



Analyzing the Use of Molasses as an Alternate and Optimal Culture Medium in MICP Process of Sandy Soils

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ABSTRACT: The use of different soil improvement methods has always been accompanied by an assessment of the effect on strength parameters, costs, and environmental impacts. Since the new and eco-friendly methods are associated with a high initial cost, optimizing these methods to commercialize them is the priority of research projects. The use of biological methods for soil improvement, despite its high environmental compatibility, has not been welcomed from the economic point of view in most parts of the world and is still being considered as an academic and not an executive method. Soil improvement, using calcium carbonate sedimentation is one of the most environmentally friendly biological methods. One of the most influential bacterial suspension parameters for calcium carbonate treatment is its culture medium, usually Nutrient Broth or Yeast extract. One of the ways to reduce the cost of biodiversity in the soil is an alternative culture medium. In this research, the use of sugar beet molasses, which is a waste of sugar and sugar factories, has been investigated as a suitable culture medium for biological improvement along with other culture media. It can reduce the cost of producing a suitable culture medium by up to 500 times. The success of soil regeneration after bacterial cultivation has been also evaluated in the present research.

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1. INTRODUCTION

Microbial geo-technology is a new branch of geotechnical engineering, Ivanov and Chu [1] which uses microbiological methods to address geological materials used in engineering. The process of confining inorganic microbial substances between soil particles in the porous medium is very common in the research of Stocks-Fischer, Galinat, and Bang [2]. Hydrolysis of urea is one of the first processes associated with carbonate precipitation due to the microbial processes which has been investigated in the late nineteenth century Ehrlich [3]. One of the most important factors affecting the activity and biology of microorganisms is their culture medium. The medium is solid, liquid, or semi-solid, designed to support the growth of microorganisms or cells [4]. As a bacterial culture medium and one of the most common sources of carbon, yeast extract has been used in many types of research, e.g., Rong, Qian, and Li [5], L. Cheng and Cord-Ruwisch [6] and Burbank, Weaver, Green, Williams, and Crawford [7]. Van Paassen *et al.* [8] improved about 100 cubic meters of soil using yeast extracts. Ammonium and Yeast extracts have also been used as a medium Zhao *et al.* [9] and Feng and Montoya [10]. Carbon-based material, as an alternative to yeast extracts, has been employed as bacterial culture media in the research of Whiffin [11]. Sugar beet molasses as one of the carbon sources, taken from the sugar factories' output, is very popular because of its low price [12]. Molasses is also used

as a microorganism nutrition source in the bioremediation process Boopathy, Manning, and Kulpa [13] and Fujita *et al.* [14].

The innovations of this research are summarized as follows:

1. Biological improvement performance of soil with a microscopic view based on analysis of the results of the FTIR, XRD, SEM, and EDS tests;
2. Evaluating of strength and geotechnical parameters of improved soil;
3. Possibility of replacing sugar beet molasses (as a carbon source) with chemicals as a medium.

2. METHODOLOGY

The materials used in this study were Firoozkooch sand, *Spoosarcina Pasteurii* bacterial strain, and four culture media including Nutrient Broth, Yeast extract, Potato extract, and Molasse.

In the present study, the improvement process is based on adding a suspension of bacteria to the soil, followed by injection of a cementation solution (containing one mole of calcium chloride and urea in one liter of sterilized and distilled water). This is equivalent to the amount of suspension of the bacteria entering the soil in the previous step. The process of entering bacteria into the soil is done in two methods for soil improvement as follows:

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- Two-step injection (marked by S)
- Bacteria flocculation mixing (marked by F)

The tests performed include three groups:

1. First group: classical soil mechanics tests including uniaxial compressive strength (UCS), direct shear (DS), and permeability test (PER).

2. Second group: physical and chemical tests including X-ray diffraction (XRD), energy-dispersive x-ray spectroscopy (EDS), Fourier-transform infrared spectroscopy (FTIR), and wet chemical analysis (WCA).

3. Third group: imaging with scanning electron microscopy (SEM)

3. RESULTS AND DISCUSSION

The use of microbial improvement methods created adhesion in sandy soils that do not have inherently adhesion between soils particle. This was mentioned by Choi, Chu, Brown, Wang, and Wen [15], Salifu, MacLachlan, Iyer, Knapp, and Tarantino [16], and Mirmohammad Sadeghi, Modarresnia, and Shafiei [17].

The improvement degree of geotechnical parameters after biological improvement depends on various parameters including grain size distribution, temperature, bacterial entry, and environmental conditions such as the presence or absence of soil contaminants. Accordingly, the uniaxial strength of the improved specimens by the bacteria, grown in the potato extract medium, does not reach even 5% of ones improved by the bacteria grown in the Yeast extract medium. On the other hand, samples made from bacteria grown in a low-cost carbon production source of molasses culture medium have a resistance equivalent to 65% of the resistance of samples made from Yeast extract medium.

Ø Permeability test: method F with nutrient broth had the lowest permeability with the permeation of 1.35×10^{-3} mm/sec in comparison to the molasse samples which had the permeation of 2×10^{-3} mm/sec.

Ø XRD analyses: The peaks derived from the interpretation of XRD data taken from Nutrient Broth and Yeast extract media showed 93% and 97.5% precipitation of calcium carbonate and the residual sodium chloride crystallites, respectively. In addition, calcium carbonate precipitation was also observed in the interpretation of precipitation data from sugar beet molasse.

Ø FT-IR analyses: Estimation and interpretation of precipitant created by the molasses medium showed an absorption bond of 3143 cm^{-1} and 3047 cm^{-1} indicating, the tensile vibration of the C-H bond in the aromatic ring. This bond also includes an absorption bond of 2810 cm^{-1} . The low-intensity vibration in the 2512 cm^{-1} denotes the carbonate group. There are two narrow absorption bands at 712 and 874 cm^{-1} in the spectrum, which is a clear indication of the calcium carbonate group presence (the two peaks are related to C-O and C = O bonds). According to mentioned interpretations, calcium carbonate compounds are clearly observable at the FTIR test peaks. Particularly, in the case of precipitant caused by the molasse medium, the presence of calcium carbonate crystallites is confirmed.

4. CONCLUSION

In summary, using the results of this study, we can hope for better, faster, and more effective improvement by mixing bacterial flocculation with soil. Also, despite obtaining better results in geotechnical tests from Nutrient Broth and Yeast extract media, but due to the much lower economic value of molasses, especially in Iran, this carbon source can reduce the cost of bacterial production to some extent and commercialize the method. Justify microbial improvement and operate on an industrial scale.

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