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FORMULATION OF HYDRAULIC CEMENT FROM NIGERIAN SEASHELL AND STAPLE CROP HUSK POWDERS

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Abstract
Cement clinker compounds are basically formed from the reaction between silica and calcium oxides to form C-S-H hydrate. This study blends the enormous agricultural waste products of seashells and staple crop husk powders in different mix proportion in order to form new cement material. The chemical analysis revealed seashells and staple crop powders contained over 80% calcium and silica oxides respectively. This work further investigated the production of cementitious materials that will conform to Portland cement without any need for chemical activation and heat curing as a practice in alkali-activated cementing material. Some of the physical requirements and chemical composition required for the cement and cement compounds were conducted for this new blended cement material. This is followed up with the determination of optimal strength and fresh properties for cement mortar and paste tests respectively. The benefits of this study include reduction in the green-house gases, re-use of waste products for economic value and better cement properties.

Keywords: Cement clinker, waste products, blended cement, heat curing, alkali-activated, optimal strength

1.0 INTRODUCTION

Palm Oil Fuel Ash (POFA) is one of the by-products from the palm oil mill industry whose recycling potential is yet to be fully exploited, Okafor and Okonkwo (2009). Palm oil is produced generally in most of the Eastern, Western and Southern parts of Nigeria, a total of about 930 metric ton of palm oil at a growth rate of 2.20 % per annum is produced in Nigeria as reported by Opeyemi and Makinde (2012). Palm oil is consumed in almost all the households in Nigeria on a daily bases leaving behind large amount of residues like fibers, nutshells and empty fruit bunches. Also, rice is a typical example of staple crop with rice husk as a byproduct of the milling process of rice paddy. The normal practice is to dispose large quantities of this rice husk and Palm oil fuel ash without any commercial returns and consequently causing environmental pollution and occupying useful space. As we know that Portland cement has been in existence for decades and due to its production cost, energy consumption, associated problems with emission of green-house gases, and durability issues, there is need for sustainable and alternative for Portland cement. In a study of Rice Husk Ash Refractory,Onojah, Agbendeh, and Mbakaan (2013) performed an open air burning of the rice husk, cooled in an open environment for 24 hours and then a Carbolite furnace is used to fire the ashes at a controlled temperature of 650℃ producing a white amorphous rice husk ash. In Ettu, Ajoku, Nwachukwu, Awodiji, and Eziefula (2013), after air-drying the rice husk, a locally fabricated combustion chamber that is below 650^0C is used to combust the husk into ashes. (Akogu & Obumneme, 2013) & Abalaka (2013) produced RHA by using a charcoal fired incinerator at a recorded maximum temperature of 838^0C. In Agbenyeku and Aneke (2014) Rice husks are sun dried, burnt in open air and calcined in an electric furnace to a temperature of about 700^0C. Oyejobi, Abdulkadir, and Ajibola (2014) carried out partial replacement of cement with rice husk ash by burning rice husk at a controlled temperature of about 700°C for a period of four hours. The ash produced are further grounded using mortar and pestle, Oyejobi et al. (2014) and hammer mill in (Akogu & Obumneme, 2013). However, in Ettu et al. (2013) while studying the compressive strength of concrete produced by partially replacing cement with RHA, did not mill the ash collected from RHA dump rather uses 600 µm sieve and discarded the large particles retained on the sieve.

In the work of Opeyemi and Makinde (2012), the result shows POFA with specific gravity of 2.02 while in Obilade (2014) the specific gravity is in the range of 1.9 – 2.4. A study of durability properties of palm oil fuel ash Self Compacting Concrete (SCC) by (Ayininuola & Olaosebikan, 2013) concluded that acid resistance and high strength SCC can be produced from the combination of Palm Oil Fuel Ash and conplast SP432MS (superplastisizer). Olivia and Oktaviani (2017) partially replaced cement at 4% with cockle and marsh clams. It was reported that mechanical properties of cockle clam are lower than the control mix of OPC while marsh clam yielded increased mechanical properties. The differences were attributed to different Calcium oxides in each of the clam. Lertwattanaruk, Makul, and Siripattarapravat (2012) utilized four types of clams with a cement replacement ranging between 5 to 20% by weight. It is discovered that there is a result of adequate strength, water requirement and increased in setting times of the mortars, although increase in the percentage of clam shells reduced the compressive strength due to the less reactivity. Umoh and Olusola (2013) studied performance of Portland-pozzolan cement in acidic medium with a mixture of OPC and Periwinkle shell ash with a ratio between 10 to 40% by volume. Increase in the percentage of periwinkle shell ash increases water requirement. Compressive strength increases with casting age but decreases with percentage increase in periwinkle shell ash due to the higher water content. Loss in compressive strength in $MgSO_4$ solution was reduced for Portland-pozzolan compared to percentage in the OPC mix. Barbachi, Imad, Jeffali, Boudjellal, and Bouabaz (2017) characterized crushed mussel shells for their possibility use in the concrete. Muthusamy and Sabri (2012) replaced coarse aggregates with cockle shell up to 30%, however, 20% replacement gave best workability and compressive strength results. Rough shape of the shell has attributed to the low workability but also improved bonding and hence compressive strength of the concrete. Ponnada, Prasad, and Dharmala (2016) substituted both fine and coarse aggregates with granite powder and cockle shells with the maximum compressive strength of 43.7 MPa for 20% and 15% of granite powder and cockle shells. Othman, Bakar, Don, and Johari (2013) used cockle shell ash to replace cement between the amount of 5 to 50% with the decrease in compressive as the percentage increases. High content of Calcium oxide causes slow hydration process. Importantly, permeability and porosity of the concrete with cockle shell ash reduced compared to the control mix. In our study, hydraulic cement is formulated from the waste products that are cementititous materials and the necessary tests are conducted on the suitability of this material in full replacement of cement.

2.0 MATERIALS AND METHODS

The following materials are used in this study for the production of hydraulic cement with their sketches in Figure 1. These include clam shells, Palm oil fuel ash and rice husk ash. These materials in their raw form are available in large quantities in Nigeria.

Figure 1: Clamshells, Rice Husk and Palm Oil Fuel Shells in their raw form

After sourcing for these materials, they are all pre-treated through washing with detergent and clean, water and then grounded to the powdery form individually as shown in Figure 2.

Figure 2: Grounded powders of Clamshells, Rice Husk and Palm Oil Fuel Shells

In order to eliminate the Carbon dioxide in the materials and to allow for the chemical reaction to take place, the materials are proportioned together following the Table 1.

Table 1: Different proportions for the hydraulic cement formulation

	Clam (kg)	POFA (kg)	RHA (kg)
Mix 1	0.84	0.10	0.07
Mix 2	0.53	0.16	0.11
Mix 3	0.45	0.09	0.09

The rationale behind these mixes is followed from the Scrivener (2003) where 80% of the limestone and 20% of shale are used as raw materials in the production of cement kiln. In our case, the clamshell materials are initially incinerated at a temperature of 700 ^{0}C for three hours for decarbonation to take place and this temperature is increased to 1200^{0}C and grounded powders of Rice husk and Palm oil Fuel shell are added and allowed to stay for another four hours for the chemical reaction and formulation of Calcium Silicate minerals. The furnace used for the incineration is shown in Figure 3. The cement clicker is further taken to grinder and this is grounded to finer particles.

Figure 3: Incineration of materials inside the furnace

3.0 RESULTS AND DISCUSSION

The clinker is tested for the following physical properties which include fineness, specific gravity and specific surface area. The particle size distribution for the three mixes is shown in Figure 4 with 80.26%, 81.64 and 87.14% passing 45 micrometer sieve size respectively. The specific surface area for the mixes is 5.18, 4.76 and 5.86 m^2/g respectively. Again, specific gravity of the hydraulic cement is slightly lower than the Portland cement with the values of 2.95, 2.93 and 2.98 respectively. The individual chemical compositions of the raw materials and that of the blended cement are shown in Table 2.

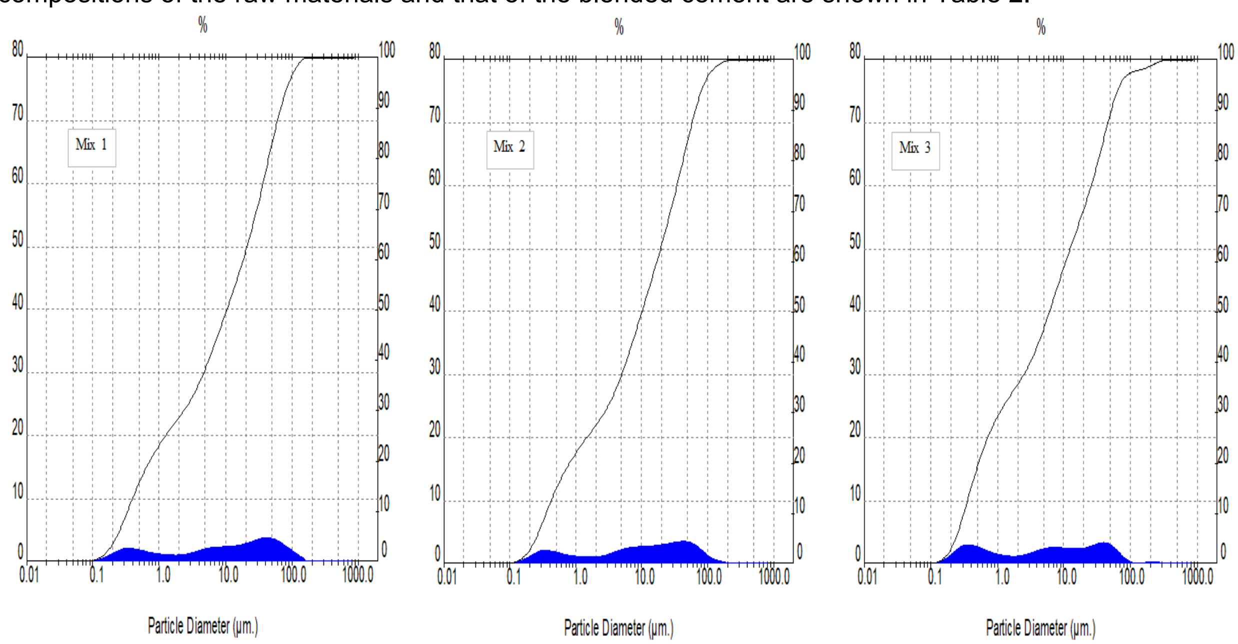

Figure 4: Particle size distributions of the cement clinker

Table 2: Chemical composition of the raw and finished cement materials

Material	Clam (%)	POFA (%)	RHA (%)	Hydraulic cement of Mix 3 (%)
SiO2	0.27	53.52	77.23	23.23
Al2O3	0.06	11.40	3.59	4.59
CaO	97.46	4.62	8.95	49.90
Fe2O3	0.22	12.68	9.85	3.42
Na2O	0.98	1.56	2.90	1.05
MgO	0.09	3.28	5.85	2.62
K2O	0.38	3.08	4.08	1.05
LOI	43	4.83	4.84	3.65

Following this chemical analysis, a paste is formed from the hydraulic cement and the initial and final setting times, consistency and flow values are determined following ASTMC191 (2008). The water requirement according to ASTMC109 (2015) is carried out and due to the higher value of specific surface area, the water demand is higher than the stated values and a higher value of 0.38 water-cement ratio is used in order to have a flowable paste as recorded in the Table 3. The initial and final setting times of the mixes are relatively close to each other with the average initial and final setting times of 68 and 137 minutes respectively.

Table 3: Fresh properties of the cement paste

	Mix 1	Mix 2	Mix 3
Initial setting time (Mins)	70	65	70
Final setting time (Mins)	130	140	140
Flow (mm)	130	135	132

On the final note, compressive strength of the mortar made from the hydraulic cement and 20% Portland cement is tested at ages of 3, 7, 14 and 28 days respectively with the results shown in Table 4 and Figure 4 respectively. The compressive strength values of the mortar at 28th day are slightly lower than the strength made from 100% Portland cement mortar in Lertwattanaruk et al. (2012) which recorded value of 15 MPa, although the strength increases with the increase in the curing age. This can be attributed to the trial combinations of the raw materials as well as the higher water – cement ratio which increases the flow and reduces the compressive strength in the turn.

Table 4: Compressive strength of hydraulic cement mortar

Compressive Strength (MPa)	Mix 1	Mix 2	Mix 3
3 days	3.20	3.50	3.60
7 days	5.00	6.20	5.80
14 days	8.40	9.30	9.00
28 days	10.50	12.40	11.80

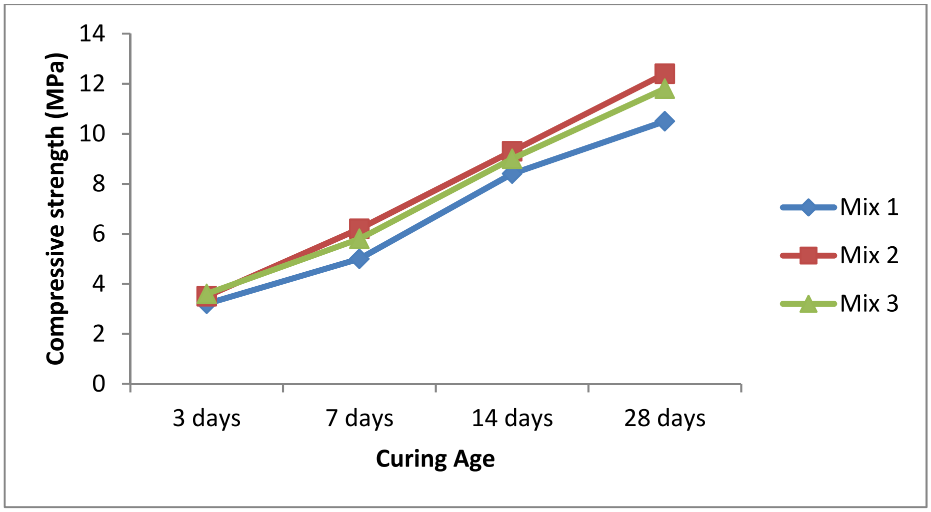

Figure 4: Compressive strength of hydraulic cement mortar at different curing ages

4.0 CONCLUSION

From the above, it can be concluded from the preliminary study that the performance study of the new cement material formulated from the waste products are possible and in addition possess comparable physical, chemical and mechanical properties similar to the Portland based mortar cement. Most of the tests are within the standard range set out for Portland cement and therefore this new cement material if commercialized on a large scale after satisfactory necessary tests can replace Portland cement and enormously reduce waste products for economic value.

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