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The Use of Microbial Technology to Soil Stabilization

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Abstract: Microbially exacerbate existing precipitation (MICP) is an emerging technique with great potential for enhancing soil quality. The study's overarching objective is to quantify MICP's contribution to black cotton soil's improved shear strength and reduced hydraulic conductivity. The findings of a laboratory study on the influence of microorganisms on the engineering properties of soil treated with MICP. The bacteria utilized in this study was called Bacillus megaterium. A mold was made with the same interior size as the vortex shear instrument, and soil samples were then tested using this setup. The presence of microbes in black cotton soil greatly improves its shear strength and decreases its hydraulic conductivity, as shown by vane shear and penetration tests.

Keywords: Cementation solution concentration, pH, temperature, injection techniques, soil characteristics, bacterial species, and MICP.

Introduction:

It has been commonplace in recent years to start construction on questionable soil. Weak soils are defined by a low strength properties and a high settling. Potential solutions include implementing engineering upgrades to weak soils. Fixing these problems may require improving the shear strength, settling, and permeability of poor soils. Chemical admixtures are often used to enhance the engineering qualities of subpar soils Introducing a biochemical mixture into the pore spaces of poor soil or blending it by hand or machine increases its shear strength, decreases its settling, and decreases its permeability. [1] The requirement for farmable land in India has grown as the country's population and industrialization have progressed. For construction can begin on any structure, the soil's suitability must be determined. As people grow more aware of environmental concerns, fascinating developments have taken place in the direction of ecologically benign and long-lasting technology.

Chemical grouting was often employed for soil stabilization prior to the development of MICP. Chemical grouting employs the use of hazardous materials such cement, lime, asphalt, glass, acrylate, lignin, urethane, and resins. Despite several studies showing that chemical grouting lowers costs but increases soil pH and groundwater and soil contamination, its usage is increasing. The rising awareness of environmental problems, however, has made it imperative to create effective approaches, such as MICP, for the stabilization of soil. Unresolved tropical residual clay situations may lead to a variety of geotechnical issues, such as settling hills and cracked foundations. Now more than ever, landslide prevention is the top priority for engineering geologists and geotechnical engineers. Using the organic chemistry strategy already available in soil, microbiologically induced calcite precipitation may be a more feasible and long-lasting alternative for soil stabilization. This is why it's crucial to

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study new developments in environmentally friendly geotechnology. The kind of bacillus utilized determines how much calcite is produced. Bacillus bacillus ATCC 14581 is not harmful to people, animals, or the environment in any way, hence it is classified as a nonpathogenic bacteria. Bacillus Megaterium is in sufficient supply at the National Chemical Laboratory.

The goal of this research is to increase the soil's shear strength and decrease its hydraulic conduction in order to make the soil more cohesive. Bacillus megaterium ATCC 14581 may have beneficial effects on soil quality, therefore study it. When land becomes more scarce, problematic soil construction is unavoidable. So, construction on the controversial soils is more susceptible to risks associated with the soil itself, such as the random settlement of an embankment or foundation, debris flow, and catastrophic landslides. Among the most noticeable aspects of soil development are the subsequent increases in shear strength, decreased hydraulic conductivity, removal of water, reduced risk of liquefaction in saturated fine sand or hydraulic fills, etc.

When removing deposits of weak soil, engineered fill is often employed. To artificially cement soil particles, chemical stabilizers are often coupled with or injected with chemical grouts that may penetrate into soils. Soil may be chemically stabilized using Portland cement, lime, and fly ash, and its physical qualities can be altered by mechanical compaction or compaction grouting. Mechanical compaction is cost-effective for sandy soils at depths of less than 10 meters. Chemical stabilization is often suggested for expansive soils. Pre-wetting and moisture barriers, two ecologically safe practices, are not suitable to large-scale construction projects like highways and railroads that run for kilometers. Traditional approaches to enhancing soil quality have considerable drawbacks. Grouts need injection at peak pressures because of their short working duration or high viscosity. Obviously, freezing is not a safe construction method. Most of these approaches are very high-priced, troublesome to urban infrastructure, dependent on heavy gear and chemicals, and have major effects on the natural environment. Thus, traditional techniques are insufficient for handling massive quantities of soil. Artificial cementation processes are both unachievable and detrimental to the environment. Nonetheless, environmentally friendly practices have the potential to lessen the need for artificial cementation tools..

Soil stability by the precipitation of calcite generated by microorganisms (MICP). As compared to the current standard of technology, the MICP approach is superior and more environmentally friendly. Microorganisms play a critical part in this strategy for achieving stability. Via their metabolic activities, microorganisms have induced calcareous precipitation into the soil structure, hence enhancing its engineering properties. As a result, we have given this method the name MICP (microbial induced carbonate precipitation). MICP has several uses in civil engineering, from enhancing the security of underground constructions like tunnels and subways to boosting the bearing capacity of shallow and stacked foundations and reducing the risk of liquefaction. Soil stabilization is a long-term process that improves the soil's physical and chemical properties. It encompasses operations like compaction, pre-consolidation, drainage, and others like them. However, When people talk about stabilizing soil, they usually mean just the methods that directly alter the soil matrix to improve its intrinsic properties [2]. To prepare naturally occurring soil for use in engineering projects, soil enhancement is performed [3]. Any combination of physical, chemical, and biological processes may be used to better the soil.

By increasing the dry unit weight, the performance of in-situ subsoils, sands, and other waste materials may be improved for geotechnical applications such reinforcing road surfaces [4]. Stabilization procedures are used to strengthen the earth by either gluing the soil particles together or water proofing the particles, or both, when the available construction soil is insufficient [5].

The concept of stability has been around for at least the last five thousand years [4] and perhaps far longer [6].

The ancient Chinese, Romans, and Ica employed a variety of soil stabilizing techniques to construct buildings and roadways that are still in use today [7]. The ancient Greeks and Romans utilized lime to fortify their dirt roads. Ancient Egypt and Mesopotamia both made use of these kinds of highways. Bricks for the pyramids were made from a mixture of lime and clay, and the Romans employed lime to improve the quality of concrete for constructions over 2,000 years ago, which explains the excellent condition of their roadways [8]. The earliest tests with soil stabilization were done in the United States in 1904 [9].

Soil stabilization as we know it now began in the 1960s and 1970s, when aggregate and fuel shortages pushed engineers to reconsider the common practice of just replacing poor soils at building sites with aggregates brought in from elsewhere due to its superior technical qualities [10]. Inadequate subgrade stability, especially on poorer soils, is a common problem, therefore modern stabilization techniques aim to address this issue.

Soil stabilization often requires a substantial investment. Construction has been stalled in certain areas due to the high cost of soil stabilization procedures and the depletion of stabilizing chemicals [4]. Every construction project has always included the time-honored practice of exploring and developing more cost-effective building techniques and materials. Thus, effective and inexpensive means of constructing highways are crucial to the economic growth of any country. In order to improve construction methods and expand road networks, it is essential to swiftly develop new, cost-effective materials.

Microbial Enzymes (Bioenzymes) as a Soil Stabilizer

Enzymes play a crucial role in biological systems, since they not only control reaction rates but also favor certain transition state geometries that lower the activation energy needed to make one product from another [15]. Protein molecules called soil bioenzymes accelerate chemical reactions to form a cementing link, which enhances soil structure and reduces soil's attraction for water [16]. Soil stability via the use of enzyme products was first conceived as a means of facilitating horticultural uses [17]. Modifications to the process led to the production of a material with potential use in enhancing the condition of the earth underneath highways. As long as the soil doesn't have too much clay, bioenzymes may decompose it [18,

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19]. Soils with a plasticity index between 8 and 35 and a clay concentration between 12 and 24% may be receptive to enzyme treatment, according to Khan and Taha [19]. When applied to an unbound road surface, enzyme emulsions may efficiently reduce dust at low application rates [20]. High concentrations of enzymatic emulsions can be used to enhance the engineering properties of road bed materials on roads, paths, roads, and property driveways [21]. After being laid down and compacted to form a thick, firm-to-hard, moisture bonded layer, the treated soils may be used as a road surface.

Comparison between Bioenzymes and Traditional Stabilizers

Traditional stabilizers like cement and lime may be up to three times more expensive than bioenzymes [22], and their already high price rises as they have to be transported great distances to low-volume road construction areas. Even still, bioenzymes are often sold as concentrated form concoctions that need to be diluted in water on the construction site before being sprayed on the soil before compaction or forcibly injected into deeper layers of dirt for treatment [23]. This allows for the possibility of reduced delivery costs. Due to the lower shipping costs, concentrated bioenzymes may be a viable choice for stabilization efforts. Hence, bioenzymes are the best organic, natural, and cheap alternative to traditional techniques of soil stabilization. As a result, researchers are looking at bioenzymes again to see whether they might be used as soil stabilizers. Traditional soil stabilizers need large amounts of stabilizers, which drives up production costs. Nevertheless, enzymes are effective at stabilizing soils with just a little amount of enzymes, which explains the difference in price, availability, and scope of use..

Clay soil

As the mineral montmorillonite accumulates, as it does in clay soil, the soil's shrinking and swelling characteristics increase. Clay soil is made up of illite, kaolinite, and montmorillonite. This little bit of dirt is only visible under an electron microscope. It has a great water-holding capacity because to its limited permeability.

Bacillus subtilis

The gram-positive, rod-shaped bacterium grows best between 25 and 35 degrees Celsius. Antibiotic secretion is facilitated by the presence of five signal peptidase genes in its genome. Endospores of B.subtilis are resistant to heat and light. It is the undisputed champion of bacterial secreted enzyme synthesis and finds extensive use in biotechnology.Bacillus magisterium

The rod-shaped, gram-positive bacterium is utilized for stabilizing soil and thrives at temperatures between 3 and 45 degrees Celsius. Oligosaccharides on the cell walls connect the cells in pairs and chains. Its use in technology for protein manufacturing has seen a rise in its popularity.

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Cementation reagent

Cementation reagent was a potential use for these compounds. Soil bacteria can only live for a short time without a nutrient broth concentration of 3g/Lt. Distilled water is added to the mixture along with the other ingredients.

Table 1 Cementation Reagent

Substance	Amo unt	Amo unt	Amo unt	Amo unt
M	0.30	0.60	0.90	1.20
$CO(NH_2)_2$ (Urea)	15.00	30.00	45.00	60.00
$CaCl_2$	27.00	48.00	69.00	89.00

Bio-augmentation Soil bacteria are added to the substrates as part of the biological augmentation process. Maximum dry density is achieved with optimal moisture content while compacting the blended soil sample. Wet gunny bags and damp sand were used for curing in this technique.

MICP When microorganisms and a cementation reagent are introduced to the soil, the soil begins to respond by precipitating calcite, which acts as a cement matrix to bind the fine soil particles together. The formed soil is compared to unformed soil to see how the qualities have changed.

Mixing Different proportions, shown in TABLE 2, are used when manually combining the soil sample. It takes 7, 14, 21, or 28 days to cure depending on the mix of microorganisms, cementation reagent, and clay soil used. Then its value may be determined by testing..

Table 2 Mixing Proportion

Mix designation	**Mix**	
2:98	0.25M cementation reagent + 2% bacillus subtilis + 98% soil (BS1)	0.25M cementation reagent + 2% bacillus megaterium + 98% soil (BM1)
4:96	0.50M cementation reagent + 4% bacillus subtilis + 96% soil (BS2)	0.50M cementation reagent + 4% bacillus megaterium + 96% soil (BM2)
6:94	0.75M cementation reagent + 6% bacillus subtilis + 94% soil (BS3)	0.75M cementation reagent + 6% bacillus megaterium + 94% soil (BM3)
8:92	1.00M cementation reagent + 8% bacillus subtilis + 92% soil (BS4)	1.00M cementation reagent + 8% bacillus megaterium + 92% soil (BM4)

Conclusion

Soil's shear strength may be improved using the MICP method by utilizing urease enzyme for urea hydrolysis, which then forms calcite precipitate. This article evaluated some of the parameters that impact MICP development, such as soil characteristics, bacterial species,

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cementation solution concentration, nutrients, pH, temperature, and injection techniques, among others. The next outcomes are a direct consequence of this cramming.

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