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Rice Husk Ash as a Partial Cement Substitute in Stabilised Laterite Blocks for Sustainable Non-Load-Bearing Wall Construction

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Abstract

This study examines the viability of partially replacing ordinary Portland cement (OPC) with rice husk ash (RHA) in stabilised laterite blocks for sustainable non-load-bearing wall construction applications. Lateritic soil was stabilised with 6% and 10% cement by dry weight, whereas cement was substituted with RHA at increments of 5%, ranging from 0% to 40%. Compressed blocks were fabricated via a manual press and subjected to curing for 7, 28, and 90 days. Tests for density, compressive strength, and water absorption were carried out in compliance with applicable regulations. The findings indicate that while compressive strength generally declined with increasing RHA level beyond 15–20%, it rose with curing age. Blocks stabilised with 10% cement had greater strengths (0.59–1.58 N/mm²) than blocks stabilised with 6% cement (0.46–0.78 N/mm²). Water absorption increased with higher RHA replacement due to increased porosity, while density decreased because of the lower specific gravity of RHA. Regression analysis confirmed that curing age, cement content, and RHA level significantly influence strength development with accuracy of $R^2 = 0.954$. Although the strengths obtained are below the 3.5 N/mm² requirement for load-bearing masonry, the results indicate that laterite blocks with 10–20% RHA replacement are suitable for non-load-bearing walling applications, offering environmental benefits through reduced cement usage and agricultural waste valorisation.

Keywords: Rice Husk Ash, Laterite Blocks, Compressive Strength, Water Absorption, Cement Replacement, Regression Prediction Model.

1.0 Introduction

The manufacturing of ordinary Portland cement (OPC) alone accounts for about 7–8% of global CO_2 emissions, making the building sector one of the biggest users of natural resources and a significant contributor to greenhouse gas emissions. In order to lessen the environmental impact of building materials and improve affordability, especially in developing nations where resource constraints are severe, researchers have been inspired to look into sustainable substitutes and additional cementitious materials made from agricultural wastes [1-2]. Rice husk ash (RHA), which is produced by carefully burning rice husk trash, has a high pozzolanic activity and is rich in amorphous silica. According to recent research, finely ground RHA can efficiently react with calcium hydroxide to produce more calcium silicate hydrate (C–S–H), improving the strength of cementitious systems and decreasing their permeability [3-4],[2]. More recently, Commeh et al. [5] demonstrated that the mechanical performance and sustainability of cementitious blends are significantly enhanced when rice husk waste is processed into both biochar and pozzolanic ash. This highlights the adaptability of rice husk derivatives as low-carbon binders and reinforces their potential for wider application in construction materials.

In addition to traditional concrete, RHA has been investigated for use in soil-based and earthen building materials, which are gaining wider recognition for their low embodied energy and suitability for affordable housing. Due to their availability and affordability, earth blocks made from lateritic soils are frequently employed in tropical areas; nevertheless, their intrinsic weakness and poor durability restrict their wider applicability [6-7]. Although cement stabilisation is frequently used to boost performance, it has a greater financial and environmental impact. Therefore, replacing some of the cement with RHA presents a viable way to improve sustainability while preserving acceptable engineering qualities.

According to recent studies on SCM-modified earth materials, when agro-wastes are applied at the right doses, they can enhance microstructure and durability. Guettala et al. [8] found that lightweight inclusions affect the density and strength of crushed earth bricks, while Bamogo et al. [9] reported improved water resistance of earth renders utilising organic waste additives. Research on RHA-stabilised soils has revealed moderate strength gains and decreases in flexibility, especially at low to moderate replacement levels [3],[1].

However, there have been few systematic investigations on the usage of RHA as a partial cement substitute in stabilised laterite blocks for walling units, and the majority of contemporary RHA research has concentrated on concrete and pavement applications. Furthermore, there is still a lack of knowledge regarding the combined effects of cement content, RHA replacement level, and curing age on the mechanical and absorption behaviour of lateritic blocks, especially in tropical environments, despite recent reviews highlighting the sustainability benefits of RHA and earth material stabilisation [2],[7],[10]. It is also rare to specify clear performance constraints, particularly in relation to structural applicability.

Thus, this study examines the effects of partially substituting rice husk ash for cement on the density, compressive strength, and water absorption of stabilised laterite blocks that have been cured for 7, 28, and 90 days. The goal is to determine the ideal RHA replacement level that strikes a compromise between environmental sustainability and mechanical performance, as well as to evaluate whether these blocks are appropriate for non-load-bearing walling applications. This work promotes the production of locally obtained, environmentally friendly building materials for cheap housing in developing regions by embracing recent advancements in the usage SCM-Modified materials [11]. Furthermore, the importance of incorporating SCMs is consistent with recent findings in pavement materials, where enhanced microstructural densification and physicochemical interactions have been shown to improve fatigue resistance and promote the restoration behaviour in bituminous materials [12]. This highlights the broader potential of SCM-modified systems to enhance durability across both cementitious and bituminous-based construction materials.

2.0 Materials and properties

2.1 Rice husk ash (RHA)

The rice husk used in this study was provided by Achala Isuani Rice Mill in the Awka North Local Government Area of Anambra State. To lower its moisture level and get it ready for controlled burning, the raw husk was first allowed to dry outside. Following drying, it was burned under regulated conditions at 500°C in a muffle furnace to produce ash rich in amorphous silica, which increases its pozzolanic reactivity [13]. In order to increase its efficacy as a partial substitute for cement in the stabilised laterite block mix, the resultant ash was then sieved through a 75-µm screen to remove coarse particles and improve fineness. Figure 1: Bio MaterialsFigure 1 shows two types of bio-

based materials: **(a)** raw rice husk waste, and **(b)** rice husk ash, used as a pozzolanic material.



(a) Rice husk waste **(b)** Rice husk ash

Figure 1: Bio Materials

2.1.2. Physical properties of RHA

The physical properties of RHA are believed to be affected by its specific gravity, mean particle size, and Blaine fineness. These properties are also believed to affect how RHA is used for structural concrete due to its impact on the mechanical and durability properties. Research investigations have revealed that the specific gravity of RHA ranges from 2.05 to 2.53, which is comparatively lower than that of the specific gravity of ordinary Portland cement, which is between 3.10 and 3.14 [13-15]. **Table 1** shows the physical properties of the RHA investigated.

***Table 1**: Physical Properties of Rice Husk Ash (RHA).*

Porosity	Specific gravity	Particle size	Bulk density	Fineness
High	2.04	6.00	2.11	94

2.1.3. Chemical composition of RHA

Table 2 shows the comparison of the chemical composition of rice husk ash (RHA) and ordinary Portland cement (OPC) obtained from chemical analysis. Calcium Oxide (CaO) constitutes the predominant component of Ordinary Portland Cement (OPC), at 63.85%, whereas Silicon Dioxide (SiO_2) is the principal component of Rice Husk Ash (RHA), with 76.95%, signifying its high silica concentration. Al_2O_3 (Aluminium Oxide)

and Fe_2O_3 (Ferric Oxide) are found in small quantities, with RHA having much lower values than OPC. The result is in line with those obtained by several researchers who studied RHA [13-14]. During the hydration of Ordinary Portland Cement (OPC), calcium silicate phases interact with water to produce calcium–silicate–hydrate (C–S–H) gel and calcium hydroxide (CH), as indicated:

$$2(3CaO{\cdot}SiO_2) + 6H_2O \rightarrow 3CaO{\cdot}2SiO_2{\cdot}3H_2O + 3Ca(OH)_2 \quad (1)$$

The amorphous silica (SiO_2) in rice husk ash combines with the released calcium hydroxide in the presence of water to produce more C–S–H gel via a pozzolanic reaction, as illustrated:

$$SiO_2 + Ca(OH)_2 + H_2O \rightarrow CaO{\cdot}SiO_2{\cdot}H_2O \quad (2)$$

This reaction can be succinctly represented using cement chemistry notation as:

$$S + CH + H \rightarrow C{-}S{-}H \quad (3)$$

where, $S = SiO_2$, $C = CaO$, $H = H_2O$ and $CH = Ca(OH)_2$.

Taking into account the fluctuating Ca/Si ratio of C–S–H, the generalised expression for the pozzolanic reaction is presented as:

$$xCa(OH)_2 + SiO_2 + (n{-}1)H_2O \rightarrow Ca_xSiO_2 + {}_x{\cdot}nH_2O \quad (4)$$

These reactions verify the high amorphous silica content of RHA, allowing it to function as an efficient supplemental cementitious material (SCM), which consumes the calcium hydroxide produced during OPC hydration and creates more C-S-H gel. As a result, RHA-blended cementitious systems have a denser microstructure, less portlandite, and better mechanical performance and durability.

Table 2: *Comparison of Chemical Composition of Rice Husk Ash (RHA) and Ordinary Portland Cement (OPC).*

Chemical compound	SiO_2	Al_2O_3	FE_2O_3	CaO	MgO	LOI	SO_3	K_2O	P_2O_5
RHA	76.95	0.73	0.76	0.78	1.65	-	0.14	1.30	2.63
OPC	20.49	4.98	3.11	63.85	2.57	-	2.69	0.99	-

Based on the results obtained, RHA has good pozzolanic activity due to its high porosity and silica content. Therefore, when properly ground, it improves durability, strengthens concrete, and promotes cement hydration. By reacting with calcium hydroxide (Ca $(OH)_2$), silica in RHA hydrates cement and produces additional hydration products that improve the mechanical and durability of concrete [4].

2.2 Lateritic Soil

The lateritic soil utilised in this investigation was acquired and processed in compliance with recognised geotechnical and materials testing criteria to assure uniformity, dependability, and appropriateness for block production. Figure 2 presents two forms of lateritic soil: **(a)** the naturally extracted lateritic soil in its raw state, and **(b)** the stabilised lateritic soil, which has been treated. The soil was extracted from a government-approved borrow pit in Awka, Anambra State, Nigeria, a region noted for mature laterite deposits with a high iron and aluminium content. Its viability as a base material for stabilised earth construction is influenced by these inherent qualities. In order to eliminate pebbles and guarantee a consistent particle size, the soil was air-dried, manually crushed, and then sieved through a 4.75 mm sieve after collection. This preparation increases stabilisation effectiveness and compaction. The principal structural component of the blocks is laterite, which, when mixed with cement and rice husk ash for sustainable walling applications, forms the main load-bearing matrix.



(a) Extracted lateritic soil **(b)** Stabilised lateritic soil

Figure 2: Lateritic Soil

2.2.1. Physical properties of Lateritic soil

The soil sample was subjected to the Atterberg Limits test in compliance with BS 1377: Part 2: 1990 [16], utilising the standard thread-rolling method for the Plastic Limit (PL)

and the Cone Penetrating method for the Liquid Limit (LL). These tests evaluate the consistency of the soil and how it responds to variations in moisture content, which are important markers of its engineering qualities, such as workability, compressibility, shear strength, and volumetric change susceptibility.

Table 3: *Results for Atterberg Limits*

LL (%)	PL (%)	PI (%)	LS (%)	Description
42.00	40.00	2.02	1.31	Lateritic soil (reddish)

The soil is categorised as an inorganic silt of low plasticity (ML) with its LL is less than 50% and its PI is extremely low, as shown in **Table 3**. The reddish colour, which is frequently linked to the presence of iron oxides, indicates that the soil is probably lateritic, with little clay mineral effect and low activity. This is consistent with the low plasticity values found, which show that the soil has steady engineering behaviour and little possibility for swelling or shrinking.

2.2.2. Chemical properties of Lateritic soil

Table 4 shows three clear peaks in the chemical constituents of the Lateritic soil: SiO_2 (52%), Al_2O_3 (12.5%), and Fe_2O_3 (7%). There are trace levels (<2%) of other oxides, such as CaO, TiO_2, and MgO. The result suggests that the lateritic soil is rich in silica, alumina, and iron, which is characteristic of tropical residual soils. High levels of alumina and iron promote cohesiveness and flexibility, but they also reduce stability unless combined with pozzolanic materials like RHA. The outcome demonstrates that the soil behaves cohesively and like clay, creating a natural binding matrix.

Table 4: *Comparison of Chemical Composition of Lateritic Soil and Ordinary Portland Cement (OPC).*

Chemical compound	SiO_2	Al_2O_3	FE_2O_3	CaO	MgO	LOI	SO_3	K_2O	P_2O_5
Laterite	52.20	12.53	7.05	0.37	0.89	-	0.05	0.20	0.26
OPC	20.49	4.98	3.11	63.85	2.57	-	2.69	0.99	-

3.0 Methods/ Experimental

3.1 Mix design

The mix consists of lateritic soil, water, ordinary Portland cement (OPC), and rice husk ash (RHA). The cement content was varied at 6%, and 10% by dry weight of soil, while RHA replaced cement at 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, and 40%. The experimental design explored 18 mix combinations to identify the optimum blend for strength and durability. In order to determine appropriate cement–RHA combinations for stabilising lateritic soil in compressed earth blocks, the mix design for this study was based on established international criteria based on prior research findings and preliminary laboratory trials. Walker [17] and Reddy [18] recommended cement concentrations of 6% and 10% (by dry soil weight) to achieve high strength and good dimensional stability in stabilised soil blocks. The decision to replace RHA levels up to 40% was based on studies highlighting its pozzolanic activity and potential as a supplementary cementitious material. Research by Habeeb [19] and Olutoge [6] found that mixes including RHA at up to 30–40% of the cement had increased strength, decreased water absorption, and improved durability. The chosen mix proportions offer a dependable and repeatable process for creating durable lateritic blocks because they are supported by research, literature, and preliminary testing. These results are presented in **Table 5**.

Table 5: *Mix Design Proportions of Cement and RHA for CSEB Production*

Cement Content (% of Soil)	RHA Replacement (% of Cement)	Effective Cement (% of Soil)	RHA (% of Soil)	Total Binder (% of Soil)
6	0	6.0	0.0	6.0
	5	5.7	0.3	6.0
	10	5.4	0.6	6.0
	15	5.1	0.9	6.0
	20	4.8	1.2	6.0
	25	4.5	1.5	6.0
	30	4.2	1.8	6.0
	35	3.9	2.1	6.0
	40	3.6	2.4	6.0
10	0	10.0	0.0	10.0
	5	9.5	0.5	10.0
	10	9.0	1.0	10.0
	15	8.5	1.5	10.0
	20	8.0	2.0	10.0
	25	7.5	2.5	10.0
	30	7.0	3.0	10.0
	35	6.5	3.5	10.0
	40	6.0	4.0	10.0

3.2 Stabilised lateritic block production

The Lateritic blocks produced were first batched and laterite was dry-mixed with the required amounts of stabilising binders (0–40% RHA replacement. The Optimum Moisture Content (OMC) was then reached by adding water. The manual press of the Nigerian Building and Road Research Institute (NBRRI), was used as a medium pressure of around 4 N/mm² to compact the mixture. The bulk density of the materials was used to determine the mould capacity, plus an extra 5% for losses. To ensure consistent distribution, the mix was put into the mould in three equal layers. It was then levelled and pressed using ten lever strokes, creating two blocks each time. Each block was appropriately labelled based on its mix proportion and had dimensions of 290 × 140 × 110 mm. The production was followed by air-curing the specimens 7, 28, and 90 days. The Figure 3 illustrates the materials and process of block production, showing

the mixing of stabilised lateritic soil with a binding agent, manual moulding of the mixture, and the resulting compressed blocks arranged for curing and drying.



Figure 3: Images of block production

3.3 Density test on stabilised lateritic blocks

The requirements of ASTM C 642 [20] were used to estimate the densities of the lateritic. At different curing ages, the densities of the samples were computed using varied percentages of the admixture content. The density demonstrated how their weight fluctuated or how dense they were as a result of their curing age and/or admixture percentages. The density of the samples was calculated by dividing their weight by their volume in kg/m^3, as indicated by:

$$\rho = \frac{M}{V} \tag{5}$$

3.4 Compressive test on the stabilised lateritic blocks

The strength development of compressed stabilised blocks at 7, 28, and 90 days of curing is measured by the compressive strength test. By dividing the highest load applied to the specimen during the test by its cross-sectional area, the compressive strength of the blocks will be determined, as indicated by equation 6. For each test, an average of three blocks will be crushed in order to minimise variability in the results and guarantee reliability.

$$F_s = \frac{Applied\ load\ (N)}{Cross-\ sectional\ area\ of\ specimen\ (mm^2)} \tag{6}$$

Load applied at 2.5 kN/sec until failure.

A calibrated universal testing machine (UTM) was used by applying axial force at a regulated rate until failure. To guarantee uniformity, the blocks were surface-dried and

their dimensional accuracy verified before testing. To evaluate the behaviour of the material, observations like the mode of failure and the pattern of cracking were also documented. Figure 4 shows the setup for the compressive strength test, where a block of dimensions 290 × 140 × 110 mm is placed between two hardened steel bearing plates and subjected to a vertical load to evaluate its structural capacity.

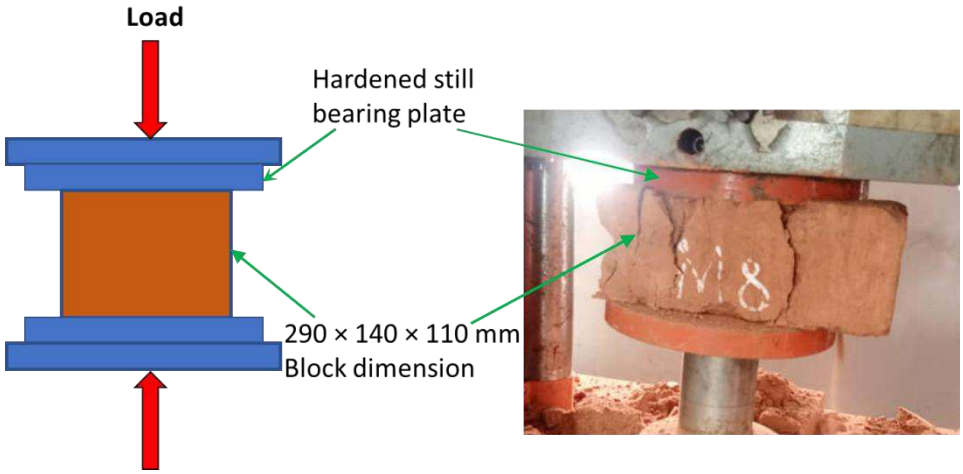


Figure 4: Loading arrangement for the Compressive test on blocks.

3.5 Water Absorption test on stabilised lateritic blocks

The water absorption test on stabilised laterite blocks measures the capacity of the block to absorb water, which gives information about its durability, pore structure, and ability to withstand moisture intrusion using standards like BS 5628 [21] and ASTM C140 [22]. In order to achieve a consistent dry weight, the block specimens are first oven-dried at 105–110°C. The dry weight (W_d) is recorded following cooling in a desiccator. After that, the dried blocks are fully immersed in room-temperature, clean water for 24 hours, to allow the pores of the specimen to absorb water. After immersion, the blocks are taken out, and surface water is wiped away with a moist cloth to avoid overestimating the weight of saturation (W_s). The water absorption (W_A) is calculated by:

$$W_A\,(\%) = \frac{W_s - W_d}{W_d}\, x100\% \qquad (7)$$

The acceptability of the result for wall building is assessed by comparing them with standard limits. Reduced absorption is an indication of increased weather resistance and durability.

4.0 Results and discussion

4.1 Density of the stabilised lateritic blocks

Figure 5 shows the density behaviour of the lateritic blocks stabilised with 6% and 10% at various Rice Husk Ash (RHA) replacement levels and curing ages (7, 28, and 90 days). The stabilised lateritic blocks studied have densities ranging from 1,570 to 1,886 kg/m³. This range falls within the acceptable density of lightweight stabilised lateritic blocks, which falls between 1,500 and 2,000 kg/m³ [8]. The result shows that densities decrease with increasing RHA content for all curing periods and stabilisation levels. Specifically, the 7-day samples show the highest density values, followed by the 28-day, then the 90-day samples. However, densities are consistently somewhat greater with the 10% laterite stabilisation (dotted lines) than with the 6% stabilisation (solid lines). These findings were consistent with those of Alam et al. [23], who discovered that the density of stabilised lateritic blocks stabilised between 4% to 10% dropped as the replacement level of sawdust ash and sugarcane bagasse ash increased. It was also observed that from 0–10% RHA, density drops moderately for both stabilisation levels, due to the lower specific gravity of RHA compared to the soil and cement. Densities vary somewhat between 10% and 25% RHA, which may be caused by pozzolanic processes momentarily enhancing compactness and fine RHA particles partially filling voids. Densities, however, tend to stabilise or progressively decrease above 25–30% RHA, suggesting that high RHA introduces more voids and less dense bonding. Also, 10% laterite stabilisation produced density values greater than 6% at almost all RHA levels and cure times. This implies that adding more stabiliser improves particle packing and bonding while decreasing pore gaps. The difference between 6% and 10% stabilisation is most apparent at lower RHA percentages (0–15%), and it becomes smaller with increasing RHA levels. The 28-day and 90-day samples have lower densities than the 7-day samples, which may be the result of ongoing hydration, pozzolanic reactions, progressive drying, and void formation, all of which somewhat lower bulk density.

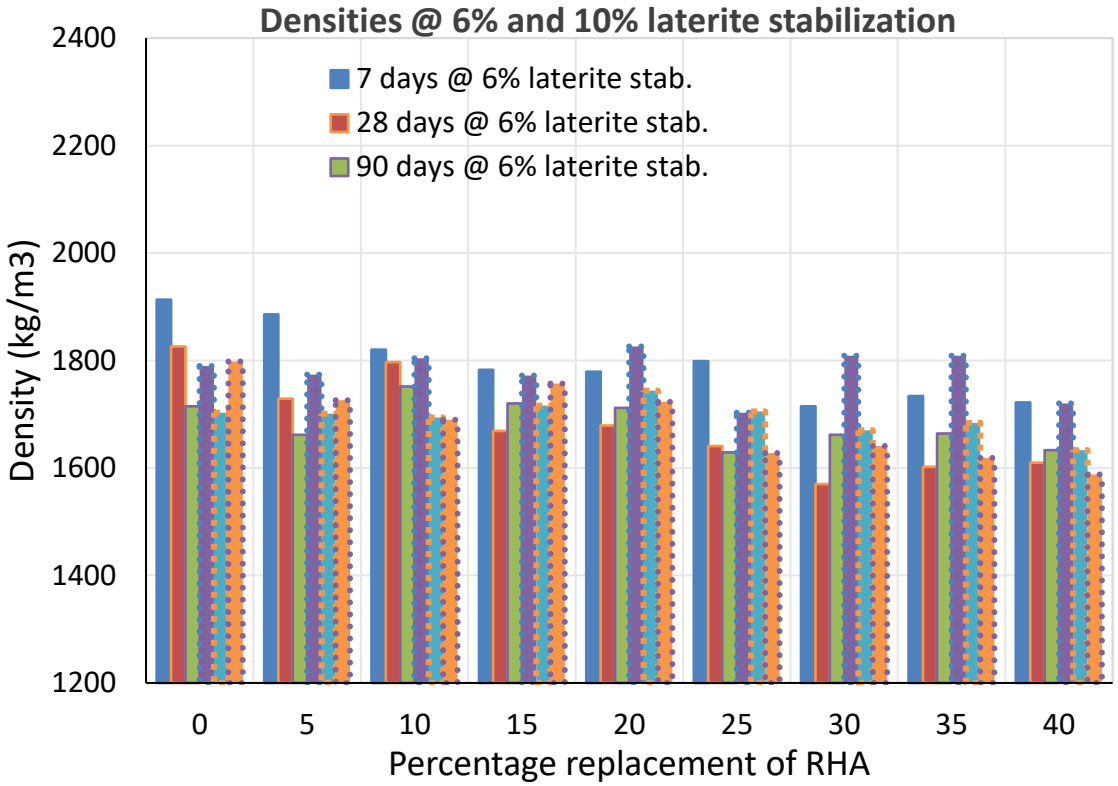


Figure 5: Density of lateritic blocks stabilised at 6% and 10% with cement and Rice Husk Ash (RHA) varies with different RHA replacement percentages, measured over 7, 28, and 90 days of curing.

4.2 Compressive strength of the stabilised lateritic blocks

Figure 6 shows how the compressive strength of laterite soil stabilised at 6% with cement and Rice Husk Ash (RHA) varies with different RHA replacement percentages, measured over 7, 28, and 90 days of curing. The Nigeria Building and Road Research Institute (NBRRI) [24] has suggested a minimum of 0.66–2.02 N/mm^2 for stabilised earth blocks used in non-load-bearing walls. For load-bearing walls, 3.5 N/mm^2 or greater is specified. For this study, the stabilised lateritic blocks have compressive strength ranging from 0.46 to 0.78 N/mm^3. However, in a similar study carried out by Sekhar and Nayak [25] at 6% stabilisation using Granulated blast furnace slag ash, 0.5 N/mm^2 was obtained. The results show that as the percentage of RHA increases, the compressive strength decreases. At 0% RHA (no replacement), the strength is at its greatest. Nonetheless, some variations were noted between 10% and 30% RHA, although there is no major strength improvement. Optimal RHA content was noticed around 20–30% replacement, where compressive strength does not decrease as much, possibly showing the best balance between pozzolanic activity and cement content. The

result also indicates that longer curing improves strength (noticeable from 7 to 28 days), which is consistent with pozzolanic materials that gain strength more slowly.

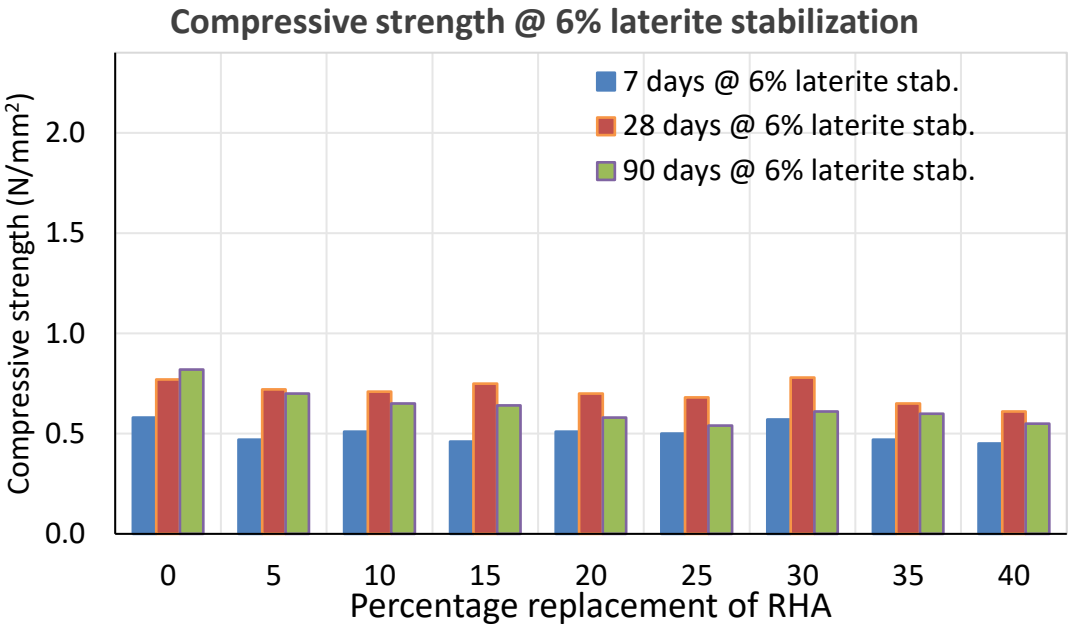


Figure 6: Compressive strength of laterite soil stabilised at 6% with cement and Rice Husk Ash (RHA) varies with different RHA replacement percentages, measured over 7, 28, and 90 days of curing.

Figure 7 shows how the compressive strength of laterite soil stabilised with 10% cement content and varying Rice Husk Ash (RHA) replacements changes over 7, 28, and 90 days of curing. The lateritic blocks studied at 10% stabilisation have compressive strength ranging from 0.59 to 1.58 N/mm^3. In a similar study carried out by Elavarasan et al. [26] at 10% stabilisation for lateritic blocks, where fly ash was used as a replacement, a compressive strength of 1.40 N/mm² Was Achieved. With Coal ash used as a replacement, changes at a similar level of stabilisation, 1.0 N/mm^2, were obtained [27]. while Hossain and Mol [28], by adding 10% volcanic ash, recorded a compressive strength of 1.2 N/mm^2. It can be seen that 15–20% is the optimal replacement rate for RHA. At this level, the long-term (90-day) strength remains good at 1.25 N/mm², but the 28-day compressive strength is at its peak at 1.5 N/mm².

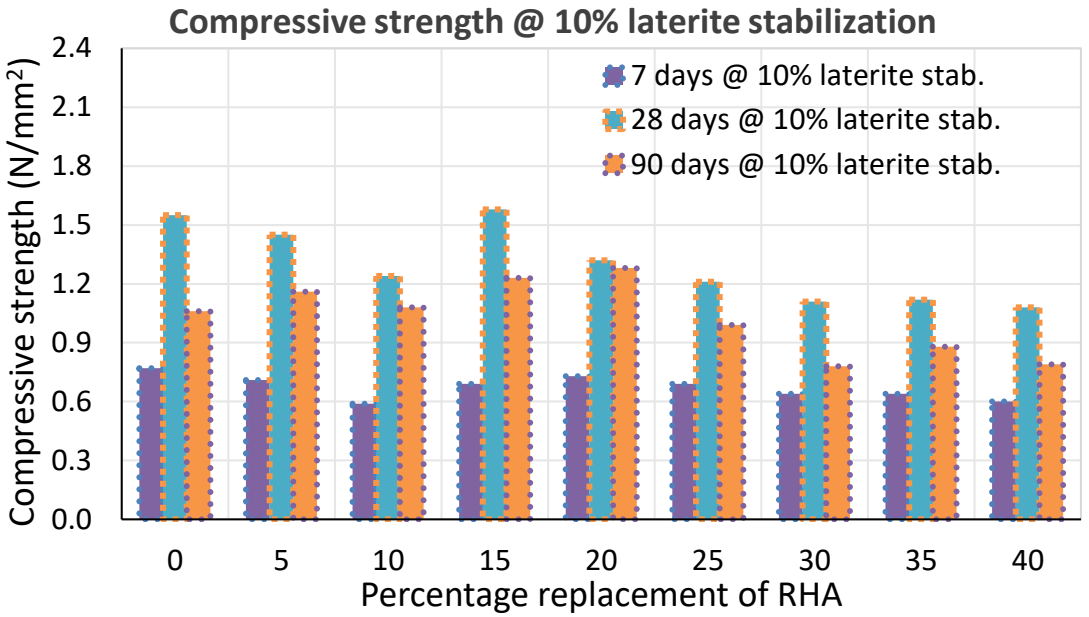
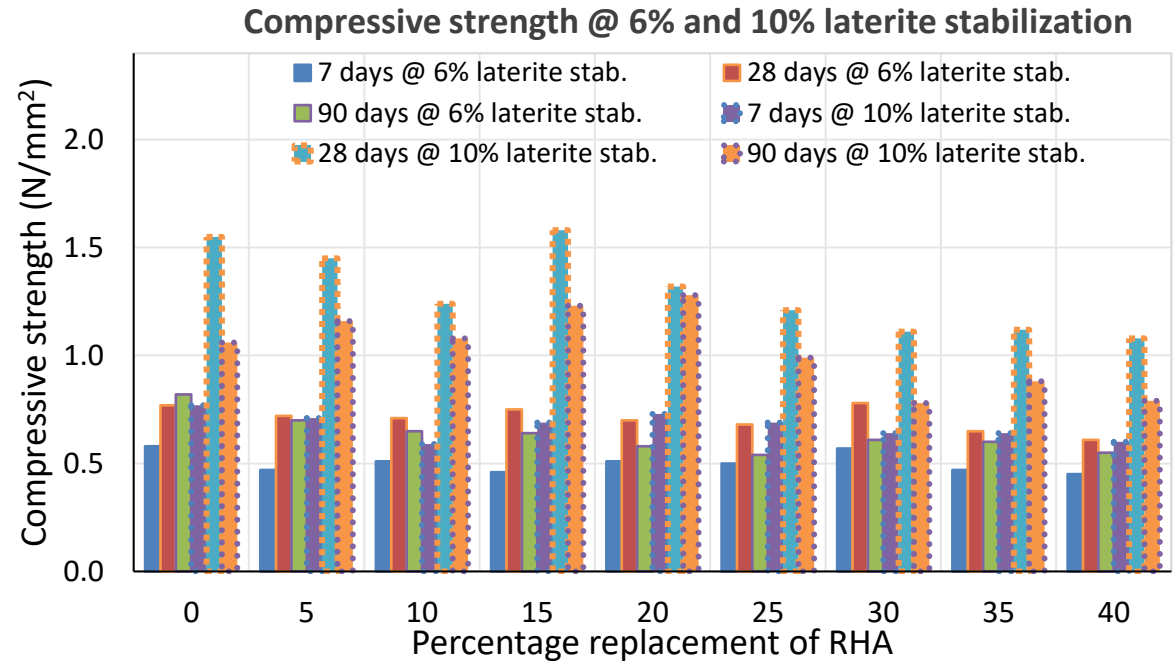
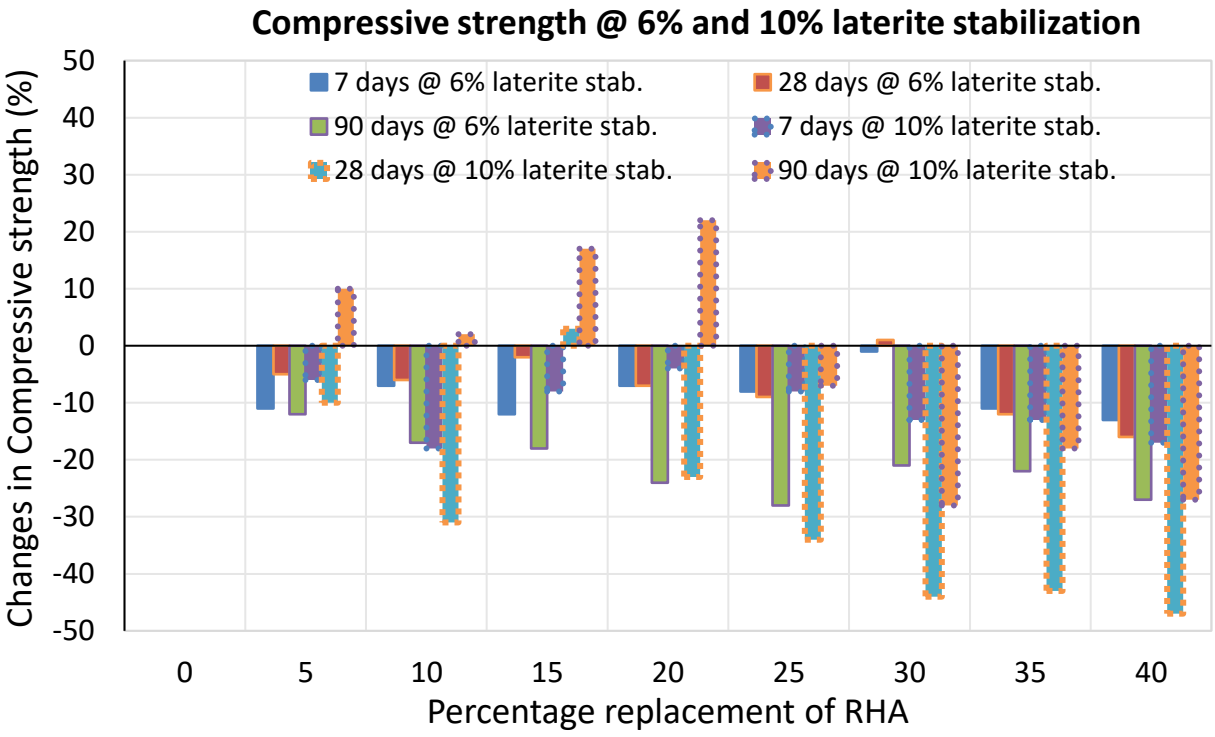


Figure 7: Compressive strength of laterite soil stabilised at 10% with cement and Rice Husk Ash (RHA) varies with different RHA replacement percentages, measured over 7, 28, and 90 days of curing.

Figure 11 shows how compressive strength varies with the percentage replacement of Rice Husk Ash (RHA) in cement for two levels of laterite stabilisation (6% and 10%), tested at 7, 28, and 90 days of curing. For both 6% and 10% laterite stabilisations, it is shown that strength typically increases with curing time. Nonetheless, compared to the 7-day samples, the 28-day and 90-day samples exhibit greater compressive strength. For the majority of RHA replacement percentages, samples with 10% laterite consistently exhibit better compressive strength than those with 6%. Although there are variations, strength tends to slightly decrease as RHA content increases. For example, there is occasionally a slight increase in strength at 15–20% replacement (particularly for 28 and 90 days at 10% laterite), which may be caused by the pozzolanic reaction of RHA.



(a)



(b)

Figure 8: Compressive strength of laterite soil stabilised at 6% and 10% with cement and Rice Husk Ash (RHA) varies with different RHA replacement percentages, measured over 7, 28, and 90 days of curing.

4.3 Statistical Modelling of the Compressive Strength

A multiple linear regression analysis was conducted to create a predictive model for determining the compressive strength of lateritic blocks stabilised with rice husk ash (RHA). The independent variables examined included RHA content (%), curing period (7, 28, and 90 days), and laterite content (6% and 10%). The modelling process aimed to create a statistically valid equation that could forecast compressive strength values within the experimental range and to assess the importance and impact of each variable.

4.3.1 Model Formulation

The 28-day curing condition was chosen as the reference category, and the curing period was handled as a categorical variable and encoded using dummy variables. As a result, the regression model is represented as:

$$\text{F} = \beta_0 + \beta_1\,(\text{Curing: 7 Days}) + \beta_2\,(\text{Curing: 90 Days}) + \beta_3(\text{RHA}) + \beta_4(\text{Laterite}) \quad (4)$$

Table 6 displays the estimated regression coefficients that came from the fitted model.

4.3.2 Coefficients of Regression

Table 6*: Compressive strength prediction regression coefficients*

Parameter	Coefficient	Interpretation
Intercept	0.20	Strength at laterite = 6%, 28-day curing, and 0% RHA
7 days curing	0.51	Strength reduction in comparison to 28-day curing
90 days curing	-0.03	Strength disparity with 28-day curing
RHA (%)	0.01	Decrease for every 1% rise in RHA content
Laterite (%)	0.22	Gain in strength per % increase in laterite

The final prediction model is obtained by substituting the coefficients into the regression equation:

$$\text{F} = 0.20 + 0.51\,(\text{Curing: 7 Days}) - 0.03\,(\text{Curing: 90 Days}) + 0.01(RHA) + 0.22(\text{Laterite}) \quad (5)$$

4.3.3 Performance of the Model

With a coefficient of determination [29,30] of $R^2 = 0.954$, goodness-of-fit statistics of the model demonstrated reasonable performance, indicating that the predictors account for around 95.4% of the variance in compressive strength. For material property prediction within the examined range, the root-mean-square error (RMSE) [30,31] of 0.152N/mm² is acceptable.

4.3.4 Strengths observed and predicted

All predicted compressive strengths of the experimental samples were then computed using the model, and the residuals (Observed − predicted) were computed [29,32]. Figure 9 presents an overview of the observed and predicted values.

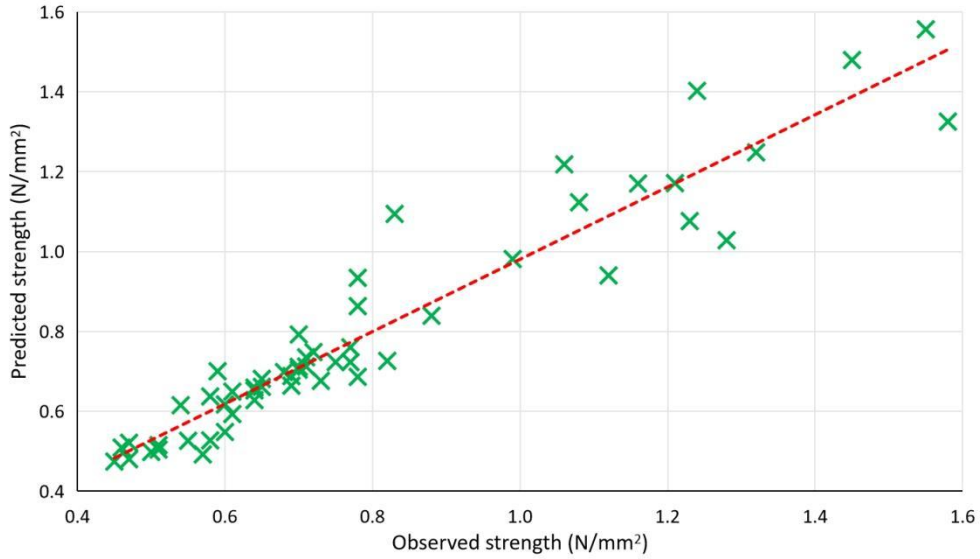


Figure 9: Observed and predicted compressive strengths of blocks, showing the scatter distribution of data points and the regression line (dashed).

4.3.5 Analysis of Residuals

The residual analysis showed the absence of systematic patterns, and the homoscedasticity and linearity criteria were largely met. A relationship between the observed and projected compressive strengths was indicated by the majority of residuals falling within ±0.20 N/mm². This demonstrates that the model may be used to interpret how RHA, laterite content, and curing conditions affect the compressive strength of the stabilised lateritic blocks. Figure 10 presents a residual plot comparing observed and predicted compressive strengths of blocks, illustrating the model's

goodness-of-fit, with residuals generally clustering around the regression line but showing some variability at higher strength values.

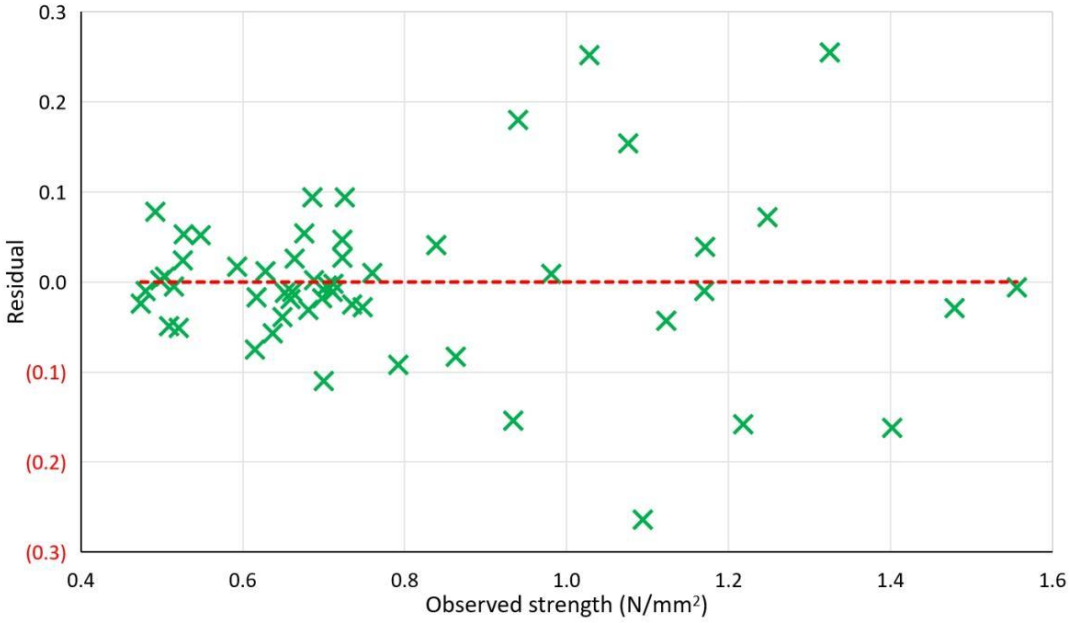


Figure 10: Observed and predicted compressive strengths of blocks, showing model fit and regression line.

4.4 Water absorption of the stabilised lateritic blocks

Figure 11 shows how the water absorption (%) of the lateritic blocks containing rice husk ash (RHA) varied for two stabilisation levels (6% and 10% laterite stabilisation) and at various replacement levels (0–40%), after 7, 28, and 90 curing days. Water absorption typically increases progressively as the percentage replacement of RHA rises at both stabilisation levels (6% and 10%). It is believed to be due to RHA being less dense and more porous than laterite, which increases the overall void ratio of the blocks. The 7-day curing exhibits the maximum water absorption of all replacement levels, suggesting inadequate hydration, while 28-day curing shows moderate absorption, and 90-day curing shows the lowest or more stabilised water absorption, indicating improved densification and pozzolanic reaction over time. Water absorption is consistently lower in blocks made with 10% laterite stabilisation than in those made with 6%. This indicates that even in the mixtures containing RHA, increasing stabilisation lowers water penetration.

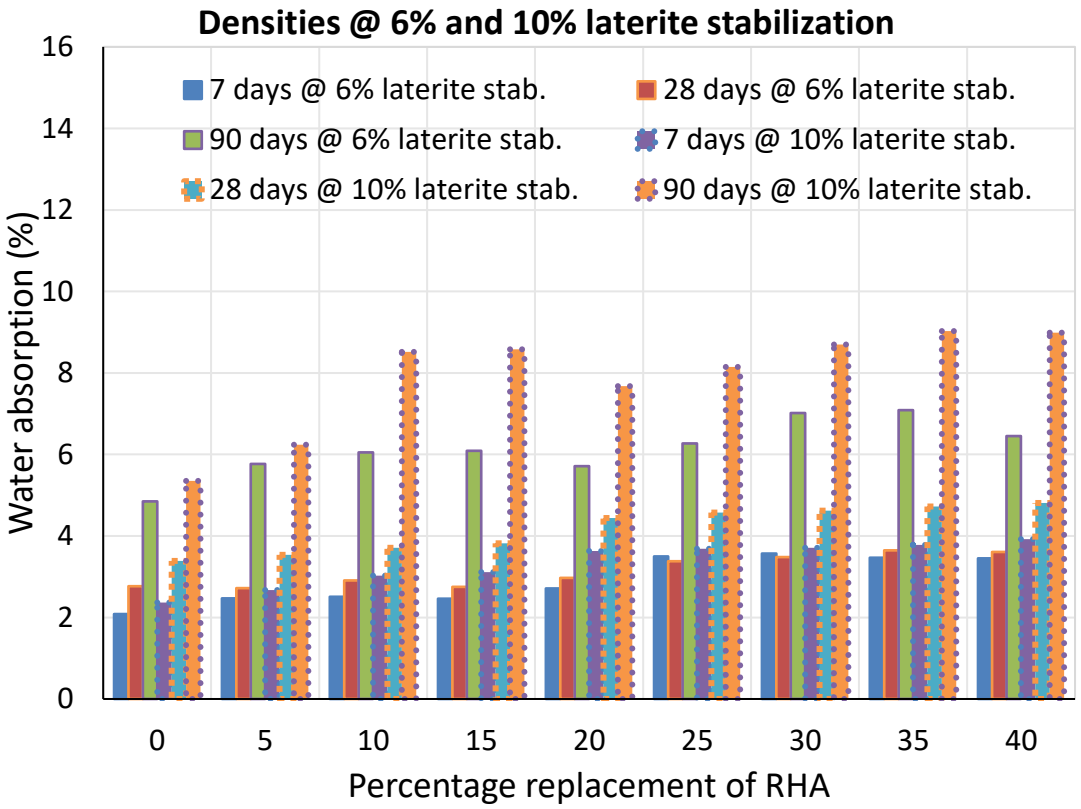


Figure 11: Water absorption of laterite soil stabilized at 6% and10% with cement and Rice Husk Ash (RHA) varies with different RHA replacement percentages, measured over 7, 28, and 90 days of curing.

5.0 Conclusions

This study assessed the impact of using rice husk ash (RHA) in place of some of the cement in stabilised laterite blocks. According to the results, compressive strength rises with curing age but falls when RHA replacement surpasses roughly 15–20% because of increased porosity and decreased cementitious bonding. Blocks stabilised with 10% cement consistently outperformed those stabilised with 6% cement in terms of strength and water absorption. Due to the low specific gravity of the RHA, the density dropped as RHA content increased.

The blocks created in this study are only appropriate for non-load-bearing walling applications since the maximum compressive strength of 1.58 N/mm² is less than the 3.5 N/mm² needed for load-bearing masonry. For lateritic blocks meant for cheap housing partitioning, an RHA replacement level of 10–20% is advised based on the harmony of strength, absorption, and sustainability.

Durability tests, including wet-dry resistance and long-term performance, were not carried out, and this study is restricted to fundamental mechanical and physical

characteristics. Future studies should concentrate on assessing long-term durability in field settings and enhancing strength using hybrid binders or fibres.

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Declarations

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Consent for publication Not applicable.

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Clinical Trial Number: Not applicable.

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