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Assessment of the Rheological properties of Aluminum dross in self-compacting concrete

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Assessment of the Rheological properties of Aluminum dross in self-compacting concrete

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Abstract. This research assessed the rheological properties of aluminium dross in self-compacting concrete. Aluminium dross, solid waste from the aluminium processing industry, was used as a partial replacement for cement in the development of eco-friendly concrete. This was done in a bid to reduce the cost of management of this waste in track with the 'waste to wealth' initiative. In this article, aluminium dross was used as a partial replacement for cement at 0, 4, 8, 12, 16 and 20% content. The rheological test (workability) was carried out according to European Federation for Specialist Construction Chemicals and Concrete Systems (EFNARC) specifications. To this end the slump test, L-box, V-funnel and J-ring test was carried out at the replacement. The slump flow result indicated satisfactory result up to 20% addition, which indicates the good flowability characteristics of the concrete. The result of the research showed that aluminium dross, to a large extent, influenced the workability of the concrete produced. At 10% addition of this solid waste, the rheology was unsatisfactory from L-Box and V-funnel test result. The outcome of this research will guide researchers, engineers, and concrete users on the proper timing for mixing the special eco-friendly self-compacting concrete in the construction industry.

1. Introduction

The generation of aluminium dross waste globally is almost sixty-one million (61) metric tons. This waste can pose a severe environmental problem when disposed of improperly. Rather than dumping them in landfill areas which leads to leaching and contamination of groundwater within its range, it can be used more effectively in an environmentally friendly way in the construction industry, especially in concrete technology. When in contact with sub-surface water in a landfill, the water can generate pockets of concentrated hydrogen, leading to combustion. The disposal of this waste is a big capital expenditure and hence the need for its re-use. To this end, this research assessed the rheology (workability) of this waste in concrete technology in a bid to develop green eco-friendly, cost-effective concrete for infrastructural development. Concrete is globally utilized as a construction material for the construction of infrastructures [1-2]. However, it is one of the significant sources of carbon emission globally. Recently, researches in concrete technology focus on the development of Supplementary Cementitious Materials (SCM) in concrete production. Additionally, the use of solid wastes has proved to be a useful supplementary cementitious material when used as a partial replacement for cement in concrete production [3]. The use of this waste will help in the reduction of solid waste and also reduce the cost of concrete production. Table 1 shows some common waste and other supplementary cementitious material in concrete technology.

Table 1. SCM and wastes in concrete.

Blast Furnace Slag [4-9]
Fly Ash
Silica Fume
Metakaolin [10-11]
Marble Waste [12]
Recycle Ceramic Waste as Aggregate [13]
Waste Glass [14-15]
Plastic waste [16]
Coconut Shell [17]
Waste Tiles [18]

According to Dai, [19] aluminium dross is defined as a by-product obtained from the aluminium smelting process. Aluminium dross is the inevitable waste product generated by the worldwide primary and secondary aluminium industries [20]. Stockburger et al., [21] states that dross is categorised according to its content. According to the same author, aluminium dross is produced from the primary and secondary aluminium smelting process, while black dross has a lower metal content and is produced during aluminium recycling (secondary industry), whereas white dross may contain recoverable metal aluminium from l5 to 70 percent. The black dross has a low metal content with high amounts of oxides, salts and granular in sand-like shape, whereas the white dross has extremely high metal content with small amounts of oxides and salts, forming large clumps or blocks. Non-metallic residues from dross smelting operations are often called 'salt cake' and contain 3 to 5% residual metallic aluminium. Approximately 4 million tons of white dross and over one million tons of black dross are recorded worldwide each year, and about 95% of this material is landfilled [22]. Every year around 4 million tons of white dross and over 1 million tons of black dross are produced worldwide, and about 95 percent of this material is landfilled [23]. Self-compacting concrete is one of the unique innovations in concrete technology. This fresh concrete flows under its own weight and does not require external vibration to undergo compaction. [24]. This research assessed the use of aluminium dross as a partial replacement for cement in self-compacting concrete.

2. Experimental methods

The aluminium dross used in this experimental study was obtained from a steel producing plant in Ota, Ogun State, Nigeria. It was collected in an airtight plastic bag and air-dried in the laboratory for some days. Solid waste in the aluminium dross sample was removed and then pulverized to reduce the surface area before using it as a partial replacement for cement in concrete. The aggregates were also sourced from Ado-Odo Ota local government in Ogun state Nigeria [25, 26]. The cement conforms with NIS 444-1 standard. It was obtained in an open market within the same location. Water-free from dirt and deleterious materials were used in the experimental research. The aluminium dross was used as a partial replacement for cement at 0, 4, 8, 12, 16 and 20% addition of the total weight of the cement. Five concrete samples were developed. The rheological properties of the self-healing concrete were assessed using EFNARC standards [27, 28]. The tests include the flowability, segregation test, passing ability test. To this end, the slump flow test, T50 slump test, L-Box test and V-funnel test were assessed using EFNARC specifications. Chloride free, superplasticising admixture based on selected sulphonated napthalene polymers (Conplast SP430) superplasticizer according to [27] specification was used in improving the workability. The mix proportion of aluminium dross with the self-compacting concrete (ALSCC) with respect to aluminium dross proportion is as shown in Table 2.

Table 2. Mix proportion of the concrete.

	ALSCC1	ALSCC2	ALSCC3	ALSCC4	ALSCC5
Water (kg)	75	75	75	75	75
Aluminium dross (ALDR) (kg)	0	5.6	11.2	16.8	22.4
Portland Limestone Cement (PLC) (kg)	140	134.4	128.8	123.2	117.6
Fine Aggregate (kg)	280	280	280	280	280
Coarse Aggregate (kg)	385	385	385	385	385

3. Results and discussion

3.1. Filling ability

It is also well known that the concrete properties can change during the pumping operation. Losses in slump consistency and changes in air-void systems are the most commonly reported, as well as changes in the filling ability. The filling ability of the developed concrete was assessed at the various addition of the solid waste. This was achieved by determining the slump and the T50 slump flow test. This was used to assess the fluidity of the fresh self-compacting concrete (SCC). The result is shown in figure 1. From the result (Fig. 1), the addition of the additive altered the filling ability of the developed concrete.

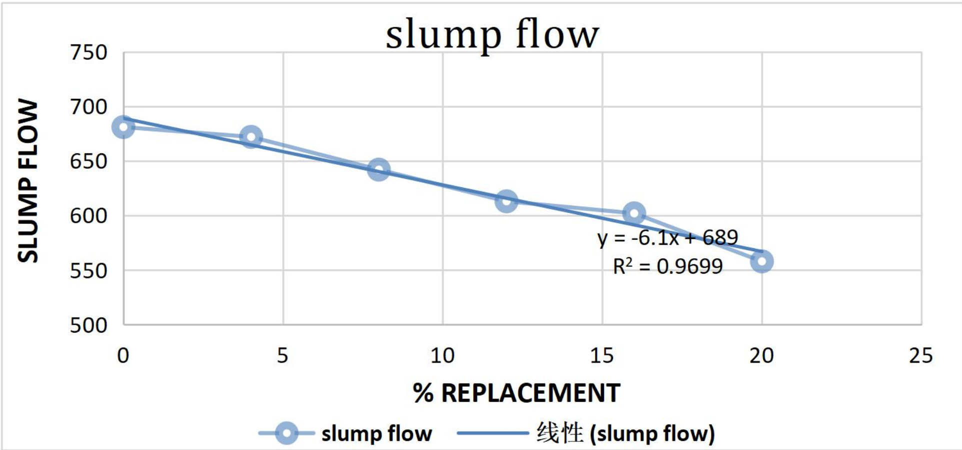

Figure 1. Slump flow at the different additions.

The concrete sample with the desirable value of T50 and the slump flow test is the concrete without aluminium dross (0%) addition (figure 2). At higher addition, the concrete became less viscous, which affected the result. This may be a result of the fact that the addition of aluminium dross accelerates the setting time of concrete [29]. The higher addition of Metakaolin implies that it will reduce the flow, making it stiffer than the control invariably; it will make pumping operations difficult for concrete infrastructure construction. Therefore, the use of these supplementary cementitious materials at higher quantities requires technical attention for pumping operations.

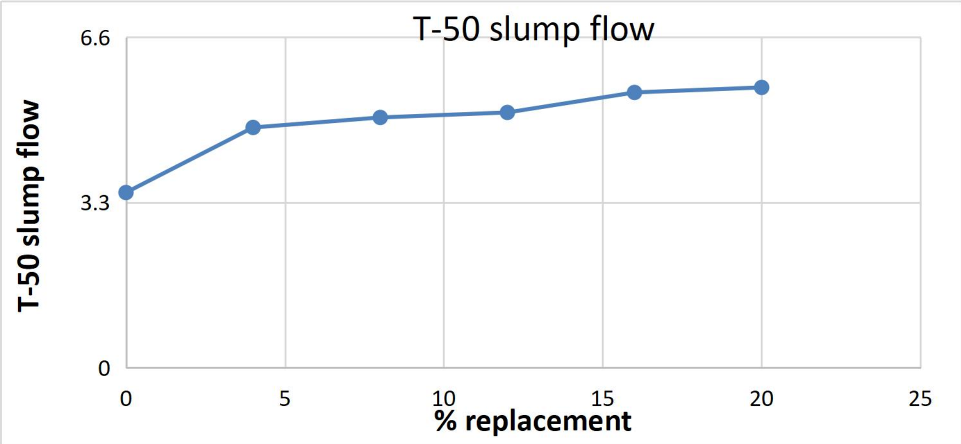

Figure 2. T_{50} Slump flow at the different replacements.

3.2. Segregation resistance

The segregation resistance of the fresh concrete was assessed using the V-funnel test. This was used to determine if the concrete is homogeneous in composition during transportation and placing. The result showed an undesirable result at a percentage above 4% addition of the solid waste see (Table 3). The result obtained (Fig. 3) was below the specification for the segregation test. This may be attributed to the low viscosity of the concrete sample at higher addition of the solid waste. The addition of more cementitious particles will lead to a decrease in plastic viscosity and the flow rate of the concrete mixture.

Table 3. V-funnel and Visual Stability Index (VSI) at the different replacements.

% Replacement	V-Funnel	(VSI)
0	9.6	1
4	9.9	1
8	11.4	1
12	12.8	0
16	13.1	0
20	13.5	0

3.3. Filling ability

The filling ability was determined using the L-Box test. The filling ability was used to assess the filling performance evaluation of self-compacting concrete. The result followed a similar trend with the V-funnel test. As shown in Fig. 3, the filling ability of the developed self-compacting concrete became undesirable at 4% addition of aluminium dross. This, according to Gozde et al [30] is due to the absorption of water over the high specific surface area. This also buttressed the findings of Flatt and Bowen, [31] affirmed that the water/cement ratio and paste volume to a large extent affects the viscosity of the fresh concrete. However, decreasing the water/cement ratio makes it more difficult to disperse the fresh concrete. This is because as the volumetric concentration increases, it alters the filling ability of the fresh concrete mixture.

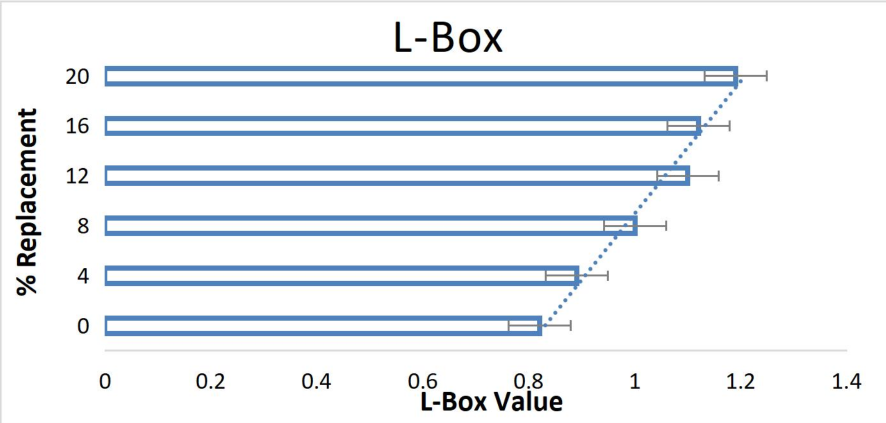

Figure 3. L-Box result.

4. Conclusion

This experimental research assessed the rheological properties of self-compacting concrete using aluminium dross as a partial replacement for cement. The aluminium dross was utilized in a bid to reduce and re-use solid waste. Filling ability, segregation ability and the passing ability of the concrete were assessed. The result of the research revealed that:

i. The addition of aluminium dross altered the workability of the concrete.
ii. The viscosity of the concrete reduced with the addition of the waste, as the addition of aluminium dross accelerates the setting time of concrete.
iii. At 4% and above addition of the waste the workability of the concrete became undesirable.

The use of aluminum dross in self-compacting concrete should be done with caution as the waste reduced the viscosity of the concrete because it impedes the setting time of concrete. It is recommended that when utilized in concrete, the mixing plant should be close to the site because of the high water-absorbing properties that increases the hardening of fresh concrete.

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