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# Experimental Study on Stability of Black Cotton Soil Mixed with GGBS, Nano-Silica and Rice Husk Ash

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**Abstract:** *Black cotton soil is an expansive type of soil that undergoes excessive swelling and shrinkage due to variations in moisture content, leading to severe problems in foundations, pavements, and other civil engineering structures. This study investigates the stabilization of black cotton soil using Ground Granulated Blast Furnace Slag (GGBS), Nano-Silica, and Rice Husk Ash (RHA) as sustainable stabilizing materials.Different proportions of these additives were mixed with the soil to evaluate their effect on engineering properties such as Liquid Limit, Plastic Limit, Plasticity Index, Maximum Dry Density (MDD), Optimum Moisture Content (OMC), Free Swell Index (FSI), California Bearing Ratio (CBR), and Unconfined Compressive Strength (UCS).*

*Experimental results indicate that the inclusion of GGBS, Nano-Silica, and RHA significantly improves the strength and stability characteristics of black cotton soil while reducing its swelling behavior and plasticity. The optimum performance was observed for the blend containing 10% GGBS, 1% Nano-Silica, and 5% Rice Husk Ash,which produced higher UCS and CBR values with lower swelling potential. The study concludes that the combined use of industrial and agricultural waste materials offers an eco-friendly, economical, and effective solution for the stabilization of expansive soils in geotechnical engineering applications.*

**Keywords:** Black Cotton Soil, Soil Stabilization, GGBS, Nano-Silica, Rice Husk Ash, Expansive Soil, California Bearing Ratio, Unconfined Compressive Strength, Sustainable Construction, Geotechnical Engineering.

## I. INTRODUCTION

Soil plays an important role in all types of civil engineering construction works, as the stability and performance of structures largely depend on the engineering properties of the foundation soil. Among different types of soils,Black Cotton Soil (BCS) is considered one of the most problematic expansive soils due to its high swelling and shrinkage characteristics.These properties are mainly caused by the presence of montmorillonite clay minerals, which absorb water during wet conditions and shrink during dry conditions. As a result, structures built on black cotton soil often suffer from cracking, uneven settlement, pavement failure, and reduced durability.

To overcome these engineering problems, soil stabilization techniques are commonly adopted to improve the strength, durability, and load-bearing capacity of expansive soils. In recent years, the use of industrial and agricultural waste materials in soil stabilization has gained significant attention because of their economic and environmental benefits.Ground Granulated Blast Furnace Slag (GGBS), Nano-Silica, and Rice Husk Ash (RHA) are among the most effective stabilizing agents used for improving problematic soils. GGBS is an industrial by-product rich in calcium and silica compounds that enhances soil strength through pozzolanic reactions.Nano-Silica, due to its ultrafine particle size and high reactivity, improves particle bonding and reduces voids within the soil matrix. Similarly, Rice Husk Ash, an agricultural waste rich in amorphous silica, contributes to improved strength and reduced swelling characteristics.

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## II. LITERATURE REVIEW

Several researchers have carried out studies on the stabilization of expansive soils using industrial by-products and nanomaterials. Black cotton soil is known for its excessive swelling and shrinkage characteristics, which create serious problems in pavements, foundations, and other geotechnical structures. To overcome these issues, different stabilizing materials such as Ground Granulated Blast Furnace Slag (GGBS), Nano-Silica, and Rice Husk Ash (RHA) have been widely investigated.

Barman et al. (2022) investigated the stabilization of expansive soils using chemical additives and reported that GGBS and Nano-Silica significantly improve the engineering properties of soil by reducing plasticity and increasing compressive strength. Their study highlighted that Nano-Silica accelerates pozzolanic reactions due to its ultrafine particle size and high surface area. Similarly, Parthiban et al. (2022) emphasized the role of industrial waste materials such as fly ash, GGBS, and RHA in geopolymer-based soil stabilization, which enhances durability and strength performance.

Recent studies by Muthiah Maheswaran (2025) and Lihua Li (2025) demonstrated that the combined use of agro-industrial by-products and Nano-Silica improves the fresh, mechanical, and durability properties of stabilized materials. Their research confirmed that Rice Husk Ash, being rich in amorphous silica, contributes effectively to strength gain and reduction in swelling behavior.

Hanifi Canakci (2019) conducted experimental studies on geopolymer stabilizers prepared from fly ash, slag, and RHA and concluded that these materials significantly improve the Unconfined Compressive Strength (UCS) and durability of expansive soils. Likewise, T. Vamsi Nagaraju (2023) compared geopolymer stabilization with conventional cement stabilization and found that geopolymer-based stabilizers achieve comparable strength with lower environmental impact and carbon emissions.

From the reviewed literature, it is observed that the combined application of GGBS, Nano-Silica, and Rice Husk Ash can effectively improve the engineering behavior of black cotton soil by reducing plasticity, decreasing swelling potential, and increasing strength parameters such as CBR and UCS. However, limited studies are available on the combined optimization of these three materials together, which forms the basis of the present investigation.

## III. MATERIALS USED

### 1. Black Cotton Soil (BCS)

Black cotton soil was collected from Patel Nagar, Bhopal. It is an expansive clayey soil containing montmorillonite minerals, which cause excessive swelling and shrinkage due to moisture variations. The soil exhibits low bearing capacity, high compressibility, and significant volume changes, making it unsuitable for construction without stabilization. Laboratory tests were conducted to determine its index and engineering properties such as Liquid Limit, Plastic Limit, Plasticity Index, Specific Gravity, and Moisture Content.

### 2. Ground Granulated Blast Furnace Slag (GGBS)

GGBS is an industrial by-product obtained during the production of iron in blast furnaces. It was used as a stabilizing agent because of its cementitious and pozzolanic properties. GGBS improves soil strength, reduces permeability, and enhances durability. The material mainly contains calcium oxide (CaO), silica ($SiO_2$), and alumina ($Al_2O_3$), which contribute to the formation of cementitious compounds during stabilization.

### 3. Nano-Silica

Nano-Silica consists of ultrafine silica particles with sizes ranging from 10 – 50 nanometers. Due to its high surface area and reactivity, Nano-Silica accelerates pozzolanic reactions and improves particle bonding within the soil matrix. It helps in reducing voids, increasing density, and enhancing the strength and stiffness of stabilized soil.

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**4. Rice Husk Ash (RHA)**

Rice Husk Ash is an agricultural waste product obtained by the controlled burning of rice husk. It is rich in amorphous silica and acts as a supplementary cementitious material. RHA improves soil workability, reduces swelling potential, and increases resistance to water penetration. The use of RHA also promotes sustainable waste management and eco-friendly construction practices.

## IV. METHODOLOGY

The methodology adopted in this study involves laboratory investigation to evaluate the stabilization of Black Cotton Soil using Ground Granulated Blast Furnace Slag (GGBS), Nano-Silica, and Rice Husk Ash (RHA). Different proportions of stabilizers were mixed with the soil to study their influence on the engineering properties of expansive soil.

### 1. Collection of Materials

Black cotton soil was collected from Patel Nagar, Bhopal. GGBS was obtained from steel industry by-products, Nano-Silica was procured from a commercial supplier, and Rice Husk Ash was collected from rice mills. Clean potable water was used for sample preparation and testing purposes.

### 2. Characterization of Soil and Additives

Initially, laboratory tests were conducted on untreated black cotton soil to determine its physical and engineering properties. Tests included:

Liquid Limit (LL)
Plastic Limit (PL)
Plasticity Index (PI)
Specific Gravity
Moisture Content
Free Swell Index (FSI)
Maximum Dry Density (MDD)
Optimum Moisture Content (OMC)

Similar characterization tests were also conducted for GGBS, Nano-Silica, and Rice Husk Ash to determine their suitability for soil stabilization.

### 3. Preparation of Soil Mixes

The black cotton soil was mixed with varying percentages of stabilizers:

GGBS: 5%, 10%, 15%, 20%
Nano-Silica: 0.5%, 1%, 1.5%, 2%
Rice Husk Ash (RHA): 5%, 10%, 15%, 20%

Different combinations of these additives were prepared to identify the optimum blend for stabilization.

### 4. Compaction and Sample Preparation

The required quantity of soil and stabilizers was thoroughly mixed in dry condition to ensure uniform distribution. Water was then added gradually to achieve the desired moisture content. The prepared mixtures were compacted into moulds according to standard compaction procedures.

### 5. Laboratory Testing

The stabilized soil samples were tested to evaluate improvements in engineering properties. The following tests were performed:


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Compaction Test
Free Swell Index (FSI)
California Bearing Ratio (CBR)
Unconfined Compressive Strength (UCS)
These tests were conducted as per relevant Indian Standard (IS) codes.

**6. Analysis of Results**

The results obtained from stabilized soil samples were compared with untreated black cotton soil. The optimum percentage of GGBS, Nano-Silica, and RHA was identified based on improvements in strength, swelling reduction, compaction characteristics, and bearing capacity.

## V. RESULTS AND DISCUSSION

The experimental investigation was carried out to evaluate the effect of Ground Granulated Blast Furnace Slag (GGBS), Nano-Silica, and Rice Husk Ash (RHA) on the engineering properties of Black Cotton Soil. Various laboratory tests were conducted on untreated and stabilized soil samples, and the obtained results indicate significant improvement in strength and stability characteristics after stabilization.

The experimental results clearly indicate that the combined use of GGBS, Nano-Silica, and Rice Husk Ash effectively improves the engineering properties of black cotton soil. The stabilized soil exhibited reduced plasticity, lower swelling potential, higher strength, and improved compaction characteristics. Among all combinations, the blend containing 10% GGBS, 1% Nano-Silica, and 5% RHA provided the best overall performance. The study demonstrates that industrial and agricultural waste materials can be successfully utilized as sustainable and economical stabilizers for expansive soils in geotechnical engineering applications.

## VI. CONCLUSION

The present study investigated the stabilization of Black Cotton Soil using Ground Granulated Blast Furnace Slag (GGBS), Nano-Silica, and Rice Husk Ash (RHA). Experimental results clearly indicate that the addition of these stabilizing materials significantly improves the engineering properties of expansive soil. The stabilized soil exhibited reduced plasticity, lower swelling potential, improved compaction characteristics, and increased strength parameters such as California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS).

Among the various combinations tested, the blend containing 10% GGBS, 1% Nano-Silica, and 5% Rice Husk Ash provided the optimum performance. This combination effectively reduced the Liquid Limit, Plasticity Index, and Free Swell Index while increasing Maximum Dry Density and compressive strength. The improvement in soil properties is mainly attributed to pozzolanic reactions and the formation of cementitious compounds, which enhance bonding between soil particles.

The study also demonstrates that industrial and agricultural waste materials can be effectively utilized for sustainable soil stabilization. The use of GGBS and Rice Husk Ash helps in waste management and reduces environmental pollution, while Nano-Silica enhances the efficiency of stabilization through its high reactivity and micro-filling capability. Therefore, the proposed stabilization method offers an economical, eco-friendly, and practical solution for improving the performance of black cotton soil in pavement construction, foundations, embankments, and other geotechnical applications.

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