Comparative Analysis of Compressive Strength of Bamboo Leaf Ash and Baggash Ash Concretes

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Abstract: Billions tons of conventional concrete are produced yearly as well as cement which emit large tons of carbon dioxide due to huge millions of metric tons produced annually. Sequel to this, there is need to produce a sustainable product due to pollutions from cement production, using agricultural waste materials which have recently been found to be of great interest to construction industries at large due to their ability to substituting cement will solve environmental and pollution related issues. Bamboo leaf ash and baggash ash are produced as a result of combustion which serves as supplementary cementitious materials and can be used for construction purposes. This study determines the compressive strength of concrete without ashes, bamboo leaf ash, and baggash ash concrete at varying percentage replacement of 5%, 10%, 15%, 20% respectively. Physical test, workability test, compressive strength test, and durability test was performed on concretes. A total of 138 cubes were produced using 100*100*100 size cube cured at 7, 28, 56 and 90 days, of which 108 cubes were to ascertain compressive strength for all the concretes, while 30 cubes were used for durability test. Based on experimental results obtained, BLA surpassed BA concrete, and concrete without ash in term of compressive strength at early and later age of curing using 10% as optimum level of replacement, thus, one way ANOVA indicated, that BLA concrete is statistically better than BA concrete and statistically the same at 56 and 90 days of curing for conventional, BLA, and BA concrete. Furthermore, BLA and BA concretes reduced durability. BA concrete increased the water absorption, permeable voids, and sorptivity. As a result, BLA and BA can be considered as a good pozzolanic material which can save cost of construction, improved concrete properties.

Keywords: Concrete, Physical Test, Compressive Strength, Durability Test, Bamboo Leaf Ash, Baggash Ash, One – Way ANOVA.

1. Introduction

There is heavy dependence on cement most especially the construction industry for the purpose of concrete production (Alabadan, Olutoye, Abolarin & Zakariya, 2005). Concrete of 10 billion tons are largely produced around the world (Mehta & Montero, 2006). Ensued, cement is one of the most vital binding materials in terms of quantity produced. It is produced at very high temperatures which consumes a lot of energy of about 4GJ (Suhendro, 2014). It emits harmful gases which pollute the atmosphere (Dhinakaran & Gangava, 2016). According to (Statista, 2017)"Cement production around the world was estimated to be 4100 million metric ton, thus, 1 ton of cement emits 0.94 ton of carbon dioxide into the atmosphere (Pan & Padavoni, 2003). As a result of this menace has led to thorough research into various materials which can be utilised as cement supplementary so as to save on construction cost, eliminate environmental hazards, and need to improve performance of concrete. Most new biogenic waste materials to date are attained by partial replacement of cement with any of the many wastes (industrial, agricultural, construction, etc.) and non-waste materials.

Bamboo leaf ash is a pozzolanic agricultural wastes due to it high silica content and it is said to be amorphous in nature (Asha, Salmad & Kumar, 2014). Bamboo leaf ash is obtained as a result of combustion of bamboo leaves. The ash content of bamboo is made up of inorganic minerals, primarily silica, calcium, and potassium. Manganese and magnesium are two other common minerals. Silica content is the highest in the epidermis (Li, 2004). Application of these waste as cement replacement not only reduces the economic and environmental problems associated with the waste disposal (Patil & Kumbhar, 2012; Wong, Hashim & Ali, 2013) but also reduces the CO2 emissions during cement manufacture which requires extreme heat (Anupam, Kumar & Ransinchung, 2013).

According to the studies conducted by (Modani et al., 2013; Subramaniyan et al., 2016; Abdulkadir et al., 2014) indicated that sugar cane baggash ash is an excellent pozzolana. Baggash is the dry pulpy left after the extraction of juice from sugar cane (Babu, 2017). Sugar cane baggash ash is a pozzolanic material which improves the strength of concrete over some period of time. It contains high amount of silica and carbon materials, some minerals like calcium, potassium, and magnesium oxide are present as minor compounds.

One way analysis or single factor analysis of variance is used for establishment of fact whether there are statistically significant differences between the means of two or more independent unrelated groups (Kim, 2017). This study has therefore established the difference which existed between conventional, bamboo leaf ash, and baggash ash concrete by using one way ANOVA test.

2. Materials and Methods

2.1 Materials

The materials employed for this research work were ordinary portland cement (OPC) type 1, bamboo leaf ash (BLA), baggash ash (BA), water, coarse aggregate (CA), fine aggregate (FA), and superplasticizer. Bamboo leaves were fetched from Mau forest located in the rift valley of Kenya. The sugar cane ash was gotten from sugar manufacturing industry located in Kakamega county of Kenya. CA, FA, superplasticizer and cement were purchased in Kenya. Lastly, portable water was used.

2.2 Methods

The methods utilised in these research are listed in Table 1. Sampling was in accordance with techniques stated in BS EN 12350-1 (2009). Cubes of sizes 100 × 100 ×100 mm was used for all the test. A total number of 132 cubes were prepared and cured in according to the methods stipulated in BS EN 12390-2 (2009) for all the test. Cubes for compressive strength test were cured for 7, 28, 56, and 90 days while the remaining cubes for water absorption, permeable void, density, and sorptivity were cured for 28 days. Three samples were produced for each test.

Table 1. Test methods

Test on Component Materials		**Test on Hardened Concrete**	
Test Conducted	**Standard Adopted**	**Test Conducted**	**Standard Adopted**
Aggregate specific gravity	BS EN 1097-6	Compressive strength	BS EN 12390-3
Sieve analysis (BLA, BA)	ASTM D7928-7	Water Absorption	ASTM C642
Sieve analysis (aggregates)	ASTM C33	Permeable voids	ASTM C642
Aggregate water absorption	BS EN 1097-6	Hardened density	ASTM C642
Voids in aggregate	ASTM C29	Sorptivity	ASTM C1585
Aggregate density	ASTM C29		

2.2.1. Test Methods for Material Characterization

Grading process for aggregates was performed in line with ASTM C 33 (2003) techniques using sieves in accordance with BS ISO 3310-2 (2013) , aggregate sampling was conducted in accordance with BS EN 932-1 (1997) requirements for purpose of batching. Bamboo leaves were allowed to sun dry to expel water content, later undergo burning to remove inorganic materials that might be present in it, it was further calcined at 650^0C using muffle furnace at 2 hours retention time, after cooling, it was sieved using 0.15mm sieve. Baggash ash was collected from the sugar industry and was sieved using sieve size 0.15mm.

2.2.2. Mix Design and Mix Procedure

The portland concrete mix design for grade 25 was carried out in line with BS EN 206 (2014) and BS 8500 -2 (2012). A total of 9 mixes were prepared. Table 2 shows the details of all the mix proportions. Water binder ratio (w/b) of 0.5 was kept constant for all the mixtures using 195kg/m^3 of water. The cement was partially replaced by 5%, 10%, 15%, and 20% BLA and

BA by weight of cement. Superplasticizer at 0.8% (by weight of cementitious material) for all mixes. Mixing was done manually as stipulated by BS EN 1881-125 (2013) [32] and was controlled with a mechanism to guard against loss of water and cementitious materials during mixing apportioning. The specific gravity for both BLA, BA, and cement were performed in line with ASTM C188 (2016), chemical analysis for both BLA, BA, and cement was executed using x-ray diffraction equipment in line with BS EN 196-2 (2013).

Table 2. Mix proportions for 25MPa concrete comprising BLA/BA

Mix Description [BLA/BA] (%)	Cement (kg/m^3)	BLA/BA (kg/m^3)	Superplasticizer (kg/m^3)	C.A (kg/m^3)	F.A (kg/m^3)	Water (kg/m^3)
Control	390	0	1.5	993	662	195
5% BLA	370.5	19.5	1.482	993	662	195
10% BLA	351	39	1.404	993	662	195
15% BLA	331.5	58.5	1.326	993	662	195
20% BLA	312	78	1.248	993	662	195

3.0. Results and Discussions

3.1 Material Characterization

Coarse aggregate (CA), fine aggregate (FA), bamboo leaf ash (BLA), and baggash ash (BA) materials were characterised in term of grading. Aggregates, BLA, BA, and cement are characterised in term of specific gravity. Aggregates are further characterised in term of fineness modulus, bulk density, water absorption, and void content.

Physical and Mechanical Properties of Materials

The specific gravity for aggregates and cementitious materials, bulk density, water absorption, silt content, fineness modulus, among others, are illustrated in Table 3.

Table 3. Physical and mechanical properties of materials

Property	BLA	BA	OPC	FA	CA
Bulk specific gravity	2.79	2.10	3.12	2.43	2.48
Bulk specific gravity based on SSD				2.52	2.56
Apparent specific gravity				2.68	2.80
Fineness modulus				2.55	
Silt content (%)				4.67	
Water absorption (%)				3.95	3.27
Loose bulk density (kg/m^3)	365	359	1398	1456	1417.5
Rodded bulk density (kg/m^3)	479	471	1435	1577	1495
Voids in loose aggregate (%)				39.33	45.75
Voids in rodded aggregate (%)				34.31	39.52
Maximum particle size (mm)	0.15	0.15	0.09	5	20

The gradation results for coarse aggregate, fine aggregate, bamboo leaf ash, and baggash ash are depicted in Figures 1 -4 respectively.

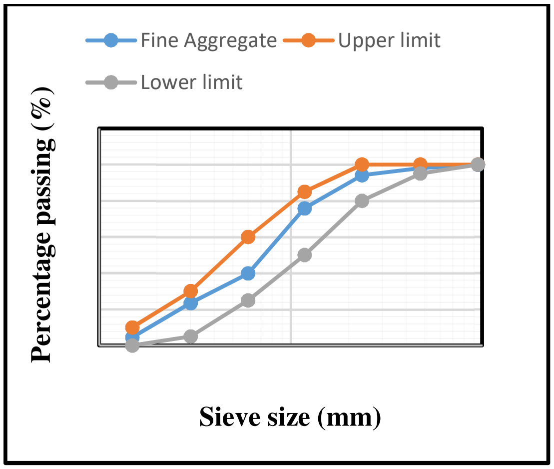

Figure.1. Particle size distribution of fine aggregate as per ASTM-33 standards

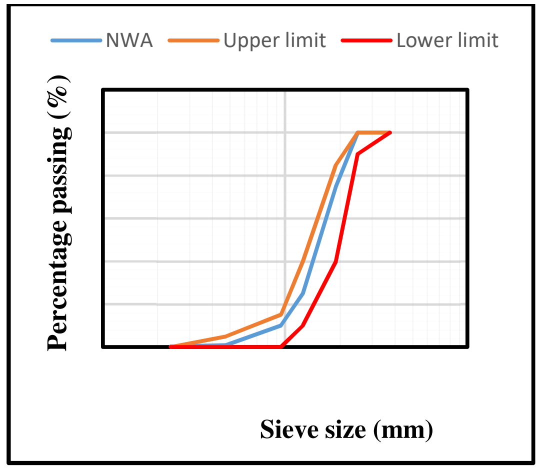

Figure.2. Particle size distribution of coarse aggregate as per ASTM-33 standard

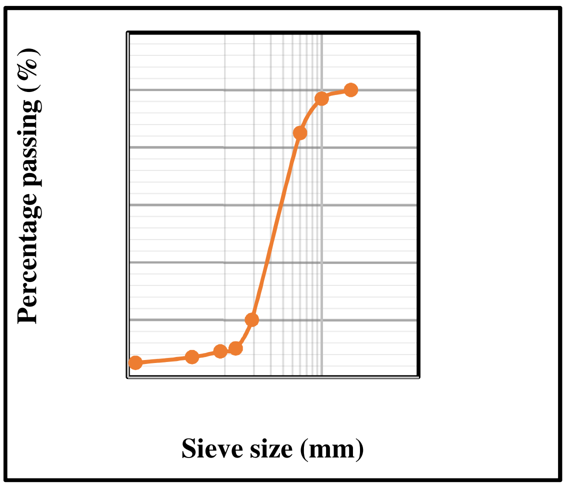

Figure 3. Particle size distribution BLA as per ASTM – D7928 standards

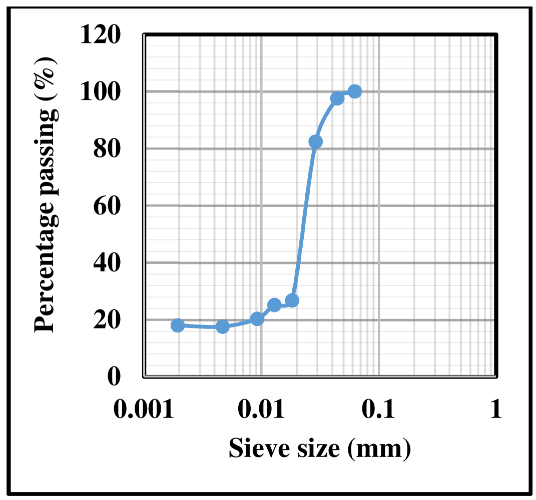

Figure 4. Particle size distribution of BA as per ASTM - D7928 standards

Figure 1 indicated that , the particle size of fine aggregate lies between 0.155 to 4.75mm within zone 2 which satisfies the requirement that the fine aggregate should be less than 45% retained on any sieve by ASTM – 33 (2003). The gradation for coarse aggregate as seen in figure 2 illustrated that ,90% of coarse aggregate were between 9.5mm and 25mm, the envelope curve was also between the upper and lower limit curve as stated by ASTM – 33 (2003). Figure 3 shows the particle size distribution of BLA, the figure indicated that, about 20% of its particles falls within 0.001mm (1 µm) to 0.02mm (2 µm) and 80% falls within 0.02mm (2 µm) to 0.15mm (150 µm) which was conforms with specifications of ASTM – D7928 (2017), based on this fineness particle behaviour, the water demand and surface area of the bamboo leaf ash was increased. The maximum particle size for bamboo leaf ash used in this work was 0.150mm (150 µm). Figure 4 shows the particle size distribution of BA, the figure depicted that, about 29% of its particles falls within 0.002mm (2 µm) to 0.02mm (20 µm) and 71% falls within 0.02mm (20 µm) to 0.070mm (70 µm) which was conforms with specifications of ASTM – D7928 (2017), due to this fineness, the water demand and surface area of the bamboo leaf ash was enhanced. The maximum particle size for baggash ash used in this work was 0.150mm (150 µm) .The fineness modulus of fine aggregate was 2.55, the fineness modulus conforms to ASTM -C33- (2003) which specified that fineness modulus should not exceed 2.3-3.1. Silt content 0f 4.67% for fine aggregate conforms to requirement of ASTM – C33 (2003) of not exceeding 5%. The specific gravity of 2.43 and 2.48 for fine and coarse aggregate was in line with the limit stated by ASTM – 33 (2003) of not exceeding 2.4 – 2.9, thus, rodded bulk density of 1577 kg/m^3 and 1495kg/m^3 for both aggregates falls within the range of 1200 - 1750 kg/m^3 according to ASTM – C33 (2003) standards. The water absorption for both aggregates was 3.95 and 3.27 conforms to ASTM – C33 (2003) of not exceeding 4. The specific gravity for BLA and BA was 2.79 and 2.10 which were 11% and 33% lesser than OPC, the bulk density of BLA and BA were about 33% and 32% of that of OPC. The lower values obtained in specific gravity and bulk density of BLA and BA could lead to reduction in concrete density. The maximum particle size of BLA, BA, and OPC were 150mm, 150mm, and 90mm. Table 4 shows the chemical compositions of BLA, BA, and cement respectively.

Table 4. Chemical composition of BLA and OPC

Chemical composition (%)	**Cement**	**BLA**	**BA**
Silica (SiO_2)	20.600	69.112	70.40
Calcium Oxide (CaO)	62.927	10.814	2.90
Aluminium (Al_2O_3)	5.985	2.523	3.54
Iron (Fe_2O_3)	3.341	1.741	3.93
Phosphorus (P_2O_5)	0.639	1.525	2.17
Chloride (Cl)	0.151	0.670	0.25
Sulphur (S)	2.622	0.406	0.27
Manganese (Mn)	0.129	0.245	0.20
Potassium (K_2O)	0.266	4.814	4.67
Loss of Ignition (LOL)	3.34	8.15	11.67

Table 4 illustrated the chemical analysis of OPC and BLA, and BA. The test was carried out by using X-ray diffraction (XRD). Based on table 4. The percentage composition of CaO in BLA is more than that of BA, though CaO for cement was higher than BLA and BA. CaO is responsible for the formation of tri calcium silicate and di calcium silicate which both react with water to form calcium silicate hydrate (C-S-H) which is the main agent for strength development of concrete. The percentage of $SiO_2 + Al_2O_3 + Fe_2O_3$ for BLA and BA were found to be 73.38% and 77.87% which was more than minimum of 70% stipulated by ASTM C618 (2008) for pozzolana. Also, loss of ignition (LOL) for BLA and BA was higher than OPC but still within the range of 12% stipulated by ASTM C618 (2008).

3.2. Hardened Properties of Concrete

Hardened Properties of Property

Table 7 shows the compressive strength (CS), water absorption (w), permeable void spaces (v), bulk dry density (bdd), and sorptivity (k) of concretes.

Table 7. Hardened properties of concrete

	CS (MPa)							
S/No	**7d**	**28d**	**56d**	**90d**	**W (%)**	**V (%)**	**Bdd (kg/m^3)**	**K (mm/h$^{1/2}$)**
0%	19.7	26.9	29	33.9	7.38	15.6	2.3	0.08
5% BLA	21	27.6	30.4	35.8	6.83	11.3	2.3	0.11
10% BLA	21.1	28.5	32.3	38.5	4.21	8.3	2.3	0.14
15% BLA	17.6	25.5	28.6	32.1	5.60	7.5	2.2	0.15
20% BLA	15.8	24.1	26.8	30.4	6.90	6.6	2.1	0.17
5% BA	16.1	21.8	25.5	29.1	7.99	15.9	2.3	0.07
10% BA	17.2	23.4	27.1	32.7	8.43	17.7	2.2	0.09
15% BA	14.9	21.1	26.2	28.3	8.72	17.9	2.2	0.12
20% BA	14.1	20.3	25.1	27.4	9.06	18.9	2.1	0.14

Average value for three replicate samples

- Compressive Strength (CS)

The compressive strength of normal, BLA, and BA concrete at curing age of 7, 28, 56, and 90 days is shown in figure 5 and 6. It was noticed that, there was an early strength generation at 7 days for percentage replacement from 5% to 10% BLA replacement and a drop in strength at 15% and 20% replacements was noticed, these trend was also applicable to 28, 56, and 90 days compressive strength. The increase in strength could be as a result of the presence of high amount of amorphous silica present in the ash and high amount of CaO which lead to the formation of tri calcium silicate and di calcium silicate which both react with water to form C-S-H which was the determining factor for strength gain, tri calcium silicate is mostly reactive at early ages which gave the ash more strength at 7 days for 5% and 10% replacement while di calcium silicate is most reactive at later ages but contributes very little to strength development unlike tri calcium silicate. As shown in figure 6, it was seen that, there was a slow generation of strength at all level of replacements of BA at 7 and 28 days, thus, compressive strength increased from 56 days and 90 days, the slow reaction could be attributed to low amount of CaO present in BA and di calcium silicate was most reactive at later ages. The maximum strength was recorded at 10% for both BLA and BA replacement at 7, 28, 56, and 90 days curing age. The BLA compressive strength obtained from this study produced better results when compared with those of (Kolawole et al., 2015; Dwivedi et al., 2006; Olutoge et al., 2017). Similar results in term of compressive strength of BA concrete was reported by (Djima et al., 2018; Modani et al., 2013; Abdukadir et al., 2014).

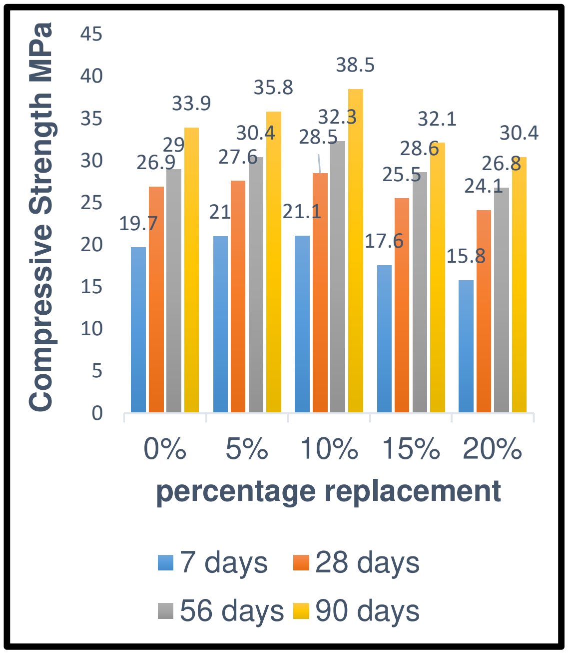

Figure.5. Compressive strength of normal BLA concretes

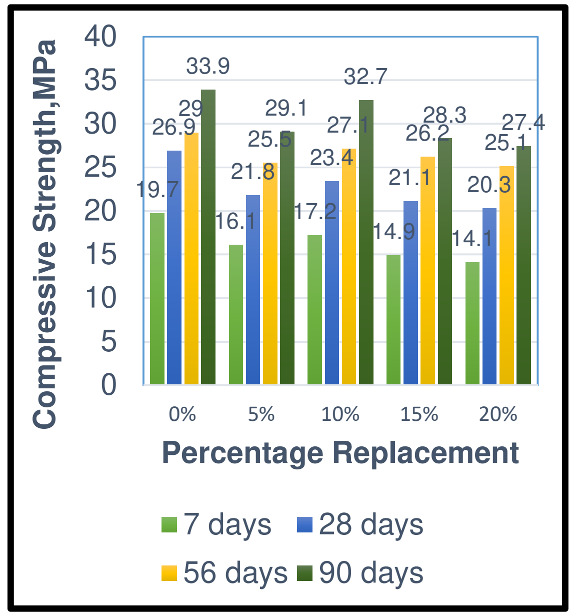

Figure.6. Compressive strength of normal and BA concretes

- Water Absorption

  The water absorption of normal concrete as well as BLA and BA concretes is shown in figure 7 and 8. It was found out that, there was a general reduction in water absorption after immersion (Wi) and after immersion and boiling (Wib) as the percentage replacement of BLA content increased. Generally, the water absorption of BLA concrete samples had low water absorption as compared with reference concrete. This reduction in water absorption could be attributed to the initial filling of the voids by BLA concretes thereby acting as water resistant. The results of this studies conforms to previous work by (Umoh & Ujene, 2014). Consequently, from figure 8, it was seen that, there was an increment in water absorption after immersion (Wi) and after immersion and boiling (Wib) as the percentage replacement of BA content increased. Thus, water absorption increased as percentage replacement of BA increased, this could be as a result of very fine particle of BA which lead to high absorptivity features. The results of this studies was in line with previous research performed by (Djima, Mang'uriu & Mwero, 2018).

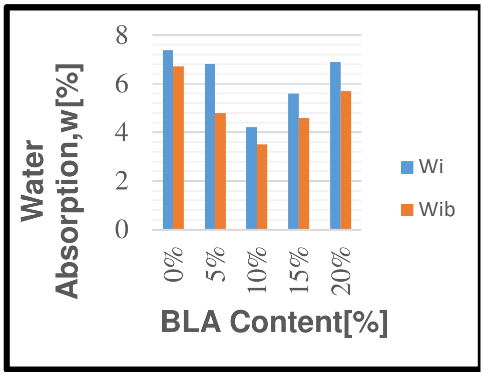

Figure.7. Water absorption of normal and BLA concretes

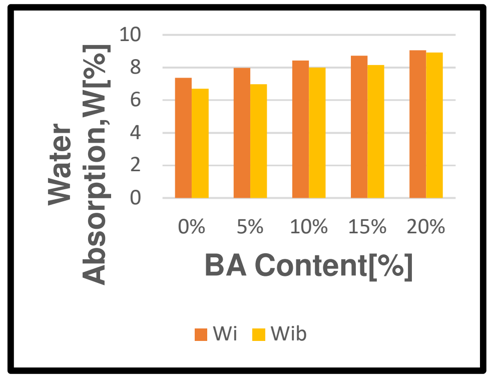

Figure.8. Water absorption of normal and BA concretes

- Volume of Permeable Void Spaces in Hardened Concrete

The permeable void spaces of BLA concrete reduced a bit as the percentage BLA content increased as seen in figure 9. This reduction in void could be as a result of increased reactions which caused a denser porosity, thus reducing the permeable void spaces. The output of this work conforms to previous research carried out by (Dhinakaran & Gangava, 2016). Furthermore, BA increased the void as the percentage replacement of BA increased as shown in figure 10. The increment could be as a result of finess nature of BA which makes the concrete less impermeable.

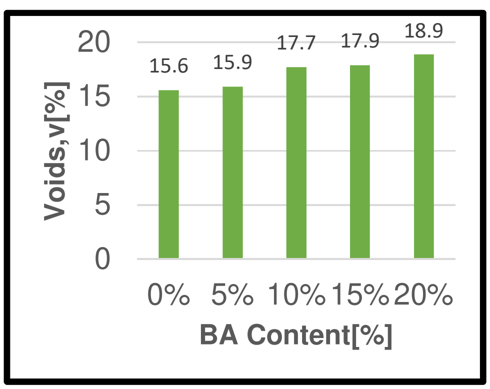

Figure 9.void of normal and BLA concretes

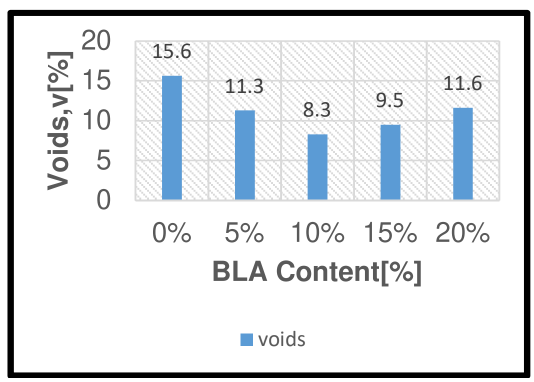

Figure 10. Void of normal and BA concrete

- Bulk Dry Density of Hardened Concrete

The apparent density (AD), bulk density after immersion (BDI), bulk density after immersion and boiling (BDIB), and bulk dry density (BDD) of BLA and BA concrete at 28 days of curing reduced with an increment in BLA and BA content as illustrated in figure 11 and 12. The reduction in density could be as a result of the lower specific gravity of BLA and BA which is 11%, 32.69% lower than that of cement thereby directly reducing the density of the matrix as the percentage BLA and BA content increased. The bulk dry density for both BLA and BA concretes were within the range of 2000 – 2600kg/m^3 for normal concrete as stated by BS EN 206 (2014). Thus, BLA and BA concrete can be classified as normal concrete. The result of this studies conformed to previous work executed by (Olutoge & Oladunmoye, 2017; Hussein, Nuruddin & Memon, 2014)

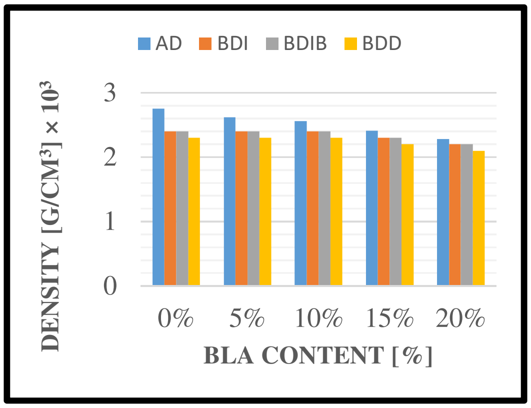

Figure.11. Hardened density of normal and BLA concretes

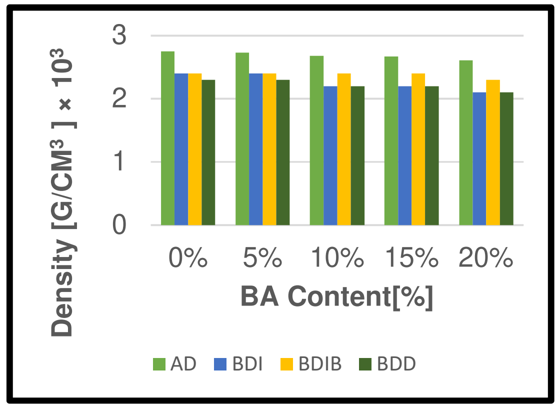

Figure.12. Hardened density of normal and BA concretes

- Sorptivity

  The results of the rate of absorption of BLA and BA concretes is given in table 9 and 10. The rate of water absorption ($mm/min^{1/2}$) was obtained from the slope of best fit line to the cumulative water absorption (I) plotted against the square root of time ($mm^{1/2}$). Thus, slope was gotten using least squares, linear regression analysis of the plot of I against square root of time ($t^{1/2}$).From table, it was noticed that, soprtivity reduces as BLA content increased. The sorptivity reduction could be due to the finer particle of BLA which filled up the air voids in the concrete, thus, hindering the intrusion of water into the concrete. Meanwhile sorptivity is increased as BA content increases. BA sorptivity increment could be as a result of fineness particle of BA which is not closely packed together thereby allowing water to pass through it. The sorptivity results of this research unveiled that , all the concretes samples conforms to limit of sorptivity value less than 6mm/$h^{1/2}$ based on the research conducted by (Hinczack, Conroy & Lewis, 1986).

Table 8. Sorptivity of conventional and BLA concretes

Sample	0%	5%	10%	15%	20%
Sorptivity, K (mm/h$^{1}/_{2}$)	0.1666	0.1451	0.1417	0.1153	0.0828
Coefficient of Determination (R^2)	0.9604	0.971	0.9737	0.9661	0.9298
Coefficient of Correlation (R)	0.9800	0.9854	0.9868	0.98290	0.9643

Table 9. Sorptivity of conventional and BA concretes

Sample	0%	5%	10%	15%	20%
Sorptivity, K (mm/h$^{1}/_{2}$)	0.1666	0.0672	0.0919	0.119	0.1405
Coefficient of Determination (R^2)	0.9604	0.7936	0.8309	0.8322	0.7790
Coefficient of Correlation (R)	0.9800	0.8908	0.9115	0.9122	0.8820

3.3. One way ANOVA

The mean compressive strength values at 7, 28, 56, and 90 days curing age ranging from 0% - 20% percentage replacement in each case for conventional, BLA and BA concretes is shown in table 10, where (A1, A2) represents BLA and BA at 7 days curing age, (B1, B2) stands for BLA and BA at 28 days, (C1, C2) connotes curing age at 56 days for BLA and BA, (D1, D2) stands for 90 days curing age for BLA and BA, Z1-Z4 represents conventional concrete at curing age of 7-90 days respectively.

Table 10. Compressive strength mean values of Conventional, BLA, and BA concretes

Group	Means
A1	18.89367
A2	15.56958
B1	26.48942
B2	21.65775
C1	29.52833
C2	25.95675
D1	34.21433
D2	29.35383
Z1	19.73633
Z2	26.93500
Z3	29.06967
Z4	33.96667

Replicates of average mean values of 12 samples (A1-D2), 3 mean values for (Z1-Z4)

Table.11. One-Way ANOVA Table

	Df	Sum Sq	Mean Sq	F value	Pr (>F)
Ashes	11	3542	322	64.65	<2e-16 ***
Residuals	96	478	5		

Signif. Codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

The null hypothesis of equal compressive strengths of control, BLA and BA concretes at diffe rent curing ages (7, 28, 56, and 90 days) was rejected given that the P-value (2e-16) was less t han the alpha (0.05). This connotes that, the compressive strengths are not significantly equal at all level of percentage replacement. Hence, post-hoc test (Tukey multiple comparisons test) was performed on the each pair order to deduce which pairs are equal or different at 95% family - wise confidence level (Kim, 2017) as shown in table 11.

Table. 12. Tukey multiple comparisons of means

Pairs	Difference	lower	upper	P adj
A2-A1	-3.3240833	-6.37619102	-0.2719756	0.0207034
Z1-A1	0.8426667	-3.98313931	5.6684726	0.9999849
Z1-A2	4.1667500	-0.65905598	8.9925560	0.1603627
B2-B1	-4.8316667	-7.88377436	-1.7795590	0.0000454
Z2-B1	0.4455833	-4.38022265	5.2713893	1.0000000
Z2-B2	5.2772500	0.45144402	10.1030560	0.0197701
C2-C1	-3.5715833	-6.62369102	-0.5194756	0.0086416
Z3-C1	-0.4586667	-5.28447265	4.3671393	1.0000000
Z3-C2	3.1129167	-1.71288931	7.9387226	0.5812337
D2-D1	-4.8605000	-7.91260769	-1.8083923	0.0000397
Z4-D1	-0.2476667	-5.07347265	4.5781393	1.0000000
Z4-D2	4.6128333	-0.21297265	9.4386393	0.0748046

Based on Tukey post hoc test shown in table 11, it was found out that;

For the pair of comparison (A2-A1), (B2-B1), (C2-C1), and (D2-D1). 0 was not contained in the confidence interval, this means that, there is significant difference between the compressive strength of BLA and BA at 7, 28, 56, and 90 days curing age. The P-values was less than the alpha (0.05) indicating that, the compressive strength of BLA and BA at all curing ages are not equal. The difference was also negative which means the compressive strength of BLA is better than that of BA at 7, 28, 56, and 90 days curing age respectively. Comparing (Z1-A1), (Z1-A2), and, 0 was contained in the confidence interval, this means that, there is no significant difference between the compressive strength of Control, BLA, and BA at 7 days curing age. The P-values were greater than the alpha (0.05) which connotes that, the compressive strength of Control and BLA at 7 days curing age are statistically equal. Furthermore, in the Pair of (Z2-B1), 0 was contained in the confidence interval, this indicated that, there is no significant difference between the compressive strength of Control and BLA at 28 days curing age. The P-value (1.000) was greater than the alpha (0.05) which shows that, the compressive strength of Control and BLA at 28 days curing age are statistically equal. Meanwhile, the pair of (Z2-B2), at 28 days shows that, the compressive strength of control sample and BA samples are not the same. Furthermore, the pair of (Z3-C1), (Z3-C2), (Z4-D1), and (Z4-D2) at 56 and 90 days curing age, indicated that, 0 values was in the confidence interval, this shows that, there is no significant difference between the compressive strength of Control, BLA, and BA at 56 and 90 days of curing . The P-values were greater than the alpha (0.05) which means, the compressive strength of Control, BLA, and BA at 56 and 90 days of curing age are statistically equal.

4. Conclusions

The comparative analysis of compressive strength of conventional, bamboo leaf ash, and baggash ash was performed. Thus, properties of conventional, bamboo leaf ash, and baggash ash concretes in term of fresh, and hardened properties were also examined. Based on the comparative analysis, experimental results, and discussions carried out, the following conclusions was made:

i. There was an increase in compressive strength of BLA concrete, while compressive strength of BA concrete increased at later age of curing beyond 28 days. The optimum level of replacement was achieved at 10% for both BLA and BA concretes.

ii. BLA concretes had lower water absorption, density, permeable voids, and sorptivity values as compared to that of control samples. BA concretes had higher water absorption, permeable voids, sorptivity, but lower density values as compared to that of control samples.

iii. BLA concrete is better than BA concrete at 7, 28, 56, and 90 days. Control sample and BLA concretes are the same at 7, 28 days , thus, control sample is higher than BA concretes at 7, 28. Control sample, BLA and BA concretes are statistically the same at 56 and 90 days respectively.

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