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COMPARATIVE EVALUATION OF CONCRETE PROPERTIES WITH VARYING PROPORTIONS OF PERIWINKLE SHELL AND BAMBOO LEAF ASHES REPLACING CEMENT

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Abstract

The paper examined the performance of ternary blended cement concrete incorporating periwinkle shell ash (PSA) and bamboo leaf ash (BLA) as cement supplements. PSA and BLA were obtained by burning periwinkle shell and bamboo leaves in a furnace at a temperature of 600°C for 20 minutes. The chemical analysis of the ashes revealed that they are amorphous in nature. A nominal mix of 1:2:4 with water-cement ratio of 0.65 was used as reference. The cement content of the reference was replaced with varying combined percentages (by weight) of PSA and BLA up to 40% given 10 mixes. A total of 360 cubes were cast, cured in water and tested at ages up to 56 days. The properties investigated were compressive and tensile strength, water absorption, porosity, and bulk density. The result revealed that at 28 and 56 days hydration, ternary blended cement concrete containing combined percentage of PSA and BLA of 20% cement replacement attained higher compressive and tensile strength and lower water absorption and porosity values than the reference. It is concluded that blended cement concrete of 20% cement replacement is the optimum proportion combination for ternary blended cement concrete.

Keywords: *Bamboo leaf ash; cement replacement; Comparative evaluation; Concrete properties; Periwinkle shell ash; Varying proportions*

Introduction

Building construction works and Civil Engineering practice in Nigeria depend, to a very large extent, on concrete as major construction material. The versatility, strength and durability of cement are of utmost priority over other construction materials. The basic materials for concrete are cement, fine aggregate (sand), coarse aggregate (granite chippings or gravel) and water. Hence, the overall cost of concrete production depends largely on the availability of these constituents. Unfortunately, its adverse environmental impact is also high.

Many researchers in material science and engineering, in recent time, are committed to utilising agricultural or industrial wastes to either partially or fully replace conventional materials of concrete. For instance, alternative materials like periwinkle shell (Adewuyi and Adegoke, 2008) and palm kernel shells (Ndoke, 2006) have been used as coarse aggregates to partially replace crushed stones or local washed gravels. Some agricultural waste materials such as corn-cob ash (Adesanya and Raheem, 2009); rice husk ash (Umoh, 2012), and Palm oil fuel ash (Tangchirapat *et al*., 2009) have been used as partial replacement for cement in concrete. In addition, numerous achievements have been made in these regards and the subject is attracting attention due to its functional benefit of waste re-usability and sustainable development. The utilization of waste materials in construction industry have been found to reduce the amount of solid waste, greenhouse gas emissions associated with Portland cement production and conserves existing natural resources (Hariheran *et al.,* 2011). The use of these materials as cement supplements is much more important in developing countries to augment the shortage of construction materials as well as in the development of low-cost construction materials that will be environmental friendly.

Recent investigation on the use of bamboo leaf and periwinkle shell ashes have shown that they are good supplementary cementitious materials as they are amorphous in nature and has good pozzolanic properties (Singh *et al*., 2007; Umoh and Olusola, 2012).

Bamboo is a natural fibre and widely available in Nigeria. It grows in natural vegetation among thick forest and in riverine areas. Bamboo is used in its natural form in rural areas as columns (nakedly or as composite with mud). The culms are also used as flooring materials, roof trusses and wall in temporary structures. In urban areas, they are predominantly used on construction sites as temporary support to formwork during concrete work and scaffolding during plastering and

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painting works. Omotoso (1983) reported that there are seven species of bamboo in Nigeria and that *bambusa vulgaris* constitute 80%. A study by Singh *et al*. (2007), shows that when the leaves of matured bamboo are calcined to a temperature above 600^0C, the resulting ash has a high reactive silica content of over 70%, thereby making it a good pozzolanic material that can be blended with cement.

Periwinkle has been described by Badmus *et al*. (2007) as small marine snails with spiral cone, shaped shells having a round opening and dull interior. The major species reported by Beredugo (1984), to be available in the lagoon and mudflats of Nigeria's Niger Delta, between Calabar in the east and Badagry in the west, are *Tympanostomus spp* and *Pachmellania spp*. A survey by Umoh and Olusola (2012) discovered that large quantities of periwinkle shells are available in many riverine communities of the South-South geopolitical region of Nigeria. Most periwinkles are edible, the fleshy (edible) parts are usually removed after boiling in water, and the shells are usually discarded. Continuous dumping of the discarded part has become a serious source of land pollution in areas where they are found. Accordingly, Dahunsi and Bamisaye (2002) reported that large quantities of periwinkle shells have accumulated in many parts of the country such as Warri, Western Ijaw, Burutu, Ogoni, Ogalaga and Lotughene of the Niger delta of Nigeria.

Methodology

Materials

The periwinkle shells and the bamboo leaves were collected from a dumpsite along Nwaniba Road and bamboo forest in the hinterland of Idoro Road, respectively in Uyo, Akwa Ibom State, Nigeria. The shells and dried leaves were separately burnt in a local kiln at a temperature of 600^oC for 20 minutes. The ashes obtained were pulverised and sieved through a mesh of 75ų̩m. The cement used was produced by 'UNICEM' (Nig.) Ltd., Calabar, cross river state, Nigeria to the specification of Nigeria Industrial Standard (NIS) 444-1:2003 and coded CEM11/B-L 32.5R which is equivalent to European BS EN 197-1:2009 Specification. The fine and coarse aggregates (sharp sand and granite chipping) were sourced from Uyo. The sieve analysis of the sand shows that it is in zone 2 with a fineness modulus of 2.78; while the coarse aggregate were predominantly of maximum aggregate size of 15mm. The water used for preparation of specimens was clean, tap water obtained from Department of Building laboratory of the University of Uyo.

Specimen Preparation

The mix proportion involved nominal mix ratio of 1:2:4 for a normal concrete as reference (i.e. 0% PSA, 0% BLA and 100% Cement). Two sets of mixes were derived from the reference. The first set (Set A) consists of replacing Portland cement with varying percentages of 10-30% of BLA combined with constant 10% of PSA; while the second set (Set B) consists of varying percentage of PSA between 10-30% combined with a constant percentage of BLA of 10%. In each set, five mixes were made thereby given a total of eleven including the reference. The water/binder ratio for the reference and the blended cement concrete in all the mixes was kept at 0.65 and this was determined through trial mix which maintained the slump between 0-25 mm.

The three binders were properly mixed until a uniform colour was attained, and then spread on already measured sand; and mixed thoroughly before the coarse aggregate and water were added. Mixing was assumed to be completed when homogeneous mix was obtained.

The specimens were cast in a cube mould of size 100mm as per the requirement of BS EN 12390-2 (2009). The hardened specimens were de-moulded at 24 hours from the time of casting and cured in a water curing tanks at room temperature until their testing ages.

Testing of Specimens

Compressive and Tensile Strength

The specimens were tested for compressive and tensile splitting strengths at ages of 7, 14, 28 and 56 days of hydration as per the requirement of BS EN 12390-3 (2009) and BS EN 12390-6 (2009), respectively using compression testing machine of capacity 2000KN. Three cube specimens were used in computing the mean on each testing age of each mix.

Water absorption, porosity and bulk density

Water absorption, apparent porosity and bulk density tests were determined at ages of 28 and 56 days. The method adopted was that postulated by Mukherjee *et al*. (2012) in which the cube specimens were dried in an oven at 110℃ for 24 hours and the weight taken as dry weight (*Wd*). The specimens were then boiled in water for 2 hours and left in the warm water for another 24 hours before weighing in water and in air. The suspended weight in water was designated as *Wsd* and the weight in air as *Wa*. The values for the water absorption, apparent porosity and bulk density were estimated thus:

Water absorption, WA = $\frac{Wa-Wd}{Wd} \times 100\%$ (1)

Apparent porosity, AP = $\frac{Wa-Wd}{Wa-Wsd} \times 100\%$ (2)

Bulk density, BD = $\frac{Wd}{Wa-Wsd}$ (3)

Results and Discussion

Periwinkle Shell and Bamboo Leaf Ashes

The chemical analysis of the PSA was found to contain up to 55 % calcium oxide while BLA has over 70 % silica oxide. The specific gravity for the PSA and BLA was 2.08 and 1.72, respectively. The higher chemical content of CaO by PSA and the predominantly content of SiO_2 in BLA made the two mineral admixtures good complementary materials suitable for ternary blended cement concrete.

Compressive Strength

The compressive strength of the specimen for each set, up to 56 days hydration is as presented in Tables 1 and 2. The results for the first set (Set A) mixes as indicated in Table 1, shows that the compressive strength generally decreases with increase in the percentage of BLA content but increases with curing age. The compressive strength attainment at 7 days, range from 9.87N/mm^2 to 15.71N/mm^2 for the blended mixes A5 to A1. It is noted that mixes A1 and A2 had over 82% of the reference. The compressive strength was observed to increase by 2.36N/mm^2, 0.51N/mm^2, 0.80N/mm^2 and 1.60N/mm^2 for mix A1, A2, A3 and A4, respectively but decreases by 0.77N/mm^2 for mix A5 at 14 days; with only mix A1 attaining over 75% of the reference. At 28 days, the compressive strength continuously increases from 18.07N/mm^2 at 14 days to 23.43N/mm^2 at 28 days for mix A1 and from 9.10N/mm^2 to 12.50N/mm^2 for mix A5; with mix A1 having a higher compressive strength value as it attained 104.61% of that of the reference, while mix A2 attained over 91% of the reference. At 56 days hydration, the compressive strength of mix A1 was noted to attain a higher strength than the reference, while mixes A2 and A3 were observed to compare favourably with that of the reference as they attained over 75% of the compressive strength of the reference mixes.

Table 1 Compressive strength of Set A concrete at various curing ages

Coding	Curing age (days)	Composition (%)			Compressive strength (N/mm^2)	Compressive strength attainment (%)
		PLC	PSA	BLA		
Reference	7	100	0	0	16.83	100.00
A1		80	10	10	15.71	93.35
A2		75	10	15	13.82	82.12
A3		70	10	20	12.37	73.50
A4		65	10	25	10.13	60.19
A5		60	10	30	9.87	58.65
Reference	14	100	0	0	19.70	100.00
A1		80	10	10	18.07	91.71
A2		75	10	15	14.33	72.74
A3		70	10	20	13.17	66.85
A4		65	10	25	11.73	59.54
A5		60	10	30	9.10	46.19
Reference	28	100	0	0	22.40	100.00
A1		80	10	10	23.43	104.61
A2		75	10	15	20.42	91.16
A3		70	10	20	16.70	74.55
A4		65	10	25	16.40	73.21
A5		60	10	30	12.50	55.80
Reference	56	100	0	0	23.27	100.00
A1		80	10	10	25.50	109.58
A2		75	10	15	21.69	93.21
A3		70	10	20	17.95	77.14
A4		65	10	25	17.10	73.49
A5		60	10	30	14.70	63.17

The results of the compressive strength for the second set as presented in Table 2 revealed that the compressive strength generally increases with curing age but decreases as the percentage of PSA content increases from 0% to 30% at constant BLA content of 10%. The compressive strength at 7 days range between 10.38N/mm^2 and 15.71N/mm^2 for mixes B5 and B1, respectively, with mixes B1 and B2 attaining over 75% of the reference mix at 7 days hydration period. At 14 days hydration period, the compressive strength for B1 increased to 18.07N/mm^2 representing 91.71% of the reference followed by B2, B3 and B4 with compressive strength of over 75 % of the reference. The compressive strength at 28 days increased to 22.40N/mm^2, 23.43N/mm^2, and 19.42N/mm^2 for the reference, B1 and B2, respectively. It is observed that B1 and B2 attained strength of 104.61% and 86.68% of the reference value, respectively. At 56 days, the mix containing B1 outperformed that of the reference with a value of 109.58%; followed by B2 which attained 86.89% of the reference strength.

Table 2 Compressive strength of Set B concrete at various curing ages

Coding	Curing age (days)	Composition (%)			Compressive strength (N/mm^2)	Compressive strength attainment (%)
		PLC	PSA	BLA		
Reference	7	100	0	0	16.83	100.00
B1		80	10	10	15.71	93.35
B2		75	15	10	14.45	85.86
B3		70	20	10	11.17	66.39
B4		65	25	10	10.38	61.70
B5		60	30	10	10.38	61.70
Reference	14	100	0	0	19.70	100.00
B1		80	10	10	18.07	91.71
B2		75	15	10	15.47	78.51
B3		70	20	10	15.00	76.14
B4		65	25	10	14.82	75.14
B5		60	30	10	10.60	53.81
Reference	28	100	0	0	22.40	100.00
B1		80	10	10	23.43	104.61
B2		75	15	10	19.42	86.68
B3		70	20	10	16.35	72.32
B4		65	25	10	16.20	72.32
B5		60	30	10	14.48	64.66
Reference	56	100	0	0	23.27	100.00
B1		80	10	10	25.50	109.58
B2		75	15	10	20.22	86.89
B3		70	20	10	16.25	69.83
B4		65	25	10	16.17	69.47
B5		60	30	10	15.10	64.89

From the results of the two sets of ternary blended cement concrete based on varying proportions of the two mineral admixtures it can easily be inferred that mix A1 or B1, which have the same composition, can contribute to higher strength development at 28 days than the use of 100% Portland cement as the only binder and that it can be used where the desire compressive strength are to be attained at 28 days. It is equally observed that at 28 days hydration, mixes A2 and B2 attained 91.16% and 86.68% value of the reference, respectively and increased to 93.21% and 86.89 at 56 days hydration. This indicates that mix A2 had better prospect than mix B2 meaning that ternary blending of BLA up to 15% with 10% PSA can be effectively utilised in normal concrete where desired strength is required at 28 days. This confirmed the assertion by Neville (2000) that when cement is blended with pozzolan, the strength produced will be in the range of 65 – 90% of the normal concrete at 28 days, and that the blended cement concrete compressive strength normally improves with age and at one year could attain the same strength as that of normal concrete. This also satisfies the strength requirement of over 75% as stipulated by ASTMC 618 (2008) for pozzolanic materials to be used as cement replacement.

The compressive strength values of mix A3 which had 77.14% of the reference value, could be suitable for construction where strength is required at later dates as from 56 days of curing. This confirmed Folagbade (2012) which posited that cement combinations usually have delay strength development at early ages.

Tensile Splitting Strength

The results of tensile splitting strength for the first and second sets are shown in Tables 3 and 4. The tensile splitting strength in each case generally increases with increase in curing age but decreases with increase in proportion combination of PSA and BLA in each set beyond 20 %. It was equally observed that, in the first set of mix, A1 attained up to 97% of the reference value at 7 days hydration whereas, in the second set, mixes B1, B2 and B3 attained over 75% of the reference at the same curing age. At 14 days, A1 and A2 had over 75% of the reference value, while B1, B2 and B3 had over 80%. A higher value was obtained at 28 days as mixes A1, A2, A3 and A4; and B1, B2, B3 and B4 attained over 75% of the value obtained for the reference. At 56 days, apart from mixes A4 and A5, and B5 for the first and second set, respectively, all other mixes attained over 75% of the reference value. It is observed that mix A1 and mix B1, for first and second set, respectively, had higher value than the reference and other mixes at 14 days and above, and that the second set blended mixes performed better than blended mixes of the second set. Based on this performance of A1 and B1, it can be regarded as an optimum mix combination that can enhance the serviceability performance of the ternary blended cement concrete with bamboo leaf and periwinkle shell ashes.

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Table 3 Tensile splitting strength for Set A concrete for various curing ages

Coding	Curing age (days)	Composition (%)			Tensile splitting strength (N/mm^2)	Reference tensile strength attainment (%)
		PLC	PSA	BLA		
Reference	7	100	0	0	1.71	100.00
A1		80	10	10	1.67	97.66
A2		75	10	15	1.28	73.56
A3		70	10	20	1.12	65.50
A4		65	10	25	1.25	73.10
A5		60	10	30	0.97	55.75
Reference	14	100	0	0	1.92	100.00
A1		80	10	10	1.95	101.74
A2		75	10	15	1.46	76.04
A3		70	10	20	1.42	73.96
A4		65	10	25	1.34	69.97
A5		60	10	30	0.94	48.96
Reference	28	100	0	0	2.02	100.00
A1		80	10	10	2.19	108.42
A2		75	10	15	1.56	77.23
A3		70	10	20	1.58	78.22
A4		65	10	25	1.60	79.21
A5		60	10	30	1.14	56.44
Reference	56	100	0	0	2.15	100.00
A1		80	10	10	2.44	113.49
A2		75	10	15	1.57	72.87
A3		70	10	20	1.67	77.67
A4		65	10	25	1.50	69.77
A5		60	10	30	1.22	56.74

Table 4 Tensile splitting strength for Set B concrete for various curing ages

Coding	Curing age (days)	Composition (%)			Tensile splitting strength (N/mm^2)	Reference tensile strength attainment (%)
		PLC	PSA	BLA		
Reference	7	100	0	0	1.71	100.00
B1		80	10	10	1.67	97.66
B2		75	15	10	1.60	93.57
B3		70	20	10	1.30	76.02
B4		65	25	10	1.28	74.85
B5		60	30	10	1.05	61.40
Reference	14	100	0	0	1.92	100.00
B1		80	10	10	1.95	101.74
B2		75	15	10	1.61	84.03
B3		70	20	10	1.59	82.99
B4		65	25	10	1.42	73.95
B5		60	30	10	1.10	57.29
Reference	28	100	0	0	2.02	100.00
B1		80	10	10	2.19	108.42
B2		75	15	10	1.77	87.62
B3		70	20	10	1.63	80.69
B4		65	25	10	1.60	79.21
B5		60	30	10	1.15	59.93
Reference	56	100	0	0	2.15	100.00
B1		80	10	10	2.44	113.49
B2		75	15	10	1.90	88.37
B3		70	20	10	1.72	80.00
B4		65	25	10	1.62	75.35
B5		60	30	10	1.22	56.74

Water Absorption

The result of water absorption, expressed in percentage, for the two sets of ternary blended cement concrete cured at 28 and 56 days are presented in Figures 1 and 2. The values of the absorbed water indicated that mix A1 had the least amount of absorbed water, and that beyond the proportion combination of 20 % of PSA and BLA, the water absorption increases in each curing age. it was also noted that the absorbed water was less at 56 days curing age than at 28 days. for instance, the water absorption values at 56 days was observed to decreased by 0.18%, 0.82%, 1.04%, 1.57%, 1.47% and 0.71% for reference, A1, A2, A3, A4 and A5 mixes, respectively. Similar trend is observed with the second set of mixes except that mix B5 had a value that did not differ significantly at both curing ages. From the Figures, it shows that mix A1 (or B1) had the least value of water absorption when compared to other mixes. A minimal water absorption by mix A1 or B1 could be attributed to the formation of less amount of pores as a result of improvement in the interface transition zone by the pozzolanic reaction and therefore a reduction in permeable voids; whereas, greater volume of pores must have been created in other mixes which could be due to excess filler materials of the BLA and PSA which have not been consumed by the pozzolanic reaction and thereby forming permeable spots for water penetration. Generally, the water absorption value in all the mixes as stated by Neville (2000) falls within the range of most good concrete of which the value do not exceed ten percent.

Porosity

The Porosity of the ternary blended cement concrete with various weight percentages of BLA combined with fixed weight percentage of PSA and vice versa, as cement replacement is presented in Figures 3 and 4. The porosity of set A mixes range between 5.95% and 12.61% at 28 days hydration and reduces to a range between 4.91% and 11.19% at 56 days curing period for A1 and A5, respectively. The porosity for set B mixes indicated an increased in the value with increased combined PSA and BLA beyond 25 weight percentage cement replacement but decreases with curing age. It can be seen that mix A1 and B1 which had a combined mineral admixtures of BLA and PSA of 20 weight percentage replacement of cement recorded the least porosity value than the reference in both sets; while mix A5 and B5 recorded the highest porosity value in each curing age. It can be said that the least value recorded by mixes containing 20% combined mass of BLA and PSA has a better permeability performance than the reference and other mixes which contain PSA and BLA combined percentage mass greater than 20% as cement replacement. The higher porosity value recorded by mixes greater than 20% replacement of cement could be attributed to the fact that many of the pores have not been filled by the formation of pozzolanic compounds. The improvement of permeability performance of ternary blended cement concrete over the reference confirmed the earlier finding by Fadzil *et al.* (2008) that the use of ternary blended cement concrete improved the water absorption and porosity of concrete as compared to normal concrete made with Portland cement alone. Therefore, it can be said that mix A1 or B1 concrete is less impermeable and therefore has better resistance to water permeability and thereby making it more durable than the normal concrete made of Portland cement as the only binder.

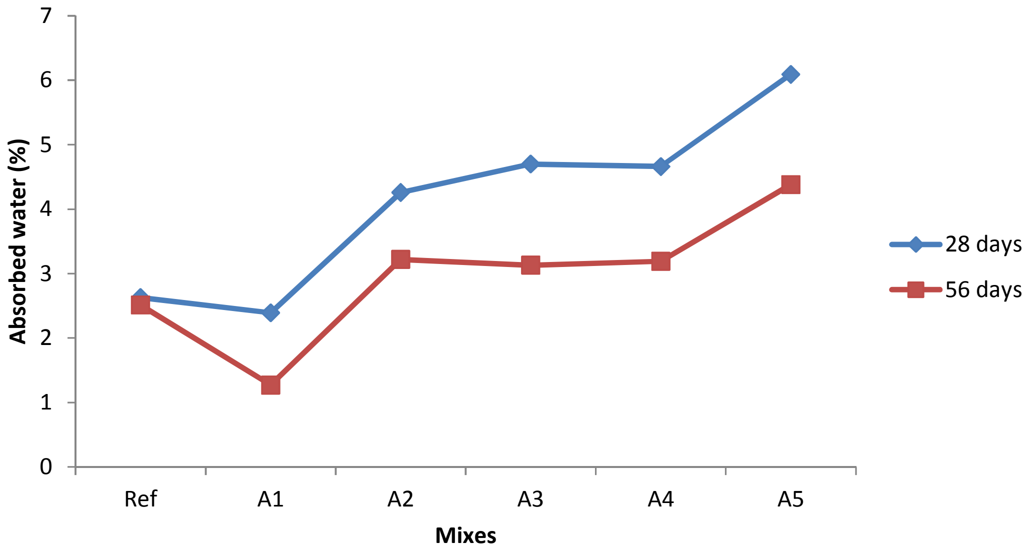

Figure 1 Water absorption for Set A mixes at 28 and 56 days hydration

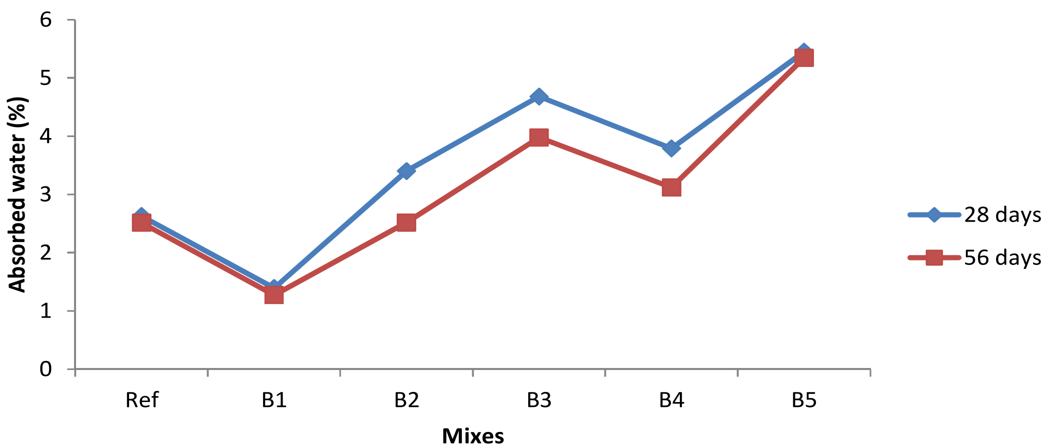

Figure 2 Water absorption for Set B mixes at 28 and 56 days hydration

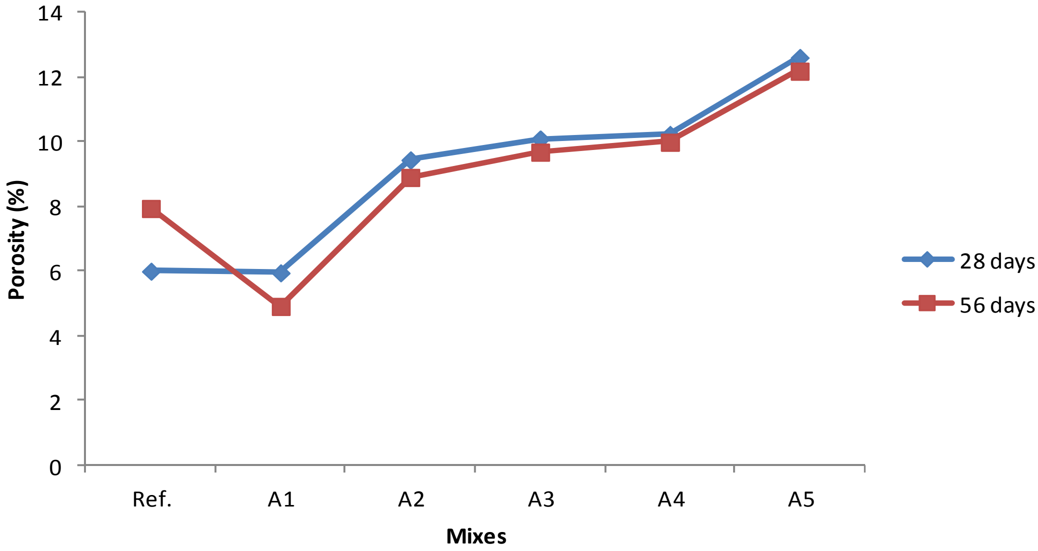

Figure 3 Porosity value for Set A mixes at 28 and 56 days hydration

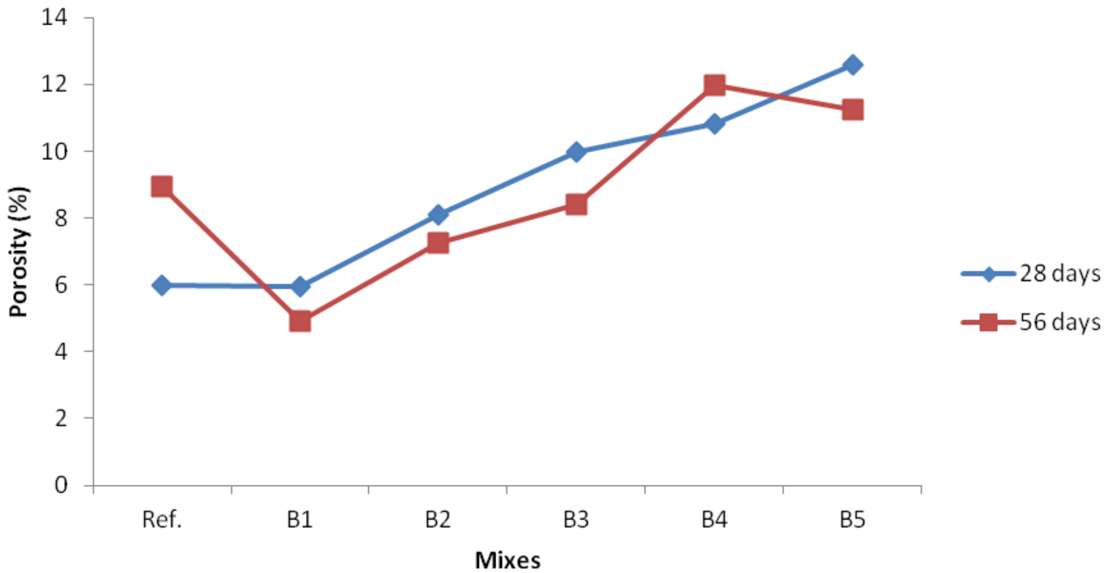

Figure 4 Porosity value for Set B mixes at 28 and 56 days hydration

Bulk Density

The results of the bulk densities for the two sets of ternary blended cement concrete shown in Figures 5 and 6 in the first set of mixes, the bulk density increases from 2380 kg/m^3 to 2420 kg/m^3 for reference and mix A1 concrete, respectively; and decreases as the percentage replacement of cement by the two mineral admixtures increases from 25% to 40% at 28 days hydration. At 56 days curing age it was noted that the bulk density has increased by 2.52%, 2.48%, 7.52%, 11.83%, 12.51% and 12.08% for the reference, A1, A2, A3, A4 and A5 mixes, respectively; but decreases as the combined percentage of the mineral admixtures increases from 25% to 40% cement replacement.

In the second set, the bulk densities at 28 days hydration follow a similar trend as that of the first set. It is also observed that at 56 days, the bulk densities increases as the combined percentage replacement of cement with the admixtures increases up to 35%.

It is noted that a lower values of bulk densities were recorded in the first set of mixes containing a combined BLA and PSA of cement replacement greater than 20% compared to similar mixes of the second set. The lower bulk densities in set A mixes could be ascribed to the fact that BLA has a specific gravity of 1.72 which is much lighter in weight than the specific gravity of PSA of 2.08, and therefore, as the quantity of the BLA is increasing with its attendance increase in the volume of the mixture, and consequently resulted in the reduction of the density of the concrete; whereas, with fixed content of BLA with increasing quantity of PSA content and for the fact that PSA is denser in weight than BLA, this has led to higher bulk density values in mixes B2, B3, B4, B5 and B6.

This finding confirmed the earlier assertion by Aggrawal (1995) that the replacement of cement or sand (dense materials) by lighter materials resulted in an increase in total volume of the mixture, and that the increase in the volume of the mixture resulted in a decrease in density of the samples.

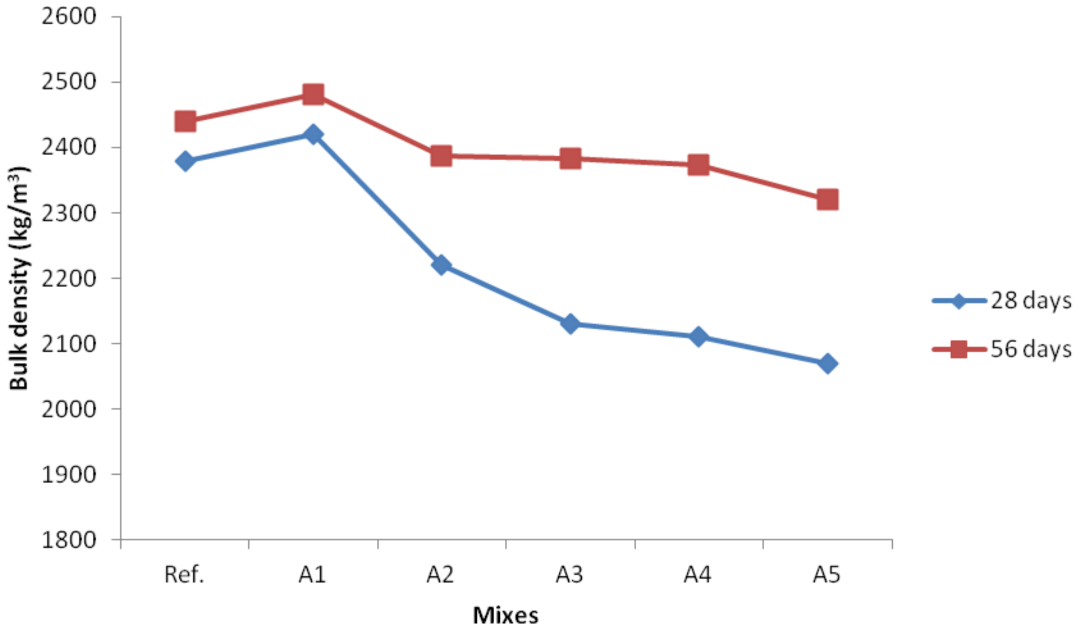

Figure 5 Variation between bulk density and mineral composition for Set A

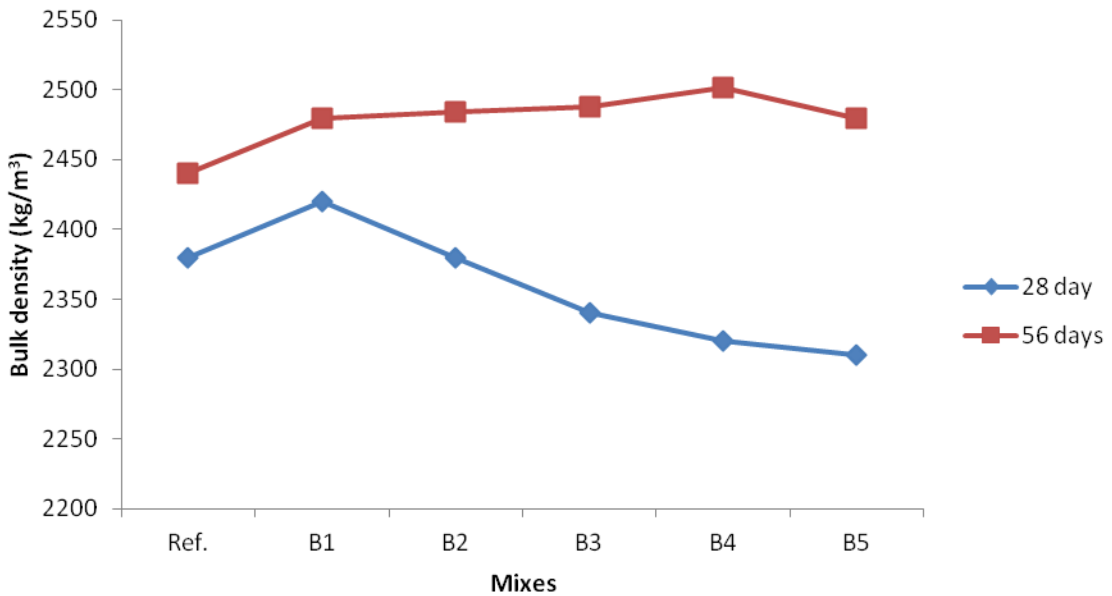

Figure 6 Variation between bulk density and mineral composition for Set B

Conclusions

From the various tests performed the following conclusions can be drawn:

1) Ternary blended cement concrete incorporating combined mass of PSA and BLA of 20% (10% each) replacing cement outperformed that of the reference in terms of improved strength and impermeability to moisture, and therefore, this percentage inclusion of PSA and BLA should be used for medium cadre concrete where higher strength development is required than the use of 100 % Portland cement as the only binder.
2) It is observed that mix A2 containing BLA up to 15% with 10% PSA can be effectively utilized in normal concrete where desired strength is required at 28 days as it satisfies the strength requirement of over 75% as stipulated by ASTMC 618 (2008) for pozzolanic materials to be used as cement replacement.
3) The compressive strength values of mix A3 which had 77.14% of the reference value, could be suitable for construction were strength is required at later dates as from 56 days of curing, this confirmed Folagbade (2012) which posited that cement combinations usually have delay strength development at early ages.

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