STRENGTH OF MICP INORGANIC SOFT CLAY AS A COMPOSITE SOIL FOR INFRASTRUCTURE APPLICATIONS

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College ***:*** *R.N.S. Institute Of Technology, Bengaluru*
Branch ***:*** *Department of Civil Engineering*
Guide(s) ***:*** *Ms. Amulya T H M*
Mr. M T Prathap Kumar
Student(s) ***:*** *Ms. Sandhya Shree A*
Ms. Divyashree S
Ms. Madhushree R Shet
Ms. Mridini V Panchal

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Introduction:

Soils and rock are used as construction materials in many infrastructure applications such as soil subgrade for pavements, earth embankments and below the foundations for structures. In many situations, strength and compressibility are mostly poor in their natural state, which need to be stabilized. For structures built on problematic soil to perform satisfactorily, their engineering properties, especially the shear strength must be improved. Microbiologically induced calcite precipitation (MICP) is an innovative technique that utilizes the microbiological activities to precipitate minerals into the soil mass. Review of literature indicated MICP involving biochemical reaction has been proven successful and sustainable technique to improve shear strength of soft/loose soils for many infrastructure applications.

MICP is a process that is carried out by adding bacterial solution into soil specimen which is continued with inoculation of cementation reagents having urea and one calcium salt for enormous times, as a result of which calcite precipitate ($CaCO_3$) is formed in the soil and stability in the soil is achieved. The following reactions are involved in the MICP process: (a) Urea hydrolysis (b) Chemical equilibrium and (c) Heterogeneous nucleation the calcite formation occurs in the cell surface, once the calcium ion activity is enough and the saturation conditions are favorable for $CaCO_3$ precipitation.

Objectives:

- Assessing the geotechnical properties of expansive soft clay soil.
- Evaluating the Maximum Dry Density (MDD) and Optimal Moisture Content (OMC) of the soft expansive clay soil
- Selection of urease active bacteria on the basis of review of literature

- Adopting mixing procedure suitable for field application for inducing bacterial solution and cementation solution as an admixture to develop a composite soil.
- Assessment of the efficiency of MICP in terms of increase in shear strength viz., unconfined compressive strength at different curing period.

Methodology and Materials Used:

Materials Used:

Black cotton soil which has predominantly *montmorillonite* as clay mineral was procured from Thippapura, Bellary District, Karnataka State and was used as a inorganic soft clay to be admired for MICP strengthening. Relevant index properties of soil indicated that the soil is classified as CH as per IS soil classification.

In the present study *Bacillus Sp* (Sporosarcina pasteurii) (NCIM-24770) was procured from National Chemical Laboratory (NCL), Pune, Maharashtra, India. *S. pasteurii* are soil-borne facultative anaerobes that are heterotrophic and require urea and ammonium for growth. The bacterial solution was cultured using nutrient broth and the procedure consisted of suspending 13gm in 1litre of water with concentration of Bacillus at OD600 nM absorbance is 0.571. After isolation of Bacillus Culture, it is kept shaken @37^{0}C for 24 Hours. After growth,it was stored in refrigerator @4-5^{0}C

Review of literature indicated that the cementation solution consisting of Urea and calcium salts at 0.5M have proven to be optimum In the present study, Cementation solution(0.5M) of 1 litre consists of 30g/L of urea, 73.5g/L of calcium chloride and 3g of nutrient broth was used as an admixture along with bacterial solution.

Soil specimen preparation:

Remolded cylindrical specimens of size 37.5mm in diameter and 75 mm height was compacted to have MDD and OMC obtained from compaction test. The specimen was cured for 3,7,14 and 28 days in standard desiccators to determine its unconfined compressive strength as per IS:2720 (Part10):1991. Similarly, specimens admixed with different concentrations of bacterial solutions at 4,8 and 12% by weight of soil along with cementation solution was remolded so that the total percentage of both the admixture was maintained to have a solution content equal to OMC of 27%. To prepare the specimen, soft air dried and pulverized soil was mixed with cementation solution first and then bacterial solution was added. The mixed soil was then poured into the mold and compacted statically to attain the desired density of 15.1 kN/m^3. The sample was then cured in a desiccator for a period of 3,7,14 and 28 days. At the end of each curing period, the unconfined compression strength was determined.

RESULTS AND CONCLUSIONS:

Compaction Test Results

Heavy compaction test indicated that the soil has OMC of =27% with a corresponding density of 15.1kN/m^3. Remolded specimens using these compaction properties were prepared to assess the effect of different bacterial concentrations on MICP strengthening of soil.

Unconfined Compressive Strength:

Unconfined Compressive Strength was performed on all cured soft clay specimens with an axial loading rate of 1.25mm/minute. The load decreased when the strain increased or until the 20% axial strain was reached. The unconfined compressive strength(UCS) at MDD and OMC was measured to be 75.69kN/m^2 indicating a lower value of shear strength even at MDD and hence considered to be soft clay that need to be strengthened. Shear strength in terms of Unconfined Compressive Strength(UCS) was measured in terms of curing period and different concentrations of cementation solution + bacterial solution. Table 1 tabulates the variation of UCS obtained for BC soil alone as well as BC soil admixed with Bacterial solution at different percentage along with cementation solution at different curing period.
Results of UCS shown in Fig1 indicate that the shear strength increases at 3 days itself for soil admixed with Bacterial solution along with nutrients. The UCS value when compared with BC soil alone at 14 days shows an increase of around 71% at 14 days curing period when admixed with 8% bacterial solution.

Table 1: Variation of UCS with curing period

PARTICULARS	UCS(kN/m^2)			
	0 days	**3 days**	**7 days**	**14 days**
BC soil alone	**75.686**	**75.672**	**75.689**	**75.779**
BC soil+cementation solution+ 4% bacterial solution		**98.08**	**106.158**	**110.31**
BC soil+cementation solution+ 8% bacterial solution		**101.31**	**115.536**	**129.27**
BC soil+cementation solution+ 12% bacterial solution		**102.03**	**107.42**	**110**

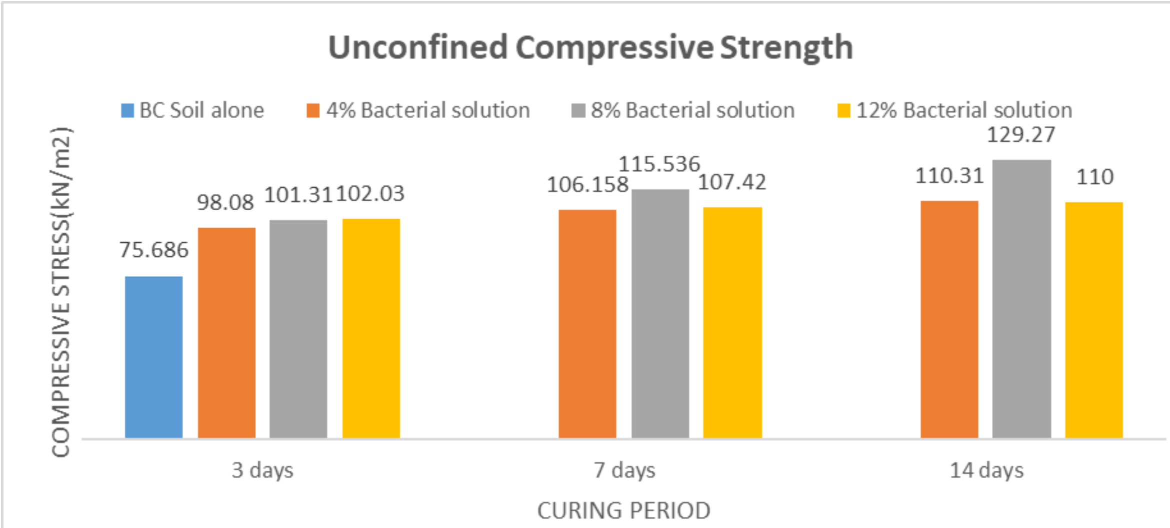

Fig1: Variation of UCS for different combinations of Bacterial Solution with curing period.

Conclusions:

On the basis of present experimental study, the following conclusions have been:

Effect of curing period indicated significant increase in UCS at 3 days curing period itself.

- BC soil alone has poor engineering properties and low shear strength with high OMC, that greatly affects infrastructure construction cost.
- MICP has proven itself as a viable method to increase the shear strength of soil.
- Factors such as bacterial and nutrient concentration affects the strength gain with curing period.
- 8% bacterial solution along with cementation nutrients is found to be optimum for inducing maximum shear strength of MICP BC soil. Hence the strength of MICP treated BC soil varies with concentration of nutrients provided. Hence the concentration of $CaCO_3$ produced by the microorganisms is a function of nutrients., viz., calcite content.

Scope for future work

The present study has evaluated efficiency of MICP process in increasing the shear strength of soft clays. The study has following further scope that need to be investigated/studied:

- Effect of increased water content and degree of softness
- Effect of remoldable water content
- Effect of changes in plasticity due to changes in soil particle structure as a result of MICP
- Long term influence of MICP strengthening.