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Characterisation and Use of Cassava Peel Ash in Concrete Production

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ABSTRACT

In this work, the utilization of cassava-peel-ash (CPA) which is an agricultural solid waste derivative as a supplementary-cementitous-materials in the production of concrete is carried out in this study; this is essential because it enhances the re-use and re-cycling of solid wastes and its derivatives which will help in achieving eco-efficient, eco-friendly and sustainable engineered infrastructure. The CPA is used to replace specified ratio of cement ranging from 0% to 40% at the hydration period of 3, 7, 28, 60 and 90days respectively to obtain a concrete mixture of coarse and fine aggregates, water, cement and CPA. The Characterization is of CPA is evaluated with respect to the physicochemical properties of CPA and mechanical properties of the concrete mix at fresh or hardened state. The results of compressive strength for 5%-replacement range from 12.56N/mm^2 to 33.26N/mm2 for the varying hydration periods as against 13.93N/mm^2 to 35.23N/mm^2 for the control-test (0%-replacement). The result of flexural strength for 5%-replacement range from 3.33N/mm^2 to 15.17N/mm^2 for the varying hydration periods as against 4.67N/mm^2 to 16.80N/mm^2 for the control. The mechanical properties results indicate that lower strength is obtained at early hydration periods but the strength increases with longer hydration period; while the strength decreases with increased ratio of the CPA. The pozzolanic-activity-index (PAI) of CPA is 75.8% which is an indication that it has high pozzolanic properties. From the results, the optimum combination level of 5%-10% replacement of the cement by CPA can be used to produce a better and more desirable concrete.

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1. Introduction

Construction materials for building works account for about forty to sixty percent of the total cost of executing the construction project which is due to exponential increase in the cost of the basic conventional materials such as aggregates and cement [1]. The cost increase of these conventional construction materials is because of the high cost expended in their production, processing and haulage. Apart from the economical aspect, the use of these conventional materials has led to a buildup of CO_2 emissions into the atmosphere which consequently lead to global warming thereby endanger our environment. To tackle this challenge, the use of supplementary cementitous materials to substitute cement in order to reduce the total construction cost and also achieve environment efficient, environment friendly, and sustainable development in terms of infrastructure [2,3]. Cassava peel which is a waste (by-product) from cassava processing and these material are generated either on domestic level (household) or industrial level. The cassava peel consist of about 20 % to 35 % of the total tuber weight especially by hand peeling [4].

Pozzolans are considered to contain silica and alumina which in finely divided state and reacts with calcium hydroxide in the presence of water to produce cementitous compounds such as calcium silicates hydrates, calcium sulfo-aluminate hydrates and calcium aluminate hydrates [5]. Pozzolanic material utilization as a building construction material is nearly as old as ancient civilization where these pozzolanic materials are used to enhance the characteristics of lime; many of these structures are still intact as a confirmation of the durability property of pozzolanic-lime concrete mixture [6]. In this research, the characterization of cassava peel ash which is a solid waste derivatives to substitute cement in concrete partially at varying ratios from 0 % to 50 % in terms of setting time, workability, flexural strength, compressive strength and pozzolanic activity index.

Concrete is used as a construction materials due to its durability property and requiring little or no maintenance concrete. Concrete structures are usually situated in highly polluted industrialized and urban areas, severe marine salty environments where some other construction materials are observed to be non-durable, the utilization of solid wastes and its derivatives which possesses alumino-silicates content with pozzolanic property in the production of concrete helps to improve its durability property as it is being situated at these environmental severe conditions. The need to obtain more sustainable cementing products in concrete makes it essential for researchers to indulge in the assessment of the pozzolanic activity of supplementary cementitous material so as to determine the safe combination level of these additives in concrete [6,7].

The importance of saving cost of construction and also to mitigate environmental degradation challenges due to indiscriminate disposal of various agricultural/industrial wastes and also oxides of carbon emission from both industrial plants and cement hydration as well as the enhancement of concrete durability performance, has led to increasing research into the utilization and re-cycling of various solid wastes and its derivatives which can be used as pozzolans [8].

Raheem *et al* [10]; in their research study, the cement was partially replaced in concrete by CPA of varying proportions from 0 % to 20 %by cement weight at 5 % interval using a mixture ratio of 1:2:4 and cured for 7 days to 28 days. The strength development and slump was observed and it was concluded that the concrete strength increases with increased hydration period but decrease with increase quantity of the CPA.

Ofutayatan *et al* [9]; in their work, cassava peel ash which is locally available is utilized as a supplementary cementitous material to partially replace conventional cement in concrete at varying ratio from 5 % to 25 %. The strength properties of the CPA concrete cured for 7 day to 180 day is determined in terms of compressive strength, flexural strength, porosity, durability, slump, water absorption and shrinkage from the results summary 10 % to 15 % produced the optimal results for the response parameters.

The physicochemical and mechanical character of natural pozzolans are derived from their behavior when situated or placed in a very aggressive environment. The pozzolans composed primarily of aluminic content are majorly chloride resistant while the silicic pozzolans serve well as sulphate resistant [10]. The pozzolanic activity is a measure of the chemical kinetics of reaction between calcium hydroxide or Ca^{2+} and a pozzolan in the presence of moisture. The intrinsic properties of the pozzolans namely; the active phase content, the surface area and the chemical composition affects the rate of pozzolanic reaction while the adsorption of physical surface is not considered due to the fact that no molecular irreversible bond are generated in the process. The pozzolanic reaction rate can be affected by externally related factors like the quantity of water, mix proportion, hydration product growth and reaction temperature [11].

2. Experimental materials and investigation methods

2.1. Experimental program

This work investigated the physicochemical properties of cassava peel ash as a pozzolan and the mechanical properties of the concrete produced using CPA as a replacement for cement in concrete at fresh and hardened state. Setting time, workability for the concrete at fresh state while flexural and compressive strength test for the concrete at varying hydration periods at hardened state. Mixtures of concrete possessing varying ratios of CPA ranging from control (0 %) to forty percent were assessed in order to determine the setting time, slump, flexural and compressive strength at varying hydration periods (3 days to 90 days). The Cassava Peel which is an agricultural wastes is burnt in a controlled incineration and is utilized as a supplementary cementitous material (SCM); strength gain rate at varying mix ratios and hydration periods is assessed to observe pozzolanic activity level of the cassava peel ash (CPA). The in other to obtain the particles of waste in a finely divided state, the ash sample is then sieved through a 150μm sieve size. The concrete's target strength of 35 N/mm^2 with a cement content of 290 kg/m^3, a coarse aggregate content of 1198.65 kg/m^3, a fine aggregate content of 766.35 kg/m^3 and a water–cement ratio of 0.45. [12,13]

2.2. Materials

Dangote Limestone Portland cement was used in carrying out this research experiment.

The cassava peel was gathered and dried under sun at Abayi-umuokoroato village, Abayi Ancient Kingdom of Obingwa L.G.A of Abia State. The cassava peel was burnt in a kiln at a temperature of about 500^0C to 850^0C in 60minutes in a control incineration set-up to prevent pollution. The burnt material was collected and sieved with 150µm sieve size in the laboratory and a very finely divided material (ash) was gotten for the experiments.

The water source used in the experiment is borehole.

The fine aggregate used in this work is clean river sand which is free from deleterious substances.

The maximum size of coarse aggregate used is 12.7 mm and very free from deleterious materials and well graded. Fig. 1 shows the mixture of CPA and cement.

Fig. 1. Cassava Peel Ash CPA and Cement mixture.

2.3. Method

2.3.1. Compressive strength

This was be obtained by dividing crushing load (N) of the concrete by the cross-sectional area of the concrete cube (mm^2). This was obtained after curing the concrete at 3, 7, 28, 60 and 90days respectively. In each of the hydration period, three cubes were casted, cured and crushed after which the average compressive strength was recorded. The dimension of the concrete cubes used is 150mm x 150mm x 150mm. The total number of concrete casted was ninety (90). [14]

Procedure:

The mixture ingredients are batched as appropriate according to the mix design and placed in a cubic metal mould of 150mm by 150mm dimension.

The concrete sample is demoulded after 24 hours and immersed in a curing tank.

At the completion of the specified hydration period, the concrete samples are tested to determine its density and compressive strength properties.

The strength properties for the compressive tests are computed with the failure load obtained from the crushing machine calculated as shown in equation below

$$\text{Compressive Strength } (N/mm^2) = \frac{crushing\ Load}{Cross\text{−}sectional\ Area\ of\ Concrete\ Sample}$$

2.3.2. Flexural strength

Ninety (90) concrete beams measuring 100m x 100mm x 400mm were casted and cured at varying hydration period from three to ninety days respectively. In each of the curing period, three beams were casted, cured and crushed after which the average flexural strength was recorded.

The concrete's flexural strength is calculated with the formula [7]

$$(F.S) = PL/bd^2$$

where: P =Load that causes beam failure (N)
L =Length of beam (mm)
b =Width of beam (mm)
d = Depth of beam (mm).

2.3.3. Setting time

This test was carried out in accordance with BS12 (1978) using VICAT apparatus. The VICAT apparatus have the initial and final setting pins for determination of the setting time of the cement-CPA mortar and that of the control. The initial setting pin is attached to the Vicat apparatus for the determination of the initial setting time of the cement-CPA mortar and it is calculated as the total duration from when water was initially added to the sample and the time the initial setting needle ceases to penetrate the Vicat mould of 5 mm. after the determination of the initial setting time, the initial setting pin is then detached from the apparatus and replaced with the final setting pin which is used to determine the final setting time of the cement-CPA mortar. The final setting time is calculated as the period from when water was initially added to the sample till the time the final setting pin makes an impression on the mould surface [15]. Fig. 2 shows the vicat test in the laboratory.

Fig. 2. Setting Time Laboratory Tests.

2.3.4. Slump test

The concrete slump test measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows. It can also be used as an indicator of a proper and improperly mixed batch. The test is popular due to the simplicity of apparatus used and simple procedure. The slump test is used to ensure uniformity for different loads of concrete under field conditions. Slump test is a simple technique used for the evaluation of concrete's consistency and it is used for checking if the correct quantity of water is added to the concrete mix [16].

2.4. Data processing

Data used for this research work will be sourced from material composition consisting of the cementitous portion of the concrete mix partially replaced by varying percentages of cassava peel ash as presented by several relevant literatures. The desired concrete's target characteristic strength of 35N/mm^2 with a cement content of 290 Kg/m^3, a coarse aggregate content of 1198.75 Kg/m^3, a fine aggregate content of 766.35Kg/m^{3}and a water cement ratio of 0.45. The cement content will be partially replaced with varying percentages of CPA from 0 to 40%. Correlation analysis and analysis of variances (ANOVA) is carried out with the control results and that of the varying replacement levels is carried to determine their significant levels at 5 % critical value. The laboratory responses will be obtained and evaluated using the following statistical software namely; Minitab 18 and Microsoft excel [17].

The correlation formula is shown below;

$$r = \left(\frac{n\sum xy - \sum x \sum y}{\sqrt{n\sum x^2 - \left(\sum x\right)^2}\sqrt{n\sum y^2 - \left(\sum y\right)^2}} \right)$$

2.4.1. Test mixture proportion

The mix proportion of the mixture constituents comprising of cement, CPA, water and aggregates is shown in table 4 below;

Table 1.
Mix Proportions for the concrete work.

Mixes	**% replacement of Cement**	**Cement (Kg/m^3)**	**Fine Aggregate (Kg/m^3)**	**Coarse Aggregate (Kg/m^3)**	**CPA (Kg/m^3)**	**Water (Kg)**	**Curing (Days)**
Mix-1	0	290	766.35	1198.65	0.00	115	3, 7, 28, 60, 90
Mix-2	5	275.5	766.35	1198.65	14.50	115	3, 7, 28, 60, 90
Mix-3	10	261	766.35	1198.65	29.00	115	3, 7, 28, 60, 90
Mix-4	20	232	766.35	1198.65	58.00	115	3, 7, 28, 60, 90
Mix-5	30	203	766.35	1198.65	87.00	115	3, 7, 28, 60, 90
Mix-6	40	174	766.35	1198.65	116.00	115	3, 7, 28, 60, 90

3. Results and discussion

3.1. Physical properties of constituents' aggregates

The aggregates sieve analysis graph presents the particle size distribution of the fine and coarse aggregates used in the concrete mixture. From the results, 94.2 % and 1.2 % is passing sieve size 2 mm and 75 μm respectively for the fine aggregate and 97.66 % and 11.41 % passing sieve size

12.7 mm and 2 mm respectively for coarse aggregate. For the cassava peel ash CPA, 75.45 % and 35.18 % are passing sieve size 0.15 mm and 75 μm respectively. The semi-log graph is shown in fig. 3.

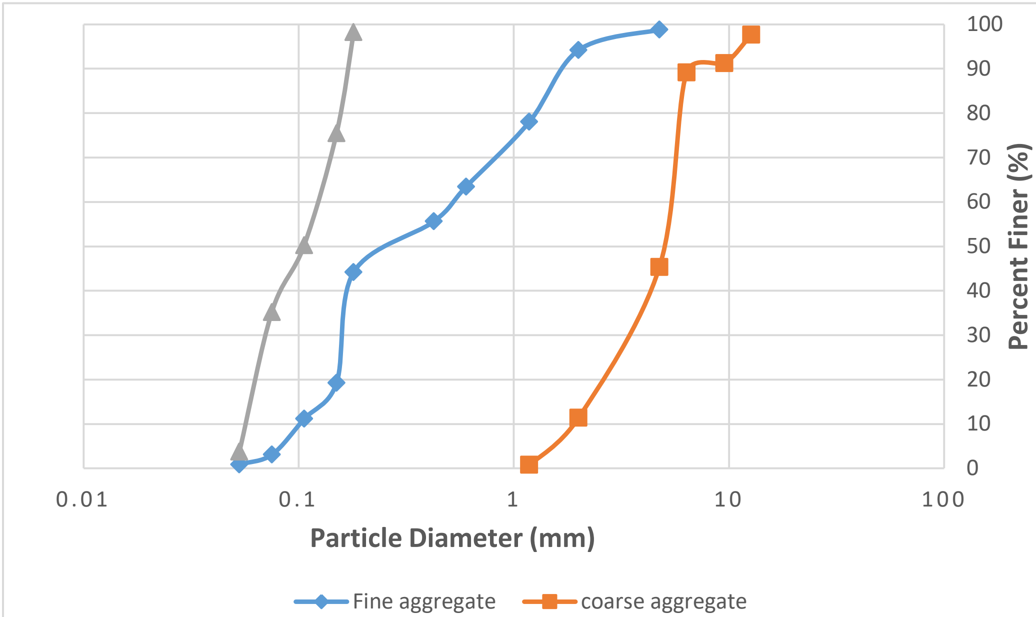

Fig. 3. Particle Size Distribution of Test Aggregates.

3.1.1. Fineness modulus (FM)

Fineness modulus of the aggregates used which is the index number that represents the mean size of the aggregate particles gotten after performing sieve analysis with standard sieves. Obtained from the sieve analysis graph. The cumulative weight retained divided by 100 gives us the fineness modulus computed from the table 2 below; the smaller the value of FM, the finer the aggregates and vice versa. FM values ranging from 2.0 to 4.0 can be classified as a fine aggregate while higher value indicates coarse aggregates [20].

Table 2.
Fineness Modulus of the Test Aggregates.

Sieve Size	Weight Retained (g)	% Weight Retained	Cumulative % Retained	Cumulative % Finer	Fineness Modulus
4.75	12.3	1.23	1.23	98.77	
2.36	45.7	4.57	5.80	94.20	
1.18	161.8	16.18	21.98	78.02	
0.6	187.8	18.78	40.76	59.24	3.18
0.425	191.2	19.12	59.88	40.12	
0.15	300	30.00	89.88	10.12	
0.075	89.2	8.92	98.80	1.20	
	994	99.40	318.33		

3.2. Chemical composition of cement and cpa

The chemical composition of the Cassava Peel Ash is presented in Table 3. From the result presents that the cassava peel ash has a combined ratio of Al_2O_3 + SiO_2 + Fe_2O_3 totaled 81.83 % which is more than 70 % and that shows a good pozzolanic material according to the requirements of ASTM C618 (1991). The Cassava peel ash contains by percentage; 55.93, 19.88, 9.85 and 6.02 for SiO_2, Al_2O_3, CaO and Fe_2O_3 respectively. The specific gravity and loss on ignition for the Cassava Peel Ash is 0.35 and 12.5 respectively. The SiO_2 and Al_2O_3 which is supplied by the Cassava Peel Ash reacts with $Ca(OH)_2$ (which occurs when the CaO which is the dominant radical in cement becomes hydrated). The hydrated lime ($Ca(OH)_2$) will then react with SiO_2 and Al_2O_3 to develop a binding property which is made possible by a process known as pozzolanic reaction. Calcium alumino-silicate hydrate is formed which is responsible for gain of strength in concrete. The surface area of the Cassava Peel Ash is 310 kg/m^2 [18,19].

Table 3.
Chemical Composition of the Test Samples.

Results of Physical and Chemical Analysis of Cassava Peel Ash	
Oxide Composition	**Percentage By Weight (%)**
MgO	3.2
Fe_2O_3	6.02
SiO_2	55.93
CaO	9.85
Al_2O_3	19.88
Na_2O	0.98
ZnO	1.4
MnO	1.55
specific gravity	0.35
Loss on ignition	12.5
SO_4	Nil
CuO	Trace
TiO_2	Trace
CdO	Trace

These analyses were carried out in PRODA, Enugu and The Chemical Composition of the cement is presented in table 4.

3.3. Test on the fresh concrete

3.3.1. Workability test result (slump)

The results obtained indicates that value of the slump test reduces with increase in the cassava peel ash content in the concrete mixture by requiring more water in order to make the mixture more workable. The high requirement of water is as a result of the presence of silica and increased surface area for the ash sample. This is because of silica-lime reaction require more water in addition to the water presented for the cement hydration reaction process [20]. The obtained result is presented in table 5.

3.3.2. Setting time results

From the obtained results, it was observed that the addition of CPA effected the increase of the initial setting time from 52 to 123 minutes; while that of final setting time also increases from 591 to 788 minutes. This is because the addition of Cassava Peel Ash reduces the surface area of the cement paste to be added in the mixture. This causes a slowdown in the hydration process causing setting time to increase. The slow hydration means low rate of heat development. This is of great importance in mass concrete construction where low heat of hydration is required. The setting time result is shown in table 6;

The graph of cement/cassava peel ash paste setting time versus % replacement is presented in figure 4. The result shows that the increase in cassava peel ash content leads to increase in both initial and final setting time of the cement/CPA paste.

Table 4.
Chemical Analysis of Dangote Cement.

Results of Chemical Analysis of Dangote Cement	
Oxide Composition	**Percentage by weight (%)**
K_2O	0.46
MgO	1.25
Fe_2O_3	4.301
SiO_2	53.2
CaO	11.52
Al_2O_3	21.4
Na_2O	1.04
specific gravity	3.1
Loss on ignition	6.78
Results of Physical Analysis of Dangote Cement	
Moisture content (%)	2.4
specific gravity	3.15
Bulk density (g/cm^3)	2.95
Fineness Modulus	0.88
pH	8.8

3.4. Mechanical property of the hardened concrete

3.4.1. Compressive strength and density of the concrete

The concrete’s compressive strength with respect to the different hydration periods and ratio of CPA replacement is shown in the table 7. The obtained results indicates that the compressive strength values for the concrete mixed with CPA has low strength at early hydration period but the strength development improves rapidly with longer hydration period. However, the strength decreases with higher ratio of CPA in the concrete mix.

Table 5.
Slump test results.

for concrete cubes (mm)					
	3-d	***7-d***	***28-d***	***60-d***	***90-d***
0% repl	8.2	8.5	7.8	8	8.7
5% repl	7.4	7.5	6.2	7.5	7
10% repl	7	7	6.9	7.1	6.5
20% repl	5.8	5.3	5	5.5	5
30% repl	4.3	4.5	4.1	4.5	4.4
40% repl	3	3.2	3.1	3	3.4
for concrete beams (mm)					
0% repl	8.8	8	7.9	8	8
5% repl	8	7.4	7.4	7.5	7.5
10% repl	7.7	6.8	6.8	6.9	7
20% repl	5.2	5.3	5	5.1	5.1
30% repl	4.6	4.2	4.7	4.9	4
40% repl	2.5	3.1	2.9	3	2.8

(-d) signifies days of cement hydration.

Table 6.
Setting time results of the Mixture samples.

Setting time		
Repl Ratio (%)	**Initial Mins**	**Final Mins**
0	52	591
5	55	596
10	74	655
20	80	673
30	98	709
40	123	788

3.4.2. Flexural strength and density of the concrete

The concrete's flexural strength of the with respect to varying hydration periods and mixed proportions is shown in the table 8 below. The obtained results indicates that similar to the compressive strength results, the flexural strength of the concrete is minimum at early period of hydration while the strength improves rapidly with longer hydration period. However, the flexural strength also decreases with higher ratio of CPA in the concrete mix.

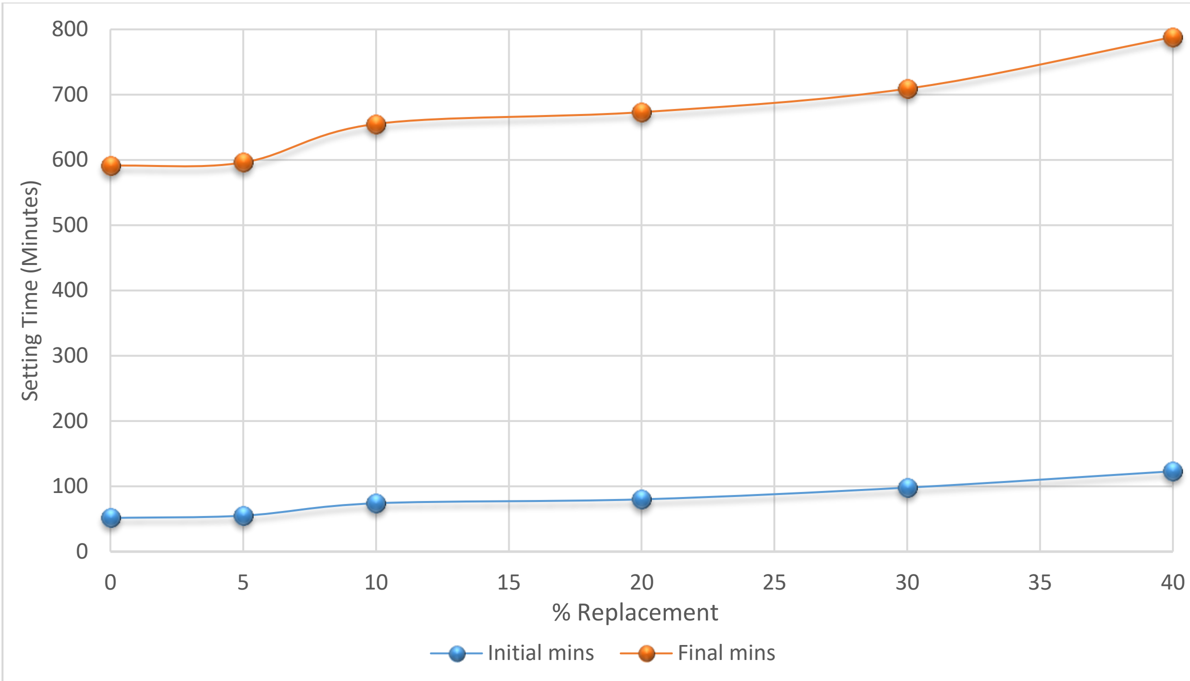

Fig 4. Setting time versus % replacement of CPA

Table 7.
Compressive Strength of Cassava Peel Ash Concrete.

	3-d (N/mm^2)	***7-d*** (N/mm^2)	***28-d*** (N/mm^2)	***60-d*** (N/mm^2)	***90-d*** (N/mm^2)
0% repl	13.93	21.93	29.33	33.17	35.23
5% repl	12.56	19.41	27.56	31.48	33.26
10% repl	10.15	15.73	26.19	30.52	32.67
20% repl	8	13.41	25.11	28.07	30.74
30% repl	5.93	11.33	23.26	26.77	29.93
40% repl	5.3	8.44	21.93	22.74	25.04

-d means hydration period (days)

Table 8.
Flexural Strength of Cassava Peel Ash Concrete

	3-d (N/mm^2)	***7-d*** (N/mm^2)	***28-d*** (N/mm^2)	***60-d*** (N/mm^2)	***90-d*** (N/mm^2)
0% repl	4.67	7.7	13.18	14	16.8
5% repl	3.33	5.25	10.73	12.48	15.17
10% repl	2.16	4.08	8.98	10.15	13.42
20% repl	1.34	3.5	7.58	8.98	12.13
30% repl	1.11	2.57	5.72	7.47	10.73
40% repl	0.82	1.52	5.02	6.07	8.98

-d means hydration period (days)

3.4.3. Compressive and flexural strength vs. concrete hydration period

The graph of average compressive and flexural strength of concrete versus hydration period of concrete is shown in figs.5 and 6. From the graph, it was observed that the compressive and flexural strength value obtained as compared to that of the control (0 % replacement)was very low and minimum at 40 % replacement for the earlier period of hydration (i.e. 3 -7 days). At moderate period of hydration (i.e. 28 days), relative increase in the strength properties were recorded while at longer hydration periods (i.e. 60 - 90 days), there is higher increase in the strength values obtained which indicates the commencement of the pozzolanic action which is as a result of the reaction of the CPA with the calcium hydroxide liberated during hydration of cement. And also the strength gain can be attributed to the cementitious products formed as a result of hydration of cement and those formed when lime reacts with the pozzolan incorporated which happens at longer period of hydration of the concrete samples.

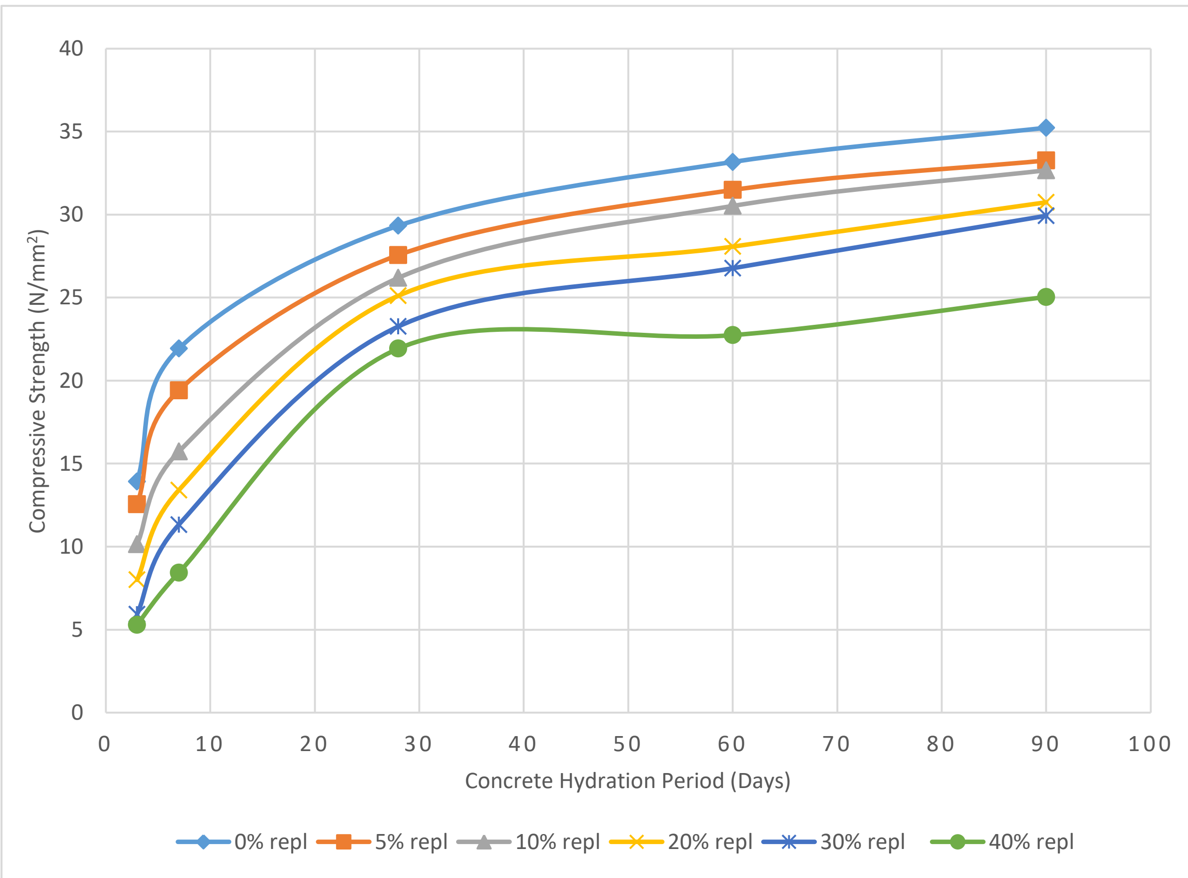

Fig. 5. Graph of compressive strength versus concrete curing age.

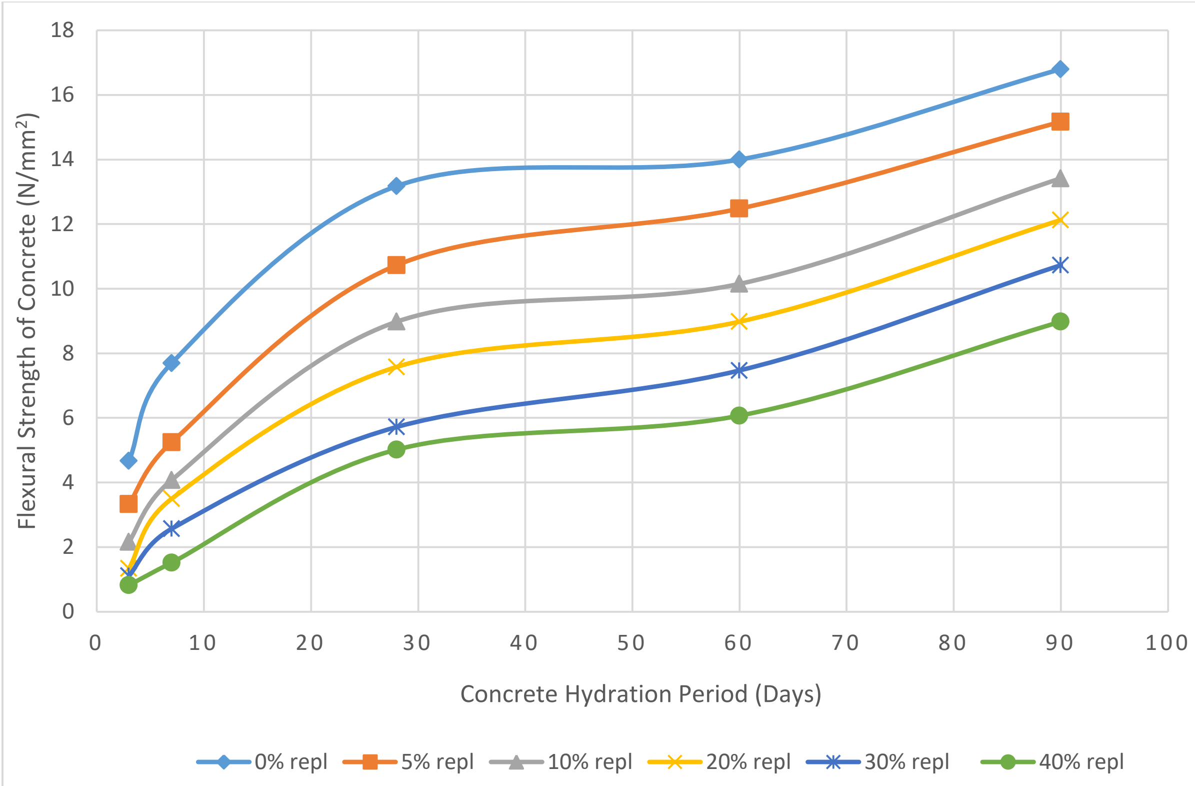

Fig. 6. Graph of Flexural strength versus concrete curing age.

3.4. Pozzolanic activity index (pai)

For the evaluation of pozzolanic activity of the CPA with cement, ASTM standard C618 – 78 prescribed the measurement of a pozzolanic activity index. This is established by the determination of strength of mixtures with a specific replacement of cement with pozzolana

$$\text{PAI} = \frac{\text{Crushing Strength of 35 \% repl. of cement with the Cassava Peel Ash at 28 days}}{\text{Crushing Strength at 28 days for the Control test}}$$

$$= \frac{20.22}{29.33} \times 100 = 75.8\%$$

Pozzolanic activity index is approved as a direct parameter for assessing pozzolanic activity of pozzolan. The pozzolanic activity index at 75.8% meet to demand of ASTM C618-00 Standard Specification. Therefore, the CPA is mechanically suitable for use as pozzolan in cement-based composite [15].

3.5. Statistical analysis and validation of results

3.5.1. Correlation analysis

The compressive and flexural strength of the concrete were averaged with respect to the three replicates and arranged as shown in table 9. This statistical analysis helps to establish relationships among the variables.

Table 9.
Parameters for the Correlation Analysis.

Compressive Strength (N/mm^2)							
hydration period	**0% repl**	**5% repl**	**10% repl**	**20% repl**	**30% repl**	**35% repl**	**40% repl**
90 days	35.23	33.26	32.67	30.74	29.93	29.90	25.04
60 days	33.17	31.48	30.52	28.07	26.77	25.54	22.74
28 days	29.33	27.56	26.19	25.11	23.26	20.22	21.93
7 days	21.93	19.41	15.73	13.41	11.33	11.15	8.44
3 days	13.93	12.56	10.15	8.00	5.93	5.44	5.30
Flexural Strength (N/mm^2)							
hydration period	**0%repl**	**5% repl**	**10% repl**	**20% repl**	**30% repl**	**35% repl**	**40% repl**
90 days	16.80	15.17	13.42	12.13	10.73	10.28	8.98
60 days	14.00	12.48	10.15	8.98	7.47	7.35	6.07
28 days	13.18	10.73	8.98	7.58	5.72	5.48	5.02
7 days	7.70	5.25	4.08	3.50	2.57	2.45	1.52
3 days	4.67	3.33	2.16	1.34	1.11	1.05	0.82

The statistical analysis was carried out using Minitab 18 Software and the correlation result is presented in the table 10.

Table 10.
Correlation analysis results.

Compressive Strength Results							
	0% repl	***5% repl***	***10% repl***	***20% repl***	***30% repl***	***35% repl***	***40% repl***
0% repl	1						
5% repl	0.998838	1					
10% repl	0.992269	0.996988	1				
20% repl	0.989473	0.994601	0.998559	1			
30% repl	0.989094	0.994404	0.999043	0.999607	1		
35% repl	0.987102	0.990632	0.993797	0.989628	0.992967	1	
40% repl	0.967866	0.976693	0.986412	0.99304	0.99102	0.969559	1
Flexural Strength Results							
	0% repl	***5% repl***	***10% repl***	***20% repl***	***30% repl***	***35% repl***	***40% repl***
0% repl	1						
5% repl	0.994248	1					
10% repl	0.994008	0.99796	1				
20% repl	0.992173	0.9961	0.998928	1			
30% repl	0.97395	0.986435	0.991464	0.994622	1		
35% repl	0.974731	0.987999	0.991618	0.99479	0.999734	1	
40% repl	0.975946	0.98929	0.993896	0.9932	0.996331	0.995682	1

The result shows a consistent and slight decrease in the correlation value from 0.9988 for 5 % to 0.9678 for 40 %replacement of the cement by CPA for the compressive strength while for the flexural strength, 0.9942 was obtained for 5 % and the correlation value decreased consistently to 0.97594 for 40 %replacement of the cement by CPA. From the results, it is observed that concrete with 5 %replacement of the cement by CPA performed better than the rest and thus the optimum combination level is between 5 % to 10 %replacement of the cement by CPA.

4. Conclusion and recommendation

In this study the effect and characterization of CPA concrete was assessed for the use of CPA which is an industrial/agricultural waste derivative for concrete production.

CPA was used to replace the cement content in the concrete varying replacement ratio was investigated in this study varying from 0 % to 40 % and also 35 % for the calculation and generation of the pozzolanic index of the CPA; this was obtained for varying hydration periods ranging from 3 days to 90 days.

The general physical behavior of the concrete aggregates, sieve analysis, fineness modulus and specific gravity was obtained to assess the gradation parameters and from the chemical analysis of the CPA samples, the total sum of Fe_2O_3, SiO_2, and Al_2O_3 is greater 70 % which indicates a good pozzolanic material.

The slump test carried out to assess the impact of cassava peel ash replacement ratio on the workability of the concrete. The results indicate that there is an indirect proportionality between the slump value and the replacement ratio.

The chemical composition of the cement and CPA is then generated to determine the dominant elemental oxides which would aid the pozzolanic reaction between the partially replaced cement paste and water. The surface area of 310 Kg/m^2 was also obtained.

The setting time results shows that the addition of CPA increases the initial and final setting time of the partially replaced cement paste.

The compressive strength was carried out for varying hydration periods to investigate the effect of CPA on early strength gain in concrete at prescribed replacement levels by cassava peel ash. It was observed that CPA concrete's strength is minimum at early stage but grows with longer hydration period but the concrete's compressive strength diminishes when the replacement ratio is increased from 5 % to 40 %.

The flexural strength result shows a better performance for the 5 % replacement while the flexural strength reduces with increased replacement ratio as observed in the compressive strength test results. This property also decrease with increased level of CPA content.

The pozzolanic activity index which is a direct parameter for assessing the pozzolanic activity of pozzolan is adapted in this study in accordance with ASTM standard C618-78 prescribed for the measurement of a pozzolanic activity index. With the index score of 75.8 %, it shows a satisfactory pozzolanic activity index for the cassava peel ash sample for concrete works.

The statistical analysis results shows a consistent decrease in the correlation value from 0.9988 for 5 % to 0.9678 for 40 % replacement of the cement by CPA for the compressive strength while for the flexural strength, 0.9942 was obtained for 5 % and the correlation value decreased consistently to 0.97594 for 40 % replacement of the cement by CPA.

Compliance with ethical standards

Conflict of interest

There are no recorded conflicts of interests in this research work.

Abbreviations

PAI – Pozzolanic activity index

CPA – Cassava-Peel-Ash

SCM – Supplementary Cementitous Materials

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