EFFECT OF CASSAVA PEEL ASH AND EGG SHELL POWDER AS PARTIAL REPLACEMENT OF CEMENT IN CONCRETE

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Abstract: The major problem facing the world today is environmental pollution. Production of Portland cement causes the emission of carbon dioxide resulting to environmental pollution and global warming. This research is on the effect of cassava peel ash (CPA) and egg shell powder (ESP) as partial replacement of cement in concrete production. The cassava peel (CP) used was sourced from a local industries while the egg shell (ES) used was sourced from bakeries and restaurants. The CP was sun dried, burnt and sieved through a 75 µm sieve, while the ES was washed, sun dried, ground and sieved through a 75 µm sieve, and both materials were characterized by X-Ray Fluorescence (XRF) analytical method. The consistency, setting times and drying linear shrinkage of cement paste with CPA and ESP of 0, 5, 10, 20, 30 and 40%, respectively by weight of cement were investigated in accordance with standard procedures. CPA and ESP were mixed in a proportion of 10:90, 20:80, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80 and 10:90, respectively for the partial replacement of 0, 5, 10, 20, 30 and 40%, respectively by weight of cement. A total of six hundred and seventy five numbers of 150 mm cubes of hardened concrete were tested for compressive strength at 3, 7, 28, 56 and 90 days of curing in accordance with standard procedures. The results of the investigations showed that CPA was predominantly of Silicon oxide (56.73%) and a combined SiO_2, Al_2O_3 and Fe_2O_3 content of 66.75%; and the result of the investigations showed that ESP was predominantly of Calcium oxide (52.75%) and combined SiO_2, Al_2O_3 and Fe_2O_3 content of 0.22%. The addition of CPA and ESP in concrete production showed slight increase in compressive strength with increase in CPA/ESP additive up to 10% and decrease in compressive strength with further increase in CPA/ESP content. The 28 days compressive strength of concrete containing 10% CPA/ESP content was 6.4% more than normal and 10% CPA/ESP would be considered as the optimum percentage replacement; while that of concrete with 20% CPA/ESP content was 14.9 % less than normal.

Keywords: Concrete, cassava peel ash, egg shell powder, compressive strength

Introduction

The over dependent on the utilization of industrially manufactured binding materials (cement) have kept the cost of construction financially high, and this has up till now prevented third world countries like Nigeria in providing cheap housing for its citizen particularly rural dwellers that are mostly agriculturally dependent (Agbede and Joel, 2011). The use of waste materials as a partial or full replacement of cement in mortar and concrete can be an important step towards sustainability in the construction industry worldwide, since cement is used as their main binder (Krammart and Tangtermsirikut, 2004). The use of alternative binders that are less pollutant and/or the use of residues could impact the construction industry towards the production of concrete with less environmental impact. According to Ramezanianpour *et al*. (2009) the cost of cement production is expected to decline when Portland cement is partially replaced by rice husk ash, a pozzolana from agro-waste product. In the other hand, a modern life style alongside the advancement of technology has led to an increase in the amount and types of waste being generated, leading to waste disposal crisis (Sunusi, 2015). This research tries to tackle problem of the waste that is generated from cassava peels and egg shell.

Cassava peel is a by-product of cassava processing, either for domestic consumption or industrial uses. According to Adesanya *et al.* (2008) 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 tons of cassava peel is generated annually and 12 million tones are 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 cassava peels.

Salau and Olonade (2011) studied the pozzolanic potential of cassava peel ash (CPA) and their results showed that cassava peel ash possesses pozzolanic reactivity when it is calcined at 700°C for 90 min. At these conditions, CPA contained more than 70 per cent of combined silica, alumina and ferric oxide, but has low calcium oxide (CaO) which is the source of binding.

Egg shell consist of several growing layers of Calcium Carbonate ($CaCO_3$) and it is a poultry waste with chemical composting nearly same as that of limestone (Kumar *et al.*, 2017). Use of egg shell waste to replace cement can have benefits like minimizing use of cement, conserves natural lime and utilizing waste materials, majority of egg shell wastes are deposited in landfill and it attracts vermin and causes human health and environmental problems (Raji and Samuel, 2015).

Okonkwo *et al*. (2012) concluded in their research that Egg Shell powder (ESP) can be used as an alternate for cement which resulted in higher compressive strength of concrete. Ultimately, they found that soil-cement-egg shell mixture can be used for road pavements. Arash *et al*. (2012) carried out an experiment on the effect of eggshell powder on plasticity index in clay and expansive soils and reported that plasticity index of the soil can be improved by adding egg shell wastes with the clay soil and can be used in construction projects including earth canals and earth dams.

The dominant oxide in ESP and CPA are CaO and SiO_2, respectively. CaO is the main source of binding and hardening compound in cement, when reacted with water (hydration reaction), which is very high in ESP and low in CPA. But, the SiO_2 in CPA reacts with Ca $(OH)_2$ (by product of cement hydration) to produce more binding property (Pozzolanic reaction). ESP is rich in CaO and would increase the amount of Ca $(HO)_2$ present in the system. The advantage of reduction in the consumption of cement leading to reduction in the greenhouse effects caused by cement usage is being exploited by the use of pozzolana in concrete and mortar production.

Materials and Methods

Materials

The sand was obtained from River Umarin Bida, Niger State, Nigeria; and the particle size distribution curve of the sand is shown in Fig. 1. The coarse aggregate is crushed granite of nominal size of 20 mm obtained from local vendors. The physical properties of the materials are shown in Table 1. Dangote brand of ordinary Portland cement of Grade 42.5N (3X) was used for this research, which complied with BS EN 197-1 (2009). The oxide composition of the cement is shown in Table 2. Cassava peel and Egg shell were sourced from local Garri Industries and Bakeries in Bida, Niger State, Nigeria. The Cassava peel and Egg shell were sundried.

Methods

The cassava peel ash (CPA) was obtained by burning the cassava peel to ash and under a controlled temperature of about 600°C in a kiln and controlling the firing at that temperature for about two (2) h and the ash was allowed to cool. After cooling, the resultant CPA grounded and sieved using BS sieve No. 200 (75 μm) sieves. The egg shells powder was obtained by cleaning the shells. The resultant egg shells were dried naturally and subsequently ground into a powder form, and the powder was sieved using BS sieve No. 200 (75 μm) sieves. Chemical composition analysis of the CPA and ESP was conducted using X-Ray Fluorescence (XRF) analytical method and the results are shown in Table 2.

Sieve analysis was used to find the particle size distribution of fine and coarse aggregates, in accordance with standard BS EN 12620 (2013). The result is shown in Fig. 1. The specific gravity test was conducted on cement, CPA, ESP, sand and crushed granite in accordance with BS 8500 (2000). The result is shown in Table 1; while the oxide composition of cement, CPA and ESP was conducted based on ASTM C311 at the Centre for Energy Research and Training (CERT) Zaria, Kaduna State. The result from this analysis is presented in Table 2. Compressive strength test was conducted on the concrete samples using different percentage of CPA and ESP (0, 5, 10, 20, 30 and 40%). Cube mould of sizes 150 × 150 × 150 mm was used to cast a total of 810 cubes for testing the effect of CPA/ESP on the compressive strength of concrete, for a proportion of 10:90, 20:80, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80 and 10:90, respectively for the partial replacement of 0, 5, 10, 20, 30 and 40%, respectively by weight of cement. The cubes were cured for 3, 7, 28, 60 and 90 days and crushed to determine their compressive strength in accordance with BS EN 12390- 3 (2009). The behavior of the effect of CPA and ESP on concrete strength was determined and average recorded.

Results and Discussion

Physical properties of concrete constituent materials

The physical properties of the constituent materials are shown in Table 1, whereas the particle size distribution curves are shown in Fig. 1. The particle size distribution curve indicates that the sand used was classified as zone 2 based on British Standard classification BS 882, Part 2, (1992) grading limits for fine aggregates and was well graded.

Table 1: Physical properties of ordinary port-land cement, CPA and ESP

Property	Value		
	OPC	CPA	ESP
Specific gravity	3.14	2.23	1.29
Fineness (% passing 90 µm sieve)	94	100	100
Loss on Ignition	1.3	5.84	42.16
Colour	Dark grey	Brownish grey	Whitish

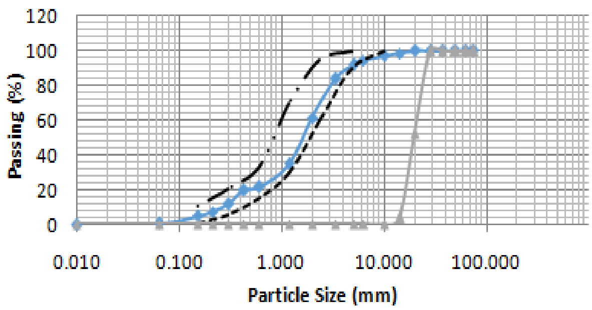

Fig. 1: Particle size distribution of fine and coarse aggregate

Chemical properties of cement, CPA and ESP

The oxide composition of cassava peel ash (CPA) is presented in Table 2 and it indicated that the predominant oxide is Silicon oxide (56.73%) and a combined SiO_2, Al_2O_3 and Fe_2O_3 content of 66.75%; The oxide composition of egg shell powder (ESP) is presented in Table 2 and it indicated that the predominant oxide isof Calcium oxide (52.75%) and a combined SiO_2, Al_2O_3 and Fe_2O_3 content of 0.22%. This shows that ESP is cementitious and may combined with CPA containing high silicon, iron and aluminium oxide in a hydrated mix and due to pozzolanic reactions to yield final products that are similar to those obtained from cement hydration process. The SO_3 content was found, which according to ASTM C618 (1993) should not be more than 5.0%. Nuruddeen (2012) reported that, the SO_3 content affect the strength of mortar and concrete specimens to some degree. The higher the SO_3 content, the higher the resultant strength.

Table 2: Oxide composition of OPC (Dangote brand) CPA and ESP

	Oxide Value (%)										
	SiO_2	Fe_2O_3	Al_2O_3	CaO	K_2O	SO_3	MgO	Na_2O	MnO	ZnO	LOI
Cement	18.1	4.82	3.10	68.37	0.35	1.82	1.48	0.32	0.03	0.00	1.27
CPA	56.73	2.78	7.24	8.65	3.93	1.30	2.58	0.41	0.78	0.05	7.842
ESP	0.09	0.06	0.07	52.75	0.31	1.54	0.73	0.00	0.00	0.00	---

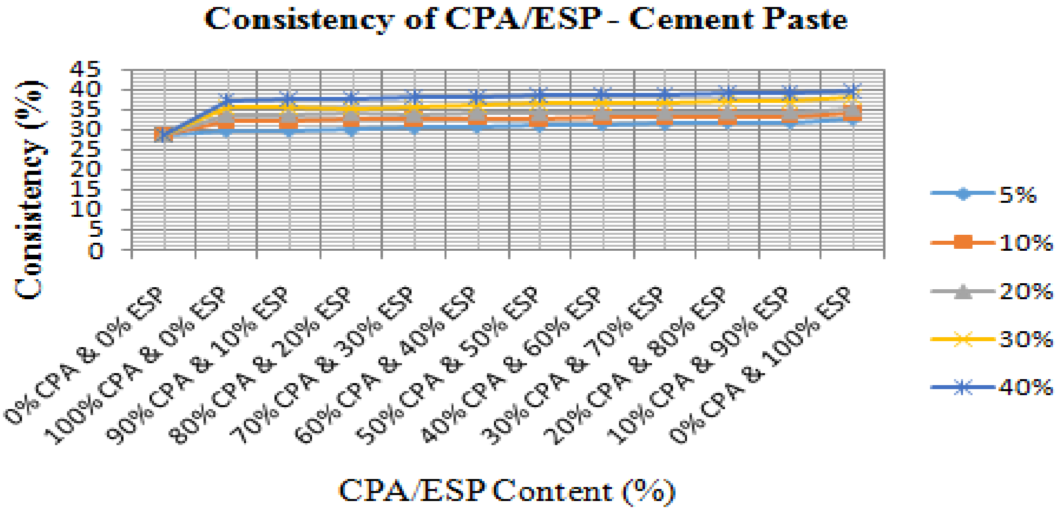

Fig. 2: Consistency of CPA and ESP- cement paste

Consistency of CPA and ESP–cement pastes

The consistency of CPA and ESP - Cement Paste is shown in Fig. 2 and it was observed that water requirement increases with increase in CPA content. This shows that CPA absorbs more water than the ESP. The normal consistency of cement paste was 31.0% while those of CPA and ESP-Cement Pastes ranged 31.2 – 39.6%, depending on CPA and ESP content. The increase in water requirement with increase in CPA and ESP content may be due to high porosity as well as high of LOI of CPA (Jaturapitakkul and Roongreung, 2003). In addition, a less specific gravity of both CPA and ESP compare to OPC, will give rise to a large volume of water to be required to properly wet excess volume of CPA and ESP added to the mix to produce CPA and ESP-cement gel and this could lead to increase in consistency of the CPA and ESP-cement paste, this is in line with the statement by Ettu *et al.* (2013).

It was observed that the higher the contents of CPA and ESP in the cement paste, the faster the setting of the cement, for all the percentage replacement of CPA and ESP with OPC. These values were all within the permissible limits as per BS 12 (1991). The behavior of setting time due to the addition of reaction activity of CPA and ESP, as the silica and alumina react with calcium hydroxide (by product from hydration) to form additional calcium silicate and calcium aluminate, may result in quick setting. This is in line with the statement by Mtallib and Rabiu (2009), Ujin *et al*., (2017) and Balamurugan and Santhosh (2017) that the high quantity of CaO in egg shell powder (ESP) paste provides additional C-S-H for the rapid consumption of C_3S in the OPC which resulted in the acceleration of hydration of the OPC.

Compressive strength of CPA and ESP – concrete

The result of compressive strength of cement-CPA and ESP blended concrete is shown in Fig. 3a – e and it was observed that the compressive strength irrespective of the amount of CPA and ESP in the mixture, increase with curing age and deceased with higher content blended CPA and ESP content. The compressive strength of control samples was less than that of samples containing up to 10% of combined CPA and ESP but higher than that of samples containing more than 10% of CPA and ESP at all ages. It was observed that the 28 days compressive strength of concrete with up to 20% CPA and ESP content exceeded the design characteristics strength, and basically meet the minimum standard in BS 1881: Part 116: (1983) which recommend compressive strength for 28 days to be 20 to 34 N/mm^2 for normal weight concrete, depending on factor such as aggregate grading, mix proportioning and w/c ratio. CPA and ESP can be used as partial replacement of cement, though to a certain limit. Based upon the chemical composition, SiO_2 rich CPA is reactive when in contact with CaO, to give more strength; ESP has significant amount of CaO, which react with SiO_2 from CPA to consume the excess CaO, resulting in enhancing in the strength of concrete.

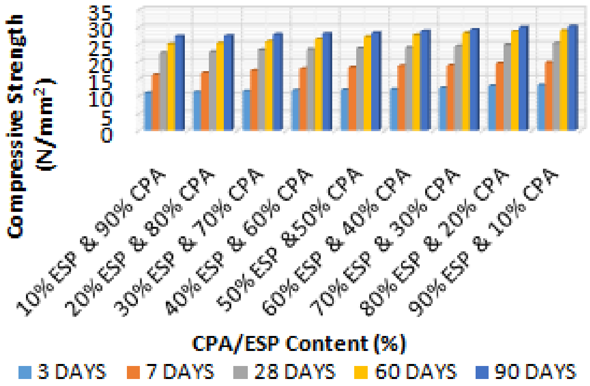

Fig. 3a: Compressive strength of CPA/ESP – concrete (5% replacement)

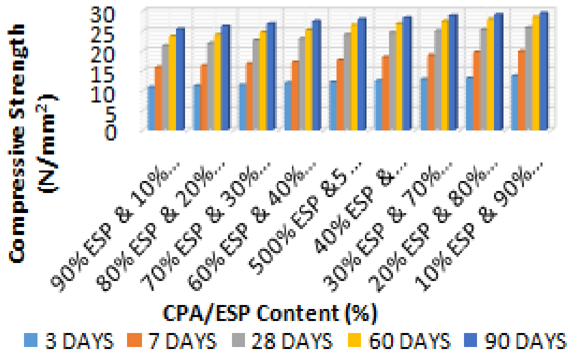

Fig. 3b: Compressive strength of CPA/ESP – concrete (10% replacement)

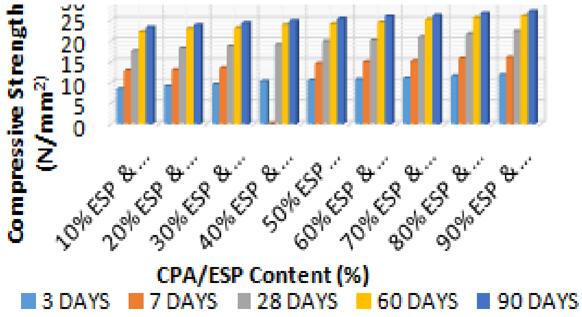

Fig. 3c: Compressive strength of CPA/ESP – concrete (20% replacement)

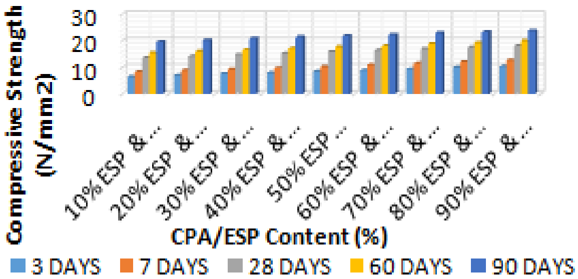

Fig. 3d: Compressive strength of CPA/ESP – concrete (30% replacement)

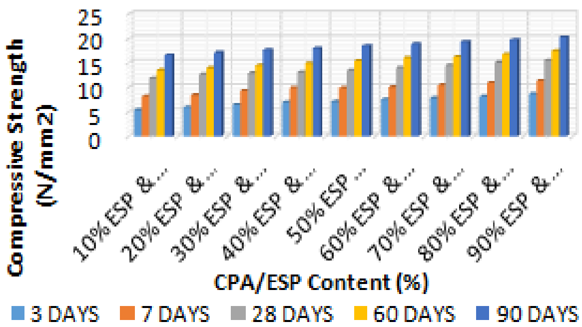

Fig. 3e: Compressive strength of CPA/ESP – concrete (40% replacement)

The decrease in compressive strength of concrete with increase in CPA and ESP content would be due to dilution effect of Portland cement and weaker formation of C-S-H gel as a result of slow pozzolanic reaction of CPA and ESP. Similarbehavior was reported by Salau (2012) on CPA and Oyekan and Kamiyo (2011) reports on rice husk ash (RHA). The drastic reduction in the compressive strength of concrete containing CPA and ESP of 20% and above may be due to the fact that CPA and ESP is a slow reactive pozzolana, which may not be combine with the lime liberated during the process of hydration and hence leading to excess silica leached out of the concrete and causing a deficiency in strength (Ogork, 2012).

Conclusions

The results obtained from the experimental works show that Cassava Peel Ash and Egg Shell Powder can replace cement in concrete production. The following conclusions can be drawn.

i) Cassava Peel Ash and Egg Shell Powder can be formed into useful binding materials.
ii) With increase in the percentage of CPA/ESP, the compressive strength of concrete increases up to an optimum value and beyond that value, the strength start reducing.
iii) By replacing with CPA/ESP above 10%, reduction in compressive strength was high at the age of 28 days, especially when the percentage of CPA is higher than that of ESP,
iv) The 28 days compressive strength of concrete with 20% CPA/ESP content exceeded the design characteristics strength, and basically meet the minimum standard, which recommend that compressive strength for 28 days to be 20 to 34 N/mm^2 for normal weight concrete, depending on factor such as aggregate grading, mix proportioning and w/c ratio.

Recommendations

On the basis of the investigations carried out on CPA and ESP as a pozzolana for partial replacement of cement in mortar and concrete, the following recommendations are made;

i) Up to 10% CPA/ESP content is recommended for production of structural concrete while 20% CPA/ESP and above is recommended for non-structural concrete.
ii) CPA and ESP content of more than 10% should be used for non-structural concrete such as blinding where advantage of the slow setting of CPA will be derived.
iii) Further investigations should be carried out in devising a more vigorous mechanism of adding CPA and ESP to improve mixing proportion.

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