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Effect of Lateritic Stone Aggregate and Coconut Husk Fiber on the Properties of Concrete

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Abstract

Natural stone aggregate forms the bulk volume of concrete and has contributed to the increased cost of concrete production. This has led to the search for alternate aggregates such as lateritic stone for concrete production. This paper investigates the engineering properties of concrete produced with lateritic aggregate (LA) as the coarse aggregate replacement and coconut husk fibre (CHF) as reinforcement. Natural stone aggregate was replaced by LA at 0%, 10%, 20%, 30%, 40%, and 50%, with 0.25% constant CHF by weight. A mix proportion of 1:1.5:3 with a water-cement ratio of 0.6 was used for producing concrete. A total of 162 specimens (90 cubes and 72 beams) were prepared and tested at the 7, 14, 21, and 28 days of curing. The highest compressive strength was 43.36 N/mm^2 (10% LA replacement) as compared to the control of 41.51 N/mm^2. The 10% LA replacement obtained the highest flexural strength of 5.35 N/mm^2 as compared with the 5.29 N/mm^2 for the control. The water absorption of the concrete increased from 2.8% (control) to 3.57% (50% replacement LA). Scanning electron microscopy (SEM) revealed micro gaps between CHF and LA concrete. The study, therefore, concludes that the use of LA and CHF positively influenced the strength properties of concrete. 10% LA replacement of coarse aggregate and 0.25% CHF is recommended to practitioners for use.

Keywords

Concrete, Coarse Aggregate, Compressive Strength, Flexural Strength, Natural Stone Aggregate, SEM

1. Introduction

The construction industry faces significant challenges, including a gap between demand and supply of concrete, along with high production costs [1]. This has called for the need to reduce building material costs, increase accessibility, connect construction to local economies, and provide job opportunities [2] [3]. Affordable housing must be environmentally sustainable and not harm the ecosystems [4] [5]. Population growth, economic shifts, and technological advancements affect infrastructure demands [6]. With the global population exceeding eight billion [7], there is increasing pressure on resources including construction materials. An important construction material that consumes many natural resources is concrete. Concrete is a vital construction material known for its versatility and resilience in various weather conditions [8].

According to researchers [9] [10], concrete is key in construction due to its usefulness in creating purposeful structures in different weather conditions. However, to cut down on the environmental impact of conventional concrete, researchers need to investigate alternatives for its constituent materials [11]. Any effort that contributes to the reduction of the cost of aggregate will have a direct impact on reducing the cost of construction. Therefore, encouraging the use of non-conventional aggregate, provided suitable data exist on the properties of concrete made from them is of great interest to the construction industry [12]. As the demand for materials for concrete production is at the increase, the need to investigate alternate constituent materials is of interest to researchers. The application of environmentally friendly concrete is paramount for the construction industry for its construction projects.

Reducing the environmental impact of concrete requires exploring alternative constituent materials [13] such as aggregate which forms the bulk of the volume of concrete. The demand for concrete materials is on the rise, prompting global research into alternate concrete materials [11] [13], especially aggregate. The use of natural aggregate for concrete production is expensive due to the high cost of the aggregate. This has generated the need for the use of alternate aggregate for concrete production. Among the types of rocks that are found in the tropic and sub-tropical regions, laterites are available and abundant for construction purposes [14]. Laterites are abundant in tropical regions, offering an alternative to natural aggregates [15].

Laterised concrete, using laterite aggregate in place of natural aggregate, is a potential construction material [16]. According to Kumar *et al*. [17], more studies are required on the use of laterite soil for mortar, concrete, and grout. Researchers should explore the use of laterite aggregates as a fractional backup for base aggregates [15]. Ogunleye [18] used laterite as fine aggregate in concrete to study the compressive and flexural strengths of the concrete. Ettu *et al*. [19] used laterite fine aggregate to replace natural sand for producing concrete for use in reinforced concrete. A study by Awolusi *et al*. [20] used laterite and sawdust ash as fine aggregate and supplementary cementitious material in concrete. However, there is a lack of research on processing lateritic aggregate for concrete production [21]. It can be observed that most of the previous studies done on the use of laterite in concrete production used laterite as a fine aggregate replacement for natural sand. There is a lack of studies on the use of laterite aggregate in concrete production as a coarse aggregate replacement of natural stones.

Aholoukpè *et al*. [22] studied the strength properties of laterite soil stabilized with Grewia bicolour bark juice and cement for construction application. Akinwande *et al*. [23] investigated the properties of laterite blocks reinforced wood fiber and waste glass. Assiamah *et al*. [24] used sawdust ash and laterite to produce interlocking blocks for construction applications. Ige and Danso [25] studied the mechanical, physical, and thermal gravimetric properties of lateritic masonry blocks reinforced with plantain pseudo-stem fibres for construction-0 applications. Coconut trees offer various benefits, including using their trunks for interior building insulation [26]. The production of coconut fibre is on the increase, driven by the demand for eco-sustainable and biodegradable materials [27]. It can be observed from above that previous studies have not considered using laterite aggregate and coconut husk fibres for the production of concrete. Therefore, this study investigates the effect of using lateritic aggregate and coconut husk fibre in concrete production.

In this paper, the properties of concrete produced with lateritic aggregate as partial replacement of natural aggregate and coconut husk fibre as reinforcement are investigated. The properties studied are compressive strength, flexural strength, and water absorption of the concrete. Scanning electron microscopy (SEM) analysis was conducted to identify the presence of any micro gaps in the concrete. This study is useful because of the use of lateritic aggregate and coconut husk waste fibres as alternative materials to natural aggregate that cannot only be beneficial to the environment but also save cost in concrete production.

2. Experimental Programme

2.1. Materials

In this experimental study, the main materials used were cement, pit sand, granitic coarse aggregate, lateritic coarse aggregate, coconut husk fibre, and water. Ordinary Portland cement grade 42.5R (**Figure 1(a)**) produced by GHACEM which meets the Ghana Standard GS 1118 [28] was purchased in the market of Kumasi, Ghana andused as a binder in the concrete. Fine aggregates were locally available natural pit sand obtained from Offinso in the Ashanti Region of Ghana, which conformed to the requirement of BS 882 [26]. The fine aggregates (pit sand) used in the study were free from impurities, with size up to 4.75 mm complying with the requirements of BS 882 [29] with a specific gravity range between 2.5 and 2.8. Coarse aggregates used in this study were crushed granites (**Figure 1(b)**) produced from a quarry crushing plant at Ntesera in the Ashanti

Region in Ghana. The crushed granites were irregular and angular shapes of sizes between 12 to 20 mm complying with the requirements of BS 882 [29] with specific gravity between 2.6 and 2.9. Lateritic aggregates (**Figure 1(c)**) used as partial replacement of coarse aggregate were abundantly lying on the earth's surface at Kentenkyere in the Atwima-Kwawoma District of the Ashanti Region of Ghana. For the comparative study, the lateritic aggregate (LA) sizes range from 12 to 20 mm complying with the requirements of BS 882 [29]. The particle size distribution details of the crushed granite and the LA are shown in **Figure 2**. The coconut husk fibre used as the reinforcement was also obtained in the form of husk from coconut sellers' outlet located at Abuakwa and Sofoline Lorry stations in Kumasi, Ashanti region of Ghana. The coconut husks (**Figure 1(d)**) were soaked in water for 48 hours, after which they were mechanically beaten on a wooden board, and the fibres (**Figure 1(e)**) were extracted and sundried for 48 hours. The scanning electron microscopy (SEM) image of a single fibre is shown in **Figure 1(f)**. Portable drinkable water was obtained from the construction laboratory at the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AMUSTED) where the experimental work was conducted.

Figure 1. Experimental materials: (a) Portland cement 42.5R, (b) Crushed granite, (c) Lateritic stones, (d) Coconut husk, (e) Coconut husk fibres, (f) SEM image of a single coconut husk fibre.

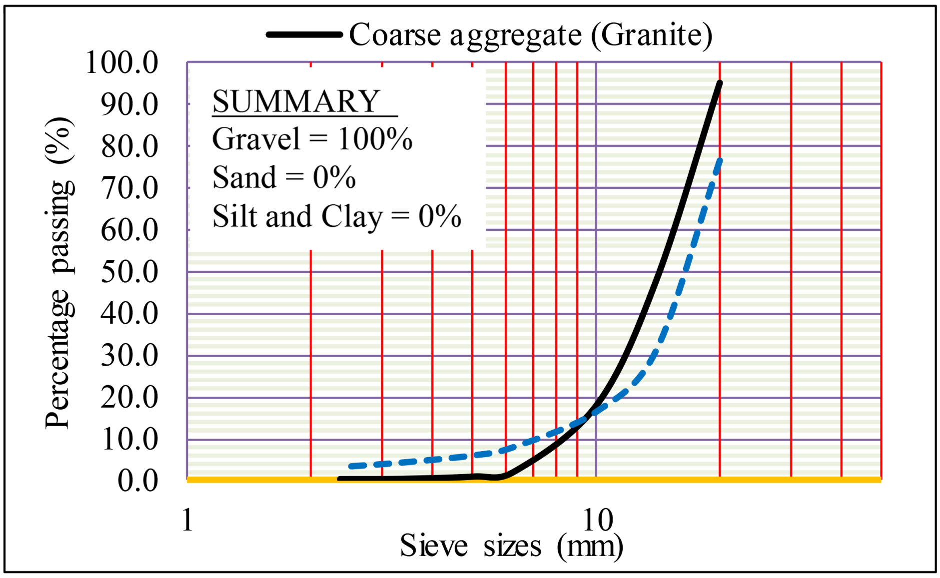

Figure 2. Particle size distribution curve of lateritic and granitic aggregate.

2.2. Preparation of Specimens

In this study, a mix ratio of 1:1.5:3 was used for the concrete work with a water-cement ratio of 0.6 (**Table 1**). Lateritic aggregate content of 0%, 10%, 20%, 30%, 40%, and 50% was used as a replacement for crushed granite with a constant 0.25% of coconut husk fibre (CHF) of 50 mm length. The control mix (0%) did not contain LA and CHF. Concrete was mixed and specimens were prepared following IS 10262 [30] specification. The required fine aggregate and cement were poured into the concrete mixer, followed by the coarse aggregate, the CHF, and finally water added while the mixer rotated to obtain the required fresh concrete. A total of 162 specimens were prepared, consisting of 90 cubes (100 × 100 × 100 mm) and 72 beams (100 × 100 × 500 mm) (see **Figure 3(a)**). The specimens were cured in water (see **Figures 3(b)-(c)**) for 7, 14, 21 and 28 days before testing.

Table 1. Mix proportion for concrete materials.

Mix design	Cement (kg)	Fine Aggregate (kg)	LA (kg)	Crush Granite (kg)	CHF (kg)	W/C
0%	34.04	51.05	0	102.11	0	0.6
10%	34.04	51.05	10.21	91.90	0.47	0.6
20%	34.04	51.05	20.42	81.69	0.47	0.6
30%	34.04	51.05	30.63	71.48	0.47	0.6
40%	34.04	51.05	40.84	61.57	0.47	0.6
50%	34.04	51.05	51.06	51.06	0.47	0.6

LA = lateritic aggregate; CHF = coconut husk fibre; W/C = water cement ratio.

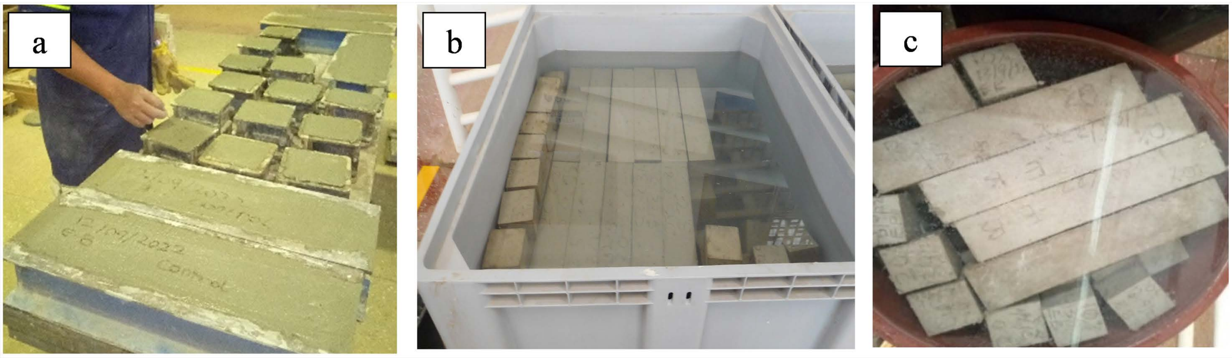

Figure 3. Preparation of specimens: (a) Moulding of beams and cubes, (b) and (c) Curing of beams and cubes.

2.3. Testing of Specimens

2.3.1. Compressive Strength Test

The compressive strength test was conducted on the hardened specimens (cubes) after 7, 14, 21, and 28 days of curing following the procedures from BS EN 12390-3 [31]. The Hydro Servo Computer Controlled Automatic 1000 kN UTM was used to conduct the test. The load on the cube was activated gradually and continuously at the amount of 140 kg/cm^2 per minute till the cube failed (see **Figure 4(a)**), and the maximum load at which the cubes failed was recorded. The compressive strength of the cubes was determined using Equation (1):

$$fc = F/A \tag{1}$$

where fc = compressive strength; F = force, and A = cross-sectional area of specimen.

2.3.2. Compressive Strength Test

The flexural strength test was conducted to determine the ability of concrete to resist bending stresses. After curing and drying of the test specimens (beams), the beams were then weighed and tested as per the BS EN 12390-5 [32]. The test was conducted with the ELE non-automatic 100 KN capacity flexural frame testing machine. Each beam was stacked with a main issue load situated at mid-range and on top of the pillar, while the base face was upheld on two just-upheld conveyors. The load was steadily and consistently applied at the pace of 180 kg/cm^2 till the beam failed (see **Figure 4(b)**), and the maximum load at which the beams failed was recorded. The flexural strength of the beams was determined using Equation (2):

$$fs = 3FL/\left(2bd^2\right) \tag{2}$$

where fs = flexural strength; F = force; L = length of beam; b = width of beam and d = depth of concrete.

2.3.3. Water Absorption Test

The water absorption test of the specimens (cubes) was conducted following the procedure of BS 1881-122:2011+A1:2020 [33], after curing the specimens for 28 days. The cubes were dried in the oven for 24 hours at a temperature of 105˚C. It was then taken out and allowed to cool for 12 hours in a dry and cool environment. The mass of the dried cubes was then taken (m1) after which they were immersed in water (see Figure 4(c)) for 30 minutes and the wet mass was recorded (m^2). The water absorption of the cubes was calculated using the Equation (3):

$$WA = (m1 - m2)/m1 \times 100 \tag{3}$$

where WA = water absorption; m1 = dry weight of cube; and m2 = wet weight of cube.

Figure 4. Testing of specimens: (a) Compressive strength, (b) Flexural strength, (c) Water absorption.

2.3.4. Microstructural Analysis

Scanning electron microscope (SEM) analysis was conducted to determine the microstructural properties of the specimens. A chosen broken piece of the specimen's microstructural properties was investigated with the help of a Phenom-World ProX SEM analyser. Each sample was put in the Phenom-World Pro-X work area with an electron magnifying lens at 320 amplifications, which uncovered holes at the edge of the filaments in the substantial network. After the sample is embedded and the Phenom entryway is shut, the sample is moved naturally to the optical imaging position. The optical camera is actuated and the picture is shown in the primary review window of the screen. The images were captured and saved.

2.3.5. Data Analysis

The data obtained from the experimental procedure were computed and presented in tables and figures using Microsoft Excel. Sigma Plot version 12 was used to process research data to establish the existence of any significant difference in different group variables. A one-way analysis of variance (ANOVA) test was used to determine significant differences and variations between the test results.

3. Results and Discussion

3.1. Compressive Strength of Concrete

Figure 5 shows the compressive strength test results for lateritic concrete samples. The purpose of the test was to assess the strength performance of concrete samples with differing amounts (0% to 50%) of LA substitution of coarse aggregate and CHF as reinforcement. The 0% of the LA and CHF concrete (control) had compressive strength values of 29.6 and 41.51 N/mm^2 on the 7th and 28th day curing periods, respectively. The 10% LA replacement with 0.25% CHF specimen had the highest compressive strength values among all the percentage replacements. The 10% LA replacement with 0.25% CHF specimen produced a compressive strength of 30.79 N/mm^2 on the 7th day curing period and a value of 43.36 N/mm^2 for the 28 days curing period. According to Yalley and Kwan [34], an increase of up to 1% in coconut fiber could further develop strength improvement in concrete. The 20% LA replacement with 0.25% CHF specimen had 28.93 and 42.06 N/mm^2; the 30% LA replacement with 0.25% CHF specimen had 28.04 and 40.75 N/mm^2; the 40% LA replacement with 0.25% CHF specimen recorded 27.59 and 39.23 N/mm^2; and the 50% LA replacement with 0.25% CHF specimen also recorded 26.33 and 36.44 N/mm^2 for the 7th and the 28th day curing periods, respectively. It can be observed that as the LA content increased beyond 30%, the compressive strength of the concrete weakened. This implies that at a higher content LA substitution of coarse aggregates may have adversely affected the strength properties of the concrete. Comparably, a study by Salau and Busari [35] found that the mean compressive strength of concrete made with granite increased with the increase in the particle sizes of the granite, but the strength decreased as the laterite content increased. It is important to express that each specimen with LA and CHF content yielded an increase in compressive strength from the 7th to the 28th day of curing periods.

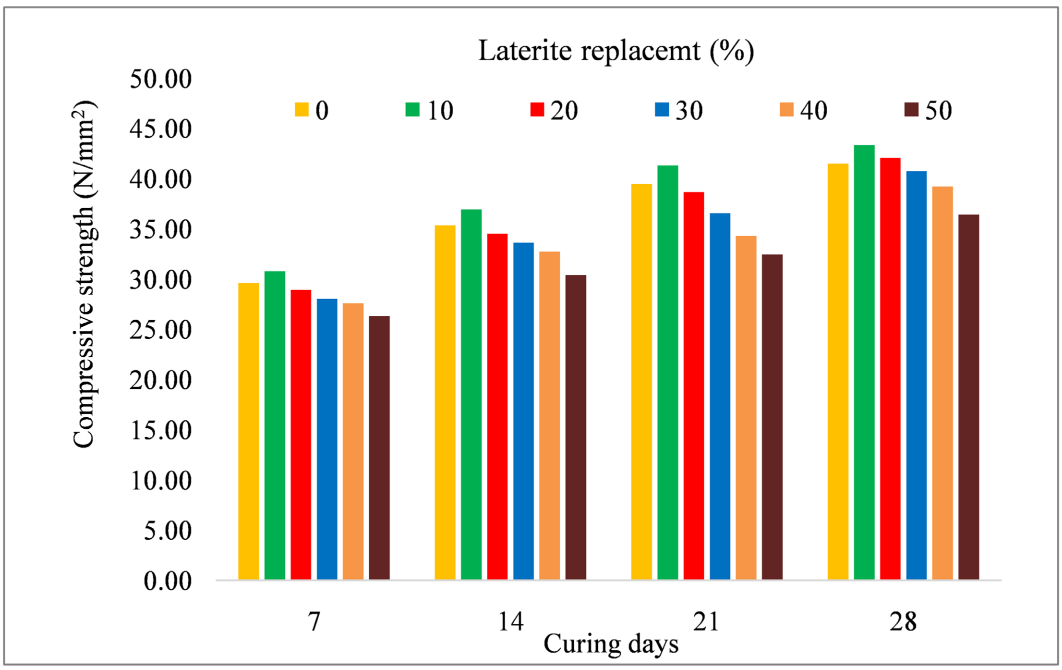

Figure 5. Compressive strength of concrete.

The results indicated that substitution of laterite aggregate up to 30% can create laterite concrete with strength between 40.75 - 43.36 N/mm^2 at 28 days of curing age and this strength satisfies the requirement for ACI, 211.2 [36]. As the amount of laterite in the concrete further increases to 50%, the mean value of the compressive strength appears to decrease. This suggests that increasing the replacement of coarse aggregate with lateritic aggregate beyond 30% may have a negative effect on the strength properties of the concrete.

To determine if the differences in the compressive strength values were significant or not, the One-Way Analysis of Variance (ANOVA) test was conducted at a 95% confidence level. The result obtained is shown in **Table 2** with a p-value of 0.006 which is less than 0.05. This therefore implies that the differences in the compressive strength values were significant. To further identify which of the mix designs provided the significant difference, pairwise comparison analyses were conducted and the result obtained is shown in **Table 3**. It can be observed that the significant differences in the compressive strength were between 0% and 50%, 10% and 50%, and 20% and 50% replacement levels. This implies that the laterite content of up to 20% as compared with the laterite content of 50% has a significant difference in compressive strengths.

Table 2. One-way repeated measures analysis of variance for compressive strength.

Descriptive statistics						One Way RM ANOVA					
Treatment Name	**N**	**Missing**	**Mean**	**Std Dev**	**SEM**	**Source of Variation**	**DF**	**SS**	**MS**	**F**	**P**
0%	3	0	41.507	0.365	0.211	Between Subjects	2	11.13	5.564		
10%	3	0	43.357	0.136	0.0784	Between Treatments	5	89.24	17.85	6.435	0.006
20%	3	0	42.063	0.676	0.39	Residual	10	27.74	2.774		
30%	3	0	40.747	1.024	0.591	Total	17	128.1	7.536		
40%	3	0	39.233	1.968	1.136						
50%	3	0	36.44	3.729	2.153						

Table 3. Pairwise comparison between P-values.

Comparison	Diff of Means	T	P	P < 0.050
10% vs. 50%	6.917	5.087	0.007	Yes
20% vs. 50%	5.623	4.135	0.028	Yes
0% vs. 50%	5.067	3.726	0.05	Yes
30% vs. 50%	4.307	3.167	0.114	No
10% vs. 40%	4.123	3.032	0.13	No
20% vs. 40%	2.83	2.081	0.484	No
40% vs. 50%	2.793	2.054	0.464	No
10% vs. 30%	2.61	1.919	0.504	No
0% vs. 40%	2.273	1.672	0.609	No

Continued

10% vs. 0%	1.85	1.36	0.745	No
30% vs. 40%	1.513	1.113	0.822	No
20% vs. 30%	1.317	0.968	0.828	No
10% vs. 20%	1.293	0.951	0.743	No
0% vs. 30%	0.76	0.559	0.831	No
20% vs. 0%	0.557	0.409	0.691	No

3.2. Flexural Strength of Concrete

The flexural strength test was conducted to determine the ability of concrete to resist bending stresses. **Figure 6** shows the flexural strength test results. The result follows a similar trend to that of the compressive strength. The flexural strengths increased as the curing age increased. It can be observed from **Figure 6** that the 10% LA replacement with 0.25% CHF specimen recorded the highest strength values of 4.65 and 5.35 N/mm^2 on the 7th and the 28th day of curing periods, respectively. The high flexural strength of the 10% LA replacement with 0.25% CHF reinforcement concrete result is similar to the study by Nadgouda [37], who found that the flexural strength of concrete on the 28-day curing increases as the fibre content in the concrete mix increases. Another study by Syed *et al*. [38] also found that when the amount of coconut husk fiber in conventional concrete increases by 0.6%, the flexural strength of the concrete also increases. The 20% LA replacement with 0.25% CHF specimen had 4.53 and 5.20 N/mm^2; the 30% LA replacement with 0.25% CHF specimen had 4.44 and 5.16 N/mm^2; the 40% LA replacement with 0.25% CHF specimen also recorded 4.32 and 5.00 N/mm^2; and finally, the 50% LA replacement with 0.25% CHF specimen obtained the lowest flexural strength values of 4.28 and 4.88 N/mm^2 on the 7th and 28th day of curing periods, respectively. It is worth affirming that every concrete specimen with LA and CHF content increased in strength from the 7th to the 28th day of the curing period.

The 10% LA replacement with 0.25% CHF reinforcement concrete flexural strength result produced about 15% and 12% of the compressive strength result of the 10% LA replacement with 0.25% CHF reinforcement on the 7th and 28th day of curing periods, respectively. According to NRMCA [39], the flexural strength of concrete could be around 10 to 20% of compressive strength. This implies that the flexural strength result of the concrete produced with LA replacement and CHF reinforcement is acceptable as compared with the compressive strength result. A similar study by Muthusamy and Kamaruzaman [40] obtained a flexural strength of about 14 to 15% of the compressive strength.

The One-Way RM ANOVA test was conducted to determine significant differences in the flexural strength between and within the test results for the control and the LA with CHF concretes specimens. The result of the One-Way RM ANOVA test is presented in **Table 4**. The result indicates that differences in the mean values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.338).

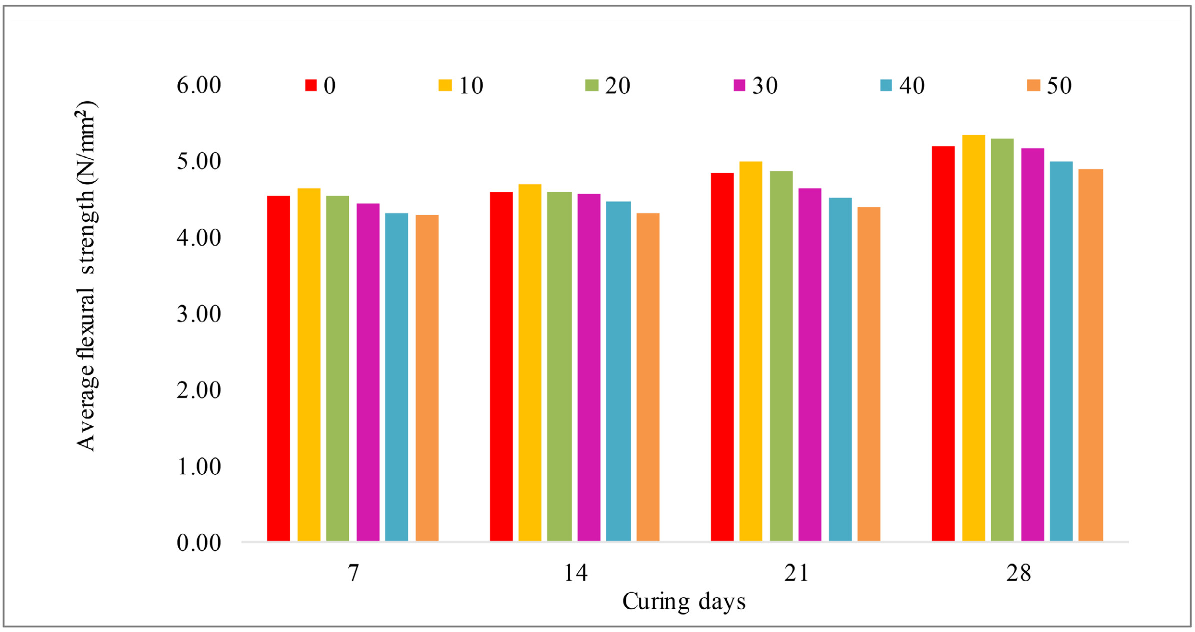

Figure 6. Flexural strength of concrete.

Table 4. The difference between the flexural strength on 28 days of curing.

Descriptive statistics						One Way RM ANOVA					
Treatment Name	N	Missing	Mean	Std Dev	SEM	Source of Variation	DF	SS	MS	F	P
0%	3	0	5.287	0.121	0.0696	Between Subjects	2	0.0973	0.0486		
10%	3	0	5.350	0.010	0.0057	Between Treatments	5	0.473	0.0945	1.298	0.338
20%	3	0	5.200	0.303	0.1750	Residual	10	0.728	0.0728		
30%	3	0	5.163	0.146	0.0841	Total	17	1.298	0.0764		
40%	3	0	5.003	0.0929	0.0536						
50%	3	0	4.877	0.526	0.304						

3.3. Water Absorption

The findings regarding the average water absorption of the cubes after 28 days of curing reveal that the control specimens outperformed the other test specimens. These results indicate that the control specimens exhibit lower porosity and, consequently, absorb less water (2.8%) as compared with the specimens containing varying proportions of LA and CHF. The result in Figure 7 illustrates that 50% LA replacement with 0.25% CHF specimen exhibited higher levels of water absorption (3.57%) compared with 3.10%, 3.21%, 3.33%, and 3.45% respectively for 10%, 20%, 30%, and 40% LA replacement with 0.25% CHF specimen, with the 10% LA replacement with 0.25% CHF specimen displaying lower water absorption among the specimens containing varying proportions of LA and CHF. It is evident that increasing the percentage of LA and CHF in the concrete leads to higher water absorption in the specimens. This is due to the fact that the LA and the CHF used in this study are more porous than the crushed granite used for the control specimens. It is important to note that this finding contrasts with the findings of a study by Muthusamy *et al.* [41]. The study of Muthusamy *et al.* [41] investigated the acid resistance and water absorption of concrete incorporating different percentages of laterite aggregates as a partial replacement for coarse aggregates. Their study demonstrated substantial low water assimilation with 10% or less lateritic content. According to Golewski [42], the water absorption rate for concrete should be within 4% - 6%. Water absorption below 5% for concrete is considered to be good quality concrete [43]. This, therefore, implies that the water absorption of all the LA replacements with 0.25% CHF specimens was within the acceptable levels.

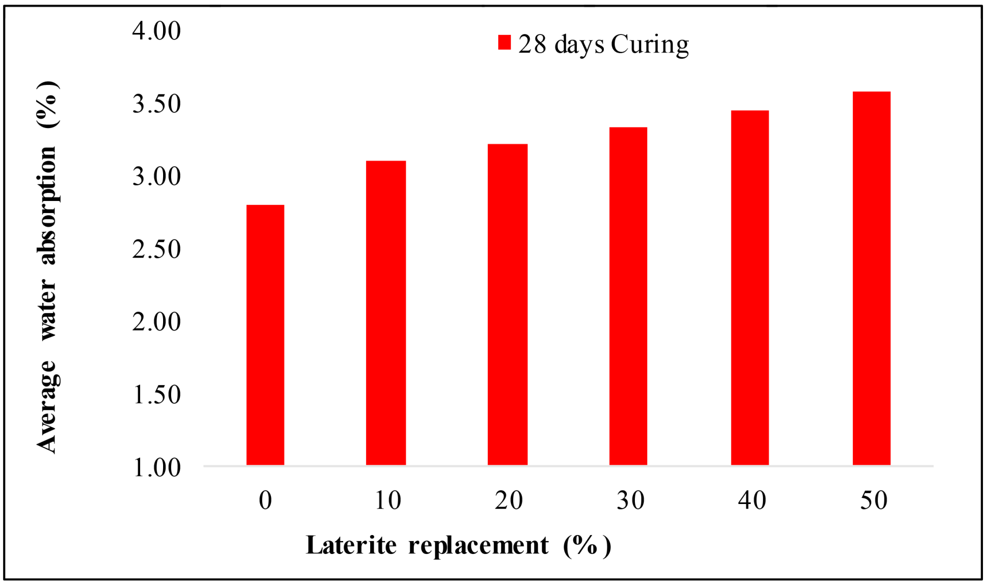

Figure 7. Water absorption of concretes.

3.4. Microstructural Analysis

Scanning electron microscope (SEM) is an effective instrument for finding and analyzing invisible or microcracks, and surface texture of materials. Microcracks in concrete can have a substantial impact on its structural integrity and mechanical qualities. Identifying these fissures is important for determining the strength and endurance of the material. To identify the internal characteristics of the concrete made with LA replacement of crushed granite and CHF, SEM analysis was conducted on the broken specimen. Figure 8(a) shows the microstructural image of the specimen which indicates that there are gaps between the coconut husk fibre and literite aggregate concrete. This implies that the bonding quality across the periphery was weak, thereby affecting the strength properties of the concrete products. It is common knowledge that gaps within concrete usually influence the strength. Danso *et al*. [44] reported that the natural fibres in a matrix always result in the creation of gaps between the fibres and the matrix as compared to steel bars in reinforced concrete. Again, the occurrence of gaps at the periphery of the coconut fibre and the laterite concrete could be attributed to the fibre shrinkage from wet to dry conditions. Fibre always tends to absorb water when it is exposed to water and then shrinks when it dries [45].

The SEM image of the lateritic stone is shown in **Figure 8(b)**. The dark spots show insoluble iron and whitish portions as aluminium oxyhydroxides within the lateritic stone. By analyzing their distribution and form, they have the potential to impact the properties of the concrete, notably in terms of durability and chemical resistance. It is critical to understand these components to optimize the concrete mix [46]. The SEM investigation of lateritic stone also revealed the presence and distribution of pores and voids. The size, form, and distribution of these voids are important elements that determine the porosity, permeability, and overall durability of the material. Understanding these properties is important for determining the concrete's resilience to external influences and long-term performance [46].

To identify the surface characteristics of the single fibre, the result obtained from the SEM analysis is shown in **Figure 1(f)**. It can be observed that the fibre strand has a rough surface and an edge with non-uniform width. This can contribute fibres' ability to bond with other materials such as binders and aggregates. Danso and Manu [47] conducted similar studies on coconut husk fibre and that the surface of the fiber is harsh and hence, can bond with the concrete matrix. Danso [48] found a comparative outcome in a prior study, uncovering that the micrograph of coconut husk strands in the matrix has a rough surface and is haphazardly dispersed in the matrix.

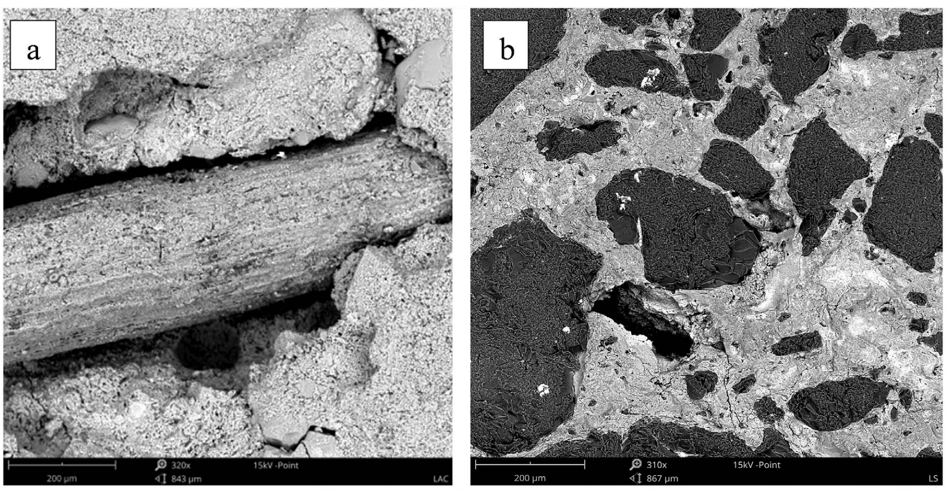

Figure 8. Microstructural analysis of specimen (a) SEM image of LA and CHF concrete (b) LA image.

4. Summary and Conclusions

The purpose of this study was to investigate the engineering properties of concrete produced with lateritic aggregate (LA) as a coarse aggregate replacement and coconut husk fibre (CHF) as reinforcement. This has provided valuable insights into the suitability of LA and CHF combination in concrete for construction applications. The key findings and implications from the different tests and analyses conducted are summarized below:

a) The study found that as the percentage of LA in concrete increased, the mean compressive strength decreased. However, there was a compressive strength of 43.36 N/mm^2 for 10% LA replacement with 0.25% CHF as compared to the control of 41.51 N/mm^2, which represents a 4.5% compressive strength increase over the control. Concrete with up to 30% lateritic aggregate still met the requirements for structural lightweight concrete applications.

b) Similarly, the flexural strength results showed that the 10% LA replacement with 0.25% CHF had the highest strength of 5.35 N/mm^2 as compared to the control with 5.29 N/mm^2. This translates into 1.1% flexural strength improvement over the control.

c) The control specimens recorded less water absorption (2.8%) as compared with 3.10% for 10% LA replacement with 0.25% CHF specimen, being the lowest water absorption among the specimens containing varying proportions of LA and CHF.

d) Scanning electron microscopy (SEM) revealed micro gaps between CHF and LA concrete. It was also observed that the fibre strand has a rough surface and an edge with non-uniform width, which contribute to fibres' ability to bond with other materials such as binders and aggregates.

The study, therefore, concludes that the use of LA and CHF positively influenced the strength properties of concrete. 10% LA replacement of coarse aggregate with 0.25% CHF is recommended to practitioners for use.

5. Limitations and Implications

This study contributes to the existing body of knowledge on sustainable concrete production by substituting coarse aggregate with lateritic aggregate and reinforcing it with coconut husk fibre. The study only investigated the mechanical properties of concrete with these alternative materials and also performed microstructural analysis to understand their interactions within the concrete matrix. Other properties such as long-term durability and chemical composition of concrete produced by substituting coarse aggregate with lateritic aggregate and reinforced with coconut husk fibre on a large scale are recommended for future research.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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