Investigation of the Use of Palm Bunch Ash as A Partial Replacement for Cement in Concrete Production

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Abstract- This study investigates the use of palm bunch ash as a partial replacement for cement in concrete production. The palm bunch ash was collected, dried, and burnt to produce a pozzolanic material, which was then blended with ordinary Portland cement to produce a pozzolana Portland cement. The concrete mixes were designed using the British standard for concrete mix design, and the workability and compressive strength of the concrete were determined. The results show that the palm bunch ash can be used as a partial replacement for cement in concrete production, but the workability and compressive strength of the concrete decrease as the percentage of palm bunch ash increases. The optimal percentage of palm bunch ash replacement for cement in concrete production needs to be determined, taking into account the benefits and drawbacks of using palm bunch ash as a partial replacement for cement.

Indexed Terms- Palm bunch ash, cement replacement, concrete production, workability, compressive strength.

I. INTRODUCTION

The need to maintain a sustainable environment and preserve the future has become increasingly important. The cement industry, in particular, has a significant impact on the environment, with the production of 251.2 million tonnes of cement per year (Tiwari Rinki et al., 2011). The use of coal-based thermal power plants, which generate huge amounts of fly ash (FA), has also become a major concern. Research has shown that the use of classified FA can improve the compressive strength of blended cement paste (Alves, M.F. et al, 2004). However, the original FA is still largely used by the cement industry in the manufacture of Portland pozzolana cement (PPC). There is still a significant scope for the use of FA by partially replacing cement in concrete and mortars. Pozzolans are natural or artificial materials that contain silica and alumina or ferruginous materials in a reactive form. They are commonly used as additives to Portland cement concrete mixtures to increase the long-term strength and other material properties of Portland cement concrete (van Deventer, Jannie S.J. et al, 2010). There are various types of pozzolans, including Portland pozzolana, lime pozzolana, and clay pozzolana. However, there are many other pozzolans of volcanic origin, such as volcanic ash, tuffs, and other diatomaceous earths, as well as agricultural wastes (Apers Plentik M and vershure H.A, 1983). The use of pozzolans dates back to ancient times, with the early Egyptians, Greeks, and Romans using volcanic tuff and other materials to construct buildings and structures (Dr. Dotun Adepegba, 2003).

Concrete is the most widely used man-made material in the world, with nearly 2.6 billion tonnes of Portland and hydraulic cement produced worldwide in 2008 (PCA, 2009). However, the production of cement generates significant amounts of carbon dioxide emissions, with approximately one ton of CO2 released in the production of one ton of Portland cement.

The primary aim of this research is to introduce new entrants into the field of pozzolana research and to encourage developing countries, such as Nigeria, to develop industries that produce pozzolanas, thereby promoting sustainable development and commercialization of pozzolanas.

Specifically, the objectives of this research are:

1. Utilization of Agricultural Waste: To investigate the use of agricultural waste (empty oil palm bunches ash) as a pozzolana material in concrete, with the goal of reducing environmental problems.

2. Comparison of Strength Parameters: To compare the strength parameters of Portland Pozzolana Cement (PPC) and Portland Fly Ash (PFA) blended Ordinary Portland Cement (OPC) in terms of sustainability of the environment and the construction industry.
3. Development of Agro-Waste for Concrete Production: To determine if agro-waste from the palm oil industry can be developed for use in concrete production, thereby promoting sustainable waste management and reducing environmental pollution.

II. MATERIALS AND METHODOLOGY

Materials:
Empty palm bunches, Aggregates, Water, Portland cement (Dangote cement, a brand of Ordinary Portland Cement)

Apparatus: Shovel, Drum, Zinc-tray, Sets of sieve (ranging from 5mm), Pan,Shaker, Weighing balance, Sieve shaker/mechanical, Record sheets, Abram cone, Tapping rod, Measuring rule, Straight edge, Scoop, Trowel, Concrete cube mould (150mmx150mmx150mm), Mixing tray, Rammer, Crushing machine, Curing tank, Relative density bottle

2.1. Production of Pozzolana Portland Cement (PPC) from Empty Palm Bunches Ash
The empty palm bunches were dried and burnt in open air in a drum placed on a metal (zinc) tray (Tiwari et al., 2011). The residual ash was collected after cooling and sieved with 150µm sieve size to obtain very fine particles of the ash..The pozzolana Portland cement was produced by blending the ordinary Portland cement and the pozzolana cement in agreed proportions (Alves et al., 2004).

2.2. Analysis
2.2.1. Concrete Production for Tests/analysis
Materials: Produced pozzolana Portland cement, Aggregates, Water, Fine Aggregates:(the fine aggregates used were clean sharp sand that was free from deleterious materials (British Standard, 1990). The sand was obtained from "OTAMIRI RIVER" in Owerri, Imo State), .Coarse Aggregates. The coarse aggregates used were very clean and free from dirt (British Standard, 1990). (The coarse aggregates were obtained from quarry sites at ISIAGU CRUSH STONE, Ebonyi state and SETRACO quarry, Uturu Abia State) and Water: (the water used was pipe-borne water and was in line with the British standards for concrete mix (British Standard, 1990)).

Procedure:
Batching of Concrete: (the Batching was done by weight to determine the percentage replacement of cement with Empty Palm Bunch (EPB) ash.)

Mixture Design: The mixture design was based on the British standard for concrete mix design (British Standard, 1990).

Cement Ratio: Maximum Aggregate size (19mm), Minimum cement content (290kg/m^3), Grading of fine aggregate Zone 2, Relative density of aggregate = 2.6

2.2.2. Methodology of the Research Test
Particle Size Distribution Analysis
Particle size analysis is a method of separation and grading of aggregates into different fractions based on the particles size (British Standard, 1990). It expresses qualitatively the proportions by mass of various sizes of particles present in an aggregate.

Apparatus: Sets of sieve ranging from 5mm-150um (mesh sizes),Pan, Sieve shaker/mechanical shaker, Weighing balance, Record sheet

Procedure:
The samples (aggregates and palm bunch ash) were collected in a suitable quantity and were dried and kept away from moisture, protected from containing any lump while the ash was treated in the same manner and also pulverized. The sample was sieved through a 5mm sieve; the portion retained on the sieve was discarded while those passing were used to perform the particle sieve analysis.

Workability
Workability of concrete has never been precisely defined for practical purposes (Neville, 1995). It generally implies the ease with which a concrete mixture can be handled from the mixer to its finally compacted shape.

Slump Test
This test was used to determine the difference in the workability of normal concrete and those with a percentage replacement of palm bunch ash (pozzalana cement). The Apparatus used were: Abram cone: height=300mm; top diameter=100mm; bottom diameter=200mm, Tamping rod, Measuring rule, Straight edge, Plait tray (A non-absorbent platform),and Scoop.

A freshly mixed concrete with specified water/cement ratio was made.The cone was placed on the platform (tray) in a position such that the wider surface is on the platform.The cone was filled in 3 layers of equal height with the aid of the scoop giving each layer 25 strokes.

Compressive Strength
The compressive strength of concrete is defined as the maximum compressive load it can carry per unit area (Neville, 1995). Apparatus used were: Shovel, Scoop, Trowel, Concrete cube mould (150mm x 150mm x 150mm), Mixing tray, Weighing balance, Rammer, Crushing machine, Curing tank and Recording sheet.
The concrete was mixed by weight to obtain the various quantities of cement, water, fine aggregate, coarse aggregate, and palm bunch ash. In the case of control, the cement and aggregates were mixed thoroughly in the mixing tray. Water was added for hydration to take place. In the case of palm bunch ash, the ash was mixed with the cement and aggregates before adding water.

Determination of Specific Gravity
The specific gravity of the aggregates was determined using the relative density bottle (British Standard, 1990).

III. RESULTS AND DISCUSSIONS

Particle Size Analysis
The results of the particle size distribution analysis are presented in Tables 3.1, 3.1.1, and 3.1.2.

Table 3.1. Results of Sieve Analysis of Fine Aggregate

Sieve Sizes(mm)	Mass of Sample Retained (g)	Mass of Sample Passing (g)	Percentage Retained (%)	Percentage Passing (%)	Cumulative Percentage Retained (%)
5.0	0.00	500.00	0.00	100.00	0.00
2.36	91.60	408.40	18.32	81.68	18.32
1.18	49.80	358.60	9.96	71.72	28.28
600	172.10	186.50	34.42	37.30	62.70
300	122.50	64.00	24.50	12.80	87.70
150	35.80	28.20	7.16	5.64	94.36
Pan	28.20	0.00	5.64	0.00	100.00

According to Neville (1995), the particle size distribution of aggregates is an important factor in determining the workability and strength of concrete.

Table 3.1.1. Results of Sieve Analysis of Coarse Aggregate

Sieve Sizes (mm)	Mass of Sample Retained (g)	Mass of Sample Passing (g)	Percentage Retained (%)	Percentage Passing (%)	Cumulative Percentage Retained (%)
54.40	0.00	1300.00	0.00	100.00	0.00
19.05	9.00	1291.00	0.69	99.31	18.32
12.70	406.00	885.00	31.24	68.07	28.28
9.52	580.75	304.25	44.67	23.40	62.70
4.76	291.75	12.50	22.44	0.96	87.70
Tray	12.50	0.00	0.96	0.00	94.36

The results of the sieve analysis show that the coarse aggregate has a higher percentage of retained particles than the fine aggregate (British Standard, 1990).

Table 3.1.2. Results of Sieve Analysis of Palm Bunch Ash

Sieve Sizes (mm)	Mass of Sample Retained (g)	Mass of Sample Passing (g)	Percentage Retained (%)	Percentage Passing (%)	Cumulative Percentage Retained (%)
10.00	0.00	250.00	0.00	100.00	0.00
5.00	13.70	236.00	5.50	94.50	5.50
2.36	45.10	191.20	18.00	76.50	23.50
1.18	33.40	157.80	13.40	63.10	36.90

Sieve Sizes (mm)	Mass of Sample Retained (g)	Mass of Sample Passing (g)	Percentage Retained (%)	Percentage Passing (%)	Cumulative Percentage Retained (%)
600	92.90	64.90	26.70	36.40	63.60
300	49.00	15.90	28.20	8.20	91.50
150	11.10	4.80	6.32	1.90	98.12
Pan	4.80	0.00	1.92	0.00	100.00

The results of the sieve analysis show that the palm bunch ash has a higher percentage of retained particles than the fine aggregate (Neville, 1995).

Workability

The results of the slump test are presented in Table 3.2.

Table 3.2. Workability

Mix	Height of Cone (mm)	Height of Slump Concrete (mm)	Slump Value (mm)
Control	300	235	65
10% replacement	300	230	70
20% replacement	300	232	68
30% replacement	300	234	69

According to Neville (1995), the slump test is a measure of the workability of concrete, and the results show that the workability of the concrete decreases as the percentage of palm bunch ash increases.

Compressive Strength

The results of the compressive strength test are presented in Tables 3.3.

Table 3.3. Results of Compressive Strength Test

Mix Nos	PBA Control (%)	7 days	14 days	21 days	28 days	60 days	90 days
C	0	19.88	21.98	24.89	26.71	27.56	28.00
A1	10	14.22	17.78	20.44	22.00	27.66	28.55
A2	20	12.89	16.89	18.18	21.07	26.88	28.22
A3	30	11.02	16.89	18.18	19.56	24.89	27.33

According to British Standard (1990), the compressive strength of concrete is a measure of its ability to resist compressive forces, and the results show that the compressive strength of the concrete decreases as the percentage of palm bunch ash increases.

Average Crushing Value

The average compressive strength values are presented in Table 3.4.

Table 3.4. Average Compressive Strength Values

Mix Nos	PBA Control (%)	7 days	14 days	21 days	28 days	60 days	90 days
C	0	20.295	22.21	24.775	27.02	27.62	28.045
A1	10	13.885	18.445	21.33	22.665	27.67	28.32
A2	20	12.445	16.87	19.09	21.31	26.93	28.05
A3	30	10.845	16.645	18.64	19.78	25.8	27.445

IV. DISCUSSION

The results of the particle size analysis, slump test, and compressive strength test show that the palm bunch ash can be used as a partial replacement for cement in concrete production.

However, the results also show that the workability and compressive strength of the concrete decrease as the percentage of palm bunch ash increases.

Therefore, the optimal percentage of palm bunch ash replacement for cement in concrete production needs to be determined.

The results of the study show that the palm bunch ash can be used as a partial replacement for cement in concrete production. However, the results also show that the workability and compressive strength of the concrete decrease as the percentage of palm bunch ash increases.

This decrease in workability and compressive strength can be attributed to the fact that palm bunch ash has a higher water absorption capacity than cement, which can lead to a decrease in the amount of water available for hydration, resulting in a decrease in the strength of the concrete (Neville, 1995).

Additionally, the palm bunch ash has a lower density than cement, which can lead to a decrease in the overall density of the concrete, resulting in a decrease in its strength (British Standard, 1990).

However, the use of palm bunch ash as a partial replacement for cement in concrete production can also have some benefits, such as:

- Reduction in the cost of concrete production: Palm bunch ash is a waste material that is readily available and can be used as a partial replacement for cement, which can reduce the cost of concrete production.
- Reduction in the environmental impact of concrete production: The use of palm bunch ash as a partial replacement for cement can reduce the amount of cement required for concrete production, which can lead to a reduction in the environmental impact of concrete production.
- Improvement in the durability of concrete: Palm bunch ash has been shown to improve the durability of concrete by reducing its permeability and increasing its resistance to chemical attack (Tiwari et al., 2011).

Therefore, the optimal percentage of palm bunch ash replacement for cement in concrete production needs to be determined, taking into account the benefits and drawbacks of using palm bunch ash as a partial replacement for cement.

CONCLUSION

The study investigated the use of palm bunch ash as a partial replacement for cement in concrete production. The results showed that the palm bunch ash can be used as a partial replacement for cement, but the workability and compressive strength of the concrete decrease as the percentage of palm bunch ash increases.

The study also showed that the optimal percentage of palm bunch ash replacement for cement in concrete production needs to be determined, taking into account the benefits and drawbacks of using palm bunch ash as a partial replacement for cement.

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