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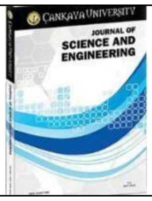

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The Role of Carbonation in Modifying Flexural and Tensile Properties of Laterized Concrete

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Keywords

Laterized concrete, Structural performance, Carbonation, Durability, Eco-friendly construction materials.

Abstract

Laterized concrete, incorporating laterite soil, offers a sustainable alternative to conventional concrete in regions where traditional materials are scarce or expensive. This study investigates the impact of carbonation on the flexural and tensile splitting strengths of laterized concrete. Carbonation, a chemical reaction between CO2 and calcium hydroxide in concrete, forms calcium carbonate, enhancing the mechanical properties of concrete. This research focuses on various laterite replacement levels (0%, 10%, 20%, 30%, 40%, 50%) and their performance under different exposure conditions (carbonation, water immersion, dry environment). The results demonstrate that extended carbonation significantly enhances the tensile splitting and flexural strengths of laterized concrete up to 40% replacement, with the most substantial improvements at 10% to 30%. Higher replacement levels (30% and above) reduce these strengths, particularly in dry conditions. The findings underscore the potential of laterized concrete as an eco-friendly building material, balancing strength and sustainability. This study contributes to advancing sustainable construction practices, promoting the use of locally available materials, and mitigating environmental impacts.

1. Introduction

Laterized concrete is a specialized type of concrete that incorporates laterite, a soil rich in iron oxide and aluminum hydroxide [1-3]. Abundant in tropical regions such as India, Nigeria, and Brazil, laterite's availability makes laterized concrete an attractive option, particularly in areas where traditional construction materials are scarce or expensive [4]. Its widespread availability makes laterized concrete an attractive option for construction, especially in regions where traditional construction materials like sand and gravel may be scarce or expensive [3]. The use of locally available laterite soil can significantly reduce construction costs and promote sustainability by minimizing the need for imported materials, thus lowering the carbon footprint associated with construction [5,6].

Tensile splitting strength and flexural strength are crucial for elements subjected to bending or shear forces. While compressive strength is often considered the primary indicator of concrete's overall strength [7], flexural and tensile strengths are vital for its performance in real-world applications [8]. Understanding and optimizing these properties is essential for structural durability and integrity. The tensile splitting and flexural strengths of concrete are influenced by various factors, including the initial composition, mix design, mixing technique, compaction, and curing process of the concrete, as well as environmental conditions [9-13]. Recent studies have shown that the incorporation of recycled materials, such as marble powder and glass waste, can significantly enhance the mechanical properties of self-compacting concrete (SCC) [14,15]. For instance, marble powder acts as a filler,

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improving the density and homogeneity of SCC, while also reducing the overall cement content without compromising workability. Similarly, using recycled glass and ceramic waste as partial replacements for fine aggregates and cement demonstrates substantial improvements in both rheological and mechanical properties, aligning with sustainability goals in concrete production. In a similar vein, the incorporation of calcium oxide in alkali-activated slag (AAS) has been explored for microbial self-healing, with findings suggesting that calcium oxide enhances microbial-induced calcium carbonate precipitation, thereby improving crack-healing ability and maintaining tensile and flexural strength over time, contributing to more durable and sustainable concrete [16]. Environmental conditions further impact the tensile splitting and flexural strengths of concrete, influencing both their initial development and long-term performance [17,18]. Additionally, research indicates that the use of grounded vitrified clay pipes as a supplementary cementitious material not only enhances mechanical properties but also improves resistance to environmental degradation, thus promoting the development of greener concrete solutions [19].

Earlier studies have extensively explored the compressive strength of laterized concrete. For example, Garba et al. [20] demonstrated that the compressive strength of laterized concrete increases with curing age but decreases with higher laterite content. Osunade [21] similarly noted that adding granite fines to laterized concrete could enhance compressive strength. However, both studies also highlighted a decline in tensile strength with increased laterite content, with Osunade [21] reporting that tensile strengths still fell within acceptable ranges for grade 30 concrete.

The flexural performance of laterized concrete has also been investigated. Babatunde et al. [22] assessed the flexural strength of fly ash-laterized concrete (FA-LATCON), finding that flexural strength increases with curing age but decreases with higher laterite and fly ash content. These studies contribute to a growing body of literature that examines the mechanical properties of laterized concrete, particularly its flexural and tensile strengths, which are crucial for elements subjected to bending or shear forces [17-20].

Excess carbon dioxide in the atmosphere poses multifaceted challenges, including global warming, ocean acidification, negative impacts on human health, loss of biodiversity, and economic consequences [23]. These far-reaching effects underscore the importance of mitigating greenhouse gas emissions and transitioning to sustainable energy practices [24].

One method of utilizing carbon dioxide to prevent its accumulation in the atmosphere involves the carbonation process in concrete [25]. Carbonation process in concrete is a chemical reaction where carbon dioxide (CO_2) from the air reacts with calcium hydroxide ($Ca(OH)_2$) in the hydrated cement paste of concrete to form calcium carbonate ($CaCO_3$). This reaction gradually reduces the pH of the concrete, leading to a decrease in alkalinity [26]. Carbonation typically occurs at the surface of concrete structures and progresses inward over time, altering the properties of concrete.

While carbonation can pose risks to reinforced concrete structures by potentially causing corrosion of embedded steel reinforcement, it also offers significant benefits for plain concrete structures, such as sidewalks and pavements, floor slabs, concrete footpaths, masonry units concrete walls, etc., [27]. In the carbonation process, CO_2 from the atmosphere reacts with calcium hydroxide in the concrete matrix, converting it into stable calcium carbonate. This process not only sequesters carbon dioxide, preventing its release into the atmosphere, but also acts as a localized form of carbon capture and storage (CCS). Furthermore, carbonated concrete often exhibits enhanced durability and resistance to degradation, which can extend the service life of concrete structures [28]. This increased longevity reduces the frequency of reconstruction or replacement, ultimately lowering the carbon footprint associated with concrete production and construction activities.

Several studies have explored the effects of carbonation on the mechanical properties of cement-based composites [23-33]. Despite the extensive body of research on carbonation and its implications for normal concrete and other cement-based composites, there is a notable lack of similar studies on the mechanical properties of laterized concrete and its variations. The distinctive composition of laterized concrete, marked by a high content of iron oxides and aluminum oxides [34], suggests potential deviations in its carbonation behavior compared to conventional concrete mixes. A recent study has examined the impact of carbonation on its compressive strength [35]. However, the current research aims to expand this exploration by investigating the effects of carbonation on the flexural and tensile splitting strength of laterized concrete.

In light of the multifaceted challenges posed by climate change and the urgent need for sustainable solutions, investigating the carbonation behavior of laterized concrete represents a critical step towards advancing both environmental stewardship and construction industry practices. This study contributes to unlocking the full potential of laterized concrete as a resilient and carbon-neutral building material, paving the way towards a more sustainable built environment.

2. Materials and Methods

2.1. Materials

In this study, ordinary Portland Cement (PC, 42.5 type), conforming to BS EN 197-1, was utilized for all concrete mixes. Potable water, meeting the requirements of BS EN 1008, was used for mixing and curing purposes. Natural river sand was employed as the fine aggregate. The coarse aggregate used was crushed granite with a maximum size of 20 mm. Laterite soil, collected locally, was air-dried and sieved through a 5 mm sieve to ensure uniform particle size distribution. A polycarboxylate ether-based superplasticizer was added to the concrete mixes to achieve the desired workability. The dosage was set at 1% by weight of the cement content, chosen to enhance workability without altering the water-cement ratio. The water-cement ratio was maintained at 0.45 for all mixes. All materials were thoroughly characterized to ensure quality and consistency in the concrete mixes. Table 1 provides the specific properties of the sand, laterite, and crushed stone. Their grading curves are presented in Figure 1, offering a comprehensive understanding of their suitability for concrete production. Additionally, the chemical composition of the laterite used is detailed in Table 2.

Table 1. Characteristics of Aggregates

Properties	**Soil type**		
	Laterite	**Sand**	**Granite**
Fineness modulus	2.85	3.01	6.99
Coefficient of uniformity	3.20	4.88	1.55
Coefficient of curvature	0.94	0.92	0.94
Specific gravity	2.51	2.66	2.72
Moisture content (%)	2.47	1.11	1.61
Liquid limit (%)	25.0	-	-
Plastic limit (%)	14.0	-	-
Plasticity index (%)	11.0	-	-

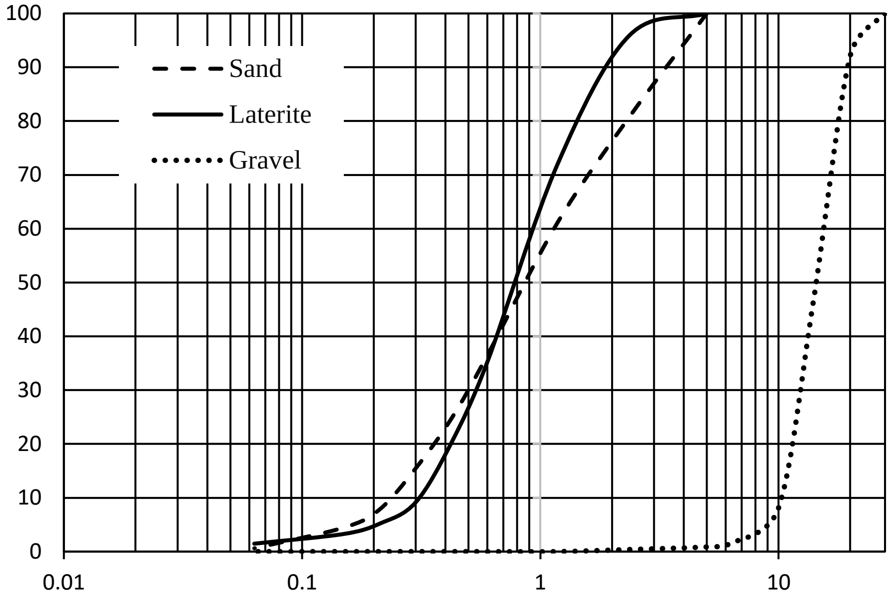

Figure 1. Gradation Curves of the Aggregates

Table 2. Chemical Composition of the Laterite

Compound	**Percentage (%)**
Iron Oxide (Fe_2O_3)	51.40
Aluminum Oxide (Al_2O_3)	26.00
Silicon Dioxide (SiO_2)	18.38
Titanium Dioxide (TiO_2)	0.50
Manganese Oxide (MnO_2)	0.12
Magnesium Oxide (MgO)	0.23
Calcium Oxide (CaO)	0.14
Sodium Oxide (Na_2O)	0.06
Potassium Oxide (K_2O)	0.12
Phosphorus Pentoxide (P_2O_5)	0.06
Moisture content	2.47

2.2. Mixing and Preparation of Specimens

The concrete mix design, following BS EN 206-1 for mix design methodology, aimed for a target compressive strength of 30 MPa. The control mix included natural river sand as the fine aggregate and crushed granite as the coarse aggregate. For laterized concrete mixes, the fine aggregate was partially replaced with laterite soil at levels of 10%, 20%, 30%, 40%, and 50% by weight. The water-cement ratio was consistently maintained at 0.45 for all mixes. The mass of materials required for each replacement level was calculated based on the total volume of concrete needed for 39 cylindrical specimens, 39 beam specimens, and 12 cube specimens per replacement level.

Table 3. Mass of the Constituent Materials Required for the Concrete

Replacement of Level of Laterite	Cement (kg)	Water (kg)	Sand (kg)	Laterite (kg)	Granite (kg)	Superplasticizer (kg)
0%	351.12	158.00	614.46	0	877.80	3.51
10%	351.12	158.00	553.01	61.45	877.80	3.51
20%	351.12	158.00	491.56	122.89	877.80	3.51
30%	351.12	158.00	430.12	184.34	877.80	3.51
40%	351.12	158.00	368.68	245.78	877.80	3.51
50%	351.12	158.00	307.23	307.23	877.80	3.51

The cement, fine aggregate (sand or laterite-sand mix), and coarse aggregate were dry-mixed to ensure a uniform distribution of materials. Subsequently, potable water and a polycarboxylate ether-based superplasticizer (1% by weight of cement) were added to the dry mix. The mixing continued until a homogeneous mix was achieved.
To ensure the consistency and quality of the concrete mixes, a slump test was performed on the fresh concrete containing each replacement of laterite to assess its workability, as per BS EN 12350-2. The results are summarized in Table 4.

Table 4. Slump Test Results for Different Laterite Replacement Levels

% Laterite Content	Water/Cement Ratio	Slump (mm)
0	0.45	67
10	0.45	64
20	0.45	59
30	0.45	57
40	0.45	55
50	0.45	52

The prepared concrete was then used to cast specimens for tensile splitting strength, flexural strength tests, and carbonation depth measurement. Cylindrical specimens with dimensions of 150 mm in diameter and 300 mm in height were cast for tensile splitting strength tests, beam specimens with dimensions of 150 mm x 150 mm x 750 mm were cast for flexural strength tests, and cube specimens with dimensions of 100 mm x 100 mm x 100 mm were cast for carbonation depth measurement. The concrete was placed in the molds in three layers, each compacted with a tamping rod to remove air voids. After casting, the specimens were covered with a damp cloth and plastic sheeting to prevent moisture loss and left in the molds for 24 hours at room temperature.

After 24 hours, the specimens were carefully de-molded to avoid damage and placed in a water tank at room temperature for 28 days to ensure complete hydration and strength development. After the 28-day water curing period, specimens designated for carbonation were air-dried in a controlled environment for 7 days to reduce their moisture content. The pre-dried specimens were then placed in a chamber with 4% CO2 concentration, 23°C temperature, and 60% relative humidity. Specimens were exposed to these conditions for different durations: 28 days, 60 days, 90 days, and 120 days.

Non-carbonated control specimens were stored in a dry environment at room temperature for the same durations as their carbonated counterparts. Additionally, another set of specimens was immersed in water after the initial 28-day curing period and maintained under water for the same durations.

2.3. Experimental Methods

The tensile splitting strength tests were conducted in accordance with BS EN 12390-6:2009 using the cylindrical specimens. The cylinders were placed horizontally between the platens of a compression testing machine and loaded along the vertical diameter until failure. The tensile splitting strength was calculated using Equation 1:

$$f_{ct} = \frac{2P}{\pi LD} \tag{1}$$

Where,

f_{ct} is the tensile splitting strength (MPa),
P is the maximum load applied (N),
L is the length of the cylinder (mm), and
D is the diameter of the cylinder (mm).

The flexural strength tests were performed as per BS EN 12390-5:2009 using the beam specimens. The beams were subjected to a three-point bending load until failure, and the flexural strength was determined with Equation 2:

$$f_{cf} = \frac{3FL}{2bd^2} \tag{2}$$

Where,

f_{cf} is the flexural strength (MPa),
F is the maximum load applied (N),
L is the span length (mm),
b is the width of the specimen (mm), and
d is the depth of the specimen (mm).

These specimens for flexural and tensile strength were tested at 0, 28, 60, 90, and 120 days after exposure to different conditions: carbonation, dry environment, and water immersion.

The depth of carbonation was measured on the cube specimens that were exposed to carbonation for 28, 60, 90, and 120 days. After exposure, the cubes were split and sprayed with a 1% phenolphthalein solution. The carbonation depth was determined by measuring the depth of the colorless region from each of the four sides of the cube and calculating the average, indicating the extent of carbonation.

3. Results and Discussion

In this section, the results of the experimental tests on the tensile splitting strength, flexural strength, and carbonation depth of concrete with varying levels of laterite replacement are presented and analyzed. The discussion will focus on the influence of laterite content and different exposure conditions on these properties. This comprehensive analysis aims to elucidate the effects of laterite as a partial replacement for fine aggregate in concrete, providing insights into its potential benefits and drawbacks.

Figure 2 showcases the tensile splitting strength of concrete with varying levels of laterite replacement under different exposure conditions over a period of up to 120 days. At 0 days (after the initial curing of all the specimens in water), the control concrete (0% laterite replacement) consistently shows the highest tensile splitting strength across all exposure conditions, at 2.420 MPa. As the laterite replacement level increases, the tensile strength decreases across all exposure conditions. This trend suggests that the incorporation of laterite reduces the immediate tensile strength of the concrete. The reduction in tensile splitting strength is likely due to the weaker bond between laterite particles and the cement paste compared to traditional fine aggregates, which results in a less cohesive internal structure [36]. These findings are consistent with previous studies [34,37,38,39].

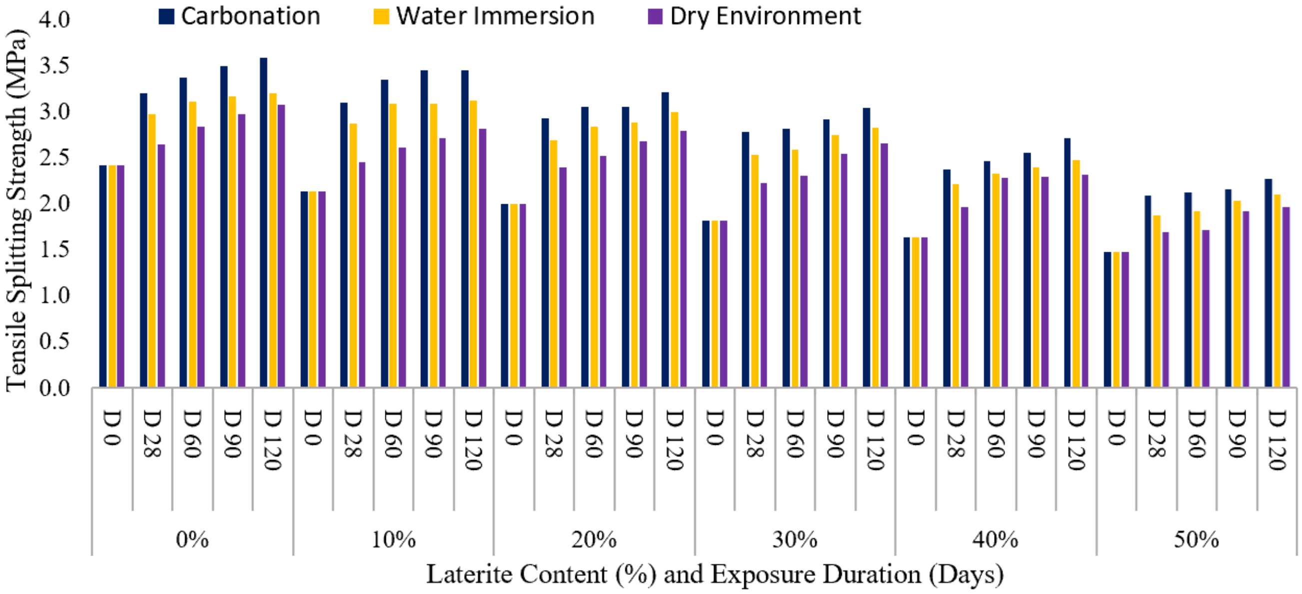

Figure 2. Tensile Splitting Strength of Laterised Concrete at Various Laterite Contents and Exposure Conditions

Under carbonation exposure, tensile strength generally increases over time across all laterite replacement levels. The highest tensile strength is observed at 120 days for 10% laterite replacement (3.454 MPa). However, with increasing laterite content, the tensile strength at 120 days shows a consistent decline, suggesting that higher laterite replacement might not be beneficial for long-term strength under carbonation conditions. This decline can be attributed to the increased porosity and reduced density of the concrete matrix when a higher amount of laterite is used. The control mix, under carbonation, peaks at 120 days (3.586 MPa), indicating that carbonation exposure effectively enhances tensile strength over time. This enhancement can be attributed to the carbonation process, which leads to the formation of calcium carbonate within the concrete matrix. This newly formed calcium carbonate fills the pores and microcracks in the concrete, leading to a denser and more cohesive structure that enhances tensile strength over time. This observation is consistent with the findings of [12] where it is shown that the tensile strength of concrete increases with the duration of carbonation exposure.

Figure 2 also illustrates the benefits of extended carbonation on the tensile splitting strength of laterized concrete. From day 28, the tensile splitting strength of 10% laterized concrete exceeds that of normal concrete at day 0 (2.420 MPa), increasing from 3.099 MPa at day 28 to 3.454 MPa at day 120. Similarly, the tensile strength of 20% laterized concrete at 28 days of carbonation (2.930 MPa) surpasses that of normal concrete at day 0, reaching 3.059 MPa at day 90 and 3.212 MPa at day 120.

For 30% laterized concrete, the strength improves from 1.821 MPa on day 0 to 3.044 MPa on day 120, surpassing the initial strength of normal concrete before day 28 of carbonation. The 40% laterite replacement shows continuous improvement from 2.772 MPa at day 60 to 2.714 MPa at day 120, although it remains lower compared to lower replacement levels but still exceeds the initial strength of normal concrete by day 60. However, the tensile splitting strength of 50% laterized concrete remains below that of normal concrete throughout the carbonation periods, with minimal improvement.

Extended carbonation significantly enhances the tensile splitting strength of laterized concrete, particularly at lower replacement levels (10% to 30%). This suggests that moderate incorporation of laterite, combined with prolonged carbonation, can improve concrete performance, making it a viable and sustainable material for construction.

In water immersion conditions, tensile strength increases over time across all laterite replacement levels but at a slower rate compared to carbonation exposure. The control mix shows a peak at 120 days (3.207 MPa). For 10% laterite replacement, there is a consistent increase in tensile strength, peaking at 120 days (3.124 MPa). Higher laterite replacements (20%, 30%, 40%, and 50%) show reduced tensile strengths, with the 50% replacement level showing the lowest strength at 120 days (2.098 MPa). This indicates that while water immersion helps in strength gain, it is less effective than carbonation, particularly at higher levels of laterite replacement.

In a dry environment, tensile strength shows the lowest values compared to carbonation and water immersion conditions. While strength increases over time, the growth rate is less pronounced, especially for higher laterite contents. For instance, 50% laterite replacement shows only a slight increase over time, reaching just 1.971 MPa at 120 days. This suggests that hydration and internal curing are less effective in a dry environment, leading to lower tensile strength development.

The likely reason carbonation exposure yields better tensile splitting strength than water immersion and a dry environment is that carbonation exposure provides a synergistic effect by improving the microstructure and promoting beneficial chemical reactions within the concrete, leading to higher tensile splitting strength compared to water immersion and dry environment conditions. This result agrees with the findings of [40].

Figure 3 highlights the flexural strength of concrete with varying levels of laterite replacement under different exposure conditions for up to 120 days. At 0 days, the control concrete (0% laterite replacement) consistently shows the highest flexural strength across all exposure conditions (3.490 MPa). As the laterite replacement level increases, the flexural strength decreases, reflecting the weakening effect of laterite incorporation on concrete. These findings align with earlier research [16,33,34] and likely result from the porous nature and higher water absorption of laterite compared to sand.

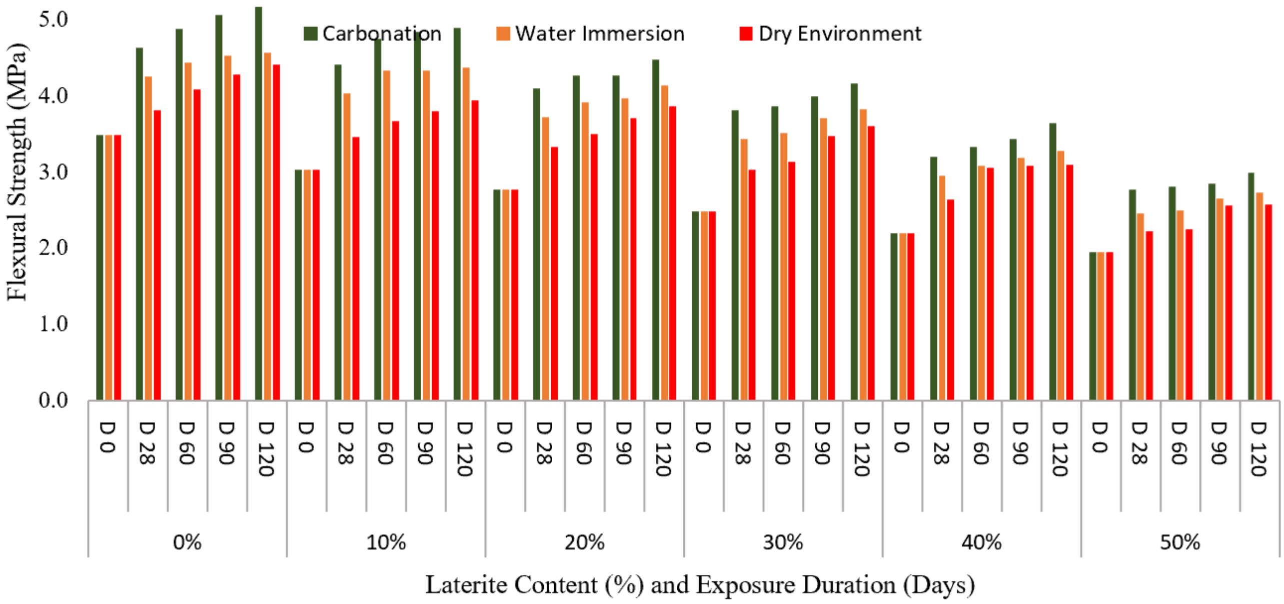

Figure 3. Flexural Strength of Laterised Concrete at Various Laterite Contents and Exposure Conditions

Carbonation exposure generally causes flexural strength to increase over time across all laterite replacement levels. This increase is attributed to the densification of concrete as carbon dioxide reacts with calcium hydroxide to form calcium carbonate. The control concrete exhibits a peak flexural strength of 5.175 MPa at 120 days. This finding corresponds with the study by [41], which also reported an increase in flexural strength with extended carbonation exposure. However, as the laterite content increases beyond 10%, the long-term flexural strength under carbonation decreases, with the 50% laterite replacement showing the lowest strength at 120 days (2.992 MPa). This trend indicates that while carbonation exposure can enhance flexural strength, higher levels of laterite replacement diminish these benefits over time.

The benefits of extended carbonation on the flexural strength of laterized concrete are demonstrated in Figure 3, showing an improvement compared to normal concrete, which has a flexural strength of 3.490 MPa at 0 days of carbonation. At 10% laterite replacement, the flexural strength surpasses normal concrete by day 28 (4.410 MPa) and improves to 4.897 MPa by day 120. Similarly, for 20% laterite replacement, the strength exceeds normal concrete by day 28 (4.096 MPa) and reaches 4.475 MPa at day 120. At 30% replacement, the strength rises above normal concrete by day 28 (3.814 MPa) and grows to 4.162 MPa by day 120.

For 40% laterite replacement, the flexural strength matches normal concrete by day 90 (3.433 MPa) and reaches 3.643 MPa by day 120. However, at 50% replacement, the strength remains below normal concrete, showing minimal improvement from 1.947 MPa at day 0 to 2.992 MPa at day 120.

Just as observed in tensile strength, extended carbonation significantly enhances the flexural strength of laterized concrete up to 40% replacement, with the most substantial improvements at 10% to 30%. This suggests that moderate laterite incorporation and prolonged carbonation can greatly improve concrete performance, making it a promising material for sustainable construction.

The flexural strength of the control concrete steadily increases under water immersion, reaching 4.573 MPa at 120 days. The 10% laterite replacement level follows a similar trend, peaking at 4.377 MPa. However, higher laterite replacements exhibit a slower rate of strength gain and lower overall values, with the 50% laterite replacement achieving only 2.728 MPa at 120 days. This suggests that while water immersion supports strength development, it is less effective than carbonation, particularly at higher levels of laterite replacement.

Flexural strength values are lower in a dry environment compared to carbonation and water immersion conditions. The control concrete peaks at 4.413 MPa at 120 days, while the 10% laterite replacement level shows a modest increase over time, reaching 3.277 MPa. Higher levels of laterite replacement exhibit even lower strength gains, with the 50% laterite replacement reaching only 2.579 MPa at 120 days. This indicates that hydration is less effective in dry conditions, resulting in diminished development of flexural strength.

Carbonation exposure yielding better flexural strength than water immersion and a dry environment can be attributed to the same reason given for tensile splitting strength, where carbonation yielded better tensile splitting strength than water immersion and a dry environment. A 10% laterite replacement level provides the best initial and long-term strength balance, particularly under carbonation exposure. Replacements above 20% lead to diminishing returns in flexural and tensile splitting strengths, especially at the 50% replacement level, where both strengths are significantly lower across all exposure conditions.

Figure 4 shows the carbonation depth of concrete with varying levels of laterite replacement over a period of up to 120 days. At 28 days, the control concrete (0% laterite replacement) and the concrete with 10% laterite replacement both exhibit a carbonation depth of 9 mm. As the laterite replacement level increases, the carbonation depth also increases, with the highest depth of 14 mm observed in the concrete with 50% laterite replacement. This indicates that higher levels of laterite replacement accelerate the carbonation process in the early stages.

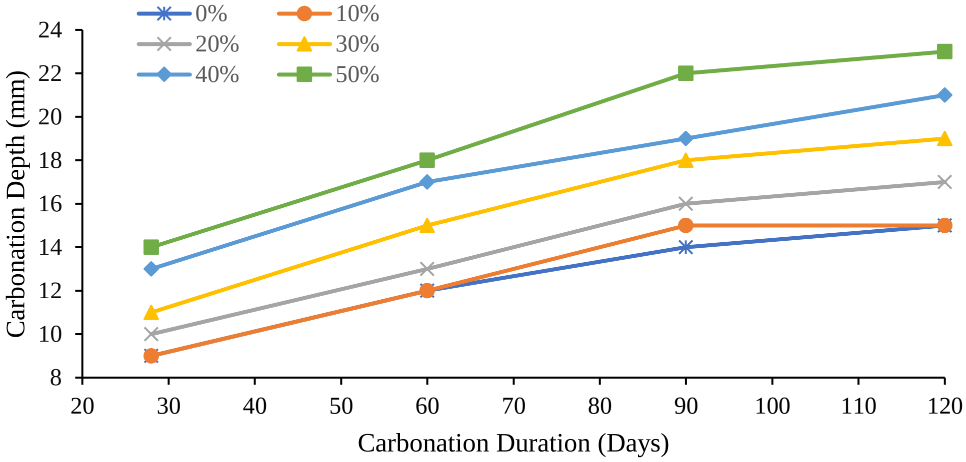

Figure 4. Carbonation Depth Over Time for Various Laterite Replacement Levels

By 60 days, the control concrete and the 10% laterite replacement maintain similar carbonation depths of 12 mm. As the laterite replacement level increases, the carbonation depth continues to rise, reaching 18 mm for the 50% laterite replacement. This trend shows that the concrete's resistance to carbonation decreases as the laterite content increases, even at this intermediate time point.

At 90 days, the control concrete exhibits a carbonation depth of 14 mm. The carbonation depth for 10% laterite replacement increases slightly to 15 mm, while higher levels of laterite replacement result in more substantial increases. For instance, the 30% laterite replacement level reaches a carbonation depth of 18 mm, and the 50% replacement level reaches 22 mm. This data further reinforces the observation that higher laterite content reduces the concrete's ability to resist carbonation over time.

By 120 days, the control concrete shows a carbonation depth of 15 mm, indicating a gradual increase over the testing period. Concrete with 10% laterite replacement maintains a similar carbonation depth of 15 mm, suggesting that low levels of laterite replacement do not significantly impact long-term carbonation resistance. However, as the laterite replacement increases, the carbonation depth also increases, with the 50% laterite replacement reaching 23 mm.

The carbonation depth increases with both time and the percentage of laterite replacement. Initially, both the control and low laterite replacement (10%) concrete show similar resistance to carbonation. However, as the percentage of laterite increases, the concrete's resistance to carbonation decreases notably. This can be attributed to the increased porosity and reduced density associated with higher laterite content, which facilitates deeper carbonation penetration. The carbonation depth progressively increases as carbon dioxide continues to react with the available calcium hydroxide in the concrete, but the rate of this increase tends to decrease over time. By 120 days, higher laterite replacement levels (30% and above) exhibit significantly higher carbonation depths, indicating a pronounced reduction in durability, especially in reinforced concrete. This increase in carbonation depth with time is consistent with prior investigations [36,42,43].

Figures 5 and 6 demonstrate that both tensile splitting strength and flexural strength increase with carbonation depth across all laterite replacement levels. The rate of increase in strength appears to correlate with the increase in carbonation depth. Higher percentages of laterite replacement generally result in lower initial strengths, but the overall trend of increasing strength with carbonation depth remains consistent. These relationships indicate that carbonation positively affects both tensile and flexural strengths, with greater effects observed at deeper carbonation depths, even as the laterite replacement level increases.

In summary, exposure conditions significantly impact the flexural and tensile splitting strengths of concrete with laterite replacement. Carbonation exposure typically enhances both flexural and tensile strengths more effectively than water immersion or dry environments. Moderate laterite replacement levels (10-20%) demonstrate optimal performance across various conditions, striking a balance between strength and durability. However, higher replacements (30% and above) result in reduced flexural strengths, particularly in dry environments, underscoring the necessity of carefully considering both the laterite replacement level and the exposure condition in concrete mix design.

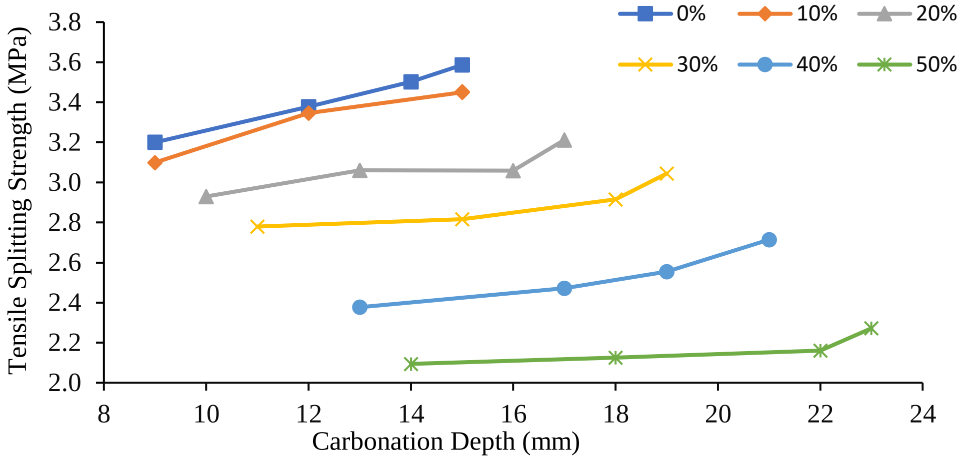

Figure 5. Tensile Splitting Strength vs. Carbonation Depth Across Various Laterite Replacement Levels Over Time

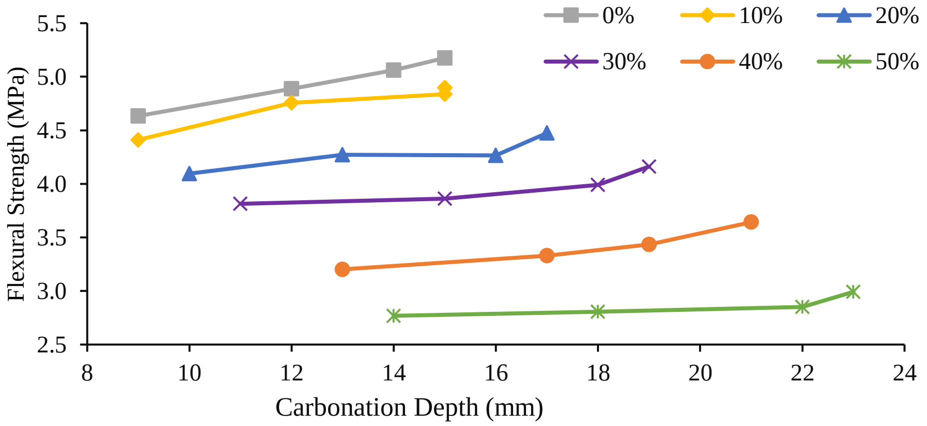

Figure 6. Flexural Strength vs. Carbonation Depth for Different Laterite Replacement Levels over Time

4. Conclusion

This study demonstrates that exposure conditions significantly influence the flexural and tensile splitting strengths of laterized concrete. Extended carbonation notably enhances these strengths, especially at laterite replacement levels between 10% and 30%, with improvements observed up to 40%. This enhancement occurs through the densification of the concrete matrix via the formation of calcium carbonate. Moderate laterite replacement levels of 10-20% offer the best performance, balancing strength and durability benefits without compromising structural integrity. Although higher laterite content of 30% and above is beneficial for sustainability, it reduces mechanical strengths, particularly in dry environments. Therefore, careful selection of laterite content based on performance needs and exposure conditions is essential.

The use of laterite as a partial replacement for fine aggregate contributes to resource conservation and aligns with sustainable construction practices. The improvement in mechanical properties through carbonation further underscores the potential of laterized concrete as an eco-friendly building material. For practical applications, concrete mix designs incorporating laterite should consider exposure conditions, strategically utilizing carbonation to enhance durability and longevity, especially in environments where carbonation exposure is feasible.

In conclusion, this research highlights the importance of considering both material composition and environmental exposure in optimizing the performance of laterized concrete. The findings provide valuable insights for the construction industry, promoting the use of sustainable materials while ensuring structural performance and durability, thereby supporting the broader adoption of laterized concrete in various construction applications.

Declaration of Competing Interest

No conflict of interest was declared by the authors.

Authorship Contribution Statement

Mark Omeiza Onipe: Conception, Data Collection and/or Processing, Analysis and/or Interpretation, Writer, Funding, Critical Review
Opeyemi Ayodeji Osadola: Design, Literature Review, Data Collection and/or Processing, Funding, Critical Review
Ovbokhan Bridget Oseghale: Supervision, Analysis and/or Interpretation, Funding, Critical Review

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