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Investigation of the effect of Sporosarcina Pasteurii bactria on the Microbial Induced Carbonate Precipitation (MICP) and the UCS of carbonate sands

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Abstract

Fast growing of engineering infrastructure to meet human requirements is directly related to the need for a resistant soil to carry out construction load. On the other hand, the importance of environmental issues has led to an ever-increasing demand for new and environmentally friendly methods for soil remediation. The method of microbial induced calcium carbonate precipitation (MICP) is considered by the researchers as one of the most environmentally friendly methods. The purpose of this study was to investigate the effect of MICP on the uniaxial strength of carbonate sand. Therefore, samples of Bushehr carbonate sand were cured after the injection of bacteria and cement solution. Then uniaxial compression tests were carried out to evaluate the compressive strength. Also, the effect of cementation solution concentration and curing time on the results of MICP method was investigated. The results show that maximum uniaxial strength of sand stabilized with MICP is about 3.5 kg/cm^2, which indicates the proper performance of MICP method for stabilization of carbonate sand. The UCS of the samples depends on the concentration of cement solution. Stabilized samples with a higher cementation of concentration solution had more uniaxial strength than samples with lower cementation concentrations. The curing time more than 14 days did not significantly affect the UCS of the samples.

Keywords: *Biological Treatment, Sporosarcina Pasteurii Bacteria, Calcite Precipitation, Calcium Carbonate, UCS of Carbonate Sand*

Extended Abstract:

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1. Introduction

The fast growing of the engineering infrastructures to meet human needs is directly related to the resistant soil to carry out construction loads. On the other hand, the importance of environmental issues has led to an ever-increasing demand for new and environmentally friendly methods for soil remediation and improvement. The method of microbial induced calcium carbonate precipitation (MICP) is considered by the researchers as one of the most environmentally friendly. The method in which the bacteria are used for precipitation of $CaCo_3$ is called Microbial Induced Carbonate Precipitation, which is briefly referred to as MICP (Harkes et al., 2010).

In the current study the effect of MICP on the uniaxial compression strength (UCS) of carbonate sands was investigated, experimentally. 12 samples of Bushehr carbonate sand were made and cured after injection of bacteria and cementation solution. Then, uniaxial compression tests were performed to evaluate shear strength of the treated samples. The influence of parameters such as concentration of the cementation solution and curing time on the results of MICP method was investigated.

2. Materials and Methods

2.1. Microorganism

The bacteria selected for MICP process was *Sporosarcina pasteurii*. The bacteria were provided by the Persian Type Culture Collection with No. PTCC 1645 and was cultivated and augmented according to the company's instructions.

2.2. Soil

The soil used in this research is carbonate sand, prepared from the coast of Bushehr port, presented in Fig. 1. Based on the grain size distribution analysis, the soil is a uniformly degraded sand (SP) in the USCS system.

Fig 1. Images of the Bushehr Carbonate Sand

2.3. Solutions

Cementation solution contains urea and calcium chloride ($CaCl_2$). The Cementation solution was prepared in two different concentrations, the composition of which is given in Table 1. The bacterial suspension includes seawater (which was simulated in the laboratory) and the bacteria was prepared in the desired volume.

Table 1. Combinations of the Cementation solution

Cementation Solution Combination	No
0.25 M $CaCl_2$ + 0.666 M urea	1
1.0 M $CaCl_2$ + 2.66 M urea	2

2.4. MICP Process

Bacterial and cementations solutions were injected into soil samples during three stages. Bacteria suspension was first injected into the soil at a flow rate of 1 l/hr. 24 hours later, cementation solution was injected into the soil at a flow rate of 1 l/hr. Then, 24 hours later, the second phase of cementation solution was injected into the soil. The solutions were injected to the specimens through the serum and needle injection. In order to increase accuracy and achieve a more reliable result, each sample was made with three replications.

2.5. Uniaxial Compression Tests

In order to measure the shear strength of the samples, treated with MICP, uniaxial compression tests were conducted on the samples, as illustrated in Fig. 2.

Fig 2. Uniaxial compression tests on the treated samples

3. Results and Discussion

The uniaxial compression strength (UCS) in samples was obtained to be between 2.4 and 3.0 kg/cm^2, which indicates the proper functioning of the MICP process for the improvement of the Bushehr carbonate sand. In the present study, the uniaxial compressive strength was obtained from zero value for crushed samples up to a maximum of 300 kPa for the treated sample of 28 days with a concentration of 1 molar cementation solution. Based on the results obtained for the single-axial

compressive strength, the MICP method shows that the soil sample is cemented and shear strength of the samples is increased.

The results show that the samples treated with 1.0 molar resulted in higher strength with respect to the samples treated with 0.25 molar concentrations of cementation solution. According to the results, it can be concluded that as the concentrations of cementation solution increases, UCS of the samples are increased. After 14 days, no significant change in the UCS of the samples was observed. The results show that the bacterial activity was increased with time and after 14 days the variation in strength was reduced.

4. Conclusions

12 samples of Bushehr carbonate sand were made and cured after injection of bacteria and cement solution. Then, uniaxial compression tests were performed to evaluate shear strength of the treated samples. The influence of parameters such as concentration of the cementation solution and curing time on the results of MICP method was investigated.

The results show that the uniaxial compression strength (UCS) of stabilized sand with MICP is between 0 to 3.5 kg/cm^2. The result demonstrates the proper performance of the MICP for improving carbonate sands. It was concluded that higher concentrations of cementation solution in the samples could increase the uniaxial compressive strength of the samples. Also, the study of the effect of treatment time concluded that the bacterial activity and the increase in uniaxial compressive strength in the samples decreased from 14 days later and had very little change.

References:

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