Prolonged Curing of Green Concrete from Domestically Derived Cassava Peels Ash (DDCPA) and Laterite

Agbenyeku Emem-Obong Emmanuel, Aneke Ikechukwu Frank

Abstract—This study incorporates two locally available materials; Domestically Derived Cassava Peels Ash (DDCPA) and Laterite in concrete production for construction purposes. The abundance of these materials in West-Africa paved way for this study. The effect of partial substitution of cement with an agricultural waste-DDCPA on the compressive strength of Laterized concrete (LATCON) was investigated. Results of the physical and chemical tests on DDCPA and Laterite revealed them to have satisfactory characteristic properties for concrete production. A total of 48 cubic specimens of 100mm dimensions were cast and cured by complete submergence in water for 56, 90, 120 and 150-days hydration period, adopting a 28-day targeted strength of 25MPa as control. The cement/DDCPA and sand/laterite replacements ratios ranged from 0 to 30%, with a view to determining the best compositions matrix. The density and compressive strength properties decreased with increase in DDCPA and laterite content. However, a gradual strength development in the DDCPA-LATCON was observed as the curing age increased. Hence, the 150-days density and compressive strength of the normal concrete was 2373Kg/m^3 and 73.57MPa while the 10%DDCPA+10%Laterite sample (i.e. best replacements matrix) had 2310Kg/m^3 and 75.64MPa respectively. The strength of the DDCPA-LATCON (75.64MPa) was higher than the strength of the control sample (73.57MPa) at the 150-day, which makes it suitable as a construction material and proves that pozzolanas can produce concrete with close characteristics as normal concrete beyond age 28-days. As such, it can be adopted in the construction of simple foundations and masonry units as reliable alternatives to the scarce and expensive conventional materials for prime cost reduction in rural housing and development without compromising standards.

Index Terms— Laterite, Laterized Concrete, Domestically Derived Cassava Peels Ash, Compressive Strength, Agricultural Waste.

1 Introduction

From economic perspective, Achuenu [1] stated that the high inadequacies in housing delivery are resultant of excessive and recurrent rise in cost of conventional materials especially cement. Thus, research trends in the development of materials have shown a global venture into other alternatives. Olusola and Adesanya [2] and Anthonio [3] recorded the difficulties in accessing fund for developmental projects, high cost and insufficiencies of conventional materials, biodegradability of the materials, need for recycling agricultural waste materials, population growth, remediation and preservation of ecological balance and the need for shelter to be among deir needs in developing countries. Hence, it is necessary as observed by Fashola [4] that the construction industries be driven towards the possibilities of utilizing the vast, unsightly and idle accumulated waste materials from industrial and agricultural activities. Efforts have been channelled toward the successful exploitation of products such as; foundry waste, fly ash, natural fibers, etc., incessantly generated.

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In developing countries the generation of supplementary cementitious materials (SCMs) is vital in achieving and advancing low-cost construction materials for the production of self-sufficient means of shelter. Apart from improving concrete properties, the main benefits of SCMs include saving natural resources and energy as well as reducing the carbon footprint by cement plants.

The use of laterite as partial substitute for fine aggregate in green concrete for building purposes have been investigate in attempts to necessitate the locally used excavated available materials as waste products [5]. The reuse of waste products will prevent environmental degradation, pollution and ecological distortions. Therefore, alternative source for potential replacement of fine aggregates in concrete is on the rise. Reasonable studies by have been done to find the suitability of laterite as substitute for sand in conventional concrete and the use of waste ash to replace cement [6], [7]. Appreciable amounts of inert fillers are acceptable as cement replacement. If the fillers have pozzolanic properties, they provide technical advantages to the resulting concrete and also enable larger quantities of cement substitution to be achieved [8]. Amorphous silica in pozzolanic materials combines with lime to form binding materials. These materials improve the durability of concrete, the rate of strength gain and can also reduce heat of hydration which prevents cracking in mass concrete.

Currently, Portland cement (PC) containing Fly ash (FA) and Silica fume (SF) are gaining grounds while PC containing artificial pozzolans like rice husk ash and burnt oil shale are commonly used in regions where they abound. Matawal [9], Ujene and Achuenu [10] stated that efforts are set toward substituting cement (totally or partly) with locally available pozzolanic materials like rice husk ash, saw dust ash, millet husk ash, pulverized fuel ash, bagasse (sugar cane ash) etc., in production of green concrete.

Laterite has been identified as a possible material for partial replacement of sand in concrete to produce laterized concrete (LATCON). Studies by Ata [11] and Olusola [12] have shown the effects of laterite in strength and serviceability of fresh and hardened concrete. In this study, however, the 28-day strength is set as a trial assessment of pozzolanic activity [13]. Hence, this paper investigates the effect of utilizing the locally available laterite soil on strength characteristics of concrete with the addition of a Domestically Derived locally available pozzolanic material-Cassava Peels Ash as partial replacement for cement. The addition of DDCPA (an agricultural waste with cyanogenic content) into concrete is viewed as an attempt to transform an agricultural waste material to an affordable and useful end product.

2 Related Literature

Lately, research trends on material out-source are on part or total replacements of cement or the substitution of sand with laterite in green concrete. Job [14] recorded that efforts are made to substitute cement with locally available pozzolanic materials. Neville [15], Shetty [16] defined "Pozzolana" as naturally occurring and artificially siliceous or siliceous and aluminous materials, which in themselves possess little or no cementitious value although, in finely divided form and in the presence of moisture chemically react with calcium hydroxide to form compound possessing binding properties. It has also been revealed that pozzolanas can produce concrete with close characteristics as normal concrete at age 28-days and beyond. Application of various ashes as potential cement substitutes and replacements in mortar and green concrete has attracted the attention of researchers because of its tendencies to: (a) reduce the quantity and consequently the costs of cement in concrete works, and (b) reduce or eliminate the classification of ashes as waste materials polluting the environment. Matawal [9], Popovics [17] explained that experimental studies have focused on variety of waste ashes and materials with pozzolanic potentials such as rice husk ash, saw dust ash, wheat ash, sugar cane fibre ash (bagasse), pulverized fuel ash, groundnut husk ash, blast furnace slag and mining tailings.

Cassava which is extensively cultivated annually is a tuberous crop as per figure 2 which provides a basic diet for well over 500 million people and is the third largest source of food in the tropical and sub-tropical regions. FMINO [18] described incinerated DDCPA as a by-product of the combustion of the massive agricultural refuse generated from cassava processing. Cassava is grown in all ecological zones of Nigeria, but predominantly in the middle belt and the southern parts of the country. It is rich in mineral constituents such as; carbohydrates, starch, protein, fats, and fiber etc., which makes it a very good meal and highly reliable source of energy, sweeteners and industrial raw material.

Laterite on the other hand, covers about one third of the earth's continental land area, extensively covering areas in tropical countries with Africa being one out of the six main regions of the world where laterite is found. LATCON has attracted the attention of researchers over time. The word "LATERITIC" possess different meanings among researchers. Hence, various definitions have been suggested based on its chemical, morphological and physical properties. Fermor [19] defined various form of lateritic soils on the basis of the relative contents of laterite constituents (Fe, Al, Ti, Mn) in relation to silica. Based on its morphological properties, Pendelton and Sharasuvana [20] defined lateritic soils as a profile in which immature laterite horizons become true laterite strata if appropriate conditions prevail. As regard to the physical properties, lateritic soils have been defined as an igneous rock, tropically weathered in-situ, which has decomposed partially or totally with the concentration of Iron and Aluminum Sesquioxides (combined Fe_2O_3 and Al_2O_3). Gidigasu [21] as cited in Olusola [12] defined laterite as all the reddish residual and non-residual tropically weathered soils as seen in figure 6, which generally forms a chain of materials ranging from decomposed rock through clay to sesquioxide (Al_2O_3+Fe_2O_3).

Laterite either in raw or improved form is commonly used in rural and urban areas for housing construction as masonry units. They are utilized in Nigeria as blocks, basically for low-cost housing schemes by some state local governments. LATCON according to Olusola [12] refers to concrete in which the fine aggregate (sand) has been totally or partly replaced with laterite; total replacement is referred to as **terracrete**. An argument by Neville [15], reported that a total replacement of sand with laterite in concrete production can rarely be stronger than 10 MPa while studies by Ata [11], Olusola [12], Osunade [22] have proven that laterite can produce concrete of higher strength. The uncertainties around the use of laterite as a construction material are enormous. Knowledge of its physical properties, strength characteristics and reliability before use are a major challenge and so is the knowledge of the actual performance of structures made from it under varying climatic conditions and quality control [2], [23]. As such, it has not been widely utilized to an equal level as sandcrete blocks and normal concrete, especially for works with structural emphasis. Investigations have revealed that stabilized laterite (i.e. laterite mixed with a certain quantity of cement ≤ 10% by weight) can be beneficially used for the production of masonry units and that laterite holds potency as a partial substitute for sand in concrete works, both for structural and non-structural purposes. Although, the general public believes that for laterite to be used on a wider range, it should be properly investigated and improved at the technical level.

3 Materials and Method

Cassava peels used in this study as shown in figure 3, were collected as refuse from a local processing factory in Ikot Ekepene, Akwa Ibom State of Nigeria where at present, a wide range of traditional cassava meal forms (such as gari, fufu, starch, abacha, etc.) are produced for consumption. The peels were dried in open air, burnt to ash and eventually calcinated up to 700°C in an electric furnace. The clinker was grinded to fine powder and passed through the 75µm sieve (see figures 4 and 5). Elemental test results in Table 1 on Laterite and CPA done by X-Ray diffraction (XRD), X-Ray fluorescent (XRF), Atomic Absorption Spectrometer (AAS) and Colorimeter Analysis, show that the total content of Silicon Dioxide (SiO_2), Aluminium Oxide (Al_2O_3) and Iron Oxide (Fe_2O_3) in DDCPA is 71.24%. This is slightly above the minimum of 70% specified in ASTM C618 [13] as such, qualifies it for use as pozzolana. Laterite was found to possess a Silica Ratio (SR) of 0.52. The Silica: Sesquioxide (S-S) ($SiO_2/Al_2O_3+Fe_2O_3$) ratio was less than 1.33 indicating a true laterite classification [19].

TABLE 1
CHEMICAL COMPOSITION OF DDCPA AND LATERITE (%)

	SiO_2	AL_2O_3	Fe_2O_3	MgO	TiO
DDCPA	61.8	4.49	4.95	6.14	-
LATERITE	28.9	21.7	34.2	-	1.26
		CaO	LOI	$SiO_2+AL_2O_3+Fe_2O_3$	Sesquioxide $SiO_2/AL_2O_3+Fe_2O_3$
DDCPA		5.42	1.45	71.24	-
LATERITE		-	-	-	0.52

Respective mixes with four levels of DDCPA and Laterite replacements, each ranging from 0 to 30% (i.e. a total of 16 trolls of samples produced in triplicates) were investigated. The plain specimen was proportioned for a targeted strength of 25MPa as per British Mix Design (D.O.E) method being the required minimum strength for structural concrete in accordance to BS8110. The cement/DDCPA and sand/laterite substitutions were computed by weight. From Table 2, physical properties from preliminary test results of the constituent materials, shows the specific gravity of the DDCPA to be (3.07) which is clearly less than that of cement (3.15) [15].

TABLE 2
PHYSICAL PROPERTIES OF MATERIAL CONSTITUENTS

	DDCPA	Sand	Laterite	Granite
Specific Gravity	3.07	2.65	2.60	2.67
Bulk Density (Kg/m³)				
Uncompacted	1402	1398	1306	13.59
Compacted	1628	1446	1359	1315
Void (%)	17.86	10.01	8.89	27.54
Moisture Content (%)		3.71	16.05	
Mechanical Analysis				
Fineness Modulus (m²/Kg)		2.45	2.87	
Coeff. Of Uniformity (Cu)		8.02	8.54	1.44
Coeff. Of Gradation (Cg)		1.02	1.25	0.91

The fine aggregate used were sand and laterite. The laterite was collected from an excavated trench in Aba North, Abia State Polytechnic, Aba, Nigeria. While the sharp river sand, free from impurities and injurious particles were obtained from Ogbo hill, Aba South. The coarse aggregate was obtained from "Rich Constructions Nigeria Limited, Aba" with specific maximum size 19mm (3/4in). Tap water was used for the concrete mixing and curing processes. All the aggregates conformed to the British Standard Specification and the particle size distribution for laterite is shown in figure 1. "Burham", locally produced ASTM Type I Portland cement was purchased from the open market and used in this study.

Series of tests were performed to investigate the effect of various percentage replacements of DDCPA and laterite on the compressive strength properties and demoulding densities of both the fresh and hardened DDCPA/OPC LATCON. For the compressive strength to be gotten, a total of 48 (100mm) dimension cubic specimens were cast and cured in water at room temperature for 56, 90, 120, and 150 days. At the end of every curing age, three specimens of each mixture were tested by crushing them under direct loading using the compression test machine and their averages were taken. Samples of DDCPA/OPC LATCON are shown in figure 7.

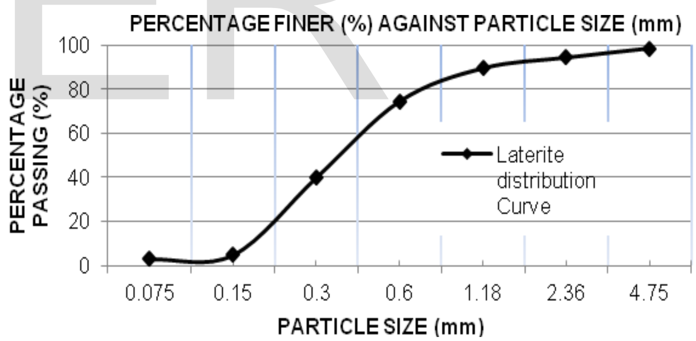

Fig. 1. Grain size distribution curve for laterite soil sample

Fig. 2. Harvested Cassava tubers

Fig. 3. Cassava peels dump

Fig. 4. Cassava clinker

Fig. 5. Incinerated DDCPA

Fig. 6. Laterite soil

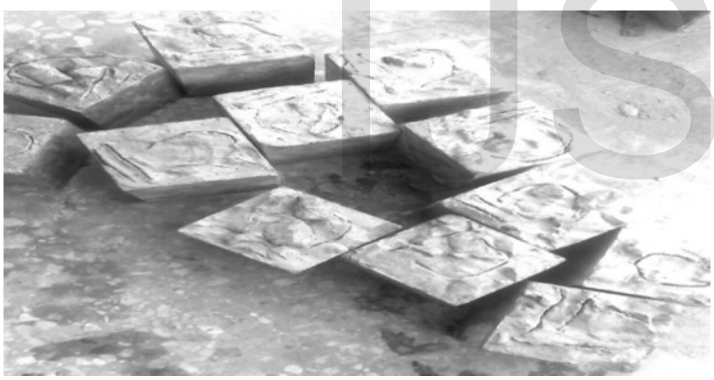

Fig. 7. DDCPA/OPC LATCON specimens

TABLE 3
DENSITY (Den-Kg/m^3) COMPRESSIVE STRENGTH (CS-MPa) of DDCPA/OPC LATCON

LAT (%)	CPA (%)	56 Den	56 CS	90 Den	90 CS	120 Den	120 CS	150 Den	150 CS
		Curing ages							
0	0	2379	36.99	2374	51.78	2374	69.86	2373	73.57
10	10	2318	34.86	2314	47.59	2311	68.95	2310	75.64
20	20	2310	29.09	2306	39.82	2304	55.74	2304	69.83
30	30	2248	24.37	2243	32.65	2241	50.04	2241	61.79

4 Results and Discussion

Values of the density and compressive strength of the investigated green concrete samples are shown in Table 3.

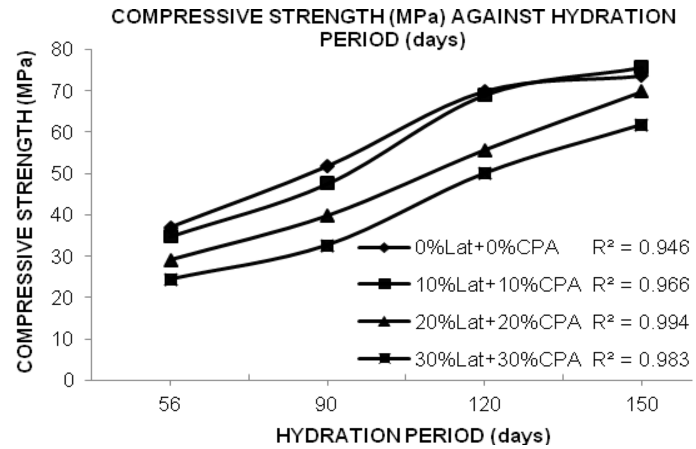

Fig. 8. Compressive strength (MPa) for equal replacement matrix (%)

Figure 8 shows the strength comparison between the control sample and equal replacement matrices. The results reveal a high Coefficient of determination (R^2 values) indicating a direct relationship and strong correlation between the strength gain and the curing ages (i.e. an increase in hydration period leads to an increase in strength). The strengths for 0%LAT+0%DDCPA replacements (i.e. the control specimen) and 10%LAT+10%DDCPA replacements (i.e. the best replacement matrix) at age 150-days, were gotten as 73.57MPa and 75.64MPa respectively.

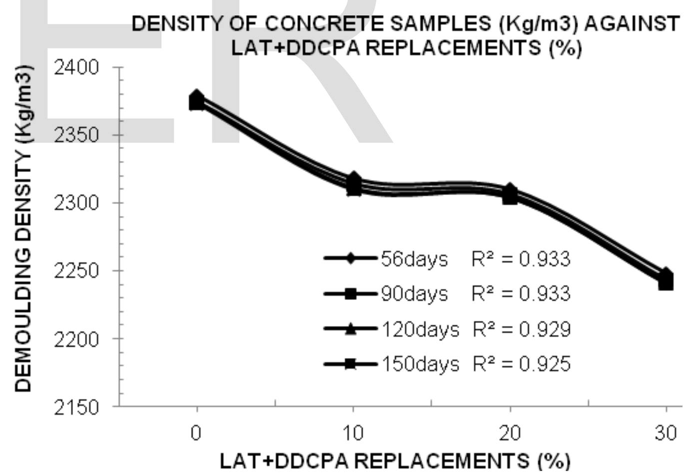

Fig. 9. Effect of LAT+DDCPA replacements (%) on Density (Kg/m^3)

There is a tendency for these green concrete samples to attain strength values similar to the control sample at prolonged curing periods, since it has been established that strength of cement blended with pozzolanas normally improves with age. However, the trend shows a gradual strength development of the DDCPA/OPC LATCON over prolonged hydration periods.

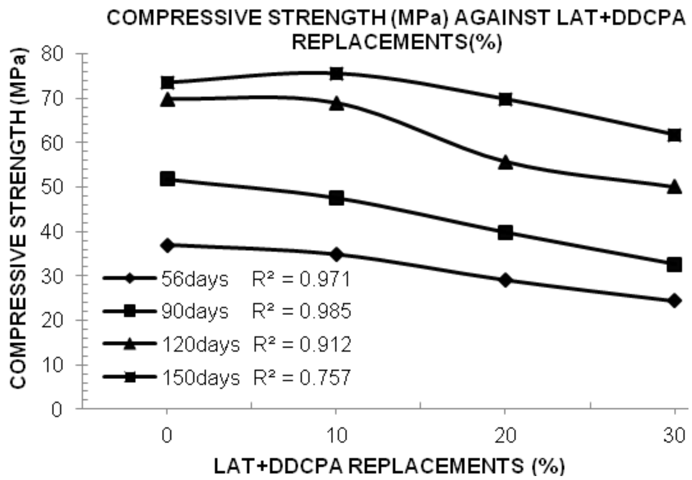

Fig. 10. Effect of LAT+DDCPA replacements (%) on Strength (MPa)

It can be seen from Figure 9 that the percentage increase in Laterite and DDCPA led to a decrease in the respective density of the green concrete. The density of the control sample was 2373Kg/m³ at the 150-day while the 10:10% replacements density was 2310Kg/m³ indicating a loss of approximately 2.7% accounted for as a result of the differences in the fineness modulus and specific gravity of the DDCPA and Laterite as compared to cement and sand respectively.

Figure 10 shows a strong correlation between the compressive strength of the samples and the percentage LAT+DDCPA replacements. The progressive drop in the strength of samples with increase in LAT+DDCPA over the different prolonged hydration periods can be attributed to the excess contents of silica and/or alumina from DDCPA and the Laterite not used up in the reaction. Hence, the excess addition of LAT+DDCPA simply contributed to the drop in strength. Although, in consonance with the requirements of ASTM C618 for 28-day strength, the 20:20% replacement is the limit to which both the cement and sand can be replaced for quality and economy.

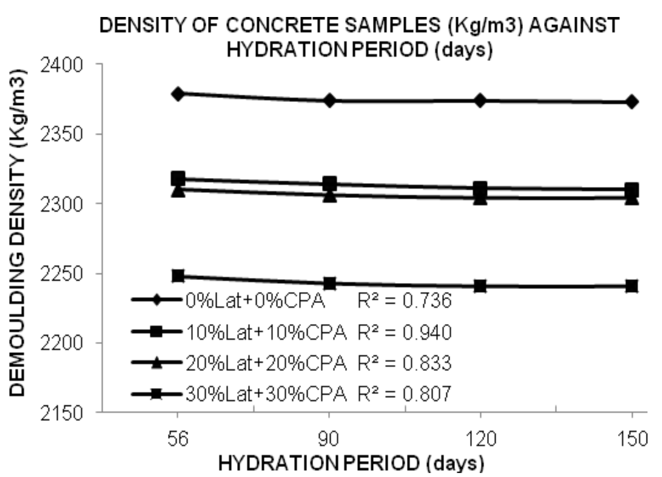

Fig. 11. Density of samples (Kg/m^3) with respect to curing Ages (days)

The drop in concrete density over the prolonged curing age as revealed in Figure 11 shows a fairly high correlation between the concrete density and the prolonged hydration period. The slight drop in density can be due to water absorption and subsequent loss in material content caused by the effect of the prolonged curing. However, the trend is linear as the densities of specimens for the respective replacements are seen to have a similar pattern of reduced material loss. This can be as a result of the saturation of the green concrete samples; which led to a reduced absorption of water and a subsequent reduction in the loss of material content.

5 Conclusion and Recommendation

- The results presented revealed that the 10%LAT+10%DDCPA replacements (i.e. the best replacement matrix) had 150-day strength of 75.64MPa, which is higher than the control specimen of 73.57MPa. Hence, satisfies the strength requirement for structural concrete in accordance to BS8110.
- The compressive strength of green concrete samples increases with increase in hydration period.
- Water absorption and simultaneous loss in materials results in the reduction of density of samples although, a linear pattern for the slight loss in density was recorded due to saturation of the concrete type over the entire prolonged hydration periods.
- The strength of cement blended with pozzolanas normally improves with age since pozzolanas react more slowly but can produce concrete with close characteristics as normal concrete beyond age 28-days.
- Significant drop in compressive strength of green concrete samples were noticed in association with excess silica and alumina content that were not utilized in the pozzolanic reaction.
- The introduction of DDCPA presents a good tendency of pozzolanic activity, the laterite content provided additional contents of silica and alumina as such this paper demonstrates the transformation of abundantly available natural soil and cheap agricultural waste into affordable resource. Hence, extended hydration periods of up to 150-days can produce DDCPA/OPC LATCON with sufficient strength for structural works.

Acknowledgment

The authors wish to thank the Federal University of Technology, Minna and Abia State Polytechnic, Aba where the initial stages of this work were done and the University of Johannesburg, South Africa where the later stage of this study was accomplished.

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