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Environmental Sustainable Application of Biomass Wastes in Cement for Structures

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ABSTRACT: The current global demand versus energy insecurity has led to the quest for increasing energy exploration from different environmental resources, with the intention to minimize our ecological versus energy footprints. In this quest, environmental sustainability must lead the path to BPEO. It's eminent that the built environment is not left out of this drive, in its quest to intensify research that could come up with sustainable replacement for the most vital and dominant constructional material ever known as cement. One of such research herein, is the application of biomass wastes (CWSA, SBA, CCA, and RHS) as PSR in cement. Impressively, CWSA has shown remarkable result as compared with the control/reference cement (POPC2), to have 58.93% CaO, 14.76% SiO_2, with 20.61% total SiO_2 + Al_2O_3 + Fe_2O. Similarly, CWSA has Specific gravity of 2.64% and LOI is 3.63%. However, CWSA compressive strength at 5, 10, 15 and 20% PSR for 28 and 56 days are 25.66, 24.77, 23.44, and 21.99 N/mm^2 as well as 35.31, 34.29, 33.01, and 29.46 N/mm^2 respectively. However, specimen CWSA, SBA, CCA, and RHS at PSR of, 5%, 10% and 15% exhibits similar characteristics at 0.5% WCr., while at PSR 20%, 25%, and 30% the materials gradually becomes stiffens i.e. less workable at 0.5% WCr., subsequent improve workability for WCr. is 0.6% this is attributed to having higher amount of silica (SiO_2) content. Furthermore, CWSA recorded a compressive strength decrease at 20%, 25% and 30% to be 18.41 N/mm2, 17.15 N/mm2 and 14.89 N/mm2, the higher MgO contents value of 4.65% and lower SiO_2 of 14.76% as against standard stipulation of 2% for MgO and 17 – 25% for SiO_2, contributed to this strength decrease. It's recommended to use SBA, CCA, and RHA at 10% - 15% as PSR in lightweight concrete structures, while CWSA can be used in both light and medium weight concretes respectively

KEYWORDS: Sustainability, Cement, Concrete, Compressive strength, Biomass, Waste, Specimen

I. INTRODUCTION

The physical environment inhabits both natural and manmade features operating symbiotically, in an ecosystem that interplay between; human existences, lands and natural resources, flora and faunas, water and air (ISO 14001: 2004). Accordance to (ISO 15392: 2008), Sustainability is the effective utilization of environmental natural resource within the ecosystem without adverse or negative ecological footprints at present and for the future generations to come. And this is in line with Brundtland Report (1987) that says; Physical human developments should meet up to both the current and future generations demand without being a hindrance to the future global existence. Hence, there is the need to moderates human consumptions of environmental resources, with the view to effectively conserve with continual improvement process. According to (ISO 15392: 2008), continual improvement involves developing all sustainability indices in relation to the built environment and the construction works over a period, including accessing the performances of all physical constructions work and procedures in line with current BPEO.

The current global environmental degradation, is a clear definition for the growing demand and consumptions of the available environmental resources that cannot be sustained continuously over time. Similarly, the construction industries are major players to the depletion of this environmental resources and with little or no compliance to the practical application of sustainability. Its applicability is only in the form of ecological reconstructioning. General implementations of sustainability defer on global scale indices (nationally, regionally, locally, at communal levels and individually). Hence, these deferential commitments can be attributed to deficiency in the transfer of newer knowledge to the local construction industries by the international research communities (Authors R&D 2020). Similarly, according to (Naess, 2006) Eco-efficiency should be another watch word for environmental sustainability, to ensuring qualitative manufacturing, productions, services, and by concurrently minimising resource consumptions and the continual undesirable environmental depletions.

Therefore, the major contributors to environmental degradation includes the cause for natural resource mining, urbanization and the industrial revolutions, while the key players to these effect is the construction industries quest to erect structures, predominantly concretes, which requires cement production and application to achieving stability. (Authors R&D 2020). According to (ISO 8402, 2015) a qualitative cement is produced under known specification with the ability to effectively produce a specified designed concrete structure that can satisfy both structural and end users requirements. Hence, the utilisation of cement product currently had become inevitable with the quest for increasing construction works. However, it's eminent that the current urban built environments in Nigeria and Africa, constitute of about 85.4% cement concrete volume, 3.2% Riprap (sizable rocks and boulders), with 7.4% lateritic soil (sand and clay), while 4% are timber and metals sheets structures respectively. Hence it can be stated that, cement is a major constituent material in the existence of the built environments, and its major by-product is limestone (Authors R&D 2019). However, limestone is finite resources/fossil mineral which are non-renewable. Cement is generally expensive in terms of cost production and does grossly contributes to air and water pollutions during mining, extraction and production process, with devastating ecological footprint on agriculture and arable lands. Furthermore, there is the need to reduce the eminent cost of mining, production, selling and the utilization of cement as well as to come up with cement supplements from agricultural and other form of solid waste materials (Authors R&D 2019).

Nigeria is agriculturally endowed for having favourable climatic condition with vast arable lands for agricultural plantations such as; Millet, Guinea-corn, Maize, Rice, Wheat, Sugarcane among others are widely practiced and are cultivated in abundance throughout both raining and dry seasons, the aforementioned remains are left in the open as residual biomass wastes. Subsequently, these wastes constitute major disposal and management problems, with an in effective disposal alternative of subjecting these wastes to open burning as method for treatment, thereby living a bulk of unwanted biomass ash on farmland for disposal by wind and rain (Authors R&D 2019). Hence, the degree of biomass generated after crop harvesting without reuse can be imagined from the below area of farmland cultivated in square kilometre (km^2) as at 2017. However, it's equally important to note that, the numbers of farmlands cultivated every year is almost doubled the current numbers in the subsequent farming seasons as at 2015. And this does not include industrial purpose farmlands.

Table 1: Statistic of crop cultivation per km^2 in Nigeria, year 2017

Agricultural produce	**Areas harvested** (Hectares)	**Square Kilometre** (km^2)
Rice	4,912,650.00	49126.5
Maize	6,743,247	67432.47
Groundnut	2,820,000	28200
Millet	2212439	22124.39
Sugarcane	890017	8900.17
Wheat	70946	709.46
Below is an example of an industrial purpose farmlands		
Rice milled equivalent	19,747,805	197478.05

Source: (knoema, 2017)

- **WOOD SAWDUST (WS)**

Sawdust are the remains of timber during and after sawing process in the wood industries or mills. However, medium and small scale wood saw-mills are predominantly located in most parts of Nigeria and other parts of the globe at large. As at November 2019 there are 23 functional medium scale wood saw-mills in Keffi local government metropolitan area of Nasarawa state, one out of the 774 LGA in Nigeria, endowed with forest vegetarians. Wood sawing is a regular activity that can be seen all around these saw-mills, with a bulk remains of sawdust blocking major drainage system and or dumped in the open for direct burning, which constitutes the third largest form of environmental and air pollution after automobile engines, and the disposal of municipal solid wastes. It's eminent that with the growing demand for urbanisation, the need to utilise timber remains topmost priority for the construction industries, because it's economically cheaper than any other major structural components in the built environment. Therefore, more wood sawdust will be available and left without sustainable management with reference to Nigeria. Therefore, there is an urgent need to sustainably utilise this sawdust wastes as renewable energy sources (Authors R&D, 2019). Similarly, this research is focusing on the predominantly (79 - 86%) known forms of sawdust and timbers available in Nigeria. Other investigation into the use of sawdust in the construction industry are available, but the parent timbers producing the sawdust are not identifiable and or not known, such research literatures includes: Udoeyo et al. (2006), "Potential of wood ash waste as an additive in concrete", Elinwa et al. (2008), "Self-compacting concrete containing sawdust ash", Wang et al. (2008), "Biomass fly ash in concrete", others are; Cheah and Ramli (2011), "The use of wood waste ash in structural grade concrete and mortar" and Onwuka et al. (2013), "Prediction and Optimization of Compressive Strength of Sawdust Ash-Cement Concrete" among other research literatures.

- **RICE HUSK (RH)**

Rice husk is an agricultural remains dumped on farmland after cultivation and harvesting of rice grain. 92% - 97% of the rice husk, as well as rice straws are left unutilised on the farmlands to decay, or being burnt in the open environment as general practice employed by farmer's and people alike in Nigeria as management process. Sometimes it's majorly used for the treatment of burnt clayed products (pots, blocks and ceramics), with its last remains as rice husk ash (RHA) and rice straws ash (RSA) (Authors R&D 2019). Research report by (Oyetola and Abdullahi, 2006) indicates that, incinerated RHA has been classified as a pozzolana, with some characteristics of 67% – 70% Silica content, while aluminium and iron oxide are 4.9% and 0.95% respectively. Similarly, the presence of silica content in RHA exist as amorphous. And hardening process is formed during liberated reaction of calcium hydroxide (CaOH) (hydration reaction) of cement so as to further advance the production of cementitious compounds. Pozzolana has been defined by (ASTM, 1976) to be composition of siliceous and aluminous materials possessing minute and or no cementitious rate, but transforms rapidly under ordinary temperature during chemical reaction with CaOH in the presence of moisture, in order to produce compounds capable of forming effective cementitious properties. According to research conducted by both (Oyetola and Abdullahi, 2006) and (Okafor and Okonkwo, 2009), revealed that RHA has enormous positive potentials on the Geotechnical properties of lateritic soils. However, it's used locally in Nigerians rural areas, during mixing and the preparation of locally clay mould blocks to sever as reinforcement membrane that can effectively control the blocks from excessive cracking (Authors R&D 2019). However, there are similar research on rice husk such as; "Thermal analysis and pozzolanic index of rice husk ash at different grinding time" by Ramadhansyah P. J. et al. (2012) and Prasetyoko D. et al. (2006), "Conversion of rice husk ash to zeolite beta Waste Manage" among others.

- **SUGARCANE BAGASSE (SB)**

According to (Osinubi and Stephen, 2005), that the fibrous remains of sugarcane after milling and extracting the liquid juicy sugar from the factory is known to be "Sugarcane Bagasse". Therefore, sugarcane bagasse ash (SBA) is the incinerated squeezed sugarcane remains (waste). However, different forms of agricultural waste ashes, will have varying chemical characteristics, but having similar physical properties, depending on the nature and constituent biomass as well as the technology of incineration used. SBA when incinerated in an air tied furnace, and regulated under high temperature will however vitalize complex but effective organic compounds (Werther et al., 2000) and (Loo and Koppejan, 2003), (ASTM, 2006) and (Authors R&D 2019). Bagasse is predominantly disposed in the open farmlands in Nigeria as agricultural solid wastes and subsequently burnt during farm clearing process, so as to pave way for the next plantation face. And only fewer industries utilize Bagasse as fuel in boilers. Research has revealed that SBA contains higher amounts of Aluminium, Calcium Oxides and Silicon. And similarly, (Silvio et al., 2008) had produced a research result showing SBA can be used as potential quartz replacement in red ceramics. And according to (Osinubi, et al., 2009a) research result shows that with an increased percentage of SBA and cement on soil, there is an increased optimum moisture content as well as decreased maximum dry density. Similarly, the following research results; (Osinubi and Stephen, 2007), (Osinubi and Ijimdiya, 2009b), and (Ijimdiya, 2010) shows an effective improvement on the geotechnical properties of soils by using SBA. Similarly, there are other related sturdies on sugarcane bagasse ash such as; "XRD, FTIR and microstructure studies of calcined sugarcane bagasse ash" by Govindarajan D. and Jayalakshmi G. (2011).

- **MAIZE CORNCOB (MC)**

Corncob is similarly a biodegradable agricultural remains of cultivated maize that is predominantly grown and cultivated in Nigeria, and the rest of the globe temperate regions. Maize is the second most grown cash crops in Nigeria, virtually 93% of its part (husks, cobs, stalks and leaves) are burnt to ashes on the farmland after trashing the useful fruit (maize grain) from the corncob for subsequent processing, while 7% of these remains are utilized and or consumed by nomadic cattle during grazing. Similarly, it's a usual practice in Nigeria as method of waste management that, 97% of the corncob are instantly burnt off on the farms after the grain is being trashed off, from the cob. Then the 3% leftover of this maize quantity are brought home for storage as seedlings for the next phase of plantation, while its remains are used as fuel during domestic cooking (Authors R&D 2019). However, according to Adesanya, et al. (2009), research outcome indicates a positive pozzolanic composition (SiO_2, Al_2O_3 and Fe_2O_3) in corncob ash on a sturdy carried out in South Africa, to have meat ASTM C618 requirement. However, Mohanraj K et al. (2012), reported from his research work that, corncob ash is characterised to have Nano SiO_2 when examined through precipitation method Optoelectrons. Similarly, other related research work carried out on corncob ash includes; "Thermal conductivity of corn cob ash blended cement mortar" by Raheem A. A. and Adesanya D. A. (2011), "Potential ecological thermal insulation material Corn's cob" by Pinto J. et al. (2011), other similar researches also includes; Faustino J. et al. (2012), "Impact sound insulation technique using corn cob particleboard" Pinto J. et al. (2012), "Characterization of corn cob as a possible raw building material" and Faustino J, et al. (2015), "Lightweight concrete masonry units based on processed granulate of corn cob as aggregate" these among other similar research works available.

- **AIM AND OBJECTIVE**

This Research aimed at exploring technically the structural potentials of some selected biomass wastes to be used as civil engineering materials. With the objective to examine major important cement characteristics (chemical, physical and mechanical properties) for both CWSA, SBA, CCA and RHA as structural concrete materials. However, it's equally important to note that, all of the aforementioned characteristics are highly important as these can affects finished concretes either positively or negatively.

- **MATERIALS, EQUIPMENT AND METHODOLOGY**

It is eminent that this research work requires both the application of quantitative as well as qualitative analysis under strict adherence to precautional measures so as to achieve effective results that truly represent the specimen. The available materials and equipment used are as follows:

- **MATERIALS**
- Research Biomass, combined wood (CW) dusts, of 75% wild grown indigenous timbers (Iroko, Mahogany, Ebeche) and 25% other unidentified wood species, SB, CC, and RH;
- Incinerated dried biomass to produce respective biomass ashes i.e. (CWSA), (SBA), (CCA), and (RHA);
- Pure ordinary Portland cement (POPC) 1 and 2 commercially and locally in use, to serve as control and or reference specimen;
- Stockpiled aggregates: Fine (river sand) and Coarse (crushed rock); and
- Normal running tap water.

- **EQUIPMENT**

Availability of functional equipment are the underlining successes to a research output. However, there are various sets of equipment employed in the cause of this research work, among the majors are:

- Specimen containers, Trowel, Wheel barrow for transporting test samples etc.;
- Set of BS sieves and electric shaker, to determine the particle size distributions for both fine and coarse aggregates as well as biomass research Specimens;
- Air tied incinerator (temperature range 37^{o}c - 1000^{o}c);
- Equipped chemical laboratory for Specimens analysis;

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- Motorised concrete mixer and vibrating table;
- Steel concrete cube moulds, Slump cones, Cube curing tank; and
- Compressive Strength Test Machine;

II. METHODOLOGY

The principal methodologies adopted in other to attaining this research objective are detailed in the following code of practices: British standard (BS) “for particle size distribution” (BS 812-1: 1971), BS methods “for structural use of concrete” (BS 8110-1: 1997), BS methods "for determination of compacting factor” (BS 1881-103: 1983), BS methods “for determination of slump” (BS 1881-102: 1983), and BS EN 12350-2 (2009) "Testing fresh concrete. Slump-test” Similarly, BS methods “for specification of Portland cement” (BS EN 12: 1989), (BS 12: 1991) and (BS EN 197-1: 2011), BS methods “for grading of aggregates” (BS 812-103: 1985), BS methods "for concrete compressive strength” (BS 1881-116: 1983), (BS EN 12390-3: 2002) and (BS EN 12390-3: 2009), so also so, BS method “for testing water used in making concretes” (BS 3148: 1993) and “Natural moisture content of cement” (BS 812 – 1: 1975), BS method “for physical testing of cement” (BS 4550-3: 1978), among others respectively. Similarly, comparative methods for the above were used so as to check for consistency and accuracies in the cause of this research work, these includes:

- Standards Organisation of Nigeria (SON). “Composition, specification and conformity criteria for common cements” (NIS 444-1: 2003);
- American Society for Testing and Materials (ASTM) 2012 namely:
- (ASTM, 2012), “Standard test method for sampling and testing fly ash or natural pozzolanas for use in Portland-cement concrete” (C311/C311M-13);
- (ASTM, 2012), “Standard test method for amount of water required for normal consistency of hydraulic cement paste” (C187-98);
- (ASTM, 2012), “Standard test method for slump flow of self-consolidating concrete” (C1611/161M-14);
- (ASTM, 2012), “Standard test method for time of setting of hydraulic cement by Vicat needle” (C191-13); and
- (ASTM, 2012), “Standard test method for compressive strength of hydraulic cement mortars” (C109/109M-02).

Furthermore, the concrete cubes were prepared at ambient temperature range (26 - 28ºc), so as to avert possible cracking of test specimens as a result of thermal stresses. The design mixes are 1:2:3 (cement, river sand and crushed rock), water-cement ratio is 0.5% to 0.6%, with the aim to examine the concretes physical and mechanical properties such as, concrete slump test (workability), and the casting of 150mm×150mm×150mm concrete cubes vice-versa demoulding after 24 hours of casting for curing in a regulated curing water tank (27ºc) at the following age periods. 7, 14, 21, 28, and 56 days, and in line with successive partial replacement by weight of 5%, 10%, 15%, 20%, 25% and 30% of CWSA, SBA, CCA, and RHA in POPC respectively. However, three (3) test cubes were prepared and casted for the individual biomass ash specimens with the aforementioned mix, curing ages, and percentage replacement. While fresh water is replaced into curing tank within an intervals of seven (7) days. Similarly, the representative results used, are the average of the summation values in each case, with view to effectively minimise error as well as to ensure minimum standards are observed.

III. RESULTS & DISCURSIONS

Table 2: Chemical analysis of research materials

Chemical Properties of Specimen Oxides	Research Specimens					
	POPC1 (%)	POPC2 (%)	CWSA (%)	SBA (%)	CCA (%)	RHA (%)
CaO → Calcium oxide	61.79	64.03	58.93	1.99	5.24	0.67
$CaSO_4$ → Calcium Sulphate	0.31	0.12	0.00	0.00	0.01	0.01
SiO_2 → Silicon dioxide	18.48	20.99	14.76	72.89	59.98	67.79
Al_2O_3 → Aluminum oxide	4.32	5.01	3.58	6.97	4.04	4.86
Fe_2O_3 → Iron oxide	3.77	3.19	2.27	4.99	4.07	0.89
MgO → Magnesium oxide	4.59	2.99	4.65	3.04	3.55	0.44
SO_3 → Sulphur trioxide	0.98	1.88	2.69	2.59	1.02	82.86
K_2O → Potassium oxide	0.21	0.39	7.96	12.86	15.79	2.91
Na_2O → Sodium oxide	0.16	0.20	1.82	0.18	0.23	0.12

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P_2O_5 → Phosphorus pentaoxide	0.15	0.08	3.98	0.13	7.03	0.8
TiO_2 → Titanium Oxide	0.05	0.07	0.06	0.03	0.04	0.03
$SiO_2 + Al_2O_3 + Fe_2O$	**26.57**	**29.19**	**20.61**	**84.85**	**68.09**	**73.54**
Physical Properties Test 0f specimen						
Mean grain size (µm)	22.40	20.87	14.97	68.6	23.56	63.8
Moisture content	0.28	0.30	0.36	6.32	0.29	0.30
LOI Temp. Range 500°c - 1000°c	3.52	3.02	3.63	5.43	4.97	5.81
Specific gravity	2.89	3.14	2.64	2.22	2.71	2.61

Source: (Authors Lab. Result, 2020)

Table 2 above illustrates the percentage chemical contents available in research specimens CWSA, SBA, CCA, and RHS at PSR, as well as two (2) selected locally available most prevalent cements POPC1 and POPC2, with the aim of analysing both cement samples so as to ensure minimum standards are adhered to during selection process, and as in accordance with (BS EN 12: 1989), (BS 12: 1991) and (BS EN 197-1: 2011) "standard specification for Portland cement" Hence, POPC2 has been chosen as control/reference cement to be used for the continuance of this research process, the reason for this option can be analysed as summarised in table 3 below as follows:

Table 3: Chemical analysis of Oxides in research materials.

Major POPC Chemical Oxides	Min - Max. (%) in POPC	**Discursions of laboratory chemical results**
CaO	**60 - 65**	The quantity of CaO or lime most be adequate in the manufacturing of POPC, it does aid the production of SiO_4 (silicates) and $CaAl_2O_4$ (calcium aluminate). Lime insufficiency will lead to decrease in cement property strength. Similarly, inadequate amount of lime will lead to rapid cement setting process.
		The expansion and disintegration of cement is a result of lime excessiveness, and higher amount of lime in cement will lead to unreliable cement quality. Equally lime or CaO originates from limestone, shells, chalks, calcareous rocks and shale.
$CaSO_4$	**0.1 - 0.5**	$CaSO_4$ exist as gypsum ($CaSO_4.2H_2O$) in cement. And it does retards cement setting period when in excess. While $CaSO_4$ and $CaSO_4.2H_2O$ both exist together.
SiO_2	**17 - 25**	Adequate quantity of Silicon dioxide (silica), is needed in the production of cement. Similarly, silica imparts concrete strength. While silica also contributes to around 30% of cements volume. SiO_2 exists in sand, calcareous rock, clay and old bottles

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Al_2O_3	**3 - 8**	Aluminium oxide (Al_2O_3) contributes to rapid cement setting properties. Similarly, adequate amount of Alumina in cement does help in lowering clinker temperature. However, it's equally important to note that excessive alumina does weakens cement strength. Al_2O_3 exists in clay, bauxite, and recycled aluminium,
Fe_2O_3	**0.5 - 6**	The presence of iron oxide serves as flux in cement, which in returns supports colour in cement. Similarly, when excess temperature is induced in the presence of Fe_2O_3 it does influence chemical reaction of calcium to form Ca_3O-$Al_2O_3Fe_2O_3$ (tricalcium aluminoferrite). While $3Al_2O_3Fe_2O_3$ (trialuminoferrite) contributes to cement strength and hardness. Fe_2O_3 exists in clay, fly ash, scrap iron and iron ore respectively.
MgO	**1 - 3**	High volume of Magnesium (Mg) is not required in cement production, most preferably 2%. Similarly, high amount of Mg compound will negatively affect concrete strength.
SO_3	**1 - 2**	High amount of SO_3 (Sulphur Trioxide) leads to cement unsoundness. Hence, it's most preferable that the amount of SO_3 in cement should not exceed 2%.
Alkaline (K_2O, Na_2O)	**0 - 1**	High amount of Alkaline substances leads to efflorescence in cement. The presence of alkaline in cement should not exceed 1% as per standard.
Source: (BS EN 12: 1989); (BS 12: 1991), (BS EN 197-1: 2011); (SON NIS 444-1: 2003); (ISO 8402: 2015); and (ASTM C150-TYPE 1)		**Source:** (Authors Analysis, 2020)

Therefore, it can be stated that these aforementioned compounds contributes immensely to cement properties for instance: Tricalcium silicate (C_3S) compound which does hydrates and becomes hardened rapidly. C_3S is majorly accountable for the early setting and strength increase in POPC. Similarly, Dicalcium silicate (C_2S) hydrates and becomes slowly hardened, but it's an effective compound principally accountable for strength gain in concretes after seven (7) days of curing. While, Tricalcium aluminate (C_3A) does releases lots of heat at initial hydration stage, however it has very small amount of strength contribution to cement. While gypsum ($CaSO_4.2H_2O$) retards hydration process of C_3A. Cement becomes sulphate resistance as a result of C_3A deficiency. Furthermore, Ferrite (C_4AF) is an important fluxing catalyst, with the ability to reduce cement kiln melting temperature with about 13.3^{o}c that is from 1648.9^{o}c to 1426.7^{o}c. C_4AF hydration process is rapid, and has just little and or no contribution to prepared cement paste strength. Other major parameters that can positively influence pure cement quality includes; thoroughness of burning, fineness of particles after grinding, sound moisture content, easily workable, ability of early hardiness, and possession of good plasticity index.

Therefore, mixing the aforementioned cement compounds properly and in accordance with set standard specification, cement can be produced and or manufactured to conform to any built environmental standards. Hence, in line with all of the above detailed properties and characteristic, there is the probability in the subsequent laboratory analysis that CWSA will be

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more suitable as partial replacement material in cement, for having mate satisfactory chemical characteristic when compared with POPC2 with a deference of 7.9% CaO acting as lime, and deference of 26.9% summation compositions of SiO_2, Al_2O_3, and Fe_2O. It's equally important to note that SBA, CCA, and RHS has 91.82% less CaO content available when compared to POPC2 value. Similarly, both SBA, CCA, and RHS has excessive summations of SiO_2, Al_2O_3, and Fe_2O compositions as comparable to POPC2. However, Silicon dioxide (SiO_2) is the major contributing parameter, which is three (3) times in excess of POPC2 comparative value.

- **PHYSICAL & MECHANICAL PROPERTIES OF RESEARCH MATERIALS:**
- **SIEVE ANALYSIS OF AGGREGATES**

Table 4: Sieve Analysis of research aggregates (Fine and Coarse)

Sieve Analysis						
Sample Location:		Nasarawa LGA River Sand and Bagobiri Quarry Site, Keffi LGA				
Collection Date:		24^{th}/11/2019		Analysis Date: 27^{th}/11/2019		
Sample No. **01**	Specific gravity **2.63**			Sample No. **02**	Specific gravity **2.66**	
Percentage (%) Water Absorption **0.75**				Percentage (%) Water Absorption **0.45**		
Weight (wt.) of dried Sample: **500gm**				wt. of dried Sample: **500gm**		
Sample type: River Sand (Fine)				Sample type: Crushed rock (Coarse)		
Sieves Ø (mm)	wt. (g) Retained	(%) Retained	(%) Finer	wt. (g) Retained	(%) Retained	(%) Finer
						100
9.500	-	-	-	351.50	70.30	29.70
8.000	-	-	-	54.80	10.96	18.74
6.680	-	-	-	31.10	6.22	12.52
4.699	-	-	-	15.30	3.06	9.46
3.327	-	-	-	19.10	3.82	5.64
2.362	-	-	**100**	4.20	0.84	4.80
1.615	11.3	2.26	97.74	**13.40**	**2.68**	**2.12**
1.168	25.6	5.12	92.62	-	-	-
0.833	21.7	4.34	88.28	-	-	-
0.589	22.9	4.58	83.70	-	-	-
0.417	105.5	21.10	62.60	-	-	-
0.295	85.4	17.08	45.52	-	-	-
0.208	11.2	2.24	43.28	-	-	-
0.147	28.9	5.78	37.50	-	-	-
0.104	46.6	9.32	28.18	-	-	-
0.074	35.9	7.18	**21.00**	-	-	-
Pan	105	21.00		**10.6**	**2.12**	
TOTAL	**500**	**100.0**		**500**	**100**	

Source: (Authors Lab. analysis, 2019)

Aggregate strength and grain structures does influences the qualities of concrete, and it forms the bulk of virtually all concrete constituents material used in mixes. However, in the course of this research mix, 1:2:3 cement constitutes 16.7% bulk of the concrete by volume, and similarly river sand (fine aggregate) constitutes 33.3%, while gravel (coarse) aggregate is 50%. This means it's important to ensure that qualitative aggregate is use in the course of concrete preparation, and in line with known standard procedure, one of which is, sieve analysis to determine the particle size distribution of aggregates used herein (BS 812-1: 1971), (BS 882:1992), (ASTM C 127-88), (ASTM C128-97), and (ASTM D3282-09). Therefore, the result as obtained in table 4 above indicates that, the particle size of the river sand passing through sieve size 3.327 Ø, but retained on sets of sieves 2.362 Ø - 0.074 Ø to be a total of 79% of the total volume of sand used with only 21% of this being percentage finer/silt particles. This means the soil type is suitable and adequate for this research. Similarly, for the coarse aggregate, the materials passing through 9.500 Ø and were retained on successive set of sieves 8.000 Ø - 2.362 Ø are, 97.32%, and the percentage finer/silt particles are 2.68% respectively.

Therefore, these aggregates are most suitable and are well graded for the intended research work as spelt out by, AASHTO soil classification system. That, granular aggregates constituent materials (Stone fragments, gravels and sands) passing through sieve No. 200 or sieve 0.074 Ø should be equal to, or less than 35% total volume of the original material to be use. Hence 35% ≤ is being given a general rating as excellent – good granular materials. While, more than 35% (> 30%) Silt – clay material passing sieve No. 200 or sieve 0.074 Ø is being rated to be fair – poor materials.

- **CONCRETE WORKABILITY**

Table 5: Fresh Concrete Slump Test

Specimen **CWSA**			Specimen **SBA**			Specimen **CCA**			Specimen **RHA**		
PSR (%)	**Cf.**	**SV (mm)**	**PSR (%)**	**Cf**	**SV (mm)**	**PSR (%)**	**Cf.**	**SV (mm)**	**PSR (%)**	**Cf.**	**SV (mm)**
300 mm Height of Slump Cone											
Design mix 1:2:3; 0.5% WCr. at PSR 0%, 5%, 10% and 15%											
0	0.94	45	0	0.94	45	0	0.94	45	0	0.94	45
5	0.94	43	5	0.93	41	5	0.94	40	5	0.93	41
10	0.93	41	10	0.91	41	10	0.92	41	10	0.90	40
15	0.91	42	15	0.90	40	15	0.90	40	15	0.89	39
Design mix 1:2:3; 0.6% **WCr.** at **PSR** 20%, 25%, and 30%											
20	0.91	40	20	0.89	38	20	0.88	37	20	0.87	37
25	0.89	38	25	0.87	36	25	0.86	37	25	0.86	38
30	0.87	37	30	0.86	36	30	0.86	35	30	0.85	36

Source: (Authors Lab. analysis, 2020)

The value of slumps in table 5 above is also a definition for some of the research materials physical characteristics, which can be influenced by factors such as: its mechanical proprieties (particles size distribution, fineness, ambient temperature, moisture content of the materials and that of the aggregates used, cementitious material, combined grading and texture etc.); others includes; air content; concrete temperature; fresh concretes mixing and equipment used; interval between the time of mixing and the testing time among others. However, specimen CWSA, SBA, CCA, and RHS at PSR of; 5%, 10% and 15% exhibits similar characteristics at 0.5% WCr. While at PSR 20%, 25%, and 30% the materials gradually becomes stiffens (less workable) at 0.5% WCr. This is attributed to the presence of higher percentage of silica (SiO_2) content as in table 2 above. However, the latter is a major pozzolanas characteristics, because SiO_2 or lime requires adequate water during hydration processes. Hence the WCr. was increased to 0.6% in order to neutralize the stiffness of the concrete and to moderate its workability, with the aim to ensuring consistency of the applicable fresh concrete prior to its setting. Similarly, it's equally observed that increasing percentage of PSR, records the decreases in slump value as well as decrease in compaction factors respectively table 5 above. Finally, this results can be summarised that; the specimens slumps value are between 35 – 43 mm, and the concrete slumps does subsides with more or less keeping to shape. Therefore, the fresh concrete is considered to be consistently workable and it characterised as true slumps.

- **COMPRESSIVE STRENGTH TEST OF CONCRETE**

Table 6: Average Compressive Strength Test of Research Specimen Cubes

SP	**Age (Days)**	**Specimens Compressive Strengths (N/mm^2)**			
POPC2	7	21.34	20.98	21.28	21.19 Avg.
	14	23.14	23.08	23.97	23.40 Avg.
	21	24.78	24.88	24.94	24.87 Avg.
	28	26.02	25.89	26.12	26.01 Avg.
	56	35.44	35.39	35.40	35.41 Avg.

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		PSR 5%	PSR 10%	PSR 15%	PSR 20%	PSR 25%	PSR 30%
CWSA	7	20.44	20.74	19.97	18.41	17.15	14.89
	14	23.05	22.90	21.00	20.01	19.14	18.25
	21	23.97	23.01	22.42	21.00	19.86	18.66
	28	25.66	24.77	23.44	21.99	20.40	19.01
	56	35.31	34.29	33.01	29.46	24.21	19.98
SBA	7	21.26	19.76	18.89	17.06	16.22	13.98
	14	22.98	20.01	19.45	18.79	17.01	14.44
	21	23.02	21.33	20.88	19.61	18.23	15.15
	28	23.87	22.00	21.04	20.31	19.01	16.99
	56	34.79	32.49	28.87	22.33	19.98	17.42
CCA	21	22.91	19.47	18.12	11.45	10.87	8.76
	28	23.19	21.23	19.46	15.77	12.88	10.11
	56	34.69	32.41	25.01	18.32	14.36	9.62
RHA	21	22.99	21.19	19.46	13.91	12.46	9.99
	28	23.87	22.00	20.98	18.45	15.68	12.77
	56	34.67	32.01	24.96	18.17	14.00	10.01

Source: (Authors Lab. analysis, 2020)

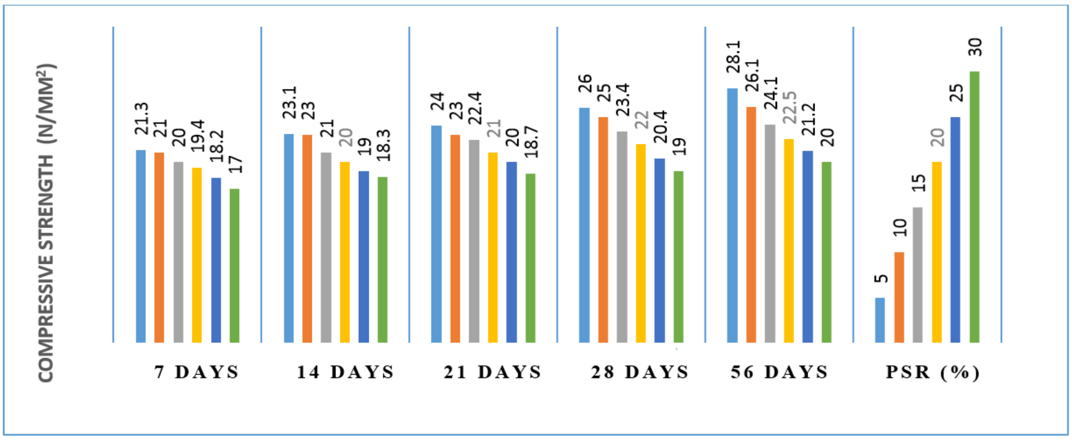

Figure 1: Compressive strength of CWSA at PSR 5, 10, 15, 20, 25 and 30%

The results from table 6 and figure 1 above, can be analysed as the characteristics compressive strengths values of the cubes, and as it can be seen, specimen CWSA had more satisfactory higher compressive strength values, with just very little or no effect to the volume of concrete when compared to the rest of the specimens on the scale of POPC2, at 5%, 10 % and 15% dosage respectively. This could also be attributed to the presence of Ca $(OH)_2$ for the production of additional calcium-silicate-hydrate (C-S-H). Equally CWSA recorded a successive compressive strength decrease at 20%, 25% and 30% to be 18.41 N/mm^2, 17.15 N/mm^2 and 14.89 N/mm^2, this could be attributed to the presence of its higher MgO contents of 4.65% and lower SiO_2 of 14.76% as against standard stipulation of 2% for MgO and 17 – 25% for SiO_2, both excess of MgO and less in SiO_2 are parameters that can affect strength development in concretes. Similarly, CWSA had exhibited a continuous improvement on its compressive strength, during successive curing periods, hence these are the same characteristic and conditions that also affects both SBA, CCA, and RHA. Moreover, CWSA exhibits better compressive strength across board and in all

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replacement values, as against that of SBA, CCA, and RHA respectively. While also SBA exhibits better results than that of CCA, and RHA.

Furthermore, it can be deduced from table 6 and figure 1 above, shows that the concrete cubes gains appreciable strengths over a period of time. This means the distinctive continuing strength increase confirms that the partially replaced cement strength improves gradually between 1 – 7 days of curing age. Similarly, the strength characteristics is an interpretation for the decrease in the concretes thermal conductivity, while an increased insulation properties is effectively supported by blending either of CWSA, SBA, CCA, and RHA in POPC2. However it's a general practice that concrete strength at 28 days of curing age is always considered as optimum strength for design mixes. Hence, it can be seen that this is not the case as in this research result were POPC2 at 28 days has strength capacity of 26.02 N/mm^2 and its strength at 56 days is 35.44 N/mm^2 which is 73.7% greater than at 28 days period. Similarly for CWSA at 28 days is 25.66 N/mm^2 while at 56 days is 35.31 N/mm^2 this is also 72.7% greater than that of 28 days curing age. Therefore the more time allotted for successive concrete curing age i.e. 7, 14, 21, 28, 56 and 90 days respectively, then instantaneous concrete maximum strength intensity will be attained. However, the strengths of CWSA, SBA, CCA, and RHA specimens can equally be improved upon by producing more microfiller effect finer ashes as well as increasing concrete curing ages from 56 to 90 days respectively.

IV. CONCLUSION

Generally, it can be concluded that, the concretes produced in this research had high densities and the contributing factors as in the results above, is due to the application of well-graded fine and coarse aggregates, and the use of minimum but adequate WCr. which is consistently workable, with little or no entrapped air voids aided by adequate vibration and consolidation during placements. However, the biomass ash used as partial replacement in cement had variance, this is due to the differences in firing procedures, plant manufacturing types, technicalities in the engineering parameters as well as ash recovery process. However, firing method does greatly influence both chemical and the physical characteristics of the burned ashes (CWSA, SBA, CCA, and RHA), because available amorphous silica content reactivity will decrease, with elimination of carbon fraction from the system due to the increasing firing temperature. The optimal firing temperature will produce much needed amorphous silica with higher specific surface areas, and in return had produced adequate engineering properties on application of the burned CWSA, SBA, CCA, and RHA in concretes cubes.

It's equally important to note that, the successive partially replaced of CWSA, SBA, CCA, and RHA in POPC2 had affected both the WCr. and the concretes slump. Resulting from increase dosage of specimen ashes from 20, 25 and 30%, the concrete water absorption capacity also increased, i.e. from 0.5% - 0.6% WCr. Furthermore, the concrete cube strength properties decreased continuously with an increased contents (5, 10, 20, 25, and 30%) of CWSA, SBA, CCA, and RHA in POPC2.

However, their characteristic strength does increased successively over the curing period as a result of the pozzolanic characteristics available in CWSA, SBA, CCA, and RHA, at PSR of, 5%, 10% and 15%, all exhibits similar characteristics at 0.5% WCr. While at PSR 20%, 25%, and 30% the materials gradually becomes stiffens (less workable) at 0.5% WCr. major reason is due to the presence of higher silica (SiO_2) content. POPC2 at 28 days has strength capacity of 26.02 N/mm^2 and for strength at 56 days is 35.44 N/mm^2 which is 73.7% greater than at 28 days period, it's the same case with CWSA at 28 days for having 25.66 N/mm^2 while at 56 days is 35.31 N/mm^2 this is also 72.7% greater than that of 28 days curing periods.

V. RECOMMENDATION

- Considering Nigerians current practice to the vast open burning of residual agricultural wastes such as; rice straws and husk, sugarcane bagasse, egusi (melon) husk, corncob, millet husk, guinea corn (sorghum) husk and groundnut shell among others, are fundamental environmental concerns as well as entrepreneurial and economic loss to the nation. Hence to curtailing this menace, there is the need to employ urgent but sustainable holistic management approach;
- Generally, there is yet inadequate knowledge and effective awareness into the conservation and utilization of agricultural wastes in Nigeria. The federal government should promote extensive research works into economical means of utilizing the numerous agricultural wastes, rather than burning it to the ground which will result to significant damage to soil fertility, loss to entrepreneurial developments as well as capitals and research opportunities;
- There is also the need to reduce the eminent cost of mining, production, selling and the utilization of cement as well as to come up with

cement supplements from agricultural and other form of solid waste materials;

- It is important to note that the rice straws are biodegradable when chopped into smaller pieces, boiled for 5 to 6 hours and allow to dry in the open sunray, it can further be processed and be used as raw material for paper production among other uses;
- It's equally recommended to consider 28 days curing period of concrete as minimum requirement, while 56 - 90 days as optimum curing periods;
- Similarly, it's recommended to adopt the use of partially replaced SBA, CCA, and RHA at 10% - 15% maximum in lightweight concrete structures, while CWSA can be used in both light and medium weight concrete, but not in HSCG, until further research is taken to identify and to determine the 25% other forms of unidentified wood species, while the 75% wood species is known to be wild grown indigenous timbers (Iroko, Mahogany and Ebeche). This research is in the pipeline;
- It's also highly recommended that the federal government and other relative stakeholders should consider holistic approach to the plantations of the indigenous tree species (Iroko, Mahogany and Ebeche), not only as timber for export, but a possible source as raw material for partial replacement in cement concretes; and
- Finally, it's important to note that, utilising biomass waste will eminently reduce and control the negative human effect of open burning of these waste, which is the third largest source of environmental pollution after automobile engines and municipal solid wastes disposal in Nigeria, for producing GHGs and VOCs. Subsequently, creates jobs for the citizenries and the industries that requires biomass wastes.

VI. NOMENCLATURE

Acronyms	Descriptions
AASHTO	American Association of State Highway & Transportation Officials
Avg.	Average Value
BPEO	Best Practice Environmental Options
CC	Corncob
CCA	Corncob Ash
Cf.	Compaction Factors
CWSA	Combined Wood Sawdust Ash
GHGs	Green House Gasses
HSCG	High Strength Concrete Grades
LOI	Loss on Ignition
N/mm^2	Newton per millimeter square
POPC	Pure Ordinary Portland Cement
PSR	Percentage Spacemen Replacements
RH	Rice Husk
RHA	Rice Husk Ash
SB	Sugarcane bagasse
SBA	Sugarcane Bagasse Ash
SCS.	Strengths Compressive Specimens
SP	Specimens
SV	Slump values
VOCs	Volatile Organic Compounds
WCr.	Water-Cement Ratio

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