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USE OF EMPTY-OIL-PALM-FRUIT-BUNCH ASH AS A PARTIAL SUBSTITUTE FOR CEMENT IN STRUCTURAL CONCRETE

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ABSTRACT

The oil palm, *Elaeis guineesis*, is an agricultural tree grown extensively in West Africa, Malaysia and Indonesia. It produces it fruits in bunches, each bunch containing 150 to 200 fruits held in sockets in one fruit bunch. During harvest, the bunch is defruited and the empty-oil-palm-fruit-bunch (EOPFB) is discarded as waste. In countries that produce red palm oil for export, this waste normally constitute environmental problems. This study investigates the possibility of using the ash produced from empty-oil-palm-bunch as a partial substitute for cement in concrete production in order to provide an economic and proper way of disposal for the agro-waste. In this regard, a nominal mix proportion of 1:1½:3 (being ratios of cement, sand and gravel) with a water-cement ratio of 0.55 was used to produce concretes containing 0%, 10%, 20% and 30% of empty oil-palm-fruit-bunch ash (EOPFBA) as a partial substitute for cement; the percentages being calculated by weight of the original cement content. 48 cubes were produced, 12 for each of the percentage substitutions. Two cubes from each of the percentage ash contents were tested for compressive strength at 7, 14, 21, 28, 60 and 90 days of water curing, and the results analyzed with graphs. The oxide composition of the ash was also investigated with x-ray fluorescence spectrometer. From the graphs it was observed that the concretes of the various ash contents hydrated like every other *pozzolana* and the strengths of 10% and 20% ash contents equalized with that of zero percent (0%) at 90 days water curing instead of 28 days as already known for rice-husk ash and fly ash. From the oxide composition it was also observed that silica, alumina and iron oxide content of the empty-oil- palm-fruit bunch ash was much lower than the values commonly found in rice husk and fly ash, and that could be the reason for the slow *pozzolanic* reaction. It was then concluded that empty-oil-palm-fruit-bunch ash is a *pozzolana* and should be used to substitute cement at 10 – 20% by weight of the original cement content in concrete. The concrete so produced should be protected from aggressive chemical as it may contain more pores relative to the control.

KEYWORDS: concrete, empty-oil-palm-fruit-bunch ash, compressive strength, hydration history, oxide composition, pozzolanic activity, percentage substitution.

1.0 INTRODUCTION

Oil-palm-fruit bunch (OPFB) is an oval shaped fruit bunch obtained from oil-palm tree. The oil palm, *Elaeis guineensis*, is an agricultural tree originating and grown extensively in west and central Africa and, more recently, in Malaysia and Indonesia. Red palm oil has been a commodity for international trade for centuries. Nigeria was once the highest exporter of red palm oil, but today Malaysia is the world's highest exporter of this commodity (Encyclopedia Britannica, ND).

The oil palm tree produces its fruits in bunches which can house as many as 150 to 200 palm fruits all held in one bunch. When the oil-palm-fruit bunch is de-fruited of the rip palm fruits (red in colour) to be processed in the oil mill for red palm oil, an empty-oil-palm-fruit bunch (EOPFB) is normally left and discarded as agricultural waste and needs proper disposal. At present EOPFB is used as fuel for firing boilers, in the oil mills, and for production of local black-soap (now obsolete); so empty-oil-palm-fruit bunch remains one of the wastes from palm oil industry that needs proper disposal to prevent environmental problems. Each oil-palm –fruit-bunch produces about 21% red palm oil, 6 – 7% palm kernel oil, 14 – 15% fiber, 6 – 7% kernel shells and 23% empty-fruit-bunch (Harizan Bt, Awang, *et al* 2018). There are millions of palm trees in Nigeria a good number of which were self-propagated. Each palm tree produces an average of four palm-fruit- bunch per year, resulting in millions of tons of EOPFB annually. The tree is rugged and resistant to destruction by bush-fires and animals, so can survive with little or no attention.

This study focused on empty-oil-palm-fruit-bunch (EOPFB) and to investigate the possibility of using the ash produced from EOPFB as a partial substitute for cement in concrete production in order to provide an economic and proper way of disposal for empty-oil-palm-fruit-bunch. In this regard the *pozzolanic* activity of empty oil-palm-fruit-bunch ash

(EOPFBA) in the cement hydration was investigated, as well as the oxide compositions of the ash. The two results were compared and contrasted with each other and with other published results on *pozzolanic* agro-wastes (e.g. Rice husk ash) to arrive at conclusions.

Pozzolanas are artificial or natural materials which contain mainly silica, alumina and iron oxide in certain proportion that makes them reactive in the presence of calcium hydroxide to exhibit cementitious property, which ordinarily they do not possess (Shetty, 2009). This means that *pozzolanic* materials are not cementitious in themselves, but when finely ground and in the presence of water, combines with lime at ordinary temperature to form compounds which have low solubility and possess cementitious property. The first known *pozzolans* are volcanic ash, volcanic tuff and diatomaceous earth (Jackson, 1981).

Today, some industrial and agro-wastes are found to possess *pozzolanic* property, e.g. fly ash, rice husk ash, etc (Oyetola and Abudullahi, 2006). *Pozzolans* are normally added to concrete in order to improve long term strength and durability of concrete, and are sometime referred to as cement extenders. A good number of published work exists on empty-oil-palm-fruit-bunch ash as a partial substitute for binder in concrete, and also on other *pozzolanic* materials used in concrete.

Coeih *et al* (2019) investigated mortar properties obtained through partial substitution of Portland cement with ash of empty-oil-palm-fruit bunch and concluded that it results in gradual reduction in compressive/tensile strength and in increase in porosity and carbonation, but at 5 – 10% ash content in mortar no significant difference was observed when compared with the control. Hanizan et *al* (2018) in their review article, concluded that empty oil palm fruit-bunch ash (EOPFBA) has a *pozzolanic* property as it contains a good percentage of amorphous silica (SiO_2), iron oxide (Fe_2O_3) and Aluminum oxide (Al_2O_3). Ayetola and Abdullahi (2006) studied the use of rice husk ash in low cost sand Crete blocks and concluded that a maximum of 30% substitution of cement with rice husk ash results in blocks of the same strength as the normal sand crete block made with Portland cement. Adinna et al (2007) in their study of the hydration history of concrete specimens containing rice husk ash, observed that concretes containing rice husk ash pozolana as partial substitute for binder increases in strength at a much lower rate at the early ages than the normal concrete, but at later ages hydrates very fast and surpasses the normal concrete at the age of 28 days, this is true for up to 30% substitution of cement with rice husk ash. Adinna, Onodagu *et al* (2020) in their study of the effect of fly on the strength and workability, concluded that at 40% fly ash content (by substitution of cement) the resulting concrete surpasses the normal concrete both in workability and strength, while the hydration history remains the same as that of rice husk ash.

As early as 1940's, fly ash was used to substitute cement by up to 40% to rebuild war- turn countries of Europe after world war II, following an article published by Professor Davis of California on fly ash and concrete (Feber, 1987) in 1930's.

In this research, oxide composition of empty oil-palm-fruit-bunch ash as well as the hydration history of the concrete with partially substituted cement content with EOPFBA was studied in order to make reasonable conclusion on its *pozzolanic* activity and possibility of gainfully disposing the agro-waste through concrete. The rationale of this work is that in this present age with its technological advancements, empty palm fruit bunch needs a good economic disposal instead of allowing it to cause environmental nuisance. This is justified by the fact that there is need for more durable and cheaper concrete infrastructures for the world's teaming population with rising standards of living. Its significance is that it can result in cheaper construction materials and less carbon dioxide emissions, when part of cement is substituted with EOPFBA in concrete production.

2.0 METHODOLOGY

(I) Materials

The materials used include empty-oil-palm-fruit-bunch ash (EOPFBA), granite coarse aggregate of 16-mm maximum size, clean river sand of 3mm maximum size, a normal hardening Portland limestone cement, CEM 42.5N (NIS, 2003). They were all purchase from local dealer. The EOPFBA was process from empty-oil-palm-bunches (EOPFB) by burning it in a locally made furnace or a basket burner at an uncontrolled temperature of about 300^{o}C for about six hours. The ash was then sieved through B.S sieve size of 45μm to enhance *pozzolanic* reaction.

(II) Experiments

The equipment used were 150 x 150 x 150-mm cube mold, a universal testing machine, slump test equipment and a curing tank.

The cement, sand and gravels were weighed out in the ratio of 1:1½:3 and thoroughly mixed on a non-absorbent base before water was added at a water-to-cement ratio of 0.55, and final mixing was continued until a uniform plastic mix was obtained. Slump text was carried out on the fresh concrete, and 12 concrete cubes cast from it according to B.S 1881 (1970). The concrete cubes were cured in water for a maximum period of 90 days. Following this procedure, 12 concrete cubes were cast for the control specimen (i.e. 0% ash content), 10%, 20% and 30% ash contents by substituting equivalent weight of the cement content with ash. At the age of 7 days, 2 concrete cubes were tested for compressive strength from each of the 0%, 10%, 20% and 30% ash contents of the 4 groups of 12 concrete cube specimens. This process was repeated at the ages of 14, 21, 28, 60 and 90 days. The average compressive strengths obtained for the various ash contents at these respective curing ages were recorded and analyzed. The oxide composition of the empty-oil-palm-fruit-bunch ash (EOPFBA) that was used was also tested using x-ray fluorescence (XRF) spectrometer.

3.0 RESULTS AND DISCUSSION

(i) Results

The result of the compressive strength test and slump for the various ash contents are presented in Table 1.0, while the graph showing the progress of hydration of the concrete with age (hydration history) is given in Fig. 1.0.

Table 1.0: Compressive strength and slump test results of concrete of various Ash (EOPFBA) content.

Samples' Descriptions				Average Compressive Strength (N/mm^2) at various ages					
Sample Group	**Group mix proportion**	**Group ash(EOPFBA) Content %**	**Group slump value (mm)**	**7days**	**14days**	**21days**	**28days**	**60days**	**90days**
1(Control)	1:1½ :3	0	58	20.30	22.78	24.78	27.02	27.72	28.00
2	1:1½ :3	10	59	13.89	18.45	21.33	22.67	27.68	28.32
3	1:1½ :3	20	60	12.45	16.78	19.15	21.31	26.93	28.05
4	1:1½ :3	30	60	10.85	16.65	18.96	19.78	25.80	27.45

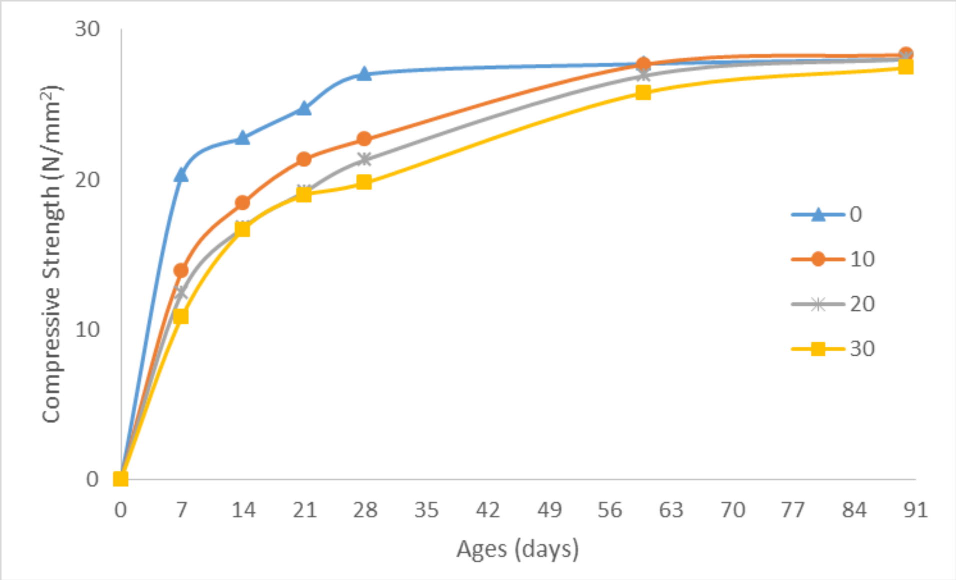

Fig. 1.0: Variation of concrete strength with age of curing (Hydration History)

The oxide composition results of Empty-Oil-Palm-fruit- Bunch Ash (EOPBA) is given in Table 2.0.

Table 2.0: Oxide Composition of EOPFBA.

Oxides	SiO	Al_2O_3	Fe_2O_3	CaO	K_2O	MgO	SO_3	LOI^-
Composition %	18	0.52	3.25	4.18	20.4	0.65	0.35	Not available

(ii) DISCUSSION

The results in Table 1.0 and Fig. 1.0 shows clearly that the strength of concretes containing ash of various percentages of 0%, 10% and 20% do not differs so much at the age of 28 days, and that the strength values are virtually equal at the ages of 60 days and 90 days.

From the graph in fig. 1.0, it can also be observed that the hydration of the concrete containing ash were relatively very gradual at the early ages, but became faster at the later ages, such that their strengths became equal to that of normal concrete. This is typical of all *pozzolanas* e.g. rice husk ash, fly ash etc. The difference here is that, at the ages 28 days the strength of concretes containing 30% or 40% rice husk ash or fly ash respectively are known to normally grow above that of normal concrete. Considering Table 2.0, showing the oxide compositions of Empty-palm-fruit-bunch ash (EOPFBA) it will be observed that the percentage of silica is only 18%; much lower that 60% and 80% of the same silica in rice husk ash and fly ash, respectively. In addition Aluminum oxide (Al_2O_3) is almost undetectable in EOPFBA, but it is about 30% and 40% in fly ash and rice husk ash ,respectively (Shetty, 2009; Ayetola and Abdullahi, 2006). This chemical composition tends to validate the results of compressive strength and hydration history, because SiO_2 is responsible for long term strength of the concrete.

4.0 CONCLUSION AND RECOMMENDATION

From the discussion and results presented so far, it can be concluded that empty-oil-palm-fruit-bunch ash (EOPFBA) is a *pozzolanic* material of low reactivity and is therefore recommended for use in massive concrete construction to reduce heat of hydration that cause cracking, and to improve long-term strength and durability of concrete by substituting cement required with EOPFBA at 10 – 20% weight of the cement. This can also be applied to other structural concretes in general except those exposed to harmful chemicals: The relatively low strength of the concrete containing EOPFBA will likely cause high porosity and may not be good for very harmful exposures.

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