Stabilization of Sand by Bacterial Concrete

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Abstract*—Soil and sand consolidation and stabilization are required to stabilize the slopes and embankments. Many methods like grouting and epoxy treatment are currently being used for the above mentioned purpose. Which are not all that effective and environmental risk are involved through such chemical addition to soil and sand. This paper presents of an investigations carried out to use Microbiologically induced Calcium Carbonate precipitation known as Bacterial Concrete which was able to adhere the sand particles together and hence the stabilization of sand.

I. Introduction

In the recent times, new construction on weak soils has become inevitable owing to the growing worldwide scarcity of land. The weak soil deposits are commonly characterized by low strength and high compressibility [1]. Stabilization of soil and sand involves various physical and chemical methods which are to improve the soil and sand for variety of engineering works [2]. The improved engineering behavior and performance of cemented soil or sand over its un-cemented state contributed to the development of artificial cementation treatment methods that could effectively cement large in situ deposits. Over the last century, various methods of treating soil with a synthetic solution/grout have been developed, and today they are used widely in geotechnical projects. The injection formulas utilized in these projects have been man-made, and when injected into the subsurface, they often alter the subsurface pH level and in a few cases have been toxic[3] .

Research has been going on around the world about a natural phenomenon, called Bio mineralization which has been developed for utilization in consolidating treatments and crack remediation. Bio mineralization is a phenomenon, in which specific bacteria are capable of producing Calcium-Carbonate crystals in conducive environment. In connection with construction materials, bacterially induced Calcium-Carbonate precipitation was first developed for protection and consolidation of ornamental stones and subsequently for crack remediation of concrete [4]. Research leading to Microbially Induced Calcium Carbonate Precipitation (MICP) and its ability to heal cracks of construction materials has led to many applications like crack remediation of concrete, sand consolidation, restoration of historical monuments and other such applications [5].

A. Microbially Induced Crack Remediation (MICP)

Microbial mineral precipitation involves various microorganisms. Considerable research on Calcium-Carbonate precipitation by bacteria has been investigated by many researchers by using ureolytic bacteria. These bacteria are able to influence the precipitation of Calcium Carbonate by the production of a Urease enzyme. This enzyme catalyzes the hydrolysis of Urea to CO2 and Ammonia, resulting in an increase of the pH and Carbonate concentration in the bacterial environment. Precipitation of Calcium Carbonate crystals occurs by heterogeneous nucleation on bacterial cell walls once super saturation is achieved. The fact that hydrolysis of Urea is a straight forward common microbial process and that a wide variety of microorganisms produce the Urease enzyme makes it ideally suited for crack remediation for building material applications. This precipitation forms a highly impermeable layer which can be used as crack remediation for concrete or any other building material. The precipitated Calcite has a coarse crystalline structure that readily adheres to the concrete surface in the form of scales. In addition has the ability to continuously grow upon itself and it is highly insoluble in water [6], [7], [8], [9]

The aim of the present study was to explore the possibility of sand consolidation by MICP technique in a laboratory scale model using PVC tubes with different bacterial strains known for its capability of precipitating Calcium-Carbonate as reported by researchers around the world and also bacteria isolated from concrete environment.

II. Materials and Methods

The experiment set was using locally available sand and building sand column using PVC pipes. The required bacterial cultures and required media was introduced into the sand column and observed for 21 days. The ability of bacteria used in the present investigation to precipitate Calcium Carbonate and its optimization with respect its optimum pH and other growth conditions are published elsewhere[7].

Sand: River sand was used as fine aggregate. The sand used for the experimental investigation was locally procured and conformed to grading zone II as per IS: 383-1970.

PVC-PIPES: PVC Pipes of diameter of 25.4mm were procured from local sources

Bacterial-source The bacteria was procured from Bacillus pasteurii (NCL-2477), Bacillus sphaericus (NCL-2478), These standard bacterial strains which were capable of precipitating calcium carbonate were obtained from National Chemical Laboratory Pune and Isolate 1.(Isolated from concrete curing tank). The procured bacteria and isolated bacteria were maintained under suitable conditions till they were used for investigation. The media composition for maintaining the culture was

Figure II.1. Experiment Setup

- P Peptone -5 g/lt.
- Beef Extract -3 g/lt. and
- NaCl -5 g/lt

Media composition used for Calcium precipitation: In order for the bacteria to precipitate Calcium Carbonate, it has to be supplied with Urea and a Calcium source and they were supplied as follows

- Urea: 20g/lt.
- Calcium source Calcium Chloride hydrate CaCl2 4H2O or Calcium Nitrate: 49g/lt.

Six PVC Tubes of 25.4mm diameter were cut to a length of 300mm, one of the ends of the tube was covered and tied. For Covering Scotch Brite Scrubber which is used for utensil cleaning was used, the reason was that it should hold the sand in position and at the same time, it will allow excess fluid to pass through it. figure II.1

The Sand was filled in each of the column, for the experimentation, three different bacteria were used namely Bacillus pasteurii, Bacillus sphaericus and Isolate 1 was with two different Calcium Sources namely Calcium Chloride and Calcium Nitrate. After filling and Compacting the sand, bacterial solution was poured into each of the Tubes, for bacteria two tubes were used so that different Calcium Source can be used. After one day urea media and Calcium source was poured. After that urea media and Calcium source was added every alternative day. Each time 5ml of Urea and Calcium source was used. The process of adding the media and Calcium was continued for 21 days.

After three weeks of treatment, the pipes were cut open and Consolidation process were observed.

III. Results and Discussion

During the treatment, initially the Urea media and Calcium source poured, after few hours was able to reach the bottom of the tube easily. After about one week, the amount of fluid reaching the bottom was reduced indicating the process of Calcium Precipitation. As the time progressed the flow reaching the bottom was very much reduced. This can be explained due to deposition of Calcium Carbonate precipitation between the pores of sand grains thereby reducing the porosity and also binding the sand particle together. However even after 30 days flow at bottom did not stop completely.

Figure III.1. Sand Column

When the tubes were cut open after 21 days the consolidation was visible with white precipitate indicating Calcium Carbonate. figure III.1.

It was also observed that among different strains of bacteria, the Isolate 1 which was isolated from concrete curing tank with Calcium Chloride as Calcium source has shown better results than Bacillus pasteurii and Bacillus sphaericus being in the next in the order of precipitation. Among the two Calcium source, Calcium Chloride has proved to be better Calcium source compared to Calcium Nitrate source in terms of Precipitation.

IV. Conclusions

From the investigation following conclusion were drawn

1) Bacterial Calcite precipitation can be applied in consolidation of sand and weak soils.
2) Consolidation by Bacterial Precipitation is effective, environmentally sustainable and more compatible.
3) Among different strains of bacteria, Isolate 1 is most preferred type of bacteria for the specific treatment.
4) Among different Calcium Source, Calcium Chloride can be used.
5) The Bacterial Precipitation not only Consolidates sand but also reduces the permeability of the sand and soil.
6) The time required for complete consolidation and required degree of reduction in permeability required is more than the time of investigation.
7) Much more research in this area has to be carried out to fine-tune the technique in terms of species of bacteria, Calcium source and other parameter like frequency of addition of media and Calcium source and its quantity. Also other environmental factors which will influence this phenomenon.
8) The number of references is very less because no investigation, except one or two has happened in the world with respect to sand consolidation with bacterial precipitation.

References

[1] W. Ng, M. Lee, and S. Hii, "An Overview of the Factors Affecting Microbial-Induced Calcite Precipitation and its Potential Application in Soil Improvement," World Academy of Science, Engineering and Technology, vol. 62, 2012, pp. 723–729.
[2] http://civil-resources.blogspot.in/2010/06/soil-stabilisation.html

[3] J. DeJong, M. Fritzges, and K. Nüsslein, "Microbially induced cementation to control sand response to undrained shear," ASCE Journal of geotechnical engineering, vol. 132, no. 11, 2006, pp. 1381–1392.
[4] J. P. Kopecsk, Katalin, "Consolidating And Strengthening Effect Of Bio Mineralization On Porous Materials," Concrete Structures, 2012, pp. 65–71.
[5] Tiano, Piero."Biomediated Calcite Precipitation for Monumental Stone," Symposium A Quarterly Journal In Modern Foreign Literature, 2003, pp. 48–51.
[6] F. Hammes, N. Boon, J. De Villiers, W. Verstraete, S. D. Siciliano, and J. De Villiers, "Strain-Specific Ureolytic Microbial Calcium Carbonate Precipitation," Applied And Environmental Microbiology, vol.69, no.8, 2003, pp. 4901–4909.
[7] B G Jagadeesha Kumar ., R. Prabhakara., and Pushpa H., "BIO MINERALISATION OF CALCIUM CARBONATE BY DIFFERENT BACTERIAL STRAINS AND THEIR APPLICATION IN CONCRETE CRACK REMEDIATION," International Journal of Advances in Engineering & Technology, vol. 6, no. 1, pp. 202–213, 2013
[8] B. G. Jagadeesha Kumar, R. Prabhakara, and Pushpa H., "Effect of Bacterial Calcite Precipitation on Compressive Strength of Mortar Cubes," International Journal of Engineering and Advanced Technology, vol. 2, no. 3, pp. 486–491, 2013.
[9] B. G. Jagadeesha Kumar, R. Prabhakara, and H. Pushpa, "Microbiologically Induced Crack Remediation A Review," in 1st International Conference on Bio energy, Environment and Sustainable Technologies (BEST2013), 2013.