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Influence of Sawdust Ash (SDA) as Admixture in Cement Paste and Concrete

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Abstract

The paper presents the findings of an investigation into the use of sawdust ash (SDA) as admixture in cement paste and concrete with a view to improve the mechanical and durability properties. The SDA used was obtained by controlled burning of sawdust in an incinerator to a temperature of 630°C and after cooling was sieved through a 75µm sieve and characterized. The effects of SDA on cement paste and concrete were investigated for addition of 0, 2, 4, 6, 8 and 10 %, respectively by weight of cement. The slump of fresh 1:2:4 concrete mixes with 0.55 water cement ratio and SDA additions was determined and a total of ninety 150 mm cubes of hardened concrete tested for compressive strength at 3, 7, 14, 28 and 56days of curing. Also the resistance of concrete specimen exposed to 2.5% concentration of sulphuric and hydrochloric acid solutions were investigated. The result of the investigations showed that SDA was predominantly of calcium oxide (50.54%), potassium oxide (19.93%) and a combined SiO_2, Al_2O_3 and Fe_2O_3 content of 12.47 %. The addition of SDA in cement decreased drying shrinkage but increased consistency, initial and final setting times and could be used as a retarder. The addition of SDA in concrete showed a decrease in slump, but increase in compressive strength, with an optimum of 2% SDA. The use of SDA in concrete also offered a better resistance to sulphuric and hydrochloric acid environments. Therefore up to 2% SDA is recommended as a retarding admixture and strength improver in normal and acidic environments.

Keywords: Acidic environment, admixture, cement paste, concrete, Sawdust ash

1. Introduction

Industrialization in developing countries has resulted in an increase in agricultural output and consequent accumulation of unmanageable waste. Sawdust is an industrial waste in the timber industry and causes nuisance to both health and environment when not properly disposed, these may create large amounts of waste byproducts that must be transported away and stored in landfills. The pollution arising from such waste is a cause of concern for many developing nations such as Nigeria [1].

High inflation in most developing countries has led to increase in the prices of traditional building materials. To lessen material and construction cost to affordable rate, many research works have been directed towards utilization of cheap and readily available local materials such as industrial and agricultural by product as substitute of aggregate or binder in infrastructure construction [1]. Studies reported by [2], [3], [4] and [5], etc on use of sawdust ash or wood ash as partial replacement in mortar and concrete work have shown that inclusion of the material in the matrix not only lowers the cost of the concrete but also offers a large potential as a cost-effective alternative to current disposal method of waste.

The use of admixture in concrete is very imperative in most situations where there is a need to upgrade the properties of either fresh or hardened concrete or both for an exact cause. In most situations the realization of such upgrading can only be achieved cost-effectively and more rapidly when suitable admixtures are used. The choice to investigate into the use of sawdust ash as admixture in concrete may enhance the economic standard of wood workers by utilizing the waste material to generate assets and will also serve as a cheaper alternative to that of conventional admixtures, with a consequent reduction in the cost of construction and also as a means of addressing the environmental pollution caused by the accumulation of unmanageable waste.

2. Materials and Methods

2.1 Materials

Ordinary Portland cement manufactured in Nigeria as Dangote brand, with a specific gravity of 3.14, moisture content of 0.63 % and bulk density of 1164 kg/m^3 was used. The oxide composition of the cement is shown in Table 1. Sharp sand from river Watari, Kano, Nigeria, with a specific gravity of 2.60 and bulk density of 1525 kg/m^3 was used. The particle size distribution of the sand shown in Fig. 1, indicate that the sand used was classified as zone -1 based on [6] grading limits for fine aggregates. The coarse aggregate is crushed granite of nominal size of 20 mm with a specific gravity of 2.67 and bulk density of 1408 kg/m^3. The particle size distribution is also shown in Fig. 1.

Sawdust was obtained from Yola timber shed in Adamawa State, Nigeria. The Sawdust Ash (SDA) was obtained by incineration of sawdust at a temperature between 600 – 630^{0}c under a control burning system for 2hours 25minutes and the ash was allowed cooling before sieving through sieve 75 µm. The SDA is of specific gravity of 2.27, bulk density of 595 kg/m^3 and moisture content of 3.53 %. The oxide composition of SDA was conducted using X-Ray Flouresence (XRF) and result is shown in Table 1.

2.2 Methods

2.2.1 Tests on Cement Paste.

Six mixes were used for the determination of consistency, setting times and drying linear shrinkage of cement paste containing SDA as admixture in accordance with [7]. MP-00 is the control mix and MP-02, MP-04, MP-06, MP-08 and MP-10 are mixes with addition of SDA of 2, 4, 6, 8 and 10 %, respectively. Three readings were taken for each mix of each test and an average found. The results are shown in Fig. 2 – 4.

2.2.2 Concrete mix Proportions

Prescribed concrete mix of 1:2:4 and water-cement ratio 0.55 was used to determine the effect of SDA as admixture in concrete. Six mixes were used, ACM-00 is the control mix and ACM-02, ACM-04, ACM-06, ACM-08, and ACM-10 representing mixes with addition of SDA of 2% to 10%, respectively.

2.2.3 Slump of SDA- Concrete

The slump of fresh Concrete with SDA addition was determined in accordance with [8] using the mixes stated above and the results are shown in Fig. 5

2.2.4 Compressive strength test on SDA-Concrete

The compressive strength of Concrete with addition of SDA was carried out in accordance with [9] for the prescribed concrete mix of 1:2:4 and water-cement ratio 0.55. Samples were cast in steel moulds of 150 mm cubes and cured in water for 3, 7, 14, 28 and 56 days, respectively. A total of ninety (90) samples were cast and at the end of every curing regime, three samples were crushed using the Avery Denison Compression Machine of 2000 kN load capacity and at constant rate of 15 kN/s and the average taken. The compressive strength behaviour is

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shown in Fig. 6.

Table 1: Oxide Composition of OPC (Dangote Brand) and SDA

Oxide (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_3	TiO_2
OPC	14.89	5.70	4.10	68.30	1.69	0.1	0.71	2.67	0.22
SDA	7.52	3.50	1.47	50.64	5.02	19.93	3.61	1.20	0.34
Oxide (%)	MnO	BaO	V_2O_5	P_2O_5	ZnO	Cr_2O_3	NiO	CuO	L.o.I
OPC	0.04	0.15	0.02	-	-	0.01	< 1	-	1.33
SDA	0.35	0.54	0.01	1.64	0.03	<0.01	<0.01	<0.01	4.20

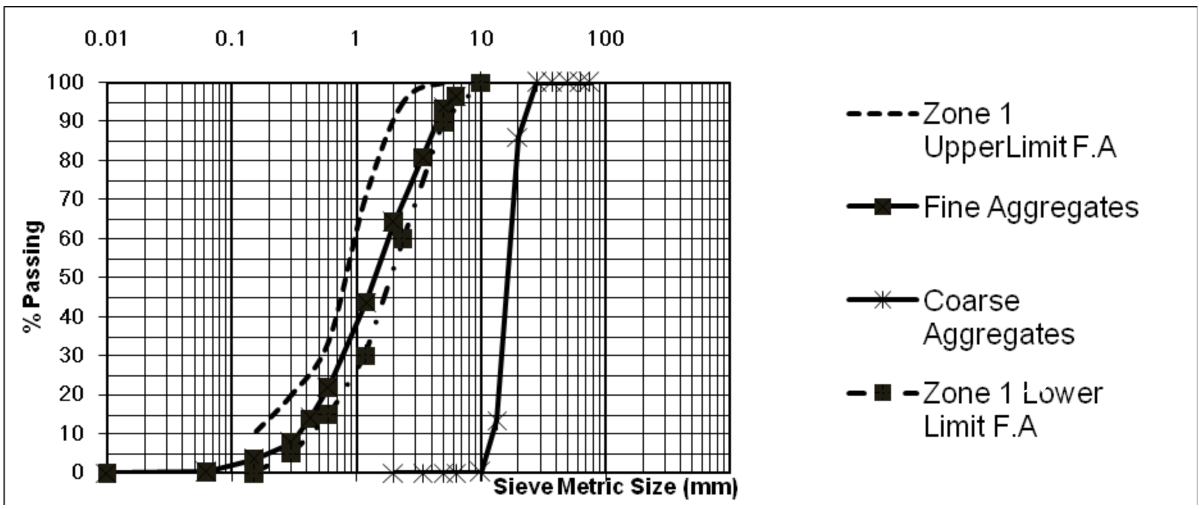

Fig. 1: Particle Size Distribution of Fine and Coarse Aggregates

2.2.5 Test of SDA-Concrete in Acids.

This was carried out using crushed samples of the cube from the compressive strength test at 28 days curing for the six mixes. Three pieces of crushed samples for each percentage addition of SDA were taken and weighed before exposure in 2.5% concentration of sulphuric acid (H_2SO_4) solution and hydrochloric acid (HCl) solution respectively. The test ran for 28 days with weight retained taken at 7days intervals. At the end of every 7th day, the samples were removed cleaned and left to dry before weighing to obtain the weight at the end of that regime. The behaviour of SDA-Concrete resistance to acidic environment was determined in terms of weight retained and is shown in Fig. 7 and 8.

3. Discussion of Results.

3.1 Cement and Sawdust Ash

The oxide composition of sawdust ash (SDA) indicate a combined SiO_2, Al_2O_3 and Fe_2O_3 content of 12.47 % which is much less than that specified by [10] for pozzolana and shows that is not a good pozzolana. The CaO content (50.67 %) in SDA also shows that it has high self cementing properties. The oxide composition of SDA also indicated a high content of K_2O (19.93 %) which may be a source of disruption in cement and concrete matrix. The chemical composition of the cement is satisfactory and has met the [11] standard.

3.2 Sawdust Ash-Cement paste

Normal consistency of cement with inclusion of SDA increases with increase in SDA content as shown in Fig. 2. Hence more water is required for wetting the particles, as the total surface area of the particle is increased [12]. Furthermore, since SDA has a less specific gravity than the OPC, a large volume of water may be required to properly wet excess volume of SDA added to the mix to produce cement gel and this could lead to increase in consistency of the cement paste [13].

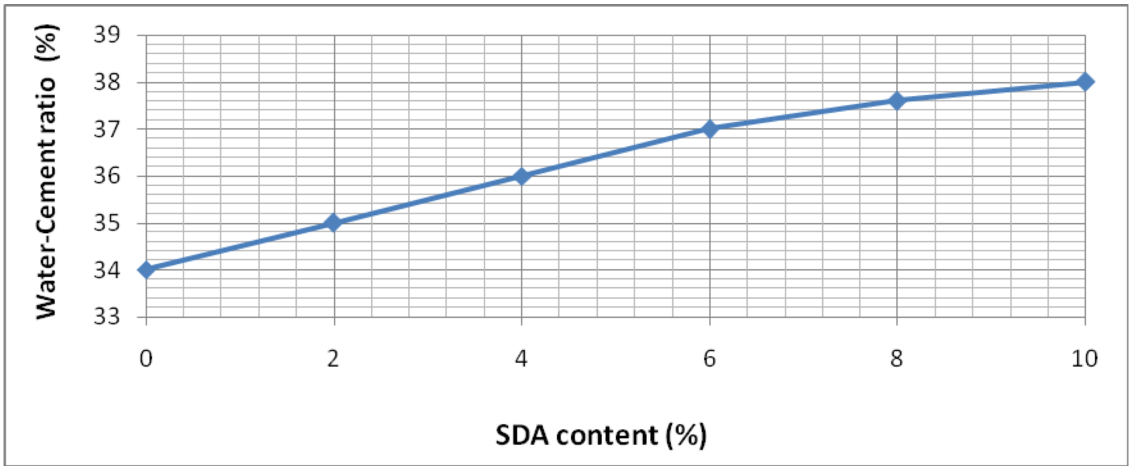

Fig. 2: Consistency of SDA-Cement Paste.

The setting times of SDA-cement increased with increase in SDA content as shown in Fig. 3. This behavior may be due to the presence of MgO, which hydrates in high-alkali medium to form $Mg(OH)_2$ with tiny crystal precipitates around the cement grains to form a protective layer, hence retarding further hydration of cement grains [14].

The drying shrinkage of SDA-Cement paste shows a decrease in linear drying shrinkage with percentage addition of SDA as shown in Fig. 4. This is due to reduction in water demand and production of finer paste structure which restrict the loss of pore water within the paste [12]. Also shrinkage decrease with increase in SDA concrete due to the presence of calcium oxide and potassium oxide which hydrates, reducing the water content as shown in eq. (1) and (2), and this indicate that the concrete can be used in a cold weather condition and may not crack since increase in percentage addition of sawdust ash reduces linear shrinkage of the concrete [15].

$$CaO(s) + H_2O(I) \rightarrow Ca(OH)_2(aq) \quad (1)$$

$$K_2O(s) + H_2O(I) \rightarrow 2KOH(aq) \quad (2)$$

3.3 Workability of SDA-concrete

The slump of concrete decrease with increase in addition of SDA content as shown in Fig. 5. This may be due high loss on ignition of SDA compound to that of cement and also may be due to high specific surface of sawdust ash for constant water content [16].

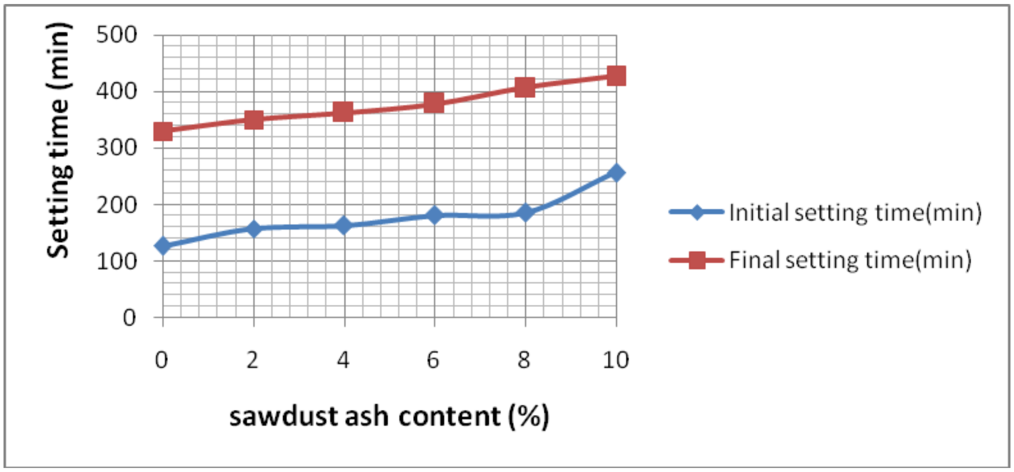

Fig. 3: Initial and Final Setting Times of SDA-Cement Paste.

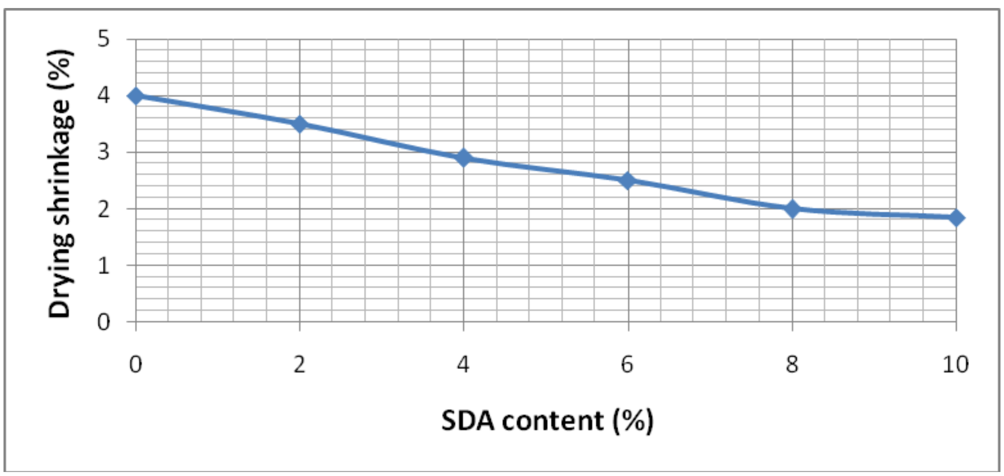

Fig. 4: Drying shrinkage of SDA-Cement paste

3.4 Compressive Strength of SDA-concrete

The compressive strength of SDA-concrete showed that compressive strength increased with curing age and also increased with addition of up to 2% of SDA. Further increase in addition of SDA led to decrease in compressive strength of the concrete as shown in Fig. 6. The increase in compression strength with curing age is due to hydration of cement and SDA. The increase in compressive strength with addition of SDA up to 2% may be due to formation of additional calcium silicate hydrates from the pozzolanic reaction of SDA. The reduction in compressive strength with addition of SDA of 4% and above may be due to saturation of the cement mix with oxides such as K_2O and MgO in SDA which form composites that may inhibit the formation of strength giving calcium silicate hydrates from cement hydration [17].

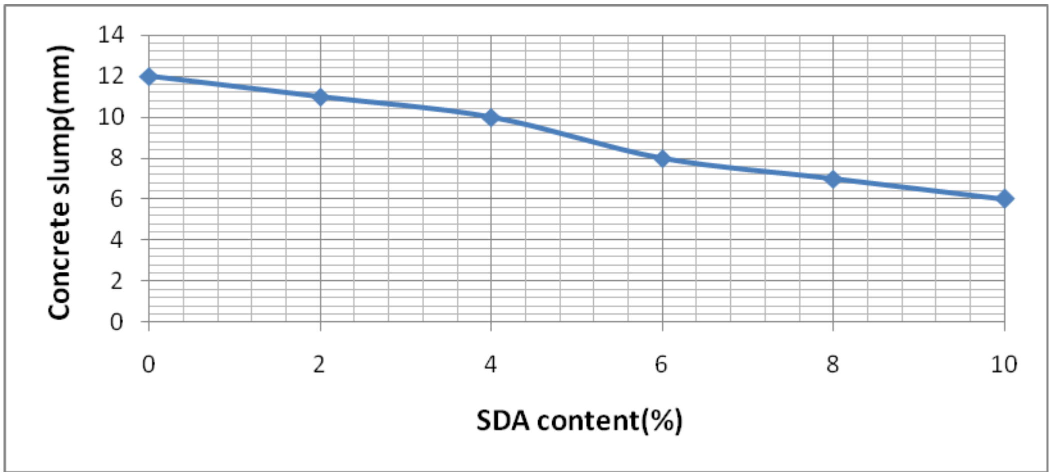

Fig. 5: Slump of SDA-Concrete.

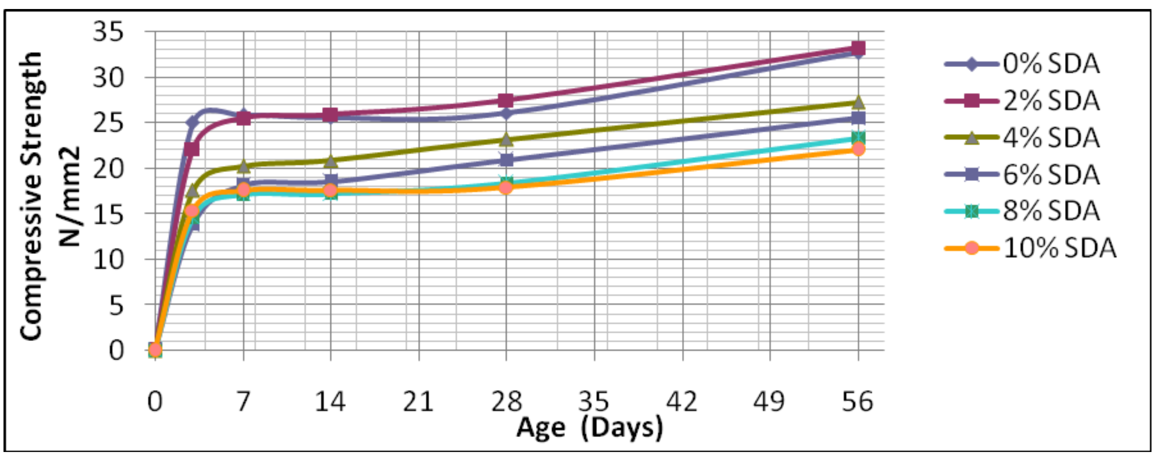

Fig. 6: Compressive Strength Development of SDA-concrete.

3.5 Effect of Acids on SDA-concrete.

Fig. 7 and 8 show the weight retained of concrete specimens during 4 weeks of exposure in sulphuric acid and hydrochloric acid environments. The weight of concrete retained decreased with increase in exposure duration but increased with increase in SDA content. There was minimal degradation in all cases tested in 2.5 % concentration of the acidic media. In case of the control mix there was about 1.0% reduction and less than 1.0% reduction in SDA concrete. The observed trend showed that SDA concrete would have a better resistance against Sulphuric and hydrochloric acids. These improvements could be as a result of the following factors.

i. SDA reacted with the lime in the paste matrix; consequently it reduced the lime present in its free format. Lime is considered one of harmful compounds as it reacts with many chemicals causing concrete degradation [17].

ii. Sawdust ash concrete had a better pore structure with greater impermeability than the ordinary concrete. This would slow down the penetration of water and chemicals into the concrete.

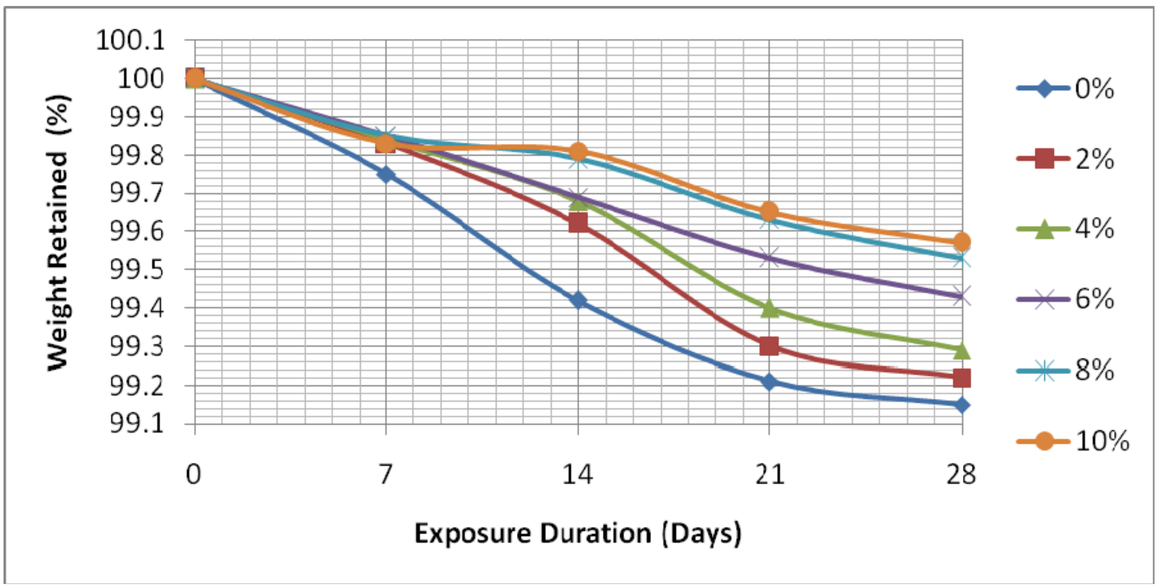

Fig. 7: Weight of SDA concrete retained after exposure in Sulphuric acid solution.

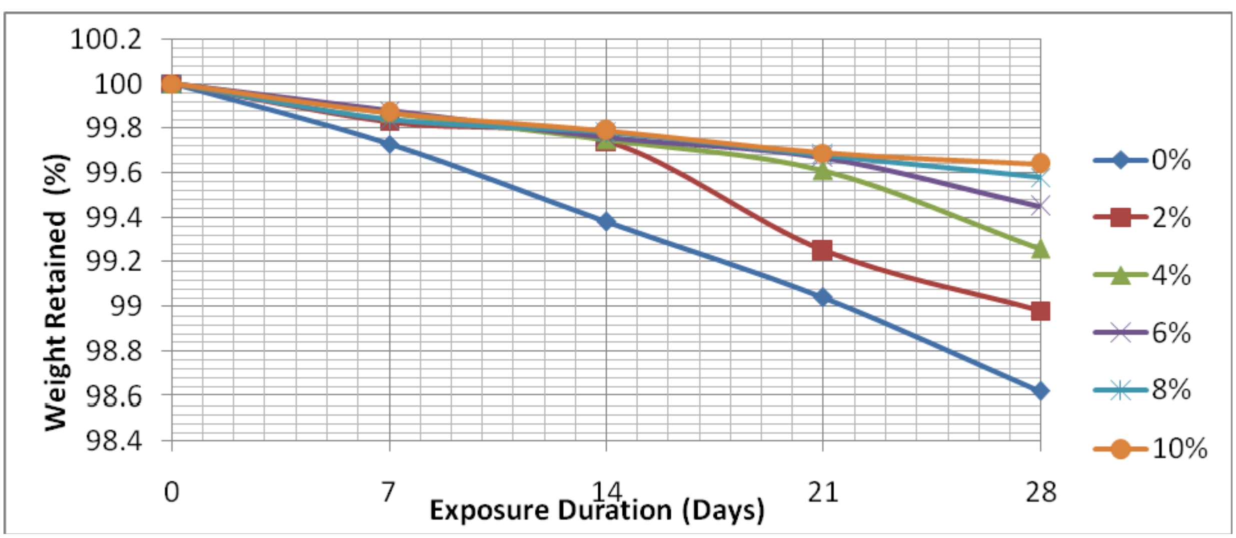

Fig. 8: Weight of SDA- concrete Retained after exposure in Hydrochloric acid solution.

4. Conclusions

i) SDA was predominantly of Calcium oxide (50.64%), Potassium oxide (19.93%) and a combined SiO_2, Al_2O_3 and Fe_2O_3 content of 12.47 % which shows that is not a good pozzolana.

ii) SDA increased the initial and final setting of cement paste and could be used as a retarder, but also has a decreasing effect on dry linear shrinkage.

iii) The addition of SDA decreased the workability (slump) of concrete.

iv) The addition of up to 2% SDA increased the compressive strength of concrete.

v) The addition of SDA increased the resistance of concrete exposed to acidic environment.

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