Sugarcane Bagasse Ash as Partial Replacement of Cement and Reinforcement of Cement Based Sandcrete

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Abstract: **- With current uprising in the cost of construction of modern building and bridges in developing nations, owing to the sudden rise in the price of construction materials especially cements commonly used as binder of other materials and the frequent reports of building collapse in most of our urban cities have necessitated the need to investigate alternative source of binder or reinforcement of cements based sandcrete using some common agricultural by product. In the study, we investigate the use of sugar cane baggase ash as a possible replacement or partial replacement of the spontaneous binding medium(cement) in the production of cement based sandcrete. Sugarcane Bagasse Ash calcined at temperature between 550^{o}C and 600^{o}C were mixed with commercial Portland cements like Dangote, Elephant and Sokoto cements at different percentage up to 50% partial substitution. The resulting mixtures were subsequently used to mould sandcrete block. Strength analysis of the blocks produced maximum strength of 5.8 N/mm^2, 4.7 N/mm^2 and 4.2 N/mm^2 for samples from Dangote, Elephant and Sokoto cements respectively, after 91 days curing period as against 1.75 N/mm^2 minimum strength set by Nigerian National Building code (2006). Compressive strength analysis of Sandcrete blocks produced after 28 days curing period showed a maximum and minimum compressional strength of 3.6 N/mm^2 and 2.7 N/mm^2 for Dangote, 3.9 N/mm^2 and 2.3 N/mm^2 for Elephant and 4.3 N/mm^2 and 1.9 N/mm^2 for Sokoto Cements, values considered better when compared with the minimum standard of 1.75 N/mm^2 recommended by the Nigerian National Building code (2006) for individual blocks and 2.0N/mm^2 by British Standard for non-load bearing walls, thus making introduction of this waste material a potential way of economic cost reduction in the production of cement based sandcrete.**

Key words: **Sandcrete block, Sugarcane baggase ash, compressional test.**

I. INTRODUCTION

Judging the last two decades, Nigeria has seen muddles of building collapse in many parts of the country;the geometrical order of population growth has been reported as the major reason for urban crowding and subsequent development of shelter of various degrees in the urban centres (Adegoroye, 2010).Adegoroye, (2010) reported that Lagos have had several cases of building collapse that claimed dozens of lives and left several others wounded in 2006.

In Nigeria, causes of building collapse have been classified by Oyewande(1992) into; faults from design (50%), faults as a result of construction site (40%) and then product (material) failure (10%). The product failure refers to the effect caused as a result of the consequence of material being used in the construction industries. According to Lafarge Cement report (2009), the pitiable state of infrastructure continues to be the reason for high cost of transportation, fuel, power, and water in the industry. In addition, manufacturers incurred more cost in trying to secure its products during production therefore, pushes the price of cement up.

These gradual hikes in price of cement bring about poor management culture which results in production failure as mentioned by Oyewande (1992).Use of agricultural waste such as Sugarcane Bagasse, Rice Husk and Ground nut Shell have been suggested as a potential reinforcement or partial replacement for cement (Zakariya, Alabadan, Olutoye, Abolarin, 2005). These materials are pozzolanic and hence could improve the compressive strengthand as well reduce the cost of concrete. SCBA has properties that can partially replace the clinker in cement production Ganesan, (K., Rajagopal, K. and Thangavel, K. (2007).Most frequently, the use of SCB for combustion energy production is one of its utmost uses (Kilicaslan, Sarac, Ozdemı´r, Ermis, 1999; Neureiter, Danner, Thomasser, Saidi, Braun, 2002). Therefore agricultural waste material shall be employ to its maximum advantage to the production of artificial pozzolanic materials for sandcrete block.

The addition of sugar cane bagasse ash could help reduce cost since this material has properties that enhances the strength and functionality of concrete (Birku and Adebe, 2012) and is also gotten in abundance in Nigeria. The properties, potential and advantage(s) of Sugarcane Bagasse ash are numerous, and it is for these reasons this study thus wishes to focus on the investigation of the pozzolanic effects of ash from sugarcane as a partial replacement/reinforcement of cement in a sandcrete block. This study aims at investigating the effect of sugarcane bagasse ash on the physicochemical properties of bagasse ash/cement based sandcrete. This study aims to calcine sugarcane bagasse at a varying temperatures and time, and then subject the calcinedash to analysis of X-Ray diffraction (XRD), X- Ray fluorescent (XRF), Scanning Electron Microscopy (SEM) and Fourier Transform Infrared Spectroscopy (FTIR).

The calcined bagasse ash shall be mix with different Portland cements samples (Sokoto, Dangote and Elephant) in different proportions of 10:90, 20:80, 30:70, 40:60, and subsequently used for moulding cement based sandcrete blocks.

To subject the sandcrete samples produced from the mixtures in to different curing time (from 7-28 days and to 91 days). Subsequently, study the curing effect of compressional strength on the produced sandcrete block afterwards.

II. MATERIALS

The major starting materials used in this research work are Sugarcane Bagasse Ash, these were obtained from a Brown Sugarfactory in Bida, Minna, Niger State and commercial Portland cements (Sokoto, Dangote and Elephant) obtained from Building materials market in Minna. Table 1.0 shows the list of equipment used.

Table 1.0 List of Equipment/Tools

Equipment/ Apparatus	Manufacturer	Source
Muffle Furnace		FUT Minna
$50cm^3$ Sandcrete Mould	Local make	FUT Minna
XRD	ICSD/POWD-12++.	National Geological survey centre Kaduna
XRF	Oxford Instrument	ABU Zaria
FTIR		Narict Zaria
SEM		Manchester University United Kingdom
Compressional TM		Federal University of Technology Minna

III. METHODS

Preparation of Sugarcane Bagasse

Bags of sugarcane sticks were bought at Guya village in the suburb of Bida. They sticks were crushed at a Brown Sugar Syrup Factory located at Bida L.G.A. of Niger state to remove the juices in it and then the bagasse obtained were dried under the sunfor five days at the sugar factory. The bagasse were earlier washed with plenty of water at room temperature in a bath to remove foreign materials like sand and other impurities present and then sun dried for four (4) days to reduce the content of moisture toward a reasonable level. The dried bagasse was then subjected to calcination at different temperatures. The procedure is in accordance with the description reported by Cordiero *et al.,* (2010).

Blending the Cement/Sugarcane Bagasse Ash Proportions.

Blends of Portland cements and SCBA was formulated using different ratios starting with control experiment (100% Portland cements) with an amount of 100 g. 10% Portland cement was replaced with SCBA to form 90:10 was properly mixed. Subsequently, more quantity of SCBA was introduced with gradual reduction in the amount of Portland cement using standard electronic weighing balance to produce blends with 80:20, 70:30, 60:40 and 50:50 respectively. This result in the Cements drops in its ratio while SCBA rise in a complementary ratio up till the ratio of SCBA/Cements (i.e. 50/50). Each blend was thoroughly mixed before been mixed with amount of sand that was subsequently used for sandcrete production.

Mortar Preparation

The mix blends of cement/SCBA in the various ratios mentioned in section 3.4 were mix with sand in the ratio of 1:6 (standard set by Nigerian National Building Code) an equivalent of (0.53kg of cement/SCBA mixture to sand 3.18 kg).The normal cements/water consistency test for various blends was used to prepare different category of mortars before casting it into moulds of $50mm^3$. At every run, different ratio of Cement/Bagasse/Sand/Water was required for the preparation of mortars with 90/10, 80/20, 70/30, 60/40, and 50/50 for the three Portland cements used.

Casting of Mortars

A mould size of $50mm^3$for the length, breadth and height was used to mould different sets of mortars using different blends produced with the three Portland cements (Dangote, Elephant and Sokoto cements).

Compressive Strength Test

The compressive strength of each mortar sample produced was tested in accordance with ASTM C 109. Mortars of control experiment and that containing ground bagasse ash were subjected to compressional strength test. After casting for 24 h, the mortar cubes of 50 mm^3 were removed from the moulds and cured in water. The samples were then tested to determine the compressive strength at the ages of 7, 14, 21, 28 and 91days. The average strength was recorded as well as the average equivalent weight of mortars was recorded.

IV. RESULTS AND DISCUSSION

The result are presented below with table 1.0 showing the XRF analysis, figure 1.0, 2.0, 3.0,4.0 and 5.0 are for FTIR XRD and graphical representation of the compressional analysis respectively while Template 1.0 and 1.2 are the SEM analysis.

4.1 X-Ray Fluorescent (XRF) of Bagasse Ash

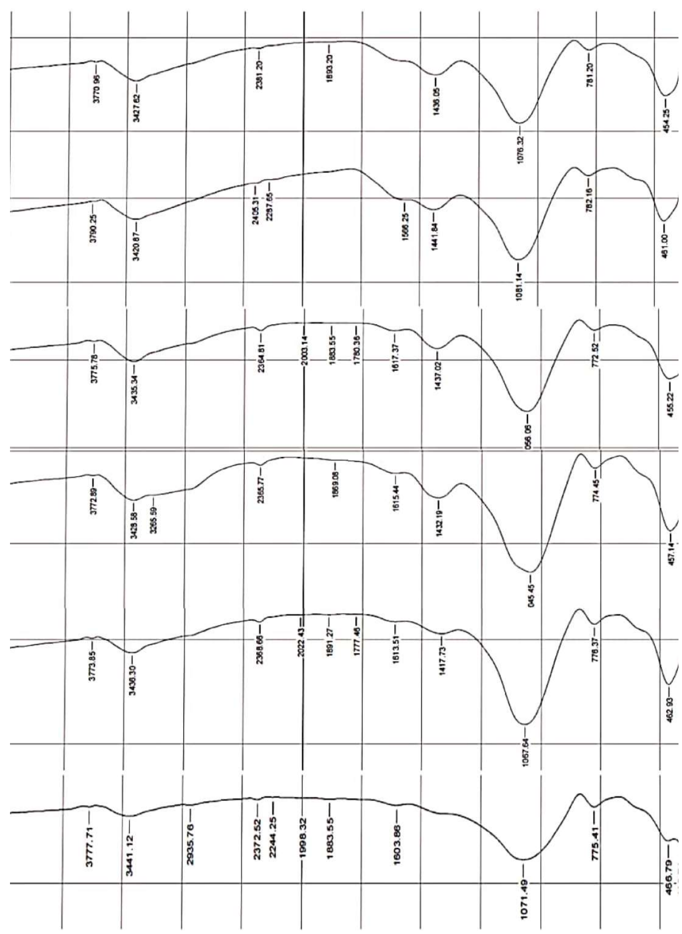
The X-ray fluorescent analysis of Sugarcane Bagasse Ash calcined at temperatures ranging from 550 ^{0}C to 1000^{0}C shows that for SCBA samples (S1, S2, S3, S4, S5 and S6) the weight percent of silicate present in the various samples increases gradually with increase in calcine temperature, except for samples S4. For instance, 17.266 wt% silicates were obtained in sample S1 that was treated at 550 ^{0}C while Sample S6 that was treated at 1000 ^{0}C showed a value of 20.642 wt% silicates. This is an indication that some components of the Bagasse Ash were lost or eliminated at high temperature, thus raising the percentage of silicate present in the SCBA, which is also an indication of higher pozzolanic content. According to Cordeiro (2006), higher temperature above 600 ^{0}C will leads to the formation of crystalline phase of the silicate, boosting the pozzolanic content of ash. However the drop in silicate in the case of S4 could be attributed to fluctuation in the unsteady nature of the temperature regulation of the furnace due to fluctuation in electricity. Cordeiro (2006), also reported that pozzolanic ash having high content of silica in amorphous decreases the formation of Calcium Hydroxides C-H and produces more calcium silicate hydrate (C-S-H) gel that improves the strength and durability of concrete in time when reacted with water (Aziz *et al.,*2014). Based on the above analysis sample (S2) treated at 600 ^{0}C (with 18.085 wt% SiO_2) seems most appropriate for the produce of Sugarcane Bagasse Ash (SCBA) with pozzolanic content that is suitable for the production of mortars

SR/No	S1 wt%	S2 wt%	S3 wt%	S4 wt%	S5 wt%	S6 wt%
Na_2O	0.405	0.486	0.432	0.789	0.334	0.000
MgO	0.00	0.00	0.000	0.053	0.000	0.000
Al_2O_3	0.460	0.472	0.512	0.455	0.455	0.563
SiO_2	**17.266**	**18.085**	**18.830**	**13.534**	**18.508**	**20.642**
P_2O_5	2.475	2.434	2.473	2.564	3.605	4.067
SO_3	1.777	1.832	1.683	2.562	2.084	2.109
Cl	1.398	1.527	1.132	1.829	0.940	0.279
K_2O	**29.518**	**27.312**	**26.086**	**33.721**	**26.070**	**23.693**
CaO	**21.346**	**21.481**	**19.691**	**21.897**	**23.297**	**22.992**
TiO_2	3.358	3.215	3.469	3.379	3.467	3.646
Cr_2O_3	0.082	0.237	0.053	0.019	0.021	0.014
Mn_2O_3	1.582	1.522	1.430	1.736	1.634	1.717
Fe_2O_3	19.495	20.570	23.352	16.514	18.440	17.895
ZnO	0.608	0.620	0.611	0.679	0.943	2.101
SrO	0.222	0.206	0.247	0.268	0.202	0.283

4.2 FTIR of Bagasse Ash

The spectrum of SCBA shows five absorption bands with a broad band at 3427cm^{-1},then weak broad band at1436cm^{-1}, followed by a hump and then a strong broad band at 1076cm^{-1} with another hump then followed by weak band at 781cm^{-1}, and finally a sharp to medium band at 454cm^{-1}. Analysis of these results showed that the band at 3427cm^{-1} represent the effect of O-H symmetric and asymmetric vibration molecules of water, the weak band noticed at 1436cm^{-1} correspond to the presence of sulphate group while the strongest band at 1076cm^{-1} represent the silicabroad which includes the aluminosilicates compound. The weak band at 781cm^{-1} indicates the presence of acid chloride perhaps Potassium chloride and finally the sharp to medium band at 454cm^{-1} that represent

sulphide stretching. It can be observed that with gradual increase in temperature the band between 1350cm^{-1} and 1450cm^{-1} begins to disappear corresponding to reduction in the sulphate ion while------------------ that between 1100cm^{-1} and 1000cm^{-1} elongates, showing the effect of crystallisation of the amorphous silica. However, the presences of carbonate ion are not noticeable in the weak to medium absorption spectra meaning that, at these temperatures, carbonate ion no longer exist. In the overall observation it can be seen that there is transformation of amorphous ash into crystalline solid as temperature increases and to be precise the crystalline phase becomes more pronounced as temperature exceed 700^{o}C



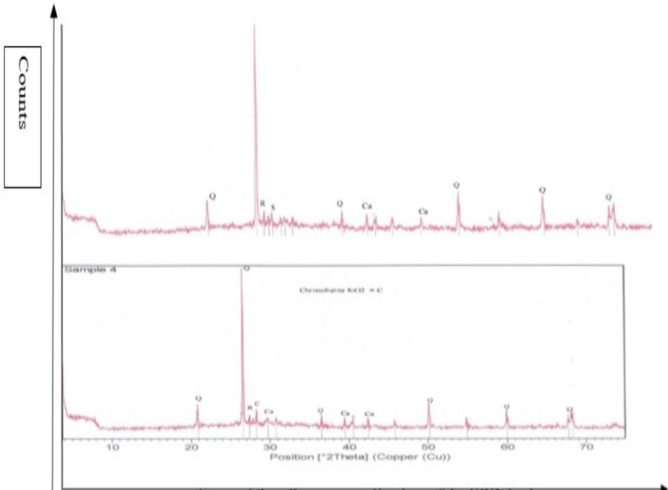


Figure: 4.2 Superimpose Graphics of the XRD Analysis

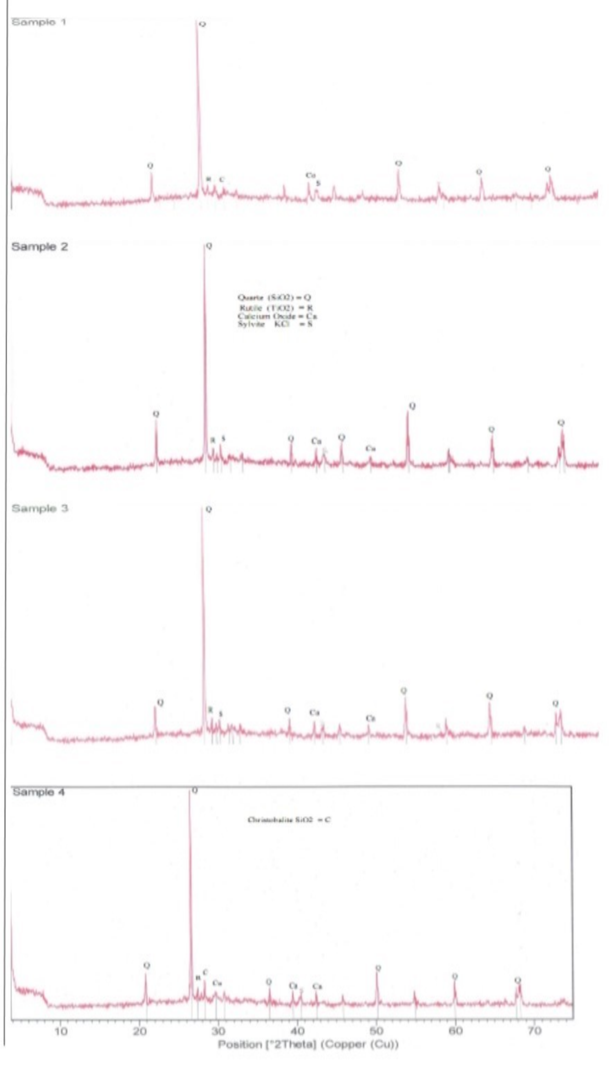
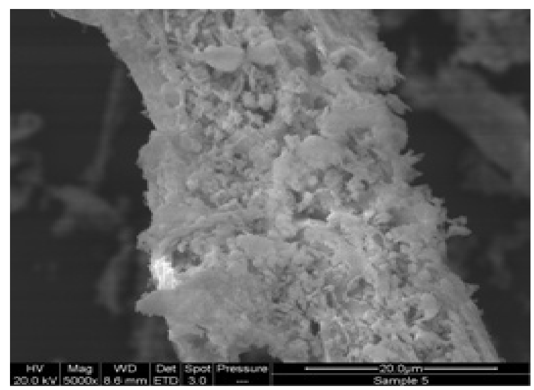
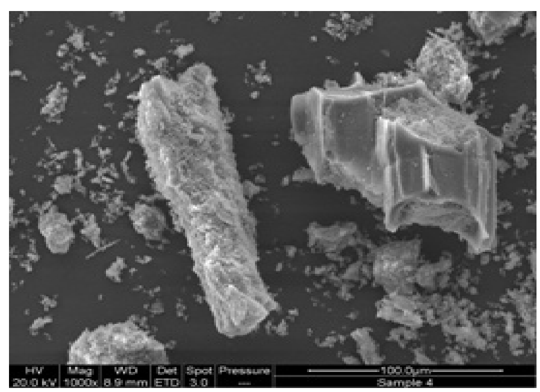


Figure: 4.2 Superimpose Graphics of the XRD Analysis

4.3 The XRD of Bagasse Ash

The XRD pattern shows the gradual transformation of phase from amorphous to crystalline as the temperature increases from 550^{0}C to 1000^{0}C. In sugar cane bagasse ash (SCBA) the most plentiful component is silica while a variety of other components like aluminium, magnesium, iron, titanium appears in small quantity. At 550^{0}C there are strong reflections of silica in the form of low quartz at 2θ at 20.09, 26.75, 50.0, 54.89 and 60.0.It can also be seen that carbon reflection are no longer existing at that temperature as this is already beyond the temperature of graphite existence while calcium aluminium magnesium and titanium continues to exist. No significant change was notice as temperature rises to 600^{0}C, 700^{0}C and 800^{0}C. With temperature raise to 900^{0}C, quartz and other compound still continue to exist while a trace of Cristobalite (another form of silicate compound) begins to appear. These occur as a result of amorphous silica re-crystallising at higher temperature (Cordeiro, *et al.,* 2010) while the composition of other compound like rutile changes to titanite which are both compounds of titanium.





Effect of Bagasse Ash on Dangote, Elephant and Sokoto Cement

The results of the effect of SCBA introduced on compressive strength of mortars produced using Dangote, Elephant and Sokoto cements blends were as presented in Figures 4.1, 4.2, and 4.3 respectively. It could be noticed that increase in the percentage replacement of cement by bagasse ash does not result in an effective increase in the compressive strength of mortars but rather compressive strengths of SCBA substituted mortars measure up to that of the control experiment, which is an indication that the reduction in cement (the binding power) does not generally cause a fall in strength as the percentage of cement replaced by bagasse ash increases from SCBA10%, SCBA20%, SCBA30%, SCBA40%and SCBA50%, the compressive strength of SCBA mortars measures close to the control experiment in all the three Portland cements in spite of the reduction up to 50%. This close compressive strength indicates that sugarcane bagasse ash brings about effective strength in mortars but usually not above the control samples (D100, E100 and S100). Though the maximum compressive strengths of 91 days records to be 5.2, 4.7, 4.2, 4.3, 3.9, and 4.4N/mm^2 for Dangote Cements; 6.4, 5.8, 3.9, 5.4, 4.7, and 3.5 N/mm^{2}for Elephant Cement while that of Sokoto Cement is 6.2, 4.2, 3.0, 5.4, 3.7, and 3.3 N/mm^{2}all corresponds to 0%SCBA, 10%SCBA, 20%SCBA 30%SCBA 40%SCBA and 50%SCBA respectively. The range of compressional strength for these SCBA's at 28 days records maximum and minimum to be 3.6N/mm^{2}and 2.7N/mm^2 for Dangote, 3.9N/mm^2 and 2.3N/mm^2 for Elephant and 4.3N/mm^{2}and 1.9N/mm^2 for Sokoto Cements are all within acceptable limits of 1.75N/mm^2 by National building code (2006) for individual block, and 2.0N/mm^2 by the British Standard for non-load bearing walls.

These indicate that sugarcane bagasse ash have significant effect in reducing cost through cement reduction, while retaining the strength of block through effective conditioning and utilisation of sugarcane bagasse ash. The result also indicate that certain compound present in the cements effective conditioning and utilisation of sugarcane bagasse ash. The result also indicate that certain compound present in the cements are being effectively complemented in spite of the reduction of the percentage of cement up to 50%, these is responsible for effective strength in the various brands of Portland cements.

Figure 1 COMPRESSIONAL STRENGTH FOR DANGOTE CEMENT

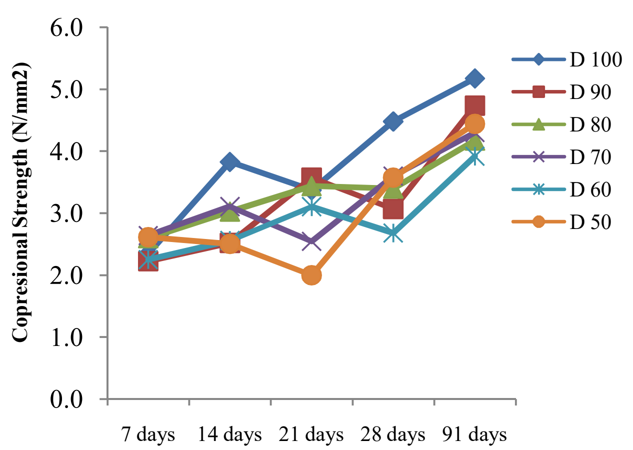


Figure 2 COMPRESSIONAL STRENGTH FOR ELEPHANT CEMENT

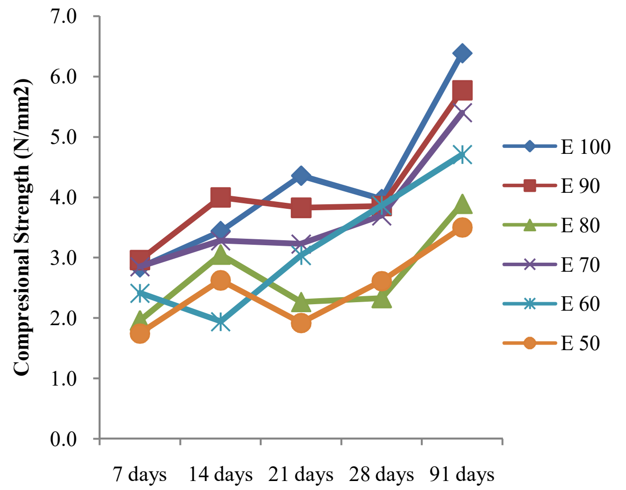
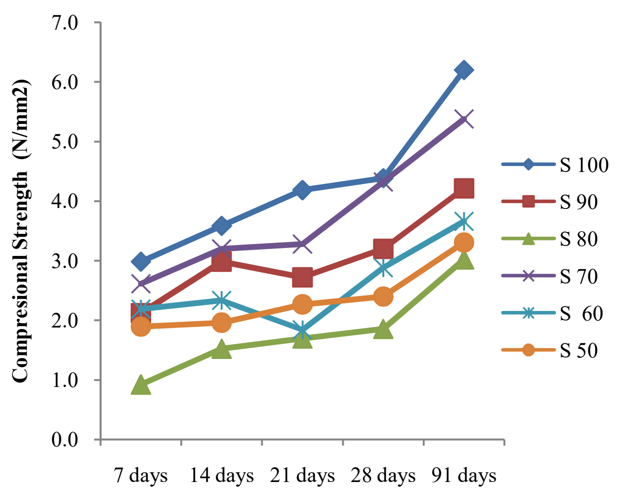


Figure 3 COMPRESSIONAL STRENGTH FOR SOKOTO CEMENT



V. CONCLUSION

1. Waste materials of agricultural product like SCBA have pozzolanic property that could enhance sandcrete block strength.
2. The maximum compressive strength of SCBA surpasses 2.0N/mm^2 for non-load bearing wall set by Bitish Standards even at 20% SCBA.
3. Compressive strength of SCBA mortars measures up to control experiment.

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