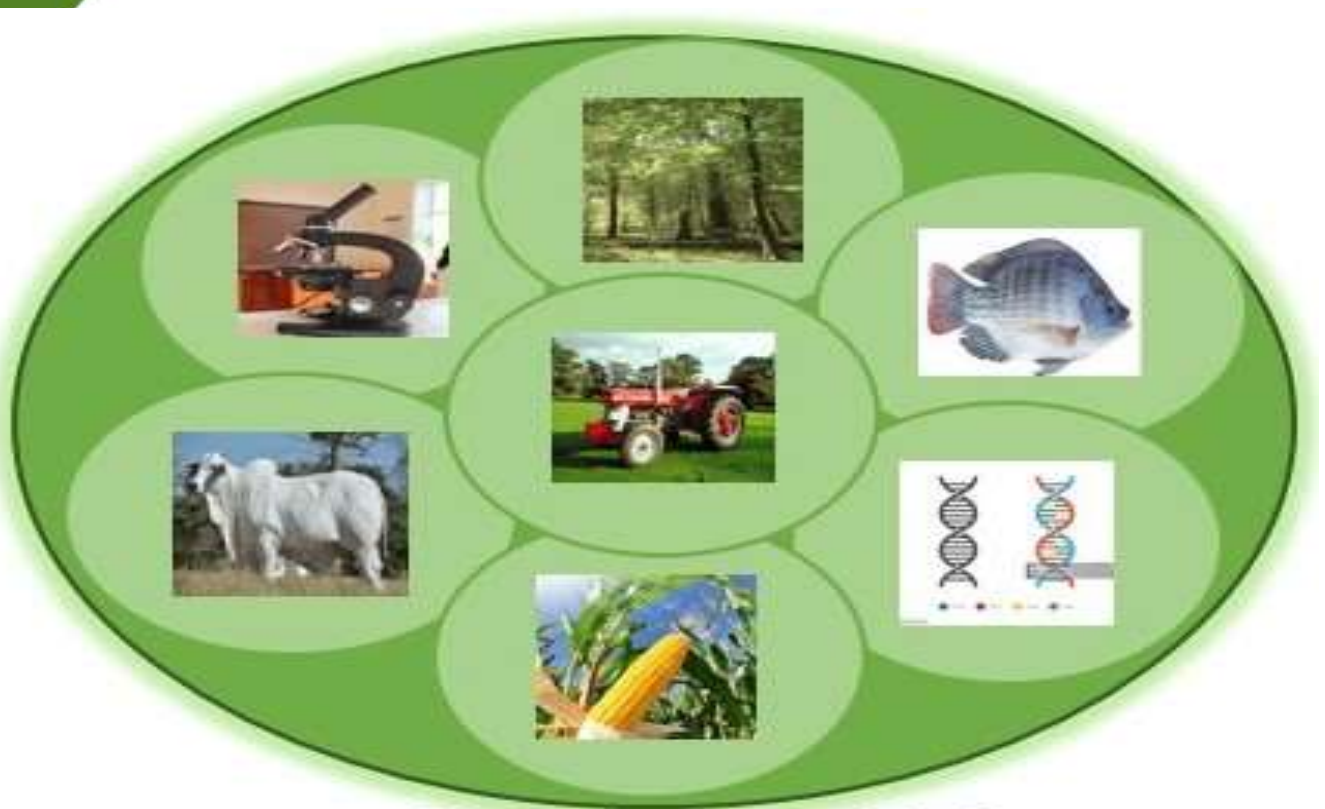




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## ASSESSMENT OF GEOTECHNICAL PROPERTIES OF LATERITIC SOIL STABILIZED WITH RICE HUSK ASH FOR ROAD APPLICATION: A REVIEW

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### ABSTRACT

The need for sustainable and cost-effective materials for road construction has led to better attention in the use of agricultural waste products for soil stabilization. This review examines the geotechnical properties of lateritic soil modified with Rice Husk Ash (RHA), focusing on its appropriateness for road applications. It discusses the effects of RHA on key soil properties like compaction characteristics, Atterberg limits, California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS), and permeability. The review findings from various studies indicate that RHA significantly improves the strength and stability of lateritic soils, making it a promising stabilizing agent in pavement construction.

**Keywords:** Laterite, soil stabilization, rice husk ash, road construction, agricultural waste products.

### Introduction

Lateritic soil is one of the most widely distributed residual soils in tropical and subtropical regions, with huge parts of Africa, South America, and Southeast Asia. In countries like Nigeria, lateritic soils are abundantly used as subgrade and subbase materials in road construction due to their local availability and ease of access. However, these soils often exhibit undesirable geotechnical properties like high plasticity, poor workability, low strength, and high susceptibility to moisture, making them inadequate for direct use in pavement layers without modification or stabilization.

Stabilization of soil is a fundamental geotechnical approach used to enhance the engineering performance of weak soils.

Traditionally, chemical stabilizers, for instance, cement, lime, or bitumen, have been used to enhance the strength of lateritic soils. While effective, these conventional stabilizers are associated with high costs and significant environmental impacts, particularly related to energy consumption and CO<sub>2</sub> emissions during production. In response to the global demand for sustainable construction practices and environmental protection, attention has shifted toward the use of agro-industrial by-products such as Rice Husk Ash (RHA) as alternative or supplementary stabilizing agents.

Rice husk is an abundant agricultural waste generated from rice milling. When burned under controlled conditions, it produces rice husk ash, a pozzolanic material rich in silica (SiO<sub>2</sub>). The high silica content enables RHA to

react with calcium hydroxide in the presence of water to form calcium silicate hydrate (C–S–H) gel, a binder responsible for strength development in stabilized soils. Thus, RHA has been recognized as a viable additive for improving soil properties, particularly in geotechnical and pavement engineering.

Incorporating RHA into lateritic soils has been shown to enhance key properties such as the CBR, UCS, and shear resistance, while reducing plasticity and permeability. Moreover, the use of RHA contributes to waste recycling, cost reduction, and environmental sustainability, aligning with global efforts to promote green infrastructure and circular economy principles.

This study presents a detailed review and assessment of the effects of RHA on the geotechnical properties of lateritic soil, focusing on its application in road construction. It examines the changes in Atterberg limits, compaction characteristics, strength parameters, and durability with

varying RHA content and curing periods. The study also discusses the optimum RHA dosage, environmental and economic benefits, and potential challenges associated with field application. The goal is to provide insights into the suitability of RHA as a sustainable and cost-effective stabilizing agent for road construction in regions where lateritic soil is prevalent.

### **Characteristics of Lateritic Soil**

Lateritic soils (Figure 1) are formed in hot and humid climatic conditions through the intense weathering of parent rocks (Ola, 1982). They are rich in iron and aluminum oxides and generally exhibit high plasticity, low strength, and poor workability (Ola, 1982). These properties necessitate stabilization techniques to enhance their performance in engineering applications (Ola, 1982). Typical geotechnical characteristics include high natural moisture content, high plasticity index, and low CBR values (Ola, 1982).



Plate 1. Sample of Lateritic soil

### Properties and Pozzolanic Activity of Rice Husk Ash (RHA)

An RHA is obtained from the protected burning of rice husks, which are agricultural residues. RHA contains a high percentage of silica (up to 90%) and exhibits pozzolanic behavior, reacting with calcium hydroxide

with the availability of water to make cementitious composites. The specific surface area and fineness of RHA (Figure 2) influence its reactivity and stabilization potential (Gautam, Batra and Singh, 2019; Givi, A. N., Abdul Rashid, S., Abdul Aziz, F. N. & Mohd Salleh, 2010).



Plate 2. Sample of RHA

### Influences of RHA on Geotechnical Properties of Lateritic Soil

#### Atterberg Limits

**Atterberg limits** are fundamental tests used in soil mechanics to define the saturated water contents of fine-grained soils. These limits are: (i) **Liquid Limit (LL)** which is the water content at which soil variations from a plastic to a liquid state. (ii) **Plastic Limit (PL)** is the water content at which soil variations from a semi-solid to a plastic state. (ii) **Plasticity Index (PI)** is the variance between the liquid limit and the plastic limit ( $PI = LL - PL$ ), representing the variation of moisture content over which the sample of soil remains plastic. Incorporating **RHA** into lateritic soils reduces their Atterberg limits, particularly the **plasticity index**, which improves the soil's

behavior under varying moisture conditions (Basha *et al.*, 2005). This makes RHA-stabilized soils more suitable for subgrade and base layers in road construction due to improved **workability, reduced shrink-swell potential, and enhanced long-term stability** (Basha *et al.*, 2005).

#### Compaction Characteristics

Compaction is the process of mechanically densifying soil to increase its dry density and strength, typically by reducing the air voids (Onyelowe, 2012). The incorporation of RHA into lateritic soils **reduces** Maximum Dry Density (MDD) and **increases** Optimum Moisture Content (OMC) due to the lightweight and porous nature of RHA. Despite the reduction in MDD, **strength and durability**

can improve through pozzolanic reactions, especially when combined with curing or chemical additives like lime or cement (Onyelowe, 2012).

### **California Bearing Ratio**

The **CBR** is a key geotechnical parameter used to evaluate the **strength of subgrade, subbase, and base course** materials for road construction (Olowofoyeku *et al.*, 2021). It is defined as the ratio of the force per unit area required to penetrate a soil mass to that required for standard crushed stone, expressed as a percentage (Olowofoyeku *et al.*, 2021). A **higher CBR is a stronger soil** (more suitable for pavement layers). A **typical CBR for untreated lateritic soil** ranges from 5 to 10% (often inadequate for heavy traffic) (Olowofoyeku *et al.*, 2021). The **CBR of lateritic soil increases significantly** when stabilized with **RHA**, especially at optimal content (6 – 10%) and with adequate curing (Olowofoyeku *et al.*, 2021). This makes RHA a viable, low-cost option, enhancing the load-bearing capacity of subgrades and a sustainable material for improving subgrade performance in road construction projects (Olowofoyeku *et al.*, 2021).

### **Unconfined Compressive Strength (UCS)**

A **UCS** is a portion of the load-bearing capacity of **cohesive soils under uniaxial compression without lateral support**. It is widely used to assess the **shear strength** of soils, especially when stabilized for **road subgrades, embankments, or earth structures**. UCS increases with RHA stabilization due to pozzolanic reactions, especially with curing time. Enhanced strength is observed with 7 – 28 days of curing (Muntohar and Hantoro, 2000). RHA significantly improves the UCS of lateritic soil, especially at **optimum content (6 – 10%)** and with proper **curing (7 – 28 days)**. This strength gain is due to pozzolanic cementation

and densification, making RHA-stabilized soils more suitable for **road construction and earthworks**. However, excess RHA beyond the optimal range may reduce strength due to poor bonding and excessive porosity.

### **Permeability:**

**Permeability** refers to the soil's ability to **transmit water** through its pores. It is expressed as the **coefficient of permeability (k)**, usually in **cm/s or m/s**. In road and geotechnical engineering, permeability affects: (i) **drainage capacity**, (ii) **soil erosion susceptibility**, and **soil strength and durability under wet conditions (Sutas, Mana and Pitak, 2012)**. Lateritic soils often have **moderate to high permeability**, especially when loose or unbound, which can be problematic for **pavement subgrades and embankments (Sutas, Mana and Pitak, 2012)**. Incorporating **RHA** into lateritic soil **reduces its permeability** by filling voids and promoting cementitious bonding through pozzolanic reactions (**Sutas, Mana and Pitak, 2012**). This results in improved water resistance, enhanced long-term performance, and better durability under wet conditions, making it ideal for road subgrades and embankments in tropical environments (**Sutas, Mana and Pitak, 2012**).

### **Optimum RHA Content and Curing Time**

When stabilizing **lateritic soil** using **RHA**, it's critical to identify: (i) the **optimum percentage** of RHA that maximizes soil performance without compromising strength or workability and the **curing time** necessary for **pozzolanic reactions** to effectively improve soil properties like **strength, durability, and permeability**. Using too little RHA results in **insufficient stabilization**, while too much leads to **wasted material, increased porosity, and reduced performance (Assiamah et al., 2022)**. The

**optimum RHA content** for lateritic soil stabilization typically lies between **6% and 10%**, while the **optimal curing time** ranges from **14 to 28 days**. Within this window, RHA maximally enhances soil properties through pozzolanic reactions, making the soil more appropriate for **road subgrades, embankments, and pavement layers**. Moreover, the optimal performance of RHA-stabilized lateritic soil is usually achieved at 6 – 10% RHA content, with curing periods ranging from 7 to 28 days. Beyond these limits, strength gains become marginal or may decline due to excess ash or incomplete pozzolanic reactions (Assiamah *et al.*, 2022).

#### **Environmental and Economic Benefits**

Stabilizing lateritic soil with RHA offers several **environmental and economic** advantages, especially in the context of **sustainable road construction and green engineering practices**. The use of RHA in soil stabilization is environmentally friendly and cost-effective. It reduces the demand for industrial binders like cement and lime, conserves natural resources, and diverts agricultural waste from landfills. This contributes to sustainable development goals and green construction practices (Sata, Jaturapitakkul and Kiattikomol, 2007).

#### **Conclusion**

The soil stabilization of lateritic incorporating **RHA** has emerged as a sustainable and cost-effective solution for enhancing subgrade and subbase materials in road construction, particularly in tropical regions where lateritic soils and rice husk are abundantly available. Based on the reviewed literature and laboratory findings, the following general conclusions can be forwarded:

- i. Incorporating RHA into lateritic soil leads to substantial enhancement in key engineering properties such as **reduced**

**plasticity, improved strength, better compaction characteristics, and improved CBR**. These improvements make the stabilized soil more appropriate for utilization in road pavement layers.

- ii. The high silica content of RHA reacts with calcium hydroxide in the soil to make **cementitious compounds**, notably calcium silicate hydrate (C–S–H), which significantly supports **strength gain** over time. This reaction is time-dependent and improves with curing.
- iii. The **optimum RHA content** for most lateritic soils lies between **6% and 10% by weight**, depending on soil type. A **curing period of 7 to 28 days** is necessary for significant pozzolanic activity and performance gain. Excess RHA may dilute the soil matrix and reduce effectiveness.
- iv. RHA fills soil pores and reduces permeability, minimizing water ingress and making the soil more resistant to volume changes caused by moisture fluctuations.
- v. The use of RHA promotes **waste recycling**, reduces the need for expensive and carbon-intensive traditional stabilizers like cement and lime, and supports **environmentally friendly construction**. It also reduces construction costs, particularly in rural and resource-constrained settings.
- vi. RHA-stabilized lateritic soils meet technical specifications for **subgrade, subbase, and in some cases base layer** applications. The improvement in bearing capacity and durability makes them suitable for **low- to medium-traffic roads**, especially in developing regions.

The use of RHA in stabilizing lateritic soils provides a **practical, sustainable, and eco-friendly alternative** in road construction. With proper mix design and quality control, RHA can play a vital role in improving rural road

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