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Performance Assessment of Incinerated Solid Waste Fly Ash from Educational Environment as a Concrete Admixture

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Abstract: *This research investigates the potential of using incinerated solid waste at 700˚C as replacement for cement at percentage replacement levels of 5 - 40% at 7, 14 and 28 days curing duration. Tests conducted include: Sieve Analysis, specific gravity, chemical composition analysis, compacting factor and slump test, compressive strength and density test. Results obtained indicated that the incinerated fly ash is composed of mainly Silica, Aluminium oxide, Iron oxide and Calcium oxide. Workability test indicates that the higher the Incinerator Fly Ash addition, the lower the workability. Strengths obtained for compressive test indicates that with higher curing duration, the incinerated ash has the potential to be used as cement replacement in certain percentages.*

Keywords: *Incinerated solid waste, fly ash, concrete, compressive strength, cement replacement.*

1. INTRODUCTION

Supplementary cementitious materials have changed the composition of concrete from the basic materials such as fine sand, coarse aggregate, cement and water to addition of materials with cementing properties in certain percentages. However, these materials before they are effectively utilized in concrete, their properties have to be investigated in order to satisfy the minimum requirements for concrete production. According to Juenger (2012) as cited in Juenger and Siddique (2015), some of the challenges with the introduction of so many new materials are finding methods to appropriately characterize them and recognizing the limitations of some existing methods that were developed for other materials. Some of the characteristics of interest when evaluating supplementary cementitious materials are their physical properties, including particle size distribution and specific surface area, and their chemical properties, including oxide composition, phase composition and amorphous content. All these affect pozzolanic reactivity, while some also affect interaction with cement hydration and water demand.

Reuse of hazardous waste has been under study for many years and interest in it is increasing worldwide for many reasons. First, if the waste has binding properties (hydraulic or pozzolanic), it allows a reduction in the use of Portland cement clinker. This leads to a reduction in the cost of the concrete and is indirectly beneficial for the environment because of the reduction of CO_2 emissions associated with the manufacture of Portland cement clinker. Secondly, it represents an interesting alternative to final landfill disposal and, again, the economic impact is significant. However, the main problem of such a practice is the environmental impact of the hazardous waste introduced into the cement-based materials (Aubert et al., 2007).

This research utilizes incinerated solid waste fly ash as a replacement for cement in concrete production.

2. MATERIALS AND METHODS

2.1. Materials

The materials used in conducting this research includes Dangote cement, a brand of Portland cement, incinerator fly ash, well graded fine aggregate (sand), well graded coarse aggregate (max size 20mm) and portable water with pH value of 7. The Incinerator fly ash was obtained from the combustion of solid waste generated within the MAUTECH campus at a temperature of about 700^{o}C at Industrial Design Department.

2.2. Mix Proportion

A control mix containing ordinary Portland cement (OPC), natural sand and crushed rock aggregate was designed for a compressive strength of about 25 MPa at 28 days with a slump range of 25-75 mm. The proportion used for Incinerated fly ash by weight of cement was 0 - 40 % at 5% interval.

Table 1. *Mix proportioning of constituents materials*

Constituent materials	Cement	Sand	Coarse	w/c ratio
Quantity (kg/m^3)	360	612.5	1137.5	0.55

2.3. Casting and Curing of Specimen

Seventy two (72) numbers of 150 x 150 x 150mm concrete cube samples was casted with the exception of the samples repeated. Each batch mix was made to produce cubes to be tested for compressive strength at 7, 14 and 28days. The fresh concrete was casted in steel mould in three layers and tampered with a tamping rod, the side of the mould rodded and compacted. Casted specimen were placed in the laboratory for 24hrs at 27 +/-1^{o}C before immersed in curing tank until testing day.

2.4. Detail of Tests

Sieve analysis was conducted in accordance to BS 410: 2000, and BS 1377-2:1990. Specific gravity based on pycnometer procedure using ASTM D854-00. Chemical composition analysis conducted on the Incinerator fly ash samples in accordance to ASTM C618-03. Slump and compacting factor was carried out according to BS 1881: Part 102: 1983 and BS 1881: Part 103: 1983. The compressive strength test and the density test were carried out in accordance to BS 1881: Part 116: 1983 and BS 1881: Part 114: 1983 respectively.

3. Results and Discussion

3.1. Physical Properties

The Incinerator fly ash (IFA) used was passed through sieve 75µm sieve size. Result of the analyses showed that the coarse aggregate is distributed from fine gravel to fine sand. Fine aggregate is distributed from coarse to medium sand, and the Incinerator fly ash showed that it has more of the smaller fine particles. Specific gravity of incinerated fly ash was found to be 3.07, while that of both coarse and fine aggregates were 2.6 respectively.

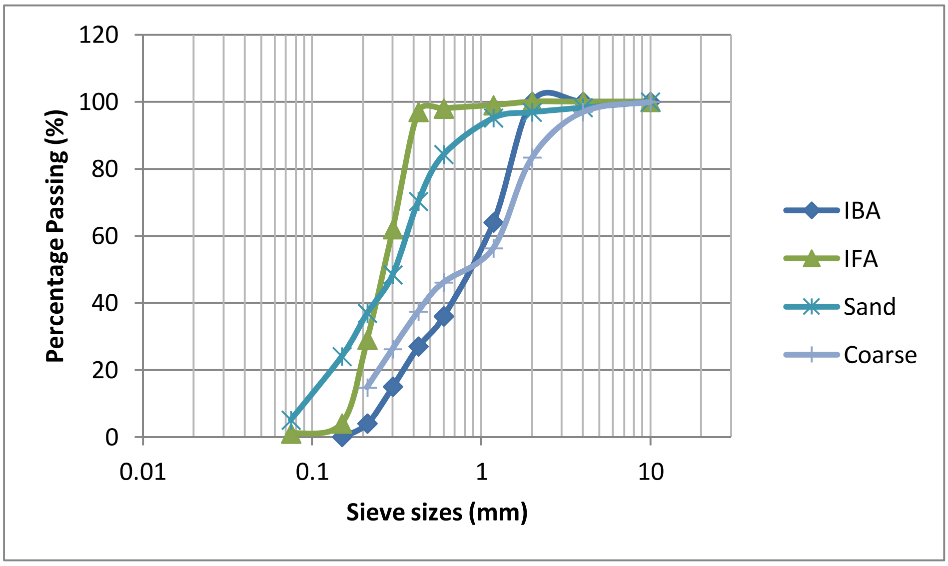

Figure 1. *Sieve Analysis of constituent materials*

3.2. Chemical Composition Analysis

The chemical composition of the incinerated fly ash is presented in table 2. The sum of the three oxides $SiO_2 + Al_2O_3 + Fe_2O_3$ gives 60.557% which is greater than 50% composition but less than 70% for class C, pozzolana. This class of ash, in addition to having pozzolanic properties also has some cementitious properties. SO_3 content is less than the maximum presented by ASTM C 618, the alkali

K_2O and Na_2O are mostly within the range of ASTM C 618 except for the former which is slightly above the standard for incinerator ash (1.65%).

Table 2. *Oxide composition analysis of IFA*

Oxide	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_3O	P_2O_5	Mn_2O_3
Percentage composition	50.923	7.583	2.051	24.207	4.910	1.632	3.042	0.366	0.677	0.143

3.3. Fresh Concrete Properties

The workability decreases as the percentage replacement of Incinerated fly ash increases as measured from slump except in few instances.

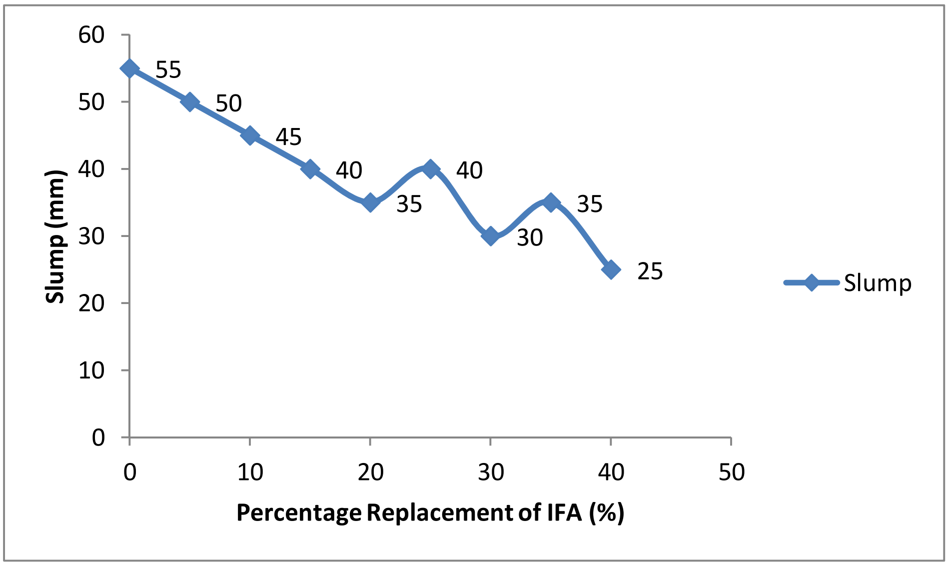

Figure 2. *Measured slump (mm)*

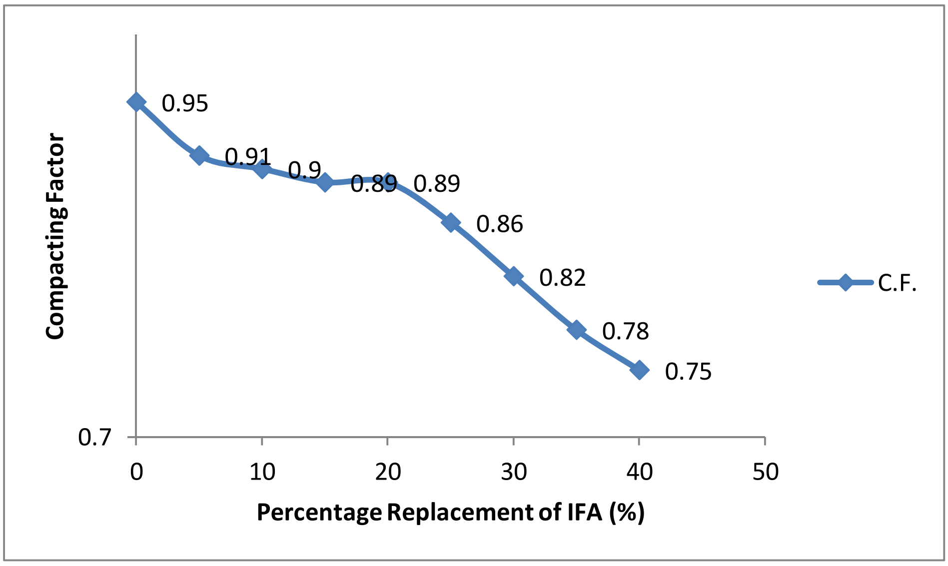

Figure 3. *Compacting factor at different percentage*

3.4. Hardened Concrete Properties

It can be seen that 25% IFA addition (fig.4) was the only percentage to have nearly attained the target strength in all the days, the reason behind this gain in strength in contrast to that of the other replacements can be attributed to the following:

- Hydration (which is a chemical reaction between the cement constituents and water accompanied by release of a considerable amount of heat);
- Packing effect (a physical phenomenon which results in a denser packing of the materials in which fine particles were not fully filled in the void spaces present);
- Nucleation reaction (occurs as a result of smaller particles of Incinerator fly ash blending with cement paste to accelerate the reaction and form smaller cementing paste)

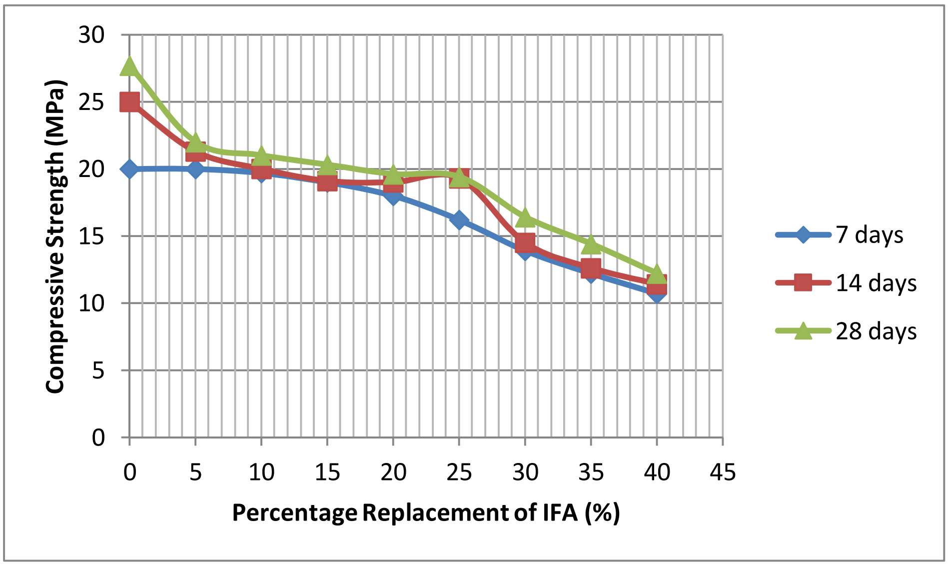

Figure 4. *Compressive strength of concrete*

The same trend was observed in the density of the samples measured.

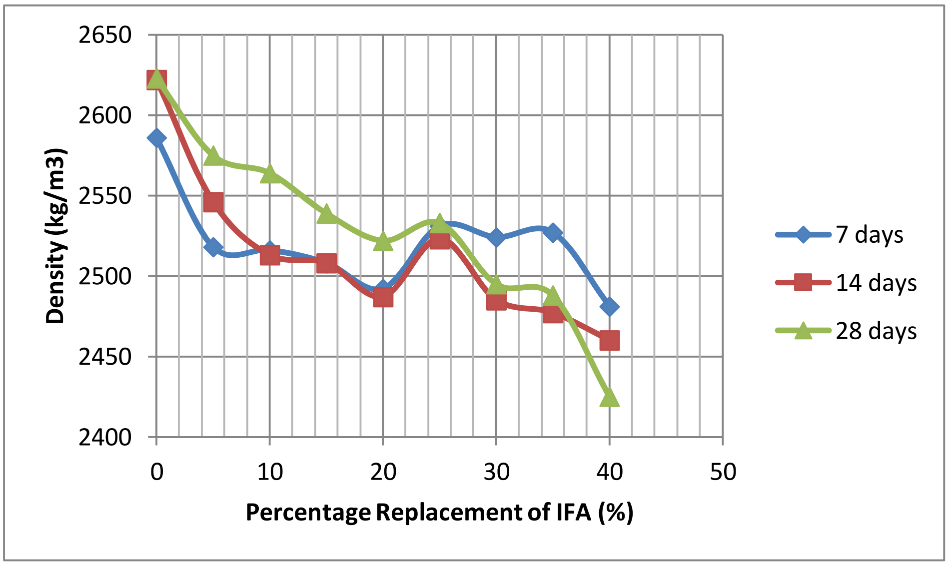

Figure 5. *Density of concrete*

4. Conclusion

The following conclusions were drawn from the evaluation of IFA concrete carried out:

- The percentage composition of silicon oxide (SiO_2), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3) was 60.557% which is above the minimum required limit of 50% specified by the ASTM C618-03. Combustion of solid waste at 700˚C produced an ash with a significant amount of calcium oxide as obtained in the chemical analysis indicating that Incinerator fly ash (IFA) has possibility to be used as a pozzolana in partial replacement with cement.
- The workability of fresh concrete mix decreases with increase in the IFA content.

- The compressive strength of (IFA) concretes increases with age but continue to decrease with increase in the level of replacement. However, concrete samples of 25% IFA replacement level attained over 70% of their control strength at 7 days, 14 days and 28 days respectively.

In order to utilize IFA in concrete, combustion of the solid waste should be at 700˚C and above to better exploit the pozzolanic reaction. The mix design should be based on constant workability instead of constant w/c ratio. Twenty five percent (25%) IFA replacement level was the most suitable and effective high volume replacement level for (IFA) concretes since it gave strengths close to the control concretes, and might probably attain the target strength (25MPa) at extended curing duration. Therefore, curing should be extended to 56 – 90 days.

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AUTHOR’S BIOGRAPHY

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