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ASSESSMENT OF STRENGTH PROPERTIES OF CASSAVA PEEL ASH-CONCRETE

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ABSTRACT

Basic conventional building materials like cement and aggregates are becoming increasingly expensive due to high cost incurred in their processes, production and transportation. The utilization of locally available materials such as cassava peel ash that can either reduce or replace the conventional ones is being considered. This paper investigated the effect of partial replacement of cassava peel ash with ordinary Portland cement at 5, 10, 15, 20 and 25%. The cassava peel ash was obtained by calcinations of cassava peel to 700^0 c temperature. Cube samples of size 150 x 150 x150 were prepared for concrete grade 30 and cured in water for 7, 14, 28, 90, 120 and 180 days after which they were subjected to compressive strength, tensile strength, durability, porosity, water absorption, slump, compact factor and shrinkage tests. The results showed that partial replacement of 10 and 15% gave compressive strength comparable to the control with 0% replacement and optimum replacement is 10%. It was discovered that the cassava peel ash contains all the main chemical constituents of cement though in lower percentage compared with OPC which shows that it can serve as a suitable replacement if the right percentage is used. However, its durability and sulphric acid resistance improved considerably at 10% replacement of cement with cassava peel ash. The study recommends that concrete made with cassava peel ash can be used for light construction works where high strength is not major requirement but where durability is a major concern.

Keywords: Cassava Peel Ash, Cement, Compressive strength, shrinkage, durability, Concrete

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1. INTRODUCTION

Building materials account for between 40-60% of the total construction cost (Ayangade et al., 2004; Olanipekun et al., 2006), and this is attributed to the fact that basic conventional building materials like cement and aggregates are becoming increasingly expensive due to high cost incurred in their processes, production and transportation. The utilization of locally available materials that can either reduce or replace the conventional ones is being investigated. In the same vein, developing nations of the world are challenged with issues of managing domestic and agricultural wastes as a result of the attendant growth in population and increasing urbanization. Reuse of these wastes provide an attractive option that promotes savings and conservation of natural resources from further depletion hence creating a sustainable environment. Solid waste and its resource potential are being appraised for reuse (Ofuyatan and Olutoge 2014). Agricultural waste such as corn cob ash and cassava peel ash inclusive is recently attracting interest (Adesanya and Raheem, 2009; Olushola and Umoh, 2012 and 2014). Cassava is known to be a major source of carbohydrates with Africa being the largest centre of production. The cassava tubers are peeled, and the discarded peel forms the first stage of the solid waste. These wastes would even be more problematic in future with increased industrial production of cassava products such as cassava flour and garri.

Concrete is widely used as construction material for various types of structures due to its durability. For a long time it was considered to be very durable material requiring little or no maintenance. Many environmental phenomena are known significantly for the durability of reinforced concrete structures. The use of rice husk ash (Salau et al., 2012), corncob ash (Adesanya and Raheem, 2009), periwinkle shell ash (Olusola and Umoh, 2012), and calcined termite mound (Olaniyi and Umoh, 2014) have been established to be suitable as cement supplements. Concrete structures are built in highly polluted urban and industrial areas, aggressive marine environments and many other hostile conditions where other materials of construction are found to be non-durable. The use of waste materials with pozzolanic properties in concrete production is a worldwide practice.. The assessment of the pozzolanic activity of cement replacement materials is becoming increasingly important because of the need for more sustainable cementing products. One way is to use certain low cost materials for partial replacement of Portland cement clinker.

Blended cements are hydraulic binders in which a part of Portland cement is replaced by other hydraulic or non-hydraulic materials. Their general behavior is quite similar to that of Portland cement since they harden when mixed with water and form the same hydration products. Cassava Peel (CP) is a by-product of cassava processing, either for domestic consumption or industrial uses. Adesanya et al. (2008) reported that cassava peel constitutes between 20-35% of the weight of tuber, especially in the case of hand peeling. Based on 20% estimate, about 6.8 million tonnes of cassava peel is generated annually and 12 million tonnes is expected to be produced in the year 2020. Indiscriminate disposal of cassava peels due to gross underutilization as well as lack of appropriate technology to recycle them is a major challenge, which results in environmental problem. Thus, there is need to search for alternative methods to recycle them (cassava peels).

Frías et al (2007), Cizer et al.(2006) and Ketkukah and Ndububa (2006) are some of the notable researchers who have demonstrated the use of ashes of rice husk, sugar cane straw and groundnut husk as pozzolan in concrete. They have shown that compressive strength of concrete incorporating these ashes increases while the workability is enhanced. In the works of Chandrasekhar et al. (2003), the use of rice husk ash reduces the effects of alkali-silica reactivity as well as drying shrinkage. Mehta and Monteiro (2004) reported that the performance of these materials, as pozzolans, depends on the type and amount of amorphous silica content they contain which further depend on duration and calcination temperature.

Chandrasekhar et al. (2003) suggested burning temperature of 650^0C for 60 minutes in the case of rice husk ash while between 800^oC and 1000^0C was used for sugar cane straw ash (Moisés et. al, 2007). Therefore, this study is aimed at assessing Cassava Peel Ash as Partial Replacement for Cement to Improve Strength Characteristic of Concrete.

2. MATERIALS AND METHOD

Ordinary Portland Lime Cement was used for this experiment which conforms to the requirements of BS 1881. River sand used for this study was obtained from Majidun River in Lagos free from deleterious materials and crushed granite from a quarry site at Lagos Ibadan expressway. The cassava peel was incinerated in an oven at 10^0C per minute up to 700^0C and was maintained at this temperature for 6 hours to produce the ash. The specific gravity was determined. The cassava peel ash (CPA) was sieved and large particles retained on the 600μm sieve were discarded while those passing the sieve were used for this work. No further grinding or any special treatment to improve the quality of the ashes and enhance their pozzolanic was applied because the researchers wanted to utilize simple processes that could be easily replicated by local community dwellers. The CPA had a bulk density of 852 Kg/m^3, specific gravity of 1.92, and fineness modulus of 2.13.

2.1. Mix Proportions and Casting of Concrete Cubes

Water/cement ratio of 0.60 and mix of 1:1:1.5 was adopted. Concrete cubes were prepared in varying percentages replacement by weight of cement to cassava peel ash of 0, 5, 10, 15, 20 and 25%. The specimens were made in accordance with BS 1881.

Cubes prepared were cured for 7, 14, 28, 90, 120 and 180 days, respectively. The cubes were weighed before testing and the densities of cubes at different time of testing were measured. The strength of the cubes were tested in accordance to BS 1881 using universal testing machine also the shrinkage test until the time of test. Splitting tensile strength was also measured on three replicate 76×152 mm cylinders loaded at a rate of 370 N/s, as outlined in procedure of ASTM C 496.

Shrinkage was measured according to ASTM C 157 on the three samples-(control) and cassava peel ash concrete mix. The aforementioned design mixture was scaled down to make 76×76×286 mm concrete prisms. These were removed from molds 24 hours after casting and allowed to cure in limewater for one week. Samples were moved to the laboratory at 23°C and 50% relative humidity to evaluate drying shrinkage. Measurements were recorded at 1, 3, 5, 7, 10, and 14 days for six weeks.

The Rapid Chloride Permeability test (RCPT), in accordance to ASTM C 1202 was performed on samples 102×203 mm concrete cylinders and moist curing at 7, 28, and 90 days. The sulfate resistance test samples 25×25×286 mm mortar bars were exposed to a 33,800 ppm sulfate solution (50 g/L sodium sulfate) at room temperature. Normal Consistency of ordinary Portland cement (OPC) and cassava peel ash (CPA) mixed cement was obtained according to ASTM C 187-98. The standard consistency was used to find out the initial and final setting time of the mortar. Also unit weight and slump was measured according to ASTM C 143. Durability test was carried out by immersing the cube samples in water at a constant temperature of 20 ± 0.5^o C for a period of 16 hours. The specimens were removed and placed in an oven pre-heated to 105^oC to dry for six hours.

3. RESULTS AND DISCUSSION

The cassava peel ash was grounded to fine particles as finer as OPCs. This was done so that the compressive strength values obtained using this ash is improved upon as compared to previous research. The bulk density and specific gravity of each of the ashes were much lower than that of OPC. Thus, partially replacing the ashes with OPC resulted in reduced weight of concrete members. Tables 1 show the oxide composition of the CPA and OPC respectively. From Table 1, CPA contains 59.72% SiO2, 11.10% Al2O3 and 1.52% Fe2O3. This gives 72.34% of SiO2+ Al2O3+Fe2O3 which is in line with ASTM C 618-78 requirement of 70% minimum for pozzolanas. Thus, CPA meets the requirement for a pozzolana. The LOI of 5.07 and SO3 of 2.08 all fall within agreeable limits. The chemical compositions of the ashes showed that cassava peel ash did satisfy the ASTM requirement that the sum of SiO2, Al2O3, and Fe2O3 should not be less than 70%. However, since the pozzolanicity test was positive, this confirms CPA as a pozzolan. It could be reasoned that the ASTM requirement does not mean any material that falls short of it is not pozzolanic; it could rather be interpreted as criterion for high pozzolanicity of materials.

Table 1 Chemical Composition of Cassava Peel Ash (CPA) and Cement

Materials	Chemical Composition %								
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	LOI
Cement	18.22	5.11	2.72	60.14	1.25	3.31	0.08	0	7.23
CPA	59.72	11.1	1.52	8.42	5.22	2.08	6.82	0.05	5.07

3.1. Slump Test

In table 2 the results of the slump test on concrete are shown with varying percentage of CPA as replacement for cement. The results show that for all mixes, the slump type was 'true slump' except for mixes containing more than 15% CPA at 0.64 water-binder (w/b) ratios, where the mixtures were very viscous and stiff due to inadequacy of water. The slump decreases with increase in amount of CPA for the same water-binder ratio. This indicates that more water is required to maintain the same consistency as the CPA content increases. Cassava peel ash has potential to absorb more water than ordinary Portland cement in the mix. The recent European standard states that the slump test is sensitive to changes in consistency corresponding to slumps between 10 and 200 mm and the test is not considered suitable beyond these extremes (Domon, 2003). Also, mix having slump between 24-31 mm is considered being plastic and required either mechanical or hand compaction.

Table 2 Slump and compacting factor values for CPA blended cement concrete

CPA content (%)	Slump (mm)	Compacting factor	Actual water/ cementitious materials ratio
0 (control)	31	0.86	0.62
5	29	0.84	0.61
10	28	0.83	0.63
15	27	0.82	0.64
20	25	0.81	0.65
25	24	0.80	0.64

3.2. Compacting Factor Test

The results of the compacting factor test conducted on samples of cement CPA blended concrete at various percentage replacements with 0.6 water binder ratios are also shown in Table 2. It is observed that compacting factor (CF) of mixes containing 20% and 25% CPA at 0.6 water-binder ratio was stiff and hard. This shows that more water is needed to achieve better workable mix. The compactor factor decrease with increase in percentage in cement replacement. According to BS 1881 103, the compacting factor lies between 0.8 and 0.92 for normal range of concrete. Compacting factor measures the effect of a standard amount of work (height of fall) on compaction, hence, requires adequate water content to achieve relatively full compaction. This is true in the case of water-binder ratios of 0.6 for all the mixes.

3.3. Density

The results for densities of concrete made with 0 to 25% at interval of 5% replacement of cement with CPA show that the densities range between 2410 and 2493 Kg/m^3 indicating that they can be categorized as normal concrete with density of 2400 Kg/m^3. It is observed that the percentage replacement level of cement with CPA did not have any appreciable influence on the densities of the test specimens of the blended concrete. This may be attributed to the lower specific gravity of the CPA which was much lower than that of cement. This further shows that the concrete density does not solely depends on the binder content but is mainly depends on the amount and density of the aggregate, how much air is entrapped or purposely entrained, and the aggregate size.

3.4. Compressive Strength

The compressive strength of the specimen for each set, up to 180 days hydration is as presented in “Fig.1”. The results show that the compressive strength generally decreases with increase in the percentage of CPA content but increases with curing age. The compressive strength attainment at control for 7, 14, 28, 90, 120, and 180 days are 20.3-, 23.4-, 29.4-, 29.47-, 30.7-, 31.4- N/mm^2 which shows percentage increase of 15.27%, 44.83%, 45.17%, 51.23%, 54.68%, respectively. This shows that the control concrete increases as the curing day increases up to the 180 days used in this study. At 5% replacement of cement with CPA, percentage deviations from control at 7, 14, 28, 90, 120, 180, days, are 95.42%, 97.99%, 97.04%, 96.37%, 96.42%, 97.45%. This shows a minimal deviation from control at all ages of curing. At 10% replacement of cement with CPA, percentage deviation is 90.64%, 93.88%, 93.44%, 95.93%, 95.67%, 95.22% while that of 15% and 20% cement replacement with CPA follows the same trend. However, the percentage deviation of the 25% cement replacement with CPA is much more lower with percentage deviation of 64%, 62%, 61%, 63%, 63.5% and 64.%.

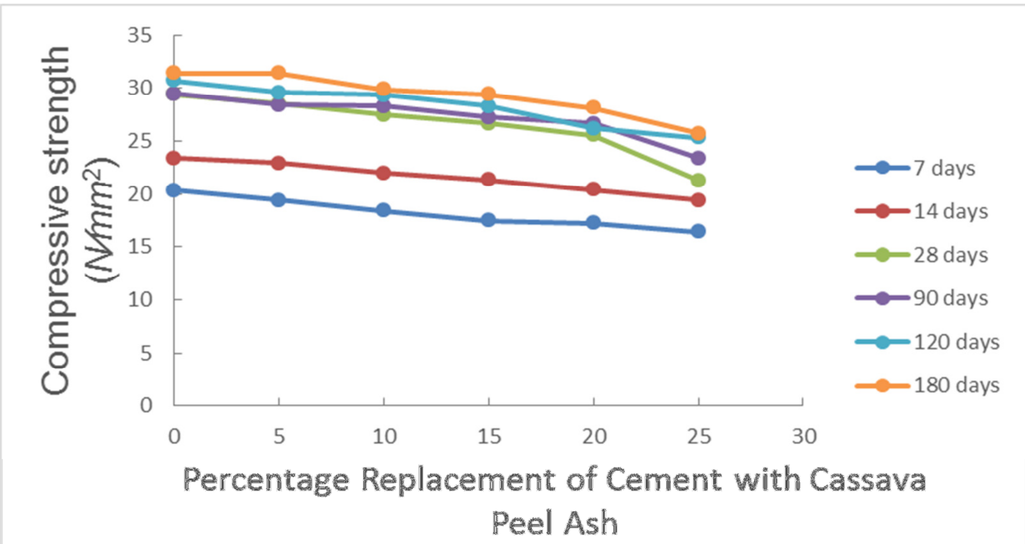

Figure 1 Compressive Strength of Cassava Peel Ash Blended Cement Concrete with Varying Curing Ages

These can only produce lightweight concrete. From above analysis, it is seen that CPA can successfully replace up to 20% of cement in a concrete and still produce a normal strength concrete. This confirmed the assertion by Bakar et al. (2010) that when cement is blended with pozzolan, the strength produced will be in the range of 65 – 90% of the normal concrete at 28 days, and that the blended cement concrete compressive strength normally improves with age and at one year could attain the same strength as that of normal concrete. This also satisfies the strength requirement of over 75% as stipulated by ASTMC 618 (2008) for pozzolanic materials to be used as cement replacement.

3.5. Tensile Splitting Strength

The results of tensile splitting strength is shown in Figure 2 The tensile splitting strength in each case generally increases with increase in curing age but decreases as the percentage of the CPA increased from 5% to 25%. It was equally observed that, 5% cement replacement by CPA had tensile splitting strength range of 2.51 to 3.82 between 7 to 180 days curing

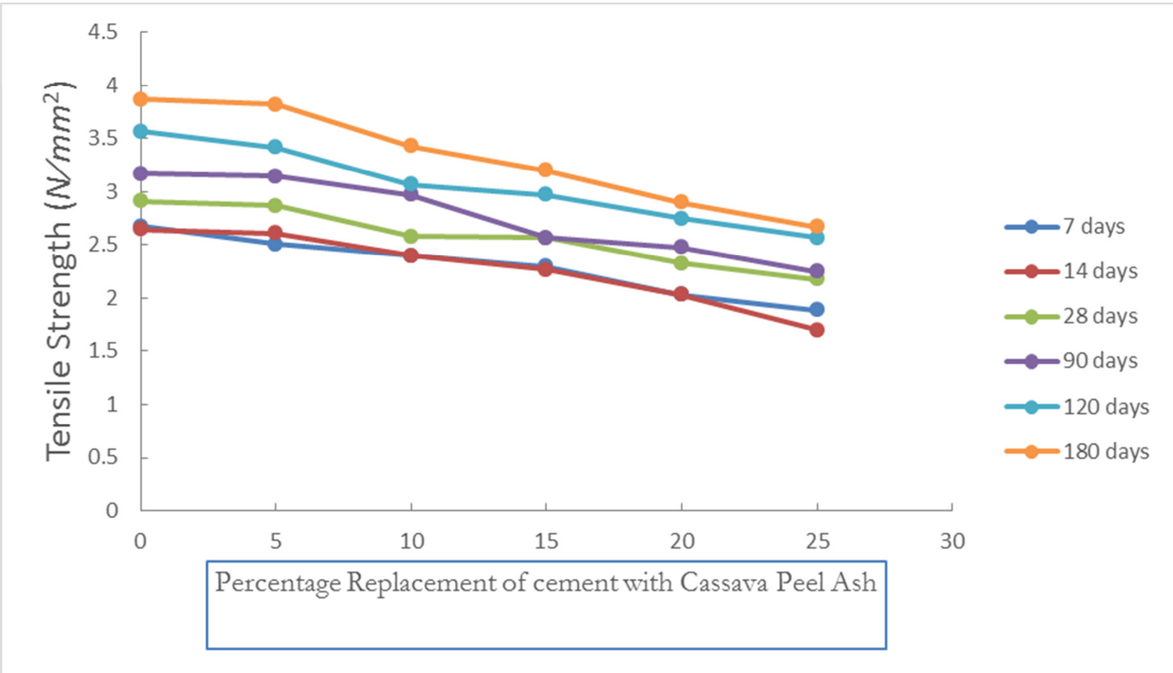

Figure 2 Tensile Strength of Cassava Peel Ash Blended Cement Concrete with Varying Curing Ages

which is 90% deviation from control, 10% had a range of 2.4 to 3.43 which is average percentage deviation of 85%, the range for 15%, 20%, and 25% are 2.3 to 3.2, 2.03 to 2.9, 1.89 to 2.69 which are 80%, 75%, and 70%, respectively. Based on this performance, 15% and 20% can be regarded as an optimum cement replacement for CPA that can enhance the serviceability performance of the binary blended cement concrete with cassava peel ash. Concrete is not normally designed to carry load in tension, hence its tensile strength is generally considered as a negligible parameter. However, the knowledge of tensile strength as stated by Bakar (2010) is of importance in concrete structures particularly with regards to crack mitigation. For serviceability Limit states, tensile strength is often a more important parameter than compressive strength.

3.6. Water Absorption

The values of the absorbed water indicated that 5% CPA cement replacement had the least amount of absorbed water while 25% had the most water absorption. The water absorption increases with each curing age. It was also noted that the absorbed water was less at 180 days than at 28days. The water absorption values at 180 days was observed to decreased by 0.20%, 0.74%, 1.26%, 1.72%, 1.57% and 0.82% for control at 5,10, 15, 20, 25, respectively. Also, 5% replacement had the least value of water absorption when compared to other percentage replacement. A minimal water absorption by mix at lower percentage replacement is attributed to the formation of less amount of pores as a result of improvement in the interface transition zone by the pozzolanic reaction and therefore a reduction in permeable voids; whereas, greater volume of pores must have been created in other percentage replacements which could be due to excess filler materials of the CPA which have not been consumed by the pozzolanic reaction and thereby forming permeable spots for water penetration.

3.8. Porosity Test Results

The Porosity of the blended cement concrete with various weight percentages of CPA is presented in Table 4. The porosity of concrete reduced with an increase in age. This is probably due to the increase in hydration of the cementious materials. The porosity for the mixes showed an increased in the values with increased cement replacement but decrease with curing age. It was also observed that 15% cement replacement had the highest porous value compare to the control. The mix containing 25% of cement replacement had a better permeability performance than the control and other mixes which contain CPA percentage mass greater than 15% as cement replacement. This could be attributed to the fact that many of the pores have not been filled by the formation of pozzolanic compounds. The improvement of permeability performance of binary blended cement concrete over the reference confirmed the earlier finding by Elinwa and Awariet (2001) that the use of binary blended cement concrete improved the water absorption and porosity of concrete as compared to normal concrete made with Portland cement alone. Therefore, it can be said that 15% concrete is less impermeable and therefore has better resistance to water permeability and thereby making it more durable than the normal concrete made of Portland cement as the only binder.

Table 4 Porosity of the Binary Blended Cement Concrete with Various Weight Percentages of CPA

	Porosity at different Ages			
Mix	**Porosity %**	**7days**	**28days**	**90days**
1	0	19.4	15.9	15.2
2	5	19.2	16.1	15.6
3	10	19.8	16.4	15.8
4	15	20.2	17.4	16.6
5	20	20.8	17.8	17.2
6	25	21.6	18.6	17.9

3.9. Drying Shrinkage:

The results showed that the CPA average particle size had a significant effect on the drying shrinkage. 20 % concrete Mixture exhibited higher shrinkage value than the control. 15% concrete was comparable, while the shrinkage for 25% was lower compared to the control. The high fineness of CPA particle size increased the pozzolanic activity and contributed to the pore refinement of the CPA concrete paste matrix. Thus, it can be concluded that the addition of micro-fine particles to concrete would reduce the drying shrinkage.

3.10. Rapid Chloride Permeability Test

The test results for the rapid chloride penetration into cassava peel ash concrete specimens at 7, 28 and 90 days were 4400, 3650 and 2464 coulombs, respectively while that of normal concrete is 6650, 5608, and 2750 coulombs, respectively. The test results showed that the cassava peel ash concrete mixes produced lower permeability results at 7, 28, 90 days.

3.11. Sulfuric Acid Resistance Test

The test for acid resistance is done by mixing 5% sulphuric acid solution in distilled water. The cubes are immersed in solution for 180 days. The weight and compressive strength of specimens were measured before and after test and compared. The weight loss compared to control mix at 5, 10, 15, 20 and 25% was 0.6, 0.9, 0.5, 1.3 and 1.9 %, respectively. It was observed that 15% had the highest resistance to acid attack.

4. CONCLUSIONS

Based on the research work carried out, the following conclusions were made:

1) The Slump and compaction factor values for the concrete shows that the slump decreased with increasing cassava peel ash replacement while the compacting factor increases with increasing CPA content and the values falls within the value for normal range of concrete.
2) The Initial and final setting time of the OPC/CPA mixes (at 5% and 10%) was found to increase with increasing replacement. This means that CPA concrete is not susceptible to the problem of false set.
3) The OPC/CPA mix had standard consistency of 28% which is greater than that of OPC.
4) The specific gravity of the CPA obtained is less than that of the OPC that it replaced which means a considerable greater volume of cementious materials will result from mass replacement.
5) It was discovered that the cassava peel ash contains all the main chemical constituents of cement though in lower percentage compared with that of OPC which means it can serve as a suitable replacement if the right percentage is used.
6) The compressive strength of concrete specimens decreased as the percentage of cassava peel ash increases. Also, compressive strength increases as the age of curing increases for each of the percentage replacement.
7) The durability and acid resistance improved considerably at 10% replacement for cement with cassava peel ash.
8) Concrete with cassava peel ash can be used for light construction works where high strength is not major requirement but where durability is a major concern.

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