Efficiency of Curing Methods on Some Properties of Sugar Cane Bagasse Ash Concrete

[*a]Usman, N. D., [b]Tiamiyu, A. I., [b]Isa, M. N., [b]Maigana, A. A. [c]Musa, J.
[a]Department of Building, Faculty of Environmental Sciences,
Modibbo Adama University, Yola, Adamawa State, Nigeria
[b]Department of Building, School of Environmental Technology,
Abubakar Tatari Ali Polytechnic, Bauchi, Nigeria
[c]Department of Building, School of Environmental Studies,
Federal Polytechnic, Nasarawa, Nigeria
*Correspondence email: napodanusman@gmail.com

Abstract

This research is aimed at investigating the most efficient curing method on concrete produced using 20% sugarcane bagasse ash (SBA) as partial replacement of ordinary Portland cement at 7, 14, 28, and 56 days of curing. This is under three commonly used curing methods namely spraying, immersion and covering with polythene with the targeted strength value of 30N/ mm^2 at 28 days. After appropriate curing, 29.0 N/mm^2, 19.0 N/mm^2 and 19.0 N/mm^2 were obtained for SBA concrete under spraying, immersion, and polythene methods at 28 days respectively. Based on the findings, it was concluded that spraying method of curing produced strongest SBA concrete compared to other forms of curing. Therefore, spraying of water is recommended as the most suitable curing method for SBA concrete at 20% replacement level.

Keywords: Concrete, Curing Method, Efficiency, Properties, Sugar Cane Bagasse Ash.

INTRODUCTION

Sugarcane Bagasse Ash (SBA) is the pozzolana produced from the ash of an agricultural waste material obtained after squeezing out the sweet juice in sugar cane and incinerated into ash (Usman, Chom, Salihu, Abubakar & Gyang, 2016). Sugar cane is grown in the world from latitude 36.70N and 31.00S, from sea level to 1000m of latitude or little more. It is considered as essentially a tropical plant. It is a long duration crop and thus it encounters all the seasons viz; wet season, winter and summer during its lifecycle (sugarcane climate). It is produced in commercial quantities in Nigeria especially in the North and the Eastern part of the country, after the extraction of all economical sugar from sugarcane, about 40-45% fibrous residues is obtained (Food & Agricultural Organization, 2006; Usman *et al*., 2016).

Curing is the process that is adopted to promote the hardening of concrete under conditions of humidity and temperature which are conducive to the progressive and proper setting of the constituent cement. Curing has a major influence on the properties of hardened concrete such as durability, strength, watertightness, wear resistance, volume stability, and resistance to freezing and thawing, creep, chemical attack and density. Concrete that has been specified, batched, mixed, placed, and finished can still be a failure if improperly or inadequately cured. Concrete curing is one of the most important and final steps in concrete production though it is also one of the most neglected and misunderstood procedures. It is the treatment given to newly placed concrete during which it hardens so that it retains enough moisture to minimized shrinkage and resist cracking (Nurruddin *et al*, 2018).

In addition to increasing the strength of concrete, proper curing reduces the porosity and provides a fine pore size distribution in concrete microstructure (Usman *et al*., 2016; Nurruddin *et al*., 2018). Most suitable curing method needed to be identified from the most known or used curing methods such as immersion into water, spraying of water, covering with polythene sheet material in order to produce the most strong, durable and reliable concrete.

The use of the sugarcane bagasse as an ash source for mineral addition into cement-based materials is subjected to two factors: the production and chemical composition of the ash. The sugarcane bagasse ash is predominantly composed of silicon dioxide, which can develop pozzolana activity depending on the characteristics of both burning and grain size. In this case, the reactivity between silica and the hydration products may improve the physical and mechanical properties of the cement-based materials. However, when a certain percentage of cement is being replaced with sugar cane bagasse ash (SBA) in the concrete production, curing conditions could affect strength differently. More so, admixture have shown to cause more compressive strength losses in uncured concrete specimens than normal concrete mixes (Usman *et al*., 2016; Usman *et al*., 2020).

Many researches were carried out on SBA and its pozzolanic properties, the material is locally sourced agricultural waste readily available which posed a disposal threat in Nigeria. This led to choosing the material to ascertain the efficiency on methods of curing on the SBA concretes with 20% replacement with view of proposing the most appropriate method for Nigeria SBA concrete.

MATERIALS AND METHOD

Sized crushed coarse aggregate with maximum size of 20mm was used in a saturated surface dry condition based on BS 812, (1996). And the fine aggregate used was also in saturated surface dry condition. The percentage passing 600µm of the fine aggregate was 40%, and conforms to BS 812, (1996). Physical properties of both aggregates are presented in Table 1.
The cement used in the study was ordinary Portland Cement of Dangote brand because is the most widely used cement for construction in Nigeria and conform to BS 12 (1996). The water used in the research for preparing concrete and curing purposes was fresh tap water in the Concrete Laboratory of Building Department of Ahmadu Bello University, Zaria.

The sugarcane bagasse was sourced locally from sugar processing company in Danja village of Danja Local Government of Katsina State. The ash was produced by controlled burning using kiln in the Department of Industrial Design of Ahmadu Bello University, Zaria. The ideal temperature used for producing SBA was 660°C adopted from Alvarez & Raphael, (2012), X-ray diffraction (XRD) was carried out in multi-use laboratory of Ahmadu Bello University Zaria to determine the chemical composition of the ash. The concrete was designed according to Department of environment method (DOE method), and the optimum dosage of SBA used was 20% (Genesan *et al*., 2007; Usman *et al*, 2020).

Table 1 Physical Properties of Aggregates

Properties	Natural aggregate	Fine aggregate
Specific Gravity	2.64	2.48
Water Absorption	0.81%	1.23%
Aggregate Crushing Value	19%	-
Fineness Modulus	2.88	7.02

A concrete of grade 30N/mm^2 at 28 days was design using the Department of Environment (DOE) Method. The design was made for 36 cubes each for both control and 20% replacement as shown in Table 2. The proportions of each ingredient for the 36 cubes is shown in Table 3.

Table 2 Summary of Concrete Mix Design

Materials quantity (kg/m³)			
Cement	Water	Coarse aggregate	Fine aggregate
360	240	1125	750

Table 3 Specimens mix proportion.

Materials	Quantity of materials (kg)	
	Control	20% SBA
Cement	12.96	10.01
SBA	-	2.59
Fine aggregate	27	27
Coarse aggregate	40.50	40.50
Water	8.64	8.64

Production of Test Specimens

The binders were dry mixed for 3 minutes to obtain homogeneous binder. The aggregates at saturated surface dry condition were added and mix for another 3 minutes. Mixing water was added and the mix continue for about 5 minutes. Workability measurement was carried out prior to casting of the concrete specimens. Cast iron moulds of 100mm x 100mm x 100mm were used to produce the concrete cubes. The moulds were oiled for easy removal of concrete cubes. The concrete was placed in approximately three equal layers and each layer was rammed with 25 strokes of 50mm round ended rod. The top of the cubes was marked after a while for identification purpose. Immediately after this, the specimens were kept in a cool place in the laboratory. The specimens were removed from the cast iron moulds at the age of 24$\pm$2hours.

Curing of Specimens

The specimens were cured under the three curing methods until the days of testing. The methods used for curing were spraying with water, immersion into water and covering with polythene. In spraying with water method, the specimens were kept moist by spraying the specimens with water two times daily (morning and evening) up to the days of crushing. For instance, the specimens were immersed into water until the days of crushing. In covering with polythene, the specimens were covered with polythene until the days of crushing. The specimens were tested at 7, 14, 28 and 56 days of curing.

Testing of the Hardened Properties of Specimens

The compressive strength, abrasion resistance and water absorption test of specimens were carried out at 7, 14, 28 and 56 days. All the specimens were tested at saturated surface dry condition. The crushing was carried out at 7, 14, 28 and 56 days respectively for the three methods of curing, using the hydraulic crushing machine of 1000kN capacity in the Building Department concrete laboratory, the failure load was divided by the cross-sectional area to obtain the strength, which is in accordance with BS 1881: Part 116; 1983 Method for determination of compressive strength of concrete cubes.

The abrasion resistance test was carried out in accordance with African Regional Standard (1996). The surface of the concrete cubes was subjected to brushing by means of a wire brush. The brushing consists of one forward and backward motion per second for one minute i.e. 60 cycles. The cubes were weighed before and after brushing and recorded the masses as M_1 and M_2 respectively. The mass of the detached matter i.e., $M_1 - M_2$ was recorded and the percentage weight loss of all the specimens were recorded and compared.

While Water Absorption test was carried out in accordance with Indian Standard 456. Dry cubes were put in an oven at a temperature of 105°C to 115°C. The weight (W_1) of each cube was recorded after allowing them to cool at room temperature. The cubes were then immersed in water for 24 hours. The specimens were then taken out of water and allow to surface dry, thereafter it was weighed again and recorded as W_2.

The water absorption in % $= \frac{W2-W1}{W1}$ x 100

RESULTS AND DISCUSSION

Chemical analysis of SBA

It can be observed that the percentage of the silicon dioxide (SiO_2), iron oxide (Fe_2O_3), aluminum oxide (Al_2O_3) gives a total of 90.5% for SBA, this satisfies the requirements of the ASTM C 618 which give a minimum of 70% of the class N (raw or calcined natural pozzolana). It was also observed that SBA contains higher content of SiO_2.

Workability Measurement

The slump test on the fresh property of concrete is displayed below. The concrete was mixed in accordance with BS 1881; Part 108, (1983) Method for making Test Cube from Fresh Concrete. The degree of workability of the concrete mixes for SBA concrete was determined by slump tests. The slump test was conducted in accordance with Method for Determination of Slump, BS 1881: part 102: 1983 (Table 4, Plate 1).

Table 4: Chemical Composition SBA

Constituents	% compositions SBA
SiO_2	78.34
Al_2O_3	8.55
Fe_2O_3	3.61
CaO	2.15
MgO	0.13
SO_3	-
Na_2O	0.12
K_2O	3.42
P_2O_5	1.07
Loss on ignition	0.42

Plate I. Slump test display on SBA concrete.

Compressive Strength Test on SBA Specimens

The results of compressive strength have been presented in graphical representation of average compressive strength versus curing age for different methods of curing used in the experiment as in figure 1.

The test was carried out in accordance with BS 1881: Part 116: (1983) Method for Determination of Compressive Strength of Concrete Cube. All the sample specimens were crushed at saturated surface dry condition. The crushing was carried out at 7, 14, 28 and 56 days respectively for the three methods of curing, using the hydraulic crushing machine of 1000kN capacity in the Building Department concrete laboratory. The results were shown in figure 1.

The SBA specimen shows an increment in compressive strength under immersion method of curing in all the curing ages but less than that of control. The SBA specimen was observed to have almost same strength to the control on the 28th day of curing under immersion method at 14 days. This may also be due to improved pore structure and lower porosity resulting from greater degree of cement hydration reaction without any loss of moisture from the control specimens. The SBA specimen under spraying method and covering with polythene methods of curing at 56days, but under the immersion method, the control is higher in compressive strength. This may also be due to improved pore structure and lower porosity resulting from greater degree of cement hydration reaction without any loss of moisture from the concrete specimens.

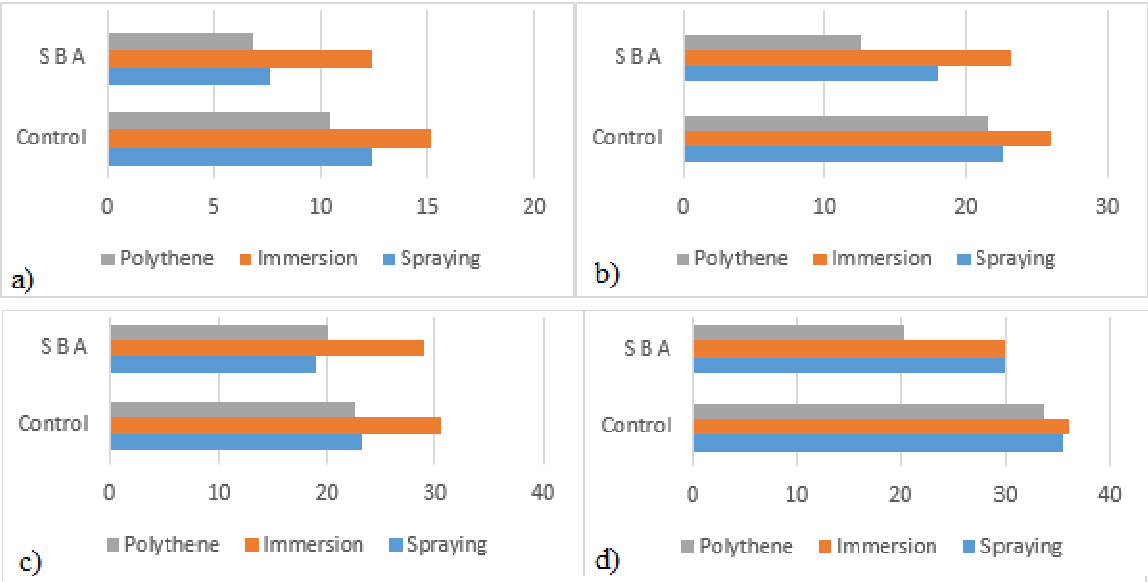
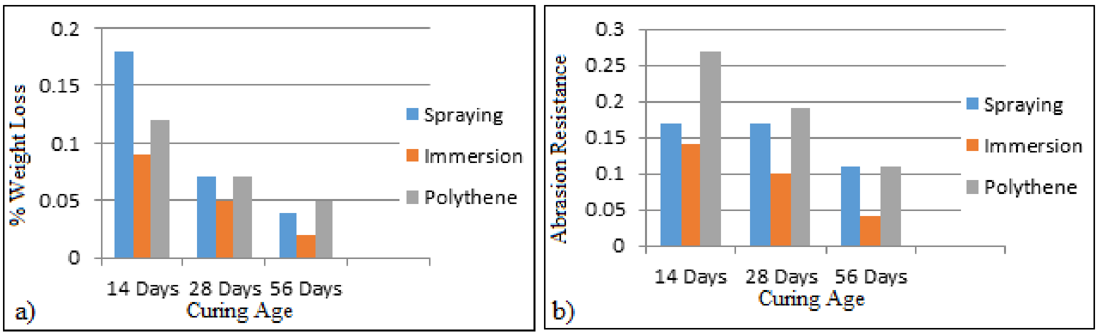


Figure 1: Compressive strength (KM/nm) tests at a) 7 days, b) 14 days, c) 28 days, d) 56 days

Abrasion resistance test for control

Figures 2 shows that the abrasion resistance of the concrete increased with the increase in maturity age. Concrete subjected to immersion having the highest abrasion resistance compared to those under spraying and covering with polythene.



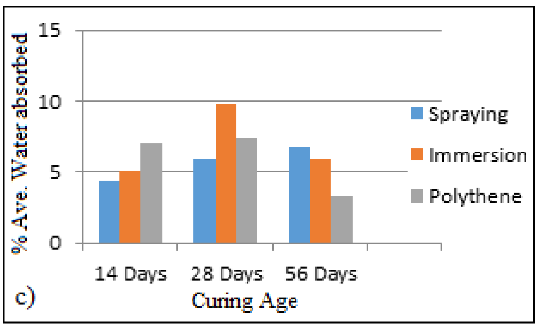


Figure 2: a) Abrasion resistance test for control, b) Abrasion resistance test for SBA, c) Water absorption test on SBA specimens

Abrasion resistance test on control samples showed that the abrasion resistance of the concrete increased with the increase in maturity age. Concrete subjected to immersion have the highest abrasion resistance compared to those under spraying and covering with polythene. This can be attributed to sufficient moisture and suitable vapour pressure which are maintained to continue the hydration of cement.

The SBA specimens was observed to have less strength compared to the control under water absorption test. This may be due to the fact that the quantity of SBA present in the mix is higher than the amount required to combine with the liberated lime during the process of hydration, thus leading to excess silica leaching out and causing a deficiency in highly strength as it replaces part of the cementitious material but does not contribute to strength.

CONCLUSION

It is concluded that SBA samples subjected to covering with polythene have a lower water absorption as the maturity age increases. One of the main sources of contamination of concrete in structures is water absorption which influences durability of the concrete and also has the risk of alkali aggregate reactions. The incorporation of pozzolan such as SBA reduces the average pore size and results in a less permeable paste. It was observed that the incorporation of SBA in the composites could cause an extensive pore refinement in the matrix and in the interface layer, thereby decreasing water permeability. The radial expansion of Portland cement hydration products in pozzolanic particles would have a pore modification effect therefore reduces the interconnectedness among pores.

Consequently, curing by immersion in water proved to be the most suitable curing method for SBA specimens, because it produces no loss of moisture, therefore enhances cement hydration reaction, followed by spraying method of curing which produces higher compressive strength than covering with polythene. This can be attributed to the reduced in moisture movement from SBA specimen leading to enhanced degree of hydration of cement. Immersion method should be use in curing SBA concrete in order to achieve good harden properties. Spraying method can be adopted in the case of water shortage instead of covering with polythene method.

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