Compressive Strength Properties of Cassava Peel Ash and Wood Ash in Concrete Production

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Abstract

High rate of increase in the prices of cement is worrisome and become burden to people in the entire construction industry. Researchers, civil engineers, builders, architects and all concerns parties in the building industry are desperate for any suitable and effective but cheaper materials that can replace cement. There is need to find an alternative binding material that can be used mainly or in partial replacement of cement. The materials used were sourced from Bida town, Niger state, Nigeria. Wood ash and cassava peel ash were obtained after burning in the furnace at National Cereal Research Institute Badeggi, Bida into ash and passed through 75 micro meter sieve to the finest texture. The water use for the work was free from impurities. The comparative study on the compressive strength of concrete when OPC was partially replaced independently by some percentage of cassava peel ash (C.P.A) and wood ash (W.A) using 0%, 5%, 10%, 15%, 20% and 25% on both materials, 0.5 water-cement ratio and mixed design ration of 1:2:4. The mean strength of concrete at control is 0% (27.11N/mm^2), 5% (24.44N/mm^2), 10% (23.25N/mm^2), 15% (23.36N/mm^2), 20% (18.52N/mm^2) and 25% (15.93N/mm^2). 25% replacement of cement has the lowest mean strength at 28 days. Replacement at 5, 10 15% are within specification of (20N/mm^2) for plain concrete while 20 and 25% are not suitable for structural concrete. The higher the pozzolanic material added to the cement in concrete production the lower the strength. The effects of Cassava Peel Ash and Wood Ash as environment pollution can be reduced when utilized as part of cement in concrete production.
Keywords: *Cassava Peel Ash, Wood Ash, Pozzolanic material, Slump, Compressive Strength, Curing.*

I. Introduction

According to Worldometer (2020), the population of Nigeria is above two hundred million (207,741,800) which give rise to the provision of affordable houses for the growing population. In engineering construction works, especially in concrete and related works, cement is a major component needed and widely known to be one of the most expensive constituents of concrete. The rate of increase in the price of cement is alarming and sometimes become unaffordable. Despite this situation, the need for housing and other constructions requiring this material keep growing as population increases. It is therefore on the above agitation that led to the ideal of looking for

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some agricultural waste products such as cassava peel ash (CPA) and wood ash as a replacement or substitutes to the use of cement in concrete works, the possibility which could minimize the use of cements and also reduces the total cost of construction. Wood Ash (W.A) and Cassava Peel Ash (C.P.A) are both pozzolans which possess little or no Cementous value but react with calcium hydroxide at ordinary temperature to form compounds possessing Cementous properties. Apozzolan is a siliceous material that can be used as partial substitution for cement in mortar mixture; pozzolan particles in a Cementous reaction with calcium hydroxide i.e. lime and alkalis. Pozzolans are effective at lowering the mortar heat of hydrated which improves workability and durability. Pieces of wood served as environmental threat in saw mill and some are collected as waste product while cassava peel are also available as agricultural waste. The application of this material could reduce the environmental impact and also serve for economic purpose when partially replaced with cement in concrete production.

II. Literature Review

a. Agricultural wastes as a pozzolans

Canadian Standard Association, (2000) defined Pozzolan as a material containing siliceous or alumina-siliceous element which in finely form and in the presence of moisture will combine with calcium hydroxide chemically at room temperature to form compounds possessing cementitious properties.

Agricultural wastes such as wood ash, sugarcane bagasse ash, groundnut husk ash, corn cob ash and cassava peel ash are good cementing materials, they combine with cement and sand to provide a good quality concrete. According to FAOSTAT (2018) Nigeria is regarded as the second-largest maize producer in Africa. Mangi et al. (2017) conducted an investigation on pozzolanic properties of sugarcane bagasse ash concluded that the that sugarcane bagasse ash can replace cement up to 5% and the combined sum of alumina, silica and ferrous oxide was 78.2 %. Cassava is a major source of carbohydrates with Africa being the world's production center. The peel from cassava tubers forms solid waste. The high rate of producing flour and garri from Cassava generates wastes which would be more problematic. To avoid this, the peels are converted for better use in concrete production.

Concrete is a construction material which possess a very good durability and widely used for various types of structures. For a long time, concrete was considered to be very durable material that requires little or no maintenance and thereby reduces cost. Some environmental phenomena are well known and significantly contribute to the durability of reinforced concrete structures. Adesanya and Raheem, (2009) conducted a study and revealed that corncob ash replaced Portland cement up to 25% and beyond this, the strength of the concrete begins to decline. Adebisi et al. (2019) reviewed 18 articles on corncob ash and gave an average optimum allowable replacement of cement with CCA as 14%. Sani et al. (2019) investigated the use of corn cob ash as a response surface for compressive strength of high-performance concrete. Cassava peel ash, rice husk ash, Neem seed husk ash, volcanic ash (VA), pulverized burnt clay (PBV) and wood ash are good pozzolanic materials because of their reaction with lime (Calcium hydroxide) to form a Cementous material that is liberated during the hydration of cement. Amorphous silica present in the pozzolanic materials such as cassava peel ash and wood ash combine with lime and forms Cementous materials. These materials help improve the strength of concrete, reduce liberation of heat which is good for mass concrete and contributes significantly to the durability of concrete (IJERT, 2012)

b. Wood Ash / Saw Dust Ash

The advantages of trees are numerous. It helps to cool the environment and also provides oxygen for human respiration. The wood ash is a good pozzolanic material, it helps to improve porosity and also impact strength to concrete. Wood ash is a solid residue of the burning wood or combustion of sawdust in air. It composed of carbonates and oxides of metals such as Calcium and potassium which is compounded in the plant's woody tissues that are present in the residue. According to the specific gravity of wood ash obtained from a bakery in Minna, Niger State, Nigeria was 2.13 and the bulk density 760 kg/m^3. Because of its being usually rich in calcium carbonate, which is a good binding agent and its other chemical components, wood ash acts as a pozzolana with good stabilizing properties. Wood ash is one of the oldest stabilizers known. It is good water proofer and has good binding properties. Elinwa (2016) reported that Saw dust ash is pozzolanic in nature, it reacts with the hydration product of cement $Ca(OH)_2$ to produce C-S-H which add strength to concrete. The results obtained from the investigation of the use of Saw Dust Ash as an inhibitor for reinforcement corrosion in concrete showed that it is very effective and can be used to control corrosion. addition of SDA to concrete can be effective in the control of corrosion (Elinwa,2016).Fajobi and Ogunbanjo (1994) used wood ash to impact greater strength to sub-grade and also established that the amount of wood ash to be added to soil for optimum compressive strength is about 10% by weight, while Amu et al. (2005) have used wood ash in the stabilization of lateritic soil. Amu et al. (2005) reported the investigation conducted on wood ash in the stabilization of lateritic soil. He got the hard wood from a sawmill in Ado Ekiti, Nigeria. The hardwood was burnt under control heating and ash obtained was light brown in colour passing through the sieve 0.2 mm aperture.

c. Cassava Peel Ash

Cassava Peel is a by-product of a processed cassava. According to Adesanya et al. (2009) cassava peel constitutes20-35% of the entire weight of tuber. Cassava peel constitutes to environmental problem and there is need to recycle them in order to make them more useful to the environment. cassava peel ash is a by-product of incinerated cassava peel which can be gotten from processing cassava. Cassava, a tuber crop is well grown in all ecological zones of Nigeria, but mostly in the southern parts of the country. Cassava is an energy given food when consumed, very rich in carbohydrate, starch, fats, protein, ash, fibres and can also be used as a raw material for production industries. (IJERT, 2012). In recent times, efforts have been geared towards the use of cassava as a pozzolanic material, to replace cement in concrete production because of its pozzolanicity. The re-use of cassava peels ash assists in protecting humans from environmental pollution and severe ecological problem. To reduce the dangers caused by CPA, it's reuse as a pozzolanic material is given good attention (IJERT, 2012).

A study conducted by Salau et al. (2011) on pozzolanic potential of CPA showed that cassava peel ash possesses 79% of combined silica, alumina and ferric oxide. The work studied the effect of CPA on workability, compressive and flexural strengths of concrete when used as a partial substitute for cement.

III. Materials and methods

a. Materials

The materials used for this work include the following; aggregates, cement, wood ash, cassava peel ash and water. The coarse aggregate used was obtained from the river bank in Bida town and the cement used for this project work was Dangote Ordinary Portland Cement. Others are wood ash, cassava peel ash obtained after burning in the furnace after burning in the furnace at Baddegi research institute, Bida into ash and passed through 75 micro meter sieve to the finest texture. The water use for this project was a pure tap water gotten from Bida town, Niger state, Nigeria.

b. Methods

The comparative study on compressive strength of concrete when O.P.C was partially replaced independently by some percentage of cassava peel ash (CPA) and wood ash (W.A) using 0%, 5%, 10%, 15%, 20% and 25% on both materials. The methodology of achieving the set goal includes;

- subjecting the cassava peel (CP) and wood ash to a controlled incineration, through drying, burning and grinding to form cassava peel ash (CPA) and wood ash.
- Carrying out the physical test and analysis of the materials properties
- Batching of the cassava peel ash (CPA) and wood ash and sourcing of other necessary materials such as ordinary Portland cement (OPC), coarse aggregate (Granite) fine aggregate (Sharp sand), water, cube moulds size 150x150x150mm, mixing pan, measuring pan, weighing machine/scale, and scoops.
- Measuring, mixing and casting of various concrete cubes with respect to BS code 8110, 1990. The concrete cubes will be produced using a specified mixing percentage (s) of cassava peel ash (CPA and wood ash respectively with cement.
- Conduct test for the strength of the concrete (Crushing strength test) of all the cubes.

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- Curing of the concrete for 7,14, 21 and 28days to get the determine the utmost strength of the concrete.
- Crushing of concrete to determine the compressive strength at various percentage replacements.

c. Compressive strength test (BS 812 part 110; 1990)

- The design mix used was absolute value method or batching by weight method
- The cement and fine aggregate (wood ash, cassava peel ash and sharp sand) were mixed thoroughly and the coarse aggregate was added, the required water for mixing was added and it was thoroughly mixed with the aggregate.
- The mould of 150mm x 150mm was quoted with lubricating oil and all the screw and nut were fastened.
- The mould was filled with the mixed sample in three layers and compacted in each later with 27 blows of the tamping rod then the surface of the mould was levelled with spatula.
- The cubes were kept for 24hours. It was de-moulded and weighed then it was placed in the curing tank to be cured.
- The cube was cured for 7,14,21 and 28 days so 56 cubes were casted, each cube were removed from the curing tank and it was weighed before crushing at their specified data
- Compressive strength = $\frac{\text{Load}}{\text{Cross-sectional Area N/mm}^2}$

Figure 1: Compressive strength machine

IV. Result and Discussion

a. Result

Table 1. Result of Chemical Analysis of Cement, Wood ash and C.P.A.

Chemical composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_3	LOI
Cement	20.80	3.10	2.50	64.50	1.70	0.23	0.85	2.50	3.40
Wood ash	42.5	17.0	5.4	8.0	3.0	1.7	5.0	4.8	7.16
C.P. A	51.79	9.57	4.23	10.20	2.9	1.37	10.74	1.52	6.10

Table 2. Slump Test

Replacement	0%	5%	10%	20%	30%	40%
Water cement ratio	0.50	0.50	0.50	0.50	0.50	0.50
Slump (mm)	0	0	2	5.5	7	0
Slump type	True	True	True	True	True	True

After the test was carried out at different replacement (0%,5%,10%,15%,20%,25%) using 0.50 water/cement ratio and mixed design of 1:2:4 and it was found that the replacements have true slump therefore all the samples are within the specification of BS 1881-102:1993.

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Table 3. Specific Gravity Result (fine aggregate)

Number of trials	A	B
Mass of glass jar + cover (g)(M1)	265.30	257.84
Mass of glass jar + cover + sample (g)(M2)	465.16	457.99
Mass of glass jar + cover + sample + water (g)(M3)	874.57	879.07
Mass of glass jar + cover + water (g)(M4)	754.83	755.81

$$\textbf{Specific gravity Gs} = \frac{M2-M1}{(M4-M1)-(M3-M2)}$$

Trial A

$$Gs = \frac{465.16-265.30}{(754.83-265.30)-(874.57-465.16)} = 2.49$$

Trial B

$$G.s = \frac{457.99-257.84}{(755.81-257.84)-(879.07-457.99)} = 2.6$$

$$\textbf{Average specific gravity} = \frac{GsA+GsB}{2}$$

$$\frac{2.49+2.61}{2} = 2.55$$

Table 4. Specific Gravity Result (wood ash)

Number of trials	A	B
Mass of glass jar + cover (g)(M1)	360	350
Mass of glass jar + cover + sample (g)(M2)	560	550
Mass of glass jar + cover + sample + water (g)(M3)	960	960
Mass of glass jar + cover + water (g)(M4)	850	850

$$\textbf{Specific gravity Gs} = \frac{M2-M1}{(M4-M1)-(M3-M2)}$$

Trial A

$$Gs = \frac{560-360}{(850-360)-(960-560)} = 2.2$$

Trial B

$$GS = \frac{550-350}{(850-350)-(960-550)} = 2.1$$

$$\textbf{Average specific gravity} = \frac{GsA+GsB}{2}$$

$$\frac{2.2+2.1}{2} = 2.15$$

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Table 5. Specific Gravity result on (cassava peel ash)

Number of trials	A	B
Mass of glass jar + cover (g)(M1)	387.31	382
Mass of glass jar + cover + sample (g)(M2)	487.31	482
Mass of glass jar + cover + sample + water (g)(M3)	710.20	700
Mass of glass jar + cover + water (g)(M4)	650.10	640

$$\textbf{Specific gravity Gs} = \frac{M2-M1}{(M4-M1)-(M3-M2)}$$

Trial A

$$Gs = \frac{487.31-387.31}{(650.10-387.31)-(710.20-487.31)} = 2.5$$

Trial B

$$GS = \frac{482-382}{(640-382)-(700-482)} = 2.55$$

$$\textbf{Average specific gravity} = \frac{GsA+GsB}{2}$$

$$\frac{2.50+2.55}{2} = 2.53$$

Table 6. Showing mix design calculation

Percentage replacement%	Coarse agg(kg)	Fine agg(kg)	Cassava ash(kg)_	Wood ash(kg)	Cement(kg)
0%	54.88	26.54	0	0	13.72
10%	54.88	26.54	0.68	0.68	12.35
15%	54.88	26.54	1.03	1.03	11.66
20%	54.88	26.54	1.37	1.37	10.98
25%	54.88	26.54	1.72	1.72	1029

Table 7. Compressive Test Result for Plain Concrete (0% Replacement)

Age	Cube No.	Weight of cube (kg)	Density of cube (kg/m^3)	Load (KN)	Compressive strength (N/mm^2)	Mean compressive strength (N/mm^2)
7	A	8	2370.37	410	18.22	
	B	9	2666.67	433	19.24	19.1
	C	8.6	2548.15	450	20	
14	A	8.3	2459.26	560	24.89	
	B	8.6	2548.14	580	25.78	25.19
	C	8.3	2459.26	560	24.89	
21	A	8.8	2607.41	540	24	
	B	9.0	2666.67	480	21.33	23.70
	C	8.7	2577.78	580	25.78	
28	A	8.2	2429.63	600	26.67	
	B	8.4	2488.89	580	25.78	27.11
	C	8.5	2518.52	650	28.89	

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Table 8 Compressive Test Result for 5% Replacement

Age	Cube No.	Weight of cube (kg)	Density of cube (kg/m³)	Load (KN)	Compressive strength (N/mm²)	Mean compressive strength (N/mm²)
7	A	8	2370.37	350	15.50	16.72
	B	8.3	2459.26	450	20.00	
	C	8.1	2400	330	14.67	
14	A	8	2370.37	454	20.17	21.02
	B	7.9	2340.74	400	17.78	
	C	8.1	2400	565	25.10	
21	A	8.1	2400	560	24.87	20.88
	B	8.2	2429.62	450	20.00	
	C	8.3	2459.26	400	17.78	
28	A	8.2	2429.62	570	25.33	
	B	8.0	2370.37	550	24.44	24.44
	C	8.6	2548.15	530	23.56	

Table 9. Compressive Test Result for 10% Replacement

Age	Cube No.	Weight of cube (g)	Density of cube (kg/m³)	Load (KN)	Compressive strength (N/mm²)	Mean compressive strength (N/mm²)
7	A	8.2	2429.62	375	16.67	
	B	8.0	2370.37	355	15.78	15.56
	C	8.1	2400.00	320	14.22	
14	A	8.4	2488.89	550	24.44	21.63
	B	8.0	2370.37	500	22.22	
	C	8.1	2400.00	410	18.22	
21	A	8.2	2429.62	555	24.67	20.00
	B	8.5	2518.52	550	24.44	
	C	8.1	2400.00	450	20.00	
28	A	8.2	2429.62	550	24.44	
	B	8.3	2459.26	500	22.22	23.25
	C	8.2	2429.62	520	23.1	

Table 10. Compressive Test Result for 15% Replacement)

Age	Cube No.	Weight of cube (kg)	Density of cube (kg/m3)	Load (KN)	Compressive strength (N/mm²)	Mean compressive strength (N/mm²)
7	A	8.1	2400	300	13.31	
	B	8.2	2429.63	280	12.44	13.33
	C	8.0	2370.37	320	14.22	
14	A	8.1	2400.00	350	15.56	
	B	8.2	2429.63	380	16.89	18.22
	C	8.0	2370.37	500	22.22	
21	A	8.3	2459.26	450	20.00	
	B	8.4	2488.89	500	22.22	22.57
	C	8.5	2518.52	570	25.33	
28	A	8.1	2400.00	500	22.22	
	B	8.3	2459.26	550	24.44	23.26
	C	8.5	2518.52	570	23.11	

Table 11. Compressive Test Result for 20% Replacement

Age	Cube No.	Weight of cube (kg)	Density of cube (kg/m3)	Load (KN)	Compressive strength (N/mm^2)	Mean compressive strength (N/mm^2)
7	A	7.9	2340.74	300	13.33	
	B	7.8	2311.11	390	17.33	14.81
	C	8.0	2370.37	310	13.78	
14	A	8.1	2400.00	350	15.56	
	B	8.2	2429.63	410	18.22	16.45
	C	8.0	2370.37	350	15.56	
21	A	8.2	2429.63	380	16.89	
	B	7.9	2340.74	360	16.00	16.74
	C	7.8	2311.11	390	17.33	
28	A	8.1	2400.00	400	17.78	
	B	8.0	2370.74	410	18.22	18.52
	C	8.5	2518.52	440	19.56	

Table 12. Compressive Test Result for 25% Replacement

Age	**Cube No.**	**Weight of cube (kg)**	**Density of cube (kg/m3)**	**Load (KN)**	**Compressive strength (N/mm^2)**	**Mean compressive strength (N/mm^2)**
7	A	7.5	2222.22	290	12.89	
	B	7.6	2251.85	300	13.33	13.33
	C	7.9	2340.79	310	13.78	
14	A	8.0	2370.74	310	13.78	
	B	7.9	2340.79	320	14.22	13.78
	C	8.1	2400.00	300	13.33	
21	A	8.1	2400.00	330	14.67	
	B	8.2	2429.63	340	15.11	15.04
	C	8.1	2400.00	345	15.33	
28	A	8.0	2370.74	350	15.56	
	B	8.1	2400.00	360	16.00	15.93
	C	8.2	2429.63	365	16.22	

Table 13. Ratio Properties

Water cement ratio	0.50
Mix proportion	1:2:4
Area of cube	150mm x 150mm = 22500mm^2

Table 14. Mean compressive strength (N/mm^2)

Days	**100% Cement (control)**	**5% (C.PA+ W.A)**	**10% (C.PA+ W.A)**	**15% (C.PA+ W.A)**	**20% (C.PA+ W.A)**	**25% (C.PA+ W.A)**
7days	19.10	16.72	15.56	13.33	14.81	13.33
14days	25.19	21.02	21.63	18.22	16.45	13.78
21days	23.70	20.88	20.00	22.27	16.74	15.04
28days	27.11	24.44	23.25	23.26	18.52	15.93

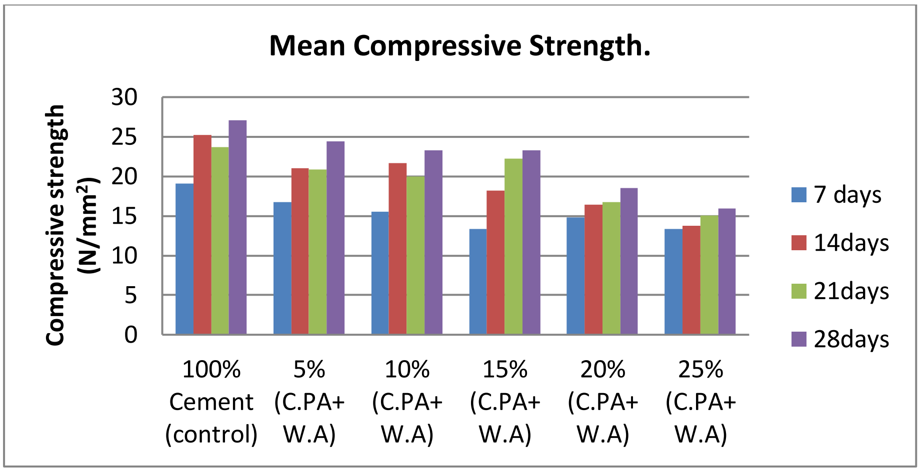

Figure 2: Graph of strength against percentage (%) for (CPA+W.A) AND O.P.C

b. Discussion of Result

The tables from 7-12 show the mean strength of concrete at 7, 14, 21 and 28 curing days. It shows that 0,5,10,15,20 and 25% replacement of OPC cement with wood ash and cassava ash has the mean strength of 0%(27.11N/mm^2), 5%(24.44N/mm^2), 10%(23.25N/mm^2), 15%(23.36N/mm^2), 20%(18.52N/mm^2) and 25%(15.93N/mm^2). From the result, 0% has the highest mean strength at 28 days and 25% has the lowest mean strength at 28 days. From the BS Code specification, a plain concrete should not be less than 20N/mm at 28 days crushing strength. Therefore, replacement at 5, 10 15% are within specification while 20 and 25% are not suitable for structural concrete.

V. Conclusion

The research work carried out on the partial replacement of cement with wood ash and cassava peel ash in concrete production drawn the following conclusions;

- that the use of cassava peel ash and wood ash can considerably reduce the amount of cement used in concrete production when partially replaced with ordinary Portland cement (OPC).
- The adequate compressive strength of concrete with pozzolainic material like wood ash and cassava peel ash can be achieved by replacing at 5%, 10%, and 15% while 20% and 25% replacement will not give an adequate concrete that conform to the BS standard which state that all plain concrete should not be less than 20N/mm^2
- The higher the pozzolainic material added to the cement in concrete production the lower the strength.
- The effects of Cassava Peel Ash and Wood Ash as environment pollution can be reduced when -utilized as part of cement in concrete production.
- The water cement ratio of 0.6 can be adopted due to lower workability when CPA and WA were being partially replaced with OPC.

a. Recommendation

From the analysis, it was observed that 28days crushing strength value at 5%, 10% and 15% replacement which are within the British standard (BS) which states that a concrete with a pozzolanic material should not be less than 20N/mm^2 at 28days crushing strength. Therefore, 5%, 10%, and 15%can be recommended for light weight concrete. Curing system can be encouraged since the higher the curing age, the higher the compressive strength of the concrete.

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