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Experimental Study to Improve the Shear Stress of Silty-Sandy Soils by Using Urease Producing Bacteria

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Abstract

In this paper, microbial calcite cementation that affect the properties of soil specially shear strength was achieved by using the common soil microorganism Bacillus Pasteurii and cementation reagent containing urea and calcium chloride. While a number of significant factors can affect the success of the microbial treatment, this study focused on the effects of microorganisms on the shear strength of silty sandy soils where the treated soil samples tested by direct shear test to evaluate the effect of microorganisms on shear strength of silty sandy soils. The results showed that the angle of internal friction decreased subsequently from 49.5° in untreated soil to 34.9°,36.8°,36.3°,33.5° with treatment period of two weeks, one month, two months and three months and cohesion of soil increased subsequently from 6.09 kPa for the untreated silty sand soil to 10.21,9.586,10.99,11.93 kPa for the same treatment period.

Keywords: Soil improvement; Biocementation; shear strength; Microbial Carbonate Precipitation.

1. Introduction

A new sustainable and maintainable method for soil improvement has recently developed called Microbially induced calcite precipitation (MICP). The calcium carbonate precipitated from microorganism's activity are used for cementing and clogging soil particles called biocementation and bioclogging, and hence to improve the overall engineering properties of the soils.

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MICP technique has also shown encouraging uses in other construction application, i.e. enhancements the strength of concrete, increase the concrete durability [1,2], and brick durability [3]. Although Calcium Carbonate precipitation by microbes is a relatively new application but there is increasing interest and many studies for numbers of researchers on this new technology. DeJong and his colleagues [4] provided a summary of possible uses of this new technique in improving the engineering properties of soil. Besides engineering, physical and chemical tests to evaluate enhancement occurred in soil properties, other unconventional methods also have been used to evaluate the enhancement occurred in the increasing interest and many studies for numbers of researchers on this new technology. DeJong and his colleagues [4] provided a summary of possible uses of this new technique in improving the engineering properties of soil. Besides engineering, physical and chemical tests to evaluate enhancement occurred in soil properties, other unconventional methods also have been used to evaluate the enhancement occurred in the.

2. Materials and Methodology

2.1 Type of Bacteria

An isolated bacterial called Sporosarcina Pasteurii (Bacillus Pasteurii) was used in this study.

2.2 Bacterial Media and Growth

Sporosarcina Pasteurii was used in all experiments, these bacteria were cultured in the Central Environmental Laboratory of Baghdad University under aerobic batch conditions in growth medium. The growth medium was prepared by dissolving 5 g peptone, 5g NaCL, 4 g Yeast extract, 1 g Beef extract and 50mL Urea Solution in one liter of distilled water. Then the medium solution was autoclaved at 121 C° for 12 minutes to kill any bacteria or viruses that may interfere contend with the growth bacteria (Sporosarcina pasteurii) and urea solution was prepared by dissolving 10 g of urea in 50 mL of distilled water, then the prepared solution was sterilized using a bacterium filter (diameter of this filter 0.25 µm), The prepared solution was cooled after getting out from autoclaving device and 50 mL of sterilized urea solution was added and shaked until homogenized.

2.3 Bacteria Culture

After preparing 1L of growth medium now the lyophilized bacteria sample was added to the growth medium, then forming solution cultivated in incubator (under aerobic batch conditions) at 25°C for 48 hours. After incubation of the bacteria in the incubator for 48 hours at a temperature of 25 C, a turbidity was formed on the surface of the liquid. This turbidity is evidence of the growth of bacteria.

2.4 Cementation Reagent

The cementation regent solution consists of 0.5 mole (0.5mol = 55.5g) of calcium chloride and 0.5 mole (0.5mol = 30.03g) of urea per liter of distilled water. Harkes and his colleagues [11] set up that injection of undiluted bacteria solution, followed by the cementation reagent (0.5 mole of calcium chloride and 0.5 mole of urea) which could successfully keep almost all bacteria solution in the silty sand soil bed. A 50 ml of bacteria solution was added for each glass tube.

3. Laboratory Setup

In this model, the MICP treatment consist of adding bacteria and cementation reagent directly to the soil to study the influence of bacteria and cementation reagent on the properties of silty sand soil and. Bacteria and cementation reagent were added to the glass tubes each containing 200 grams of soil.

3.1 Soil Treatment Procedures

Soil improvement was performed by preparation of a bacterial solution and cementation reagent, then adding the formed solution to the soil specimens. The temperature was observed from time to time during the treatment procedure. Upon the achievement of the treatment, the soil was undergone direct shear test to study the change of shear strength of silty sandy soil after bacterial treatment.

4. Results and Discussions

4.1 Results of Direct Shear Tests on Untreated and Treated Silty Sandy Soil Samples

Direct shear test is used during this study to measure the behavior of shear strength parameters, angle of internal friction (Φ) and cohesion(c) for silty sandy soil before bacterial treatment and after bacterial treatment with different periods of treatment (two weeks, one month, two months and three months). Figure (1) demonstrates the results of direct shear test conducted on the silty sand soil before treatment while Figures (2,3,4,5,) show the results of shear stress (kPa) versus horizontal displacement (mm) after treatment.

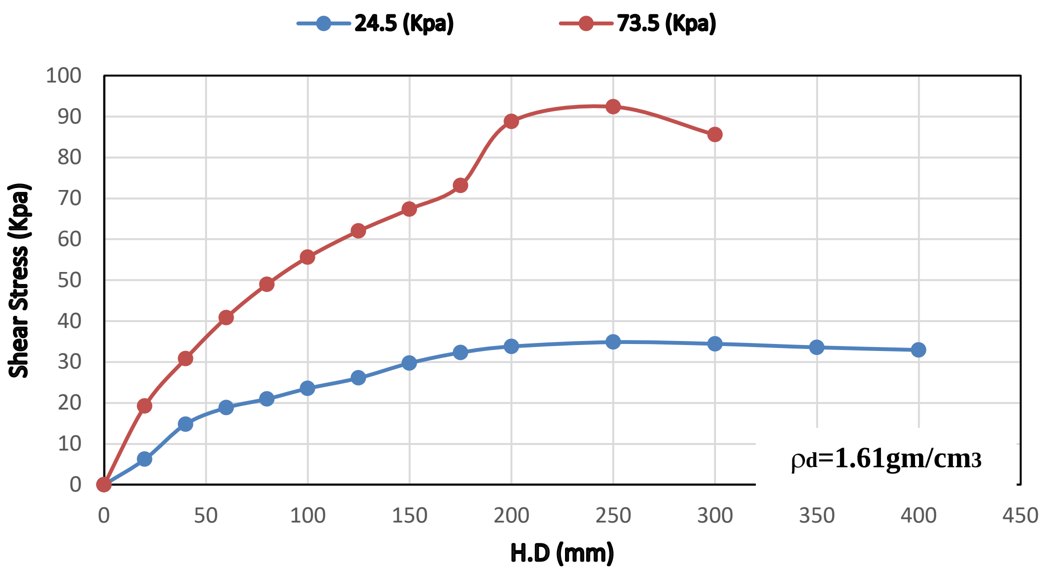

Figure 1: Shear stress versus horizontal displacement for untreated silty sandy soil

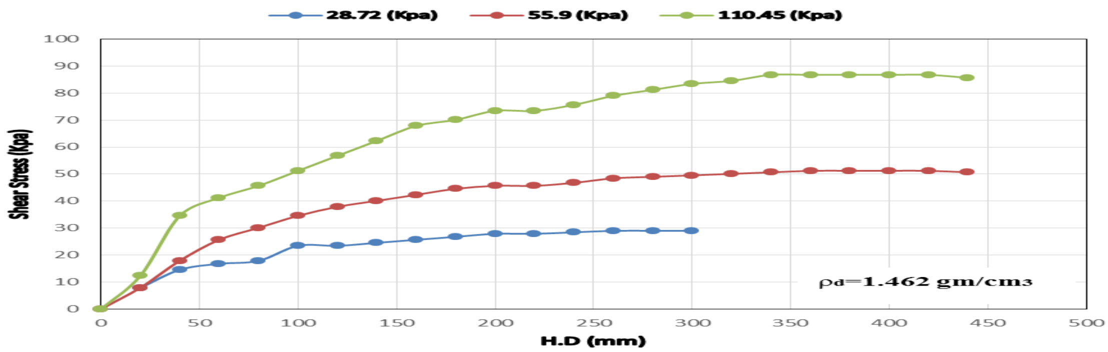

Figure 2: Shear stress versus horizontal displacement after two weeks of treatment of silty sandy soil

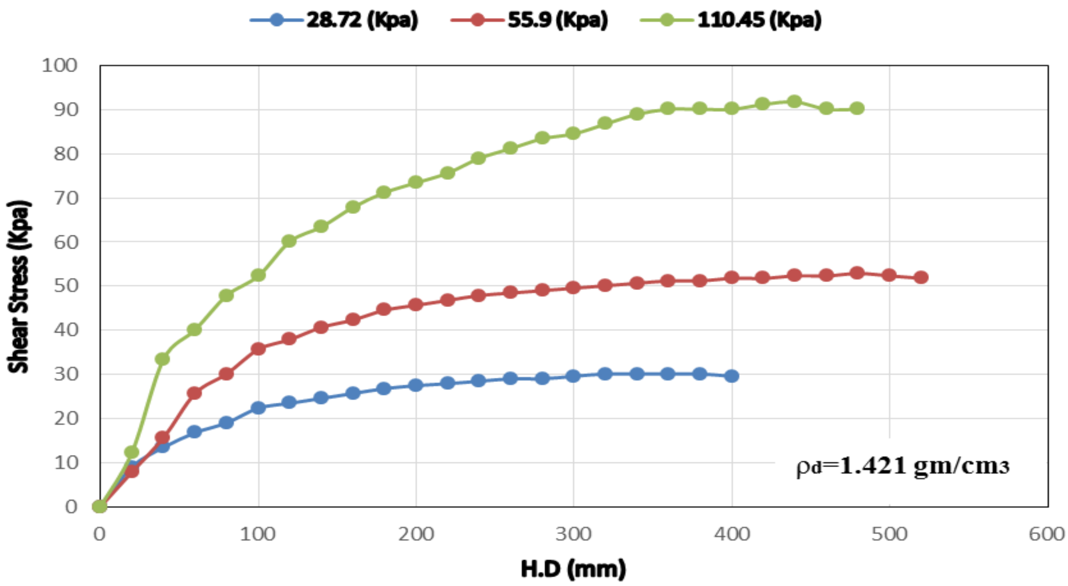

Figure 3: Shear stress versus horizontal displacement after one month of treatment of silty sandy soil

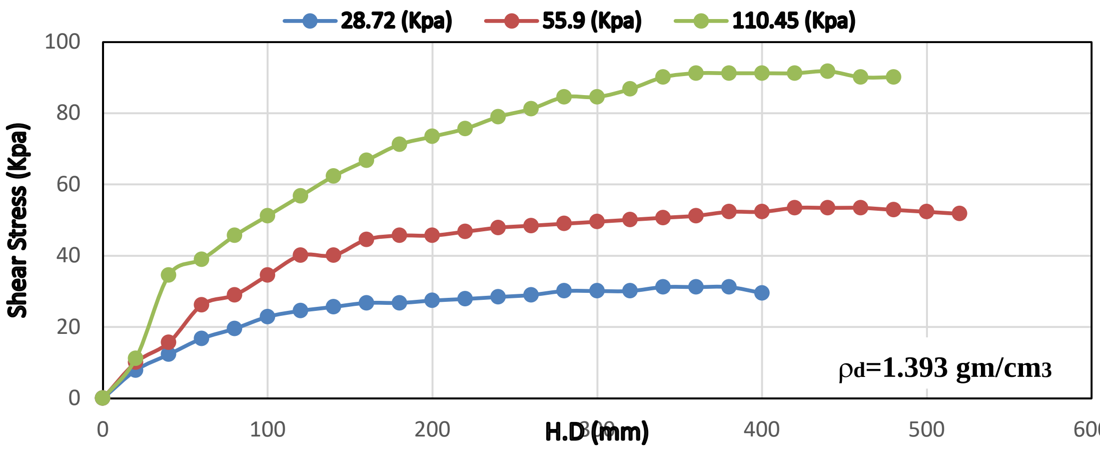

Figure 4: Shear stress versus horizontal displacement after three months of treatment of silty sandy soil

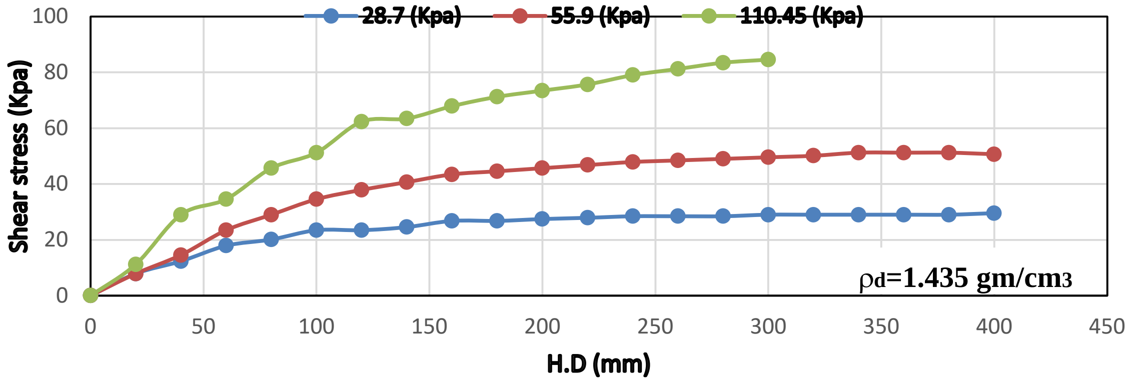

Figure 5: Shear stress versus horizontal displacement after three months of treatment of silty sandy soil

4.2 Effect of Bacterial Treatment on the Angle of Internal Friction with Treatment Period

Figure (6) show the effect of bacterial treatment on the angle of internal fraction of silty sandy soil with treatment periods. The angle of internal friction was decreased from 49.5° in untreated soil to 34.9°,36.8°,36.3°,33.5°subsequently during treatment periods of two weeks, one month, two months and three months. It seems that the angle of internal fraction decreased, after bacterial treatment because calcium carbonate particles deposited in soil voids tended to make the soil behave closely to clay soil, thus reducing the friction angle between soil particles

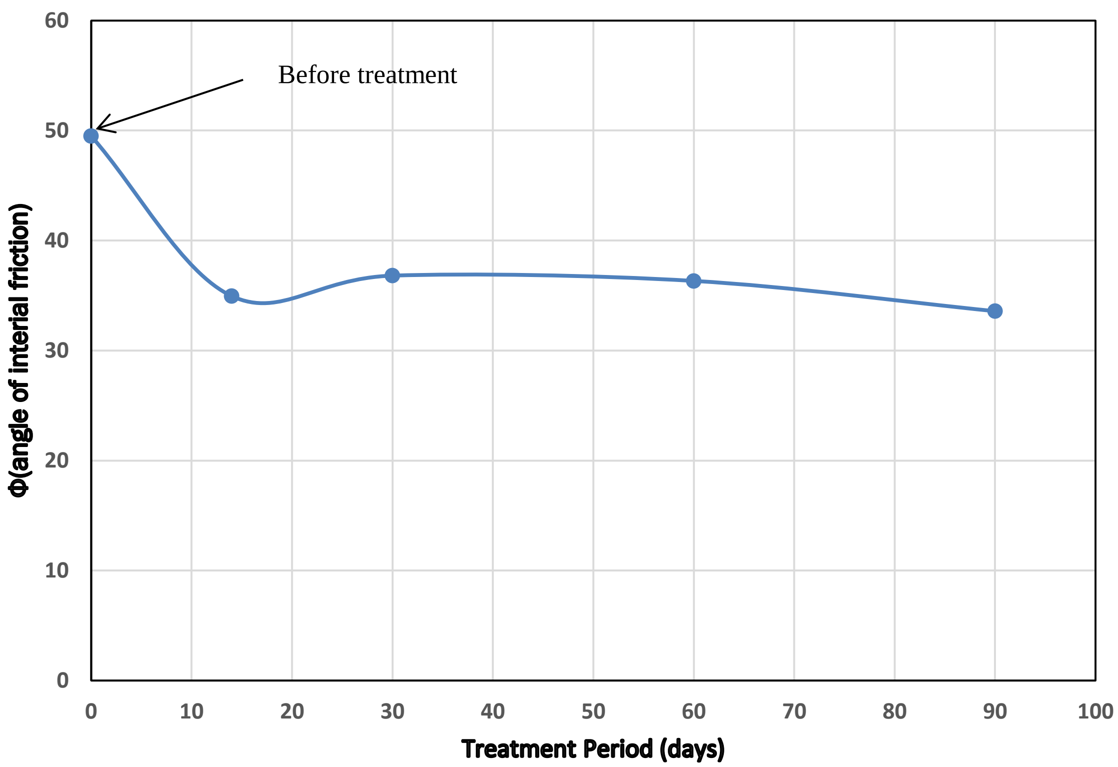

Figure 6: Effect of bacterial treatment on the angle of internal fraction

4.3 Effect of Bacterial Treatment on the Undrained Shear Strength (Cohesion)

Figure (7) demonstrates the effect of bacterial treatment on the cohesion of silty sand soil with treatment periods, whereas the cohesion of soil increased from 6.09 kPa for the untreated silty sand soil to 10.21,9.586,10.99,11.93 kPa subsequently with treatment periods of two weeks, one month, two months and three months. It seems that the cohesion of silty sand soil increase after bacterial treatment where these results seem reasonable because calcium carbonate particles deposited in soil voids tended to make the soil behave closely to clay soil, thus increase the cohesion of the soil.

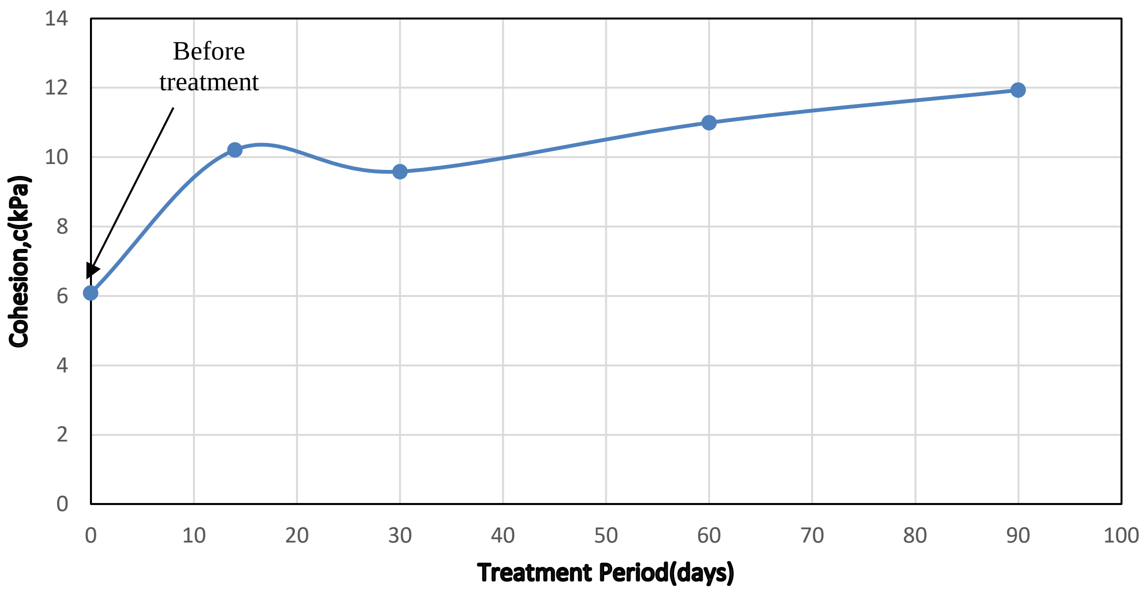

Figure 7: Effect of treatment period on undrained shear strength

5. Conclusions

After series of direct shear tests were carried out to investigate the effect of microorganisms and cementation reagent on the performance of bio-mediated soil improvement. The calcite precipitate has effect on angle of internal friction and cohesion of soil, where the angle decreased 32% after treatment in the third month of treatment where the angle of internal friction was 49.5° before treatment and became 33.5° in the third month which represent maximum decrease in the angle of internal friction during the periods of treatment. While the cohesion increased 48% after treatment where the cohesion of silty sandy soil before treatment was 6.09 kPa and reached to 11.93 kPa in the third month of treatment. The increase in the cohesion of s soil and decrease of internal friction, make the silty sandy soil approaching to behave as clay soil behavior where the small calcium carbonate particles deposited between soil particles and filled the pore reduced the friction of sand particles and increase the cohesion.

References

[1] De Muynck W, Debrouwer D, De Belie N & Verstraete W, “Bacterial carbonate precipitation improves

the durability of cementitious materials" CEMENT AND CONCRETE RESEARCH, vol. 38(7), pp. 1005-1014,2008.

[2] Achal V, Pan X & Özyurt N, "Improved strength and durability of fly ash-amended concrete by microbial calcite precipitation," Ecol. Eng., vol. 37, pp. 554-559, 2011.

[3] Sarda D, Choonia H, Sarode D & Lele S, "Biocalcification by Bacillus pasteurii urease: a novel application," J. Ind. Microbiol. Biotechnol., vol. 36, pp. 1111-1115, 2009.

[4] Dejong JT, Mortensen BM, Martinez BC & Nelson DC, "Bio-mediated soil improvement," Ecol. Eng., vol. 36(2), pp. 197-210, 2010.

[5] Qian C, Pan Q & Wang R, "Cementation of sand grains based on carbonate precipitation induced by microorganism," Sci. China Technol. Sci., vol. 53, pp. 2198-2206, 2010.

[6] Al Qabany, A., Soga, K., Santamarina, C. "Factors Affecting Efficiency of Microbially Induced Calcite Precipitation," journal of geotechnical and geoenvironmental engineering, ASCE,Vol. 138,pp.992-100,2012.

[7] Martinez BC, Barkouki TH, DeJong JT & Ginn TR, "Upscaling of microbial induced calcite precipitation in 0.5m columns experimental and modeling results," Geo-Frontiers, pp. 4049-4059, 2011.

[8] van Paassen LA, Daza CM, Staal M, Sorokin DY, van der Zon W & van Loosdrecht Mark CM, "Potential soil reinforcement by biological denitrification," Ecol. Eng, vol. 36, pp. 168–17, 20105.

[9] Kucharski ES, Cord-ruwisch R, Whiffin V & Al-thawadi SM, "Microbial biocementation," United States Patent, 2008.

[10] Ivanov V & Chu J, "Applications of microorganisms to geotechnical engineering for bioclogging and biocementation of soil in situ," Rev. Environ. Sci. Biotechnol., vol. 7, pp. 139-153, 2008.

[11] Harkes, M. P., van Paassen, L. A., Booster, J. L., Whiffin, V. S., van Loosdrecht, M. C. M. "Fixation and distribution of bacterial activity in sand to induce carbonate precipitation for ground reinforcement". Ecol. Eng., Elsevier journal, Vol. 36, pp.112-117,2009.