International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(Research Article)

Strength characteristics of Cocoa Leaf Ash (CLA) blended cement Laterized concrete

Olatunde Oluwatosin Farayibi [1,*], Olaniyi Alake [1], Olurotimi Olusegun Ekundayo [1], Bamidele Samuel Ojo [1] and Ademola Olufemi Adeleke [2]

[1] *Department of Building, Federal University of Technology, Akure, Ondo State, Nigeria.*
[2] *Department of Building, Moshood Abiola Polytechnic, Abeokuta, Ogun State, Nigeria.*

International Journal of Science and Research Archive, 2024, 13(01), 989–1003

Publication history: Received on 08 August 2024; revised on 22 September 2024; accepted on 24 September 2024

Article DOI: https://doi.org/10.30574/ijsra.2024.13.1.1753

Abstract

This study characterises Cocoa Leaf Ash (CLA), which was obtained by the calcination of cocoa leaves at 600°C for 2 hours. The pozzolanic properties of CLA was obtained by using the X-ray Fluorescence (XRF) test and the ash was blended with Ordinary Portland Cement (OPC) at 0%, 10%, 15% and 20% CLA contents by weight of cement. Fresh samples of laterized concrete (LATCON) were obtained by substituting fine sand with 0%, 10%, 20% and 25% of laterite fines and the resulting fresh blended cement LATCON samples were evaluated for their workability. After 7, 14, 21 and 28 days of total immersion of hardened concrete specimens, the mechanical property (compressive strength) was measured. The incorporation of CLA into the LATCON matrix performed averagely with respect to the compressive strength obtained for the evaluated samples. Primarily at a replacement level of 10% CLA of OPC and 10% lateritic soil replacement of fine sand, CLA-LATCON achieved 79.44% of the target strength at 28 days of curing. Therefore, CLA and LATCON can be effectively engaged and combined to produce green concrete which could be used for foundation footings, pavements, building blocks and masonry.

Keyword: Compressive Strength; Blended Cement; Laterized Concrete; Cocoa Leaf Ash (CLA)

1. Introduction

The construction industry (CI) plays a vital role in the economic development of any nation. In Nigeria, the activities of the industry has helped to achieve socioeconomic development goals via provision of habitat and other infrastructures together with the generation of employment opportunities. The construction industry therefore contributes to the nation's Gross Domestic Product (GDP) and also act as a multiplier effect to others sectors of the economy [23]. According to [1]. (2018), Nigeria's construction market is expected to grow by 5.7% in 2022, with an annual average growth of 3.2% between 2022 and 2026. However, the construction industry is a major contributor to environmental degradation, resource depletion and greenhouse gas emissions. Therefore, sustainable construction materials will be a readily available solution to mitigate these negative impacts [24].

Materials are crucial to the construction industry as they play a significant role in the overall success and sustainability of construction projects [3]. Structural elements of buildings are produced from these materials there by ensuring adequate strength, durability and safety. [32] (2024) opined that materials account for a significant part of the cost of construction. Hence material selection is a critical factor in budgeting and cost management. [8] (2004) also stated that the cost of materials is about sixty seven per cent of the total cost of producing building structures. As materials are important to infrastructural development, they have a great influence on the environment as they create resource depletion, waste generation and carbon emissions [2].

* Corresponding author: Farayibi Olatunde Oluwatosin

Concrete in a ubiquitous and important material that is made up of a mixture of aggregate and cement and it has played a crucial role in infrastructural development and sustainability. It is a versatile, commonly used material in the construction of building roads, bridges, airports and dams of adequate strength, durability and safety. Concrete can be modified to suite various environment and applications such as high strength concrete (HSC) for skyscrapers or specialized concrete for nuclear containment structures. Its innovative characteristics have been displayed with advancement in materials science, nanotechnology and 3D printing expanding its potential applications and sustainability. A holistic overview of concrete shows that its production contributes 5-7% of global CO_2 emissions and because it requires large amounts of raw materials, there arise the problem of resource depletion [29]. Green or sustainable concrete which is an environmentally friendly concrete, made by incorporating recycled material into traditional concrete can be used to reduce the consumption of natural resources; reduce wastes sent to landfills and minimizes the environmental impact of mining and quarrying

Portland cement, the binder in the production of concrete continues to be in very high demand globally for construction purposes. The high demand of this basic material coupled with the astronomical increase in its price, is definitely a hindrance to the smooth delivery of shelter to the Nigerian populace. Also, the production of cement accounts for approximately 8% of global CO_2 emissions and this constitutes a major human health hazard and serious environmental degradation [26]. Blended cement is a combination of Portland cement and supplementary cementitious material (SCM) that helps concrete to achieve long term strength and better durability. The use of blended cement has gone a long way to advance sustainable construction and reduce environmental impact by reducing waste, conserving resources, saving energy and reducing greenhouse emissions [30]. According to [35] (2021), the addition of industrial and agricultural based SCM in bricks, mortar and concrete is one of the ways of supporting sustainable development in the building industry.

Pozzolans are specific types of SCM that react with Calcium Hydroxide (CaOH) to form Calcium Silicate Hydrate (CSH), which contributes to the strength and durability of concrete. Pozzolans can replace a significant amount of cement in concrete mixture with properties akin to Portland cement. Some commonly used pozzolans are fly ash, silica fume, metakaolin, cocoa leaf ash, cocoa pod husk ash, volcanic ash amongst others [22]. Cocoa pod husk ash (CPHA) which is expected to have similar pozzolanic characteristics with Cocoa leaf ash (CLA) contains reactive silica and alumina which indicates its pozzolanic characteristic. It can also react with (CH) to form CSH and CAH. Cocoa leaf ash (CLA) is a sustainable and renewable material obtained by drying and burning cocoa leaves at very high temperature. It reduces wastes in cocoa production and it also has the potential to reduce cement content in concrete mixes. It’s expected pozzolanic properties may offer improved strength and durability to concrete.

Laterized concrete is a concrete in which fine sand is substituted partially or wholly with laterite soil [25]; [20]; [7]; [19]. The efficient structural applications of laterite soil as a component in concrete has been the subject of numerous studies. It is a type of soil commonly found in tropical regions and used as a sustainable construction material [7]; [34]; [21]. Laterized concrete (LATCON) is a composite material that integrates traditional concrete and laterite soil. This concrete offers a sustainable approach to construction and capitalizes on the availability of laterite soil in laterite-rich regions. Laterized concrete has shown promising results in laboratory experiments, with potential applications in diverse engineering projects [33]. Previous studies have also shown that LATCON possesses high compressive strength similar to that of conventional concrete when prepared from nominal structural concrete mixes [18]; [31].

The combination of these sustainable construction materials (CLA and LATCON) is expected to produce a green concrete that will be suitable for sustainable construction. This study, therefore, intends to investigate the mechanical properties of the resulting concrete (CLA-LATCON) with particular emphasis on its strength characteristics.

2. Materials and methods

2.1. Materials

The materials used for the study are shown below.

2.1.1. Cement

The ordinary Portland cement (OPC) used for this research is of grade 32.5N of the Dangote Cement brand, confirming to the Nigerian Industrial Standard specifications (NIS 444-1: 2018). This was used as the binder for the concrete mix and it was sourced at the open market in Akure, Ondo State, Nigeria. The fineness and setting tests was conducted on the cement in accordance with BS EN 197-1: 2000; BS 1881- 131: 1998, to ascertain its suitability. The chemical composition of the cement was also analyzed.

2.1.2. Cocoa leaf ash (CLA)

The cocoa leaf ash (CLA) was obtained from cocoa leaves which was sourced from a cocoa plantation in Akure, Ondo State. The leaves was dried in the sun in open air for complete combustion and then subjected to heating at a temperature of 600°C for a period of 2 hours in a muffle furnace. After the calcination, the ashes obtained was ground and sieved to obtain a fineness similar to that of OPC. The ashes was thereafter kept in a sealed polythene bag to prevent moisture absorption and attacks from environmental elements which might reduce its strength. The chemical composition of the CLA was also carried out and shown in Table 3.1. The fineness of CLA was determined in accordance with ASTMC 618. Other properties of CLA such as chemical composition, colour, specific gravity and density were also determined.

2.1.3. Coarse aggregate

Crushed basaltic rock aggregate was used for this investigation. The aggregate was of almost the same size not exceeding 19mm confirming to the British Standard recommendation (BS 882, 1992). This material was sourced from a local supplier in Akure, Ondo State. The physical properties of the granite used for this study determined through tests conforming to ASTM standards.

2.1.4. Fine aggregates

In this study, two distinct materials were employed as fine aggregates. Clean river sand of a size range finer than 4.75mm aperture, obtained from Akure and laterite fines from a borrow pit along Akure – Ikere road, Ondo State, Nigeria. River sand was subjected to various tests which include fineness modulus, bulk unit density, specific gravity, absorption and moisture content. The following physical parameters were tested for laterite fines. They include bulk density, specific gravity, particle size distribution and Atterberg limit test. These tests were performed in compliance with the specifications of BS EN 933: part 1 (1997), BS EN 812: part 2 (1997) and BS EN 1097: part 6 (2000).

2.1.5. Water

Portable water from the Materials and Structure laboratory of Department of Building, Federal University of Technology, Akure (FUTA), was engaged for all mixing and curing carried out.

3. Results and discussion

3.1. Preliminary investigation of aggregates

The fineness modulus, specific gravity, moisture content and other physical properties of the aggregates are shown in Table 1. Below. The results indicate that the aggregates used for this research are suitable for making good concrete and conform with the requirements of BS 812-2:1995, ASTM C127-18 and ASTM C128-18.

Table 1 Physical properties of aggregates used

	Sand	**Granite**	**Laterite**
Fineness Modulus	3.14	6.80	3.00
Specific gravity	2.60	2.67	2.54
Moisture content %	16.60	3.89	3.39
Plastic Limit	-	-	14.30
Liquid Limit	-	-	34.80
Plastic Index	-	-	20.50
Coefficient of uniformity (C_n) 3.26	-	-	3.86
Coefficient of curvature (C_v) 0.87	-	-	1.19

3.2. Physical properties of OPC and CLA

The physical properties of OPC and CLA used for this study are presented in Table 2. The fineness modulus of OPC was obtained by the percentage of mass retained on 45um and 90um sieves as 29% and 4% respectively. For CLA, 30% and

3.66% were observed to be retained respectively. All these met the standard set by ASTM C618-08 (2008). The initial and final setting times of OPC and CLA used were obtained as 110min and 210min; 140min and indefinite respectively. The setting times of OPC are within the limit stipulated by BS EN 197-1:2000 while those of CLA are greater than OPC because it contains little or no cementitious chemical property on its own.

Table 2 Physical properties of materials used

Parameters	**OPC**	**CLA**
Fineness (% residue on 45 μm sieve)	29	30
(% residue on 90μm sieve)	4	3.66
Consistency (%)	28	100
Initial Setting time (min)	110	140
Final Setting time (min)	210	-
Soundness (min)	0.00	0.00
Specific gravity	3.14	2.00
Bulk density (g/cm^3) (Uncompacted)	1.04	0.40
(Compacted)	1.30	0.60

3.3. Chemical properties of OPC and CLA

Table 3. below shows that CLA has high silica content hence it falls under class F pozzolans as classified by ASTM C618-08 (2008). As stipulated by BS EN 197-1(2009), CLA has a silica content than

25%. Also, the combined oxide content ($SiO_2 + Al_2O_3 + Fe_2O_3$) of CLA is higher than the minimum of 70% requirement for class F pozzolans stated by ASTM C618-08 (2008). Likewise, the same standard stipulates the maximum loss on ignition (LOI) of class F pozzolans as 6% and CLA satisfied this specification since it exhibited 4.20% LOI. The Cao and Free lime content of CLA are 4.98% and 0.05 respectively, hence it cannot be regarded as a cementitious material but a pozzolan [27].

Table 3 Chemical properties of OPC and CLA

Elemental Oxides (%)	**OPC**	**CLA**
SiO2	16.91	68.73
Fe_2O_3	2.41	2.32
CaO	60.51	4.03
MgO	1.40	1.19
SO3	1.64	0.55
Mn_2O_3	0.06	0.92
LOI	9.87	4.13
Free Limc	0.36	0.06
$S0_1O_2$+Al_2O_3 + Fe_2O_3	23.74	74.20

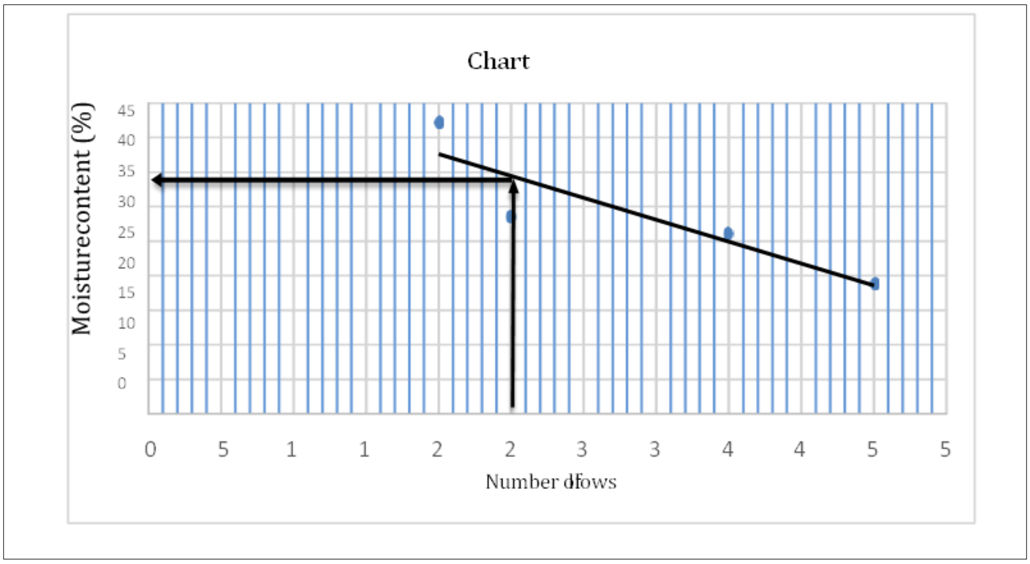

Figure 1 Graph of Liquid Limit.

Liquid limit = 34.8%

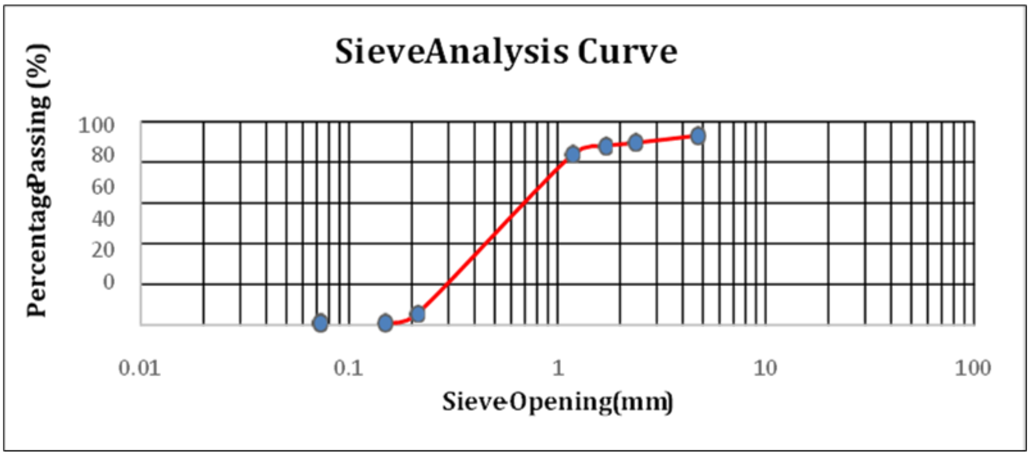

Figure 2 Sieve analysis curve for sand

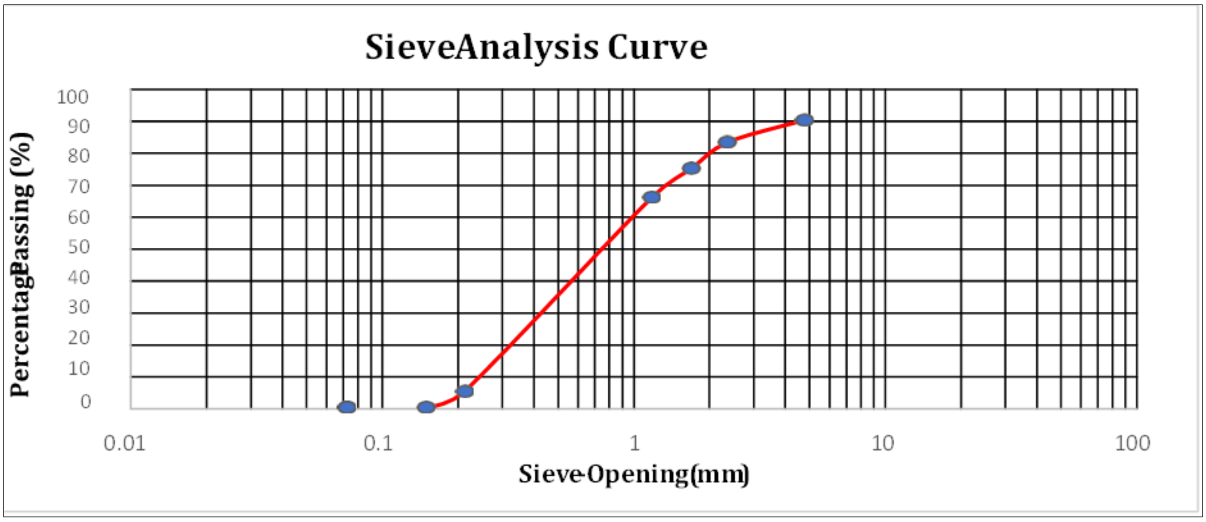

Figure 3 Sieve Analysis Curve for Laterite

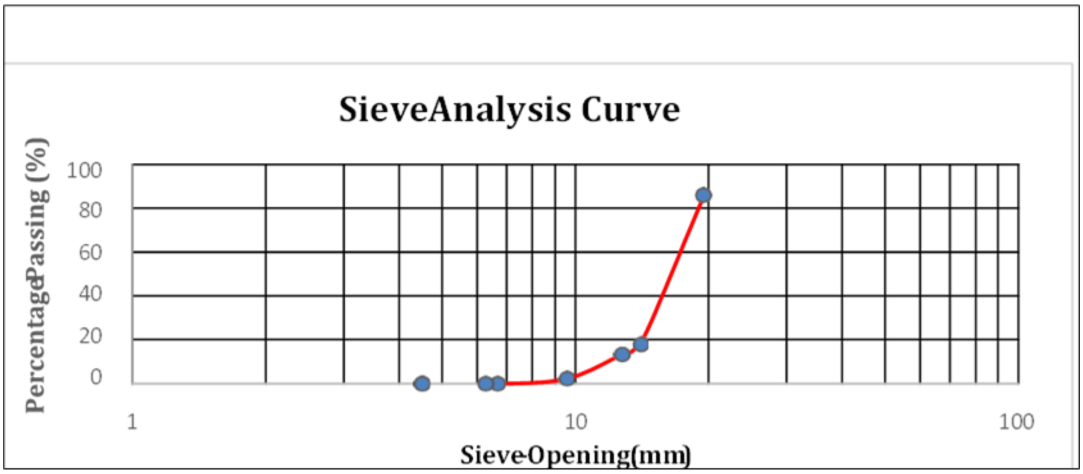

Figure 4 Sieve analysis curve for granite

3.4. Physical characteristics of blended cements

OPC and CLA constituted the blended cements at different percentages of replacement level. The fineness of the blended cements for the 45um ranged between 3.36% and 4%, while it ranged between 29% and 31% on the 90um sieve. The residue on the 90um sieve for the blended cements are less than that of the control. Hence, this indicates that finer blended cements were formed and this conforms to the requirements of BS 3892-1 (1996) and ASTM C618-08 (2008). The consistency of the blended cements increased with increase in CLA content. This is expected as CLA requires more water for standard consistency in comparison to OPC. The initial and final setting times for all the blended cements ranged from 40min to 110min and 103min to 244min respectively. All blended cements have setting times less than or equal to that of the control (OPC). This is likely to occur because CLA are finer than OPC, hence it possess more specific area to react and hydrate faster. Soundness of all blended cements conform to ASTM C618-08 (2008) and BS EN 197-1 (2009). According to Shetty (2006), unsoundness in cement is often due to excess free lime, magnesia and sulphate in the form of SO_2. The specific gravities of the blended cements are less than that of control. This is expected as the specific gravity of CLA is smaller than that of OPC.

Table 4 Physical characteristics of CLA blended cements

Parameters	Replacement levels			
	1	2	3	4
Fineness (% residue on 45 μm sieve)	30	31	30	31
(% residue on 90 μm sieve)	4	3.76	3.76	3.52
Consistency (%)	28	29	32	32
Initial Setting time (min)	110	50	110	60
Final Setting time (min)	210	126	227	110
Soundness (min)	0.0	0.0	1.0	1.0
Specific gravity	3.14	1.95	2.45	2.25

3.5. Chemical characteristics of CLA

Table 5. Shows the chemical composition and characteristics of blended cements. Batching by weight was engaged for blending CLA with OPC. The composition at all replacement levels conform to the requirements of BS EN 197-1:2009 and ASTM C618-08:2008.

Table 5 Chemical characteristics of CLA blended cements

Elemental Oxides (%)	Replacement levels 1	2	3	4
S1O2	61.93	62.12	66.78	32.05
Al_2O_3	4.42	4.11	5.31	6.48
Fe_2O_3	2.41	2.35	2.76	3.12
CaO	60.51	53.82	49.54	44.04
MgO	0.06	0.05	0.05	0.60
SO_3	1.65	1.55	1.46	1,28
MnO_3	0.06	0.05	0.05	0.60
LOI	9.87	9.21	8.51	7.82
Free Lime	0.36	0.22	0.25	0.17
SO_3	1.65	1.55	1.46	1.28

3.6. Workability

The slump tests results indicate that the concrete slump decreased as the laterite concrete increases. The results also revealed that the blended cement laterized concrete becomes stiffer and less workable as the level of replacement of the pozzolan increases. [27] (2012) revealed that the silica content of a cementitious material, the higher the water needed for hydration. It was further stated that the silica-lime reaction of a pozzolan cement requires more water in addition to the water required during hydration of cement. The specimen slumps therefore lie within low and medium classes according to BS 1881: Part 102 (1983).

Table 6 Slump values for CLA blended laterized concrete (CLA-LATCON)

Cement	Sand	Laterite	CLA (%)	LATCON Mix	Slump	Label
(%)	(%)	(%)		Identification	(mm)	
100	100	0	0	A0	60	1
100	90	10	0	A1	50	2
100	80	20	0	A2	40	3
100	75	25	0	A3	20.	4
90	100	0	10	B0	10.	5
90	90	10	10	B1	20	6
90	80	20	10	B2	10	7
90	75	25	10	B3	5	8
85	100	0	15	C0	10	9
85	90	10	15	C1	10.	10
85	80	20	15	C2	10	11
85	75	25	15	C3	10	12
80	100	0	20	D0	8	13
80	90	10	20	D1	8	14
80	80	20	20	D2	8.	15
80	75	25	20	D3	8	16

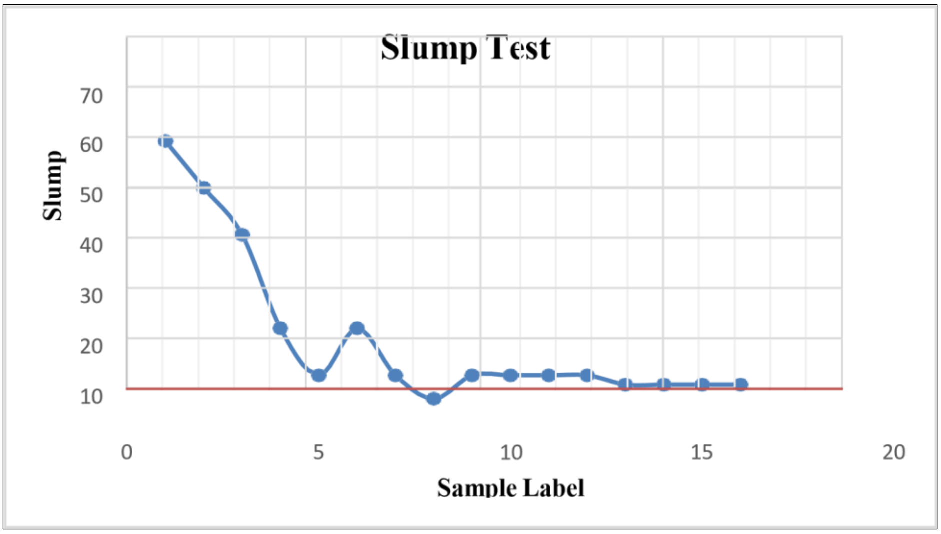

Figure 5 Effect of CLA and Laterite Content on Slump of CLA Laterized Cement Concrete

3.7. Compressive Strength

The results of the compressive strength for the cocoa leaf ash blended cement laterized concrete (CLALATCON) cubes are presented in Tables 7 and 8. The tables indicate the curing ages of the concrete cubes, percentage replacement of OPC with CLA, river sand with laterite fines, mean compressive strength values of three replicas of the cubes and the percentage attainment of the target strength of 25 N/mm^2 at 28 days curing. Generally, the compressive strength of CLA-LATCON increases with curing ages and decreased with increase in CLA and laterite fines.

The results at 7 days of curing as presented in Table 7. Reveals that the control A0 (0% laterite and 0% CLA) achieved 70.72% of the 25 N/mm² target strength. This, therefore, satisfied the requirements of normal concrete strength development of 66% as stipulated by BS 8110-2 (1985) for 7 days of curing. Replacement level B0 (0% laterite and 10% CLA) has 52.72 of the target strength and closely followed by C0 (0% laterite and 15% CLA) that achieved 45.38% of the target strength. Replacement level B1, which has both laterite and CLA content (10% laterite and 10% CLA) achieved 44.24% of the target strength at 7 days of curing. Only replacement levels A0, A1 and A2 satisfied 60% - 80% percentage attainment of concrete target strength as specified by [17].

The compressive strength results for 14 days of curing shows similar trend to those of 7 days. The control specimen, A0, achieved 87.92% of the target strength, B0 (60.64%), C0 (51.64%) and B1 (55.44%). Still following the same trend at 21days of curing, the control A0 achieved 95.68% while B0 (67.48%), C0 (56.40) and B1 (63.84%).

At 28 days of total immersion in water, the control specimen achieved 100.72% of the target strength while replacement levels B0, B1 and C0 achieved 83.00%, 79.44% and 63.84% respectively. From all the above, it can be stated that OPC can be partially replaced with 10% CLA and sand replaced with10% laterite (B1) to form a green concrete (CLA-LATCON) that could be used for lightly-loaded structures, drainage structures, low-height retaining walls, building blocks and masonry as specified by ACI 318-19. None of the other binary combinations performed favourably as regards their strengths to that of the control at 28 days of curing, probably because CLA has little or no adequate lime content. Therefore, with a compressive strength of 19.86 N/mm² at 28 days of curing, CLA-LATCON can be used in the building and construction industry.

Table 7 Compressive Strength of CLA Blended Cement Concrete Specimen at 7 and 14 days Curing Ages.

Curing Age(days)	LATCON Mix Identification	Mean Compressive (N/mm²)	Percentage target Strength (%)
	A0	17.68	70.72
	A1	15.70	62.80
	A2	15.06	60.24
	A3	13.24	52.96
	B0	13.18	52.72
	B1	11.06	44.24
	B2	9.72	38.88
7	B3	8.64	34.56
	C0	10.89	45.38
	C1	8.84	35.36
	C2	6.93	27.72
	C3	5.24	20.96
	D0	8.86	35.44
	D1	7.12	28.48
	D2	5.87	23.48
	D3	4.12	16.48
	A0	21.98	87.92
	A1	18.72	74.88
	A2	17.06	68.24
	A3	15.18	60.72
	B0	15.16	60.64
	B1	13.86	55.44
14	B2	11.78	47.12

	B3	10.16	40.64
	C0	12.91	51.64
	C1	11.86	47.44
	C2	9.78	39.12
	C3	21.98	87.92
	D0	18.72	74.88
	D1	17.06	68.24
	D2	15.18	60.72
	D3	15.16	60.64

Table 8 Compressive Strength of CLA Blended Cement Concrete Specimen at 21 and 28 days Curing Ages.

Curing Age(days)	LATCON Mix Identification	Mean Compressive (N/mm²)	Percentage target Strength (%)
	A0	23.92	95.68
	A1	20.18	80.72
	A2	19.54	79.16
	A3	17.82	71.28
	B0	16.87	67.48
	B1	15.96	63.84
	B2	13.12	52.48
21	B3	12.38	49.52
	C0	14.10	56.40
	C1	13.72	54.88
	C2	11.88	47.52
	C3	10.02	40.08
	D0	11.93	47.72
	D1	10.28	41.12
	D2	8.96	35.84
	D3	7.18	28.72
	A0	25.18	100.72
	A1	21.79	87.16
	A2	21.86	87.44
	A3	20.72	82.88
	B0	20.75	83.00
	B1	19.86	79.44
28	B2	15.38	61.52
	B3	12.78	51.12
	C0	15.96	63.84
	C1	14.12	56.48
	C2	12.64	50.56

	C3	10.18	40.72
	D0	13.82	55.28
	D1	11.87	47.48
	D2	10.34	41.36
	D3	9.06	36.24

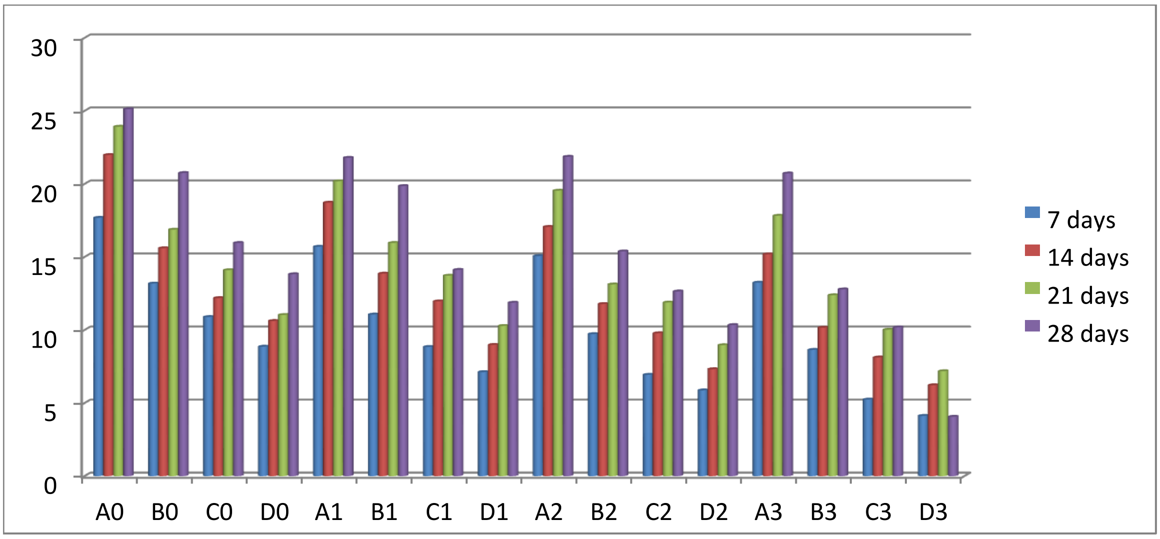

Figure 6 Compressive Strength of Laterized Concrete for Different Percentage Replacement

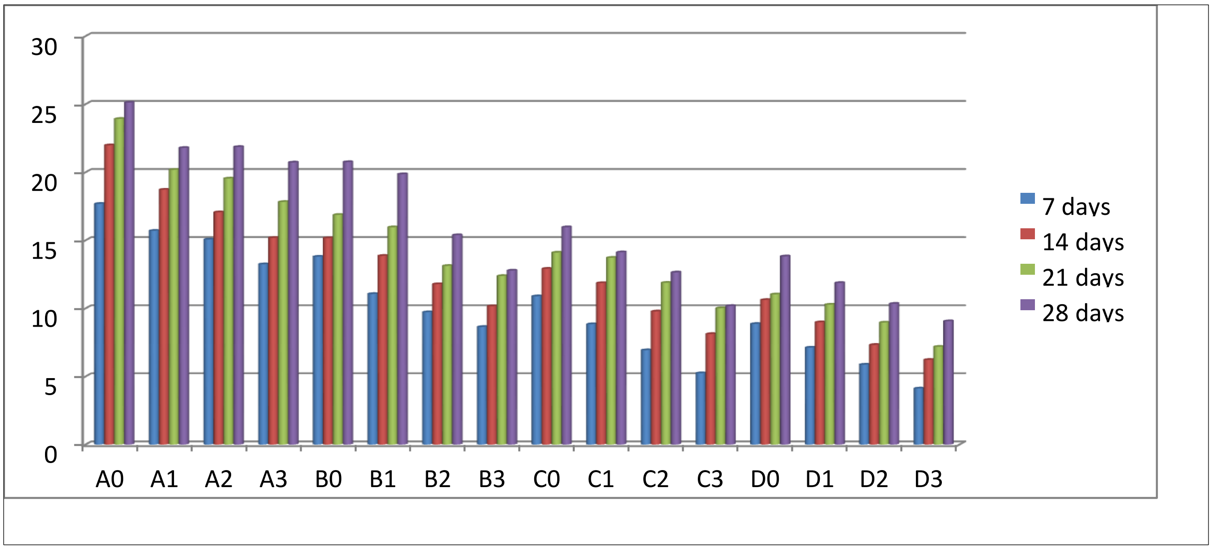

Figure 7 Compressive Strength of CLA Concrete for Different Percentage Replacement

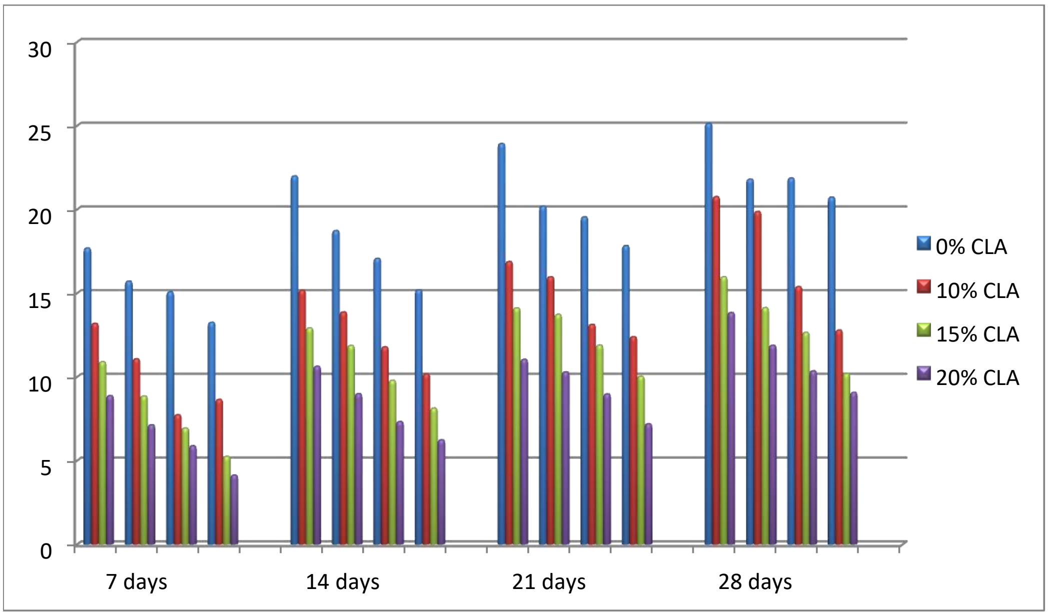

Figure 8 Compressive Strength of CLA Concrete for Different curing ages

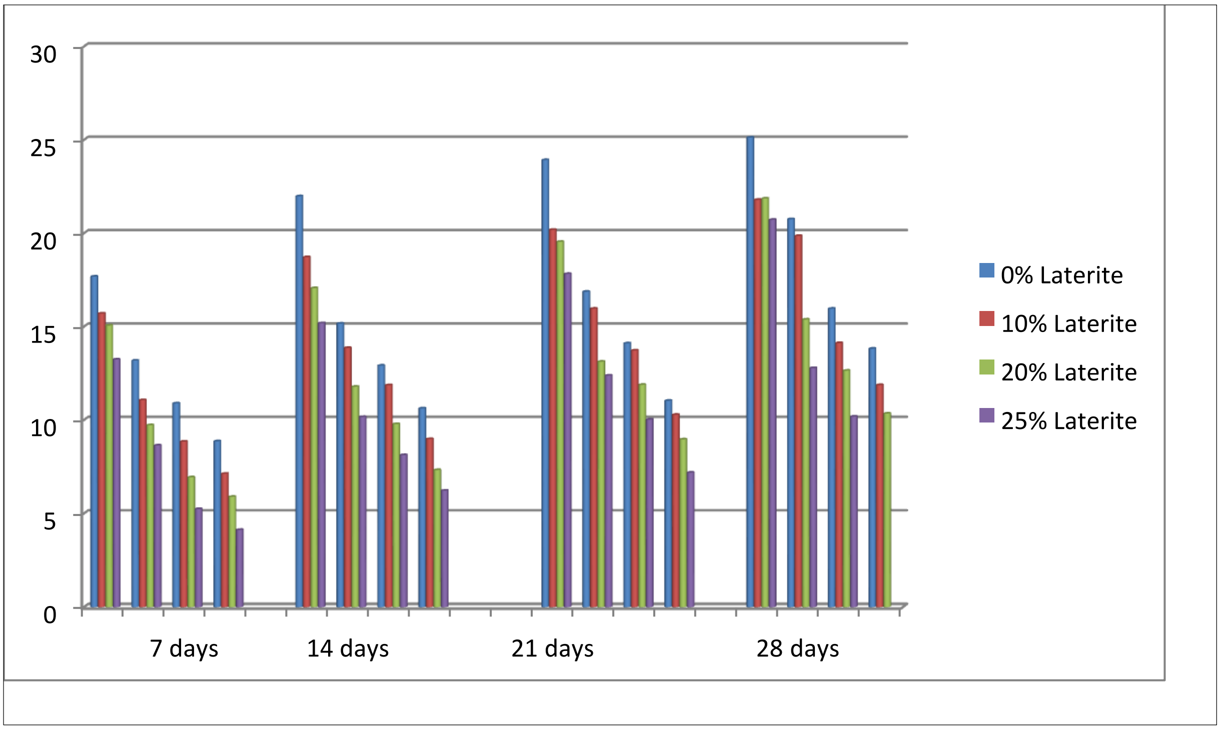

Figure 9 Compressive Strength of Laterized Concrete for Different Curing Age

4. Conclusions

CLA calculated at 600°C has a silica content higher than 25% minimum specified by BS EN 197- 1, as it exhibited a very high combined acidic content of 86.31% and this conforms with the requirements of Class C pozzolans as stipulated by ASTM C618.

Chemical composition by XRF indicate that CLA has a high content of silica (80.33%) and low content of lime (4.4%) when calcinated at 600°C.

Blended cements obtained from CLA and OPC satisfied the requirements of relevant standards with regards to their physical and chemical properties and hence, CLA can be referred to as a good pozzolan.

More water will be required for the desired slump, hydration and silica-lime reaction as the silica (SiO_2) content of the CLA-LATCON increases as the replacement level increases.

The compressive strength of CLA-LATCON increases with age but decreases with increase in replacement levels of laterite and CLA.

4.1. Recommendation

This paper presents the experimental details the compressive strength of cocoa leaf ash blended cement laterized concrete. The water cement ratio (w/c) for the concrete is 0.5. The following main conclusions and recommendations are drawn based on the obtained results for using a concrete of characteristic strength of 25 N/mm^2 at 28 days of curing.

The following recommendations are made based on the study's findings:

CLA should be used as a pozzolan in form of concrete as the leaves exist as abundant waste in the environment. This will help in reducing the consumption of OPC and thereby reducing costs.

Superplasticizer should be added to this blended cement LATCON in order to achieve desired slump without compromising strength characteristics.

Since the pozzolan performed averagely well with respect to the compressive strength, there’s need to investigate the long-term effect of the pozzolan on the strength development of LATCON as compared to traditional concrete.

Compliance with ethical standards

Acknowledgments

The authors are grateful to all the staff of the Laboratory and Workshop in the Department of Building, Federal University of Technology, Akure, for their contributions towards the success of the experiments.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] bubakar, M., Abdullahi, M. and Bala, K. (2018). Analysis of the casualty links between the growth of the construction industry and the growth of the Nigerian economy. Peterbilt Universiti Sains Malaysia. Vol. 23, Iss. 1, pp.103-113.

[2] Adesina, A., and Awoyera, P. (2019). Overview of trends in the application of waste materials in self- compacting concrete production. SN Applied Sciences, 1, 1-18.

[3] Akanni, P. O., Oke, A. E., and Omotilewa, O. J., (2014). Implications of rising cost of building materials in Lagos State, Nigeria. SAGE, October – December, 2017. DOI: 12.1177/2158244.

[4] American Concrete Institute (2019). Standard specification for compressive strength ranges 2500 to 8000 psi (17 to 55 MPa). ACI 318-19.

[5] American Society for Testing and Materials (2008). Standard specification for coal fly ash and raw or calculated natural pozzolan for use in concrete. ASTM C618-08.

[6] American Society for Testing and Materials (2018). Standard specification for measuring the consistency of hydraulic cement. ASTM C128-18.

[7] Awoyera, P. O., Akinmusuru, J. O., Dawson , A. R., Ndambuki, J. M. and Thom, N. H. (2018). Microstructural characteristics, porosity and strength development in ceramic-laterized concrete. Cement and Concrete Composites, 86, 224-237.

[8] Ayangade, J.A., Olusola, K.O., Ikpo, I.J., and Ata, O. (2004). Effect of granite dust on the performance characteristics of kernelrazzo floor finish. Building and Environment, Vol.39, pp. 1207-1212

[9] British Standard Institution (1983). Specifications for methods of determining slunp of fresh concrete. BS 1881: part 102 BSI, London.

[10] British Standard Institution (1992). Specification for aggregates from natural sources for concrete. BS 882, BSI, London.

[11] British Standard Institution (1997). Specifications for testing aggregate impact value (AIV) of aggregates of concrete. BS 812-2, BSI, London.

[12] British Standard Institution (1997). Specification for particle size distribution of aggregates of concrete. BS 933-1, BSI, London.

[13] British Standard Institution (1998). Specification for testing flexural strength of concrete. BS 1881-131, BSI, London.

[14] British Standard Institution (2000). Cement composition, specification and conformity criteria for common cement, BS EN 197-1, BSI, London.

[15] British Standard Institution (2000). Specification for testing particle density and water absorption of aggregates of concreteqq, BS EN 1097-6, BSI, London.

[16] British Standard Institution (2009). Cement composition, specification and conformity criteria for common cement, BS EN 197-1, BSI, London.

[17] Domone, P. L., & Illston, J. M. (2010). Construction materials: Their nature and behaviour (4th ed., pp. 150-160). CRC Press.

[18] Ettu, L. O., Ibearugbulem, O. M., Ezeh, J. C., and Anya, U. C. (2013). The suitability of using laterite as sole fine aggregate in structural concrete. Int. J. Sci. Eng. Res, 4(5), 502-507.

[19] Folagbade, S. O., and Osadola, O.A. (2019). Workability, compressive strength and initial surface absorption of laterized concrete. Journal of Materials and Engineering Structures. Vol. 6, No. 3. (2019).

[20] Joshua, O., Amusan, L.M., Fagbenle, O.I., and Kukoyi, P.O. (2014). Effects of partial replacement of sand with lateritic soil in sandcrete blocks. Covenant Journal of Research in the Built Environment, 1(2), 91-102.

[21] Musbau, K. D., Kolawole, J. T., Babafemi, A. J., and Olalusi, O. B. (2021). Comparative performance of limestone calcined clay and limestone calcined laterite blended cement concrete. Cleaner Engineering and Technology. Volume 4, October 2021, 100264.

[22] Odeyemi, S. O., Atoyebi, O. B., Kegbeyale, O. S., Anifowose, M. A., Odeyemi, O. T., Adeniyi, A. G., and Orisadare, O. A. (2022). Mechanical properties and microstructure of high performance concrete with bamboo leaf ash as additive. Cleaner Engineering and Technology 6, 100352. https://doi.org/10.1016/j.clet.2021,100352.

[23] Oladinrin, T., Ogunsemi, D.R., and Aje, I. (2012). Role of construction sector in economic growth: Empirical evidence fromNigeria. FUTY Journal of the Environment. Vol.7 No.1. ISSN: 1597-8826.

[24] Omopariola, E.D., Oladolapo, I.O., Idowu, A., Ayodeji, E.O. and Sunday, B. I. (2022). Sustainable Construction in the Nigerian Construction Industry: unsustainable practices, barriers and strategies. Journal of Engineering, Design and Technology. Vol. 22 Issue 4. ISSN: 1726-0531 https//doi.org/10.1016/j.clet.2021.100264

[25] Osadebe, N.N. and Nwakonobi, T.U. (2007). Structural characteristics of laterized concrete at optimum mix proportion. Nigerian Journal of Technology, 26(1), 12-17.

[26] Panagoda, L.P., Sandeepa, R.A., Perera, D.M., Sandunika, S.M., Siriwardhana, M.K., and Alwis, S.H. (2023). Cement manufacturing process and its environmental impact. J. Res. Technol. Eng. 4(3), 2023, 161-168.

[27] Raheem, A.A., Olasunkanmi, B.S., and Folorunso, C.S. (2012). Sand dust ash as a partial replacement for cement in concrete. Journal of Organisation, Technology and Management in Construction. Vol.4, Iss. 2, pp 474-480.

[28] Shetty, M.S. (2006). Concrete Technology: Theory and Practice, New Delhi, India, S. Chand and Company Limited, 637p.

[29] Singh, D., and Singh, J. (2016). Use of agrowaste in concrete construction. International Journal of Environment, Ecology, Family and Urban Studies, 6(1), 119-130.

[30] Tae-Hyun, K., Tae-Woo, K., & Sang-Woo, L. (2007). Sustainable construction: Methods to reduce environmental impact by minimizing waste, conserving resources, saving energy, and reducing greenhouse emissions. Journal of Sustainable Construction, 15(2), 123-134.

[31] Tijani, A. M., and Mustapha, Z. (2017). Compressive strength of concrete based on laterite and sea sand mixture. International Journal of Architecture, Engineering and Construction, 6(4), 44-49.

[32] Tulsyan, V.(2024). Material management: What is its importance in construction. www.in4velocity.com Feb. 27, 2024.

[33] Ukpata, J. O., Ejeh, S. P., & Akpan, U. E. (2024). Performance of laterized concrete in laboratory experiments and its potential applications in engineering projects. Journal of Advanced Concrete Research, 18(1), 45-55

[34] Yaragal, S. C., Gowda, S. N. B., and Rajasekaran, C. (2019). Characterization and performance of processed lateritic fine aggregate in cement mortars and concretes. Construct. Build. Mater. 200, https//doi.org/10.1016/j.conbuildmat.2018.12.072

[35] Zeyad, A. M., Johari, M. A. M., Abutaleb, A., and Tayeh, B. A. (2021a). The effect of steam curing regimes on the chloride resistance and pore size of high strength green concrete. Construct. Build. Mater. 280, 122409. https://doi.org/10.1016/j.