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Experimental Study of the Microbial Induced Carbonate Precipitation (MICP) Effect on the Permeability of Carbonate Sands

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Abstract

Microbial induced carbonate precipitation (MCIP) is an environmentally and suitable method for soil remediation. In this method, urea is hydrolyzed by the urease enzyme, that is splashed from Sporosrcina Pasteurii bacteria. The calcium carbonate is formed in the presence of calcium ion. Calcium carbonate connects the soil particle like a bridge and improve its engineering characteristics. In the present research, the effect of MICP on the permeability of carbonated sand was investigated. The effect of factors such as concentration of the cementation solution, curing time and relative density on soil permeability have been studied. To consider the effect of different factors on the MICP performance, number of samples have been treated with MICP method and then constant head permeability test were conducted on the treated samples. the results show that as the concentration of cement solution was increased, the permeability of the samples was decreased. Loose Samples resulted in more decrease in permeability with respect to the dense samples. Also, bacterial activity was increased with time and after 14 days the variation in permeability was reduced. The highest rate of permeability reduction was around 60% for the sample prepared in loose state and cured with one molar concentration of cementation solution for 28 days.

Keywords: *MICP, Bactria, Calcium carbonate crystal, bio cementation, constant head permeability test*

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Extended Abstract:

1. Introduction

Due to the increasing population in urban areas and decreasing suitable ground for construction, there is a need for improving the soil exist in the sites (Dejong et al, 2010). Over the past 10 to 15 years, new fields of bio-geotechnics have emerged in which the geotechnical engineer seeks to find new technologies for improving the ground with more environmentally-friendly methods and more cost-effective than other methods (El Mountassir et al, 2018). Microbial induced carbonate precipitation (MICP)is a well-known environmentally and suitable method for soil remediation. In this method, urea is hydrolyzed by the urease enzyme, that is secreted from Sporosrcina pasteurii bacteria and calcium carbonate is formed in the presence of calcium ion. Calcium carbonate connects the soil particle like a bridge and improve soil engineering characteristics. In this study, microbial induced carbonate precipitation (MICP) used to stabilize the carbonated sandy soils. The effect of MICP on the permeability of Bushehr carbonated sand was studied by a series of treatment programand permeability tests in the laboratory.

2. Materials and methods

2.1. Selected Microorganism

The bacteria selected for MICP process was *Sporosarcina pasteurii*. The bacteria was provided by the Persian Type Culture Collection with No. PTCC1645 and was cultivated and augmented according to the company's instructions.

2.2. Soil

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

2.3. Solutions

Cementation solution contains urea and calcium chloride ($CaCl_2$). The Cementation solution is 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

Combinations of Cementation solution	No
0.25 M $CaCl_2$ + 0.666 M urea	1
1.0 M $CaCl_2$ + 2.66 M urea	2

2.4. Injections and Curing Process

Bacteria cementations solutions were injected into soil samples during three stages. Figure 1 shows the MICP process used in the current study. In order to increase accuracy and achieve a more reliable result, each sample was made with three replications.

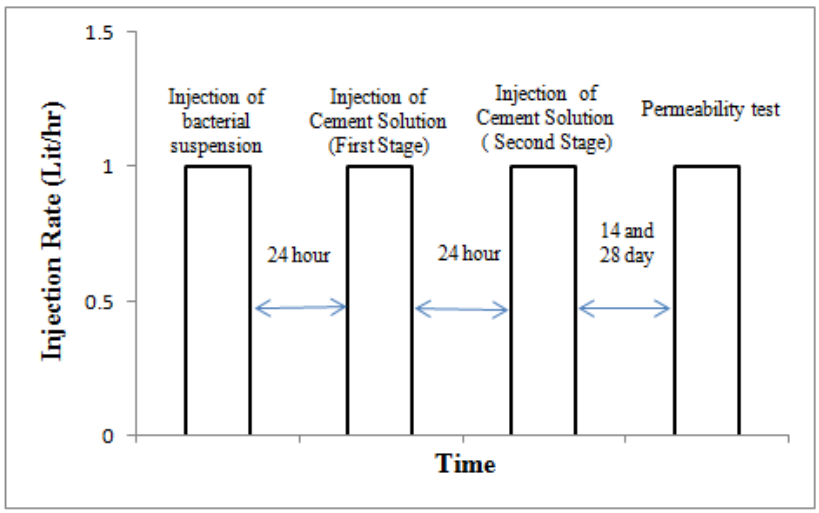

Fig. 1. MICP Process Chart

2.5. Permeability Tests

In order to measure the permeability of carbonate sand before and after treatment with MICP, constant head permeability test was used.

3. Tests results

3.1. Effect of Cementation solution concentrations on permeability

The results of the permeability tests on treated samples present that the permeability reduction in samples of 0.25 molar is about 32 to 46 percent and in samples with 1.0molar is about 40 to 49 percent. The results show that the reduction of permeability in samples with a concentration of 1 molar calcium chloride is more than samples with 0.25 mol.According to the results, it can be concluded that decreasing of permeability in samples that have been treated with higher concentrations of cementation solution has lower permeability.

3.2. Effect of soil density on permeability

The results of the permeability tests on treated samples present that the permeability reduction in loose samples is about 52 to 59 percent and in dense samples is varies from41 to 50 percent.The results show that the reduction of permeability in loose samples is higher than dense samples. According to the literature, MICP is more effective in loos material with respect to the dense material.

3.3. Effect of MICP duration on permeability

Reduced permeability in treated samples after 14daysvaried from 30% to 39% and varies from 34% to 40% after 28days. After 14 days, no significant change in the permeability of the samples has been observed. The results show that the bacterial activity was increased with time and after 14 days the variation in permeability was reduced.

4. Conclusion

24 samples were treated with MICP and the permeability of the samples were measured. Based on the tests results following conclusions are made:

In general, MICP has reduced the average permeability of carbonate sand from 36 to 58 percent.

The higher concentration of cementation solution in the samples leads to a greater reduction in the permeability of the samples.

The samples with lower densities showed lower permeability due to MICP.

The bacterial activity was increased with time and after 14 days the variation in permeability was reduced.

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