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INFLUENCE OF AGRICULTURALLY BASED SCMS ON DIFFERENT TYPES OF COMMONLY USED CEMENT FOR CONCRETE WORKS IN SOUTH-WEST NIGERIA

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Abstract: This paper aimed at understanding the influence of agricultural Supplementary Cementitious Materials (SCMs) such as Rice Husk Ash (RHA), Snail Shell Powder (SSP), Cow Bone Ash (CBA) and Pulverized Cow Bone (PCB) on different types of commonly used cements in South-West Nigeria, Products sampled include Dangote, Lafarge and Purechem cements. The cement samples were analyzed using methods for physical tests of cement specified by British Standards (BS 4550-3.4:1978). Fineness, consistency and setting time tests were performed on the cement pastes; slump test was performed on the control and modified fresh concrete; compressive and flexural strength tests were performed on the control and modified hardened concrete. Mix ratio of 1:0.9:2.8, characteristic strength of 40N/mm² and water cement ratio of 0.35 were used to cast concrete suitable for rigid pavement. The concrete were subjected to compressive strength test after 28, 90 and 120 days; flexural strength test of 7 and 28days. The SCMs were used to modify the concrete at partial replacement of cement at 0%, 5%, 10%, 15% and 20%.
Keywords: Agricultural Wastes, Cement, Compressive Strength, Flexural Strength, Supplementary Cementitious Material

1. INTRODUCTION

Cements may be defined as adhesive substances capable of uniting fragments or masses of solid matter to a compact whole (Ghosh 1983). The various types of Portland cement used in the construction industry are: Ordinary Portland Cement(OPC), Rapid Hardening Portland Cement(RHPC), Sulphate resisting Portland Cement(SRPC), Low Heat Portland Cement(LHPC), Blast Furnace Portland Cement(BFPC), Portland Pozzolana Cement(PPC), Modified Portland Slag Cement(MPC) etc.

Cement functions by forming a plastic paste when mixed with water, which develops rigidity (sets) and steadily increases in compressive strength (hardness) by chemical reaction with the water (hydration). When a material increases in strength even when stored under water after setting it, the material is said to be hydraulic (Lea 1970).

The properties of the final products of Portland cements are dependent on the chemical and morphological composition of clinker, gypsum and other additives introduced during the process of grinding. Changes in cement properties could occur during subsequent storage. Since the cement quality can be overwhelmingly dependent on the quality of clinker, it therefore means that any consideration of its characteristics requires a basic understanding of the factors that control the clinker quality and clinkerization process (Bye 1983).

Cement, being the most expensive component in a cubic metre of concrete, its properties affect the properties of concrete the most. The compressive strength of concrete according to Adewoke, et al (2014) largely depends on the quality and quantity of cement that serves as the major strength giver in concrete, as it binds the fine and coarse aggregate together to form a rigid/solid mass that is capable of sustaining load.

Cement concrete is the most widely used building material due to its satisfying performance in strength requirements and its ability to be moulded into a variety of shapes and sizes. The situation in Nigeria is not an exception as most of the infrastructures in Nigeria such as building, bridges, concrete roads, highway drainages, runway, sea ports and harbours etc are constructed with concrete. However, over the years, many waste materials like fly ash and ashes produced from various agricultural wastes such as palm oil waste, rice husk ash, millet husk ash have been tried as pozzalona or secondary cementitous materials. The supplementary cementing materials play an important role when added to Portland cement because they usually alter the pore structure of concrete to reduce its permeability, thus increasing its resistance to water penetration and water related deterioration such as reinforcement corrosion, sulphate and acid attack. The use of SCMs in concrete is increasing internationally. These materials enhance the durability of concrete, providing protection against cracking due to alkali silica reaction, delayed ettringite formation, sulfate attack, thermal gradients, and more. Furthermore, they can be more economical than cement and may be more readily available in times of cement production shortages (Juenger, M. 2008).

Industrial and agricultural wastes are becoming a health and environmental problem especially in the developing nations where technology for efficient waste disposal is lacking. According to Falade et. al. (2012), one of the agricultural wastes, whose generation runs to millions in tonnes is cow bone wastes.

A few unfavourable results have been obtained with use of SCMs which has been attributed to difference in cement types. CBA and PCB, for instance, as used in a few research works in concrete have shown unpredictable results which can be attributed to the various sources. This therefore implies that commonly recognized SCMs may not perform favourably with all types of cement. This research therefore assessed the physical properties of three major cement brands in South-West Nigeria (Dangote 42.5 Cement, Lafarge cement and Purechem cement), their structural capacities and their performance when they are partially replaced with these SCMs.

2. MATERIALS AND METHODOLOGY

— Ordinary Portland cement

The Dangote 3X, Lafarge and Purechem Portland cements were used in this study and were sourced locally.

— Rice Husk Ash (RHA)

Rice Husk were gotten from a rice farm at Ota (6.6927°N, 3.2365°E), Ogun State, Nigeria and then burnt at Federal Institute of Industrial Research, Oshodi (FIIRO), Lagos state, Nigeria. The ash used passed through B. S sieve of 75 microns.

— Snail Shell Powder (SSP)

The Snail Shell Powder were obtained from its deposits at a local market in Oje (7.389°N, 3.909°E), Ibadan, Oyo State, South-Western Nigeria. The shells were deposited as wastes by snail sellers at an unauthorized dumpsite around the market area. The collected shells were washed, cleaned, dried and crushed before it was blended into fine powder using commercial milling machine.

— Pulverized Cow Bone (PCB) and Cow Bone Ash (CBA)

PCB was obtained from grounding cow bones and CBA was obtained from burning cow bones. The cow bones, after careful removal of adhering flesh and tissues, were cleaned, sun-dried, and then grounded. They were grounded with hammer mill to fine powder at Federal Institute of Industrial Research, Oshodi (FIIRO), Lagos state, Nigeria and passed through B. S sieve of 75 microns. The cow bones used for this work was obtained from a local abattoir in Oko-oba (6.47°N, 3.933°E), Agege, Lagos State.

— Aggregate

The fine aggregate used was Ogun river sand obtained at Abule-Egba (6.6484°N, 3.2992°E), Lagos, Nigeria. The sand was washed to remove any impurities and dried. The coarse aggregate is the commercial granite stone quarried, crushed and graded. For this study, 20 mm maximum nominal size aggregate was used.

The laboratory tests conducted are presented in Table 1.

In this research, 540 cubes and 360 beams were cast. Concrete was prepared by replacing the different cement types with RHA, SSP, CBA and PCB at 0-20%. The cast concrete were cured in fresh water. A Grade 40 concrete using mix ratio of 1:0.9:2.8 by weight was adopted with water/cement ratio of 0.35. The mix proportions are summarized in Table 2.

Table 1: Laboratory tests conducted

Material/ Combination	Laboratory Test
Cement, Sand, RHA, SSP, CBA, PCB and Coarse Aggregate	» Sieve Analysis (Sand only). » Chemical Analysis (OPC, RHA, SSP, CBA, PCB only). » Fineness (Cement only) » Setting Time (Cement only) » Consistency (Cement only) » Specific Gravity
Control Sample (For the different types of cement)	» Workability (Slump test) » Compressive Strength, cube tests (28 days, 90 days & 120 days cured). » Flexural Strength test (7 & 28 days).
Modified concrete with partial substitution of the different cement types with 0-20% variation of the SCMs.	» Workability (Slump test) » Compressive Strength, cube tests (28, 90 & 120 day cured). » Flexural Strength test (7 & 28 days).

Table 3: Sample ID And Their Meanings

Sample ID	Meaning
M_{0}	Control Sample
M_{5S}	Sample with 5% SSP and 95% Cement
M_{10S}	Sample with 10% SSP and 90% Cement
M_{15S}	Sample with 15% SSP and 85% Cement
M_{20S}	Sample with 20% SSP and 80% Cement
M_{5R}	Sample with 5% RHA and 95% Cement
M_{10R}	Sample with 10% RHA and 90% Cement
M_{15R}	Sample with 15% RHA and 85% Cement
M_{20R}	Sample with 20% RHA and 80% Cement
M_{5P}	Sample with 5% PCB and 95% Cement
M_{10P}	Sample with 10% PCB and 90% Cement
M_{15P}	Sample with 15% PCB and 85% Cement
M_{20P}	Sample with 20% PCB and 80% Cement
M_{5C}	Sample with 5% CBA and 95% Cement
M_{10C}	Sample with 10% CBA and 90% Cement
M_{15C}	Sample with 15% CBA and 85% Cement
M_{20C}	Sample with 20% CBA and 80% Cement

Table 2: Mix Proportions of M40 grade with W/C of 0.35

Sample ID	Water (Kg/m³)	Cement (Kg/m³)	Sand (Kg/m³)	Granite (Kg/m³)	SSP (Kg/m³)	RHA (Kg/m³)	PCB (Kg/m³)	CBA (Kg/m³)
M_{0}	170.54	487.26	438.53	1364.33	0	0	0	0
M_{5S}	170.54	462.90	416.60	1364.33	24.36	0	0	0
M_{10S}	170.54	438.53	394.68	1364.33	48.73	0	0	0
M_{15S}	170.54	414.17	372.75	1364.33	73.09	0	0	0
M_{20S}	170.54	389.81	350.82	1364.33	97.45	0	0	0
M_{5R}	170.54	462.90	416.60	1364.33	0	24.36	0	0
M_{10R}	170.54	438.53	394.68	1364.33	0	48.73	0	0
M_{15R}	170.54	414.17	372.75	1364.33	0	73.09	0	0
M_{20R}	170.54	389.81	350.82	1364.33	0	97.45	0	0
M_{5P}	170.54	462.90	416.60	1364.33	0	0	24.36	0
M_{10P}	170.54	438.53	394.68	1364.33	0	0	48.73	0
M_{15P}	170.54	414.17	372.75	1364.33	0	0	73.09	0
M_{20P}	170.54	389.81	350.82	1364.33	0	0	97.45	0
M_{5C}	170.54	462.90	416.60	1364.33	0	0	0	24.36
M_{10C}	170.54	438.53	394.68	1364.33	0	0	0	48.73
M_{15C}	170.54	414.17	372.75	1364.33	0	0	0	73.09
M_{20C}	170.54	389.81	350.82	1364.33	0	0	0	97.45

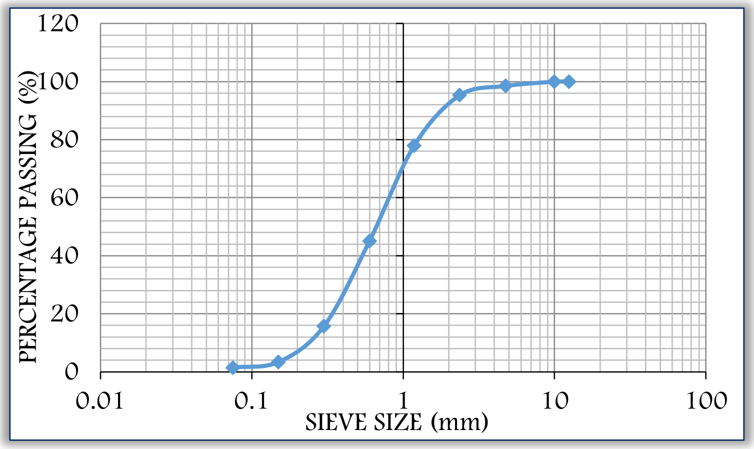


Figure 1: Particle-Size Distribution Curve of Sand

Table 4: Specific Gravity Test Results

Materials	Cement	Sand	RHA	SSP	CBA	PCB	Granite
Specific Gravity	3.07	2.65	2.10	3.04	2.05	2.22	2.70

The three different cement types used in this study; Dangote, Lafarge and Purechem are designated by D, L and P respectively. Table 3 explains the meaning of the sample IDs

3. RESULTS AND DISCUSSION

— Specific Gravity

The specific gravity of the materials used for this study is summarized in Table 4.

— Sieve Analysis

The results of the sieve analysis carried out on the sand used is presented in Figure 1.

The Coefficient of Uniformity C_u, the Coefficient of Curvature C_c and Fineness Modulus of the sand used are 3.20, 1.01 and 2.65 respectively which indicate that the sand is Uniformly Graded and medium-grained (Braja, 2010).

— Chemical Analysis

The chemical composition of OPC, RHA, SSP, CBA and PCB was determined using. X- Ray Fluorescence Spectrometry (XRF Fused Bead Test). The result of the chemical analysis is presented in Table 5.

Table 5: Chemical Analysis Result

Compound	Dangote Cement	Lafarge Cement	Purechem Cement	RHA	SSP	CBA	PCB
SiO_2	20.8	19	22	72.18	0.78	3.30	9.37
Al_2O_3	5.37	6.5	5.0	6.06	2.02	3.99	3.05
Fe_2O_3	3.41	2.8	2.3	4.21	0.78	1.48	1.47
CaO	60.38	63.4	63.1	3.12	67.19	77.31	70.87
MgO	2.68	3.0	0.85	1.16	0.93	2.22	3.89
Na_2O	0.42	0.8	0.9	1.15	1.44	1.31	2.98
K_2O	0.63	1.6	1.78	2.31	0.17	1.25	1.82
SO_3	1.81	0.35	1.75	0.31	0.24	-	2.55
Na_2Oe	-	-	-	2.47	-	-	-
C	-	-	-	2.91	-	-	-
P_2O_5	-	-	-	-	0.21	6.59	-
TiO_2	-	-	-	-	0.03	-	-
MnO	-	-	-	-	-	1.10	1.34
Cl	-	-	-	-	0.04	-	-
LOI	2.02	1.5	2.05	4.12	26.14	1.37	2.45

— Preliminary Tests on Cement

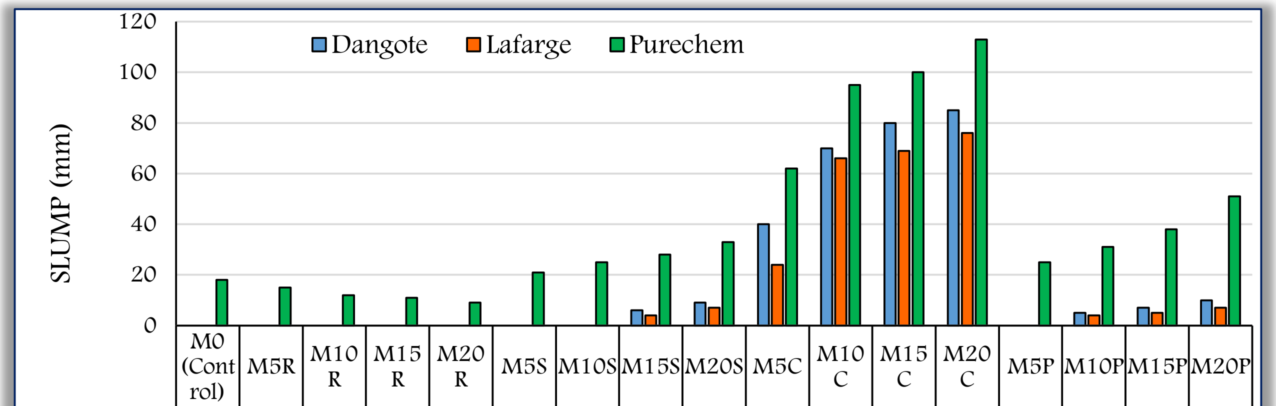
The preliminary tests include fineness test, Consistency test, specific gravity test and setting time test. The results obtained are shown in Table 6 and expressed in figures 2-6.

Table 6: Preliminary Test Results on Cement

CEMENT TYPES	DANGOTE	ELEPHANT	PURECHEM	ASTM STANDARD
Initial Setting Time (mins)	155	98	158	30-202
Final Setting Time (mins)	228	170	236	185-312
Specific Gravity	2.92	3.01	2.9	3.05-3.15
Consistency (%)	32.5	32	30	26-33%
Fineness (%)	78.1	77.2	77.6	90%

— Workability (Slump Test)

The slump test result obtained is expressed in Figure 2. The slump result showed that RHA reduces workability, SSP and PCB slightly improved the workability of the concrete and CBA improved the workability of the concrete significantly. Purechem cement was more workable than the other cement brands used. Lafarge and Dangote were close in terms of workability but with Dangote slightly better.



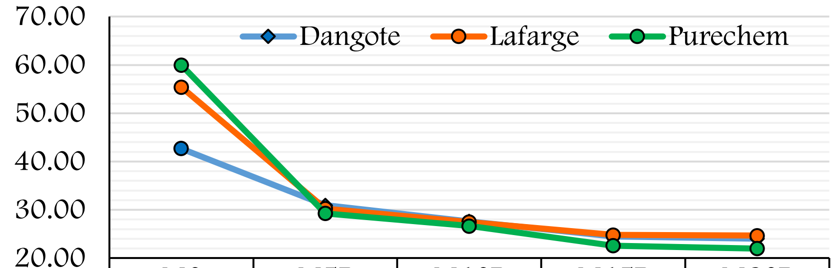
	M0 (Control)	M5R	M10R	M15R	M20R	M5S	M10S	M15S	M20S	M5C	M10C	M15C	M20C	M5P	M10P	M15P	M20P
Dangote	0	0	0	0	0	0	0	6	9	40	70	80	85	0	5	7	10
Lafarge	0	0	0	0	0	0	0	4	7	24	66	69	76	0	4	5	7
Purechem	18	15	12	11	9	21	25	28	33	62	95	100	113	25	31	38	51

Figure 2: Slump Value of Fresh Concrete for the Different Sample

It was observed that the fresh concrete was increasingly difficult to work with increase in crumb rubber which means that crumb rubber reduces the workability of concrete. The addition of RHA improved the workability slightly but then decreased with increasing quantity of crumb rubber. This same trend was observed with the addition of SSP, the result obtained with RHA was however better than that of SSP. The addition of CBA and PCB improved the workability of rubbercrete significantly, PCB giving the best result but in all cases, increase in crumb rubber reduced the workabilty.

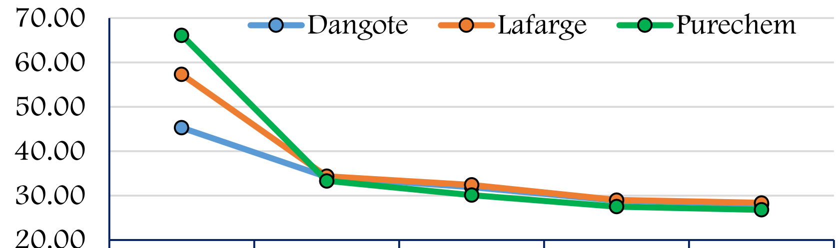
— Compressive Strength

Figures 3-10 show the compressive strength at 28 and 90days for the soil samples. It is observed that RHA caused a decrease in compressive strength for all the cement brands sampled and this was observed all through the curing regimes. Increase in RHA did not improve the decline in compressive strength. SSP proved it could improve the strength of concrete for all cement brands, but better with Purechem cement and at optimum quantity of 10%. CBA and PCB showed little prospect in its suitability for replacing cement as it improved the 28th day strength of Dangote cement at 5% replacement, however, strength was observed to decline with increase in curing age for all cement brands and therefore not recommended for concrete works.



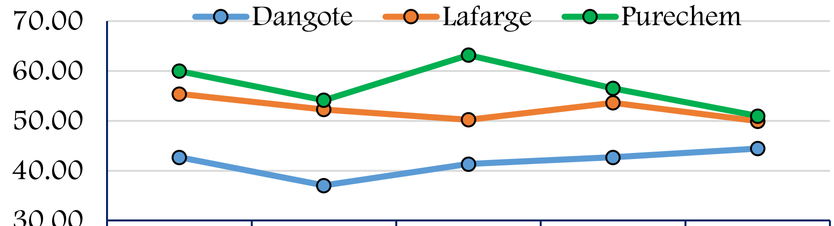
	M0	M5R	M10R	M15R	M20R
Dangote	42.67	30.96	27.63	24.52	24.04
Lafarge	55.41	30.26	27.48	24.81	24.67
Purechem	60.00	29.26	26.66	22.59	22

Figure 3: 28th Day Compressive Strength of Samples Containing Varying Percentages of RHA



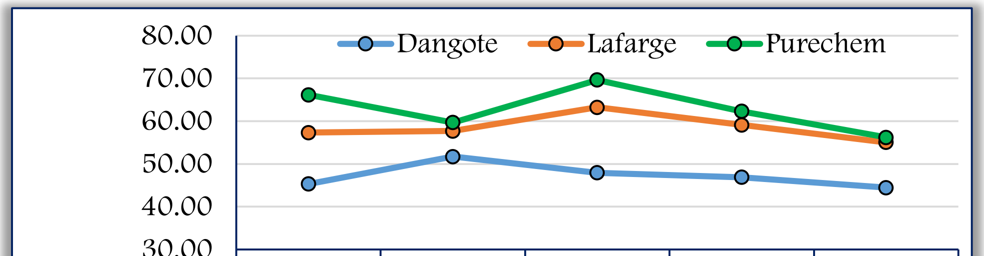
	M0	M5R	M10R	M15R	M20R
Dangote	45.33	34.22	31.93	28.89	28.08
Lafarge	57.33	34.37	32.45	29.04	28.37
Purechem	66.15	33.33	30.15	27.56	26.82

Figure 4: 90th Day Compressive Strength of Samples Containing Varying Percentages of RHA



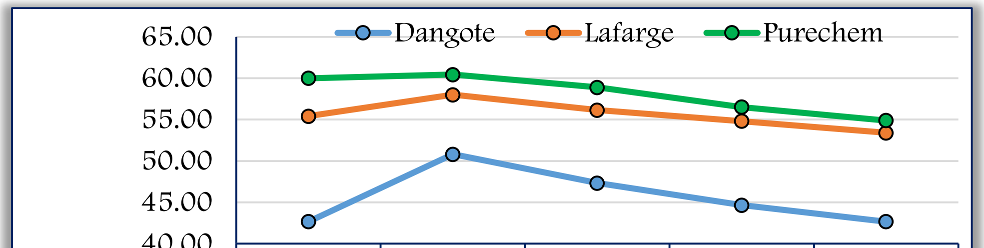
	M0	M5S	M10S	M15S	M20S
Dangote	42.67	37.04	41.33	42.67	44.44
Lafarge	55.41	52.3	50.22	53.63	49.93
Purechem	60.00	54.15	63.19	56.52	50.96

Figure 5: 28th Day Compressive Strength of Samples Containing Varying Percentages of SSP



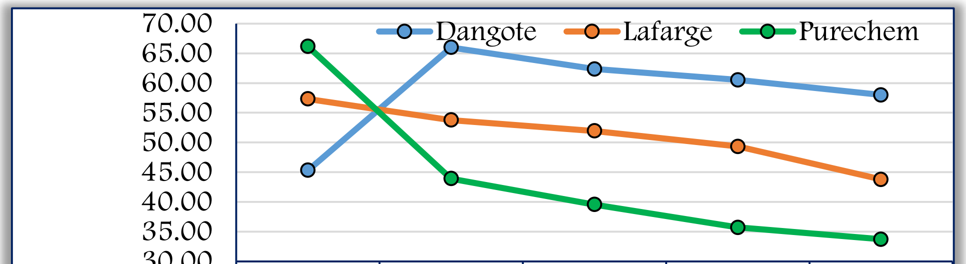
	M0	M5S	M10S	M15S	M20S
Dangote	45.33	51.7	47.93	46.89	44.44
Lafarge	57.33	57.7	63.26	59.11	55.04
Purechem	66.15	59.7	69.63	62.3	56.22

Figure 6: 90th Day Compressive Strength of Samples Containing Varying Percentages of SSP



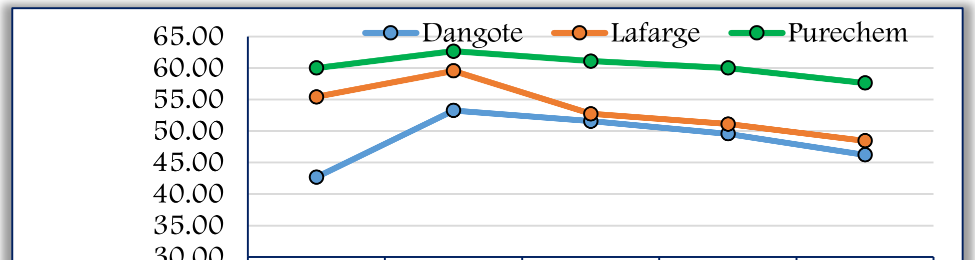
	M0	M5C	M10C	M15C	M20C
Dangote	42.67	50.81	47.33	44.67	42.67
Lafarge	55.41	58.00	56.15	54.81	53.41
Purechem	60.00	60.44	58.89	56.52	54.89

Figure 7: 28th Day Compressive Strength of Samples Containing Varying Percentages of CBA



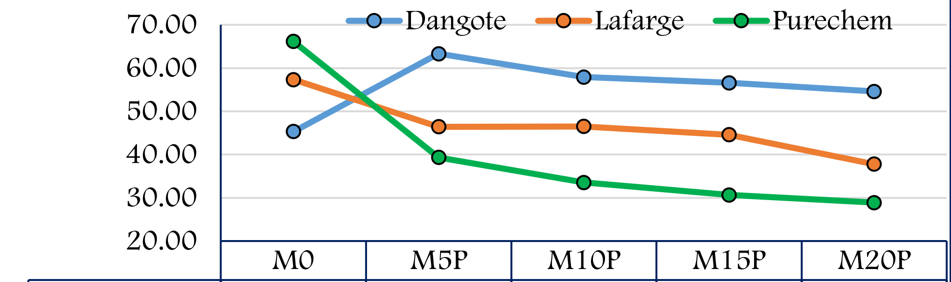
	M0	M5C	M10C	M15C	M20C
Dangote	45.33	66.00	62.37	60.52	58.00
Lafarge	57.33	53.78	51.93	49.33	43.78
Purechem	66.15	43.93	39.56	35.70	33.70

Figure 8: 90th Day Compressive Strength of Samples Containing Varying Percentages of CBA



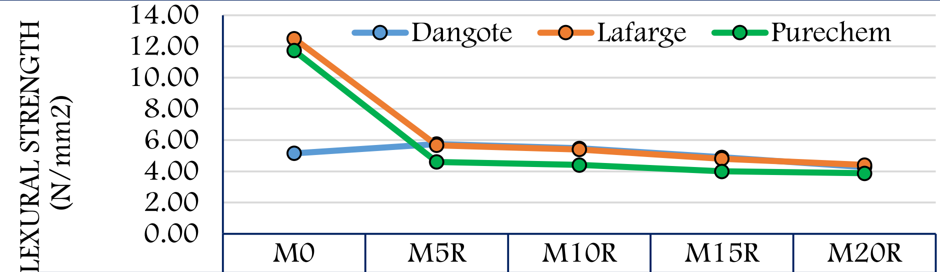
	M0	M5P	M10P	M15P	M20P
Dangote	42.67	53.26	51.56	49.56	46.22
Lafarge	55.41	59.56	52.74	51.11	48.44
Purechem	60.00	62.67	61.11	60.00	57.63

Figure 9: 28th Day Compressive Strength of Samples Containing Varying Percentages of PCB



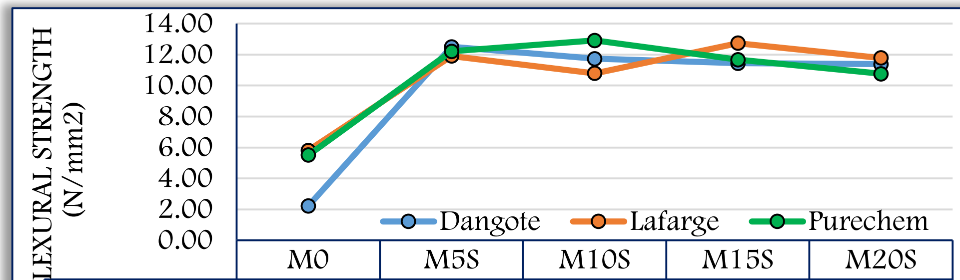
	M0	M5P	M10P	M15P	M20P
Dangote	45.33	63.33	57.93	56.59	54.59
Lafarge	57.33	46.44	46.52	44.59	37.78
Purechem	66.15	39.33	33.56	30.67	28.89

Figure 10: 90th Day Compressive Strength of Samples Containing Varying Percentages of PCB



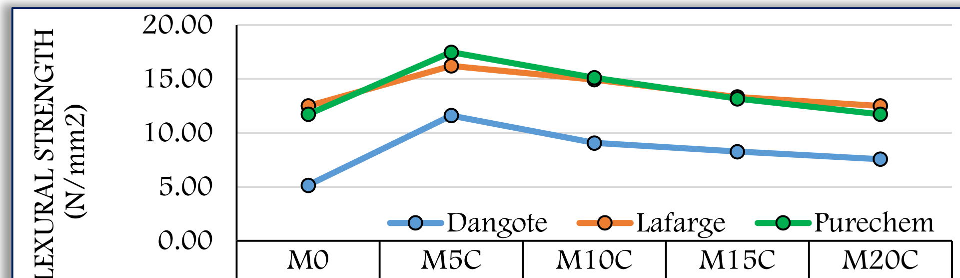
	M0	M5R	M10R	M15R	M20R
Dangote	5.15	5.75	5.47	4.9	4.27
Lafarge	12.50	5.67	5.4	4.8	4.4
Purechem	11.73	4.6	4.4	4	3.87

Figure 11: 28th Day Flexural Strength of Samples Containing Varying Percentages of RHA



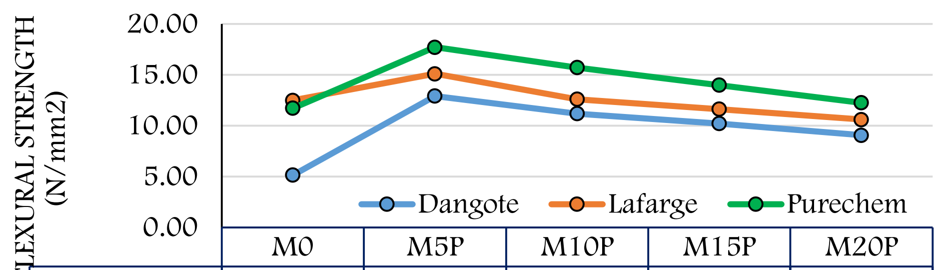
	M0	M5S	M10S	M15S	M20S
Dangote	2.22	12.5	11.73	11.44	11.38
Lafarge	5.81	11.91	10.79	12.74	11.79
Purechem	5.51	12.21	12.92	11.67	10.76

Figure 12: 28th Day Flexural Strength of Samples Containing Varying Percentages of SSP



	M0	M5C	M10C	M15C	M20C
Dangote	5.15	11.61	9.07	8.27	7.56
Lafarge	12.50	16.21	14.93	13.33	12.50
Purechem	11.73	17.48	15.11	13.16	11.73

Figure 13: 28th Day Flexural Strength of Samples Containing Varying Percentages of CBA



	M0	M5P	M10P	M15P	M20P
Dangote	5.15	12.92	11.20	10.22	9.07
Lafarge	12.50	15.11	12.62	11.64	10.61
Purechem	11.73	17.72	15.73	13.99	12.27

Figure 14: 28th Day Flexural Strength of Samples Containing Varying Percentages of PCB

— **Flexural Strength**

The flexural strength obtained for the rubcrete samples are presented in figures 11-14. The result showed that RHA improved the flexural strength of Dangote cement at 5% replacement but caused a decrease in flexural strength for other cement brands, same trend with increase in RHA content. SSP increased the flexural strength of concrete for all cement brands; best results obtained with Lafarge cement and at 20% replacement. CBA and PCB improved the flexural strength of concrete but increase in CBA and PCB contents resulted in decreasing the strength.

4. CONCLUSIONS

— The specific gravity and fineness of the cement brands fell short of the standard.
— The cement brands met the standard for consistency.
— The cement brands met the standard for setting time, however, with the exception of Lafarge cement falling short of the standard in terms of the final setting time.
— CBA improved workability of concrete significantly, while SSP and PCB improved workability slightly, RHA decreased the workability of concrete. Purechem proved to be more workable than other cement brands sampled.
— RHA is not suitable for replacing cements mostly used in South-West Nigeria as it reduces the compressive strength of concrete.
— SSP improves compressive and flexural strength of concrete, best suitable for Purechem cement at 10% replacement and Lafarge cement at 20% replacement.
— CBA and PCB improves flexural strength of concrete, performing best with purechem cement at 5% replacement but not impressive in improving compressive strength and therefore not recommended for replacing cement obtainable in South-West Nigeria.

In view of the results presented in this study, it is recommended that SSP be used in partially replacing commonly used cement for concrete works in South-West Nigeria. It is also recommended that methods of producing RHA be studied as this may be the reason for poor results obtained with RHA.

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