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Flexural Strength Characteristics of Pawpaw Leaf Ash and Bamboo Leaf Ash Blended Cement Concrete

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ABSTRACT: This research focuses on flexural strength characteristics of pawpaw leaf ash and bamboo leaf ash blended cement concrete. Several tests were carried out, according to BS and ASTM requirements to determine the physical and mechanical properties of pawpaw leaf ash and bamboo leaf ash blended cement concrete, investigate the effects of curing age on flexural strength characteristics of pawpaw leaf ash and bamboo leaf ash blended cement concrete and examine the effects of percentage replacement of cement with pawpaw leaf ash and bamboo leaf ash blended cement concrete on flexural strength characteristics. A total of 60 cubes were cast, cured in water for 7, 14, 21 and 28days. Test results showed that the flexural strength of the concrete cubes increases with an increase in the curing age and decreases with increasing percentage replacement of cement with pawpaw leaf ash and bamboo leaf ash. The optimum replacement level of pawpaw leaf ash and bamboo leaf ash was obtained to be 5%. The study concluded that concrete containing the cement blends of cement and Pawpaw leaf ash and bamboo leaf ash at a replacement level of 5% is only recommendable for use in light concrete works construction.

KEYWORDS: pawpaw leaf ash, bamboo leaf ash, blended cement concrete, flexural strength

1.0 INTRODUCTION

In the past few years, concrete has become the second most consumed substance in the world after water and the most used material ever created by humans, due to its low cost, versatility and durability (Sakshi *et al*., 2022). Studies by Sakshi *et al*. (2022) further revealed that due to the advancements in infrastructure and the exploding global population, concrete has evolved into one of the most adaptable and diverse building materials ever discovered. Concrete is a synthetic material resulting from the mixtures of cement, fine aggregates, coarse aggregates and water in proper proportion (Tiza and Ahangba, 2016). However, until today, the construction industries are facing quiet a number of problems regarding productivity in relation to the provision of adequate housing for Nigeria's teeming urban and suburban areas, which is said to be as a result of the high cost of raw materials such as cements in the construction industry.

The need to provide adequate housing for Nigeria's teeming urban and suburban areas, as well as many other parts of Africa, has compelled researchers to continue looking for ways to reduce the cost of construction projects by reducing the consumption of raw materials such as cement in the construction industries, while also protecting the environment and enhancing the quality of the cement used to produce concrete (Ettu *et al*., 2013). Efforts have therefore, intensified at sourcing for suitable and more affordable local materials like industrial by products that could be used as partial replacement for Ordinary Portland Cement (OPC) in civil engineering and building works (Olugbenga, 2007).

Some of the affordable local materials now used are industrial or agricultural by-products (wastes) and the mixture of Ordinary Portland Cement with these industrial by products forms what we now call blended cements (Asha *et al*., 2014). Blended cements are cements in which a percentage of the Portland Cement clinker is substituted by industrial waste materials, such as pawpaw and bamboo leaf ash, specific types of volcanic material (natural pozzolanas), or limestone. (John and Choo, 2003). All kinds of construction work require cementitious binders. In recent decades, the usage of pozzolans as substitutes for the widely used Portland cement has been revived in the construction industry (Asha *et al.,* 2014).

According to Bakar *et al.* (2010) supplementary cementitious materials have been proven to be effective in meeting most of the requirements of durable concrete and blended cements and is now used in many parts of the world. The supplementary cementitious materials used as partial replacement for Ordinary Portland Cement in this project are pawpaw leaf ash (PLA) and bamboo Leaf Ash (BLA). Pawpaw leaf ash is the powdery residue left after the pawpaw leaf has been air-dried, pulverized into smaller particles, and calcined into ashes in a fabricated furnace at temperatures generally below 650°C (Ettu *et al*.,2013). Bamboo leaf ash is the powdery residue left after the bamboo leaf has been fired in an open atmosphere and then heated at about 600°C for 2 hours in a furnace. (Olugbenga *et al.*, 2010). The mixture of Ordinary Portland Cement with pawpaw leaf ash and bamboo leaf ash is what forms the blended cements used for this research work. The behaviour of blended cements is quite similar to that of Ordinary Portland Cement (OPC) since they hardened when mixed with water and form the same hydration products (Dwivedia, *et al.*, 2006).

The strength of construction material is very essential to engineers. The knowledge of tensile strength is used to estimate the load under which cracking will develop. This is especially useful in the design of concrete pavement, airfield runway, and railway track (Gambhir, 2006). Based on Gambhir analysis, Tensile strength also known as tearing strength can be said to be a material characteristic value for the evaluation of strength behavior and the maximum mechanical tensile stress with which a specimen can be loaded. If the tensile strength is exceeded, the material fails: the absorption of forces decreases until the material specimen ultimately tears. The material however undergoes plastic deformation (residual) before reaching the actual tensile strength value. Tensile strength is also used in both serviceability and ultimate limit state calculations such as the evaluation of cracking moment for prestressed elements, the design of fibre-reinforced concrete, developing moment curvature diagrams, and the calculation of deflection of structural members. (Ettu *et al.*, 2016). The maximum tensile stress value under bending before the beam or rod fails is considered its flexural strength. Flexural strength, also known as bending strength is the maximum stress in a material just before it yields either by bends, ruptures, tears or breaks in a bending test (Marc and Krishan, 2009).

This research investigated the flexural strengths characteristics of concrete after replacing certain portions of the Ordinary Portland Cement used to produce the concrete mixture with pawpaw leaf ash (PLA) and bamboo leaf ash (BLA). The successful utilization of bamboo leaf ash and pawpaw leaf ash in ternary combination with Ordinary Portland cement for making concrete would increase the value to these wastes and reduce the volume of Ordinary Portland Cement now required for civil engineering and building works.

2.0 MATERIALS AND METHODS

2.1 Materials

The materials used were Ordinary Portland Cement (Dangote brand) obtained from a local cement dealer at FUTA Northgate, Akure and was ascertained to be in conformity with the requirements of BS EN 197-1:2000, a naturally occurring smooth and fine textured fine aggregate (sharp sand) with angular grains of sharp edges and corners and was obtained from Ilara reserve area, Akure by a local supplier, ¾ sized course aggregate (granite) with a low porosity and was obtained from a quarry site located at Ipinsha by a local granite supplier in Akure. The Pawpaw leaves and bamboo leaves were obtained from a local farm located at Ilara, Akure and then, air dried, and calcined into ashes. The ashes obtained were sieved and the large particles retained on the 600µm sieve were discarded while those passing the sieve was used for this research work. The water used for the casting and curing of the concrete cubes was a portable tap water with no taste or odour and was obtained from the Building workshop at the Federal University of Technology, Akure.

The moisture content of the sand was obtained to be 5.59%. This indicates that the sand has a good water retention capacity. The value for the fineness modulus for PLA was also obtained to be 3.60 which shows low grading compared to BLA and sand. This indicates that PLA is finer compared to BLA and sand. The value for the fineness modulus for BLA was also obtained to be 4.10 which shows higher grading compared to PLA and a lower grading compared to sand. This indicates that the BLA is finer than sand and less fine than PLA. The value of Coefficient of uniformity (C_U) and Coefficient of curvature (C_C) obtained for sand were 4 and 1.18 respectively. These values show that the sand is well graded and suitable for making good concrete. The value for the fineness modulus was also obtained to be 5.97 which shows high grading. This indicates that the sand has higher coarser particle present in the soil sample. The specific gravity of BLA was obtained to be 2.05, giving it a density of 0.10g/ml. While that of PLA and fine aggregate were obtained to be 3.49 and 2.68 respectively, giving it a density of 0.31g/ml and1.18g/ml respectively. This shows that the density of BLA is lesser than the density of the PLA and fine aggregate used.

2.2 Methods

2.2.1 Mix proportions

A mixture of 1:2:4 mix ratio representing cement: fine aggregate: coarse aggregate was used as the reference mix. The cement constituent was subsequently replaced with some percentage combination of pawpaw leaf ash and bamboo leaf ash (by mass). The percentage of the PLA and BLA was varied between 5% and 20%, at 5% intervals, which gives a total of five mixes. In each mix, water cementitious materials ratio varied from 0.94 to 1.21 and the fine and coarse aggregate kept constant. The various batching combinations are presented in Table 1.

2.2.2 Mixing of Constituent Materials

The cement, PLA, and BLA were measured and mixed together until a uniform colour was obtained. The blended mix was spread on already measured fine aggregate placed on an impermeable flat form and mixed thoroughly before the coarse aggregate and water were added. Workability test was conducted on the fresh concrete with the aid of slump cone apparatus and the value obtained range between 25-50mm.

2.2.3 Workability tests

Before the start of casting of the concrete cubes and just after mixing the constituent materials, the workability was measured by the slump test. The slump test was carried out in accordance with BS EN 12350 (2000) to ensure the uniformity of the concrete mix and quality. The slump cone apparatus, which is 300 mm in height, was filled in approximately 4 layers and tamped in each layer with 35 strokes of the round end tamping rod. The excess concrete was removed using the trowel. The cone was removed, and the difference in the height of the slump cone apparatus and the slump was measured and recorded.

2.2.4 Casting and curing of specimens

The specimens were cast in well lubricated 100mm wooden cube sized moulds. A total of 60 cube specimens were cast for the research. After casting they were covered with wet woolen bags and stored in a place free from vibration and not exposed to direct sunlight for a day; de-moulded and immersed in water curing tanks until their testing ages.

2.2.5 Compressive Strength Test

The test specimen met the requirements of BS EN 12350-1, EN 12350-2 and EN 12350-3. The concrete specimens were tested for flexural strength using a mechanically operated compressive testing machine conforming to BS EN 12390-4 and 6 in accordance with BS EN 12390-3 at ages of 7, 14, 21 and 28 days respectively. Three specimens were used in computing the mean on each testing age of each mix; and the flexural strength in cube, F_c, estimated thus:

$$F_c = \frac{M}{I} \qquad (1)$$

Where,

M = Bending moment (Nmm) and

I = Moment of inertia for cube-cross section (mm^4)

Table1. Batching proportions of the cements, PLA, BLA, sand and granites for the 1:2:4 mix ratio at different replacement level.

% Replacement	Cement (Kg)	PLA (Kg)	BLA (Kg)	Sand (Kg)	Granite (Kg)	W/C Ratio
0	3.73	0	0	7.46	14.92	0.94
5	3.54	0.093	0.093	7.46	14.92	0.97
10	3.36	0.187	0.187	7.46	14.92	1.04
15	3.17	0.280	0.280	7.46	14.92	1.12
20	2.98	0.373	0.373	7.46	14.92	1.21

3.0 RESULTS AND DISCUSSIONS

3.1 Results

Table 2. Summary of flexural Strength results of PLA and BLA Blended Cement Concrete Specimen at all curing ages

% replacement of OPC with PLA and BLA	Curing Age (days)	Flexural Strength (KN) 1	2	3	Mean Flexural strength (KN)	Mean Flexural strength (MPa)
0	7	31.70	38.30	54.60	41.53	4.15
	14	38.31	30.62	60.10	43.01	4.30
	21	41.20	47.60	47.70	45.50	4.55
	28	58.00	36.20	54.40	49.53	4.95
5	7	18.70	29.50	23.30	23.83	2.38
	14	35.40	30.60	25.50	30.50	3.05
	21	34.50	31.10	31.90	32.50	3.25
	28	24.00	29.40	25.30	26.23	3.45
10	7	12.40	14.70	25.60	17.57	1.76
	14	23.10	25.50	22.70	23.77	2.38
	21	22.10	26.50	24.60	24.40	2.44
	28	31.30	27.00	19.60	25.97	2.60
15	7	15.60	15.80	16.50	15.97	1.60
	14	23.10	21.53	22.02	22.22	2.22
	21	24.00	23.60	24.40	24.00	2.40

	28	31.60	23.90	20.20	25.23	2.52
20	7	15.00	14.60	14.71	14.77	1.48
	14	15.80	19.80	17.50	17.70	1.77
	21	18.00	22.40	19.60	20.00	2.00
	28	25.60	22.40	19.60	22.53	2.25

Table 3. Result for mix 1:2:4 slump test

BLA and PLA Content (%)	Cone Height	W-C Ratio	Slump	Slump Type
0	300	0.94	50	True
5	300	0.97	45	True
10	300	1.04	43	True
15	300	1.12	38	True
20	300	1.21	35	True

3.2 Discussions

3.2.1 Slump Test

Table 3 shows the result of the slumps indicating the workability of the PLA and BLA blended cement concrete. The workability varied from 35mm to 50mm at different replacement levels which is within the stipulated range of 25-50mm for low workability concrete as stipulated by the Department of Environment. From Table 3, it was also noticed that the concrete slump decreased as the PLA and BLA content increased. All the slumps formed were true slumps and the highest slump was at a w-c ratio of 0.94 as shown in Table 3. An increase in the workability of the concrete on the introduction of PLA and BLA to the mix was observed. Upon observation it was reflected that there was gradual increase in the water cement ratio as the PLA and BLA percentage content increased. Therefore, to attain the workability level of 25-50mm in the mix containing PLA and BLA with that of convectional concrete a higher water content was required.

3.2.2 Flexural Strength Test

The blended cement concrete cubes were cast from the mix proportion 1:2:4 and were tested for their flexural strengths using a ELE 2000KN digital compression testing machine. The results of the flexural strength of PLA and BLA blended cement concrete at different curing ages and at different percentage replacement level of PLA and BLA content are shown in Table 2, Figure 1 and Figure 2 respectively.

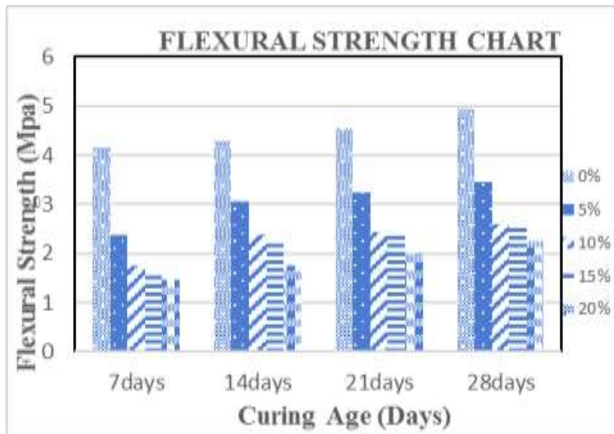

Figure 1. Flexural strength of PLA and BLA blended cement concrete for different curing ages

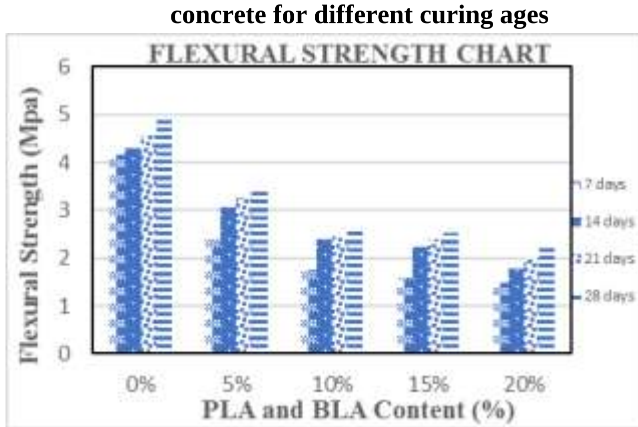

Figure 2. Flexural strength of PLA and BLA blended cement concrete for different percentage

The concrete cubes were cast from the mix proportion 1:2:4 and were tested for their flexural strengths using a ELE 2000KN digital compression testing machine, for each curing age at the percentage replacement level of cement with PLA and BLA at 0%

5%, 10%, 15% and 20%. From the results obtained, the flexural strengths at 7days for 5%, 10%, 15% and 20% replacement of cement with PLA and BLA replacement are 2.38 MPa, 1.76 MPa, 1.60 MPa and 1.48MPa respectively as against the control value of 4.15MPa, the flexural strength at 14days for 5%, 10%, 15% and 20% replacement of cement with PLA and BLA replacement are 3.05 MPa, 2.38 MPa, 2.22 MPa and 1.77 MPa respectively as against the control value of 4.30 MPa, the flexural strength at 21 days for 5%, 10%, 15% and 20% replacement of cement with PLA and BLA replacement are 3.25 MPa, 2.44 MPa, 2.40 MPa and 2.00 MPa respectively as against the control value of 4.55 MPa and the flexural strength at 28 days for 5%, 10%, 15% and 20% replacement of cement with PLA and BLA replacement are 3.45 MPa, 2.60 MPa, 2.52 MPa and 2.25 MPa respectively as against the control value of 4.95 MPa. The variations of flexural strength at different curing ages with varying percentage replacement of cement with PLA and BLA are investigated. It was observed upon investigation that the flexural strength of concrete cube specimens increases with curing age and decreases with increase in PLA and BLA content from 0% to 20% replacement level of cement with PLA and BLA as shown in Table 1. The higher the water binder ratio, the lower the flexural strength of concrete cubes. It was observed from Figure 1 upon incorporation of PLA and BLA that the PLA and BLA blended cement concrete had decreased flexural strength at an early age but gain more flexural strength at later ages. Figure 2 shows that 0% PLA and BLA replacement has the highest flexural strength but beyond 0% replacement of PLA and BLA the flexural strength was observed to be lower than the control at all curing ages. A close observation of the Figure 2 however shows that high percentage replacement of PLA and BLA is not beneficial to flexural strength development. Therefore, the highest flexural strength for the blended cement concrete was recorded where the PLA and BLA replacement was 5% at 28 days of curing. Hence, 5% is the optimum replacement level. It can be concluded from this that calcined PLA and BLA is a weak pozzolanic material.

3.3.3 Regression Analysis

Multiple linear regression model (MLR) was built with two independent variables: Calcined PLA and BLA and Curing Age (CA), and a dependent variable, flexural strength. MLR was used to create a mathematical model to predict the flexural strength of OPC-PLA and BLA cement blend if the percentage replacement level and curing age is provided. It also produced an analysis to show whether the independent variables in the study have any effect on the dependent variable, and the extent to which they are related. The general formula for MLR is given by:

$$y=\beta+\alpha_1 x_1+\alpha_2 x_2+\alpha_3 x_3+\ldots\ldots+\alpha_n x_n \qquad (4.1)$$

where y is the predicted flexural strength, $\alpha_1, \ldots \alpha_n$ are the statistical coefficients and $x_1, \ldots x_n$ are the input parameters.

The results of the analysis for all the curing days are presented in Table 4. From Table 4, the Multiple R value shows the coefficient correlation between the dependent variable – flexural strength and the two independent variables – Calcined PLA and BLA, and the curing age. The value of 0.930235792 indicates a strong linear correlation. The R square value represents the variance in flexural strength caused by the Calcined PLA and BLA, and the curing age. It's value of 86.5% indicates that both independent variables have a strong influence on the flexural strength of the concrete. The Adjusted R value takes into account the independent variables, checks and corrects for bias and errors. The Standard Error is a measure of the average distance of observed values from the regression line and it takes the unit of the dependent variable. In this analysis, it is 0.406 MPa. There was a total of 20 observations in this analysis. From Table 5, the Significance F value is 3.96795E-08 which is significantly less than 0.05 which indicates that there is a linear relationship between the flexural strength, Calcined PLA and BLA, and the curing age. From Table 6**,** the probability output is used to determine the normal distribution of flexural strength. As observed in Figure 3, the plot has a fairly consistent linear trend line, proving the distribution to be normal.

From equation 4.1, our mathematical model for predicting flexural strength, taking OPC-PLA and BLA percentage replacement level (PR) and curing ages (CA) as our independent variables, is given by:

$$y = 3.307 + 0.0405CA – 0.127PR \qquad (4.2)$$

Where y is the flexural strength of the concrete cube; PR is Calcined PLA and BLA (% replacement level) and CA is curing age (days).

From Table 7, the intercept of the P- value is not equal to 0 which further indicates that both curing age and percentage replacement level play a significant role in predicting the flexural strength of the concrete sample. From table 7, it can be also be seen that PR carries a minus (-) sign, indicating that as the % replacement level increases, the flexural strength reduces. Meanwhile, a plus (+) sign is attributed to CA, pointing to the fact that the concrete's flexural strength increases with increasing curing ages.

4.0 CONCLUSION AND RECOMMENDATION

All tests were carried out in strict compliance with standard requirement. From the experimental results, the following conclusions were drawn concerning the flexural strength characteristics of pawpaw leaf ash and bamboo leaf ash blended cement concrete;

a. the BLA and PLA blended cements have higher setting times than the control; hence, they are most applicable where low heat development is required such as in mass concreting. This shows that PLA and BLA blended cement is good as low heat cement;

b. the slump value decreases as the PLA and BLA content increases. This means that the concrete becomes less workable (stiff) as the PLA and BLA content increases. Hence there is a higher demand for water with increasing PLA and BLA content;
c. the flexural strength of PLA and BLA blended cement concrete is lower than that of plain concrete (control – 0 %) at early curing ages but improves significantly at later ages and has higher rate of strength gain later. The optimum level of replacement from structural load view point is 5 %;
d. beyond 5% replacement level of PLA and BLA with OPC in concrete mixes (10%, 15%, 20%), the flexural strength of the concrete reduces and is lower than the strength of control, indicating that calcined PLA and BLA is a rather weak pozzolanic material;
e. the flexural strength of OPC-PLA and BLA concrete increases with an increase in the curing ages, demonstrating the proportional relationship between flexural strength and the curing ages of concrete;
f. the flexural strength of OPC-PLA and BLA concrete decreases with an increase in the % replacement level of PLA and BLA with OPC, demonstrating the proportional relationship between flexural strength and the % replacement level of concrete;
g. multiple linear regression model was developed to predict the flexural strength of OPC-PLA and BLA concrete as a function of curing age and % replacement level of OPC with PLA and BLA. It predicted the flexural strength of OPC- PLA and BLA concrete up to an average precision level of 86.5% ($R^2 = 0.865$).

From the foregoing, the following recommendations can be made;

a. calcined PLA and BLA is a pozzolan and therefore, recommended for use as binders in concrete;
b. concrete containing the cement blends of OPC and PLA and BLA at a replacement level of 5% is only recommendable for use in light concrete works construction;
c. pozzolanic concrete with blends of OPC and PLA and BLA are best used for construction works where early age strength isn't of priority.

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Table 4. Multiple linear regression analysis

Regression Statistics	
Multiple R	0.930235792
R Square	0.865338629
Adjusted R Square	0.849496115
Standard Error	0.406493868
Observations	20

Table 5. ANOVA

	Df	SS	MS	F	*Significance F*
Regression	2	18.0509465	9.02547325	54.62129421	3.96795E-08
Residual	17	2.8090335	0.165237265		
Total	19	20.85998			

Table 6. Probability output

Percentile	Flexural strength
2.5	1.48
7.5	1.48
12.5	1.6
17.5	1.76
22.5	1.77
27.5	2.22
32.5	2.25
37.5	2.38
42.5	2.38
47.5	2.4
52.5	2.44
57.5	2.52
62.5	2.6
67.5	3.05
72.5	3.25
77.5	3.45
82.5	4.15
87.5	4.3
92.5	4.55
97.5	4.95

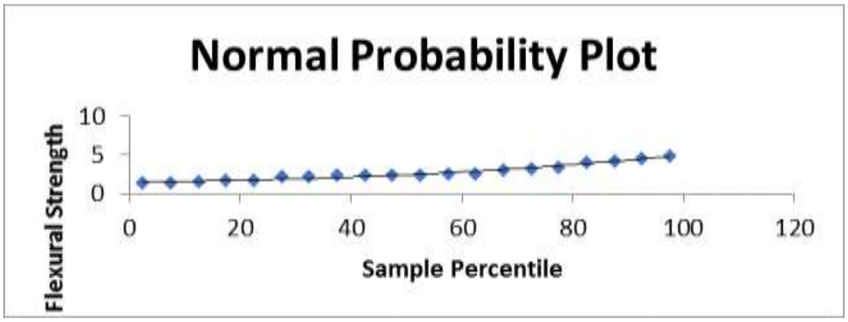

Figure 3. Flexural strength of PLA and BLA blended cement concrete for different percentile

Table 7. Coefficients of the intercept and independent variables

	Coefficients	*Standard Error*	*T Stat*	*P-value*	*Lower 95%*	*Lower 95.0%*	*Lower 95.0%*	*Upper 95.0%*
IT	3.3065	0.25709	12.86129	3.46E-10	2.76409	3.84891	2.76408	3.84891
CA	0.04051	0.01161	3.48837	0.00281	0.01601	0.06502	0.01601	0.06502
PR	-0.12665	0.01285	-9.85261	1.92E-08	-0.15377	-0.09952	-0.15377	-0.09953

From the table PR = Calcined PLA and BLA (% replacement level), CA is curing age (days) and IT = Intercept.

Table 8. Result of natural moisture content test conducted for fine aggregate

	Sample A	Sample B	Sample C
Mass of container (g), M_1	44.0	44.0	61.2
Volume of wet sample (ml)	130	130	130
Mass of container + Mass of sample (g), M_2	206.8	209.6	237.3
Mass of container + Mass of dry Sample (g), M_3	198.2	200.8	228.0
Moisture content (%) = $\frac{Mass\ of\ moisture}{Mass\ of\ dry\ sample}$ x 100%			
Mass of dry sample (g), M_3-M_1	154.2	156.8	166.8
Mass of moisture (g), M_2-M_3	8.6	8.8	9.3
Moisture content (%) = $\frac{M_2 - M_3}{M_3 - M_1}$ x 100%	5.58	5.61	5.58
Mean Moisture Content (%)		5.59	

Table 9. Results of the particle size distribution for bamboo leaf ash

Sieve Size (mm)	Mass of Sieve (g)	Sample Mass+ Sample Retained (g)	Sample Mass retained (g)	Percentage Retained (%)	Percentage Passing (%)	Cumulative Percentage Retained (%)
4.75	378.9	381.7	2.8	2.8	97.2	2.8
2.36	478.6	481.0	2.4	2.4	94.8	5.2
1.7	367.3	369.0	1.7	1.7	93.1	6.9

1.18	361.4	366.1	4.7	4.7	88.4	11.6
0.6	341.7	346.8	5.1	5.1	83.3	16.7
0.5	363.5	378.0	14.5	14.5	68.8	31.2
0.425	356.2	361.9	5.7	5.7	63.1	36.9
0.212	345.2	366.6	21.4	21.4	41.7	58.3
0.15	346.8	357.3	10.5	10.5	31.2	68.8
0.072	340.5	343.3	2.8	2.8	28.4	71.6
pan	138.6	167.0	28.4	28.4	0.00	100

100

Table 10. Specific gravity result conducted for bamboo leaf ash

	Sample A	Sample B	Sample C
Mass of empty glass jar (g), M_1	77.6	77.6	77.6
Volume of water (ml)	90	90	90
Volume of sample (ml)	90	90	90
Mass of glass jar (g) + Mass of sample (g), M_2	86.5	86.6	86.4
Mass of glass jar (g) + Mass of sample (g) + Water (g), M_3	379.5	380.1	380.2
Mass of glass jar (g) + Water (g), M_4	375.1	375.3	375.7
Unit mass of sample (g), $M_2 - M_1$	8.9	9.0	8.8
Unit mass of water (g), $(M_4 - M_1) - (M_3 - M_2)$	4.5	4.2	4.3
Specify Gravity = $\frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$	1.98	2.14	2.04
Mean Specific Gravity		2.05	

Table 11. Results of the particle size distribution for pawpaw leaf ash

Sieve Size (mm)	Mass of Sieve (g)	Sample Mass+ Sample Retained (g)	Sample Mass retained (g)	Percentage Retained (%)	Percentage Passing (%)	Cumulative Percentage Retained (%)
4.75	378.9	380.5	1.6	1.6	98.4	1.6
2.36	478.7	480.3	1.6	1.6	96.8	3.2
1.7	367.2	369.6	2.4	2.4	94.4	5.6
1.18	361.4	362.6	1.2	1.2	93.2	6.8
0.6	341.5	346.3	4.8	4.8	88.4	11.6
0.5	363.1	370.5	7.4	7.4	81.0	19.0
0.425	354.9	357.1	2.2	2.2	78.8	21.2

0.212	345.2	365.3	20.1	20.1	58.7	41.3
0.15	346.2	379.1	32.9	32.9	25.8	74.2
0.072	340.5	341.7	1.2	1.2	24.6	75.4
Pan	138.6	163.2	24.6	24.6	0.00	100

100

Table 12. Specific gravity result conducted for pawpaw leaf ash

	Sample A	Sample B	Sample C
Mass of empty glass jar (g), M_1	78.3	78.3	78.3
Volume of water (ml)	70	70	70
Volume of sample (ml)	90	90	90
Mass of glass jar (g) + Mass of Sample (g), M_2	106.4	106.5	106.4
Mass of glass jar (g) + Mass of Sample (g)+ Water (g), M_3	395.0	395.3	395.5
Mass of glass jar (g) + Water (g), M_4	375.0	375.2	375.4
Unit mass of sample (g), $M_2 - M_1$	28.1	28. 2	28.1
Unit mass of water (g), $(M_4 - M_1) - (M_3 - M_2)$	8.13	8.1	8.0
Specify Gravity = $\frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$	3.47	3.48	3.51
Mean Specific Gravity		3.49	

Table 13. Results of the Particle size distribution for fine aggregate (sand)

Sieve Size (mm)	Mass of Sieve (g)	Sample Mass+ Sample Retained (g)	Sample Mass retained (g)	Percentage Retained (%)	Percentage Passing (%)	Cumulative Percentage Retained (%)
4.75	378.9	415.9	37.0	7.4	92.6	7.4
2.36	478.7	514.3	35.6	7.12	85.48	14.52
1.7	367.2	377.0	9.8	1.96	83.52	16.48
1.18	361.4	391.3	29.9	5.98	71.54	22.46
0.6	341.5	437.8	96.3	19.26	58.28	41.72
0.5	363.1	454.3	91.2	18.24	40.04	59.96
0.425	354.9	377.1	22.2	4.44	35.60	64.40
0.212	345.2	454.4	109.2	21.84	13.76	86.24
0.15	346.2	373.4	27.2	5.44	8.32	91.68
0.072	340.5	341.1	0.6	0.12	8.2	91.80
pan	182.0	223.0	41.0	8.2	0.00	100

500

Table 14. Specific gravity result conducted for fine aggregate (sand)

	Sample A	Sample B	Sample C
Mass of empty glass jar (g), M_1	78.4	78.4	78.4
Volume of water (ml)	40	40	40
Volume of sample (ml)	90	90	90
Mass of glass jar (g) + Mass of sample (g), M_2	184.3	184.2	184.5
Mass of glass jar (g) + Mass of sample (g) + Water (g), M_3	440.5	448.2	449.0
Mass of glass jar (g) + Water (g), M_4	379.0	379.9	380.2
Unit mass of sample (g), $M_2 - M_1$	105.9	105.8	106.1
Unit mass of water (g), $(M_4 - M_1) - (M_3 - M_2)$	4.44	37.5	37.3
Specify Gravity = $\frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$	2.39	2.82	2.84
Mean Specific Gravity		2.68	