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ENHANCING THE BEARING CAPACITY OF BLACK COTTON SOIL BY USING COPPER SLAG, PLASTIC AND CALCIUM CARBIDE

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Abstract - Expansive black cotton soils are prevalent globally and pose a major threat to infrastructure integrity. Soil stabilization means improvement of the bearing capacity of soil can be enhanced through controlled compaction, proper proportioning, or the incorporation of appropriate admixtures or stabilizers. Due to their significant swelling and shrinkage properties, black cotton soils pose challenges for highway engineers. So in this research, a material such as copper slag, plastic and calcium carbide was used to improve the strength properties of soil. California Bearing Ratio and Standard Proctor test were conducted with different percentages of copper slag, calcium carbide (10%, 25%), and Plastic bottle strips (1.0%, 2. %). The characteristics of black cotton soil have been observed to change when mixed with copper slag, calcium carbide and plastic bottle strips are suitably enhanced. For this research work vane share test, standard proctor test, unconfined compression test, sieve analysis, and pychnometer test were conducted. We had performed a vane share test and found the shared strength of selected soil was increased from 5.23×10^{-4} N/mm^2 to 10.24×10^{-4} N/mm^2

Keywords: *Expansive Stabilization; Swelling; Shrinkage; California Bearing Ratio; copper slag*

1 INTRODUCTION

The requirement for an effective and sustainable solution is essential in geotechnical engineering has gained significant attention due to the increasing demand for infrastructure development and the limitations of traditional soil improvement methods. Black cotton soil, a type of expansive soil,presents considerable challenges due to its low bearing capacity, high shrink- swell behavior, and susceptibility to deformation under moisture variations. These issues often lead to structural failures, making it imperative to enhance the engineering properties of such soils. This research investigates an innovative approach to enhance the bearing capacity of black cotton soil by utilizing waste materials such as copper slag, plastic, and calcium carbide residue. Copper slag, a byproduct of copper smelting, is rich in silica and iron, making it a potential stabilizer for soil. Plastic waste, which poses significant environmental concerns, canbe repurposed to enhance soil reinforcement. Calcium carbide residue, a waste product from acetylene production, has been shown to improve soil strength through chemical stabilization.

The integration of these materials not only addresses the engineering challenges posed by black cotton soil but also contributes to waste management and environmental sustainability. By combining the mechanical reinforcement of plastics with the chemical stabilization properties of copper slag and calcium carbide, this study aims to provide a comprehensive solution for enhancing the soil's load-bearing capacity while reducing the environmental footprint of construction activities. The following sections of this paper will explore the properties of the materials used, the methodology adopted for soil stabilization, experimental results, and their implications for practical applications. This research holds promise for the development of cost-effective, sustainable, and high-performing ground improvement techniques for black cotton soil.

2 LITERATURE REVIEW

Black cotton soil, a type of expansive soil, poses significant challenges in construction due to its high shrink-swell potential, poor strength, and low bearing capacity. Researchers such as **Chen (1975) and Vanapalli et al. (1996)** have noted that black cotton soil undergoes volume changes with moisture variation, leading to structural instability. Consequently, soil stabilization techniques are crucial to improving its geotechnical properties for construction purposes.

Copper slag, a by-product of copper extraction, is gaining popularity in soil stabilization due to its high specific gravity, angular particle shape, and pozzolanic properties. Studies by **Al-Jabri et al. (2011) and Harish et al. (2017)** demonstrated its effectiveness in improving the shear strength and load-bearing capacity of soils. Additionally, using copper slag reduces the environmental burden associated with its disposal.

The integration of shredded or granulated plastic waste into soil stabilization aligns with waste management objectives and sustainability goals. Research by **Kumar et al. (2016) and Ramesh et al. (2019)** has shown that adding plastics enhances soil's ductility and resistance to cracking. Plastics also contribute to reducing settlement and increasing the soil's ability to withstand dynamic loads.

Calcium carbide residue, a by-product of acetylene gas production, is rich in lime content and exhibits excellent pozzolanic activity. Studies such as those by **Muntohar et al. (2013)** have demonstrated its potential in improving soil strength and reducing swelling. The synergistic use of calcium carbide residue with other stabilizers has shown promising results in enhancing the overall performance of expansive soils.

Recent studies highlight the benefits of combining multiple stabilizers for soil improvement. **Ramesh et al. (2020)** observed that integrating copper slag, plastics, and calcium carbide residue significantly enhances the bearing capacity and minimizes environmental impacts. Such hybrid approaches leverage the complementary properties of individual materials to address multiple deficiencies of black cotton soil.

The reuse of industrial by-products like copper slag and calcium carbide residue aligns with sustainable development goals by promoting resource recovery and waste minimization. Studies by **Das et al. (2018)** emphasize the economic benefits of utilizing waste materials in geotechnical applications, reducing construction costs and mitigating environmental risks.

3. MATERIALS & IT's METHODS

3.1 Black Cotton Soil

Black cotton soil, also known as Regur soil, is primarily found in the Deccan Plateau of India, characterized by its dark color due to high organic matter content and its clayey texture. This soil type is rich in calcium, magnesium, and iron, making it highly fertile and suitable for cotton cultivation, hence its name. It has excellent moisture retention capacity, which supports crops during dry periods. However, it can become hard and compacted when dry, posing challenges for tillage. Black cotton soil is also known for its ability to expand and contract with moisture changes, affecting its structural stability. Sustainable management practices are essential to maintain its fertility and prevent degradation due to overuse or improper agricultural practices.

Black cotton soil

3.2 Copper Slag

Copper slag is a byproduct of copper extraction from ores during the smelting process. Composed primarily of iron silicates, it typically contains silica, iron oxides, alumina, and calcium oxide. The material is dense, with a glassy appearance, and has a high melting point, making it chemically stable. Copper slag has various applications, including use as a partial replacement for sand in concrete, enhancing strength and durability, and as an abrasive for sandblasting. It also serves as a lightweight aggregate in construction and a cover material for landfills due to its low leachability. Research is increasingly focused on recycling copper slag for metal recovery and exploring its potential in wastewater treatment. Overall, copper slag presents both challenges and opportunities for sustainable resource management in the mining and construction industries.

Copper Slag

3.3 Polyethylene Plastic

Polyethylene is a widely used plastic, produced from the polymerization of ethylene monomers. It comes in various forms, such as low-density polyethylene, high-density polyethylene, and linear low-density polyethylene, each possessing unique characteristics. LDPE is flexible and suitable for bags and films, while HDPE is stronger and used for containers and pipes. Polyethylene is valued for its chemical resistance, moisture barrier, and cost-effectiveness, making it ideal for packaging applications. However, its non- biodegradable nature raises environmental concerns, leading to increased focus on recycling and sustainable alternatives. Efforts include mechanical recycling and innovations in chemicalrecycling to reduce plastic waste. The future of polyethylene involves balancing its widespreadutility with environmental responsibility through improved recycling technologies and sustainable production practices.

Polyethylene Plastic

3.4 Calcium carbide

Calcium carbide (CaC_2) is a chemical compound primarily used in the production of acetylene gas, which serves as a fuel and a building block for various organic chemicals. It appears as a grayish-black solid and is highly reactive, particularly with water, producing acetylene and calcium hydroxide. Calcium carbide is also utilized in the steel industry to remove sulfur and in the manufacture of calcium cyanamide, a nitrogen-rich fertilizer. Due to its reactivity, it must be handled with care, as it can pose fire and explosion hazards when in contact with moisture. Its applications extend to the production of certain plastics and as a desulfurizing agent. Environmental considerations include the management of waste and byproducts during its use.

Calcium carbide

3.4 METHODS

3.4.1 Atterberg's limit test

Liquid limit test

The liquid limit test provides an estimate of the compression index, which is essential for settlement analysis. If the natural moisture content of the soil exceeds the liquid limit, the soil is considered soft. Conversely, if the moisture content is below the liquid limit, the soil is classified as brittle and stiffer. Additionally, the liquid limit is a key parameter in soil classification and offers insights into the soil's plasticity.

Plastic limit test

The Plastic Limit is determined by repeatedly remolding a small ball of moist plastic soil and rolling it into a thread of 1/8 inch diameter. A plastic limit roller device can also be used to perform this test. The Plastic Limit corresponds to the moisture content at which the soil thread crumbles before it is completely rolled out.

Plasticity index

The plasticity index (PI) of a soil is a dimensionless value calculated as the numerical difference between its liquid limit (LL) and plastic limit (PL), both of which are expressed as moisture contents. It is given by the formula:

$$\text{Plasticity Index} = \text{Liquid Limit} - \text{Plastic Limit} \qquad (1)$$

3.4.2 California Bearing Ratio Test:-

The California Bearing Ratio (CBR) Test is a widely used geotechnical test designed to evaluate the strength of subgrade soil, subbase, and base layers in road and pavement construction. It provides a measure of the soil's load-bearing capacity by comparing it to a standard crushed stone material. The test helps engineers design pavements by ensuring they can withstand expected traffic loads.

Apparatus:- CBR Mould, Loading Machine, Dial Gauge ,Weights, Penetration Piston, Soaking Tank.

California Bearing Ratio Test

3.4.3 Standard Proctor Compaction Test

The Standard Proctor Compaction Test is a laboratory procedure used to determine the optimal moisture content (OMC) and maximum dry density (MDD) of soil for achieving maximum compaction. It is a critical test in geotechnical engineering and is widely used in the construction of roads, embankments, and foundations. The test ensures that soil is compacted to achieve the required strength and stability.

Standard Proctor Compaction Test

4. RESULT AND DISCUSSION

Atterbergs Limit

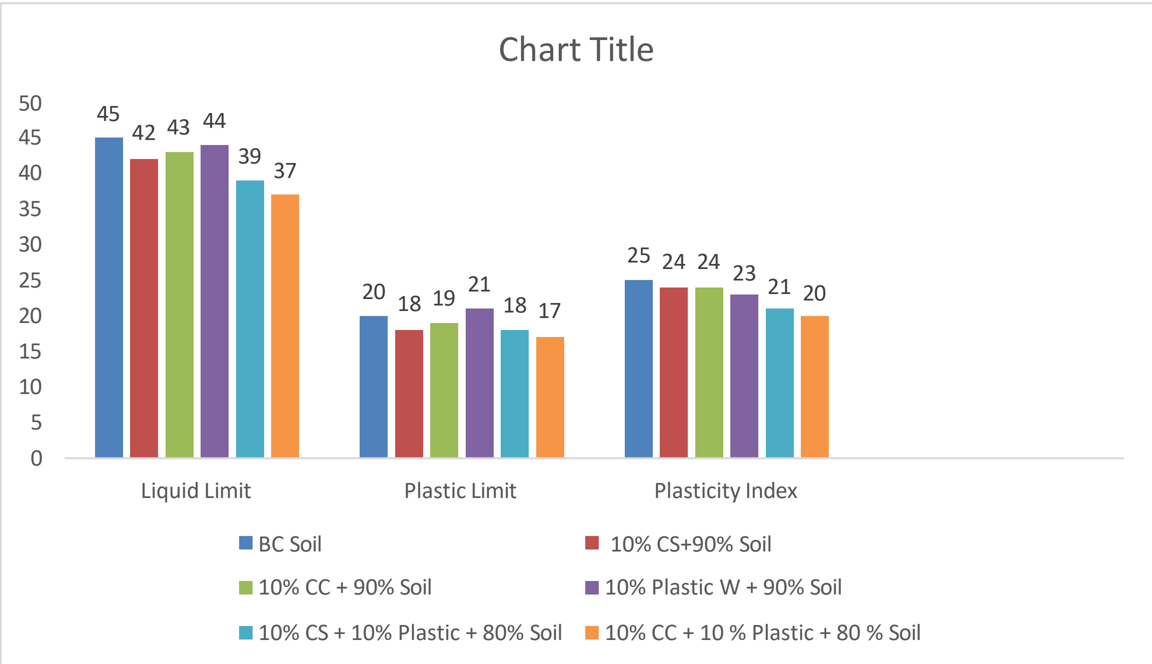

Chart -1: Atterbergs Limit.

5 RESULT & DISCUSSION

To study the effect after adding Copper Slag and Calcium Carbide in the Black Cotton soil, all the test were conducted.

- **Atterberg's Limit**. The addition of copper slag and calcium carbide to black cotton soil is likely to result in decreased liquid limits and plasticity indexes while potentially increasing or stabilizing plastic limits, depending on the specific conditions and amounts used.

- **California Bearing Ratio** The combination helps in reducing plasticity and swelling potential while improving strength, making the soil more stable under load.

- **Standard Proctor Test**. Conducting the Standard Proctor Test on black cotton soil with varying percentages of copper slag and calcium carbide will provide specific data on how these additives influence the compaction properties.

6 CONCLUSIONS

On the basis of the result of Experimental test performed :-

- In Atterberg's Limit, as we went on adding the percentage of admixture, the liquid Limit decreased
- In plastic Limit, with Increase in addition of copper & Calcium Carbide there was decrease in plastic limit.
- In CBR, there was an Increase in CBR value with Increase in Percentage of copper Slag & Calcium Carbide.

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