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Effect of Concentrations of Biocementation Solution on Enzyme Induced Calcium Carbonate Precipitation (EICP)

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Abstract: ***The need to accommodate a growing global population has become major concern in many societies and has pushed human inventiveness to new levels. There is an increase in need for engineering technologies to improve the mechanical properties of the ground. Mostly soil strengthening is done by applying cement or chemical products to enhance the mechanical properties of soil. However, the usage of those products can possibly disturb improved soil and the production process of cement and chemical products can create harmful products. Enzyme Induced Calcium Carbonate Precipitation (EICP) is one sustainable method where calcium carbonate precipitation occurs via hydrolysis of urea (ureolysis) catalysed by plant-extracted urease enzyme for soil improvement . This study analysed the effect of different concentrations of urea- $CaCl_2$ (0.5M, 1M, 1.5M) and urease enzyme (5 g/l) which forms the biocementation solution on the mechanical properties of soil. Direct Shear test is done to analyse the shear strength parameters. The optimum EICP treatment solution was obtained as urea- $CaCl_2$ (1 M) at urease enzyme (5 g/l). It was observed that there was an increase in cohesion (0.16kg/cm^2) and angle of internal friction (35º) at 7 days was to cohesion(0.18kg/cm^2) and angle of internal friction (36º) at 14 days .***

Keywords: Soil strengthening, Urease enzyme, Ureolysis, Biocementation solution

I. INTRODUCTION

Despite being widely used, traditional ground improvement techniques like compaction, preloading, vibration and chemical grouting are typically costly and frequently have very high energy and CO_2 footprints. A relatively new field and possibly sustainable alternative technique for ground improvement is the use of biological processes, particularly bio-cementation. The most extensively researched bio-cementation processes are microbially induced calcium carbonate precipitation (MICP) and enzyme induced calcium carbonate precipitation (EICP). Through the precipitation of calcium carbonate ($CaCO_3$), which is aided by urease enzymes produced by bacteria cells or plants for MICP and EICP respectively, enhance the soil. MICP method is quite time consuming as it may take upto 2 months. In order to enhance the reaction time EICP method can be used which will take only 7 days for the reaction to take place.

[1] Enzymatic ureolysis is catalyzed by the urease enzyme which hydrolyzes the urea ($CO(NH_2)_2$) into carbon dioxide (CO_2) and ammonia (NH_2).

$$CO(NH_2)_2 + 2H_2O \rightarrow 2NH_4^+ + CO_3^{2-} \quad (1)$$

$$CaCl_2 \rightarrow Ca^{2+} + 2Cl^- \quad (2)$$

$$Ca^{2+} + CO_3^{2-} + CaCO_3 \downarrow \text{(Precipitated)} \quad (3)$$

II. MATERIALS AND METHODOLOGY

A. Sand

The sand used for the study was collected from Marian Engineering College campus, Kazhakoottom, Thiruvananthapuram. Sand samples were dried and then passed through 4.75 mm sieve were used for the experimental investigation. The sand sample finally had the specific gravity of 2.66. Furthermore, its maximum and minimum densities were equal to 2.04 g/cc and 1.74 g/cc respectively and relative density at 50% as 1.893 g/cc whereas its cohesion C and internal friction angle ϕ were equal to 0.04kg/cm^2 and 31º respectively. According to these properties, the sand sample was considered as poorly graded sand(SP) in the Indian Standard Soil Classification System.

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B. Biocementation Solution and Sand Reactor

For the experiment, a Biocemented Sand Reactor (BSR), which was a crystal-clear plastic container of 15.5 x 8 x 7.5 cm was used. The urase enzyme used for the study is Jack bean meal urease extrapure. Then, 630g of sand sample were premixed with 120ml biocementation solution(1 pore volume). Biocementation solution of various concentrations (C_1-0.5M $CaCl_2$-Urea, C_2- 1M $CaCl_2$-Urea, C_2- 1.5M $CaCl_2$-Urea) at 5g/l Urease Enzyme(20ml) and placed in the BSR in 3 layers. A height of 5cm were maintained by adding deionised water. The lids of the container were kept closed for 7 days and 14 days curing period. The samples were dried and subjected to direct shear test.

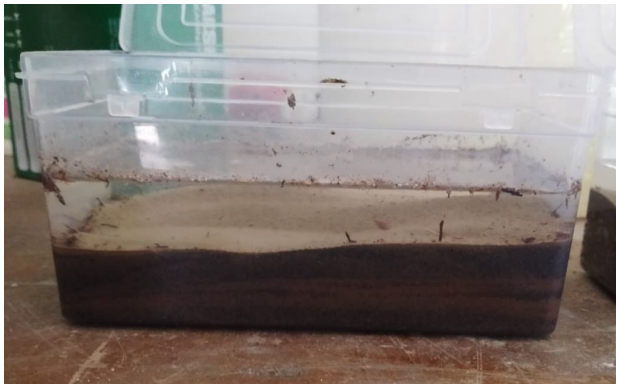

Fig. 1 Test Setup

III. TEST RESULTS

Table 1 shows the direct shear tests results according to the IS 2720-13(1986). For the control (unbiocemented) dry sand samples, the cohesion is equal to 0.04kg/cm^2, and the internal friction angle is equal to 31º. For. There was an increase in cohesion and angle of internal friction .This confirms the improvement of sandy soil properties in terms of cohesion and internal friction angle.

TABLE I Direct Shear test results for 7 and 14 days curing period

Concentration	7 Days		14 Days	
	Cohesion(kg/cm^2)	Angle of Internal Friction(º)	Cohesion(kg/cm^2)	Angle of Internal Friction(º)
C_1	0.06	31	0.08	32
C_2	0.16	35	0.18	36
C_3	0.08	32	0.12	33

IV. CONCLUSIONS

The concentration of $CaCl_2$- Urea at 5g/l urease enzyme has effect on improving the cohesion and angle of internal friction. Concentration C_2 is obtained as the optimum with a cohesion of 0.16kg/cm^2 and angle of internal friction of 35º at 7 days to cohesion of 0.18kg/cm^2 and angle of internal friction of 36º at 14 days. This could indicate that the state of sand sample has changed from loose sand to medium sand and hence an increase in shear strength.

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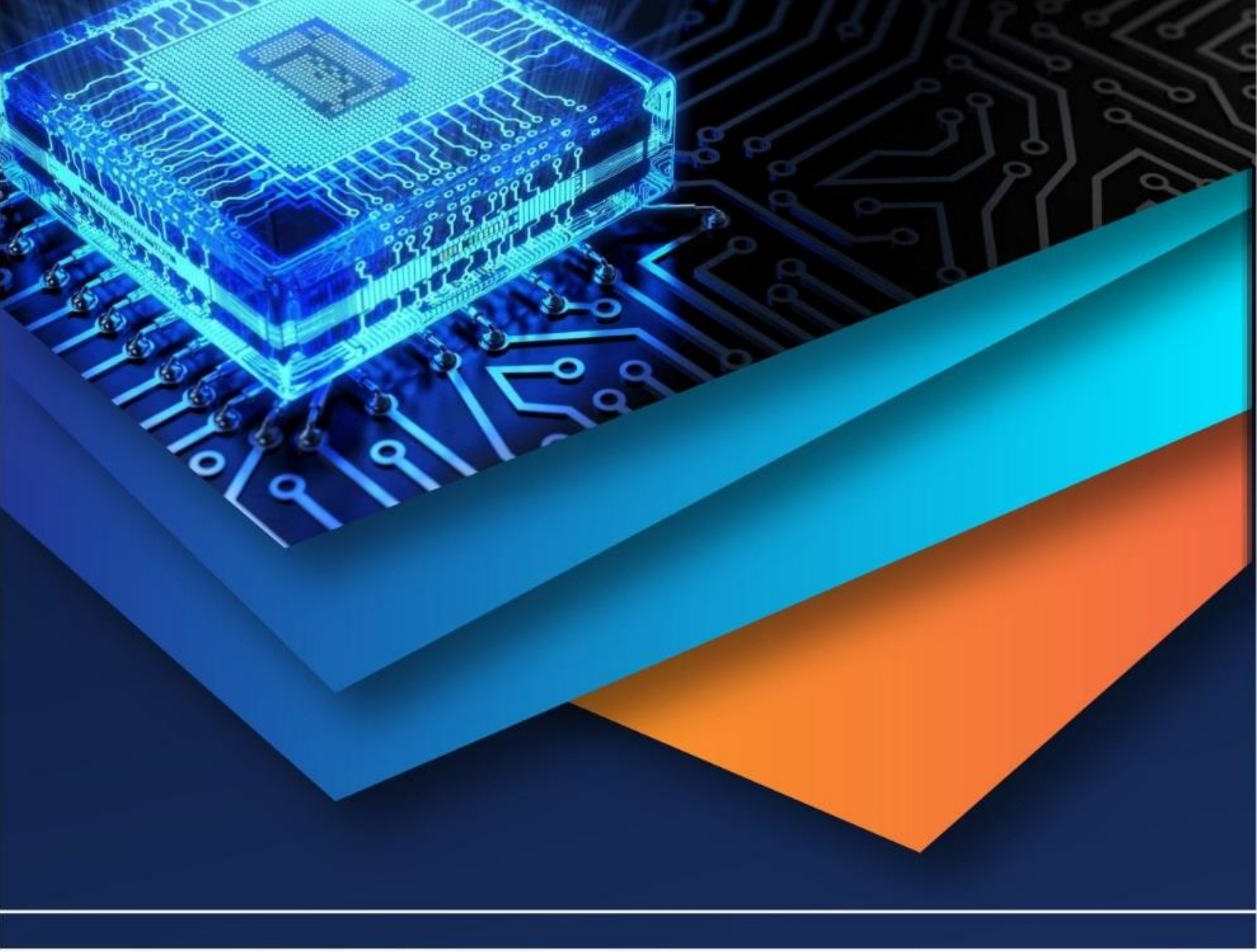

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