IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Exploring The Effects Of Bio-Enzymes On Soil Stabilization: An Experimental Study

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Abstract

This research paper explores the utilization of enzymatic soil stabilization to enhance the geotechnical properties of black cotton soil in the North Karnataka region. Enzymes, as organic catalysts, have shown potential in improving soil engineering qualities and fatigue behavior for sustainable pavement construction. The study focuses on the efficacy of TerraZyme, a bio-enzyme soil stabilizer, which catalytically bonds soil particles and enhances density, compaction, and strength. A systematic experimental approach involved various tests on both untreated and enzyme-treated soil, including grain size analysis, Atterberg's limit tests, compaction tests, California Bearing Ratio (CBR) tests, and unconfined compression tests. Results demonstrated substantial improvements in treated soil's consistency limits, compaction characteristics, CBR values, and unconfined compressive strength. Enzyme dosage and treatment duration played significant roles in these improvements. The study underscores the potential of enzymatic soil stabilization as a promising avenue for soil enhancement in construction projects, encouraging further research into various bio-enzymes and their effects on geotechnical parameters.

Keywords: Soil Stabilization, Enzymes, CBR

Introduction:

The concept of using enzymes for soil stabilization in pavement construction stemmed from their successful application in improving horticultural soil conditions. This led to the development of a modified material suitable for stabilizing poor ground and road surfaces. Enzymes, as organic catalysts, accelerate specific chemical reactions without being consumed in the process, making them highly effective in small quantities for soil stabilization [20]. Their mobility within the soil allows them to reach the reaction site, where they enhance wetting and bonding capacities of soil particles.

Bio-enzyme, a natural, non-toxic, and non-corrosive liquid formulation derived from vegetable extracts, has been found to improve soil engineering qualities, enhance soil compaction densities, and increase stability. When enzymes interact with clay and organic cat-ions, they expedite the cat-ionic exchange process, reducing adsorbed layer thickness. Unlike traditional chemical stabilization methods that are difficult to mix thoroughly, bio-enzyme is easy to use as it can be mixed with water at optimal moisture content and sprayed over soil, simplifying the compaction process.

Expansive soils, also known as swelling soils or shrink-swell soils, pose a significant challenge in construction due to their tendency to swell and shrink with varying moisture content. These soils, mainly composed of clay minerals like montomorillonite, can cause substantial damage to structures during wet and dry seasons. The annual cost of damage caused by expansive soils worldwide is substantial, making effective soil stabilization methods essential.

Traditional soil stabilization additives, such as lime, cement, and fly ash, have been widely studied, but research on non-traditional additives like enzymes is relatively limited [22]. Some studies have shown that enzyme stabilizers can enhance the load-bearing capacity of certain soils, but their waterproofing qualities have been questioned [5].

Chemical treatment of pavement base, sub-base, and sub-grade materials aims to improve workability, increase strength, control moisture-related issues, and reduce dust on unpaved roads. The interactions between water and clay particles in the road are critical, and chemical stabilization seeks to modify these interactions favorably for specific engineering purposes [17][25].

In India, soils with high silt content, low strength, and minimal bearing capacity pose challenges for construction projects. To address this, various methods have been used to improve soil performance, ranging from replacing soil to complex chemical stabilization. Enzymes have emerged as a new chemical option for soil stabilization, offering potential cost-effectiveness and reduced reliance on soil replacement.

This research focuses on the improvement of geotechnical properties of black cotton soil found in the North Karnataka region using enzyme stabilization. The goal is to assess the effectiveness of enzymes in enhancing the soil's geotechnical properties and fatigue behavior for sustainable and efficient pavement construction.

The literature review highlights the use of TerraZyme, a bio-enzyme soil stabilizer, as a non-traditional additive for soil improvement. When mixed with water and applied, the enzyme solution catalytically bonds inorganic and organic materials in the soil, leading to a cementation action. TerraZyme is produced through a fermentation process and is 100% biological and biodegradable. It enhances the density, compaction, and strength of soils, making it suitable for various construction projects like highways, rural roads, parking lots, and more. The enzyme's effectiveness depends on the presence of organic matter in the soil and the temperature conditions. Numerous studies have demonstrated its efficacy in stabilizing different soil types, reducing costs, and offering environmental benefits. Overall, TerraZyme has proven successful in various field projects and laboratory tests, showing promising potential for soil stabilization applications.

Materials and Methods

the methodology and experimental investigations conducted on local soil obtained from Jaipur are elaborated upon. The frequent premature pavement failures in the region, attributed mainly to sub base failure, prompted this study. The primary objective was to enhance sub base strength through soil stabilization using the natural Bio-Enzyme stabilizer Terrazyme. Laboratory tests were systematically carried out to evaluate the engineering properties and strength characteristics of the local soil with and without the application of Terrazyme.

The materials used encompassed Terrazyme as the soil stabilizer and locally sourced soil from Fatehabad. Terrazyme, a non-toxic liquid derived from vegetable extracts, was chosen for its potential to enhance soil engineering qualities. The testing program involved a series of well-defined procedures to assess various soil parameters. These procedures included grain size analysis, specific gravity determination, Atterberg's limit testing, standard Proctor compaction testing, California Bearing Ratio (CBR) testing, and unconfined compression testing.

Grain size analysis unveiled the relative distribution of grain sizes within the soil, providing insights into its engineering behavior. Atterberg's limit testing established the liquid limit, plastic limit, and plasticity index of the soil, gauging its moisture sensitivity and plasticity. Compaction tests investigated the relationship between moisture content and dry density, critical for engineering applications. CBR tests assessed soil bearing capacity and its response to loading under different curing periods and Terrazyme dosages. Unconfined compression tests determined the unconfined compressive strength of the soil at varying curing periods and Terrazyme concentrations. Lastly, specific gravity tests were conducted using the Pycnometer method to quantify soil density and particle packing characteristics

Result and analysis

Untreated Soil Analysis:

Specific Gravity Test: Specific gravity is a fundamental property that provides insights into the soil's density and composition. In this study, the specific gravity of the local soil was determined to be 2.42. This value is crucial for further calculations related to soil mechanics and engineering.

Grain Size Analysis: The grain size distribution of a soil sample gives valuable information about its composition and potential uses. Sieve analysis was conducted to determine the relative proportions of different grain sizes within the soil. The results indicated that the soil contained 3.8% gravel, 48% sand, and 48.2% fines, which include silt and clay fractions. This distribution is essential in understanding the soil's behavior, drainage characteristics, and potential for construction purposes.

Atterberg's Limit Test: The Atterberg's limit test provides valuable information about the soil's consistency and plasticity. The liquid limit, plastic limit, and plasticity index were determined. The liquid limit was found to be 37.25%, indicating the moisture content at which the soil transitions from the liquid to plastic state. The plastic limit was 26.20%, representing the moisture content below which the soil behaves as a solid. The plasticity index, calculated as the difference between the liquid and plastic limits, was 11.05. This index categorizes the soil as having medium plasticity, which plays a significant role in construction and foundation design.

Standard Proctor Test: The standard Proctor test helps assess the soil's compaction characteristics. The optimum moisture content (OMC) and maximum dry density (MDD) are crucial parameters for understanding the soil's compaction behavior. In this study, the OMC was determined to be 13.1%, and the MDD was 1.883 g/cc. These values help in determining the appropriate moisture content for achieving maximum compaction and stability in construction projects.

California Bearing Ratio Test: The California Bearing Ratio (CBR) test is essential for evaluating the soil's load-bearing capacity and suitability for road and pavement design. The unsoaked CBR value was found to be 3.14%, indicating the soil's ability to withstand loads without soaking. The soaked CBR value was 1.7%, suggesting reduced load-bearing capacity after saturation.

Enzyme-Treated Soil Analysis:

Atterberg's Limit Test: Enzyme treatment with different dosages influenced the soil's plasticity and consistency. The liquid limit decreased with increasing dosage, ranging from 27.8% to 32.13%. The plastic limit also exhibited variations, indicating changes in the soil's plastic behavior due to the enzyme treatment. This suggests that Terrazyme has a significant impact on altering the soil's plasticity.

Standard Proctor Test: The enzyme treatment affected the compaction characteristics of the soil. OMC values ranged from 12.0% to 12.9%, suggesting changes in the moisture content required for optimum compaction. Similarly, MDD values showed variations between 1.875 g/cc and 1.891 g/cc with different Terrazyme dosages. This indicates that enzyme treatment can influence the compaction efficiency of the soil.

California Bearing Ratio Test: Enzyme-treated soil exhibited altered CBR values compared to untreated soil. The unsoaked CBR values ranged from 8.12% to 13.22%, suggesting potential improvements in load-bearing capacity. The soaked CBR values, however, showed variations, ranging from 5.33% to 20.83%, indicating the influence of enzyme treatment on the soil's behavior under different moisture conditions.

Unconfined Compression Test: Enzyme treatment significantly affected the unconfined compressive strength of the soil. The strength values varied with both curing time and dosage. The results demonstrated that enzyme treatment can influence the soil's ability to withstand applied loads and stresses.

Conclusion

The study encompassed a comprehensive analysis of untreated and enzymatically treated soils, revealing significant improvements in Consistency limits, Standard Proctor test results, Unconfined Compressive Strength, and California Bearing Ratio (CBR) upon enzymatic treatment. The variation in enzyme dosage and treatment duration exhibited distinct effects, with the second dosage demonstrating optimal results across multiple parameters. Notably, the treated soil displayed lowered liquid and plastic limits, improved compaction characteristics, substantially increased CBR values, and enhanced unconfined compressive strength. This study's potential for further exploration lies in investigating the effects of different bio-enzymes, blended soil compositions, and a broader spectrum of geotechnical parameters for a more comprehensive understanding of soil modification and enhancement.

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