ASSESSMENT OF STRENGTH PROPERTIES OF MUNICIPAL SOLID WASTE INCINERATOR ASH-CONCRETE

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Abstract

Conventional materials for the production of concrete like cement and aggregates are ~~becoming~~ gradually becoming expensive due to high cost acquired in their processes- production and transportation. The exploitation of locally available materials such as wastes ash that can either reduce or replace the conventional materials should be considered. This research work is on the assessment of strength property of municipal solid waste incinerator ash-concrete. The investigation into the effect of partial replacement of municipal solid waste incinerator ash with ordinary Portland cement at 5, 10, 15, 20, 25 and 30% was carried out in accordance with the standard. The municipal solid waste incinerator ash was obtained from an incinerator in Bida and its environ. Total number of 84 cubes of size 150x150x150 mm specimen were casted from a mix ratio of 1:2:4 by weight and water cement ratio of 0.55 were used. The addition of Municipal solid waste incinerator ash (MSWIA) in concrete showed slight increase in compressive strength with increase in MSWIA additive up to 10% and decrease in compressive strength with further increase in MSWIA content, though the compressive strength of 15% replacement is almost the same as control. The 28 days compressive strength of concrete with 10% MSWIA content was 14.71 % more than normal, while that of concrete with 15% MSWIA content was 3.36% less than normal.

Keywords: Municipal Solid Waste Incinerator Ash, Cement, Pozzolana, Workability, Compressive strength,

Introduction

The use of waste materials as a partial or full replacement of cement in concrete can be an important step towards sustainability in the construction industry worldwide, since cement is used as their main binder, (Krammart, and Tangtermsirikul, 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 Ahmadi, *et al*. (2007) 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). The exploitation of locally available materials that can either partially or wholly replace the conventional material (cement) is being investigated. In the same vein, developing nations of the world are challenged with issues of managing domestic and agricultural wastes as a result of the attendant growth in population and increasing urbanization.

According to Singh *et al*. (2017) waste management and utilization strategies are major concern in many countries. The common technique used for treating waste is incineration to reduce waste mass by 70% and volume by up to 90%. Reuse of these wastes provide an attractive option that promotes savings and conservation of natural resources from further depletion hence creating a sustainable environment. Solid waste and its resource potential are being appraised for reuse (Ofuyatan *et al.*, 2014).

Agricultural waste such as corn cob ash and cassava peel ash inclusive is recently attracting interest (Adesanya and Raheem, 2009; Olushola and Umoh, 2013 and 2015). In view of the rising environmental tribulations faced today and also considering the fast reduction of conventional materials, the use of materials from by-products and solid waste materials from different industries are highly desirable. One such alternative is municipal solid waste incinerator ash, which is a form of domestic and industrial solid waste.

There is need to search for alternative methods to recycle the waste materials. Frías *et al* (2012), Cizer *et al*.(2006) and Ketkukah and Ndububa (2006) are some of the notable researchers who have demonstrated the use of ashes of rice husk, sugar cane straw and groundnut husk as pozzolan in concrete. They have shown that compressive strength of concrete incorporating these ashes increases while the workability is enhanced. According to Chandrasekhar *et al*. (2003), the use of rice husk ash reduces the effects of alkali-silica reactivity as well as drying shrinkage. Mehta and Monteiro (2004) reported that the performance of these waste materials, as pozzolans, depends on the type and amount of amorphous silica content they contain which further depend on duration and calcination temperature.

Municipal solid waste incinerator ash (MSWIA) is the ash that is left over after waste is burnt in an incinerator. This ash is made up of different materials like glass, brick, rubble, sand, grit, metal, stone, concrete, ceramics and fused clinker as well as combustive products such as ash and slag, (Gupta and Chandak, 2017). Martin *et al.*, (2012) stated that the composition of MSWIA is generally more complex than in the case of coal ashes but MSWIA differ highly in dependence on technology used and on composition of incinerated wastes.

Many studies have been carried out on the possibility of re-utilizing broad range of materials as a partial replacement for cement and aggregate in the production of concrete. This research work look in to the possibility of using MSWIA to increase the strength there by helping to reduce the cost, since MSWIA is readily available and cheaper against other cementitious materials which are expensive to carry out.

Materials Preparation

The material used for this research work are fine aggregate (which correspond to zone 2 based on sieve analysis carried out in accordance to BS 882 code of practice), coarse aggregate, Ordinary Portland cement (Dangote 3X), Municipal solid waste incinerator ash (MSWIA) and water–cement ratio of 0.55 which was obtained from mix design. The MSWIA used in this study was obtained from a mass-burn MSW incinerator in Bida and its environ. The ash used in this study was a combination of top and bottom ash. This mixture is generally the end product of most incinerators and carries a high pH value as a result. The chemical composition of the ash is presented in Table 1.

MSWIA was collected and then dried to remove the moisture content, after which the dried sample is then grinded and sieved using BS sieve (75µm), and the residue was thrown away and the sieved MSWIA was then stored in a cement bag ready for use. Casting and testing of concrete cubes; a total of 84 cubes of 150mm by 150mm dimensions were cast based on 28 days target compressive strength of 25N/mm^2.

Methodology

This research work involved the collection and preparation of MSWIA, and the mix design in accordance with BS 5328: Part2; 1990 was adopted, then followed by casting, curing and testing of concrete cubes. The total numbers of 84 cubes of 150mm by 150mm dimensions were caste in which 12 cubes was caste for each percentage replacement of MSWIA admixture, and 3 cubes from each mix (i.e. 84 cubes) were tested at 7, 14, 21 and 28 days of curing were tested for each percentage mix and average taken and recorded. The cubes were caste using 0%, 5%, 10%, 15%, 20%, 25% and 30% of MSWIA as partial replacement of cement and slump test was carried out during casting to check the workability of each concrete mix. Casting of the cubes was carried out immediately after the workability test for the determination of compressive strength; the cubes were left for 24 hours before de-moulding. At the end of each curing regime (7, 14, 21 and 28 days), three specimens from each mix were tested for compressive strength at room temperature and the average value recorded.

Results and Discussion

The physical and chemical properties of the MSWIA shows that ~~MSWIA~~ it has a specific gravity of 2.16 and a loss on Ignition (Lol) value is within ASTM C618 acceptable limit of 10% for class N pozzolana. This therefore indicates that the MSWIA was properly burnt. However, the chemical properties of the MSWIA indicate a combined SiO_2, Al_2O_3 and Fe_2O_3 content of 78.8% which is higher than the minimum value of 70% recommended in ASTM C618 for a good pozzolana, and would therefore be a high reactive pozzolana. The chemical composition of the MSWIA indicated a high content of SiO_2 of 58.8% and a high CaO content of 13.2%, which shows that it has some self-cementitious properties. The X- Ray diffraction analysis of MSWIA is shown in table 1 below.

Table 1: Chemical Composition of MSWIA

Ingredient	Percentage (%)
SiO_2	53.8
Al_2O_3	15.6
Fe_2O_3	9.4
CaO	13.2
MgO	4.1
SO_3	0.97
Na_2O	1.8
K_2O	0.9
CuO	0.4
ZnO	0.2

Setting Time Test Result

The water requirement of the MSWIA blended cement paste at various percentages of mix increased. It was noted that at 30% of MSWIA blended cement exhibited a longer setting time than other percentage of mix. The final setting time of all additional level was within the specification of the code (BS 812 part 3, 1975), which stipulate a final setting time of not more than 600 minutes. This is logical as the increase of MSWIA content reduce the cement content in the mix and also reduce the surface area of the cement. As a result of slow down in hydration process the setting time increases, (Ogunbode and Akanmu, 2012). The slow hydration means low rate of heat development. The delay in setting times is due to lower cement content and dispersion effect provided by the mineral additives on the cement particles, (Gesoglu and Erdigan (2007) and Ezziane et al (2010)).

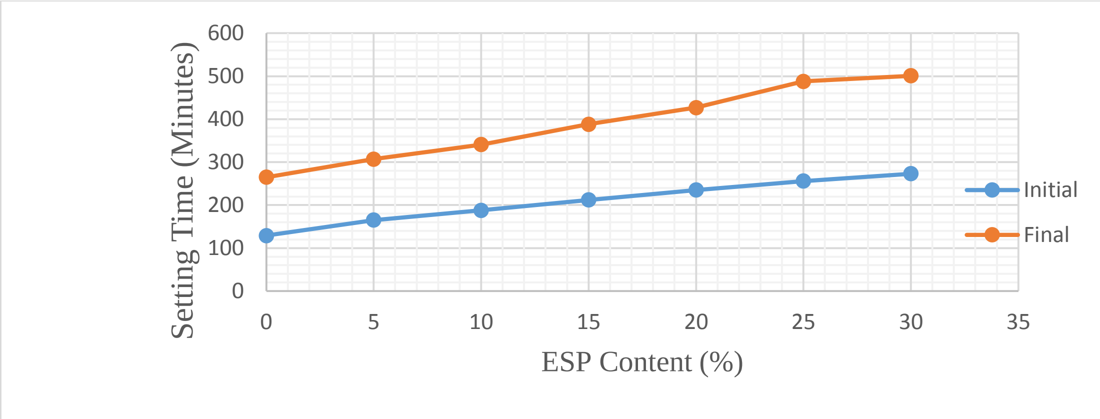

Figure 1: Setting Time of MSWIA Concrete

Workability of fresh concrete

The workability of fresh concrete mix in terms of slump is shown in figure 2. A slump value of 45mm was determined for control. The workability of fresh MSWIA concrete decreased with increase in the percentage of MSWIA by weight due to high absorption of water by MSWIA as shownin Figure 2. Further addition of MSWIA in concrete mix requires more water to improve the workability as MSWIA absorbs moisture in environment.

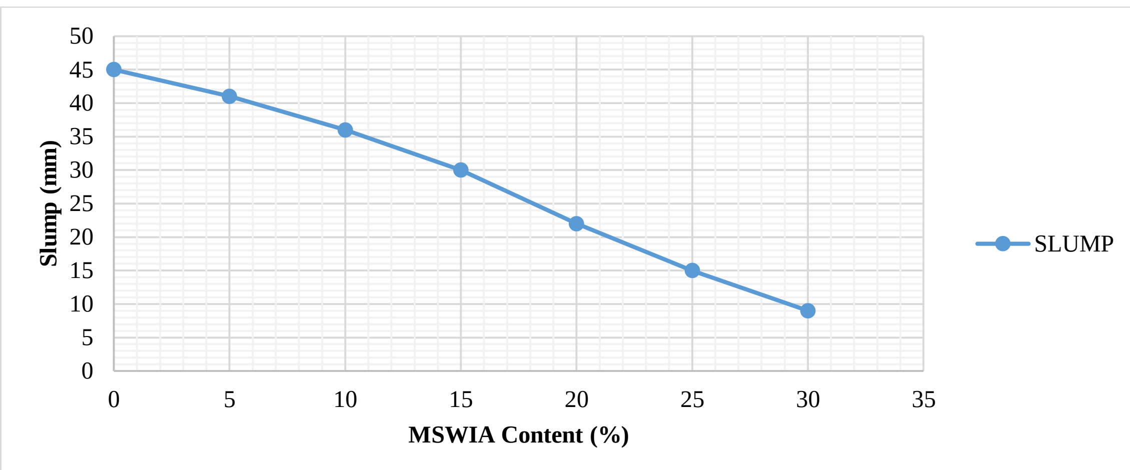

Figure 2: Slump of MSWIA-Concrete

Compressive Strength of Concrete

The compressive strength of hardened concrete specimens was carried out in accordance with BS1881-119 (1983) using (100mm x 100mm) cubes loaded uniaxially in the universal compressive machine. The average compressive strength values of the concrete specimens at each percentage of addition and age is presented in Table 2. The compressive strength of MSWIA concrete increased with age, the compressive strength at 28 days ranged from 29.50 to 25.20N/mm^2, which depends on the percentage addition of MSWIA. This result indicated that the MSWIA mixture could be used as a cementitious material in concrete.

Table 2: Summary of Total Compressive Strength Test

Percentage mix (%)	Compressive Strength N/mm^2			
	7 Days	14 Days	21 Days	28 Days
0	18.62	26.6	28.91	29.50
5	21.47	27.96	29.44	32.72
10	23.98	29.14	32.42	34.59
15	20.08	24.99	26.46	28.51
20	17.66	20.08	22.56	24.22
25	14.33	17.09	19.51	21.16
30	12.08	14.72	16.36	18.42

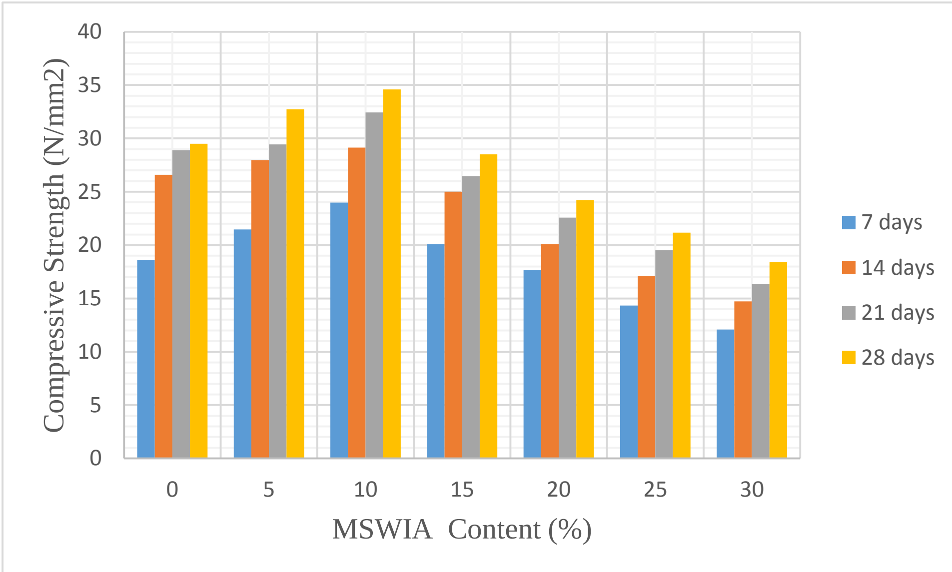

Figure 3: Compressive strength of MSWIA-Cement Concrete

The compressive strength of cement- MSWIA blended concrete, irrespective of the amount of MSWIA in the mixture, increases as the age of curing increases. The result of compressive strength of cement-MSWIA concrete is shown in Figure 3. The compressive strength increases till 10% MSWIA and decreases as MSWIA content increases.

It was observed that the difference in strength between the normal concrete and MSWIA blended concrete increase progressively with age till 10% MSWIA replacement and reduce progressively throughout the replacement levels at 28 days. This also indicates that MSWIA has potential to contribute to strength development when not more than 10% by weight of cement is used. This behavior suggests that MSWIA possesses pozzolanic characteristics. The drastic reduction in the compressive strength of concrete containing MSWIA of 15% and above, may be due to delay in the combination 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

Based on the research work carried out, the following conclusions were made:

- ✓ The chemical analysis shows that MSWIA is a good pozzolana.
- ✓ The Slump test for the concrete shows that the workability of the fresh concrete decreased with increasing in percentage of MSWIA replacement.
- ✓ The Initial and final setting time of the MSWIA-cement paste was found to increase with increasing in percentage of MSWIA.
- ✓ The concrete compressive strength increase with increase in percentage replacement of cement with MSWIA up to 10% replacement.
- ✓ The 10% MSWIA is considered as the optimum content with corresponding 28 days strength values of 34.59N/mm^2.

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