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An Experimental Study to Analyze the Black Cotton Soil Strength by Combining GGBS and Rice Husk Ash Powder Using CBR Test

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ABSTRACT- The technological advancement ensures the durability of the constructed roads in a cost friendly manner. The utilisation of soil additives, such as lime, cement, cement kiln dust, Ground Granulated Blast Furnace Slag (GGBS) Powder, Rice husk ash (RHA), limestone ash and asphalt, has become a prevalent technique for enhancing the geotechnical characteristics of substandard building materials, particularly expansive soils. The present study aims to examine the impact of (GGBS) Powder and rice husk ash on the engineering characteristics of black cotton soil (BCS). In this work, the strength of BCS has been examined by incorporating different concentration of GGBS and rice husk ash power for both soaked and unsoaked soil samples using California Bearing Ratio (CBR) test. The findings of the study suggested that the optimal combination of materials for achieving the highest soaked CBR value is a proportion of 10% Rice husk ash powder and 8% GGBS Powder when added to soil. Therefore, this ratio can be utilized in the construction of road pavements and embankments.

KEYWORDS- CBR test, Ground granulated blast furnace Slag, Rice husk ash, Road pavement, Expansive soil, Black cotton Soil strength

I. INTRODUCTION

The Expansive soils, commonly known as Black Cotton Soil (BCS), are widely distributed across the globe, with a notable prevalence in India. The characteristic blackish-grey coloration of BCS is a distinguishing feature of these soils. The geographic distribution of this entity is concentrated in the Indian states of Maharashtra, Madhya Pradesh, Gujarat, Tamil Nadu, Andhra Pradesh, and Karnataka [1]. It is estimated to occupy a land area of approximately 76.4 million hectares, representing a significant proportion of the country's total land area [2]. The fundamental characteristics of BCS are its susceptibility to swelling and shrinkage, which can potentially compromise the integrity of foundations, structures, roadways, railways, and other constructions built upon it. This phenomenon occurs due to the fluctuation of water content within the soil, causing it to expand and contract correspondingly. The primary component of BCS or reactive soil is clay [3-4]. The volumetric behaviour of clay is primarily influenced by variations in the moisture content of the surrounding soil. the process of expansion upon hydration and contraction upon desiccation. The construction of roads/buildings on expansive soils is frequently associated with excessive motion, which is caused by non-uniform soil moisture adjustments. This motion can result in cracking and ultimately lead to damage related to distortion [5-6]. Hence, stabilization of soil is required. The process of stabilization involves the incorporation of additives into soil to improve its properties. The system has the potential to incorporate the blending of soils in order to achieve a desired gradation. This can be achieved by utilizing commercially available additives that can modify the texture, gradation, or plasticity of the soil [7]. The application of this technique is aimed at reducing the swelling potential of expansive soils and enhancing their shear strength. The enhancement of bearing capacity of foundation soils is a requisite for construction [8]. The stabilization process offers several advantages that are worth considering I which characterstics of the BCS has been improved [9]

The objective of this study is to enhance the settlement reduction, shear strength, and resistance to harsh environmental conditions such as thawing and freezing, while simultaneously mitigating the challenges associated with weak soils. Therefore, a more detailed discussion of these options will be provided in comparison to alternative choices. The current research examines properties of sub grade soil via laboratory and site studies. The waste materials generated from various industrial processes, such as fly ash, silica smoke, ground “granulated blast furnace slag” (GGBS), and Alccofin, have found their way into the construction industry. These materials are being reused after undergoing certain stabilisation processes. This trend has been observed in recent times. For this work, we performed the experimental analysis utilizing the “Ground Granulated Blast Furnace Slag” (GGBS) and Rick husk ash (RHA) in a combination to increase the soil's durability. This research primarily focused on the following experimental findings:

- To examine the various aspects of expansive soils samples

- To determine the properties of soaked and unsoaked soil.
- To analyze the C.B.R value for different percentages of GGBS and Rice husk ash powder.
- Analyze the merits of GGBS and rice husk ash in order to enhance the strength of soil using CBR test.

Limited research has been conducted on the utilisation of combined GGBS and RHA powder as a soil stabilizer in order to enhance the strength of the soil by considersing the different percentages of soil samples to investigate the best CBR value during the experimental study. The present study focuses on the stabilisation of expansive soils through the utilisation of GGBS Powder and Rice husk ash powder as chemical additives.

Further the paper is organized as section 2 describes the literature review, section 3 presents the methods and materials used in the proposed work, section 4 provides the result and discussion and finally, the section 5 discussed the conclusion and future scope of the work.

II. LITERATURE REVIEW

The present literature work focused on the different methods used in order to enhance the strength of the sub-grade soil using the CBR testing. The two-waste material GGBS and RHA also explored in the literature section.

A. Sasui et al. (2018)

Discussed the need of RHA in stablizing the soil properties for constructing roads and adobe homes which are an essential kind of housing for many communities in developing nations that have limited incomes. Rice husk, in either its raw or ash form, is a popular natural ingredient used in many construction materials as a stabilizer owing to its pozzolanic tendency. Adobe specimens' compressive strength, stability, water absorption, and volumetric shrinkage were tested, and the effects of Raw Rice Husk (RRH) and heap burnt Rice Husk Ash (RHA) as stabilizers were compared. Both types of stabilizer (RRH and RHA) were applied at a rate of 2% by dry soil weight. The RRH- containing samples performed noticeably better than the RHA samples. This indicates that the cementation capabilities of RHA were diminished due to the high combustion temperature in the heap. The research shows that in flood-prone locations, local adobe dwellings built using raw rice husk as a stabilizer are more resilient to water damage than those built with heap burnt rice husk ash [10].

B. Singh, R. R., (2019)

discussed the role of RHA in order to improve the strength of the concrete. Over the last several decades, concrete technology has expanded into many fields in an effort to improve the material's qualities and functionality. New varieties of concrete, such as self-compacting concrete (SCC), high strength concrete (HSC), and ultra- high strength concrete (UHSC), have also been developed and introduced. The high cement binder is necessary for the widespread usage of various concrete kinds at the present time. Because one ton of cement produces around one ton of CO2 during production, a high cement content represents a substantial loss to the environment. As a result, new supplemental cementitious materials, many of which are industrial by-products, must be introduced to minimize cement consumption and increase debris control. One example is ash from rice husks. It's been shown that rice husk ash may be used as a cement substitute or additive. In order to achieve the highest possible compressive strength in concrete [11].

C. Tangri, A. et al. (2021)

presented a study to investigate the impact of RHA on soil strength. The rice husk is a byproduct of the rice-milling process. Historically, soil modification has been proposed to enhance soil's construction qualities. Lime, concrete, and mineral additives including silica dust, fly ash, and rice husk ash are just a few of the many options for use in soil enhancement. Soil's optimal moisture content increases as RHA concentration rises and its maximum dry density (MDD) falls [12]

D. Samantasinghar, S., et al. (2021)

Described the need of soil stabilization. The process of internal erosion which needs to be stabilized in order to enhance the geoengineering qualities of the soil. A number of different experiments are carried out as part of a research project to determine the strength of soil. The geopolymer composed of fly ash and slag (FA-GGBS) is effective in the process of stabilizing soil. In order to determine whether or not geopolymer stabilized granular soil is suitable for use as a building material, the experimental program focused on the compaction properties, unconfined compressive strength, bearing resistance, and durability of the soil. An examination of the material's microstructure has been carried out and associated with the increase in strength. According to the findings of the tests, a maximum unconfined compressive strength of about 7 MPa and a California bearing ratio (CBR) that ranges from 52% to 416% have been determined. Excellent resistance to wetting–drying and freezing–thawing cycles, slaking water, and harsh chemical conditions was shown by the geopolymer-stabilized soil [13].

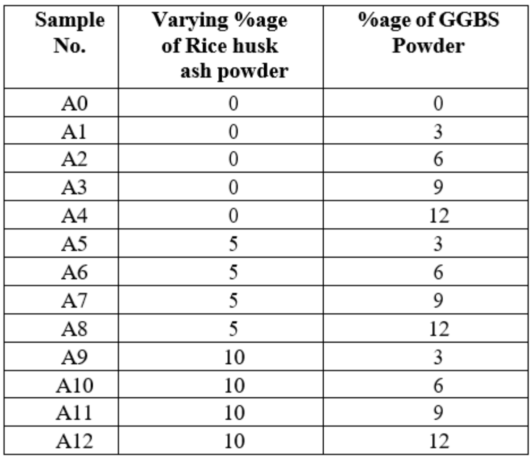
E. Lam, A., et al. (2023)

The purpose of this study is to analyze the mechanical characteristics and chemical reactions of an earth concrete binder made from ground granulated blast-furnace slag (GGBS). This research demonstrates that the presence of dicalcium silicates in the binder powder results in the development of calcium silicate hydrates (C-S-H) at an early age. The presence of portlandite is also highlighted, which triggers calcium activation of the GGBS. The intermediate and long-term products of this latent reaction include phases like C-S-H and C-A-H. In this study, the superior mechanical qualities of earth concrete using this binder are highlighted. It demonstrates the ability of pozzolanic reactions with calcium-activated GGBS to produce low carbon earth concrete with high strength. This binder might encourage the use of earth concrete in construction, which would improve thermal comfort, energy efficiency, and environmental effect [14].

III. METHODOLOGY AND MATERIAL

Material used for the improvement of subgraged soil has been discussed. The proper selection of the combination for material like GGBS and RHA requires testing and experimentation to arrive at the correct results. Performing the tests is the best way to calculate the CBR value. Sample A1 will be prepared utilising solely 3% GGBS powder, without the inclusion of rice husk ash powder. In samples A2, A3, and A4, the percentage of GGBS Powder will be incrementally increased to 6%, 9%, and 12%, respectively. Sample A4 will not contain any rice husk ash powder. The findings of this study will provide insight into the effectiveness of GGBS Powder as a stabiliser and aid in determining the optimal dosage of rice husk ash powder. Samples A5, A6, A7, and A8 will be analysed with varying ratios of GGBS Powder, specifically 3%, 6%, 9%, and 12%, while maintaining a constant percentage of 5% rice husk ash powder. Samples A9, A10, A11, and A12 will be prepared with varying percentages of GGBS powder (3%, 6%, 9%, and 12%, respectively) while maintaining a constant dosage of 10% rice husk ash powder.

Table 1: Designation of samples

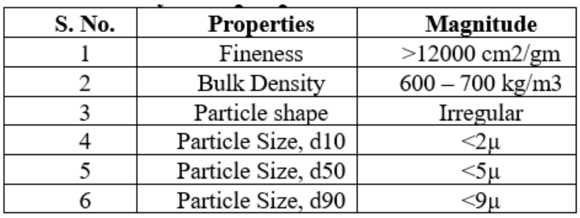


Sample No.	Varying %age of Rice husk ash powder	%age of GGBS Powder
A0	0	0
A1	0	3
A2	0	6
A3	0	9
A4	0	12
A5	5	3
A6	5	6
A7	5	9
A8	5	12
A9	10	3
A10	10	6
A11	10	9
A12	10	12

A. *Rice Husk Ash (RHA)*

Rice husk ash (RHA) is commonly utilised for agricultural applications due to its low nutritional value. It is frequently employed as animal feed or fertiliser. The rice husk exhibits a notable attribute in that its combustion enthalpy is roughly 13.4 MJ / kg, indicating a relatively elevated mean calorific value [16].

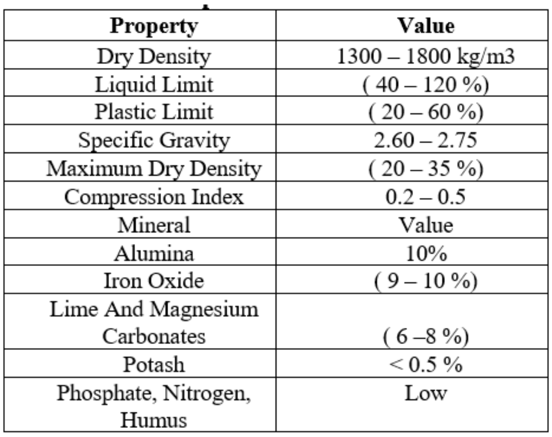
Table 4: Physical properties of Rice husk ash powder



S. No.	Properties	Magnitude
1	Fineness	>12000 cm2/gm
2	Bulk Density	600 – 700 kg/m3
3	Particle shape	Irregular
4	Particle Size, d10	<2μ
5	Particle Size, d50	<5μ
6	Particle Size, d90	<9μ

The present study utilises soil that is readily accessible in the local area. The soil in question has been identified as expansive soil and its characteristics have been classified in accordance with the Indian Standard of soil classification (IS 1498:1970), as outlined in Table 2.

Table 2: Properties of soil

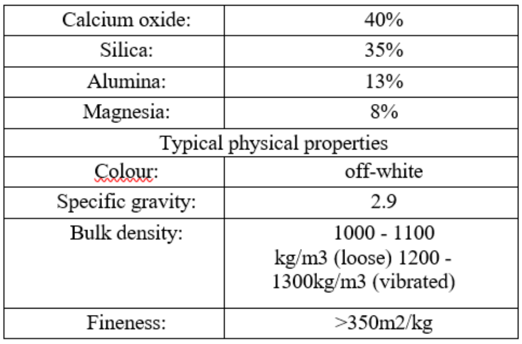


Property	Value
Dry Density	1300 – 1800 kg/m3
Liquid Limit	(40 – 120 %)
Plastic Limit	(20 – 60 %)
Specific Gravity	2.60 – 2.75
Maximum Dry Density	(20 – 35 %)
Compression Index	0.2 – 0.5
Mineral	Value
Alumina	10%
Iron Oxide	(9 – 10 %)
Lime And Magnesium Carbonates	(6 –8 %)
Potash	< 0.5 %
Phosphate, Nitrogen, Humus	Low

B. *Granulated Blast Furnace Slag (GGBS)*

The GGBS is a secondary material generated during the production of pig iron. It is produced through rapid cooling of the molten slag using either water or molten slag. However, it has been observed that when the slag is cooled gradually through exposure to air, it loses its hydraulic properties and the resulting crystallised slag cannot be utilised as a pozzolanic material [15].

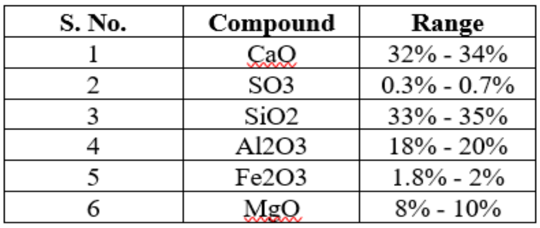
Table 3: Chemical composition of GGBS powder



Calcium oxide:	40%
Silica:	35%
Alumina:	13%
Magnesia:	8%
Typical physical properties	
Colour:	off-white
Specific gravity:	2.9
Bulk density:	1000 - 1100 kg/m3 (loose) 1200 - 1300kg/m3 (vibrated)
Fineness:	>350m2/kg

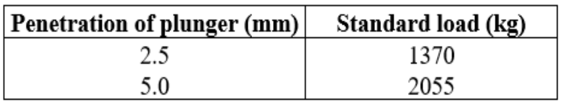
The CBRtest, which stands for California bearing ratio test, is a commonly used penetration test in the assessment of subgrade strength. The CBRvalue is determined by dividing the determined resistance by the standard resistance, which is obtained from tests on crushed stone that has a defined CBRvalue of 100% [17].

Table 5: Chemical composition of Rice husk ash



S. No.	Compound	Range
1	CaO	32% - 34%
2	SO_3	0.3% - 0.7%
3	SiO_2	33% - 35%
4	Al_2O_3	18% - 20%
5	Fe_2O_3	1.8% - 2%
6	MgO	8% - 10%

Table 6: Standard loads adopted for the standard material



Penetration of plunger (mm)	Standard load (kg)
2.5	1370
5.0	2055

IV. THE TESTS

A sufficient quantity of soil was collected from the adjacent terrain. The sample underwent a sieving process utilising a 2.36mm IS sieve, and was subsequently mixed thoroughly.

A. Sieve Analysis of Soils

The established protocol outlined in I.S. 2720 (1) is followed for the preparation of soil samples for grain size analysis. The grain size analysis is performed following the standard protocol outlined in I.S. 2720 (4). The determination of the percentage of soil retained on the sieves is followed by the calculation of the percentage of soil that is finer than each respective sieve. The soil contains 63% sand, 37% silt & clay

B. Liquid Limit Test

The test employs the fraction of soil that passes through the 425- micron aperture of the International Standard sieve. The procedure being utilised for soil testing is the tentative procedure

I.S. 2720 (5). To obtain optimal results and an adequate number of data points for the curve, it is recommended to gradually and consistently increase the water content of the sample. It is necessary to obtain a flow curve, which is a plot of water content percentage versus number of blows (on log scale). The liquid limit of a substance can be determined by analysing its flow curve and measuring the water content after subjecting it to 25 blows.

C. Plastic Limit Test

The soil fraction that is able to pass through the I.S. 425-micron sieve is utilised in the experimental procedure. The point of minimum plasticity of soil is referred to as the plastic limit, which is determined by its moisture content. Upon reaching the plastic limit, the soil exhibits characteristics of a semi-solid substance. The plastic limit of a soil is determined by identifying the water content at which the soil exhibit initial signs of crumbling. upon being rolled into a thread of 3mm in diameter. The plasticity index is defined as the variation in moisture content or the gap between the liquid and plastic limit. The liquid and plastic limit test observations and results could not be obtained due to the soil being Black Cotton soil.

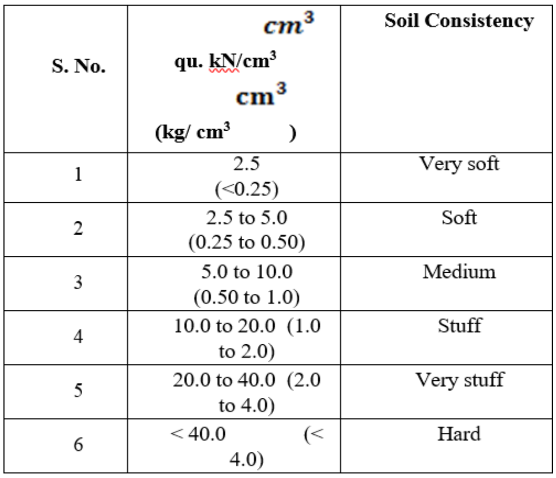
D. Compaction Test

This Compaction test of soil is a common practise in engineering and construction as it has been found to enhance the strength of soil, reduce the potential for further settlements, and decrease its permeability. Thus, the soil is often placed in a compacted state to achieve these desired outcomes. The experiment is being conducted in accordance with the provisional technique I.S. 2720 (8), utilising a cylindrical mould with an internal diameter of 100mm and a height of 127.3mm, which has a volume of 1000 cubic millimetres. A standard hammer weighing 2.6 kg is being used. amalgam and the amalgamation process is repeated manually to achieve homogenization. The test is conducted in accordance with the specifications outlined in I.S. 2720 (8).

E. Unconfined Compression Strength Test (UCS)

The UCT is frequently employed to assess the short-term stability of foundations and slopes in situations where the loading rate is rapid but drainage is sluggish. The UCS of a soil sample is determined by dividing the failure load by the cross-sectional area of the sample, provided that it is subjected to lateral pressure. The test can be classified as undrained due to the rapid rate of load application, which prevents any pore water from draining and thus inhibits the dissipation of pore water pressure

Table 7: Soil consistency and unconfined compression strength correlation



S. No.	cm^3 qu. kN/cm³ cm^3 (kg/ cm³)	Soil Consistency
1	2.5 (<0.25)	Very soft
2	2.5 to 5.0 (0.25 to 0.50)	Soft
3	5.0 to 10.0 (0.50 to 1.0)	Medium
4	10.0 to 20.0 (1.0 to 2.0)	Stuff
5	20.0 to 40.0 (2.0 to 4.0)	Very stuff
6	< 40.0 (< 4.0)	Hard

F. Compression Test

The initial length and diameter of the specimen should be measured as the first step. Subsequently, place the specimen onto the lower plate of the loading apparatus. The upper plate should be adjusted in order to establish contact with the sample. The load dial gauge and the strain (compression) dial gauge were both reset to zero. The sample should be compressed until visible cracks have formed, the stress strain curve has surpassed its peak, or a vertical deformation of 20 percent has been achieved. Measure the load dial reading at intervals of approximately 1mm deformation of the sample.

Calculation:

1. Strain (€) = $\Delta L/l0$

Where, ΔL = Change in specimen, as read from the strain.

$l0$ = Initial length of the specimen.

2. Cross sectional area (A) = $A0$
1−€

Where, $A0$ = initial average area of specimen.

3. Compressive Strength (σ) = P
A

Where, P = Compressive force.

A scatter plot is constructed to visualise the relationship between the standard deviation (σ) and the exchange rate (€).

The values of the unconfined compressive strength can be determined by analysing the maximum stress obtained from the curve. In cases where a maximum value is not present, it is customary to consider the stress at 20 percent axial strain as the unconfined compressive strength.

V. RESULT AND DISCUSSION

A. *Grain size distribution*

Grain size analysis is employed to determine the percentage of different sizes of a specific type of particle in a dry soil sample. The process of determining the percentage of individual grain sizes present in a soil sample is commonly referred to as grain size analysis or mechanical analysis of soils. The preparation of soil samples for grain size analysis follows the standard method I.S. 2720 (1), while the grain size analysis itself adheres to the standard procedure outlined in I.S. 2720 (4).

Table 8: Grain Size Distribution of Soil

Sieve (mm)	Mass (g)	% retained	% passing
6.3	3.9	1.3	98.7
4	0.6	0.2	99.8
2	2.9	1.0	99.0
0.4	5.4	1.8	98.2
0.2	13.1	4.4	95.6
0.08	31.0	10.3	89.7
0.075	72.5	24.2	75.8
0.063	198.8	66.3	33.7
pan	1.8	0.6	

The methodology involves determining the proportion of soil that is retained on individual sieves, followed by the computation of the proportion of soil particles that are smaller than each respective sieve size. The process of dry sieving through a 75-micron sieve was found to be challenging. As a result, the decision was made to perform a washing procedure on the material that was retained on the 75-micron sieve. The soil retained on the sieve after washing is dried and sieved again. The results obtained provided precise determination of the amount of soil that was retained on the 75-micron sieve.

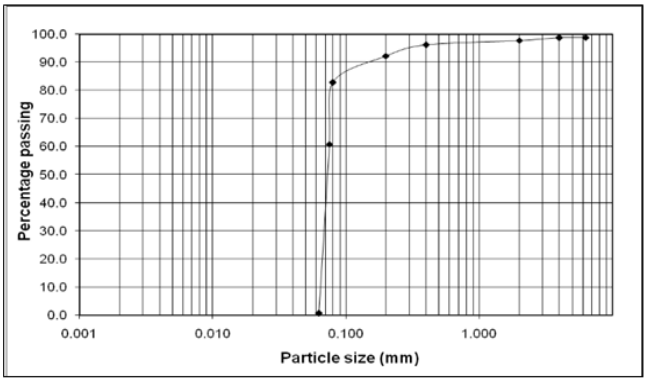


Figure 1: Graph of Grain Size Distribution of Soil

B. *Standard Proctor Test*

The compaction of soil is a physical process that involves the reduction of air voids by constraining soil particles to be more closely packed together. The observed effect is a reduction in the volume of air- filled spaces within the material, leading to a corresponding increase in its dry density. The observed outcome may potentially lead to an augmentation in the shearing strength. Dry density is the typical quantitative measure used to assess the degree of compaction. The phenomenon of compaction pertains to the swift or gradual decrease in the air voids primarily due to the application of a short-term load. The increase in dry density of soil resulting from compaction is primarily influenced by two factors.

The study examines the effect of compaction on moisture content. Specifically, the research investigates the relationship between the amount of compaction and moisture content.

Table 9: Compaction Test for Different GGBS Powder Mixes

S.NO.	Designation	MDD (gm/cc)	OMC (%)
1	A0	2.19	7.97
2	A1	1.91	9.60
3	A2	1.82	10.87
4	A3	1.74	14.17
5	A4	1.65	15.27

Calculation

- Wet density (gm/cc) = $Wt.\ of\ compacted\ soil$
- $Capacity\ of\ mould$
- Dry density (gm/cc) = $Wet\ density$

$1+w$

Whereas, w represents the moisture content of the soil

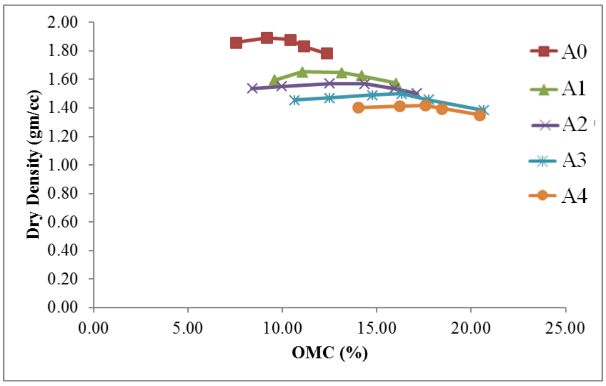


Figure 2: Graph of Compaction Test for Different GGBS Powder Mixes

C. *Optimum Moisture Content & Maximum Dry Density*

It has been observed that in the soil mixes containing GGBS Powder, there is a reduction in the maximum dry density and an increase in the optimum moisture content as the percentage of GGBS Powder is increased.

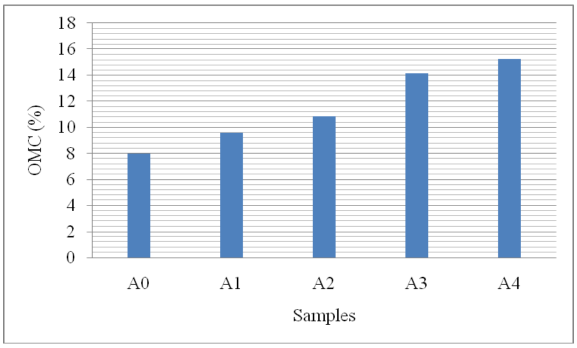


Figure 3: O.M.C. of Soil-GGBS Powder mix

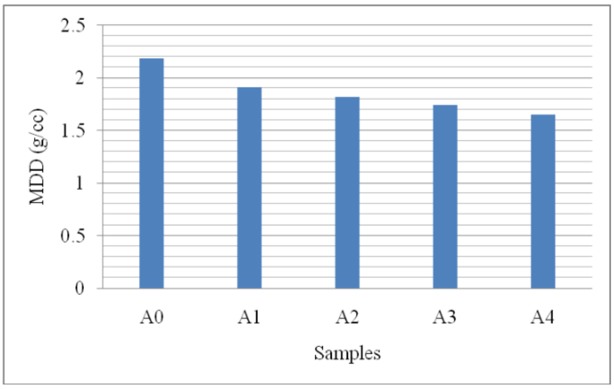


Figure 4: Dry Density of Soil-GGBS Powder mix The results of the study indicate that the maximum dry density of soil exhibits variation, ranging from 1.89

gm/cc for untreated soil to 1.43 gm/cc for soils mixed with 12% GGBS Powder. The dry density of the soil exhibits a decrease upon the introduction of varying proportions of GGBS Powder. The observed reduction in soil dry density resulting from the incorporation of GGBS Powder may be attributed, at least in part, to the relatively low specific gravity (i.e., low density) of the GGBS Powder, as well as to the mechanical action of the powder.

D. Unconfined Compression Test

The specimens have been appropriately prepared and compacted. The corresponding water content on both the dry and wet side of the optimum (as per the standard Proctor and modified tests) has been determined. The specimens have been subjected to testing using an unconfined compression testing machine. A set of unconfined compression tests were conducted on Black Cotton soil using different proportions of GGBS Powder and Rice Husk Ash Powder.

Table 10: Unconfined Compression Test for Different GGBS Powder Mixes

S.No.	Designation	Unconfined Compressive Strength (kgf/cm2)	Unconfined Compressive Strength (kPa)
1	A0	1.73	169.66
2	A1	1.85	181.05
3	A2	1.45	142.04
4	A3	1.34	131.04
5	A4	1.25	123.03

The diameter of each sample in the study is 38 mm. However, the length of the samples varies between 76 mm to 85 mm. The dry state homogenous mixing of soil containing varying percentages of GGBS Powder and Rice husk ash powder was conducted. Subsequently, the addition of water is carried out, followed by a thorough mixing process. Cylindrical specimens are fabricated through the application of static loading, and subsequently extracted using an extractor. Load deformation behavior of unsterilized Black Cotton soil and Black Cotton soil stabilized with GGBS Powder or Rice husk ash powder at different percentage as specified above are studied. The determination of the unconfined compressive strength of stabilised soil involves a series of steps. The soil was amended with varying proportions of GGBS powder, specifically 3%, 6%, 9%, and 12%.

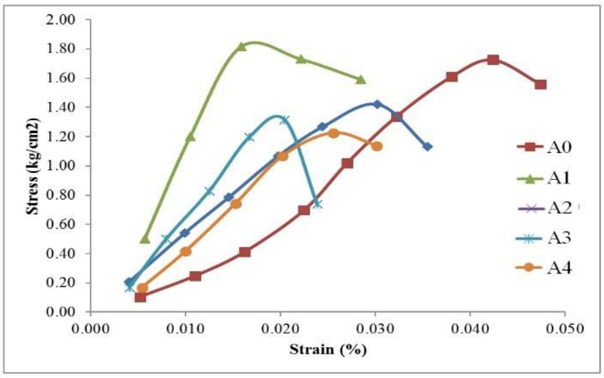


Figure 5: Graph of Unconfined Compression Test for Different GGBS Powder mixes

Various proportions of rice husk ash powder were incorporated into the soil. The findings indicate that there is a positive correlation between the percentage of GGBS Powder used in soil replacement and the values of unconfined compressive strength. GGBS Powder is a finely powdered substance composed of small spherical particles of silicon and alumina glass, with a minor proportion of CaO. This is the underlying cause for its properties. Upon exposure to water, the free lime present in the dust undergoes a chemical reaction and transforms into a cementitious material. This process ultimately results in an increase in the soil's strength.

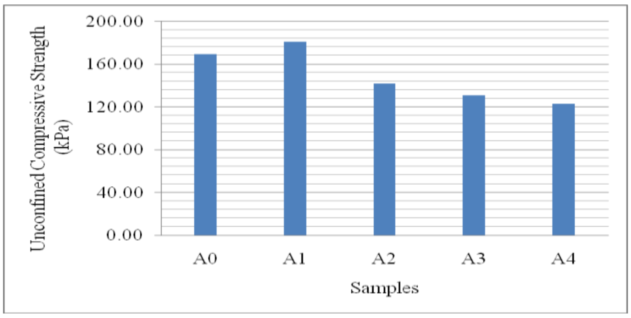


Figure 6: Unconfined Compressive Strength of Soil GGBS Powder Mix

The observed increase in strength can be attributed to the mechanical stabilisation resulting from the combination of fine dust particles with the coarse particles of the soils. The unconfined compressive strength of soil exhibits a range of variability between

1.73 kg/ and 1.81 kg/. The results indicate that the combination of soils, available alumina and silica, and free lime from GGBS Powder undergoes a gradual reaction, leading to an increase in strength over time. It has been observed that the strength begins to decrease as the percentage of GGBS Powder surpasses 4%. Upon incorporation of GGBS Powder into soil at a high percentage exceeding 4%, the material exhibits distinct characteristics that are imparted onto the resulting GGBS Powder-soil composite samples. It is worth noting that GGBS Powder is inherently a coarse material.

Table 11: Unconfined Compression Test for Different GGBS Powder & 5% Rice husk ash powder Mixes

S.No	Designation	Unconfined Compressive Strength (kgf/cm2)	Unconfined Compressive Strength (kPa)
1	A0	1.73	170
2	A5	1.73	169.66
3	A6	4.73	464.13
4	A7	6.06	594.17
5	A8	7.69	754.21

The experimental results indicate that the incorporation of Rice husk ash powder and GGBS Powder into soil leads to an increase in its compressive strength by 5% and 16%, respectively.

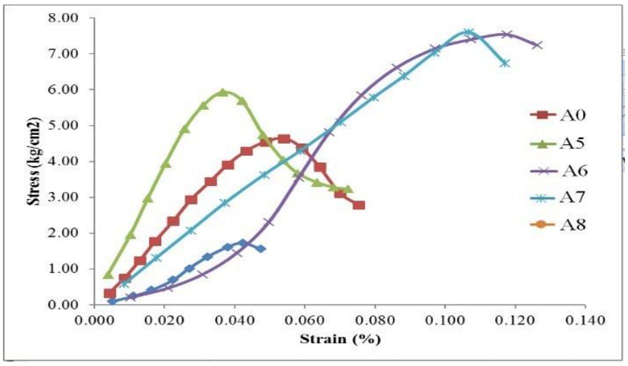


Figure 7: Graph of Unconfined Compression Test for Different GGBS Powder + 5% Rice husk ash powder mixes

The findings indicate a significant enhancement in the compressive strength of all soils following treatment with GGBS Powder and 5% Rice husk ash powder.

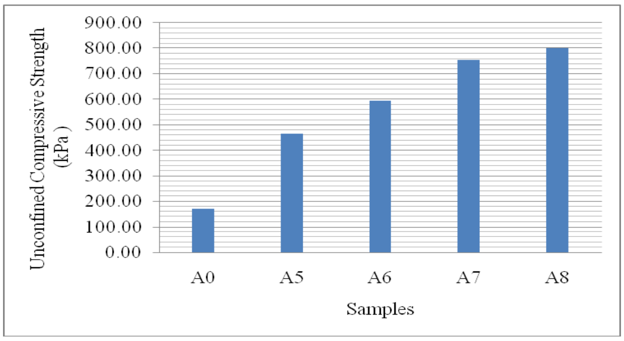


Figure 9: Unconfined Compressive Strength (U.C.S) of Soil with 5% Rice husk ash powder mix

The results indicate that the unconfined compressive strength values exhibit an increase with the progressive replacement of soil with GGBS Powder and 5% Rice husk ash powder. The unconfined compressive strength of soil exhibits a range spanning from 1.73 kg to 7.69 kg. The Figure 10 and 11 illustrate the relationship between the percentage of 10% Rice husk ash powder and the corresponding variation of

U.C.S Test. The samples are prepared by mixing Rice husk ash powder (5% and 10%) and GGBS Powder (%, 6%, 9%, and 12%) by weight of soil. California Bearing Ratio evaluations, encompassing both soaked and unsoaked conditions, are also executed.

Table 12: Unconfined Compression Test for GGBS Powder &10% Rice husk ash powder Mixes

S.No.	Designation	Unconfined Compressive Strength (kg/cm2)	Unconfined Compressive Strength (kPa)
1	A0	1.73	170
2	A9	1.81	178
3	A10	5.0	490
4	A11	5.31	521
5	A12	5.73	562

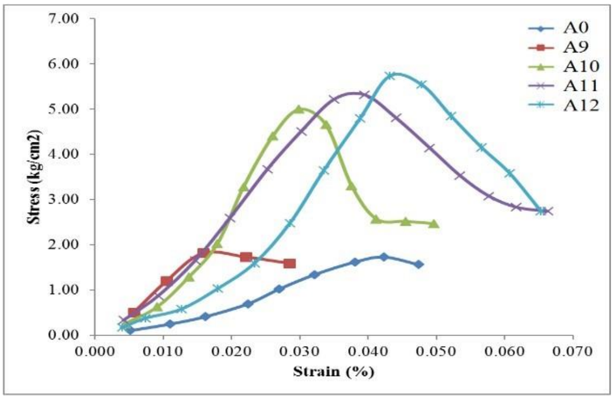


Figure 10: Graph of U.C.S Test for GGBS Powder and 10% Rice husk ash powder Mixes

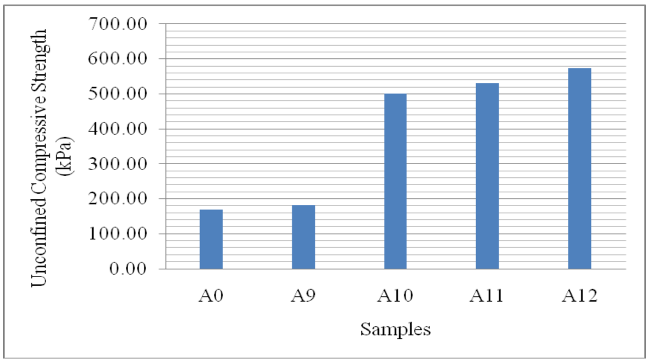


Figure 11: UCS of Soil with 10% Rice husk ash powder mix

E. CBR Test

The findings indicate that the incorporation of GGBS Powder leads to an increase in the CBR values of soil. The unsoaked California Bearing Ratio (CBR) value of the soil was determined to be 10.77%.

Table 13: CBR Test for Different GGBS Powder Mixes both Unsoaked and Soaked Condition

S.No.	Designation	Unsoaked C.B.R. Values (%)	Soaked C.B.R. Values (%)
1	A0	10.77	5.70
2	A1	28.29	14.89
3	A2	33.25	15.87
4	A3	33.75	16.87
5	A4	35.74	17.81

The incorporation of 3% of Ground Granulated Blast Furnace Slag (GGBS) Powder resulted in a 28.29% increase in the “California Bearing Ratio” (CBR) value. At a GGBS powder content of 12%, the CBR value was determined to be 35.74%. The soil's soaked CBR value was determined to be 5.70%.

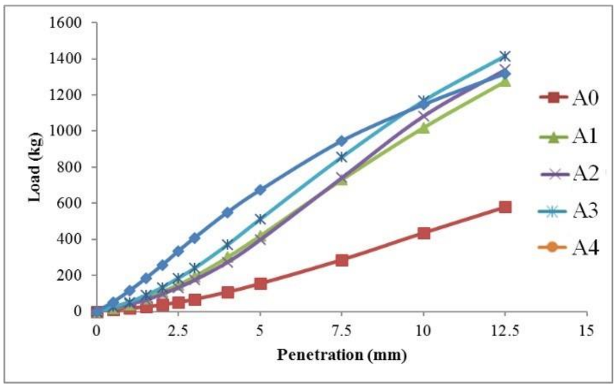


Figure 12: Graph of Unsoaked CBRTest for Different GGBS Powder Mixes.

The incorporation of 3% of Ground Granulated Blast Furnace Slag (GGBS) Powder resulted in a 14.89% increase in the CBR value.

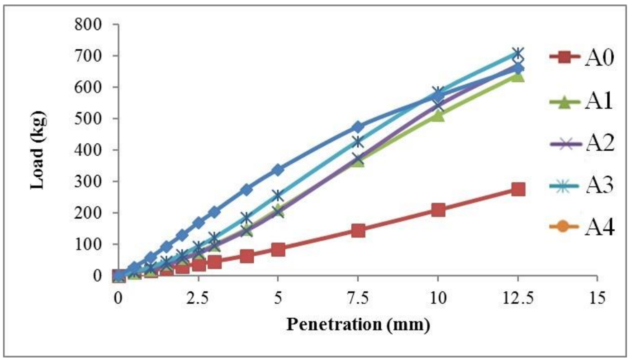


Figure 13: Graph of Soaked CBRTest for Different GGBS Powder Mixes

A CBR value increase of 17.81% was observed with the addition of 12% GGBS powder.

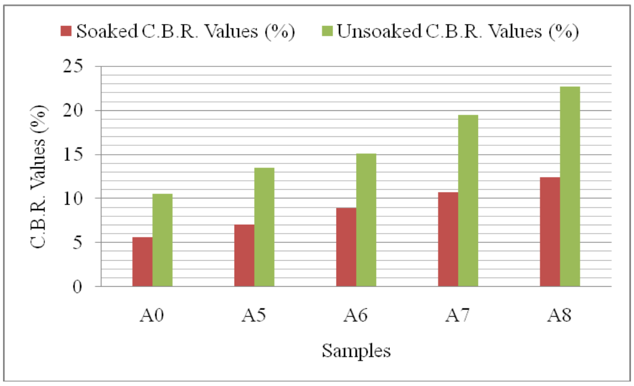


Figure 14: CBR Values Unsoaked and Soaked Condition of Soil GGBS Powder Mix

Figure 12 and 14 illustrate the changes in unsoaked and soaked. CBRas the percentage of GGBS Powder varies.In the laboratory, the CBR values of soil mixed with varying percentages of GGBS Powder and 5% Rice husk ash powder content are determined for both unsoaked and soaked conditions Which is represented in Figure 15 and 17.

Table 14: CBRTest for Different Rice husk ash powder Mixes both Unsoaked and Soaked Condition

S.No.	Designation	Unsoaked C.B.R. Values (%)	Soaked C.B.R. Values (%)
1	A0	10.77	5.70
2	A5	13.74	7.20
3	A6	15.38	9.08
4	A7	19.85	10.91
5	A8	23.15	12.67

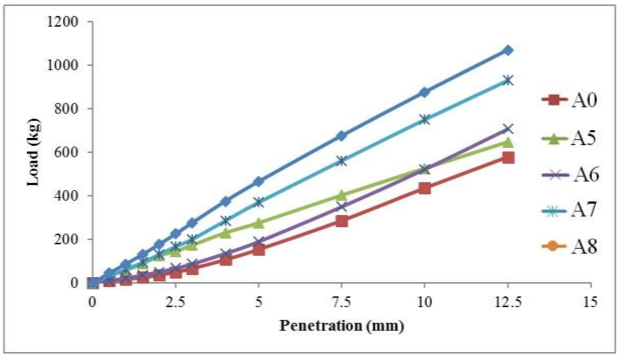


Figure 15: Graph of Unsoaked CBRTest for GGBS Powder + 5% Rice husk ash powder Mixes

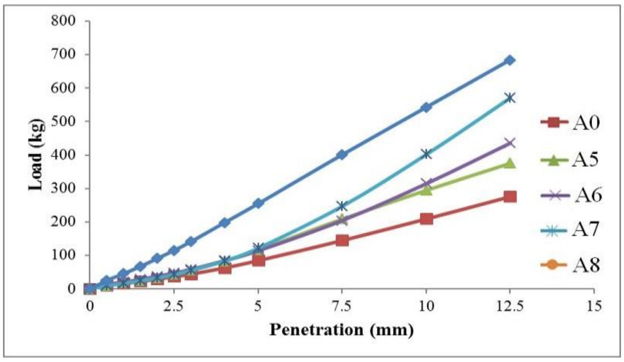


Figure 16: Graph of Soaked CBRTest for GGBS Powder + 5% Rice husk ash powder Mixes

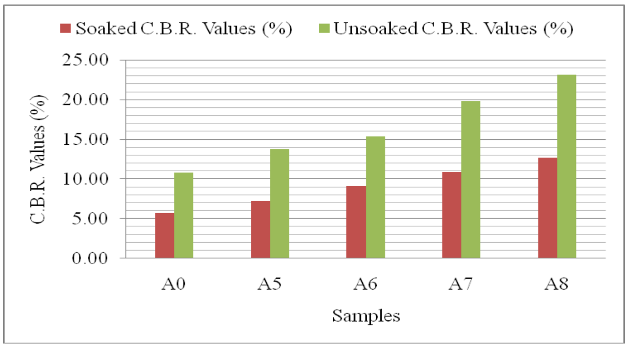


Figure 17: CBR Values Unsoaked and Soaked Condition of Soil with 5% Rice husk ash powder Mix

The test results indicate that the CBR value of soil, whether soaked or unsoaked, exhibits an increase as the GGBS Powder content increases in the presence of 5% Rice husk ash powder.

Table 15: CBRTest for GGBS Powder and 10% Rice husk ash powder Mixes both Unsoaked and Soaked Condition

S.No.	Designation	Unsoaked C.B.R. Values (%)	Soaked C.B.R. Values (%)
1	A0	10.56	5.59
2	A9	27.74	14.60
3	A10	26.27	19.46
4	A11	24.61	12.0
5	A12	23.34	11.43

The laboratory determined the CBR values for soil mixed with varying percentages of GGBS Powder and 10% of Rice husk ash powder content, both in unsoaked and soaked conditions. The results indicate that the unsoaked California Bearing Ratio (CBR) values of the soil-GGBS Powder mixture do not exhibit an increase with an increase in GGBS Powder content, while maintaining a fixed percentage of Rice Husk Ash Powder.

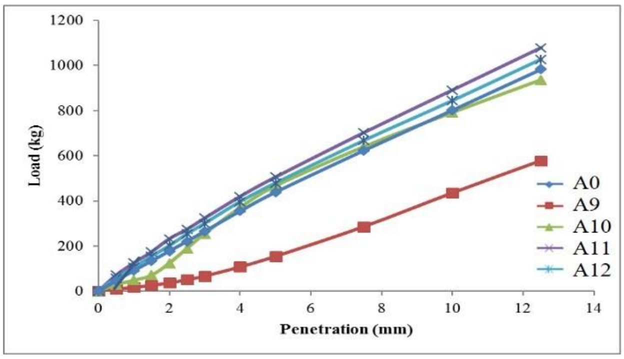


Figure 18: Graph of Unsoaked CBRTest for GGBS Powder and 10% Rice husk ash powder Mixes

The CBR value of the soil was determined to be 10.77%. The incorporation of 3% GGBS powder and 10% rice husk ash powder resulted in a 27.74% increase in the CBR value. The incorporation of 12% GGBS powder and 10% rice husk ash powder resulted in a CBR value of 23.34%. The results indicate that the incorporation of GGBS Powder into the soil sample has a positive effect on the soaked CBR value.

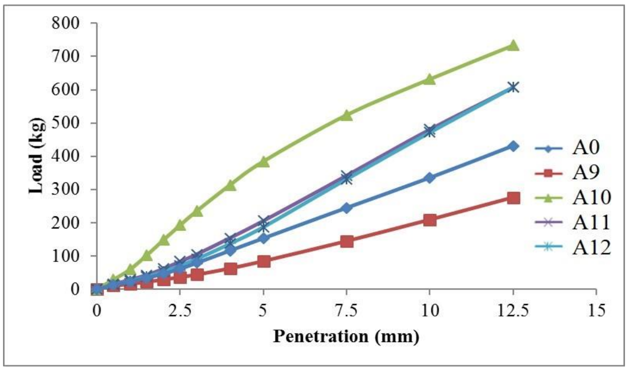


Figure 19: Graph of Soaked CBRTest for GGBS Powder and 10% Rice husk ash powder Mixes.

Specifically, the soaked CBR value of the soil- GGBS Powder mix increased from 14.6% to 19.46%.

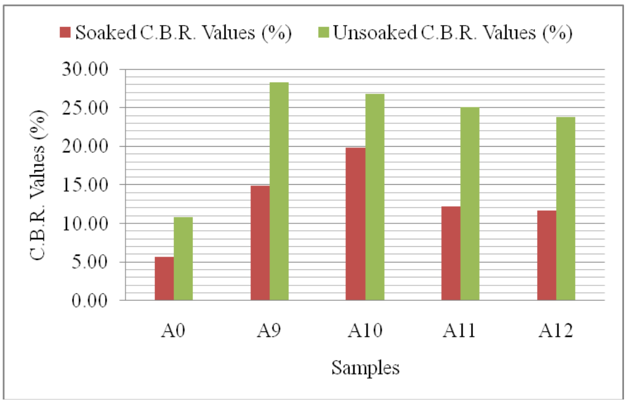


Figure 20: CBR Values Unsoaked and Soaked Condition of Soil-GGBS Powder and Rice husk ash powder mix

The findings of the study suggest that the optimal combination of materials for achieving the highest soaked CBR value is a proportion of 10% Rice husk ash powder and 8% GGBS Powder when added to soil. Therefore, this ratio can be utilised in the construction of road pavements and embankments. Figure 4.23 and 4.24 illustrate the changes in unsoaked and soaked CBRvalues as the percentage of GGBS Powder varies, with the addition of 10% Rice husk ash powder.

VI. CONCLUSION AND FUTURE SCOPE

The findings indicate a significant enhancement in compressive strength for all black cotton soil samples following treatment with GGBS Powder and 5% and 10% of Rice husk ash powder. The findings indicate that the CBR value of both unsoaked and soaked soil increases in proportion to the GGBS Powder content, when combined with 5% Rice husk ash powder. The results indicate that the unsoaked California Bearing Ratio (CBR) values of the soil-GGBS Powder mixture do not exhibit an increase as the GGBS Powder content increases, while maintaining a fixed percentage of Rice Husk Ash Powder. Based on the results obtained, it can be inferred that the optimal combination of materials that yields the highest soaked CBR value is a mixture of 10% rice husk ash powder and 8% GGBS powder in soil.

In future, the study under consideration has limited the replacement of GGBS Powder with BCS to a maximum of 16 percent. Further investigation is required for the remaining percentages. It is imperative to investigate the impact of different types of reinforcement on various waste materials such as stone quarry, plastics, recycled aggregates, and polythene bags. The durability of rice husk ash powder necessitates examination through the implementation of tests for varying curing periods.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest

REFERENCES

[1] Sharma, A. K., & Sivapullaiah, P. V. (2016). Swelling behaviour of expansive soil treated with fly ash–GGBS based binder. Geomechanics and Geoengineering, 12(3), 191–200. https://doi.org/10.1080/17486025.2016.1215548

[2] Amadi, A. A., & Lubem, S. (2014). Assessing Stabilization Effectiveness of Combined Cement Kiln Dust and Quarry Fines on Pavement Subgrades Dominated by Black Cotton Soil. Geotechnical and Geological Engineering, 32(5), 1231–1238. https://doi.org/10.1007/s10706-014-9793-0

[3] Akshay, W. (2020). Study of Black Cotton Soil and Settled Soil near Bhatghar Dam by using Lime Rice Husk Ash and Fly Ash Stabilized. International Journal for Research in Applied Science and Engineering Technology, 8(4), 468–472. https://doi.org/10.22214/ijraset.2020.4075

[4] Blayi, R. A., Sherwani, A. F. H., Ibrahim, H. H., & Abdullah, S. J. (2020). Stabilization of high-plasticity silt using waste brick powder. SN Applied Sciences, 2(12). https://doi.org/10.1007/s42452-020-03814-8

[5] Patel, M. l, & N.G.Raval, N. G. R. (2011). Study on Relation Between CBR Value of Subgrade Soil and Miosture Content. Indian Journal of Applied Research, 1(10), 86–87. https://doi.org/10.15373/2249555x/jul2012/28

[6] Singh, H. (2021). Stablization of Clayey Soil Via Lime and Plastic Fibre for Advanced Foundation Proposition. International Journal for Research in Applied Science and Engineering Technology, 9(9), 172–180. https://doi.org/10.22214/ijraset.2021.37941

[7] Zumrawi, M. M. E. (2014). Prediction of In-situ CBR of Subgrade Cohesive Soils from Dynamic Cone Penetrometer and Soil Properties. International Journal of Engineering and Technology, 6(5), 439–442. https://doi.org/10.7763/ijet.2014.v6.738

[8] Firat, S., Khatib, J. M., Yilmaz, G., & Comert, A. (2017). Effect of curing time on selected properties of soil stabilized with fly ash, marble dust and waste sand for road sub-base materials. Waste Management & Research, 35(7), 747–756. https://doi.org/10.1177/0734242x17705726

[9] Mir, B. A., & Sridharan, A. (2013). Physical and Compaction Behaviour of Clay Soil–Fly Ash Mixtures. Geotechnical and Geological Engineering, 31(4), 1059–1072. https://doi.org/10.1007/s10706-013-9632-8

[10] Sasui, Jinwuth, W., & Hengrasmee, S. (2018). The Effects of Raw Rice Husk and Rice Husk Ash on the Strength and Durability of Adobe Bricks. Civil Engineering Journal, 4(4), 732. https://doi.org/10.28991/cej-0309128

[11] Singh, R. R., & Singh, D. (2019). Effect of Rice Husk Ash on Compressive Strength of Concrete. International Journal of Structural and Civil Engineering Research, 223–226. https://doi.org/10.18178/ijscer.8.3.223-226

[12] Tangri, A. (2021). Effect of lime and RHA on clayey soil A review. Materials Today: Proceedings, 37, 2239– 2241. https://doi.org/10.1016/j.matpr.2020.07.683

[13] Samantasinghar, S., & Singh, S. P. (2021). Strength and Durability of Granular Soil Stabilized with FA-GGBS Geopolymer. Journal of Materials in Civil Engineering, 33(6). https://doi.org/10.1061/(asce)mt.1943-5533.0003736

[14] Lam, A., Hamzaoui, R., & Kindinis, A. (2023). Structural and mechanical studies of a ground-granulated blast-furnace slag (GGBS) based binder and its use in earth concrete. Materials Today: Proceedings. https://doi.org/10.1016/j.matpr.2023.07.283

[15] Lindh, P., & Lemenkova, P. (2022). Effects of GGBS and Fly Ash in Binders on Soil Stabilization for Road Construction. Romanian Journal of Transport Infrastructure, 11(2), 1–13. https://doi.org/10.2478/rjti-2022-0010

[16] Ogbuagu, N.J., et al. (2018). Evaluation of rice husk ash and Portland cement reinforced clay for use as road subgrade using the CBR test. (2018). Journal of Bioresources and Bioproducts, 3(2), 65-70 https://doi.org/10.21967/jbb.v3i2.166

[17] Zabielska-Adamska, K., & Sulewska, M. J. (2014). Dynamic CBR Test to Assess the Soil Compaction. Journal of Testing and Evaluation, 43(5), 20130256. https://doi.org/10.1520/jte20130256