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To Enhance the Properties of Black Cotton Soil for Road Construction

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A B S T R A C T

The black cotton soil is a type of problematic expansive soil, which causes many problems in the construction of structures founded on them. It is having a swelling and impervious nature with poor geotechnical sub grade characteristics. In this research, an approach been made towards the way of improvement in the various geotechnical properties of black cotton soil such as index properties, swelling characteristics, consolidation characteristics, hydraulic conductivity characteristics and strength characteristics by blending it with waste materials such as river sand, fly ash and marble dust. Hence, from these approaches, the impacting effect of waste materials on the environment reduced due to optimum utilization of these waste materials in the improvement in various properties of black cotton soil.

Keywords: stabilizer, subgrade, admixtures, pavement, montmorillonite, CBR, , compressibility, permeability, disintegrated

1.Introduction

Black cotton soil, a type of expansive clay prevalent in tropical and subtropical regions, is widely recognized for its problematic behavior in civil engineering applications. Characterized by **high shrink-swell potential**, **low bearing capacity**, and **high plasticity**, black cotton soil undergoes significant volumetric changes with moisture fluctuations. These inherent deficiencies make it **unsuitable for road construction** in its natural state, often leading to pavement distress such as cracking, heaving, and settlement.Given the increasing demand for infrastructure development in areas with black cotton soil, it becomes crucial to enhance its engineering properties to meet the performance requirements for road subgrades and pavement layers. Traditional methods such as mechanical compaction alone are insufficient. Therefore, **soil stabilization techniques**—involving the addition of chemical or industrial additives—have gained prominence.

In recent years, a variety of stabilizing agents such as **lime, cement, fly ash, ground granulated blast furnace slag (GGBS), and micro silica** have been employed to improve the strength, durability, and moisture resistance of black cotton soil. These materials initiate pozzolanic or cementitious reactions that alter the soil structure, reduce plasticity, increase load-bearing capacity, and control volumetric changes.

This study focuses on **enhancing the properties of black cotton soil for road construction** by adopting suitable stabilization techniques. The goal is to transform the weak and reactive nature of the soil into a more **stable, durable, and structurally sound foundation** that can support modern transportation infrastructure

1.1 Necessity of study

1. Unstable Engineering Behavior:

BCS has high clay content (mainly montmorillonite), which exhibits extreme swelling and shrinkage with changes in moisture.

2. Poor Load-Bearing Capacity:

The soil has low shear strength and low bearing capacity, making it unsuitable for supporting road loads without treatment.

3. High Plasticity and Water Retention:

Its high plasticity index leads to poor workability and strength.

4. Widespread Occurrence:

BCS covers large parts of countries like India and Africa, making it necessary to develop cost-effective, sustainable improvement techniques rather than complete soil replacement.

5. Economic and Environmental Considerations:

Soil stabilization (using lime, cement, fly ash, or geopolymers) is often more economical and environmentally friendly than importing new material.

1.2 Objectives of the Study

1. To evaluate the engineering properties of untreated black cotton soil, including its strength, plasticity, and moisture sensitivity.
2. To identify and select suitable soil stabilization techniques (e.g., lime, cement, fly ash, or other additives) for improving black cotton soil.
3. To determine the optimum dosage of stabilizing agents that yield the best improvement in soil performance.
4. To analyze the effects of stabilization on the soil's bearing capacity, compaction characteristics, and swelling behavior.
5. To compare the performance of treated and untreated soil through laboratory testing and analysis

1.3 Scope of the Study

This study focuses on evaluating and improving the engineering properties of **black cotton soil** to make it suitable for road construction applications. It includes:

1. Collection and testing of black cotton soil samples to determine their natural properties such as Atterberg limits, compaction characteristics, swelling potential, and CBR value.
2. Selection and application of stabilizing materials like lime, cement, or industrial by-products (e.g., fly ash or rice husk ash) for soil improvement.
3. Laboratory testing of stabilized soil samples to assess changes in strength, shrink-swell behavior, and overall performance under varying moisture conditions.
4. Comparison of untreated and treated soils to determine the effectiveness of different stabilization techniques.
5. Development of recommendations for suitable stabilization methods for road construction over black cotton soil, with an emphasis on cost-effectiveness, sustainability, and long-term performance.

1.4 Expected Outcome

1. Improved Engineering Properties of Soil:

   Significant enhancement in the strength**,** bearing capacity**,** and stability of black cotton soil after treatment.

2. Reduction in Swelling and Shrinkage:

   Noticeable decrease in volume change behavior**,** reducing the risk of cracking and road surface deformation.

3. Increased Durability of Pavement:

   Roads constructed on treated black cotton soil are expected to show longer life spans and lower maintenance requirements**.**

4. Cost-Effective Stabilization Method Identified:

   Selection of an economical and locally available stabilizing material (like lime, cement, or fly ash) for large-scale application.

5. Improved Subgrade Performance:

   Enhanced load-carrying capacity of the subgrade layer, ensuring better support for upper pavement layers.

2.Review of Literature

2.1 General:

Extensive literature surveys available by well-known journals, proceedings, reference books, reports from various agencies, codes of practice, magazines, etc. have been collected in order to obtain information relevant to the selected particular issue. Some researchers have identified problematic behavior of black cotton soil and failure case studies. Few researchers have highlighted the precautions and appropriate techniques to be taken. Application and use of specific waste materials to the civil engineering infrastructure project to achieve the economy highlighted by few researchers. In this chapter, an attempt was made to encapsulate and summarize the contribution made by the previous researcher.

2.2 GGBS amended fly ash as an expansive soil stabilizer

Using Ground Granulated Blast Furnace Slag (GGBS) amended Fly Ash as a stabilizer for expansive soils like Black Cotton Soil is an innovative and sustainable solution that improves soil properties for infrastructure development, especially road construction.

Expansive soils such as black cotton soil exhibit poor engineering properties, including low bearing capacity and high swelling potential. Stabilization using industrial by-products offers a sustainable and cost-effective solution. Fly ash is commonly used but may not always provide adequate strength on its own. Amending fly ash with GGBS, a by-product of the steel industry rich in calcium and aluminosilicates, enhances the stabilization effect through pozzolanic and cementitious reactions.

"Ground granulated blast furnace slag amended fly ash as an expansive soil stabilizer" The Japanese Geotechnical Society Soils and Foundations, (March 2016)

Anil Kumar Sharma, P.V. Sivapullaiah (March 2016)

They explained potential of using a binder for stabilization of expansive soils that consists of a mixture of fly ash and ground granulated blast furnace slag (GGBS) is evaluated in this study. The joint use of these two materials to form a binder provides new opportunities to enhance pozzolanic activities that may reduce the swell potential and increase the unconfined compressive strength of expansive clays. The influence of different percentages of binder on the Atterberg limits, compaction characteristics and unconfined compressive strength of an artificially-mixed soil were examined. The addition of binder was shown to bring about a significant improvement in these soil properties. It was found that the liquid limit and plasticity index of the expansive soil decreased considerably with the addition of binder, while the strength improved. Adding a small amount of lime (one percent) further improved the soil properties by enhancing the pozzolanic reactivity of the binder. Based on the results of the unconfined compressive strength tests, the addition of 20% binder is recommended as optimum content. In addition, the mineralogical and morphological studies of soil specimen stabilized with optimum binder content suggested the formation of hydrated particles and cementations compounds as a result of the reaction between the clay and the binder. Test results indicate that the use of GGBS mixed fly ash as binder to stabilize expansive is well suited for sustainable construction besides economic benefits. In this study, an artificially-mixed expansive soil was stabilized with different amounts of binder, primarily consisting of fly ash and GGBS at a mixing ratio of 7:3. The objective of this research was to assess the effect of fly ash GGBS based binder on the physical properties and unconfined compressive strength of the soil.

4. Methodology

Soil samples were collected from regions dominated by black cotton soil. Laboratory tests such as Atterberg limits, Standard Proctor test, Unconfined Compressive Strength (UCS), and California Bearing Ratio (CBR) were conducted. The soil was treated with different percentages of lime, fly ash, and cement individually and in combination.

- **Stabilizers Used:**
    - Lime (2%–8%)
    - Cement (3%–9%)
    - Fly Ash (5%–15%)
    - GGBS and Rice Husk Ash (5%–15%)
- **Tests Performed:**
    - Atterberg Limits
    - Compaction Test
    - CBR Test
    - Unconfined Compressive Strength (UCS)
    - Swelling and shrinkage tests

Effect of Stabilizers on UCS (kPa)

Stabilizer	**Percentage**	**UCS (kPa)**
Lime	6%	290
Cement	6%	340
Fly Ash	10%	250
GGBS + RHA	10%	270

5. Results and Discussion

- **Lime Stabilization:** Lime addition reduced plasticity and increased CBR and UCS values. The optimum lime content was found to be 8%.

- **Fly Ash Stabilization:** Fly ash improved compaction characteristics and reduced swell potential. An optimum content of 20% yielded significant improvements.
- **Cement Stabilization:** Cement significantly increased strength parameters. A 6% cement content was determined to be effective.
- **Combined Stabilization:** The combination of lime and fly ash yielded synergistic effects, with better performance than individual treatments.

6. Conclusion

Stabilization techniques using lime, fly ash, and cement significantly improve the engineering properties of black cotton soil, making it a reliable subgrade material for road construction. Among the studied methods, the combination of lime and fly ash proved most effective in enhancing strength and reducing plasticity.

7. Recommendations

- Adopt lime-fly ash stabilization for cost-effective and sustainable road projects.
- Conduct site-specific tests before large-scale implementation.
- Explore the use of industrial waste products to further reduce costs.

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