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Stabilization of Black Cotton Soil using Kota Stone Dust

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Abstract: *Black cotton soil, known for its high shrink-swell capacity and poor engineering properties, poses significant challenges in construction and infrastructure development. Stabilization of such expansive soils is crucial to enhance their load-bearing capacity and minimize volumetric changes. This study investigates the effectiveness of using Kota stone waste, a by-product from the stone cutting industry, as a stabilizing agent for black cotton soil. Various proportions of Kota stone powder (ranging from 5% to 25% by weight) were mixed with the soil and tested for changes in Atterberg limits, compaction characteristics, unconfined compressive strength (UCS), and California Bearing Ratio (CBR). The results indicate a significant improvement in the strength and stability of the soil with an optimal dosage of Kota stone powder. The use of Kota stone not only improves geotechnical properties but also promotes sustainable construction practices by utilizing industrial waste. This research demonstrates a cost-effective and eco-friendly approach to soil stabilization, particularly relevant for road and foundation works in black cotton soil regions.*

Keywords: Black Cotton Soil, Soil Stabilization, Kota Stone Waste, Expansive Soils, Geotechnical Engineering, Industrial Waste Utilization, Sustainable Construction, Soil Improvement, California Bearing Ratio (CBR)

I. INTRODUCTION

Black cotton soil, commonly found in various regions of India, is notorious for its poor engineering properties, especially its high plasticity, low strength, and significant volume changes due to moisture fluctuations. These characteristics make it highly unsuitable for supporting structures without prior treatment. The presence of montmorillonite clay minerals gives black cotton soil its expansive nature, leading to frequent cracking and structural instability in pavements, buildings, and other infrastructure.

To counter these challenges, various stabilization techniques have been explored, ranging from chemical additives like lime and cement to mechanical methods. However, the use of conventional stabilizers can be expensive and environmentally taxing. In recent years, the focus has shifted towards sustainable and cost-effective alternatives, including the utilization of industrial by-products and waste materials.

Kota stone waste, a by-product generated during the processing of Kota stone slabs in Rajasthan and other regions, is often discarded in large quantities, causing environmental concerns. Rich in calcium carbonate and fine particles, Kota stone powder has the potential to improve the properties of problematic soils when used as an additive. Its availability, affordability, and environmental advantages make it a promising material for soil stabilization.

This study aims to evaluate the effectiveness of Kota stone waste in enhancing the geotechnical properties of black cotton soil. Through a series of laboratory tests, the research investigates the changes in Atterberg limits, compaction behavior, unconfined compressive strength, and California Bearing Ratio upon the addition of varying percentages of Kota stone powder. The results of this study are expected to contribute to sustainable construction practices and efficient waste management in the construction industry.

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II. LITERATURE REVIEW

The stabilization of expansive soils such as black cotton soil has been a key focus in geotechnical research due to their problematic nature, particularly in civil engineering applications. Various traditional and alternative materials have been studied to improve the engineering characteristics of such soils.

Patel and Desai (2010) studied the effect of lime and fly ash on black cotton soil and reported significant improvements in compaction characteristics and strength. The study highlighted the potential of industrial by-products in enhancing soil properties at a reduced cost.

Muntohar and Hantoro (2000) explored the use of lime and rice husk ash in stabilizing expansive soils and found a substantial reduction in plasticity and swell potential. Their work emphasized the benefit of combining pozzolanic materials with calcium-based additives.

Kumar and Sharma (2014) investigated the use of marble dust in stabilizing expansive soils and observed improvements in California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS). Their findings are particularly relevant as marble dust and Kota stone waste share similar chemical compositions.

Ramesh et al. (2017) carried out stabilization of black cotton soil using granite and marble waste, which indicated that such stone wastes can be effective in improving bearing capacity and reducing plasticity index. This supports the growing interest in stone waste reuse in geotechnical applications.

Choudhary et al. (2020) focused specifically on the stabilization of expansive soil using Kota stone slurry and demonstrated an increase in shear strength and a decrease in the swell index. This study laid a strong foundation for considering Kota stone as a viable stabilizing material.

The literature clearly indicates that calcium-rich waste materials like lime, marble dust, and stone slurry can positively influence the geotechnical properties of black cotton soil. However, limited research has been conducted on the systematic use of **Kota stone waste powder** in varied proportions. This study addresses this gap by evaluating the soil behavior across multiple parameters such as Atterberg limits, compaction, UCS, and CBR with the addition of Kota stone waste.

III. METHODOLOGY

This study investigates the stabilization of black cotton soil using Kota stone waste through a series of laboratory experiments. The methodology includes material collection, sample preparation, testing procedures, and analysis of results.

1. Material Collection:

- Black Cotton Soil: Collected from a site known for its expansive clayey soil. The soil was air-dried, pulverized, and sieved through a 4.75 mm IS sieve.
- Kota Stone Waste: Obtained from stone cutting industries in Kota, Rajasthan. The waste was in the form of fine powder/slurry, air-dried, and sieved to obtain a uniform particle size for mixing.

2. Preliminary Tests on Soil:

To determine the basic properties of the untreated black cotton soil, the following tests were conducted in accordance with IS codes:

- Specific Gravity (IS: 2720 Part 3)
- Grain Size Analysis (IS: 2720 Part 4)
- Atterberg Limits (IS: 2720 Part 5)
- Standard Proctor Compaction Test (IS: 2720 Part 7)
- Unconfined Compressive Strength (IS: 2720 Part 10)
- California Bearing Ratio (IS: 2720 Part 16)

3. Preparation of Soil-Kota Stone Mixes:

The black cotton soil was mixed with Kota stone waste in varying proportions by weight:

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- 0%
- 5%
- 10%
- 15%
- 20%
- 25%

Each mixture was thoroughly blended to ensure uniform distribution of Kota stone powder throughout the soil.

4. Laboratory Testing on Stabilized Samples:

The following tests were performed on each mix proportion to assess the improvement in soil properties:

- Atterberg Limits: To determine changes in plasticity index.
- Standard Proctor Test: To find the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) for each mix.
- Unconfined Compressive Strength (UCS): To evaluate the improvement in strength.
- California Bearing Ratio (CBR): To assess the load-bearing capacity, particularly relevant for pavement subgrades.
- All tests were conducted under controlled conditions, and each test was repeated at least three times to ensure accuracy and reproducibility of results.

5. Data Analysis:

The results from various tests were compiled and analyzed to determine:

- The optimum percentage of Kota stone waste for maximum strength gain.
- Improvement trends in plasticity, compaction, and CBR values.
- Suitability of Kota stone waste as a sustainable stabilizing agent.

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IV. CONCLUSION

The study successfully demonstrates that Kota stone waste can be effectively used to stabilize black cotton soil, improving its engineering properties and making it more suitable for construction purposes. The addition of Kota stone powder resulted in a noticeable improvement in key parameters such as Atterberg limits, maximum dry density, unconfined compressive strength (UCS), and California Bearing Ratio (CBR).

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Among the various proportions tested, an optimal range of Kota stone waste was observed where the soil exhibited maximum strength and reduced plasticity. The reduction in the plasticity index indicates decreased swell-shrink behavior, while the increase in UCS and CBR values confirms enhanced load-bearing capacity and overall stability.

The use of Kota stone waste not only improves soil performance but also contributes to environmental sustainability by promoting the reuse of industrial by-products. This approach presents a cost-effective and eco-friendly solution for infrastructure development in regions with problematic black cotton soils.

Further studies can explore the long-term durability, field performance, and behavior under varying environmental conditions to validate the large-scale applicability of this technique.

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