The study of Subgrade Treatment using Biopolymers

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ABSTRACT

Calcite produced by Enzyme Induced Calcite Precipitation (EICP) helps to increase the shear  strength of the soil and reduce permeability. Calcite causes the pore space to settle and holds the  soil together. This approach helps reduce costs and carbon footprint compared to sustainable model. In the EICP method, urea is hydrolyzed with the help of urease and calcite precipitates in the  presence of calcium ions in the solution. The advantage of EICP over microbially induced calcite precipitation (MICP) is the use of urease in agriculture, which bypasses the incubation stage of  bacteria and reduces the impact of disease division or growth on the environmental cycle.  
This article explores the feasibility of the EICP method as a soil reclamation and examines the  properties of EICP treated soils. Factors affecting the EICP process are also reviewed.

Keywords: Bio-cementation, recompaction, vibrofloatation, enzyme, bio-clogging,   
  
I. INTRODUCTION  
  
Methods used to improve the properties of granular soil include piles, lifting and recycling, dynamic compaction, vibratory flotation, and chemical grouting. However, safety concerns with today's techniques have prompted geotechnical experts to seek biological soil improvement.

Bio-based soil development includes two technologies:

i) bio-mediated processes that use living organisms, and

ii) bio-inspired processes that unnecessarily disturb living organisms. Biogeochemical processes include geochemical reactions carried out by subterranean microorganisms, including calcite precipitation, biogas production, and biofilm formation. The biomedical process increases shear strength and reduces permeability and compressibility through calcite precipitation of interparticle contacts formed by cement bonds.

Microbial calcite precipitation (MICP) is a biological treatment that uses Sarcina sarcii to release urease, which catalyzes the hydrolysis of urea to carbon dioxide (CO2) and ammonia (NH3). In aqueous solutions, CO2 is converted to carbonate, which is precipitated as calcium carbonate (CaCO3) in a calcium-rich environment at the right pH. Calcite precipitation using free enzymes is referred to here as enzyme-induced calcite precipitation (EICP) and is considered a biologically inspired process because no organisms directly live on it.

The reactions involved in the process are:  
CO(NH2)2 + 2 H2O CO,+2NH,  
  
Ca++ CO  
  
→ CaCO3 (ppt)  
The work discussed in this paper uses urease enzyme extracted from Jack Bean plant. Small size of urease enzyme (12nm) and its solubility in water has advantage over microbial urease whose size is in the range of 500-5000nm, limiting its ability to penetrate into soil which may result in bio-clogging.  
  
II. APPLICATIONS  
  
The enzyme-induced calcite precipitation method is applicable to a wider range of soils due to the small size of the urease enzyme and its solubility in water.

Biocrust for the construction of water ponds:

In this case, urease-producing bacteria precipitate a layer of calcium carbonate on the surface of the sand. This layer of hard crust has a permeability of less than 10-7 m/s and can therefore be used as an impermeable layer for water storage or erosion control on beaches or sandy riverbanks. This method is much more economical than conventional methods. This thin layer of calcium carbonate is brittle and can break when bent, so it may only be suitable for temporary use.

Bio-injection for road construction or repair:

A fermenter is used to produce a soluble calcium solution with residual limestone in it as a white solution in a cylindrical vessel. The bacterial suspension and urea are then added to form the bio-grout solution. This solution can be applied directly to the surface of soil or crushed stone. Once this layer dries, a bio-injected plate is created.

Bio-injection for dam protection:

When cement or chemicals are used to treat soil, the amount of improvement in shear strength of the soil depends on the amount of cement or chemical used. Similarly, when using bio-cement, the shear strength of the soil is affected by the amount of precipitated minerals.

Removal of heavy metals:

Calcites can be incorporated by heavy metals (e.g. Pb 2+ ) on their surfaces through the substitution of suitable divalent cations (Ca 2+ ) in the calcite lattice, after which these compounds change from soluble heavy metals to insoluble forms, i.e. detoxify the heavy metals.

Properties of the material used

Due to the fixed particle size of the urease enzyme, this technique also depends on the pore size of the material used. This treatment is done on Gujrat Sand.

Baseline soil tests are performed on material prior to EICP treatment. Table 1 presents the properties of the material used.

Table 1

|  |  |  |
| --- | --- | --- |
| S.No. | Property of Sand | Value |
| 1 | Mean Specific Gravity | 2.65 |
| 2 | Minimum dry Density | 1.36 gm/cc |
| 3 | Maximum Dry Density | 1.55 gm/cc |
| 4 | Minimum Void Ratio | 0.94 |
| 5 | Maximum Void Ratio | 0.70 |
| 6 | D50 | 0.28 |
| 7 | Cc | 0.83 |
| 8 | Cu | 1.87 |

III. METHODOLOGY  
  
Sample preparation  
  
Samples for UCS tests are prepared in PVC molds. A plastic lining is placed around the columns to facilitate subsequent suction and testing of the treated soil. The setting is a stable framework that maintains dimensional stability. A percolation method is used to treat soil columns and dry sand with a relative density of around 45% is placed in each cylinder. EICP solution is added from the bottom to each sample in a volume corresponding to one pore volume. Four samples are prepared with a progressively increasing number of cycles (from 1 to 4) and in the subsequent treatment cycle the volume of the EICP solution is to be maintained at 70%, 60% and 50% of the pore volume. The samples are allowed to cure for 7 days at room temperature after each treatment cycle. After curing, each column is gravity drained by perforating the base with a pipe and the samples are rinsed with one pore volume of deionized water. After rinsing, the samples are dried in an oven at 50 °C until a constant weight is reached.

Cementing media:

Cementing media that are used to provide chemical compositions for ureolysis include urea, CaCl2 . 2H2O, and urease enzyme. 4 columns (height 12 cm, diameter 5 cm) are treated using an optimal EICP treatment solution of 1 M urea, 0.67 M calcium chloride and 3 g/L enzyme.

Determination of CaCO3 content:

To determine the precipitated CaCO3 in soil samples, the samples are crushed and dried in an oven. The dry soil is washed in HCl solution (0.1 M) to dissolve the precipitated calcite and dried in an oven. The difference between these two masses is taken as the mass of CaCO3 that precipitates in the sample.  
  
Important Outcomes:

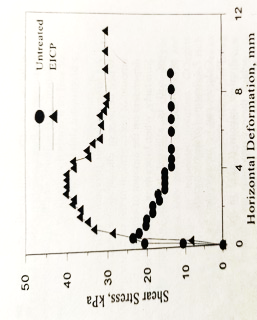


Fig. 1 Variation of Shear Stress with horizontal deformation

Fig. 1 shows the change in shear stress during horizontal deformation under a normal load of 50 kPa. Both the bacteria and the enzyme improve the shear strength of the soil. In the case of EICP, the increase in strength is up to 60% above the strength of untreated sand.

Effect of urease concentration:

Four different urease concentrations were selected to study the effect of urease concentration on UCS strength. The sand treated with 2.5 g/L urease was still loose and could not form a strong processed sample, but as the concentration of urease increases, the strength of the sample increases.

Influence of cementing medium concentration:

At a concentration of 0.25 M Ca, the prepared treated sample is not solid and there is no UCS result for this concentration. But with an increase in the concentration of the cementing medium, the strength of the treated samples increases.

Effect of curing conditions:

The effect of curing conditions on urease-treated samples is smaller. However, samples treated with bacteria are relatively stable and technical properties are not affected.

IV. CONCLUSIONS  
  
Enzyme-induced precipitation of calcite using urea. hydrolysis is a complex biochemical process, especially when it takes place between sand particles to improve soil engineering properties. The results showed that EICP holds promise as a soil improvement technique by improving soil engineering properties. There are many factors that can affect this process. Some of these reported factors are urease concentration, cementing medium concentration, soil type, and curing conditions. Direct shear tests were performed on samples treated with EICP solutions. EICP is also favourable for practical use because it can withstand harsh environmental conditions unlike bacteria, which otherwise require a critically controlled environment.

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