Turning waste to wealth: Potential of Laterized Concrete Using Cassava Peels Ash (CPA) Blended Cement

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Abstract

This paper discusses the experimental results of tests carried out on the Strength properties of Laterized concrete (LATCON) made with Cassava peels ash (CPA) an agricultural waste at varying levels of replacement to Ordinary Portland cement (OPC) up to 40%. The Strength properties, namely compressive strength, initial surface absorption and Density were measured in the laboratory on 375 100x100x100mm cube specimens with the view of establishing the percentage of the ash and laterite that can be used in the cement matrix and fine aggregate compositions respectively. The best strength performance was obtained at 30% of cement replacement while the laterite (lat.) will perform better at 30% fine aggregate replacement for concrete production which was comparable to normal concretes (i.e. Control). It is therefore concluded that the CPA/OPC LATCON has sufficient strength and adequate density to be accepted as structural concrete.

Keywords: agricultural waste, cassava peels ash (CPA), compressive strength, laterite (lat.), laterized concrete, workability,

1.0 Introduction

Excellent efforts have been made for the successful exploitation of the efficient use of various agricultural and industrial by products (such as Natural fibers, corn cob ash, fly ash, rice husk ash, foundry waste) that have being continuously generated. The reuse of this waste products will help to save our environ from environmental pollution and severe ecological (green) problem. Due to this reality, an alternative source for the potential replacement of fine aggregates in concrete has gained good attention. As a result, reasonable studies have been conducted to find the suitability of laterite replacement for sand in conventional concrete and the use of waste ash to replace cement [1-7]. The high cost of building materials in Nigeria has made inexpensive housing out of reach of the average national of the country. This difficulty has lead to inward sourcing of some local wastes as alternatives to conventional materials in the construction industry. Small amounts of inert fillers have always been acceptable as cement replacement. If the fillers have pozzolanic properties, they convey not only technical advantages to the resulting concrete but also enable larger quantities of cement replacement to be achieved [8]. Cassava Peel ash, Baggash ash, Rice husk ash, Pulverized Burnt Clay (PBC), Volcanic ash (VA), and FA are pozzolanic materials because of their reaction with lime (calcium hydroxide) that is liberated during the hydration of cement. Amorphous silica present in the pozzolanic materials combines with lime and forms cementitious materials. These materials can also improve the durability of concrete and the rate of gain in strength and can also reduce the rate of liberation of heat that is beneficial for mass concrete. Over recent decades, Portland cements (PCs) containing FA and silica fume have gained increasing acceptance while PC containing artificial pozzolans like rice husk ash and burnt oil shale are common in regions where these materials are available.

Incinerated cassava peel ash is a by-product of the combustion of refuse generated during cassava processing. Cassava is a root and tuber crop grown in all ecological zones of Nigeria, but most predominantly in the southern parts and middle belt of the country. It is rich in carbohydrates, starch, protein, fats, ash, fibre etc. which make it a very good and highly reliable source of food energy, sweeteners and industrial raw materials [9].

Laterite is defined by Encarta English Dictionary [10] as red tropical soil: a reddish mixture of clayey iron and aluminium oxides and hydroxides formed by weathering of basalt under humid, tropical conditions. Fermor, [11] defined various forms of laterite soils on the basis of the relative contents of the constituents (Fe, Al, Ti, Mn) in relation to Silica. A chemical definition based on the Silica Sesquioxides (S-S) ratio ($SiO2/Al_2O_3+Fe_2O_3$) has been proposed, the conclusion being an s-s ratio $\leq$ 1.33 implies a true laterite; an s-s ratio between 1.33 and 2.0 refers to a lateritic soil; and an s-s ratio $\geq$ 2.0 indicates a non-lateritic typically weathered soil.

Laterized concrete was defined as concrete in which stable laterite fines replace sand wholly or partially, whole replacement is also referred to as terracrete [12]. Adepegba [13] was the first to consider the possibility of replacing sand in concrete with Laterite in Nigeria. He studied the effect of using laterite fines instead of sand in relation to the density, compressive strength, tensile strength, modulus of elasticity and resistance to exposure to high temperature .He concluded that their properties fared well in comparison with those of normal concrete, thereby offering that Laterite fines in place of sand can be used for structural members. Balogun and Adepegba [14] discovered that the most suitable mix of laterized concrete for structural purpose is 1:1.5:3 using batching by weight with a water/cement ratio of 0.65, provided that the laterite content is kept below 50% of the total aggregate content .The water/cement ratio used conforms to the recommendation of Lasisi and Ogunjide [15] who obtained a linear relationship between the laterite-cement ratio (Y) and the optimum w/c ratio (X). The equation was given as $Y=0.9+3.85X$. Chandrakaran et al. [16] also reported that for fully laterized concrete, the compressive strength is 50% of that of normal concrete. A study by Lasisi and Ogunjimi [15] on source and mix proportions as factors in the characteristics strength of laterized concrete presented the average characteristic strength for laterized concrete as 27 N/mm^2 for 1:1:2, 17 N/mm^2 for 1:2:3 and 16 N/mm^2 for 1:2:4. A comparison with Adepegba [17] results shows that the differences in strength arise due to different chemical composition, method of compaction and difference in maximum size of aggregate used. They discovered that the source of lateritic soil, grain size, the mix proportion and age are highly significant to strength achieved by laterized concrete as they are in normal concrete. Adepegba [13] and several other authors maintains that laterized concrete would require slightly more cement than normal concrete to obtain a mix which would yield the same compressive strength as normal concrete. Influence of duration of curing and mix proportions on the compressive strength of laterized concrete has also been researched on [18]. Water curing was found to give the highest strength values, while air-cured specimens gave the lowest strength values and for this reason, Water curing method was adopted for this research. Rai et al, [19] reveals that water absorption characteristics of laterized concrete were higher than that of ordinary concrete. The water requirement increases enormously for the workability of concrete with laterite fines. The workability of concrete for given water-cement ratio decreases with an increasing replacement level of sand with laterite as fine aggregate. The review hereby have uncovered that part substitution of sand with laterite (≤ 50%) holds guarantee as far as strength and serviceability requirements are concerned. The previous works done on pozzolana have centered purely on its effect on performance characteristics of normal concrete and lateritic soils, No much work as being recorded on cassava peel ash. This study will concentrate on effect of the introduction of an artificial pozzolana (i.e. Cassava peel ash) on the performance characteristics of laterized concrete for structural use. The physical and chemical properties of CPA and laterite will be examined while the compressive Strength of CPA/ OPC laterized concrete containing varying amount of laterite up to 40% by weight of fine aggregate and also CPA of 40% by weight of cementitious material will be investigate for a 28 days target strength of $25N/mm^2$, over an hydration period of 7days, 21days, 28days, 56days, 90days.

MATERIALS AND METHODS

Sample Collection

CPA used in this investigation was collected from Ogbomoso North Local Government Area of Oyo State in Nigeria as a waste from the garri (cassava flakes) processing factory. The cement used was locally manufactured ASTM Type I Portland cement called 'Dangote' which was purchased from the open market and is believe to conform to BS EN 197 [20]. The laterite is obtained from a borrow pit in Federal university of technology, Minna permanent site, The sharp sand used was river sand, free from deleterious substances obtained from Sarkin pawa area in Niger State, Nigeria, Portable Clean water which was obtained from bore hole water supply was used for the concrete mixes and curing.

Sample preparation

CPA collected was sun dried and burnt into ash, the ash was subsequently calcined to 1000^0c, and the resulting powder was grinded and sieved with 75µm Sieve in Building Department Laboratory of the Federal University of Technology, Minna. Chemical Analysis was carried out on the CPA and laterite sample in the Chemistry laboratory of West African Portland Cement Company (WAPCO) - Shagamu Works Department via an X-ray Fluorescent Analysis using a Total Cement Analyser model ARL 9900 XP. The following preliminary test was carried out on the constituent of the concrete to obtain it physical properties: consistency, sieve analysis, slump, workability, bulk density.

Mixture Proportioning and casting details

The work entailed laboratory test conducted on normal and Laterized concrete mix of 25N/mm^{2,} for 28 day strength, adopting the British Mix Design (D.O.E) method been the required minimum strength for structural concrete in accordance to BS8110 [21]. The test specimens were 100x100x100 mm cubes as per BS1881-part 116 [22] for compressive strength, total three cubes were cast from each sub mix with a workability of 75 to 120 mm. The effect of CPA on the workability of different fresh OPC/CPA Laterized Concrete mixes was studied by conducting slump tests as per ASTM C 143 [23].

The slump values were determined from 25 different sub mixes. The setting time values were also gotten from the mean values of three test results of various mix proportion of CPA and OPC. Specimen of Laterized concrete (LATCON) mixtures was made up of Five levels of Cassava peels ash (CPA) replacements at 0%, 10%, 20%, 30% and 40% and five levels of laterite replacement ranging from 0 to 40% at 10% intervals (i.e. a total of 25 levels of specimens produced in triplicates) were tested, equating to a total number of 375 cubes. It contains a cementitious material content of 309 kg/m^3, fine aggregate content of 680 kg/m^3, coarse aggregate content of 1430 kg/m^3, and water cementitious materials ratio of 0.65 giving a free water content of 190 kg/m^3. The range of laterite and sand used were those that passed through 5mm British Standard (BS) sieve, while the Cassava peels Ash was 75µm sieve.

Testing Procedure

Series of tests were performed to investigate the effect of different percentages of both CPA and laterite on the compressive strength and other properties of CPA/OPC Laterized concrete. The specimens were demoulded after 24 hours of casting and cured under water at a room temperature until testing for compressive strength at 7, 21, 28, 56 and 90 days using the compression testing machine.

3. RESULTS AND DISCUSSION

The Summary of Physical Properties of Constituent Materials are shown in Table 1, The laterite used in the replacement of the sharp sand at varying percentages was found to have a specific gravity of 2.54, bulk density of 1375 kg/m3, moisture content of 15.79%, fineness modulus of 2.91, coefficient of uniformity Cu of 8.68 and coefficient of curvature Cc of 1.23 during the preliminary laboratory test. Chemical properties of CPA and Laterite are shown in Table 2. The Chemical analysis indicates that the CPA is principally composed of silica (about 62.3%). CPA has cementitious compounds like calcium oxide, alumina and iron oxide (total about 13.31%), and the total content of Silicon Dioxide (SiO_2), Aluminium Oxide (Al_2O_3) and Iron Oxide (Fe_2O_3) is 70.45% which is slightly above the minimum of 70% specified in ASTM C618[24]. The laterite used has Silica: Sesquioxide ($SiO_2/Al_2O_3+Fe_2O_3$) ratio also simply referred to as Silica Ratio (SR) of 0.54 as shown in Table 2 which presents the result of Chemical Analysis carried out on the laterite sample. The S-S ratio was computed and found to be less than 1.33 indicating a true laterite classification as specified by Fermor

[11]. The sand on the other hand has a specific gravity of 2.59, bulk density of 1458 kg/m3, moisture content of 3.67%, fineness modulus value of 2.41, Cu of 8.00, and Cc of 1.04. These results reflect that both the laterite and sand samples are well graded. The granite sample has a specific gravity of 2.64, bulk density of 1287 kg/m3, Cu of 1.42, and Cc of 0.94, reflecting a uniform sample. All the aggregates conformed to the British Standard Specification. The particle size distributions of the aggregates (laterite, sharp sand and granite) were performed according to BS EN 933-1 [25].

Table 1: Summary of Physical Properties of Constituent Materials

Parameters	**CPA**	**Sand**	**Laterite**	**Granite**
Specific Gravity	3.04	2.59	2.54	2.64
Bulk Density(kg/m^3)				
Uncompacted	1394	1337	1267	1792
Compacted	1649	1458	1375	1287
% Void	18.29	9.05	7.85	28.18
Moisture Content(%)	-	3.67	15.79	-
Sieve Analysis				
Fineness Modulus(m^2/Kg)	304	2.41	2.91	-
Coefficient of Uniformity	-	8.00	8.68	1.42
Coefficient of Curvature	-	1.04	1.23	0.94

Table 2: Chemical composition of CPA and Laterite (% by mass)

Chemical composition	**Fe_2O_3**	**SiO_2**	**AI_2O_3**	**CaO**	**MgO**	**TiO_2**	**LOI**	***Sio_2+Al_2O_3 +Fe_2O_3***	***Sesquioxide SiO_2/Al_2O_3+Fe_2O_3***
CPA	4.37	62.30	3.77	5.17	5.05	-	1.68	70.45	-
Laterite	33.50	29.10	20.30	-0.65	-0.64	1.14	-	-	0.54

The initial and final setting times of blended cement mixes are presented in Table 3. The trend of variation of setting times shows an increase of both setting times with the increase of CPA content. As the CPA content is increased from 0% to 40%, the initial setting time was found to increase from 95 minutes to 140 minutes and the final setting time increased from 155 minutes to 230 minutes. This is logical as the increase of CPA content reduces the cement content in the mix and also decreases the surface area of the cement. As a result hydration process slows down causing setting time to increase. The slow hydration means low rate of heat development [26]. This is of great importance in mass concrete construction and it is there that CPA/OPC cement can be mostly used.

The variation of slump for mixes having different percentages of CPA and laterite is presented in Table 4. The high absorption of water by CPA in the initial stages of mixing caused balling-up of cement and a loss of slump [26]. As a result of this, the aggregate was made saturated surface dry before casting of concrete so as to avoid it balling. The slump value for the mixes was found to decrease with the increase of laterite replacement and increase of CPA. For instance, (110 to 38 mm) when there is increase in laterite replacement from 0% to 40% and 0% to 40% of CPA introduction. The lighter the mix, the less is the slump values. The reason for this is that the work done by gravity is lower in the case of lighter laterite. Due to lower fine aggregate (laterite) density, structural low-density concrete does not slump as much as normal density concrete with the same workability. The demoulded density of the CPA/OPC laterized concrete mixtures decreases as the percentage CPA replacement increases, so also as the lat content increases. At 0% CPA/0% lat., the density was 2537 kg/m^3 and at 30% CPA / 30% lat., the density was 2204 kg/m^3(Tables 4).

As shown in Table 5, the compressive strength is found to decrease with the increase of Laterite and CPA content, 46% reduction in strength is observed at 0%lat./30CPA replacement and 45% reduction in strength at 30%lat./30CPA replacement when compared to 0%lat./0%CPA (control mix) sample at 28 day hydration and a gradual increase in strength was observed at a later curing day of 56 and 90 days . This is logical owing to the fact that reductions of ordinary Portland cement and sharp sand content in the mix with the increase of CPA and Laterite content. The finely divided silica (62.3%) in CPA can combine with calcium hydroxide (liberated by the hydrating Portland cement) in the presence of water to form stable compounds like calcium silicates, which is known to possess cementitious properties [27]. Such pozzolanic action of CPA contributes to the enhancement of strength and long-term durability [27]. The strength is reduced by 54.3%, 52.6%, 52.4, 56.8% and 17.7% for 7, 21, 28, 56, and 90days respectively when CPA content in the resulting concrete is increased from 0% to 40% at 0% laterite introduction. Also at 30% laterite introduction, the strength reduced by 43.9%, 40.0%, 39.7%, 54.9%, and 52.9% for 7, 21, 28, 56, and 90days respectively when CPA content in the resulting concrete is increased from 0% to 40% (Table 6). It was observed that the strength reduction is decreased gradually and experienced an increase at 56 day and dropped at 90 day of hydration age.

Table 3. The Initial and Final Setting Time (Mins) of Cassava peels ash/OPC Mortar paste.

Mix Designation	CPA Content (%)	Setting Time	
		Initial (Mins)	Final (Mins)
100%OPC/0%CPA	0	95	155
90%OPC/10%CPA	10	105	170
80%OPC/20%CPA	20	115	185
70%OPC/30%CPA	30	125	205
60%OPC/40%CPA	40	140	230

Mins = Minutes

Table 4. Summary of Demoulded Density (Kg/mm^3) and Slum (mm) of CPA/OPC Laterized Concrete

Laterite Content (%)	Cassava peels ash (CPA) Content (%)	Demoulding Density (Kg/m^3)	Slum (mm)
	0	2537	95
	10	2446	92
0	20	2409	74
	30	2315	63
	40	2230	50
	0	2452	110
	10	2438	95
10	20	2416	90
	30	2382	72
	40	2378	60
	0	2419	84
	10	2387	80
20	20	2342	75
	30	2275	62
	40	2214	51
	0	2331	75
	10	2284	66
30	20	2227	58
	30	2204	52
	40	2123	48
	0	2287	60
	10	2160	58
40	20	2113	52
	30	2060	44
	40	1995	38

Table 5. Summary of Compressive Strength (N/mm^2) of Fly ash/OPC Laterized Concrete

Laterite Content (%)	Cassava peels ash (CPA) Content (%)	Curing Age (Days)				
		7	21	28	56	90
		Compressive Strength (N/mm^2)				
0	0	29.10	29.29	29.40	34.00	35.00
	10	22.10	22.31	22.50	29.63	31.03
	20	16.50	16.93	17.20	19.23	19.90
	30	15.00	15.78	16.00	16.70	18.00
	40	13.30	13.88	14.00	14.70	28.80
10	0	25.20	26.12	26.64	27.44	33.44
	10	20.81	21.37	21.82	23.63	30.02
	20	16.64	17.09	17.41	19.26	26.63
	30	14.89	15.43	16.96	18.77	23.38
	40	13.78	14.67	15.03	16.99	19.42
20	0	22.90	23.91	25.90	27.77	31.60
	10	19.00	19.98	20.10	21.23	29.60
	20	17.10	17.44	17.60	19.67	23.90
	30	14.05	15.27	16.20	16.43	18.30
	40	14.75	14.96	15.10	16.30	18.90
30	0	19.60	20.65	24.20	27.03	29.80
	10	18.00	19.24	20.30	20.70	28.40
	20	16.70	17.81	18.20	20.40	23.70
	30	14.40	14.93	16.30	17.25	22.15
	40	11.00	13.01	14.60	12.33	14.05
40	0	18.70	19.22	19.90	20.50	26.50
	10	16.00	16.87	17.30	18.23	23.70
	20	13.87	14.60	15.70	15.83	17.50
	30	12.60	12.98	13.90	15.33	18.30
	40	10.95	11.53	12.70	13.23	15.30

Table 6. Compressive Strength in Percentage of 28 Day Strength

CPA Content (%)	Laterite Content (%)	Curing Age (Days)				
		7	21	28	56	90
		Compressive Strength in percentage of 28 day strength (%)				
0	0	99	99	100	117	119
	10	75	76	77	101	106
	20	56	58	59	65	68
	30	51	54	54	56	61
	40	13	47	48	50	98
10	0	86	89	90	93	114
	10	71	73	74	80	102
	20	57	58	59	66	91
	30	51	52	58	64	80
	40	47	50	51	58	67
20	0	78	81	88	95	107
	10	65	68	68	72	101
	20	58	59	60	66	81
	30	48	52	55	56	62
	40	50	51	51	55	64
30	0	67	70	82	92	101
	10	61	65	69	70	97
	20	57	61	62	69	81
	30	49	51	55	59	75
	40	37	44	50	41	47
40	0	64	65	68	70	90
	10	54	57	59	62	81
	20	47	50	53	54	60
	30	43	44	47	52	62
	40	37	39	43	45	52

4. Conclusion

This paper demonstrates how the use of appropriate technology can transform abundantly available, cheap natural soil, and agricultural waste which could be potential environmental hazards into a natural resource and hence, can be used in the construction of masonry walls, simple concrete composites and simple foundations. It is confirmed from the research that the Cassava peel ash can be used as a resource in cement matrix and the corresponding laterite as a potential for replacing fine aggregate, it can be used in low cost construction especially in areas where this materials are dominant. The following conclusions are drawn: that although the CPA/OPC laterized concrete only had compressive strength values ranging between 49% and 75% of the 28 to 90 day strength (for 30% lat. / 30% CPA), the introduction of Cassava peel ash (CPA) presents a good tendency of pozzolanic activity, while research studies towards boosting the property of the cassava peel ash sample from the study area will be a welcome development in the continued search for alternatives.

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APPENDICES

Plate 1: Cassava Tuber.

Plate2: Cassava Peels waste Dump.

Plate 3: Cassava Peels ash.

Plate 4: Slump for CPA/OPC Laterized concrete

Plate 5: Laterized Concrete cubes.

Plate 6: sieve shaking of aggregates