FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 10 No. 18, September, 2026, pp 317 – 325
DOI: https://doi.org/10.33003/fjs-2026-1018-5791

Performance of Concrete Incorporating Naka Lateritic Rock Fines as Partial Replacement of River Sand

***Jagba Aondona Shadrack, Aper E. Zava and Chaver Ujam Jeremiah**

Department of Civil Engineering, Joseph Sarwuan Tarka University Makurdi, Benue State, Nigeria.

*Corresponding authors' email: aondona.shadrack@uam.edu.ng

Received: 21 Aug. 2026
Accepted: 21 Sep. 2026
Published: 29 Sep. 2026

ABSTRACT
The search for sustainable and locally available materials for concrete production has increased interest in lateritic materials as alternatives to conventional aggregates. This study investigated the performance of concrete incorporating Naka Lateritic Rock Fine (NLRF) as a partial replacement for river sand. Concrete was produced using a mix ratio of 1:2:4 with a water-cement ratio of 0.58. River sand was replaced with NLRF at 0%, 25%, 50%, 75% and 100% by weight. A total of 45 concrete cubes and 45 cylinders were produced and cured for 7, 14 and 28 days. The aggregates were assessed for particle-size distribution and specific gravity, while the concrete was tested for workability, water absorption, density, compressive strength and splitting tensile strength. NLRF recorded a coefficient of uniformity of 3.40, coefficient of curvature of 1.20 and fineness modulus of 3.10, compared with 2.82 for river sand. Materials passing the 75 µm sieve were 3% for NLRF and 2% for river sand. Slump values ranged from 55–90 mm and generally decreased with increasing NLRF content. Specific gravity values were 2.53, 2.37 and 2.62 for river sand, NLRF and granite, respectively. Water absorption increased from 1.3% to 3.6%. Compressive and splitting tensile strengths ranged from 11.83–26.03 N/mm² and 1.92–2.63 N/mm², respectively. The 25% NLRF replacement produced the highest compressive strength of 26.03 N/mm² at 28 days and was identified as the optimum level. Therefore, the study recommends that 25% NLRF is suitable as a partial replacement for river sand in concrete production.

Keywords: Naka Lateritic Rock Fines, Fine Aggregate, Concrete, River Sand.

INTRODUCTION
Concrete is one of the most widely used construction materials because of its strength, versatility, availability, and durability (Surahyo et al., 2019). It is a composite material consisting mainly of cement, fine aggregate, coarse aggregate, and water, with admixtures sometimes added to improve specific properties (Obam et al., 2024). Gambhir (2013) described hardened concrete as an artificial stone in which the voids between coarse aggregate particles are filled by fine aggregate, while the remaining spaces are filled by cement paste. Aggregates constitute a substantial proportion of concrete and significantly influence its physical, mechanical, and durability properties. Neville (2006) defined aggregates as naturally occurring inert granular materials such as sand, gravel, and crushed stone, although recycled and synthetic materials are increasingly being considered as alternatives. Aggregates are generally classified into fine and coarse aggregates according to particle size.

Fine aggregate is an important constituent of concrete and plays a major role in determining both fresh and hardened concrete properties (Dessalegn, 2021). Its characteristics influence workability, density, strength development, permeability, and long-term durability (Neville, 2015; Mehta & Monteiro, 2017). In conventional concrete, fine aggregate fills the spaces between coarse aggregate particles, thereby improving particle packing and reducing internal voids. This contributes to the production of a denser and more compact concrete matrix, which can enhance the strength and durability of hardened concrete (Shetty, 2019). Consequently, the availability and quality of suitable fine aggregate are important factors in economical and sustainable concrete production.

Sand has traditionally been the principal material used as fine aggregate in structural concrete. In Nigeria, the most commonly used sources include river sand, erosion sand, and dune sand (Belay, 2021). River sand is particularly popular because of its suitability for concrete production. However, increasing construction activities, urbanisation, and infrastructure development have intensified the exploitation of natural river sand. Kachalla et al. (2026) reported that the growing demand for concrete has increased the exploitation of natural river sand, resulting in material scarcity, increased construction costs, and environmental degradation associated with excessive sand mining. Ogunbode et al. (2021) reported that the depletion of accessible sand deposits contributed to more than a 60% increase in river sand costs. Akinwumi et al. (2020) reported significant losses of riverbank vegetation and stream degradation associated with excessive dredging activities. Ararsa et al. (2018) similarly noted that the increasing construction activities in Nigeria have contributed to the depletion and shortage of natural sand resources. These challenges have increased the need to investigate locally available materials that can serve as alternatives to conventional river sand in concrete production.

The problem is particularly significant in areas where conventional fine aggregate must be transported over long distances. In Naka District of Gwer West Local Government Area of Benue State, river sand supplied to construction sites is obtained from locations approximately 70–120 km away. Such long-distance transportation increases energy consumption, transportation costs, and the overall cost of concrete production. The high cost and limited availability of conventional fine aggregate therefore create a need for cheaper and readily available local materials that can be used without compromising the performance of concrete.

Naka District is located in Gwer West Local Government Area of Benue State, Nigeria, approximately between latitude 7.63°N and longitude 8.22°E (Nigeria Geographic Names Database, 2017; Kwaghsaa, 2025). Naka serves as the headquarters of Gwer West Local Government Area, which covers approximately 1,094 km² (Kwaghsaa, 2025). The area is characterised by the availability of lateritic materials that can potentially be utilised as construction materials. The use of locally available lateritic materials could reduce dependence on transported river sand and consequently lower the cost of concrete production in the area.

Lateritic materials are products of intense tropical weathering and are commonly characterised by reddish-brown or dark colours. They may contain secondary oxides of iron, aluminium, and manganese (Ogunleye, 2023; Afolabi & Ajibade, 2026). Lateritic rock has been investigated as an alternative aggregate, particularly in areas where conventional granite aggregates are scarce or expensive. Afolabi and Edidi (2025) reported that lateritic rock can be used as a substitute for conventional coarse aggregate in concrete production. The lateritic rock available in Naka is generally fine-grained, with a brownish exterior caused by oxidation and a grey interior. Although it has mainly been utilised as coarse aggregate, the fine fraction produced during crushing may have potential as a partial replacement for conventional fine aggregate.

Previous studies have established the potential of lateritic materials as partial replacements for conventional fine aggregate in concrete. Isah et al. (2024) identified 10% laterite replacement as the optimum level, while Garba et al. (2024) reported reduced strength at replacement levels above 10%. Ambrose et al. (2018) found that lateritic sand could replace river sand by up to 50%, although workability decreased with increasing laterite content. However, limited studies have specifically examined lateritic rock fines from Naka, whose properties may differ from materials obtained elsewhere. Therefore, this study investigates the performance of concrete incorporating Naka Lateritic Rock Fines as partial replacement of river sand.

MATERIALS AND METHODS

Materials

Cement

Dangote Portland Limestone Cement (PLC), strength class 42.5N, obtained locally in Makurdi, Benue State, Nigeria, was used as the binder. The cement conformed to the requirements of BS EN 197-1 (2000).

River Sand

River sand was obtained from the River Benue area near the New Bridge, Makurdi, Benue State, Nigeria.

Coarse Aggregate

Crushed granite with a maximum nominal particle size of 20 mm was used as coarse aggregate. The granite was obtained from Court 5, North Bank, Makurdi, Benue State, Nigeria.

Naka Laterite Rock Fine (NLRF)

Naka laterite rock was obtained from Naka, Gwer West Local Government Area, Benue State, Nigeria.

Water

Potable water obtained from Joseph Sarwuan Tarka University, Makurdi, was used for concrete mixing and curing.

Preparation of Samples

Preparation of Naka Lateritic Rock Fines

Naka lateritic rock was sieved so as to exclude the clay content as well as the coarse aggregate contents of lateritic soils. The range of size used was 0.3 mm to 4.75mm.

Mix Proportion

The control concrete consisted of cement, normal fine aggregate (river sand), and coarse aggregate (granite), with the fine aggregate comprising 100% normal river sand. In the other mixtures, normal river sand was partially or completely replaced with Naka Laterite Rock Fines (NLRF) at replacement levels of 25, 50, 75, and 100% by weight, as presented in Table 1. A mix ratio of 1:2:4 for cement, fine aggregate, and coarse aggregate, respectively, was adopted for all concrete mixtures, while the water–cement ratio was maintained at 0.58 throughout the study.

Table 1: Mix Proportions of Naka Lateritic Rock Fines (NLRF)

Sample	NLRF (%)	Normal Fine Aggregate (%)	Cement (kg/m³)	NLRF (kg/m³)	Normal Sand (kg/m³)	Coarse Aggregate (kg/m³)	Water (kg/m³)
Control	0	100	336	0	672	1,344	195
NLRF-25	25	75	336	168	504	1,344	195
NLRF-50	50	50	336	336	336	1,344	195
NLRF-75	75	25	336	504	168	1,344	195
NLRF-100	100	0	336	672	0	1,344	195

Preparation of Concrete Specimens

Concrete specimens were prepared using cube and cylindrical moulds to facilitate the determination of concrete properties. The cube and cylindrical moulds had dimensions of 150 × 150 × 150 mm and 150 × 300 mm, respectively. For each Naka Laterite Rock Fines (NLRF) replacement level, nine (9) cubes and nine (9) cylinders were cast, giving a total of 45 cubes and 45 cylinders for the five mix proportions. The freshly mixed concrete was placed into the moulds in three approximately equal layers. Each layer was thoroughly compacted to remove entrapped air, ensure adequate consolidation, and achieve uniform distribution of the constituent materials. After casting, the specimens were left undisturbed for 24 hours to allow initial setting and hardening. The cube samples were demoulded and transferred into curing tanks containing clean water. The specimens were completely immersed in water and cured for 7, 14, and 28 days. The water-curing procedure was carried out in accordance with BS 1881-111 (1983).

Experimental Method

Sieve Analysis

Sieve analysis was conducted on the fine and coarse aggregates to determine their particle-size distribution and grading characteristics. A series of standard sieves was used to separate the aggregate particles according to size. The procedure was conducted in accordance with BS 812-103:(1990).

Specific Gravity Test

The specific gravity of the aggregates was determined to establish the ratio of the density of the aggregate particles to the density of an equivalent volume of water. The specific gravity test was carried out in accordance with the method described in BS EN 1097-6:(2022). The specific gravity was calculated using equation (1).

$$Gs = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)} \quad (1)$$

Where, Gs = specific gravity, M_1 = weight of empty flask, (g), M_2 = weight of empty flask + weight of the sample, (g), M_3= weight of empty flask + weight of the sample + water, (g), M_4 = weight of empty flask + water, (g)

Slump Test

The slump test was conducted to determine the consistency and workability of the fresh concrete. The test was carried out immediately after mixing, before significant loss of moisture or commencement of setting. The procedure was conducted in accordance with BS EN 12350-2:(2019).

Water Absorption Test

The water absorption test was conducted to determine the amount of water absorbed by the hardened concrete cube specimens. The test was carried out in accordance with BS 1881-122:(1983). Water absorption was calculated using equation (2):

$$W_a = \frac{W_2 - W_1}{W_1} \times 100 \quad (2)$$

W_a = Water absorption (%), W_1 = weight of oven dried cube (kg), W_2 = weight of wet cube (kg)

Density of Concrete Test

The concrete density was determined by dividing the mass of each cube by its volume as specified by BS EN 12350-6:(2019). The volume of each specimen was calculated using equation (3).

$$\text{Density } (\rho \text{ in kg}/m^3) = \frac{\text{mass of cube (kg)}}{\text{volume of cube } (m^3)} \quad (3)$$

Compressive Strength Test

The compressive strength test was conducted to determine the load-bearing capacity of the hardened concrete. The cured 150 × 150 × 150 mm cube specimens were tested using a compression testing machine at the specified curing ages. The test was conducted in accordance with BS EN 12390-3:(2019). The compressive strength was calculated using equation (4).

$$\text{Compresive Strength } (\sigma \text{ in N/mm}^2) = \frac{\text{crushing load of cube (N)}}{\text{Area of cubes (mm}^2)} \quad (4)$$

Splitting Tensile Strength

The splitting tensile strength test was conducted in accordance with the provision of BS EN 12390-6:(2023) using universal testing machine with accuracy of ± 1% of test force. In order to obtain the splitting tensile strength (Ts), the expression in equation (5) was used.

$$Ts = \frac{2P}{\pi l d} \quad (5)$$

Where: Ts is the splitting tensile strength (N/mm^2), P is the maximum applied load (in Newtons) by the testing machine, l is the length of the specimen (mm), and d is the diameter of the specimen (mm).

RESULTS AND DISCUSSION

Sieve Analysis

Figures 1 and 2 present the particle-size distribution characteristics of the river sand, granite, and Naka Laterite Rock Fine (NLRF). The river sand recorded a coefficient of uniformity (Cu) of 2.09 and coefficient of curvature (Cc) of 1.00, while granite recorded Cu and Cc values of 1.61 and 1.16, respectively. The relatively low Cu values indicate comparatively narrow particle-size distributions, while the Cc values suggest reasonably continuous grading characteristics. These parameters are useful for assessing the particle-size distribution and packing characteristics of aggregates (FHWA, 2006). The Naka Laterite Rock Fine exhibited a higher coefficient of uniformity of 3.40 and a coefficient of curvature of 1.20. These findings agreed with the results reported by Obam *et al.* (2024) and Obam *et al.* (2025). The results further agree with Nwogu (2022), who reported that a coefficient of curvature (Cc) within the range of 1 to 3 indicates a favourable distribution of particle sizes when considered alongside the coefficient of uniformity

The river sand had a fineness modulus (FM) of 2.82, compared with 3.10 for NLRF. Fineness modulus is an index of aggregate coarseness, with higher values indicating relatively coarser particles (Saberi et al., 2021). Thus, the higher FM of NLRF indicates that it was coarser than the river sand. This difference in grading may be beneficial when the materials are blended because aggregates with different particle-size distributions can improve particle packing and reduce voids within the aggregate skeleton. Similar findings have shown that combining fine aggregates with different grading characteristics can modify particle-size distribution and improve the performance of cement-based materials (Omoregie & Alutu, 2016). The percentage passing the 75 µm sieve was 2% for river sand and 3% for NLRF. These relatively low values indicate limited quantities of very fine materials such as silt, clay and dust. Controlling excessive fines is important because high fines content can increase specific surface area, water demand and cement-paste requirements, thereby affecting concrete workability and performance (BS EN 12620, 2013). The 2% and 3% values obtained therefore indicate relatively low fines contents in both materials.

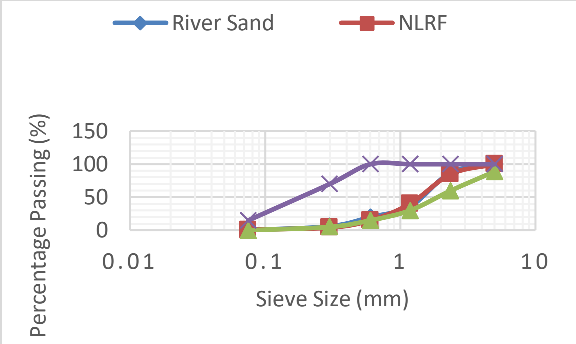

Figure 1: Grading Curve for River Sand and Naka Laterite Rock Fine

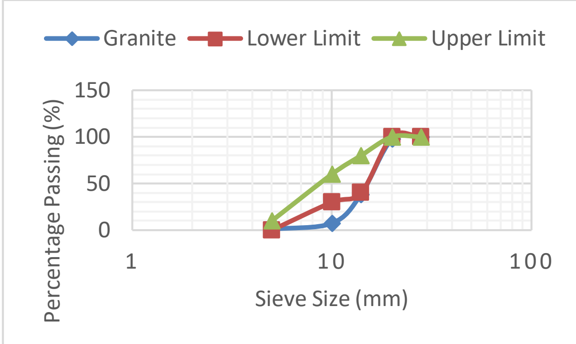

Figure 2: Grading Curve for Granite

Specific Gravity

Table 2 shows the specific gravity values obtained for river sand, Naka laterite rock fines (NLRF), and granite, which were 2.53, 2.37, and 2.62, respectively. The values obtained in this study are generally comparable with those reported by Obam et al. (2024), indicating consistency with previous findings on similar aggregate materials. The specific gravity of NLRF (2.37) is relatively close to the value of 2.44 reported by Zaheer et al. (2022). This slight difference may be attributed to variations in the mineralogical composition and source of the laterite materials. The specific gravity obtained for granite (2.62) falls within the range of 2.6–3.0 reported by Neville (1997) is also consistent with the typical range of 2.6–2.7 for granite aggregates. The results further indicate that the river sand and granite possess adequate density characteristics for use as fine and coarse aggregates, respectively, in concrete production.

Table 2: Results of Specific Gravity Tests of the River Sand, Naka Laterite Rock Fine and Granite

Description	River sand		Naka Laterite Rock Fine		Granite	
Soil specimen	**Test 1**	**Test 2**	**Test 1**	**Test 2**	**Test 1**	**Test 2**
Mass of flask + sample + water (M_3) g	111.50	111.20	105.00	106.20	117.00	116.00
Mass of flask + sample (M_2) g	38.20	38.30	45.50	45.00	47.00	46.20
Mass of flask + water (M_4) g	105.3	105.00	95.10	96.20	105.30	104.30
Mass of flask (M_1) g	28.00	28.00	28.00	28.00	28.00	28.00
$(M_2 - M_1)$ g	10.20	10.30	17.50	17.00	19.00	18.20
$(M_4 - M_1)$ g	77.30	77.00	67.10	68.20	77.3	76.30
$(M_3 - M_2)$ g	73.30	72.90	59.50	61.50	70.0	69.80
$[(M_4 - M_1) - (M_3 - M_2)]$ g	4.00	4.10	7.60	7.0	7.30	6.90
$Gs = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$	2.55	2.51	2.30	2.43	2.60	2.64
Average Specific Gravity	2.53		2.37		2.62	

Slump Test

Figure 3 presents the results of the slump test conducted on the concrete mixtures. The recorded slump values ranged from 55 to 90 mm, indicating a true slump and acceptable workability. The results are consistent with findings reported in previous studies. Zaheer et al. (2022) recorded slump values ranging from 52 to 75 mm, while Zerdi et al. (2016) reported values between 55 and 95 mm.

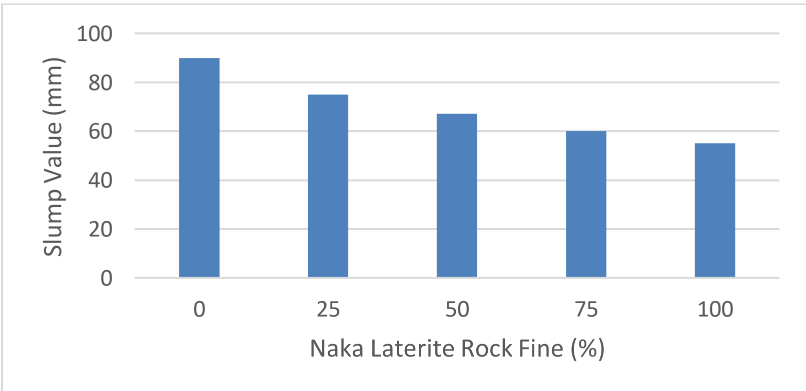

Figure 3: Slump Test Result

The introduction of laterite as a partial replacement for fine aggregate was observed to influence the workability of the concrete mixture. Generally, increasing the laterite content resulted in a reduction in slump value. This reduction may be attributed to the relatively higher water absorption capacity and greater fineness of laterite particles compared with conventional fine aggregates. Consequently, more water is absorbed by the laterite particles, reducing the quantity of free water available for lubrication and thereby decreasing the workability of the fresh concrete (Garba et al., 2024). Similar observations were reported by Aliyu et al. (2020), who noted reduced workability with alternative fine aggregate materials. According to Neville and Brooks (2010), slump values of 50–100 mm represent medium workability. Therefore, the concrete mixtures investigated in this study can be classified as having medium workability and a true slump, making them suitable for normal construction applications.

Water Absorption Test

Water absorption is an important property of concrete because it influences its durability and resistance to moisture-related deterioration. Figure 4 presented result for water absorption test. The results obtained in this study indicate that the water absorption values ranged from 1.3% to 3.6%, with a general increasing trend as the percentage of Naka Laterite Rock Fines (NLRF) increased.

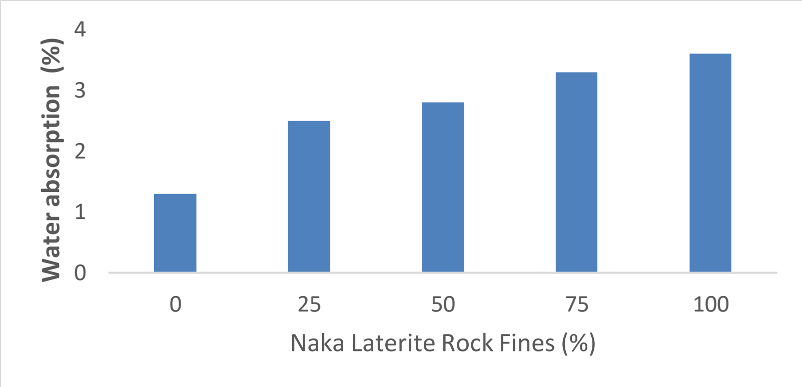

Figure 4: Result for Water Absorption Test

This increase may be attributed to the finer and more porous nature of NLRF, which can provide additional pathways for moisture penetration into the concrete matrix. Nevertheless, most of the specimens recorded water absorption values below the 5% limit specified for normal concrete (Nadir & Sujatha, 2018). The findings are also consistent with Ukpata et al. (2024), who reported water absorption values ranging from 2.48% to 3.65% for laterized concrete. Moisture ingress can contribute to reinforcement corrosion and deterioration caused by repeated wetting and drying. According to Neville (2012), concrete with water absorption below 10% can be considered sufficiently durable. Therefore, the results suggest that incorporating NLRF slightly increases water absorption but maintains acceptable durability and permeability characteristics for structural applications.

Density of Cubes

Density is an important property of concrete because it influences its self-weight, load-carrying capacity, and suitability for structural applications. In this study, the density of the concrete specimens ranged from 2,435 to 2,568 kg/m³ at 7 days, 2,414 to 2,652 kg/m³ at 14 days, and 2,528 to 2,611 kg/m³ at 28 days as shown in Figure 4.

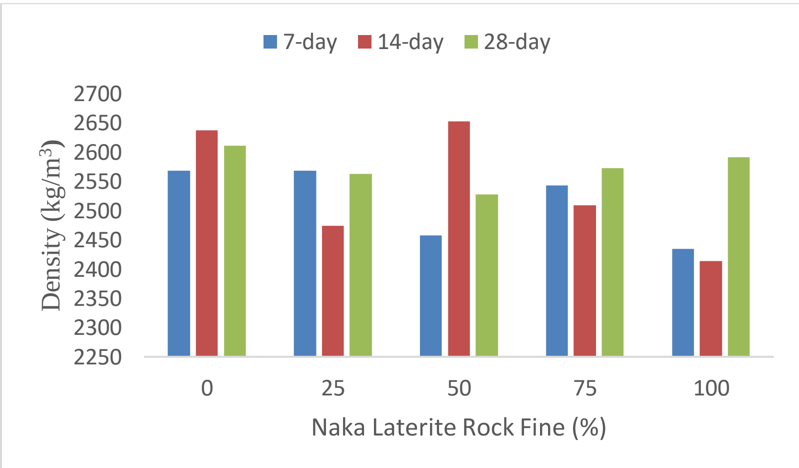

Figure 5: Result for Density Test

The results indicate that the density did not exhibit a consistent or significant trend with increasing Naka Laterite Rock Fines (NLRF) content. This suggests that the incorporation of NLRF had limited influence on the overall density of the concrete. According to Falade et al. (2011), concrete can be classified as lightweight, normal-weight, or heavyweight concrete, with density ranges of 300–1,920 kg/m³, 2,240–2,480 kg/m³, and above 2,500 kg/m³, respectively. Based on these ranges, most of the concrete produced in this study falls within the normal-weight range, although some density values exceeded 2,500 kg/m³. However, exceeding this value alone does not necessarily classify the concrete as conventional heavyweight concrete, which is typically produced using high-density aggregates for specialised applications. The observed values are consistent with the density ranges reported by Neville and Brooks (1997) and Neville (2011). Similarly, Anum et al. (2014) reported concrete density values ranging from 2,441 to 2,558 kg/m³, which are comparable to the values obtained in this study.

Compressive Strength Test

The compressive strength of concrete is a critical property in structural engineering because it forms the basis for the design and assessment of concrete structures and is commonly specified by relevant standards and design codes. Figure 6 shows compressive strength result**.** In this study, the compressive strength values ranged from 11.83 to 16.09 N/mm² at 7 days, 14.16 to 19.33 N/mm² at 14 days, and 16.71 to 26.03 N/mm² at 28 days. These results are generally consistent with previous findings reported by Adetayo et al. (2019), Olutoge et al. (2016), Adeyemi and Olowu (2017), Olanitori et al. (2016), Adepegba et al. (2016), Ambrose et al. (2018), Oladimeji et al. (2022), and Nwankwo and Okafor (2021), reported that the compressive strength achieved at optimal replacement of laterite ranges from 24-29.0 N/mm².

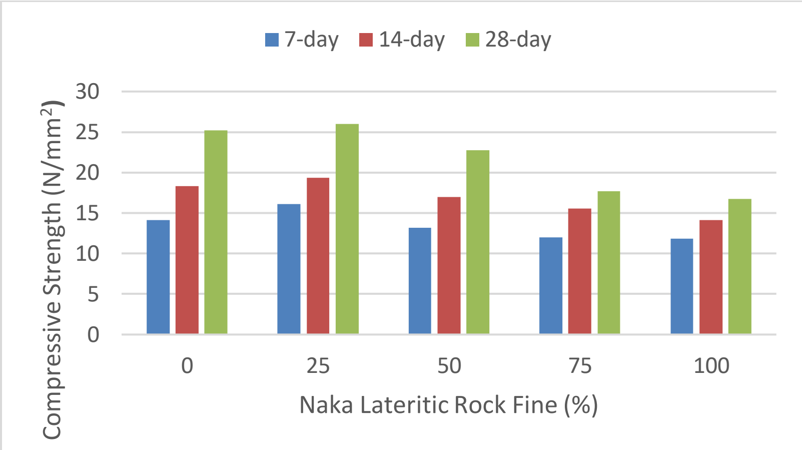

Figure 6: Compressive Strength Result

The results show that compressive strength increased with the incorporation of NLRF up to the optimum replacement level of 25%, after which a sharp reduction was observed. This trend agrees with Ozioko et al. (2025), Ajagbe et al. (2018), and Adetayo et al. (2019), who identified 25% laterite replacement as optimum. However, Isah et al. (2024) reported 10% as optimum, while Garba et al. (2024) observed strength reduction above 10%. In contrast, Ambrose et al. (2018) reported that lateritic sand could replace river sand by up to 50%.

Split Tensile Strength Test

Figure 7 presents the average split tensile strength of the concrete specimens containing different percentages of Naka Laterite Rock Fines (NLRF) as partial replacement of fine aggregate. The split tensile strength ranged from 1.92 to 2.25 N/mm² at 7 days, 2.11 to 2.46 N/mm² at 14 days, and 2.29 to 2.63 N/mm² at 28 days. The progressive increase in strength with curing age indicates continued hydration and development of the concrete matrix. These results are comparable with the findings of Christopher et al. (2020), who reported split tensile strength values ranging from 0.55 to 3.23 N/mm². Similarly, Obam et al. (2024) obtained values between 1.20 and 3.40 N/mm².

The results further revealed that the maximum split tensile strength was achieved at 25% replacement of fine aggregate with NLRF. This shows that a moderate quantity of NLRF may improve particle packing and enhance the bonding characteristics of the concrete matrix. However, further increases in NLRF content resulted in a gradual reduction in tensile strength. This finding differs from Zaheer et al. (2022), who reported optimum split tensile strength at 20% laterite replacement, similarly, Afolabi and Ajibade (2026), who found that 5% laterite replacement produced the highest tensile strength of 3.01 N/mm². These differences may be attributed to variations in laterite properties, aggregate characteristics, mix proportions, and curing conditions.

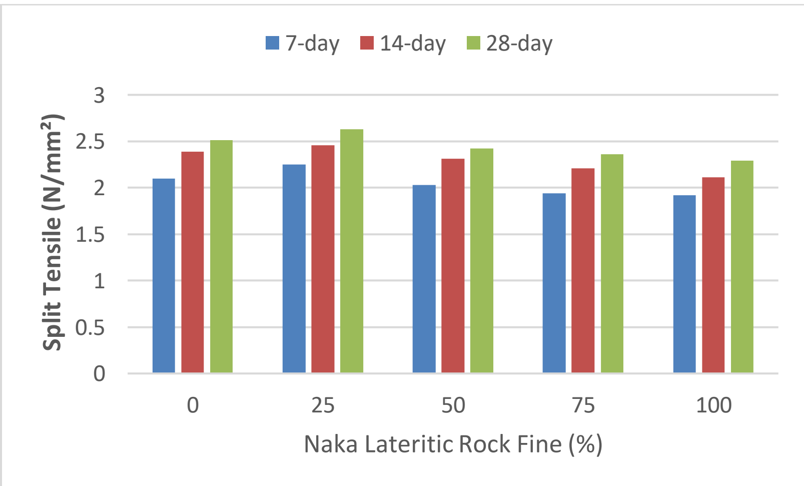

Figure 7: Split Tensile Strength Test

CONCLUSION

Based on the findings of this study, Naka Laterite Rock Fine (NLRF) demonstrated good potential as a partial replacement for river sand in concrete production. The grading characteristics showed that NLRF had a coefficient of uniformity (Cu) of 3.40 and coefficient of curvature (Cc) of 1.20, compared with Cu = 2.09 and Cc = 1.00 for river sand and Cu = 1.61 and Cc = 1.16 for granite. The fineness modulus was 3.10 for NLRF and 2.82 for river sand, while the percentage passing the 75 µm sieve was 3% and 2%, respectively. The concrete exhibited medium workability, with slump values ranging from 55 to 90 mm, although workability generally decreased as NLRF content increased. The specific gravities of river sand, NLRF and granite were 2.53, 2.37 and 2.62, respectively, while water absorption increased from 1.3% to 3.6% with increasing NLRF content. Concrete density ranged from 2,435–2,568 kg/m³ at 7 days, 2,414–2,652 kg/m³ at 14 days and 2,528–2,611 kg/m³ at 28 days. Compressive strength increased with curing age, ranging from 11.83–16.09 N/mm² at 7 days, 14.16–19.33 N/mm² at 14 days and 16.71–26.03 N/mm² at 28 days. Split tensile strength also increased with curing age, with values ranging from 1.92–2.25 N/mm², 2.11–2.46 N/mm² and 2.29–2.63 N/mm² at 7, 14 and 28 days, respectively. The highest compressive strength of 26.03 N/mm² at 28 days was achieved at 25% NLRF replacement. Therefore, 25% NLRF replacement of river sand is identified as the optimum level under the conditions of this study, providing a favourable balance of workability and mechanical performance. Further investigation using intermediate replacement levels is recommended to establish the response between the tested replacement percentages and determine whether a more precise optimum level exists

with this research. The study was conducted independently and objectively, and there are no financial, personal, institutional, or other relationships that could have influenced the design, execution, analysis, interpretation, or reporting of the findings.

REFERENCES

Adepegba, D., Balogun, A., & Ogunbode, E. (2016). Alternative fine aggregates for sustainable concrete production. *International Journal of Civil Engineering and Technology, 7*(4), 102–110.

Adetayo, O. A., Amu, O. O., & Ilori, A. O. (2019). Cement stabilized structural foundation lateritic soil with bone ash powder as additive. *Arid Zone Journal of Engineering, Technology and Environment, 15*(2), 479–487.

Adeyemi, T. A., & Olowu, O. A. (2017). Evaluation of sandy soil as partial replacement for fine aggregate in concrete production. *International Journal of Engineering Research and Technology, 6*(8), 412–418.

Afolabi, O. A., & Ajibade, O. E. (2026). Compressive strength and workability of concrete incorporating laterite as partial replacement of fine aggregate. *International Journal of Research and Innovation in Applied Science, 11*(3), 1306–[page range not provided]. https://doi.org/10.51584/IJRIAS.2026.11030100

Afolabi, O. A., & Edidi, S. I. A. (2025). Effect of partial replacement of cement with rice husk ash on concrete performance characteristics. *Journal of Civil Engineering (NAUJCVE), 4*(2), 15–23.

Ajagbe, W. O., Afolayan, J. O., & Oyekan, G. L. (2018). Structural behaviour of laterized concrete in structural applications. *Nigerian Journal of Technology, 37*(2), 376–383.

Akinwumi, A. M., Adewumi, J. R., & Obiora-Okeke, O. A. (2021). Impact of climate change on the stream-flow of Ala River, Akure, Nigeria. *Sustainable Water Resources Management, 7*, Article 9. https://doi.org/10.1016/j.heliyon.2021.e07941

Aliyu, I., Sulaiman, T. A., Mohammed, A., & Kaura, J. M. (2020). Effect of sulphuric acid on the compressive strength of concrete with quarry dust as partial replacement of fine aggregate. *FUDMA Journal of Sciences, 4*(1), 553–559.

Ambrose, E. E., Ekpo, D. U., Umoren, I. M., & Ekwere, U. S. (2018). Compressive strength and workability of laterized quarry sand concrete. *Nigerian Journal of Technology*, *37*(3), 605–612. https://doi.org/10.4314/njt.v37i3.3

Anum, I., Williams, F. N., Adole, A. M., & Haruna, A. C. (2014). Properties of different grades of concrete using mix design method. *International Journal of Geology, Agriculture and Environmental Sciences, 2*(6), 6–10.

Ararsa, W., Quezon, E. T., & Aboneh, A. (2018). Suitability of Ambo sandstone fine aggregate as an alternative river sand replacement in normal concrete production. *American Journal of Civil Engineering and Architecture, 6*(4), 140–146. https://doi.org/10.12691/ajcea-6-4-2

Belay, M. D. (2021). Evaluation of the effects of coarse aggregate size on concrete properties. *Journal of Construction Research.*

British Standards Institution. (1983). *BS 1881-111:1983: Testing concrete—Method for normal curing of test specimens*. British Standards Institution.

British Standards Institution. (1990). *BS 812-103:1990: Testing aggregates—Methods for determination of particle size distribution*. British Standards Institution.

British Standards Institution. (1997). *BS EN 933-1:1997: Tests for geometrical properties of aggregates—Determination of particle size distribution—Sieving method.* British Standards Institution.

British Standards Institution. (2000). *BS EN 197-1:2000: Cement — Part 1: Composition, specifications and conformity criteria for common cements*. BSI.

British Standards Institution. (2019). *BS EN 12350-2:2019: Testing fresh concrete—Part 2: Slump test*. British Standards Institution.

British Standards Institution. (2019). *BS EN 12350-6:2019: Testing fresh concrete—Part 6: Density*. British Standards Institution.

British Standards Institution. (2019). *BS EN 12390-3:2019: Testing hardened concrete—Part 3: Compressive strength of test specimens*. British Standards Institution.

British Standards Institution. (2022). *BS EN 1097-6:2022: Tests for mechanical and physical properties of aggregates—*

Part 6: Determination of particle density and water absorption. British Standards Institution.

British Standards Institution. (2023). *BS EN 12390-6:2023: Testing hardened concrete—Part 6: Tensile splitting strength of test specimens*. British Standards Institution.

BS EN 12620. (2013). *Aggregates for concrete*. British Standards Institution.

Christopher, A. F., Blessing, A. A., & Babatunde, I. F. (2020). Splitting tensile strength and compressive strength ratios and relations for concrete made with different grades of Nigerian Portland limestone cement (PLC). *FUW Trends in Science & Technology Journal, 5*(3), 802–808.

Dessalegn, M. (2021). Evaluation the effects of coarse aggregates size on concrete properties. *Journal of Construction Research, 3*, 49. https://doi.org/10.30564/jcr.v3i2.4049

Falade, F., Ikponmwosa, E., & Arogundade, A. (2011). Investigation of some structural properties of foamed aerated concrete. *Journal of Engineering Research, 16*, 67–80.

Federal Highway Administration (FHWA). (2006). *Soils and foundations reference manual*. U.S. Department of Transportation.

Gambhir, M. L. (2013). *Concrete technology: Theory and practice* (5th ed.). McGraw Hill Education.

Garba, I., Kaura, J. M., Sulaiman, T. A., Aliyu, I., & Abdullahi, M. (2024). Effects of laterite on strength and durability of reinforced concrete as partial replacement of fine aggregate. *FUDMA Journal of Sciences, 8*(1), 201–207. https://doi.org/10.33003/fjs-2024-0801-2210

Isah, G., Sulaiman, T. A., Kaura, J. M., & Abdullahi, M. (2024). Optimization and predictive models on strengths and durability of reinforced laterized concrete. *Covenant Journal of Engineering Technology, 8*(1). https://journals.covenantuniversity.edu.ng/index.php/cjet/article/view/4002

Kachalla, A. M., Waziri, B. S., Mohammad, A. S., & Ibrahim, Y. (2026). Suitability of locally sourced soils as fine aggregates in concrete production: A review. *Arid Zone Journal of Engineering, Technology and Environment, 22*(2), 526–535.

Kwaghsaa, K. S. (2025). Assessment of ground water quality in Naka Town, Gwer-West Local Government Area of Benue State, Nigeria. *International Journal of Research Publication and Reviews, 6*(3), 7261–7264. https://doi.org/10.55248/gengpi.6.0325.12128

Mehta, P. K., & Monteiro, P. J. M. (2017). *Concrete: Microstructure, properties, and materials* (4th ed.). McGraw Hill Education.

Nadir, Y., & Sujatha, A. (2018). Durability properties of coconut shell aggregate concrete. *KSCE Journal of Civil Engineering, 22*, 1920–1926. https://doi.org/10.1007/s12205-017-0063-6

Neville, A. M. (1997). *Properties of concrete* (4th ed.). Longman.

Neville, A. M. (2006). *Properties of concrete*. Pearson Education.

Neville, A. M. (2011). *Properties of concrete* (5th ed.). Pearson Education.

Neville, A. M. (2012). *Properties of concrete* (5th ed.). Pearson.

Neville, A. M. (2015). *Properties of concrete* (5th ed.). Pearson Education.

Neville, A. M., & Brooks, J. J. (1997). *Concrete technology* (2nd ed.). Longman.

Neville, A. M., & Brooks, J. J. (2010). *Concrete technology*. Prentice Hall.

Nigeria Geographic Names Database. (2017). *Gwer West, Gwer West, Benue State*. http://nga.geonamebase.com/node/49150

Nwankwo, C. N., & Okafor, F. O. (2021). Performance evaluation of lateritic soil as partial replacement of fine aggregate in concrete production. *Nigerian Journal of Technology, 40*(3), 456–464. https://doi.org/10.4314/njt.v40i3.8

Nwogu, C. P. (2022). *Effect of coarse aggregate grading on properties of concrete* [Unpublished bachelor's project, Nnamdi Azikiwe University].

Obam, S. O., Ijoh, H. U., & Adeke, T. P. (2025). Effect of heat on some properties of normal and pozzolanic concrete. *Engineering Research Journal, 4*(10), 44–58. https://doi.org/10.5281/zenodo.14628016

Obam, S. O., Jagba, A. S., & Adeke, P. T. (2024). Regression models for prediction of compressive and tensile concrete strength. *CEDTECH International Journal of Engineering & Applied Science, 5*(2).

Ogunbode, E. B., Makun, C. S., Ango, J. A., Hassan, I. O., Lawal, A. T., & Ibrahim, S. M. (2021). Chloride ingress resistance of rice husk ash-based green concrete composites containing steel fibres. *Environmental Technology and Science Journal, 12*(1), 71–80.

Ogunleye, E. (2023). Innovations and applications of laterized concrete in sustainable construction. *Global Journal of Engineering and Technology Advances, 16*(3), 107–120.

Oladimeji, O. T., Ogunbode, E. B., & Adesanya, D. A. (2022). Performance of sandy soil in concrete mixes as alternative fine aggregate. *Journal of Building Engineering, 44*, 103330.

Olanitori, L. M., & Olotuah, A. O. (2006). Strength characteristics of laterized concrete. *Construction and Building Materials, 20*(10), 1057–1062. https://doi.org/10.1016/j.conbuildmat.2005.02.027

Olutoge, F. A., Adeniran, K. M., & Oyegbile, O. B. (2013). The ultimate strength behaviour of laterised concrete beam.

Science Research, 1(3), 52–58. https://doi.org/10.11648/j.sr.20130103.14

Omoregie, A., & Alutu, O. E. (2016). The influence of fine aggregate combinations on particle size distribution, grading parameters, and compressive strength of sandcrete blocks. *International Journal of Engineering Research and Applications.*

Ozioko, H. O., Eze, E. E., & Ekunie, A. C. (2025). Suitability assessment of laterite soil as alternative to sharp sand in cement block production: Performance evaluation and predictive analysis. *Nigerian Journal of Technology, 44*(4), 518–532. https://doi.org/10.4314/njt.v44i4.1

Saberi, S. S., Mohamed, A., & Eltwati, A. S. (2021, August). Mechanical and physical properties of recycled concrete aggregates for road base materials. In *Journal of Physics: Conference Series* (Vol. 1973, No. 1, p. 012236). IOP Publishing**.**

Shetty, M. S. (2019). *Concrete technology: Theory and practice* (8th ed.). S. Chand Publishing.

Surahyo, A., Surahyo, L., & Luby. (2019). *Concrete construction* Springer International Publishing (pp. 239-255)

Ukpata, J. O., Ewa, D. E., Success, N. G., Alaneme, G. U., Out, N. O., & Olaiya, B. C. (2024). Effects of aggregate sizes on the performance of laterized concrete. *Scientific Reports, 14*, 448.

Zaheer, M., Jaseer, M. Z., Sheikh, S. N., & Charan, K. S. (2022). Investigation on the utilization of laterite as replacement of fine aggregate to develop ecofriendly concrete. *International Research Journal of Engineering and Technology, 9*(5), 963.

Zerdi, T. A., Hussain, S. S., Ali, S. Z., & Ansari, Q. (2016). Suitability of using laterite as partial replacement of fine aggregate in concrete. *International Journal of Engineering and Technology, 6*(5).