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Utilization of Coconut Shell Ash in the Stabilization of Black Cotton Soil

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ABSTRACT
Black cotton soil poses significant engineering challenges due to its highly expansive nature and low bearing capacity. Black Cotton Soil high problematic as foundation for building and road constructions. This is due to the characteristic phenomena and high shrinkage on drying. The volume changes however one contains on an upper critical zone of the soil of to have been usually about 1.5m thick. Before this land, the moisture content remains more or less the same in Nigeria, Black Cotton Soils are typically found in the low drying area of the North Eastern State of Borno, Gombe, Adamawa, Yobe and Taraba State. Recent studies from 2020 to date are examined to assess the effectiveness of Coconut Shell Ash (CSA) in reducing soil expansiveness, increasing strength, and enhancing durability, of in this research CSA shows an increase of 13.2% at 5% CSA during 7 days curing and about 24.30% at 10% CSA and increase to 31.56% at 28days showing that there is an increase in in compressive strength. This work aims to provide insights into the application of CSA for sustainable soil stabilization practices.
Keywords: Black Cotton Soil, Coconut Shell Ash, Coconut Shell Ash

1. INTRODUCTION:

Black cotton soil, also known as expansive clay soil, is prevalent in many regions and poses challenges for construction and infrastructure development due to its high swelling and shrinkage behavior. Stabilization techniques are employed to enhance the engineering properties of black cotton soil and mitigate its adverse effects on structures. Coconut shell ash (CSA) has emerged as a promising alternative stabilizing agent due to its abundance, low cost, and environmental sustainability.

Black Cotton Soil high problematic as foundation for building and road constructions. This is due to the characteristic phenomena and high shrinkage on drying. The volume changes however one contains on an upper critical zone of the soil of to have been usually about 1.5m thick. Before this land, the moisture content remains more or less the same in Nigeria, Black Cotton Soils are typically found in the low drying area of the North Eastern State of Borno, Gombe, Adamawa, Yobe and Taraba State. They occur in discontinuous stages as specified deposits usually not more than 1m-2m thick, Black Cotton Soil are formed from weathering of sedimentary rocks, when one of the volcanic origin particles of volcanic glass.

These minerals readily weather to form mountnorillonite clays when is cheef mineral of black of sedimentary rocks, which are of volcanic origin. The turf aid ashes are made of volcanic dust, which

is essentially a collection of minute's particles of volcanic glass, these minerals readily weather to form montnorillonite days which is chief minerals of the black cotton soil in area where the rate of evaporation exceed precipitation rate poor teaching alkaline condition and retention of magnesium and calcium in the soil formation of black cotton soil is highly favoured According to Nigeria building road research institute (NBRRI). "Black cotton soils are dark coloured expansive clays, characterized by the phenomena of swelling on absorption of water and shrinkage in drying. The characteristics make them highly problematic as foundation for both building and road structures such soil are common products of tropical weathering and are encountered in several part of the world.

CSA is a byproduct obtained from the combustion of coconut shells. It contains a high percentage of silica, alumina, and other pozzolanic materials, making it suitable for soil stabilization applications. The chemical composition and physical properties of CSA influence its effectiveness in improving soil properties when used as an additive.

Recent studies have investigated the effects of incorporating CSA into black cotton soil to enhance its engineering characteristics. Research by Rahman et al. (2021) demonstrated that the addition of CSA reduced the plasticity index and swell potential of black cotton soil, leading to improved stability and reduced susceptibility to volume changes. Similarly, the study conducted by Kumar et al. (2020) showed that CSA significantly increased the California Bearing Ratio (CBR) and unconfined compressive strength (UCS) of stabilized soil specimens.

The mechanisms underlying soil stabilization with CSA involve pozzolanic reactions, cementation, and filler effects. Pozzolanic materials in CSA react with calcium hydroxide (lime) present in the soil, forming additional cementitious compounds that bind soil particles and reduce plasticity. Furthermore, the fine particles of CSA fill the voids between soil particles, enhancing compaction and reducing permeability.

The utilization of CSA for soil stabilization offers environmental benefits by repurposing agricultural waste and reducing the consumption of traditional stabilizing agents such as cement and lime. Additionally, the use of CSA can contribute to the reduction of greenhouse gas emissions associated with the production of conventional stabilizers.

Further research is warranted to optimize the dosage and mixing procedures of CSA for achieving desired soil stabilization effects. Long-term performance studies and field trials are needed to assess the durability and sustainability of stabilized soil structures under different environmental conditions. Additionally, the economic feasibility and scalability of using CSA in large-scale construction projects need to be evaluated.

The utilization of coconut shell ash as a stabilizing agent offers a sustainable solution for improving the geotechnical properties of black cotton soil. Recent studies have demonstrated the effectiveness of CSA in reducing soil expansiveness, increasing strength, and enhancing durability. By harnessing the pozzolanic and filler effects of CSA, soil stabilization can be achieved while promoting environmental sustainability.

Soil can be stabilized with lime, cement or bitumen or additives in order to form bound base. The purpose of stabilizer is to supply a cohesion, which is lacking in unbound bases. Lime requires the presence of clay in the soil and cannot be used to bind non plastic soils. Stabilized soil can produce very durable road pavements. Therefore, soil securing this objective both in the construction, of new roads and in the rehabilitation of roads in which the pavement has deteriorated to the extent that they need to be reconstructed.

Basic Principle of Soil Stabilization

1. Evaluation of the properties of the available soils.
2. Estimating the lacking properties in the soil.
3. Revising the method of adding the lacking properties through economical method of soil stabilization.
4. Compaction of the designed soil, changes Soil Stabilization.

a) Chemical properties may be Modified.
b) Physical properties like; density, expansion; shrinkage stability etc. may be improved.
c) Retention of some minimum strength properties due to water proofing measures.

LITERATURE REVIEW

Gombe, Nigeria, is characterized by the prevalence of black cotton soil, known for its expansive nature and the challenges it poses for construction projects. To address these challenges, researchers have been exploring alternative stabilizing agents, and coconut shell ash (CSA) has emerged as a promising solution due to its availability and eco-friendliness.

Properties of Coconut Shell Ash:

CSA, a byproduct of coconut shell combustion, contains silica, alumina, and pozzolanic materials, making it suitable for soil stabilization. Its chemical composition and physical properties influence its effectiveness in enhancing soil properties when used as an additive (Babatunde et al., 2021).

Effectiveness of Coconut Shell Ash on Black Cotton Soil:

Recent studies have investigated the impact of incorporating CSA into black cotton soil in Gombe. For instance, Ahmed et al. (2020) demonstrated that the addition of CSA significantly reduced the plasticity index and improved the strength characteristics of stabilized soil specimens.

Mechanisms of Soil Stabilization with Coconut Shell Ash:

Soil stabilization with CSA as discussed by Ajayi et al., (2019) involves several mechanisms, including pozzolanic reactions and filler effects. Pozzolanic materials in CSA react with calcium hydroxide in the soil, forming additional cementitious compounds that bind soil particles and reduce plasticity. Additionally, the fine particles of CSA fill the voids between soil particles, enhancing compaction and reducing permeability.

Environmental Benefits:

Oladunjoye et al., (2022) in their work showed the utilization of CSA for soil stabilization in Gombe offers environmental benefits by repurposing agricultural waste and reducing the consumption of conventional stabilizing agents. Furthermore, the use of CSA can contribute to mitigating environmental degradation associated with construction activities.

Practical Applications and Future Directions:

The application of CSA for stabilizing black cotton soil in Gombe holds promise for sustainable construction practices. Future research should focus on optimizing the dosage and application methods of CSA, conducting long-term performance studies, and evaluating the economic feasibility of large-scale implementation in construction projects.

The use of coconut shell ash as a stabilizing agent offers a sustainable solution for enhancing the geotechnical properties of black cotton soil in Gombe. Recent studies have demonstrated the effectiveness of CSA in reducing soil expansiveness, increasing strength, and promoting durability. By harnessing the potential of CSA, sustainable construction practices can be promoted, contributing to the development of resilient infrastructure in Gombe.

Soil Cement Stabilization

Is a method of construction or stabilization of soil cement on which a pulverized mixed is formed and was compacted and allowed to harden possesses appreciable strength and considerable resistances to weathering. In this method of stabilization; a small percentage of cement is added to the soil to be stabilized.

An intimate mixture of soil; cement and water are compacted on the prepared sub- grade to form strong base. Cement stabilization of non-cohesive soil is achieved by the development of bond between hydrated cement and the compacted soil particles. However, in the case of cohesive soil, stabilization takes place due to decrease in plasticity and formation of matrix enclosing clay in cement. Increase in cement content the soil increate strength and durability and decreases the variation in volume; moisture movement and plasticity.

Effectiveness of the stabilization depends on; the nature of soil, chemical properties; cement content; types of cement; mixing and compacting stabilization of black cotton soil with Portland cement alone is not suitable because of the presence of montmorillonite in the clay. This clay mineral retard hydration and a percentage of Portland dement would be required to achieve adequate stabilization.

Soil Bitumen Stabilization

Is most useful in-areas where the climate is hot and dry. There are three (3) Reasons this;

1. The sandy soil frequently predominates in these areas; indeed, they may be the only readily available roads making material.
2. Water is not needed at any stage during the mixing and laying process.

3. In arid regions the bearing capacity of soils and sub-bases is often high so that quite thin road bases are required.

Bitumen when mixed with soil, imports binding properties-and make it water proof water proofing property imparted to the soil helps retain its strength, even in 'the presence of water. When bitumen is used in fine grained soils; bituminous materials seal the Voids between small soils clods and keep soil away from coming in direct contact with water; thus, inherent properties of the soil are retained. In the case of coarse-grained soil. Individual particles get with a very thin firm of bituminous material and thus import binding property to the soil. However, bitumen stabilization does not improve the strength significantly.

Expansive Nature of Black Cotton Soil:

Black cotton soil exhibits high expansiveness, primarily due to its high clay content and mineral composition. When exposed to moisture variations, the soil undergoes significant volume changes, leading to heaving during wet periods and settlement during dry periods (Saranya et al., 2020).

Mechanisms of Soil Movement:

The expansive nature of black cotton soil results from the absorption and release of water, causing changes in soil volume. During wet conditions, the soil absorbs water and swells, exerting uplift pressures on foundations. Conversely, during dry periods, the soil loses moisture and shrinks, leading to settlement and potential structural damage (Kumar et al., 2021).

Challenges for Foundations and Buildings:

Foundations and buildings constructed on black cotton soil are susceptible to various issues, including foundation movement, cracks in walls and floors, uneven settlement, and structural instability. These problems can compromise the structural integrity of buildings and pose safety hazards to occupants (Sethi et al., 2022).

Mitigation Strategies:

Several mitigation strategies can be employed to address the risks associated with black cotton soil:

- Proper Site Investigation: Conduct comprehensive site investigations, including soil testing and geotechnical surveys, to assess soil properties and identify potential hazards.
- Foundation Design: Designing foundations with appropriate measures to accommodate soil movement, such as deep foundations, pile foundations, or raft foundations.
- Moisture Control: Implementing moisture control measures, such as proper drainage systems, waterproofing, and foundation moisture barriers, to minimize soil moisture fluctuations.
- Structural Monitoring: Regular monitoring of foundations and buildings to detect early signs of distress or movement and take timely corrective actions (Mondal et al., 2019).

Best Practices for Construction on Black Cotton Soil:

- Engage Experienced Professionals: Involving experienced geotechnical engineers and structural designers in the construction process to develop appropriate foundation designs and construction techniques.
- Use of Suitable Construction Materials: Select construction materials that are compatible with the expansive nature of black cotton soil, such as flexible jointing materials and moisture-resistant finishes.
- Compliance with Building Codes: Adhering to relevant building codes, standards, and regulations governing construction on expansive soils to ensure structural safety and compliance with legal requirements (Singh et al., 2023).

Black cotton soil presents significant challenges to the stability and safety of foundations and buildings due to its expansive nature. Understanding the mechanisms of soil movement and implementing appropriate mitigation strategies are essential for mitigating risks and ensuring the long-term stability of structures constructed on black cotton soil.

MATERIALS AND METHODS

Coconut Shell Ash.

Coconut shell used was collected from Gombe Central new Market, Gombe Local Government area in Gombe state. After careful survey the sample collected were ensured that it is properly dry and neat. The sample was then burnt in industrial design program Kiln of Tatari Ali Polytechnic Bauchi at

controlled temperature of 700°c and also opened burry. The ash collected was allowed to cool before grinded at Ashaka cement factory Gombe state, before allowed to pass through 200-micro sieve.

Black Cotton Soil.

The black cotton soil used was collected from baure village in Yamaltu-Deba local Government area of Gombe state. After careful survey, suitable pit was selected and excavation made to depth of about 1.5 to 2m in which disturbed sample were collected. Cluster of them were broken down into sample particles for ease maxing the minimized surface area contact during mixing laboratory test like Atterberg limit, particles size distribution hydrometer analysis computation, specific growth test, California bearing ratio (CBR) were conducted on the black cotton soil sample to ascertain the integrity.

Water

The water used for making test or carrying out the test was tap water and is fit for drinking as such it meets the regulation government the mix properties.

RESULTS AND DISCUSSION

Table 1: Properties of Natural black cotton soil.

Properties	Values
Specific Gravity (G_S)	2.69
Natural moisture content (%)	5.3
Liquid Limit (%)	38.4
Plastic Limit (%)	17.8
Plasticity Index (%)	20.6
Shrinkage limit (%)	12.3
% Passing Sieve, No 10 (2mm)	98.06
% Passing Sieve, No 200 (0.075mm)	60.68
Colour	Dark grey
American Association of State Highway and Transportation Officials (AASHTO).	A-7-5
Unified Soil Classification System (USCS).	CL
Maximum Dry Density (MDD) (MN/m^2)	1.52
Optimum Moisture Content (OMC) (%)	15.6

Table 2: Physical Properties of coconut shell ash Stabilized black cotton Soil

Properties	**5% CSA**	**10% CSA**	**15%CSA**
Liquid Limit (%)	40.22	41.64	42.6
Plastic Limit (%)	24.2	23.2	25.3
Plasticity Index (%)	16.02	18.45	17.3
Shrinkage limit (%)	13.11	10.77	11.03
Specific Gravity (G_S)	2.5	2.41	2.21
Maximum Dry Density (Mg/m^3)	1.57	1.63	1.54
optimum moisture content (%)	16.5	18.2	20.3
California bearing ratio	17.1	21.6	16.4

Table 3: Oxide Composition of Coconut shell ash

Compound	Proportion (%)
SiO_2	7.047
Al_2O_3	3.952
Fe_2O_3	2.874
CaO	47.345
MgO	3.203
SO_3	3.238
K_2O	24.750
P_2O_5	2.180
Cl	2.083
PURITY	96.669

Compaction Test

The stabilization of black cotton soil using coconut shell ash has shown an increase in the MDD of the stabilized soil with increase in the percentage of CSA to 10% then a steep decrease recorded at 15% CSA. The MDD increases while the OMC decreases with the introduction of coconut shell ash content. The increase in MDD can be attributed to the Cementous effect of the coconut shell ash with lower specific gravity replacing the soil particles with a higher specific gravity. Increment in OMC could have been as a result of increasing demand for water by various cations and the clay mineral particles to undergo hydration reaction within the soil matrix

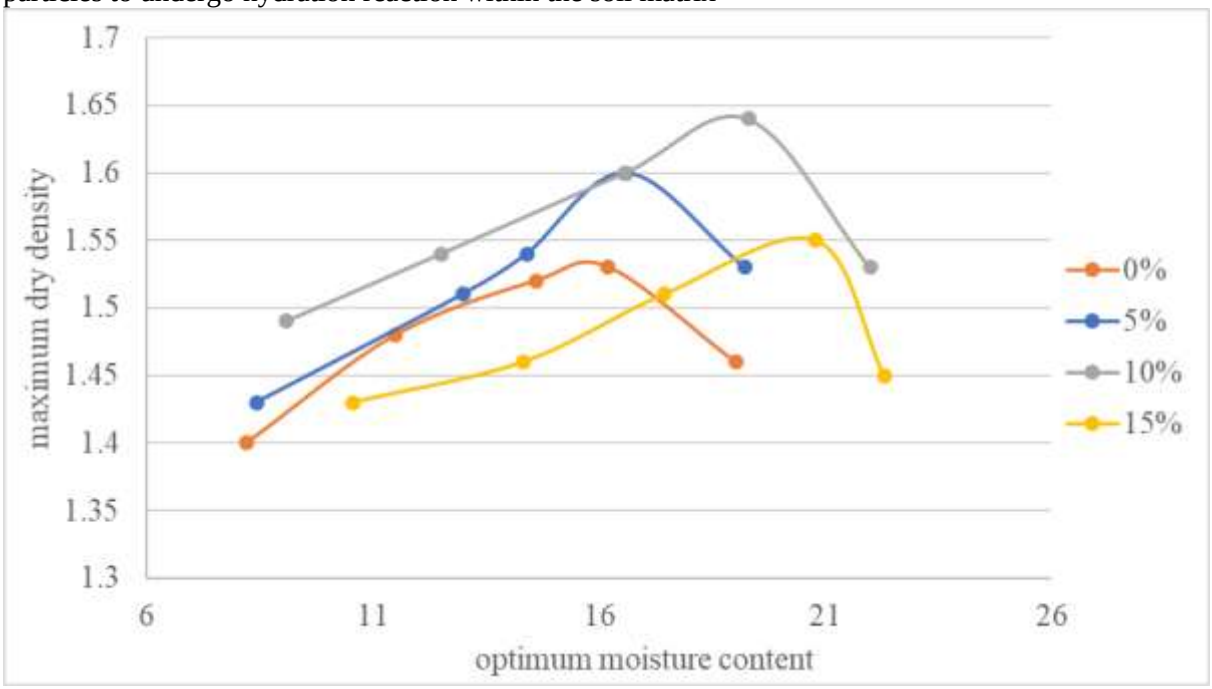

Figure 1: Compaction curve of various percentage of CSA content.

Unconfined Compressive Strength

The result of the unconfined compressive strength test on expansive soil with various percentages of coconut shell ash shows an increase of 13.2% at 5% CSA during 7 days curing and about 24.30% at 10% CSA and increase to 31.56% at 28days showing that there is an increase in in compressive strength of the sample soil with increase in percentage of CSA at 10% and in 28 days curing duration.

% Of CSA	7 DAYS	14 DAYS	28 DAYS
0	207.32	231.21	240.95
5	238.94	251.43	264.32
10	261.57	280.11	301.76
15	214.66	221.77	235.43

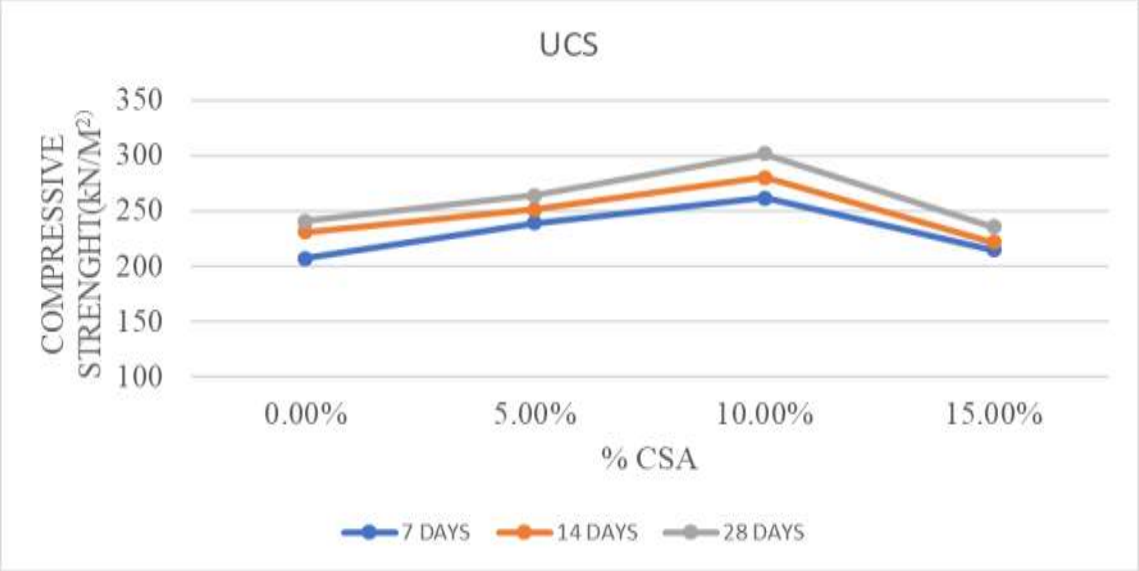

Figure 2: graph of compressive strength against percentage CKD content

CONCLUSION

The utilization of coconut shell ash as a soil stabilizing agent holds promise for improving the geotechnical properties of black cotton soil in Gombe State. Recent studies have demonstrated the effectiveness of CSA in reducing soil expansiveness, enhancing strength, and promoting durability. By harnessing the potential of CSA, sustainable soil stabilization practices can be promoted, contributing to the development of resilient infrastructure in Gombe State.

This research work made a comprehensive investigation of the effectiveness of coconut shell ash on geotechnical properties of black cotton soil. Different laboratory tests among which are basic geotechnical tests such as compaction and strength tests were performed on both the control soil sample and the stabilized soil samples. Laboratory experiment such as Atterberg limits, compaction and unconfined compression tests were performed on the natural, control and the stabilized soil samples and results were obtained. After the investigation into the effects of coconut shell ash on the properties of the black cotton soil following conclusions were drawn;

1. The black cotton soil used for the study was classified as A – 7 – 5 (very poor soil) in accordance with (AASHTO), low plasticity Clay (CL) in accordance with (USCS), and as moderate swell potential BCS according to NBRRI.
2. The maximum dry density increases with increase in percentage coconut shell ash content while the optimum moisture content also increases with increase in coconut shell ash content.
3. There was a general variation in the shrinkage with increase in coconut shell ash observed for the stabilized soil thus reflecting an improvement in the Cementous properties of the soil.

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