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Stabilization of Black Cotton Soil with Cement, Rice Husk Ash and Granite Tile Powder

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Abstract: This investigation examines the efficacy of cement, rice husk ash (RHA) and granite tile powder (GTP) as stabilizing additives for black cotton soil (BCS), with the aim of upgrading its performance as a sub-base material for roads, runways, and other pavement structures. Given the inherently poor geotechnical characteristics of BCS, a response-surface methodology employing a central composite design (CCD) was adopted to optimize the RHA–GTP blend for maximal improvement in engineering properties. The study demonstrates that RHA and GTP exert pronounced influence on key parameters: maximum dry density (MDD), optimum moisture content (OMC), unconfined compressive strength (UCS), and California bearing ratio (CBR). Incorporation of 6 % RHA and 4 % GTP reduced MDD from 1.64 Mg m^{-3} to 1.41 Mg m^{-3}, a decline attributable to the porous microstructure of the additives which elevates void ratio and lowers bulk density. Conversely, OMC increased from 18.9 % to 27.5 % owing to the high silica content in RHA and GTP that forms a moisture-retentive gel upon hydration. The CBR response exhibited a non-linear trend: up to 6 % RHA and 3 % GTP, the unsoaked CBR rose from 13 % to 37 %, signifying enhanced bearing capacity. Numerical optimization via CCD identified an optimal formulation of 5 % RHA and 2 % GTP, yielding OMC = 23 %, MDD = 1.5 Mg m^{-3}, UCS = 845 kPa, soaked CBR = 22.5 %, and unsoaked CBR = 32.8 %. These results confirm that tailored RHA–GTP blends can substantially ameliorate the geotechnical performance of BCS, thereby contributing to sustainable and cost-effective pavement construction. The work concludes with a synthesis of key findings, novel contributions, and recommendations for future research directions.

Keywords: *Stabilization, Black cotton soil, Rice husk ash, Granite dust, Optimization*

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1. Introduction

Black cotton soils (BCS) are problematic tropical soils, prevalent in countries like Nigeria (Kennedy et al., 2018; Aliyu et al., 2022). They are expansive due to high clay content, particularly montmorillonite, causing swelling when wet and shrinkage when dry (Oriola, 2010). These soils, formed from weathered basaltic rocks and clayey sediments, are known for poor drainage, low bearing capacity, and excessive volume change, leading to structural damage in pavements and foundations (Ola, 2015). To mitigate these issues, researchers are exploring the use of agricultural and industrial waste materials like rice husk ash (RHA) and broken tiles (granite tile powder, GTP) for soil stabilization (Ghutke and Agrawal, 2018). RHA, a byproduct of rice husk combustion, is highly pozzolanic due to its high silica content (Bui, 2001; Klaassen and Kentgens, 2008). Studies show that adding RHA and GTP improves soil properties: reduces maximum dry density, increases optimum moisture content, and enhances compressive strength and California bearing ratio, making BCS suitable for sub-base material in construction (Ibrahim, 2019). The use of these waste materials not only improves soil properties but also promotes sustainable construction practices by recycling waste and reducing environmental pollution.

Improving the properties of soil requires stabilization technique (Matawal et al., 2006; Mai-Bade et al., 2021; Rehman and Mujeeb. 2020). Several types of stabilization materials have been used for BCS stabilization.

Stabilization of Black Cotton Soil with Rice Husk Ash (RHA)

A comprehensive investigation into the influence of rice husk ash (RHA) on the engineering properties of black cotton soil (BCS) has been conducted by several researchers. Antush (2023) examined the combined effect of ground granulated blast furnace slag (GGBS) powder and RHA on BCS, assessing both soaked and unsoaked California Bearing Ratio (CBR). The study concluded that an optimal blend of 10% RHA and 8% GGBS yielded the highest soaked CBR value, indicating a significant improvement in soil strength.

Hullur et al. (2022) explored the stabilization of BCS with RHA and reported enhanced strength characteristics. Their findings revealed that a 10% replacement level of RHA achieved the maximum dry density and peak CBR values, suggesting its suitability for flexible pavement construction.

Tangri et al. (2021) investigated the impact of RHA on soil strength, noting that increasing RHA content led to a rise in optimum moisture content (OMC) and a reduction in maximum dry density (MDD). This trend is consistent with the pozzolanic properties of RHA, which contribute to improved soil stability.

Ghutke & Agrawal, (2018) evaluated the effect of RHA addition on the index and strength properties of BCS. Their results showed that liquid and plastic limits initially increased with up to 4% RHA addition, followed by a decline. Additionally, specific gravity and MDD decreased with increasing RHA content, while CBR values peaked at 12% RHA, indicating an optimal ash content for soil stabilization.

Sasui et al. (2018) discussed the role of RHA in stabilizing soil properties for road construction and adobe homes. Their comparative study of raw rice husk (RRH) and heap-burnt RHA revealed that RRH-containing samples exhibited superior performance, likely due to the diminished cementation capabilities of RHA resulting from high combustion temperatures.

Raj et al. (2016) examined the influence of RHA on the engineering properties of clayey and alluvial soils. Their findings indicated a reduction in liquid limit, free swell index, and OMC with increasing RHA proportions, accompanied by significant improvements in MDD, CBR, and angle of internal friction. Notably, an 80% RHA mixture resulted in a 160% increase in CBR for alluvial soil and a 55% increase for clayey soil.

Prakash et al. (2017) investigated the effect of RHA addition on the strength properties of poor subgrade soil. Their results showed that increasing RHA content led to a decrease in liquid limit and MDD, while OMC increased. The CBR value peaked at 10% RHA content, beyond which it declined, suggesting that silica in RHA can replace exchangeable ions in clay minerals, thereby reducing shrinkage and swelling properties.

Stabilization of Black Cotton Soil with Broken Tile Waste (BTW)

Mohammad and Bahareh (2021) presented a study on the use of broken tile waste (BTW) in the stabilization of problematic soils. Their research involved varying particle sizes of BTW (10%, 20%, and 30% by soil dry weight) and cement content (2.5%, 5%, and 7.5% by soil dry weight). The results demonstrated that increasing cement content enhanced durability, CBR, and compressive strength. However, the CBR test revealed an optimal BTW content of 20%, beyond which the CBR value decreased. The maximum unconfined compressive strength was 3.7 MPa and 3.2 MPa for coarse and fine-grained BTW, respectively.

Al-Bared and Marto (2019) utilized recycled blended tiles (RBT) of two different sizes (0.063 mm and 0.15 mm diameter) to stabilize marine clay. Their findings indicated that RBT addition increased MDD while decreasing OMC, attributed to reduced water molecule attraction. The optimal RBT content was found to be 30%, with further increments leading to a decline in MDD. Notably, the 0.15 mm RBT exhibited more consistent results at 40% content compared to the 0.063 mm RBT.

Muralidharan et al. (2019) explored the use of vitrified tile waste powder combined with calcium hydroxide to enhance clayey soils. Their study revealed that increasing the proportion of tile waste and calcium hydroxide up to 15% and 10%, respectively, led to decreased liquid and plastic limits, while MDD, CBR, and shear strength increased. Beyond these ratios, the results showed a reverse trend, indicating an optimal mixture for soil classification change from clay (CH) to silt (M).

2. Materials and methods

2.1. Materials

The materials used were
(i) Black cotton soil,
(ii) Rice Husk Ash
(iii) Broken Tiles
(iv) Water

Preparation of Rice Husk Ash (RHA)

Rice husk was obtained from a rice factory at Sabon-kaura, Bauchi metropolis. After collection, the rice husk was burnt in a furnace at a temperature of 700ºC at the Industrial Design Laboratory, ATBU Bauchi. The resulting fine powder residue was passed through a sieve size 150µm, to obtain the finer sample of RHA.

Granite Tile Powder

Granite tile powder is a waste from tile industries and during installations of tiles in buildings that are usually found at the end of polishing and finishing and normally discarded. This was obtained from Saheli company, Bauchi. This piece of tiles which were discarded as waste during installation and production was collected at negligible cost. They were broken with a crusher machine and sieved with 150 µm.

Black Cotton Soil (BCS)

Black cotton soil was collected from Umar Ismail Garkuwa Farms, Garin-Lanotali, Gombe, Nigeria. The soil sample was taken at a depth of 0.90m from the ground surface to avoid organic matter. The material collected was tested at the soil mechanics laboratory of the Abubakar Tafawa Balewa University, Bauchi in accordance with BS 1377 (1990).

Water

The water for the research work was clean and portable water in accordance with BS EN 1008:2002, and was obtained from the tap at Abubakar Tafawa Balewa University, Bauchi. Clean and portable water is of great importance in the stabilization process because the presence of impurities in water can affect the cementitious process and reduce the compressive strength and durability of the stabilized soil.

2.2. Methods

Experimental Design

The statistical software package used for experimental design, analysis and optimization responses is Design-Expert software 13 face centred design space. The software was used for design, analysis optimization of responses. The factor level is in Table 1.

Table 1: Factor and Factor Levels of Mixture

Factor	Units	Low	Middle	High
Rice husk ash	%	2	4	6
Tile Powder	%	2	3	4

at constant 5% cement

The responses are

(i) Compaction test (OMC and MDD)
(ii) Unconfined Compressive Strength (UCS)
(iii) California bearing ratio (CBR) Soaked and Unsoaked

3. Results and Discussion

3.1. Properties of Black Cotton Soil

The properties of black cotton soil used are presented in Table 2.

Table 2: Properties of Black Cotton Soil

Property	Value
Natural moisture content (%)	35.6
Percentage passing BS No 200 sieve	85.1
Liquid limit (%)	74
Plastic limit (%)	38
Plasticity index (%)	36
Linear shrinkage (%)	15.8
Specific gravity	2.43
Maximum Dry Density (MDD) (mg/m^3)	1.64
Optimum Moisture Content (OMC) %	18.9
UCS at 28 days (kN/m^2)	110
Soaked CBR (%)	6
Unsoaked CBR (%)	13
Dominant clay mineral	Montmorillonite
AASHTO Classification	A - 7 – 6 (Fair to poor)
NBRRI Classification	High swell potential
UCSC Classification	CH
Colour	Greyish black

Table 2 shows the test conducted for the properties of BCS. The liquid limit, plastic limit and plasticity index of the natural soil were 74%, 38 and 36% respectively. This shows that the soil is highly plastic. The results from the Atterberg limits and sieve analysis test classified the soil as A-7-6 according to the American Association of States Highway and Transportation Officials (AASHTO, 2004) and Clay of high plasticity (CH) in accordance with the Unified Soil Classification System (ASTM, 1992).

The result for hydrometer test for BCS is presented in Figure 1..

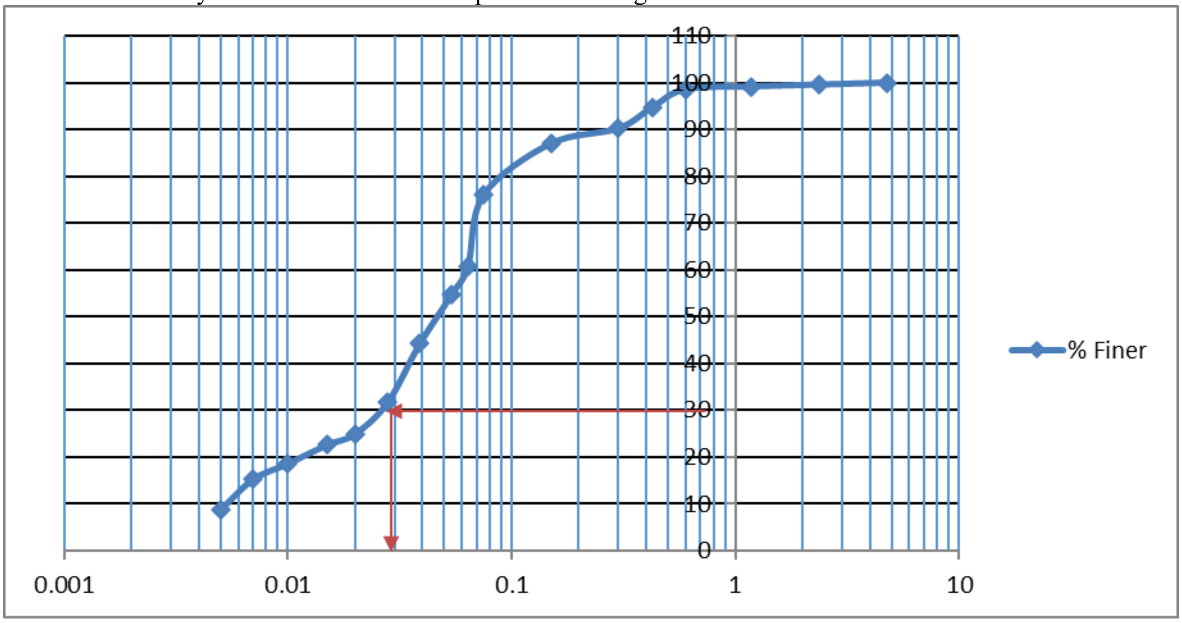

Figure 1: Particle size distribution graph for BCS

Result

D60 = 0.07

D30 = 0.03

D10 = 0.003

CU = 0.07 / 0.003 = 23

CC = (0.03)2/ (0.07*0.003) = 4

3.2. Test Results of Admired Black Cotton Soil

The summary of experimental investigation conducted on both control and admixed BCS with RHA, GTP and 5% cement is shown in Table 3.

Table 3: Summary of results.

Run	Factor 1 A:RHA %	Factor 2 B:GTP %	Response 1 OMC %	Response 2 MDD mg/m^3	Response 3 UCS kN/m^2	Response 4 CBR soaked %	Response 5 CBR unsoaked %
Control (BCS only)	0	0	18.9	1.64	110	6.0	13.0
1	2	3	22.3	1.51	610	16.4	25.2
2	2	2	22.4	1.5	590	14.8	24.5
3	4	3	22.5	1.55	752	21.5	32.5
4	6	2	25.2	1.52	880	23.5	34.2
5	6	4	27.5	1.41	980	25.8	35.5
6	2	4	21.5	1.53	630	17.8	25.8
7	4	3	22.5	1.55	752	21.5	32.5
8	4	4	23.5	1.53	595	22.1	31.7
9	4	3	22.5	1.55	752	21.5	32.5
10	4	3	22.5	1.55	752	21.5	32.5
11	4	3	22.5	1.55	752	21.5	32.5
12	4	2	21.3	1.56	718	20.1	28.9
13	6	3	26.1	1.43	910	24.3	37.0

Table 3 presented the summary of results of this finding. The addition of 6% RHA and 4% GTP decreases the MDD value from 1.64 to 1.41 mg/m3. This decrease is attributed to the porous nature of both materials, which increases the void ratio and reduces the density of the soil. 6% RHA and 4% GTP increases the OMC value from 18.9% to 27.5%. This increase is due to the high silica content in RHA and GTP, which reacts with water to form a gel-like substance that retains more moisture. The effect of RHA and GTP on CBR is more complex. Up to 6% RHA and 3% GTP content, the unsoaked CBR value increases from 13% to 37%, indicating improved bearing capacity. This result follows the trend established by various researchers such as Obeta et al. (2019), Jayesh et al. (2022), and Hullur et al. (2022).

3.3. Performance Evaluation and Analysis of Test Results

Optimum moisture content (OMC)

The ANOVA result for OMC is shown in Table 4.

Table 4: ANOVA for OMC

Source	Sum of Squares	df	Mean Square	F-value	p-value
Model	40.48	5	8.10	65.01	< 0.0001
A-RHA	26.46	1	26.46	212.48	< 0.0001
B-T. P	2.16	1	2.16	17.34	0.0042
AB	2.56	1	2.56	20.56	0.0027
A^2	8.21	1	8.21	65.93	< 0.0001
Residual	0.8717	7	0.1245		
Lack of Fit	0.8717	3	0.2906		
Pure Error	0.0000	4	0.0000		
Cor Total	41.35	12			

The P-values less than 0.05 indicate model terms are significant. In this case A, B, AB, A^2 are significant model terms. Values greater than 0.1 indicate the model terms are not significant. Table 11 shows that values of OMC ranged between 21.3 to 27.5 % compared to the control of 18.9%. Table 8 shows the ANOVA for OMC. The Model F-value of 65.01 implies the model is significant. Table 5 shows that Fits statistics for OMC.

Table 5: Fit Statistics for OMC

Parameter	Value
R^2	0.9789
Adjusted R^2	0.9639
Predicted R^2	0.7855
Adeq Precision	24.2933

The Predicted R^2 of 0.7855 is in reasonable agreement with the Adjusted R^2 of 0.9639; i.e. the difference is less than 0.2. The model equation for OMC in coded factor is shown in Equation 1.

OMC = 27.5-3.6*A-0.545*B+0.4*AB+0.43*A^2-0.076* B^2 … (1)

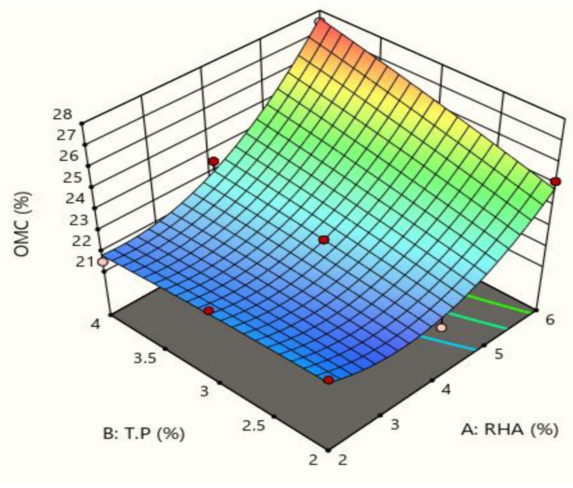

Figure 2: 3D Response Graph of Effect of Tile Powder and Rice Husk Ash on OMC

Figure 2 shows 3D surface graph of interaction between RHA and GTP and the influence on optimum moisture content. The 3-D surface reveals the link between the variables (OMC) and the independent variables (RHA and GTP). The graph shows that increase in Mk and sand causes an increase in OMC.

Result of Maximum Dry Density (MDD)

The ANOVA result of MDD is presented in Table 6 and the Fit statistics in Table 7.

Table 6: ANOVA for MDD

Source	Sum of Squares	df	Mean Square	F-value	p-value

Model	0.0262	5	0.0052	48.00	< 0.0001
A-RHA	0.0054	1	0.0054	49.45	0.0002
B-T.P	0.0020	1	0.0020	18.47	0.0036
AB	0.0049	1	0.0049	44.87	0.0003
A^2	0.0127	1	0.0127	116.72	< 0.0001
Residual	0.0008	7	0.0001		
Lack of Fit	0.0008	3	0.0003		
Pure Error	0.0000	4	0.0000		
Cor Total	0.0270	12			

Table 6 shows the analysis of variance for MDD. The Model F-value of 48 implies the model is significant. P-values less than 0.05 indicate model terms are significant. In this case A, B, AB, A^2 are significant model terms. Values greater than 0.1 indicate the model terms are not significant.

Table 7: Fit Statistics for MDD

Parameters	Values
R^2	0.9717
Adjusted R^2	0.9514
Predicted R^2	0.7652
Adeq Precision	23.89

The Predicted R^2 of 0.7652 is in reasonable agreement with the Adjusted R^2 of 0.9514; i.e. the difference is less than 0.2. Adeq Precision measures the signal to noise ratio. A ratio of 12.079 indicates an adequate signal. The model equation for MDD in coded factor is shown in Equation 2

MDD=1.24 + 0.17*A + 0.009* B-0.02*AB-0.017* A^2+ 0.01* B^2…(2)

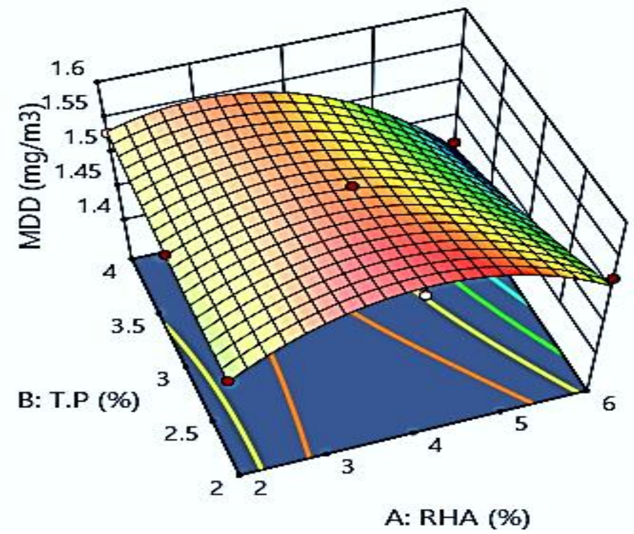

Figure 3: 3-D Response Graph of Effect of RHA and GTP on MDD

Figure 3 shows the 3D surface graph of interaction between RHA and GTP and the influence on maximum dry density. The 3-D surface reveals the correlation between the MDD and the independent variables (RHA and GTP). The graph shows that increase in RHA shows significant increase in MDD from 2 to 5% before it declines while GTP caused slight increase in MDD from 2 to 4%.

Result of UCS at 28 days

The ANOVA result of unconfined compressive strength at 28 days is presented in Table 8 and the fit statistics in Table 9.

Table 8: ANOVA for UCS

Source	Sum of Squares	df	Mean Square	F-value	p-value
Model	1.473E+05	2	73657.42	22.81	0.0002
A-RHA	1.473E+05	1	1.473E+05	45.60	< 0.0001
B-G. T. P	48.17	1	48.17	0.0149	0.9052
Residual	32298.09	10	3229.81		
Lack of Fit	32298.09	6	5383.01		
Pure Error	0.0000	4	0.0000		
Cor Total	1.796E+05	12			

Table 9: Fit Statistics for UCS

Parameter	Value
R^2	0.8202
Adjusted R^2	0.7842
Predicted R^2	0.6379
Adeq Precision	11.684

Table 8 shows Model F-value of 22.81 which implies that the model is significant. P-values less than 0.05 indicate model terms are significant. In this case, A is a significant model term while B is not significant but kept for hierarchy. The Predicted R^2 of 0.6379 is in reasonable agreement with the Adjusted R^2 of 0.7842; i.e. the difference is less than 0.2. Adeq Precision measures the signal to noise ratio. A ratio of 11.685 indicates an adequate signal. The model equation for UCS in coded factor is shown in Equation 3.

UCS= 422.244 + 78.3333 * A + 2.83333 * B …(3)

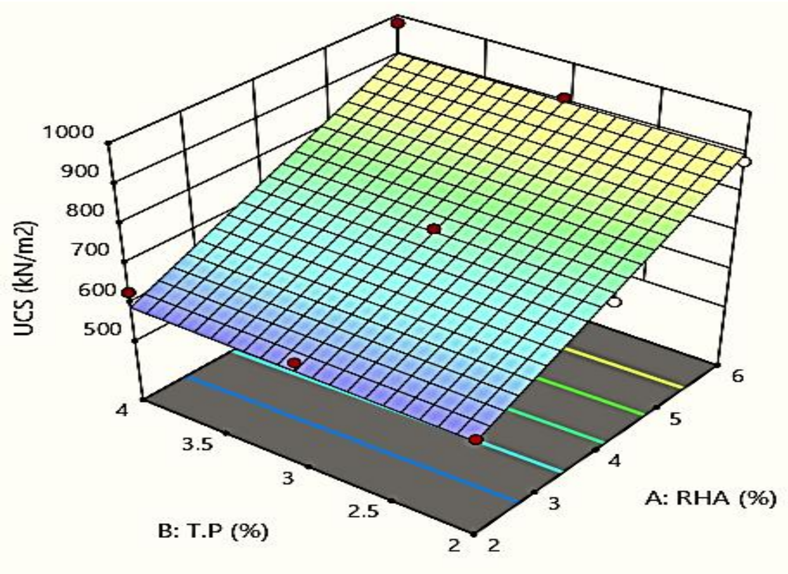

Figure 4: 3-D Response Graph of Tile Powder and RHA on UCS

Figure 4 shows 3D response surface graph of interaction between RHA and GTP and the influence on UCS. The 3-D surface elucidates the correlation between the dependent variables (responses) and the independent variables (factors). The graph shows that increase in RHA causes a significant increase in UCS. The high increase by RHA is connected to the its high pozzolanic properties.

Result of soaked CBR (SCBR)

The ANOVA result of CBR (Soaked) is presented in Table 10.

Table 10: ANOVA of Quadratic model for **S**CBR

Source	Sum of Squares	df	Mean Square	F-value	p-value
Model	112.85	5	22.57	396.56	< 0.0001
A-RHA	100.86	1	100.86	1772.05	< 0.0001
B-T. P	8.88	1	8.88	156.05	< 0.0001
AB	0.1225	1	0.1225	2.15	0.1858
A^2	2.22	1	2.22	39.00	0.0004
B^2	0.0593	1	0.0593	1.04	0.3413
Residual	0.3984	7	0.0569		
Lack of Fit	0.3984	3	0.1328		
Pure Error	0.0000	4	0.0000		
Cor Total	113.25	12			

Table 10 shows Model F-value of 396.56 which implies that the model is significant. The P-values less than 0.05 indicate model terms are significant. In this case A, B, A^2 are significant model terms. The result of Fit statistics for CBR (Soaked) is shown in Table 11.

Table 11: Fit Statistics for SCBR

Parameters	Value

R^2	0.9965
Adjusted R^2	0.9940
Predicted R^2	0.9698
Adeq Precision	65.6061

The Predicted R^2 of 0.9965 is in reasonable agreement with the Adjusted R^2 of 0.9940; i.e. the difference is less than 0.2. Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. The ratio of 65.6061 indicates an adequate signal. This model can be used to navigate the design space. The model equation for soaked CBR in coded factor is shown in Equation 4.

$$SCBR = 3.6 + 4.1 * A + 2.45 * B - 0.09 * AB - 0.224 * A^2 - 0.15 * B^2 \ldots (4)$$

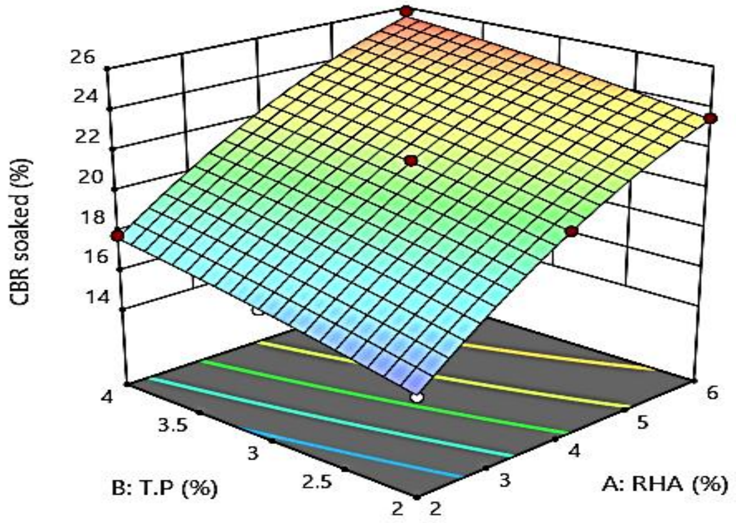

Figure 5: 3-D Response Graph of Effect of RHA and GTP on CBR (soaked)

The Figure 5 shows 3D response surface graph of interaction between RHA and GTP and the influence on CBR (soaked). The 3-D surface elucidates the correlation between the dependent variable (CBR) and the independent variables (RHA and GTP). The graph shows that increase in RHA and GTP causes increase in CBR (soaked).

Result of unsoaked CBR (UCBR)

The analysis of variance and Fit statistics for UCBR are presented in Tables 24 and 25.

Table 12: ANOVA for Unsoaked CBR

Source	Sum of Squares	df	Mean Square	F-value	p-value
Model	182.11	5	36.42	83.47	< 0.0001
A-RHA	162.24	1	162.24	371.81	< 0.0001
B-T.P	4.86	1	4.86	11.14	0.0125
AB	0.0000	1	0.0000	0.0000	1.0000
A^2	2.09	1	2.09	4.78	0.0650
B^2	7.69	1	7.69	17.63	0.0040
Residual	3.05	7	0.4364		
Lack of Fit	3.05	3	1.02		
Pure Error	0.0000	4	0.0000		
Cor Total	185.16	12			

From Table 12, the Model F-value of 36.42 implies the model is significant. The P-values less than 0.05 indicate model terms are significant. In this case A, B, B^2 are significant terms.

Table 13: Fit Statistics for Unsoaked CBR

Parameters	Value
R^2	0.9835
Adjusted R^2	0.9717
Predicted R^2	0.8472
Adeq Precision	28.8989

The Predicted R^2 of 0.8472 is in reasonable agreement with the Adjusted R^2 of 0.9717; i.e. the difference is less than 0.2. Adeq Precision measures the signal to noise ratio. The ratio of 28.9 indicates an adequate signal. The model equation for UCBR in coded factor is shown in Equation 5.

UCBR = 0.75+4.34*A+10.9*B-2.7e-15*AB-0.22*A^2-1.67*B^2…(5)

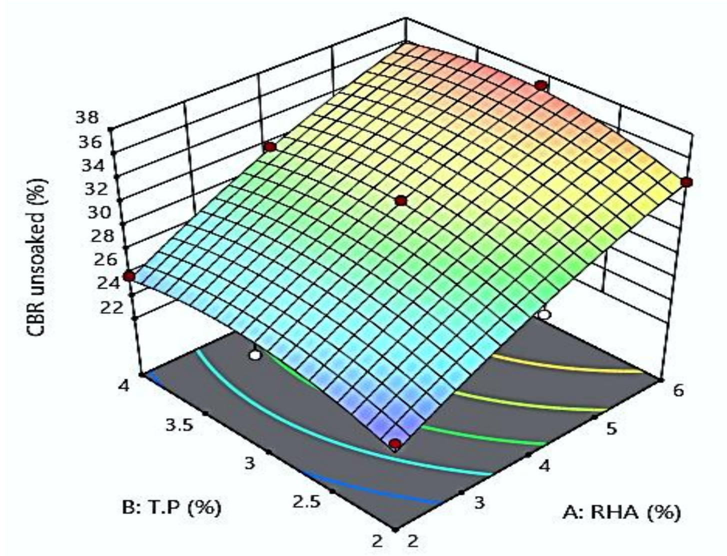

Figure 6: 3-D Response Graph of Effect of GTP and RHA on Unsoaked CBR

3.4. Optimization of Mixtures by Numerical Method

The automatic optimization function is shown in Figure 7.

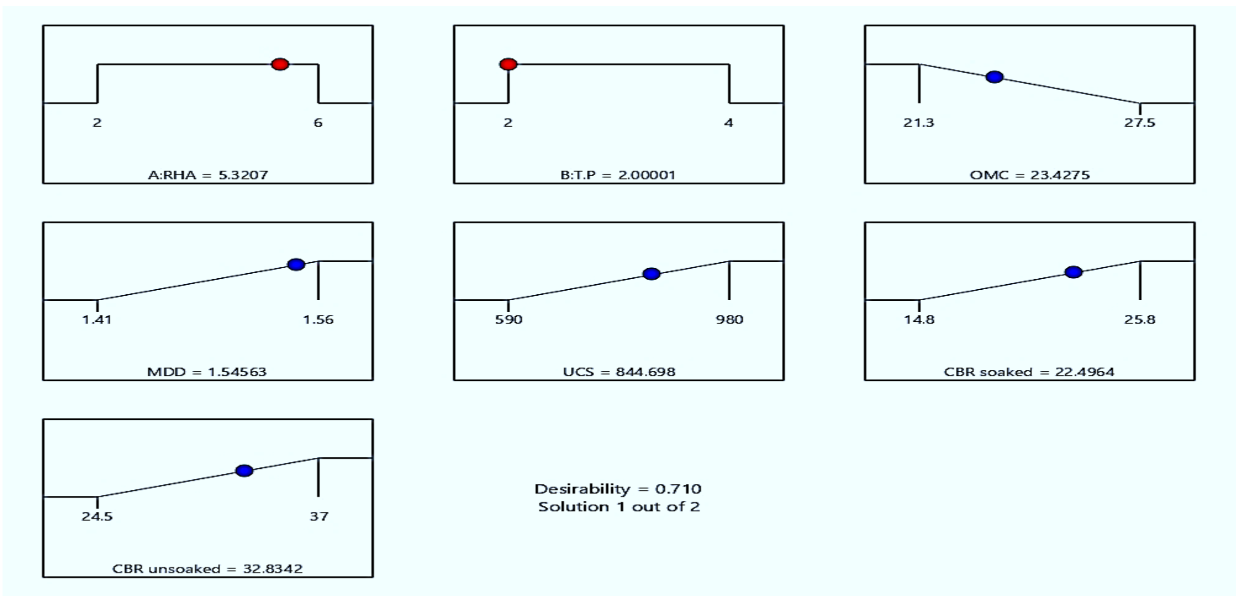

Figure 7: Ramp Plot Showing the Optimal Values for Factors and Responses

4. Conclusion

The investigation into the stabilization of black cotton soil (BCS) using rice husk ash (RHA) and granite tile powder (GTP) yielded the following key findings:

- Soil Classification and Properties- BCS was classified as A-7-6 and CH according to the AASHTO and Unified Soil Classification Systems, respectively.
- Effects of RHA and GTP on Soil Properties- The addition of 6% RHA and 4% GTP resulted in a decrease in MDD from 1.64 Mg/m³ to 1.41 Mg/m³, attributed to the porous nature of both materials, which increases the void ratio and reduces soil density.
- The OMC increased to 27.5% due to the high silica content in RHA and GTP, which reacts with water to form a gel-like substance that retains more moisture.

- The effect of RHA and GTP on California Bearing Ratio (CBR) was more complex, with an increase in CBR value to 37% observed up to 6% RHA and 3% GTP content, indicating improved bearing capacity.
- Model Development and Validation- Model equations were generated for the responses (OMC, MDD, UCS at 28 days, CBR soaked, and CBR unsoaked) using Central Composite Design (CCD) with Design Expert 13 software. The optimized results were validated, and the deviations between predicted and actual values were found to be less than 0.05, indicating an excellent fit between the optimized and validated results and confirming the accuracy and reliability of the model.
- These findings demonstrate the potential of RHA and GTP as effective stabilizers for improving the engineering properties of black cotton soil, making it more suitable for construction applications.

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References

Al-Bared, M. A. M., & Marto, A. (2019). *Stabilization of marine clay using recycled blended tiles.* Elsevier.

Aliyu A., Abdulkarim I. I. and Umar S. Y., (2022). effect of mining tailing waste on properties of cement stabilized black cotton soil. *Global Journal of Engineering and Technology Advances*, 2022, 11(03), 031–036. https://doi.org/10.30574/gjeta.2022.11.3.0090

Antush, A. (2023). *Stabilizing black cotton soil with rice husk ash and ground granulated blast furnace slag.* Springer.

Bui, D. D. (2001). Rice husk ash as a pozzolanic material. *Journal of Materials Science, 36*(4), 845-852.

Ghutke, S., & Agrawal, V. (2018). Effect of rice husk ash on index and strength properties of black cotton soil. International *Journal of Civil Engineering and Technology, 9*(13), 150-159.

Hullur U.G, Krishnaiah S. and Prakash K.B, (2022). *Stabilization of black cotton soil with rice husk ash*. Wiley.

Ibrahim A. Ikara. (2019). Predicting CBR Values of Black Cotton Soil Stabilized with Cement and Waste Glass Admixture Using Regression Model. *American Journal of Traffic and Transportation Engineering.* Vol. 4, No. 1, 2019, pp. 31-36. doi: 10.11648/j.ajtte.20190401.15.

Jayesh P., N H Joshi, and Arpita P. (2022): A Review on Stabilization of Black Cotton Soil Using Industrial Waste (Copper Slag). *IJCRT*. Volume 10, Issue 8. ISSN: 2320-2882

Kennedy, T. Amgbara, P. Paulinus, (2018): Geotechnical properties of black cotton soils in Nigeria. *Nigerian Journal of Engineering, 25*(2), 45-53.

Klaassen, R., & Kentgens, A. (2008). Rice husk ash as a supplementary cementitious material. *Cement and Concrete Research, 38*(6), 787-795. (link unavailable)

Mai-Bade U.Y., Chinade A.U., Batari A., and Saeed S.M., (2021). Stabilization of Black Cotton Soil Using Various Admixtures: *A Review, Composite Materials.* (5) 2:37-45. doi: 10.11648/j.cm.20210502.12

Matawal, D. S., Umar, S.Y and Bala, Y. U. (2006). *Soil improvement using industrial and agricultural wastes.*

Mohammad, A., & Bahareh, S. (2021). *Use of broken tile waste in stabilization of problematic soil.* Taylor & Francis.

Obeta, I. N., Ikeagwuani, C. C., Attama, C. M., & Okafor, J. (2019). Stability and durability of sawdust ash-lime stabilised black cotton soil. *Nigerian Journal of Technology, 38*(1), 75.

Ola, S. A. (2015). *Expansive soils in Nigeria: Problems and solutions*.

Oriola, F. O. P. (2010). *Black cotton soils: Engineering properties and treatment*.

Prakash, J., Kumari, K. and Kumar, V.: (2017). Effect of rice husk ash on strength properties of poor subgrade soil. *International Journal of Civil Engineering, 15*(4), 567-575.

Raj, R. R., Banupriya, S. and Dharani, R. (2016): Impact of rice husk ash on engineering properties of clayey and alluvial soils. *Journal of Materials in Civil Engineering, 28*(10), 04016093.

Rehman and Mujeeb (2020). *Comparative Study on Stabilized Black Cotton Soil.* 05.:46-52.https://www.researchgate.net/publication/344.

Sasui, Jinwuth, W., & Hengrasmee, S. (2018). Rice husk ash in stabilizing soil properties for road construction and adobe homes. *Construction and Building Materials, 186*, 120-128.