Role of Microbially Enticed Calcite Precipitation in Stabilization of Cohesive Soils

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Abstract.

A novel soil-improving technique called "bio grouting" is based on microbiologically calcium carbonate precipitation that was induced. A solution containing urea is added to the soil before bacteria that can turn urea into ammonium and carbonate, tailed by solution of urea & calcium chloride. The calcium then precipitates with the carbonate that is formed, the Clay particles are connected by bridges made of carbonate crystals, increasing the strength within the soil mass. The objective of this endeavour is to identify the ideal bacillus composition solution containing subtilis bacteria to stabilise soil and assess the mechanical properties changes of the soil's stabilising bacillus subtilis bacteria solution and combination of cure times and a cementation solution. Bacillus subtilis bacteria are inserted into the soil in amounts ranging from 10 mL to 30 mL, and the curing duration is between 7 and 28 days. According to the results of a laboratory test measuring unconfined compressive strength, samples injected with bacteria tested at 1.70 kg/cm2 and samples tested without bacteria tested at 1.20 kg/cm2. Using the bio-grouting approach to stabilise clay soil with bacteria results in an increase in the soil's bearing capacity.

Keywords. Bio-Grouting, Bacillus Subtilis, Ground-Improvement, Cohesive soil, UCS.

1. INTRODUCTION

The most crucial component in any work involving building foundation and structure is the soil [1]. Ground settlement, especially in areas that are very susceptible to settlement, such clay soil, can cause structural failure. Many different approaches of improving soil that exhibits swelling-shrinkage characteristics have been used, including soil stabilisation. In order to enhance one or more of the features of a natural soil material, a particular soil may be apportioned, added, or withdrawn, or another chemical substance may be introduced. This process is known as soil stabilisation. Mixing natural coarse- and fine-grained soil to create a mixture that produces sufficient internal friction and cohesiveness is one of the most popular stabilising techniques. Some examples include stabilisation, which uses a grouting technique with various materials as suspense (cement, clay-cement, bentonite, pozzolana etc.) or emulsions (asphalt, etc.) that are not environmentally friendly [2]. Therefore, it is

strongly advised to identify ecologically friendly alternatives for grouting methods. One of such alternatives is the use of microorganisms (called as bacteria) that may create calcite and can turn sand into sandstone. This process called as "bio-grouting". There have been a number of initiatives completed earlier, such as the Microbiologically enticed Cementation for Checking Sand Response to Undrained Shear [3]. Bacillus pasteurii was the microbe used in this experiment. Another effort is ground improvement using microbially enticed carbonate precipitation, which is used as a material for soil improvement [4]. The work uses bacteria Sporosarcina pasteurii, a species of bacterium with a high concentration of the urease enzyme, were used in the method. Last but not least, Bacterial carbonate precipitation for bio grouting looked for alternative materials that might be used to improve soil strength by exploiting microorganisms demands without considering the data volume. The majority of bio grouting research involve bacteria, particularly B. subtilis, which produces the urease enzyme [3]. A nutritional thesaurus containing yeast extract (20 g/L), a trace amount of nickel chloride (10 M) and ammonium chloride (10 g/L), is used to cultivate these microorganisms aerobically in the lab, and the cultures are harvested after roughly 24 hours. Solution of urea & calcium chloride is added to the soil along with the suspension containing the bacteria. The hydrolysis of urea into carbonate and ammonium is catalysed by the microbial urease. When calcium ions are present, the carbonate ions that are formed precipitate as calcite crystals, which cement the gaps within the sand grains.

$$CO(NH_2)_2 + 2H_2O \rightarrow 2NH^{4+} + CO3^{2-}$$

$$Ca^{2+} + CO3^{2-} \rightarrow CaCO_3\,(s)$$

The idea of biologically treated soil enhancement technology put out by [5] and many other researchers have already tried it [3], [4], [6], [7] etc. Although there are many other types of bacteria in soil, Bacillus subtilis is frequently utilised to produce microbial cementation of soil particles. This is due to the fact that Bacillus subtilis converts urea into ammonia, which raises the pH of the surrounding environment and causes CO^{2-} and Ca^{2+} to precipitate as $CaCO_3$.

2. MATERIALS AND METHODS

2.1. Microorganisms

The catalase-positive bacteria Bacillus subtilis (gram –positive), also referred as the grass bacillus or hay bacillus, is found within soil and the ruminant & human gastrointestinal tracts. Bacillus subtilis, a rod-shaped member of the genus that can create a hard, protective endospore that allows it to withstand against harsh environmental circumstances. Though there is evidence to suggest that B. subtilis is facultative aerobe, it has already previously been categorised as compel aerobe. B. subtilis is most well-studied gram-positive bacterium, which is also used as a model to research bacterial cell development and chromosome replication. B-subtilis is one among the bacterial leaders in the synthesis of secreted enzymes which is utilised on a large scale in biotechnology businesses.

2.2. Cohesive Soil

Locally accessible clay soil was utilised for this research. If a particle's size is less than 0.002 mm, it is considered to be clay. The properties of cohesive soil involve its tiny grain size, that is below than 0.002 mm, low permeability, cohesiveness, high increase in water

capillary, sluggish process of consolidation and high degree of swelling-shrinkage. In terms of the chemical and physical characteristics of soil, clays play a significant role. The amount of clay-sized particles, which have a significant impact on soil physical qualities such as aggregation, porosity, water transport and storage, aeration, and workability, is chemically active.

2.3. Bacteria Culture

Because of its potent inhibitory action versus commercially significant avocado post-harvest pathogens, B. subtilis (B246), which was first derived out of the avocado phylloplane (Korsten et al,1988), was chosen for improving mass cell making. The antagonists were lyophilized with 30% v/v glycerol-solution Ringer's at -78 °C while being maintained over standard 1 nutritional agar (STD) (Biolab) slants. For each starter volume used—20-, 50-, 100-, and 200-ml STD broths—six replicates were prepared. B. subtilis 107 cells/ml were used to inoculate each starter volume; they were acquired by washing 24-hold STD slant in sterile quarter-strength Ringer's solution (Merck). Under a Zeiss phase contrast microscope, counts were performed using a Petroff-Hausser counting chamber and modified as necessary. At room temperature (22–28 °C), inoculated starting quantities were put on a rotary shaker (76 rpm). Following a 24-hour shaking incubation period, the complete volume of each starter culture was introduced to distinct 1,3 (STD broths in 2,5 I Erlenmeyer flasks.

3. TEST SETUP

The test is conducted in a prefabricated mould that contains an entrance, an outlet, and flow control. The tool is an acrylic split mould having internal diameter (ID) of 40 mm & a height 80 mm. Set-up comprises an effluent collector, an inlet and output valve, a prefabricated mould, and a reagent tank.

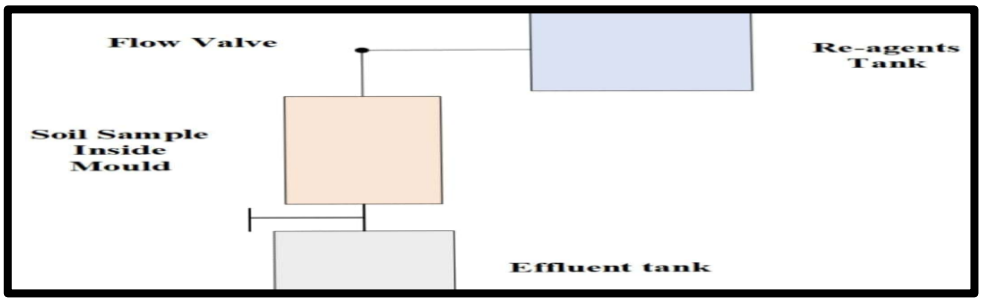

Figure 3.1. Depiction of a typical experimental study setting

4. TREATMENT OF SOIL

Prior to being treated in the prefabricated mould, the soil was compacted at their respective MDD and OMC. To evenly saturate the sample, soil was first cleaned with tap water. The soil sample was given time to pass through a bacterial suspension. The bacteria were given two hours to adhere to the soil grains during the fixing period. After two hours, the soil was treated with a 0.5M urea solution and a 0.5M calcium chloride solution, which were left to

react in the soil for 24 hours. This process was done once more 24 hours later. For two weeks, this process was continued.

5. RESULTS AND DISCUSSIONS

A specific instance of a triaxial compression test in which the all-around pressure is equal to zero is the unconfined compression test. Only saturated samples that are able to stand without any lateral support are used for the tests. Therefore, the test is only applicable to cohesive soils. The test, which is undrained, is conducted under the premise that no moisture will be lost. One of the easiest and quickest tests for figuring out how strong cohesive soils are in shear is the unconfined compression test. Following were the outcomes:

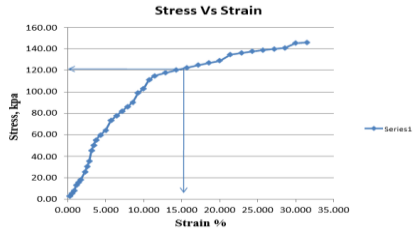

Figure 5.1. Stress vs strain (without treatment)
Unconfined compressive strength (q_u)=120 kPa
Cohesion of soil (c) = 60 kPa

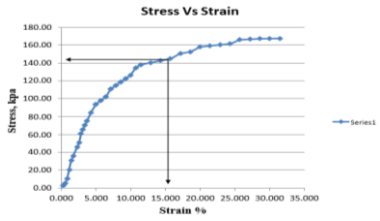

Figure 5.2. Stress vs strain after 7days curing
Unconfined compressive strength (q_u)=142 kPa
Cohesion of soil (c) = 71 kPa

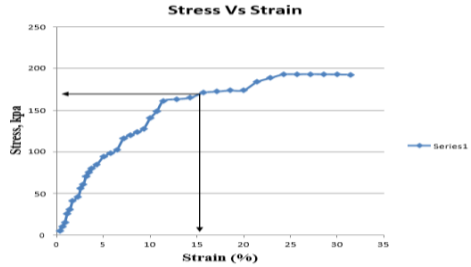

Figure5.3. Stress vs strain after 28 days curing.
Unconfined compressive strength (q_u) = 170 kPa
Cohesion of soil (c) = 85 kPa

The increase in soil characteristics earlier and after introducing bacteria is the only parameter this study used to judge the automatic suitability of Bacillus subtilis as a material for soil improvement based on the results of testing and their analysis. The results of this study can therefore be used to guide for future researchers and studies. For the purpose of reducing the amount of special treatments that must be carried out during the mixing process, It has been suggested that Bacillus subtilis should be the subject of further research. In order to check and compare the response of such bio-grouting process to different types of soil, it is also necessary to combine Bacillus subtilis with other types of soil.

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Biographies

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