samples prepared by mixing, adsorption and injection methods. The results of these experiments are shown in Table 2.

Obviously, the results of the UCS test, it is clear that the addition of biocementation solution to the soil after making the sample in their proper placement between the grains is "more" effective than the mixing method. Only those sediments are effective in the MICP that cause the aggregation of soil grains, and the formation of sediment in voids or grain surfaces has almost no effect on improving soil properties. In adsorption and injection methods, the solutions are actually allowed to move between the soil grains to the corners where the grains join, thus resulting in the formation of effective sediment at the joint seeds. Among the methods of adding solutions after making the sample, the adsorption method has a better performance than the injection method, which apparently refers to the excessive injection pressure relative to the density of the sample, and in fact the penetration of the solution as adsorption The surface due to gravity has a better performance for the density of samples in this study. In fact, the solution has less opportunity to settle between the soils and may require more injections.

4- Conclusions

In this study, for specific optimization of concentration and pH value of cementation reagent in clay fine-grained soil, three concentrations of 0.25, 0.5 and 0.75 M at two pH value, 7 and 9 were investigated. The results of this study show that the highest compressive strength of the sample stabilized with B. megaterium occurred at a concentration of 0.25 M at pH9. Previous research on the effect of cementation reagent concentration on the improvement of sandy soil with B.megaterium reported the best MICP performance at 0.5 M concentration of cementation reagent. This distinction indicates the effect of soil type and reaction conditions on bacterial function is known.

The samples improved by the adsorption method showed more resistance than the mixing and injection method. In fact, adding biocementation solution to the soil after making the sample in their proper placement between the soil grains has been more effective than the mixing method, and in fact the solutions have been allowed to Move between the soil grains to the corners where the grains join, resulting in the formation of effective sediment at the grains junction.

To evaluate the time parameter treatment duration in the soil improvement process studied in this study, the compressive strength of the samples at 10 days and 40 days after construction were compared. The results showed a significant increase in pressure over time. In fact, by the tenth day of treatment, approximately 60% of the forty-day recovery of the sample has occurred.

the addition of biocementation solution to the sample of consolidation test and the Atterberg Limit test reduced the soil void ratio changes from 0.584 to 0.354 and the plastic index from 26 to 17.

References

[1] B. Krajewska, 2018. “Urease-aided calcium carbonate mineralization for engineering applications: A review”. Journal of Advanced Research, 13, September, pp. 59-67.

[2] A. Sharma, R. Ramkrishnan, 2016. “Study on effect of microbial induced calcite precipitates on strength of fine grained soils”. Perspectives in Science, 8, April, pp. 198-202.

HOW TO CITE THIS ARTICLE

S. Karami, J. Khazaei, M. Sharifipour, R. Sharifi, Improvement and stabilization of soft and loose fine-grained soils by Microbial Induced Calcite Precipitation (MICP) method (Case study: fine-grained soil of Kermanshah Faculty of Agriculture) , Amirkabir J. Civil Eng., 54(9) (2022) 659-662.

DOI: 10.22060/ceej.2022.18917.6997