Effect of Bio Cementation on Soil

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Abstract- *Bio cementation is a very interesting phenomena in which bio-activity of microorganism is used to improve the various engineering properties of soil. We will try to find out change in the strength of soil with time and try to find out any mathematical relation to show change in strength with time. We will also try to find strength difference in between soil which is not induced with bacteria and the soil which is induced with bacteria. After that we will see change in structure of soil after the microbial induced calcite precipitation and finally we will also see where microorganism causing any pH change in the soil and see whether microorganism is producing any harmful substance which effect human, soil and surrounding environment negatively. Amount of microorganism required for particular amount of soil. We also try to see other positive effect of bacteria in geotechnical engineering. Finally we find out how microorganisms help to decrease the cost of stabilization and see how it will have an advantage over other soil stabilization techniques.*

Keywords- Bio cementation, Bacteria, Nutrient broth, Calcite precipitate, particle bonding, Permeability.

I. INTRODUCTION

In present life land for construction remain no more, so there is need to stabilize the soil which was earlier abandoned for construction because it is not suitable for construction. Bio cementation and bio clogging play a very important role in stabilizing the soil. It is a very cheap source and cost of transportation is also saved as compared to transportation cost require other stabilization equipment like rollers. There is also any harmful effect not seen till to soil, human and to the surrounding area.

With the increase in urbanization and to get benefits of urban life rural population is attracting towards urban area. To accommodate such a large population large amount of construction is required and to provide various facilities various types of infrastructure is required for schools, hospitals, malls, commercial and residential buildings. Various types of methods are available for improvement of soil. All these method improve the engineering properties of soil like unconfined strength of soil, permeability of soil, resistance against the washing. Compaction of soil is generally done for increasing the density of soil and apart from that various types of ingredients like lime, cement, fly ash, accelerators and chemicals are mixed to get the desired results for the construction on soil. But all these method are very expensive and on the other hand chemicals added also cause negative effects on soil, human and surrounding soil on which construction is going to be done.

Microorganisms play a very important role in soil stabilization. Microorganisms act in soil to provide the bonding between the particles of soil. Microorganism together with the urea causes the bio cementation of soil and this bio cementation finally leads to the increase in the strength of soil. For constructing high rise buildings which put large amount of load on soil require high strength of soil. Due to increase shear strength of soil in future no settlement and no decrease in durability of soil take place. Finally we can say engineering properties of soil are improved.

With bio cementation, microorganisms also do other beneficial phenomena called bio clogging of soil which leads to the decrease in permeability of soil. Generally conventional method like compaction is used for the increase in the density of soil. But the bio clogging also decreases the permeability by decreasing the voids present in soil. Voids are also decreases by the microorganism and the urea present in soil. Finally gelatinous precipitate of calcite precipitate is formed which is responsible for all these benefits

Microbial geotechnology plays a very important role in future in growth of bacteria in soil to give various benefit. Until we don't have bacteria we can't progress to do bio cementation and bio clogging of soil. Proper environment for growth of bacteria is required because at uneven temperature and pressure they will die. Also proper amount of food is also required for growth of bacteria. This is done by the nutrient broth and it will give bacteria proper nourishment for its growth. Autoclaving and inoculation are very important processes which are very indispensable for growth of bacteria. Every equipment used is properly sterilized because small amount of dirt or infected equipment can make the bacteria to die. So, basically properprecaution should be taken before doing work and when we are doing work. Sterilization of all glass equipment should be must so that all unwanted microorganisms will die before doing important work of

growth of bacteria. After formation of bacteria there inoculation is done to get the culture for use in soil.

Application of bacteria on soil and handling must be done properly and also proportion of bacteria must be according to the amount soil on which microorganism is going to act. Bacteria must be properly mixed in soil and together with urea and calcium chloride is also added for proper bonding of soil particles because gelatinous mix need calcium for its formation which is provided by calcium chloride. Finally we can say that this work is due to the microbially-induced calcite precipitate (MICP). MICB is bio-geochemical process in which that bacteria produce calcite precipitate in the soil. Urea hydrolysis is the process in which microbes induces precipitate of calcite. This technique is very new and sustainable soil improvement technique.

This technique uses bio-activity to produce precipitate of calcite to improve engineering properties of soil by bonding and coating between soil particles.

This process is like green construction because has minimal effects on surrounding and soil. This process exist in view that some urea producing bacteria is existing in soil and ground water. This technique uses calcite forming bacteria and cementation reagent in soil matrix. After formation of gelatinous mix we properly stabilized soil having all mechanical properties improved.

II. OBJECTIVE

Our main aim is to find out the effect of particular microorganism on the strength of soil and growth of bacteria in soil. When bacteria act on a soil some of the engineering properties of soil are changed and we will check whether they get improved or not. Because if they get improved it is very beneficial for the geotechnical engineering. Firstly we will check whether strength will improve or not and after that will also check whether permeability is increases or decreases. Apart from that we will also see the change in the structure of soil if possible.

III. SCOPE OF WORK

Bio cementation has huge scope of study and in future a lot of research in this field is going to be done. Still a lot of research is taking place in this field. We know some bacteria which help bonding of soil particles and there must be many more such type of bacteria existing in nature which are going to be find out. Bacteria which are needed to be finding out are must be such that they can act in all type of temperature and pressure, So that they can be used on soil in all places where climate is very extreme. Bacteria must be such that it will take only small amount of time to act on the soil, so that time of whole project can be decreases and it will finally help financially. Bacteria has a big impact on soil and the extent of impact depends on the types of bacteria, amount of bacteria required in soil, favorable temperature required for bacteria, bacterial cell concentration, fixation and distribution of bacteria in cell, availability of food of bacteria which is nutrient broth, pH of soil which is need be between 7.5-8.0,reactant concentration, . In future we need to find out such types of bacteria which require less handling and give maximum output by improving the properties of soil. Microorganism requires for bio cementation and bio clogging can be produced commercially and can be used at required place before construction. Search of those bacteria is required which take very less time for bio cementation and bio clogging of soil. Bacteria should be such that which can't cause any type of harm to human, animals and surrounding environment so that life remain uninfected due to the bacteria. Bacteria should be such that their growth can't be effect by other microorganism present in soil already. Also we need to find out the type of soil this bio cementation is beneficial.

Basically we want to state that this field has huge scope of work in future which requires biotechnology help to find out the various type of microorganism. Finally these microorganism help geotechnical engineers by improving the properties of soil. Already a lot research is done but still a lot of research is going to be done. Further the extent of bio cementation and bio clogging by the bacteria is need to be find out. So we can say that with time a lot of improvement is going to be done.

IV. REVIEW OF LITERATURE

This paper deals with the effect of microorganisms on soil. In last 300 years a lot of research is done on mechanical properties of soil but effect of bio-activity remains unexplored. So in this paper we will see bio cementation of soil and improvement of different engineering properties of soil. Microorganism play a very important role in formation of fine grained soil and it will also change various properties of soil. This paper use the microbial concept and its potential for the advancing the state of knowledge and practice in geotechnical engineering. Microorganism also accelerates the various geochemical reactions by high order of magnitude, promote both weathering and aging. So extensive research is need for the effect of biomass and biochemical reaction on soil and it has huge scope in future.

Microbial Geotechnology is a new branch which deals with application of microbial technology on geotechnical material used in the construction. Aim of this application is to improve the mechanical properties of soil. Bio cementation is the generation of particle binding material through the biological processes. Another similar term called bio clogging is used for the generation of pore filling material which finally decrease the size of voids and also decreases the permeability of soil. The most suitable bacteria for the bio cementation are facultative anaerobic and micro-aerophilic bacteria. Apart from those anaerobic fermenting bacteria, anaerobic respiring bacteria and obligate aerobic bacteria may also be used for bio cementation of soil and improve geotechnical properties of soil. Microbial Geotechnology is still in laboratory stage because it will require coordination of microbiology, ecology, biochemistry and geotechnical engineering.

Till various method available has its own advantages and drawbacks based on methodology like accessibility to site, economy, effectiveness, environment impact. So there is a need of exploration of suitable method of soil improvement because suitable land for the construction is scare. This paper uses microbial biological processes for the improvement of initially loose and collapsible sand. MICP is achieved using the microorganism bacillus pasteurii, aerobic bacteria generally found in natural soil deposits. Microbes are introduced in liquid medium in soil and properly mixed to get the desired results and finally various tests are done to find the improvement of various engineering properties of soil.

Bio cementation of soil depends upon the consolidation of soil particles due bio-activity of microorganism in soil. Bacteria used is ureolyticbacteria (bacillus pasteurii) which causes the calcite precipitation in soil to provide bonding between different soil particles. Bonding of particle is done in presence of urea and calcium ions. Calcite precipitate is a gelatinous mix which is the ultimate substance which causes final bonding between soil particles. Energy dispersive X-ray and electron microscope reveal the bonding of soil particles.

Microorganism can also be used in coastal sands to improve the various engineering properties of soil. After bio cementation soil becomes more resistant to the damage from storm on soil like coastal infrastructure, highways, buildings, pipelines and other utilities. Finally bacteria together with urea and calcium flood in soil and then various tests are done to get the desired results. Unconfined compressive test is done to check the improvement in strength of soil.

V. EXPERIMENTAL INVESTIGATION

In experiment work we use following steps to do our work to get the final results:-

- Preparation of sample
- Isolation of bacteria from soil
- Pore plating
- Streaking
- Inoculation
- Nutrient broth preparation
- Transfer in test tube
- Sterilisation
- Inoculation
- Optical density

1). Preparation of sample: - First of all sample is prepared to extract the bacteria from the sample. To prepare sample soil is taken in a beaker and some water is also added in the soil. Then beaker is properly shacked so that soil get mixed in the added water. This mixture of soil and water is our sample which is used later.

2). Isolation of bacteria from soil: - Sample which is prepared is used to get the bacteria. We know that soil contain large number of bacteria in it and it may be from ⟦10⟧^9to⟦10⟧^12 in 1 kilogram of soil. So when we add water to soil then bacteria come in water from soil and mixed in water uniformly during shacking. Using properly sterilised pippete we can take out some water having microorganism and make their culture.

3). Pore plating: - It is a technique used to find out numberof bacterial colony in particular amount of sample of soil. First of all we will properly dilute the sample and note down the dilution factor. Then we will drop some amount of sample from water on empty sterile plate and agar into it and inoculate it for 24-48 hrs. Then after 1-2 days see so many colony on sterile plate. We will count the number of colony in plate. Then using a particular relation we will get the colony forming unit (CFU).

4). Streaking: - Before using bacteria for any type of work it should be identified and must be isolated from other types of bacteria. Generally many types of bacteria are present in a small amount of soil and we need to take out useful bacteria from the soil. First of all we take the sample prepared and use a sterilised wire to put line on agar medium. This is technique is based on the principle that a single microorganism separated from other microorganism on same plate give rise to growth of same local bacteria. After streaking we will wait for two – three days and we will get different colony of different types of bacteria. Then we carefully take out one colony and grow it

in presence of nutrient broth at suitable temperature and pressure. Finally we have a culture of particular type soil bacteria. For culture preparation it is a very indispensable technique and used commonly in biotechnology.

5). Nutrient broth preparation: - nutrient broth is a food of bacteria and its composition for 1 litre is-

Peptic digest of animal tissue	5.0g/l
sodium chloride	5.0g/l
beef extract/yeast extract	3.0g/l

It will also require a proper pH at 25 degree Celsius of 7.4-7.6. It should be autoclave at 15 Pascal (lbs.) (121 degree Celsius) for 15 minutes.

Here we will make only100 ml of nutrient broth so various ingredients require is also become one-tenth of 1 litre of sample. So composition becomes:-

Peptic digest of animal tissue	0.5g/l
sodium chloride	0.5g/l
beef extract/yeast extract	0.3g/l

Other things remain same like temperature and the pressure.

6). Transfer in test tube: - we will take six test tubes and quantity of bacteria culture in each test is different. One control test tube is also made to compare results with other test tubes. First of all we will add 2.5ml of nutrient broth in each test tube. Then we will add equal amount of soil in each test tube. Then in first test tube we add zero bacterial culture, in second we add 0.5ml bacterial culture, in third we add 1.0ml bacterial culture, in fourth we add 1.5 ml bacterial culture, in fifth we add 2.0 ml bacterial culture, in sixth we add 2.5 ml bacterial culture. To make the value of all solution same we will add 2.5ml nutrient broth in first test tube, 2.0ml in second test tube, 1.5ml in third test tube, 1.0ml in fourth test tube, 0.5ml in fifth test tube, 0ml in sixth test tube. Then we will put a cotton plug on mouth of test tube, so that they can't get infected from various microorganisms present in atmosphere and also not effect by the human activity. Cotton plug can be made by rolling cotton tightly in between any clean cloth and cotton plug should be properly fit in the mouth of test tube. After that test tube should are put in inoculator at proper temperature and pressure.

7).Sterilization: - It is the processes of properly making the various instrument used infection free. Various instrument used are test tube, beaker, micropippte, three beakers, etc. In sterilization every instrument is washed with ethanol and put in ultraviolet rays for 10 mins. Hands should be washed with ethanol during sterilization. This is the one of the very important technique in biotechnology, without it all work becomes useless.

8).Inoculation: - Inoculation is a process in which microbes are put at particular temperature and pressure in sealed state by paraffin wax. Due to this soil remain unaffected from various microorganisms present in surrounding.

9).Optical density: - Optical density is the ratio of amount of light falling on substance and the radiation transmitted through the substance. Optical density varies with wavelength and this variation causes the apparent color of object. A spectrophotometer is used to find out the optical density at a particular wavelength.

Table.1 Optical density

S. no.	Culture	Absorbance
1	0	0.000
2	0.5	0.699
3	1.0	0.721
4	1.5	0.769
5	2.0	0.793
6	2.5	0.813

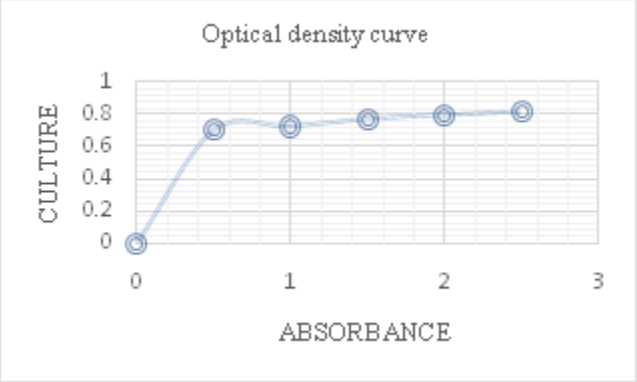


TABLE 2: Result Obtained from Direct Shear Test

Normal load(KN/m^2)	**Shear Stress (KN/m^2)**
50	37.11
100	69.32
150	97.21

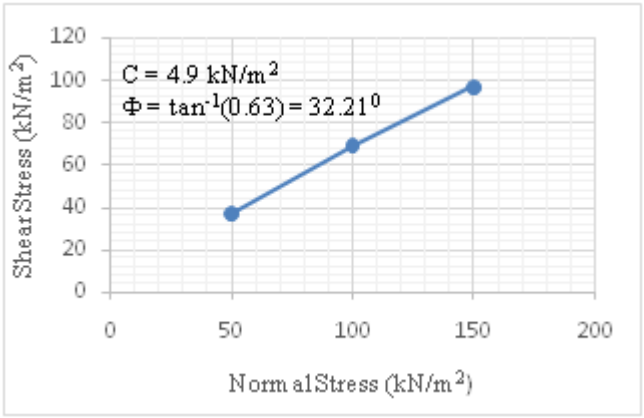
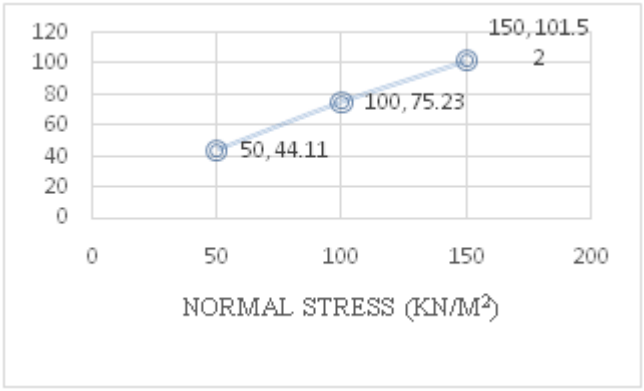


Table3: Result Obtained from Direct Shear Test

Normal load(KN/m^2)	Shear Stress (KN/m^2)
50	44.11
100	75.23
150	101.52



The variation in cohesion (c-value) indicates that due to biocementation shear strength of soil is increased.

VI. RESULT AND DISCUSSION

Various results we get are as follows and all the results we get are through the coordination of biotechnology department. Following results we get:-

1) Presence of bacteria in soil

We find that bacteria are present in soil and there are various types of bacteria in soil because after pore plating we see that colony comes on the plate. So we can say that microorganism's presence in soil and we can easily isolate them from the soil using various biotechnological properties.

2) Different types of bacteria present in soil

After streaking on agar plate we saw different types of bacteria present in soil because we get different types of bacterial colony on plate. Some are yellow colony and some are white or light yellow. So these different types of colony show presence of different types of bacteria.

3) Growth of bacteria is more in soil than water

Test tube in which soil is added shows because optical density value is more in test tube having soil as compared to test tube having no soil. Optical density gives us the scattering of light and scattering is more in test tube having soil.

4) Growth of bacteria with increases bacterial culture

Test tube having more bacterial culture shows more growth of bacteria. This means with increase in bacterial culture engineering properties of soil increases more rapidly.

5) Increase in strength of soil

When we add bacteria to soil and properly mixed them and add urea to soil and we also provide calcium to soil. Then we saw bonding of soil particles due to formation of gelatinous material consists of calcite precipitate.

6) Decrease in size of voids of soil

Due to formation of bonding material voids of soil decreases because voids are filled with gelatinous material. Bacteria decrease the size of voids both in fine and coarse grain soil.

7) Decreases in permeability of soil

Permeability is due to interstitial space in soil but these interstitial spaces are chocked by the formation of gelatinous material formed on cell wall of bacteria.

8) Resistance to washing also increases in soil

Strength of soil increases which leads to resistance to washing due to water.

9) Water tightness of soil also increases.

10) Bacteria are not harmful to soil and surrounding environment.

VII. CONCLUSION

- MICB leads to the bonding of soil particles which finally causes increases in strength of soil. Calcite precipitate is the bonding material present in soil formed from urea and calcium.
- MICB also decreases the permeability of soil due to decrease and chocking of voids of soil.
- Resistance to washing also improved in soil on bio-activity of bacteria.
- Bacteria cause no harm to human and surrounding environment of soil.
- This technique can be used anywhere required and also in extreme conditions.

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REFERENCES

[1] James K. Mitchell and J. Carlos Santamarina, 2005, Biological Considerations in Geotechnical Engineering, Journal of geotechnical and geo environmental engineering ASCE / October 2005, J. Geotech. Geoenviron. Eng. 2005.131:1222-1233.

[2] Volodymyr Ivanov and Jian Chu, 2008, Applications ofmicroorganisms to geotechnical engineering for bio clogging and biocementation of soil in situ, Rev Environ SciBiotechnol (2008) 7:139–153

[3] Jason T. DeJong, Michael B. Fritzges, and Klaus Nüsslein, 2006, Microbially Induced Cementation to Control Sand Response to Undrained Shear, ASCE J. Geotech. Geoenviron. Eng. 2006.132:1381-1392.

[4] Salwa M. Al-Thawadi, 2013, Consolidation of Sand Particles by Aggregates of Calcite Nanoparticles Synthesized by Ureolytic Bacteria under Non-Sterile Conditions, Journal of Chemical Science and Technology, July 2013, Vol. 2 Iss. 3, PP. 141-146.

[5] Montoya B.M. and Feng K., Shanahan C., 2013, Bio-mediated soil improvement utilized to strengthen coastal deposits, Proc. of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris 2013, 2065-2068