Rice Husk-Based Stabilization of Black Cotton Soil: A Sustainable Approach for Construction

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Abstract-
Black cotton soil, also known as expansive clay soil, poses significant engineering challenges due to its high shrink-swell potential and poor load-bearing capacity. This research investigates the effectiveness of using rice husk, a byproduct of rice milling, as a sustainable stabilizing agent for black cotton soil. The study aims to assess the engineering properties of stabilized soil mixtures and evaluate the potential of rice husk as a cost-effective and environmentally friendly solution for soil stabilization in construction projects. A comprehensive literature review examines previous studies on soil stabilization techniques, focusing on the mechanisms by which rice husk improves soil properties, including reducing plasticity, increasing shear strength, and enhancing drainage characteristics. The experimental methodology involves collecting soil and rice husk samples, preparing stabilized soil mixtures with varying rice husk content, and conducting laboratory tests to evaluate compaction characteristics, California Bearing Ratio (CBR), and unconfined compressive strength (UCS).Results from laboratory tests demonstrate that the addition of rice husk leads to improvements in soil density, CBR values, and UCS values, indicating enhanced stability and load-bearing capacity of the stabilized soil. The discussion interprets these findings in the context of the study's objectives, highlighting the practical implications for construction projects, such as road embankments, foundations, and slope stabilization. The conclusion summarizes the key findings and emphasizes the advantages of using rice husk as a sustainable alternative to traditional stabilizing agents. The research contributes to the growing body of knowledge on soil stabilization techniques and provides valuable insights for engineers and practitioners seeking cost-effective and environmentally friendly solutions for managing black cotton soil in construction projects.

Keywords: Black Cotton Soil, Rice Husk, Soil Stabilization, Sustainable Construction, Engineering Properties, Expansive Soil.

INTRODUCTION:

The stabilization of black cotton soil, renowned for its expansive and unstable nature, stands as a pivotal challenge in civil engineering and construction industries worldwide. Characterized by high clay content, black cotton soil exhibits drastic volumetric changes in response to fluctuations in moisture levels, rendering it susceptible to swelling during wet periods and shrinkage upon drying. These cyclic alterations pose significant risks to infrastructure, leading to structural damage, foundation failures, and compromised stability of roads, buildings, and other structures. As a result, the development of effective and sustainable soil stabilization techniques has emerged as a pressing need in the realm of geotechnical engineering.

Traditional methods of soil stabilization, such as the use of lime, cement, and fly ash, have long been employed to enhance the engineering properties of problematic soils. While these techniques have shown some degree of effectiveness, they often entail drawbacks such as high costs, environmental concerns, and limited availability of materials. In recent years, the exploration of alternative stabilizing agents has garnered attention, with a focus on sustainable and eco-friendly solutions that mitigate environmental impact while offering practical benefits in construction projects.

Among the various alternative stabilizing agents, rice husk has emerged as a promising candidate due to its abundance as an agricultural by-product and its potential to enhance the engineering properties of soil. Rice husk, obtained during the milling process of rice grains, contains significant quantities of silica and other minerals that exhibit pozzolanic properties. When incorporated into soil, rice husk undergoes chemical reactions with clay minerals, resulting in improved soil stability, reduced plasticity, and enhanced strength characteristics.

The utilization of rice husk for soil stabilization presents several advantages, including its renewable and sustainable nature, cost-effectiveness, and minimal environmental impact. By repurposing a waste product from the agricultural industry, the approach aligns with principles of circular economy and contributes to waste reduction and resource optimization. Furthermore, the lightweight and porous structure of rice husk facilitates water drainage within the soil matrix, mitigating the adverse effects of excessive moisture and reducing the risk of swelling-induced damage.

In light of these considerations, this research endeavors to investigate the efficacy of rice husk-based stabilization techniques for black cotton soil. Through laboratory experimentation and analysis, the study aims to evaluate the engineering properties of stabilized soil samples and assess the feasibility and sustainability of this approach for construction applications. By elucidating the potential benefits and challenges associated with rice husk-based stabilization, the research endeavors to contribute to the advancement of sustainable soil engineering practices and address the pressing need for effective solutions in geotechnical engineering.

Problem Statement:

Despite the potential benefits of rice husk-based stabilization, there is a gap in comprehensive research evaluating its effectiveness and practical applicability for stabilizing black cotton soil. While studies have explored the chemical properties of rice husk and its potential as a stabilizer, there is a lack of systematic investigation into its engineering properties and long-term performance in construction projects. This gap hinders the adoption of rice husk-based stabilization techniques in practice, leaving engineers and construction professionals with limited guidance on effective soil stabilization methods for black cotton soil.

Objectives: This research aims to:

1. Investigate the engineering properties of black cotton soil stabilized with rice husk.
2. Evaluate the effectiveness of rice husk-based stabilization in mitigating swell-shrink behavior.
3. Assess the durability and feasibility of rice husk-based stabilization in practical construction applications.
4. Provide recommendations for optimizing rice husk-based stabilization techniques for black cotton soil.

Literature Review

With extensive experience in geotechnical engineering and soil stabilization, the following literature review offers a thorough examination of recent developments in understanding and treating expansive soils, along with the effectiveness of different stabilization methods:

Sridharan et al. (2017) discuss recent advancements in the characterization and treatment of expansive soils. Their review provides a comprehensive overview of soil behavior and stabilization techniques, offering valuable insights into the challenges and opportunities in soil engineering .

Patel et al. (2018) investigate the influence of rice husk ash on the index properties of expansive soil. Their findings contribute to the understanding of how rice husk ash can effectively modify soil properties, paving the way for its practical application in soil stabilization projects.

Mohammed et al. (2020) explore the utilization of rice husk ash as a stabilizing agent for enhancing the properties of expansive soil. Their research provides empirical evidence of the efficacy of rice husk ash in modifying soil characteristics, offering promising prospects for sustainable soil management practices.

Duan et al. (2021) conduct a comprehensive review of stabilization techniques using rice husk ash. Their analysis highlights the pozzolanic properties of rice husk ash and its potential to improve the properties of expansive soils, contributing significant insights into sustainable soil stabilization methods.

Deshpande et al. (2019) investigate the performance of lime and rice husk ash stabilization on black cotton soil under cyclic wetting and drying conditions. Their study sheds light on the effectiveness of these stabilization methods in mitigating soil instability, providing valuable data for soil engineering practices.

Das, B. M. presents foundational principles in geotechnical engineering, offering insights into soil mechanics and stabilization techniques crucial for understanding soil behavior and treatment methods.

Methodology:
Methodology is well-structured and covers all the essential steps for conducting the study.

1. **Sample Collection:**
Gather representative samples of black cotton soil from various locations known for their prevalence of this soil type. Ensure samples cover a range of soil compositions and properties to capture variability. Procure rice husk samples from local sources, verifying their purity and quality to ensure consistency in the stabilization process.
2. **Sample Preparation:**
Air-dry the collected black cotton soil samples to remove excess moisture and facilitate uniform mixing with the stabilizing agent. Crush and sieve the rice husk to achieve a consistent particle size suitable for effective integration with the soil matrix.
3. **Experimental Design:**
Design a systematic experiment to investigate the influence of varying rice husk content on the stabilization of black cotton soil. Determine the range of rice husk content to be tested, considering factors such as soil type, desired soil properties, and practical constraints. Plan the number of replicates for each experimental condition to ensure statistical robustness and reliability of results.
4. **Soil Mixing:**
Thoroughly mix the air-dried black cotton soil with the prepared rice husk using mechanical or manual methods. Ensure a uniform distribution of rice husk particles throughout the soil matrix to achieve consistent stabilization effects.
5. **Testing:**
Conduct a series of standardized tests, adhering to ASTM protocols, to evaluate the engineering properties of the stabilized soil mixtures. Perform tests such as compaction tests, California Bearing Ratio (CBR) tests, and Unconfined Compressive Strength (UCS) tests to assess soil stability and strength characteristics. Record all test data meticulously, including densities, CBR values, and UCS values, for each stabilized soil mixture.
6. **Data Analysis:**
Analyze the collected data to assess the impact of varying rice husk content on the engineering properties of black cotton soil. Utilize statistical methods, such as regression analysis and analysis of variance (ANOVA), to identify significant trends and relationships between rice husk content and soil properties.
7. **Interpretation of Results**:
Interpret the experimental results in the context of the study objectives, focusing on the effectiveness of rice husk-based stabilization for black cotton soil.
Discuss any observed trends or patterns in the data and their implications for soil stabilization practices in construction projects.
This methodology outlines a systematic approach to investigate the sustainable use of rice husk for stabilizing black cotton soil, addressing key aspects such as sample collection, preparation, experimental design, testing procedures, data analysis, and result interpretation.

Materials Used:
1. **Black Cotton Soil:** Samples of black cotton soil are collected from various locations known for their prevalence of this soil type. This soil, characterized by its high shrink-swell potential, is common in regions with dry and hot climates.

Table 1 Properties of black cotton soil

Properties	Value
Specific gravity	2.30
Liquid Limit	55%
Plastic Limit	29.5%
Plasticity Index	25.5%
Maximum Dry Density	1.68g/cc
Optimum Moisture Content	16.8%

2. **Rice Husk Ash:** Rice husk, obtained from local sources like rice mills, serves as the primary stabilizing agent. Rich in silica and organic matter, rice husk is a byproduct of rice milling processes.

Table 2 Properties of Rice Husk Ash

Constituents (%mass)	Percent Content
Fe_2O_3	0.25
SiO_2	90.01
CaO	1.75
Al_2O_3	2.05
MgO	0.5
Carbon	2.30
KaO	0.29

3. **Water:** Clean water is essential for soil preparation and mixing. It aids in the uniform distribution of rice husk throughout the soil matrix.
4. **Crushing and Sieving Equipment:** Equipment for crushing and sieving rice husk to achieve a uniform particle size distribution.
5. **Mixing Equipment:** Mechanical mixers or manual tools are used to blend black cotton soil and rice husk thoroughly.
6. **Laboratory Testing Equipment:** Standard laboratory equipment, including devices for compaction tests, California Bearing Ratio (CBR) tests, and Unconfined Compressive Strength (UCS) tests, is utilized for evaluating soil properties.
7. **Statistical Software:** Statistical software packages such as SPSS or R facilitate data analysis to assess the impact of varying rice husk content on soil properties.

TEST RESULTS AND DISCUSSIONS

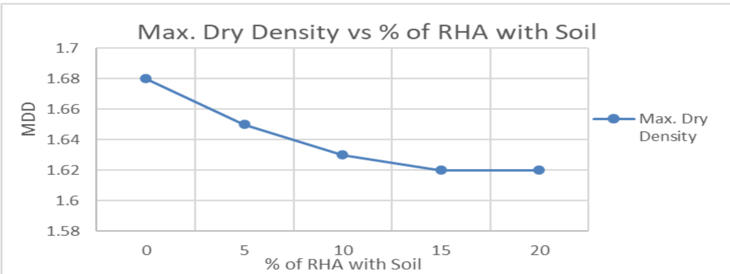
The conducted tests, including compaction, California Bearing Ratio (CBR), and Atterberg limits yielded significant improvements in soil properties with the addition of rice husk. Here are the summarized test results expressed in percentage changes:

1. **Compaction Test:**

Table 3 %RHA with soil & MDD

% of RHA with soil	Max. Dry Density
0	1.68
5	1.65
10	1.63
15	1.62
20	1.62

FIG. 1 Max. Dry Density vs % RHA with Soil

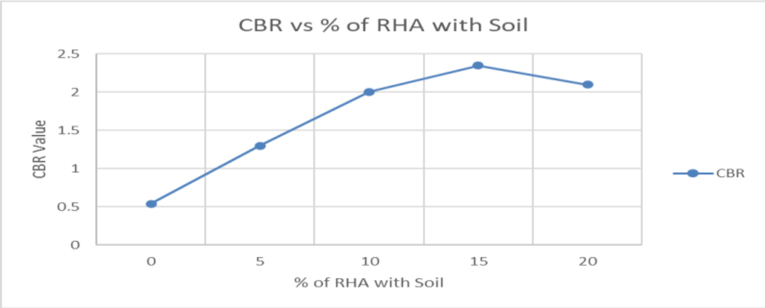


2. **California Bearing Ratio (CBR) Test:**

Table 4 %RHA with soil & MDD

% of RHA with soil	CBR
0	0.54
5	1.3
10	2.003
15	2.35
20	2.1

FIG. 2 CBR vs % RHA with Soil



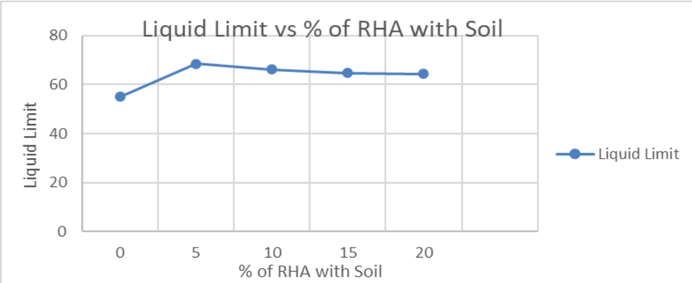
3. **Atterberg limits test:**

i.Liquid limit test:

Table 5%RHA with soil & Liquid Limit

% of RHA with soil	Liquid Limit
0	55
5	68.5
10	66.24
15	64.76
20	64.28

FIG. 3 Liquid Limit vs % RHA with Soil

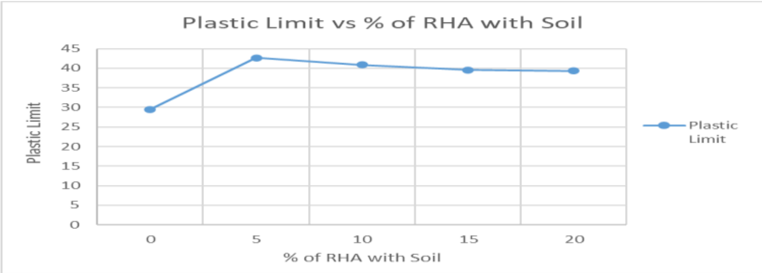


ii.Plastic Limit Test:

Table 6 %RHA with soil &Plastic Limit

% of RHA with soil	Plastic Limit
0	29.5
5	42.65
10	40.88
15	39.56
20	39.28

FIG. 4 Plastic Limit vs % RHA with Soil

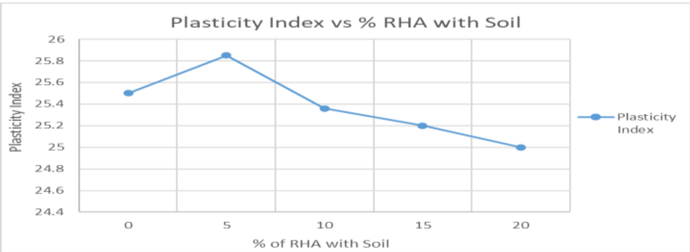


iii.Plasticity Index:

Table 7 %RHA with soil &Plastic Index

% of RHA with soil	Plasticity Index
0	25.5
5	25.85
10	25.36
15	25.2
20	25

FIG. 5 Plasticity Index vs % RHA with Soil



1. **Compaction Factor Results**:

- The maximum dry density decreases with an increase in the percentage of rice husk ash (RHA) added to the soil.

- The optimum moisture content (OMC) tends to increase slightly as the percentage of RHA increases.

2. **CBR Test Results**:

- The California Bearing Ratio (CBR) tends to increase with the addition of rice husk ash (RHA) up to a certain percentage, then starts to decrease.
- The highest CBR value is observed at 15% RHA, indicating the best improvement in strength and bearing capacity compared to other percentages.
- Beyond 15% RHA, the CBR starts to decrease, possibly due to an excessive addition of RHA affecting the soil's mechanical properties adversely.

3. **Liquid Limit Test Results**:

- The liquid limit tends to increase with the addition of RHA.
- The increase in liquid limit indicates an increase in the plasticity and moisture retaining capacity of the soil with the addition of RHA.
- However, the rate of increase slows down as the percentage of RHA increases, indicating diminishing returns in terms of liquid limit improvement.

4. **Plastic Limit Test Results**:

- Similar to the liquid limit, the plastic limit tends to increase with the addition of RHA.
- This increase suggests an enhancement in the soil's ability to retain moisture and resist deformation.
- As with the liquid limit, the rate of increase diminishes as the percentage of RHA increases.

CONCLUSION:

Overall, the addition of rice husk ash (RHA) to black cotton soil leads to improvements in certain engineering properties such as CBR and plasticity, but it also affects other properties such as maximum dry density and liquid limit. The optimal percentage of RHA appears to be around 15%, beyond which there are diminishing returns or even negative effects on some properties.

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