

Original Research Article

Harnessing of Saccharum Officinarum (Sugarcane) Bagasse Ash as Cement Replacement Material for Oil Well Cementing

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Abstract: This study tries to determine sugarcane bagasse ash (SCBA) as a cement replacement material and its effect on the mortar compressive strength, water absorption, setting times, water consistency, soundness, and specific gravity of SCBA (sugarcane bagasse ash) -Portland limestone cement (PLC) blend at cement replacement from 0 - 8 wt.% at interval of 2 wt.%. Calcination of sugarcane bagasse and the obtained ash was conducted at 600°C at 120 mins with a higher Si + Al + Fe content from the analysis of ash obtained via X-ray fluorescence spectrometer and then employed as cement replacement material for this research. The compressive strength was carried out using strength testing machine; consistency and setting times of the blended cement samples were carried out using Vicat apparatus, while the soundness and specific gravity were conducted using Le Chatelier apparatus and density bottle respectively according to ASTM standards. Results showed an increase in the mortar compressive strengths of SCBA-cement blends was experienced as the curing days progressed from 3 to 14 days. PLC blended with SCBA produced an enhanced early strength due to the presence of lime which tends to accelerate the rate of formation of hydration assembly. Whereas at a high cement replacement of 6.0 wt.%, SCBA produced exceptional mortar compressive strength especially at 14 days despite clinker diminution indicating pozzolanic activity due to SCBA content. The optimal cement replacement with SCBA was observed at 4.0 wt.% in comparison with control especially at 7 days and did not adversely affect its strength owing to pozzolanic activity. There was an increase in the water consistency and setting times of SCBA cement pastes as SCBA content was increased from 2.0 – 8.0 wt.% which was attributed to unburnt carbon present in the ash due to its high loss on ignition, LOI. The elongated setting times could also be due to clinker diminution by cement replacement with SCBA and high-water demand. The SCBA-cement blends produced accelerated setting time results compared to PLC owing to lime present in SCBA which enhances early hydration. The volume expansion of the SCBA cement pastes experienced an increase as SCBA was increased due to lower density of SCBA compared to PLC and increased lime content due to increased SCBA content while the specific gravity diminished.

Keywords: Sugarcane Bagasse Ash, Compressive Strength, Water Absorption, Setting Times, Consistency, Soundness, Specific Gravity.

1.0 INTRODUCTION

Oil well cementing plays a crucial role in the petroleum industry as it ensures zonal isolation, wellbore stability, and prevents fluid migration. Cementing is performed by pumping cement slurry into the annular space between the casing and the formation, thereby creating a strong bond. To enhance the performance of oil well cementing, additives are commonly used. These additives improve the cement properties, such as setting time, strength, and fluid loss control.

Many by-products, either from industrial waste or agricultural waste are proposed for the purpose of partial replacement of cement. This is because both of these waste types contain the pozzolans characteristic in them. Pozzolans consist of materials that contain high silica dioxide which promotes the hydration process. Fly ash is a final very fine byproduct obtained from the combustion of coal in the power plant at a high temperature.

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Coal fly ash (CFA) also known as fly ash is a predominant waste by-product of coal combustion which is disposed of in open ash dams that utilize large pieces of land. This waste material is classified as a hazardous substance in South Africa as well as in other countries due to its fine particles that are easily blown to the atmosphere and the unacceptable levels of heavy metals and persistent organic pollutants (Maria *et al.*, 2024). Fly ash has lime silica content like cement and the properties of fly ash is similar to cement; so the fly ash is used in concrete. Fly ash is a constituent material used in concrete rather than cement. It will enhance the workability and strength in the concrete. Fly ash mainly causes land filling problems; so, to overcome the environmental problem fly ash is used in concrete (Maddikeari, 2017).

The replacement of cement in concrete by various wastes creates a tremendous saving of energy, costs and also leads to important environmental benefits. As a result, the use of different cement replacing materials has become a common practice in the construction industry (Kejela, 2020). Supplementary cementitious materials (SCMs) are being utilized as partial replacement of cement. In 2016, Savita *et al.*, reviewed the cement replacement materials in concrete and concluded various materials as cement replacing materials. These materials are ceramic waste, paper pulp, ground granulated blast furnace slag, Silica fume, Hypo sludge, Fly ash, Paper sludge, Waste glass powder, Waste paper sludge ash (Kejela, 2020). All these researchers are using the industrial waste as cement replacement. Industrial waste is the by-products of large industries such as power plants, paper factory or even wastewater treatment plants.

The ready-mix concrete industry in the U.S. employs clinker reduction strategies by partially substituting OPC or PLC with supplementary cementitious materials (SCMs) in concrete. In other countries, blended cements are produced primarily at the cement plant instead of the concrete plant. In addition to the environmental benefits of this practice, SCMs contribute to improving the hardened concrete properties through hydraulic or pozzolanic activity (Nassiri *et al.*, 2025; Chen *et al.*, 2025; Feng *et al.*, 2024; Liao *et al.*, 2024). All of them have a few common similarities which are abundance in amount and pozzolanic in nature. Thus, since these byproducts are industrial in scale, using them as partial cement replacement will not only going to cut the cost and save the environment but at the same time make a way of handling and disposing of such waste materials. Besides that, fly ash has also been used as a supplement to enhance concrete integrity.

SCBA is used in the factory, for example in the manufacturing of sugar. The vast availability of this agricultural by-product made it great candidate for many types of research. Also, Saeed *et al.*, 2014 proved that the amount of SiO₂, Al₂O₃ and Fe₂O₃ are approximately 77.85% which for a material to be pozzolans the amount of silica, alumina and ferric components have to be more than 70% (Alp *et al.*, 2009; Saeed *et al.*, 2014). Thus, this shows that SCBA is a very good pozzolan material. Based on the research conducted, it was observed that incorporating SCBA into concrete enhances its pozzolanic activity, improving compressive strength up to an optimal percentage beyond which the strength diminishes due to the dilution effect (Ahmad, *et al.*, 2021; Chukwuemeka, 2024).

About 30-32% of bagasse is produced from 1 ton of sugarcane. Since bagasse is a by-product of the cane sugar industry, the quantity of production is in line with the quantity of sugarcane produced. Bagasse is the fibrous residue of the cane stalk left after crushing and extraction of juice. It consists of fibre, water and relatively small quantities of soluble solids; mostly sugar. A typical chemical analysis of bagasse (on dry weight basis) is as follows: Cellulose 38.4-47.0 percent, hemicelluloses 23.2-27.0 percent, lignin 19.1-32.4 percent, ash 1-2.8 percent (Mkhize *et al.*, 2016).

Sugarcane bagasse is also used as a raw material for paper making because of its fibrous texture; about 0.3 tons of paper can be made from one ton of bagasse. Burning this trash creates a pozzolanic ash composed of amorphous silica. It has been discovered that industrial ashes may be used as binders, especially as a partial substitute for cement, and that they also have a pozzolanic activity. Using agricultural by-products as a cement replacement material could affect the price of producing concrete and other construction materials like mortar, concrete pavers, concrete roof tiles, and soil cement interlocking block due to the fact that most of this waste, especially in Africa, is not sold but dumped on lands and into water bodies (Kumar, V. and Kumar, P., 2023).

Pozzolanic material was discovered, for the first time, in the form of volcanic soil of a reddish-brown color in the city of Pozzuoli, Italy, hence, the term pozzolan. It has been proven that Minoan, Greek, and Roman civilizations were using volcanic stone and pumice in construction many centuries ago. For example, the Pantheon and the Pont du Gard aqueduct were built using lime-pozzolan mortars and concrete; their longevity clearly demonstrating the remarkably durable properties of the binding materials employed (Snellings, 2012). Nowadays, different kinds of pozzolans are used as a substitute for cement content. These pozzolans are obtained from by-products of industrial and Agro-industrial processes and are used to reduce the energy required for clinker production and so reduce the harmful effects on the environment (Jhonatan *et al.*, 2022).

Pozzolana is defined as a siliceous or siliceous and aluminous materials which in itself possess little or no cementing properties, but will in a finally divided form and in the presence of moisture react with Ca(OH)₂ at ordinary temperature to form compound possessing cementitious properties (Moawad *et al.*, 2021; Eldidamony *et al.*, 2008). The

pozzolana property of sugarcane bagasse ash comes from the silicon content of the ash. This silicon undergoes a pozzolanic reaction with hydration products of cements and results in a reduction of free lime in concrete. According to Singh *et al*, 2000, the ash produced by controlled burning of agrowaste materials below 700°C transforms silica content of the ash into amorphous silica and can be used as a pozzolanic material. SCBA has proved to be a viable by-product for admixture in cement, with its intrinsic characteristic such as high content of silica in the form of quartz (Govindarajan and Jayalakshmi, 2011). However, the high carbon content is an obstacle for its use in cement/mortar. Therefore, it would be valuable if the unburned carbon in SCBA could be removed and used for other applications.

This amorphous silica content in SCBA makes it a suitable material for replacing cement in concrete. However, experimental evidence has shown that the silica content in the ash can vary depending on several factors, such as the incineration process and temperature, the soil types where the sugarcane is grown, and the properties of the raw material (Ramon *et al.*, 2025; Bahurudeen *et al.*, 2016).

1.1 Problem Statement

In the oil and gas industry, there is a growing concern for sustainable practices and environmental impact reduction. Traditional cement additives may have drawbacks in terms of environmental impact and cost. Therefore, there is a need to explore alternative additives that are eco-friendly, cost-effective; and have comparable or improved cementing properties.

1.2 Aim and Objectives of the Study

1.2.1 Aim

The aim of this research is to investigate the effects of replacing cement with SCBA on the mechanical properties of cement mortar.

1.2.2 Objectives

The specific objectives include:

- Calcination of the SCBA at various temperatures and time to establish the ash with the optimum pozzolanic activity.
- To characterize the SCBA using XRF for the chemical composition.
- To determine the compressive strength of binary cement.
- To analyze the specific gravity of the cement paste.
- To investigate the effect of sugarcane bagasse ash on the setting time and consistency of oil well cement.
- To investigate the effect of sugarcane bagasse ash on the absorption and soundness of the binary cement.

1.3 Significance of the Study

The findings of this study will contribute to the understanding of the potential of sugarcane bagasse ash as cement replacement material in oil well cementing. If proven effective, this eco-friendly and cost-effective additive can reduce the environmental impact associated with traditional cementing practices while maintaining or improving the performance of oil well cement. The study's results will provide valuable insights for the oil and gas industry and contribute to sustainable practices in the field.

1.4 Scope and Limitations

This study focuses specifically on investigating the harnessing of sugarcane bagasse ash as an additive in oil well cementing. The investigation involves laboratory experiments to evaluate the effects of sugarcane bagasse ash on cement properties. The research is restricted to analyzing the properties and performance of oil well cement with sugarcane bagasse ash under controlled laboratory conditions. This will be done by conducting strength test, consistency test, setting time test, absorption and soundness after 3, 7 and 14 days.

2.0 METHODOLOGY

2.1 Chemical Analysis

The chemical analysis of the sugarcane bagasse ash was determined using the X-ray fluorescence equipment (XRF).

2.1.1 Sieve Analysis

This is also known as a gradation test; sieve analysis has been used for decades to monitor material quality based on particle size distribution. Sieve analysis assumes that all particles will be round or nearly round and were passed through the square openings. For elongated and square particles, a sieve analysis will not yield a reliable result. The sugarcane bagasse ash was sieved using 75-micron sieve. A very fine sieve was used to provide enough surface area which speeds up the rate of reaction i.e., more surface area, more available sites for reaction.

2.1.2 Apparatus for Sieve Analysis

The apparatus used for sieve analysis include:

- Weighing balance
- Sieve mounted on suitable frames, designed to leak

2.2 Procedure

The sieves' sizes were selected in accordance with the specifications and the samples were weighed to the nearest 1.0g by total weight of the sample. The sieves were nested in order of decreasing size from top to bottom, the sample was poured; then agitation and shaking began for the sample for a sufficient amount of time. After obtaining the weight of the sample retained on each sieve down to the pan (ensure that all trapped materials are recovered). Finally, the results were tabulated for BS sieves, weight retained in grams and percentage retained, cumulative percentage retained and cumulative percentage passing are calculated.

2.2.1 Cement Mortar Mix Design

The cement mortar mix design was used to make Portland cement mortar specifically for this experiment. Mix designs were based on volumetric measurements. Therefore, a mix design most commonly gives a clue for making the cement mortar mix based on the weights. A very simple method for mixing is 1:3 for water and cement respectively was used, mixed thoroughly and later cast in moulds.

2.2.2 Curing of Cement

Cement needs time to completely hydrate before it acquires strength and hardness; the mortar mix must be cured once it has achieved initial setting. Curing is the process of keeping the mortar mix under suitable environment conditions until hydration is complete. In an attempt to make the hydration reaction to proceed at a faster pace the mortar was kept in a tank full of water at room temperatures so as to avoid the effect of thermal stress caused by rise in temperature from any external factor, like the ambient room temperature itself which may deviate from normal as a result of it being affected by external factors too. The curing of the mortar was done over a period of 3, 7 and 14 days; after which it was removed for crushing in order to test for the effects on strength of the supplementary cementitious materials as cement replacement in mortar.

2.2.3 Compressive Test Determination Procedure

The cubes were cast by mixing the materials thoroughly with water and placing the mixture into the mould. The cubes were removed after 24 hours and placed in a curing tank. After the days set for curing, the cubes were removed from the curing tank and air-dried; then weighed and the weights were recorded. The cubes were placed in the crushing machine and the machine was switched on. A similar procedure for individual cubes for different substitutions of sugarcane bagasse ash was done. The procedure was repeated for varying curing ages of 3, 7 and 14 days according to ASTM standard.

2.2.4 Consistency Test of SCBA-PLC

Firstly, 300 gm of SCBA-PLC was taken into a tray and mixed with a known percentage of water by weight of cement and then it was increased by 2% until the normal consistency was achieved. Cement paste was prepared by adding 30% of water to 300 gm of SCBA-cement and then mixed properly ensuring that the time of mixing is not less than 3 minutes, nor more than 5 minutes and the mixing was completed before any sign of setting occurred. The mixing time was counted from the time of adding water to the dry SCBA-cement until the filling of the mould. Filled Vicat mould was resting upon a non-porous plate (glass plate). After completely filling the mould with cement paste leveled with the top surface, extra cement was removed from the top to make it smooth and shaken to remove any extra air. The SCBA-cement paste-filled mould was placed together with the non-porous resting plate, under the consistency test plunger in the Vicat apparatus. The plunger was lowered to touch the top surface of mould filled with paste, and quickly released, allowing it to sink into the paste. The penetration value on the Vicat apparatus scale was observed. It should be around 33 to 35mm from the mould filled with cement paste. If it is not, then increase the % of water and repeat the steps.

2.2.5 Setting Times Determination

A 300 gm of SCBA-PLC paste sample was prepared and the water required was added for its standard consistency to prepare homogenous cement paste. Vicat's mould was filled with cement paste and kept under Vicat's apparatus with initial setting time (IST) needle attached to it; IST needle was allowed to penetrate into the paste by releasing the pin to observe the total penetration. The time at which IST needle will give required penetration was noted down. IST needle was replaced with FST needle and the FST needle was allowed to penetrate into the same cement paste. The time at which FST needle will give the just impression on a cement surface was noted down as the final setting time according to IS: 4031 (Part 5)-1988.

2.2.6 Soundness Test of SCBA-CEMENT

Soundness of cement is mainly measured by EN-196 (1995), which is based on the Le Chatelier test method, according to IS:4031-Part 3-1988. The mould and glass plates were oiled before conducting the test and 300 gm of cement sample was taken. The standard consistency for the test is 30% of water, then water percentage for soundness is $0.78 \times 30\% = 23.4\%$. Well-mixed paste of cement was used to fill in Le-Chatelier mould taking care to keep the edges of the mould gently together during the operation. The upper surface was cleaned and made smooth and a small weight was placed over the cover plate, and the assembly was placed quickly in water at a temperature of $27^{\circ}\text{C} \pm 2^{\circ}\text{C}$ and it was kept there for 24 hours. The mould was then taken out from water and the distance between the indicator’s points was measured as Reading-1. The assembly was placed in boiling water for 25 to 30 minutes and kept boiling for 3 hours. The mould was removed from the water and allowed to cool at room temperature. The distance between the indicator points was measured as Reading-2. The soundness of cement = (Reading-2) – (Reading-1).

2.2.7 Specific Gravity Test of SCBA-CEMENT

The IS code for the Specific gravity of cement test is IS: 2720-Part 3. The Le-Chatelier flask was cleaned before use to be free from moisture. The weight of the empty flask was taken as W_1 , and around 50 gm of cement was taken to fill in the flask. The stopper on the flask was fixed and the flask was weighed with cement as W_2 . The kerosene in the flask was filled up to the neck of the bottle. Cement and kerosene were thoroughly mixed in the flask ensuring that no air bubble was left in it and the weight was recorded as W_3 . The flask was emptied and cleaned. The kerosene in it was filled up to the neck of the bottle and the weight was recorded as W_4 . The specific gravity of the cement formula is as follows,

$$= (W_2 - W_1) / ((W_2 - W_1) - (W_3 - W_4)) \times (0.79)$$

Where,

W_1 = Weight of Empty Flask

W_2 = Weight of Flask + Cement

W_3 = Weight of Flask + Cement + Kerosene.

W_4 = Weight Flask + Kerosene.

Here, the specific gravity of kerosene is 0.79g/cc.

Table 1: X-ray Fluorescence Results of Sugarcane bagasse ash burned at 600°C temperature for 2 hours

SCBA Component	600°C (120min)
SiO ₂	52.76
Al ₂ O ₃	7.68
Fe ₂ O ₃	2.955
CaO	11.303
MgO	1.226
SO ₃	0.874
K ₂ O	5.941
Na ₂ O	1.182
P ₂ O ₅	1.151
Mn ₂ O ₃	0.182
TiO ₂	0.406
LSF	7.122
Silica ratio	49.61
Alumina ratio	5.599
Calcium Carbonate	20.173
LOI	10.22
Sum of Conc.	85.661
C ₃ S	63.1973

Table 2: Mortar compressive strength of SCBA cement blends at various cement replacement.

S/No	SCBA content wt. %	3 Days (N/mm ²)	7 Days (N/mm ²)	14 Days (N/mm ²)
1	0	24.96	35.57	49.44
2	2	25.21	40.17	50.39
3	4	35.04	40.71	50.87
4	6	31.64	39.75	48.11
5	8	33.25	35.11	38.13

Table 3: Water absorption at various replacement level

S/No	SCBA content (wt. %)	3 Days (wt. %)	7 Days (wt. %)	14 Days (wt. %)
1	0	4.56	4.67	4.73
2	2	3.65	4.59	5.14
3	4	3.76	4.43	4.47
4	6	3.50	3.83	4.89
5	8	3.49	3.59	4.00

Table 4: Setting times at various replacement level

SCBA content (wt. %)	Initial setting times (mins)	Final setting times (mins)
0	97	186
2	93	147
4	94	149
6	97	155
8	101	164

Table 5: Water consistency and water demand at various replacement level

SCBA content (wt. %)	Water consistency (%)	Water demand (ml)
0	31	93
2	32.1	96.3
4	33.1	99.3
6	34.2	102.6
8	35	105

Table 6: Soundness at various replacement level.

SCBA content (wt. %)	Volume expansion (mm)
0	1.0
2	1.0
4	1.0
6	1.0
8	1.5

Table 7: Specific gravity at various replacement level

SCBA content (wt. %)	Specific Gravity
0	2.90
2	2.86
4	2.78
6	2.76
8	2.68

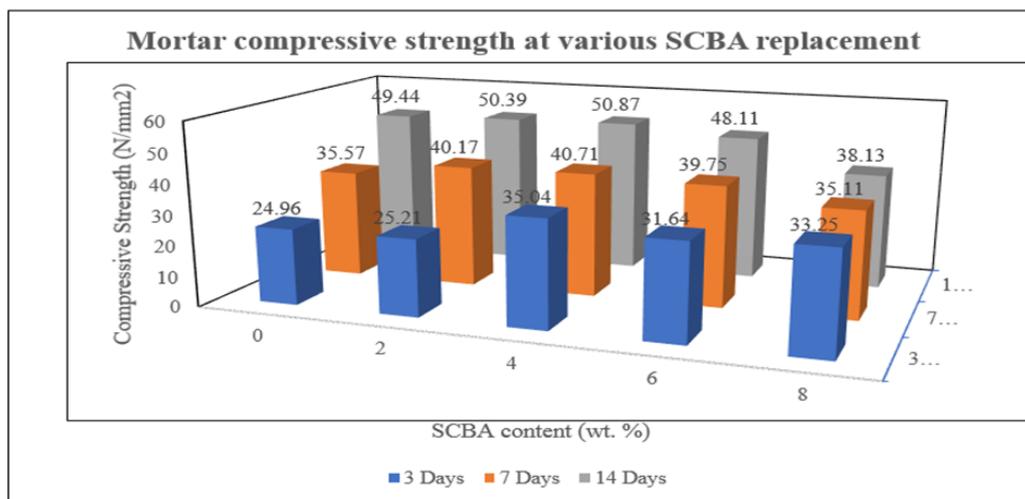


Figure 1: Effect of SCBA content on the mortar compressive strength of SCBA cement blends at various cement replacement.

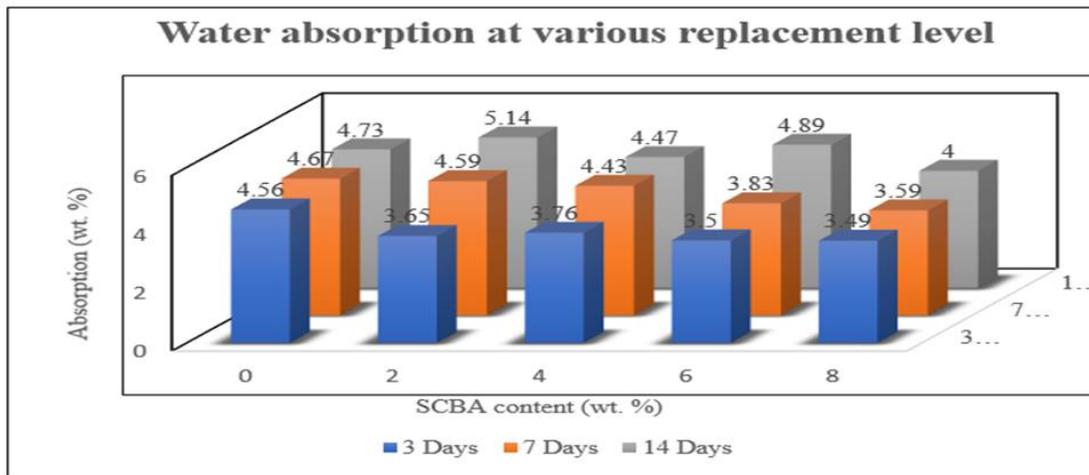


Figure 2: Effect of SCBA content on the mortar water absorption of SCBA cement blends at various cement replacement.

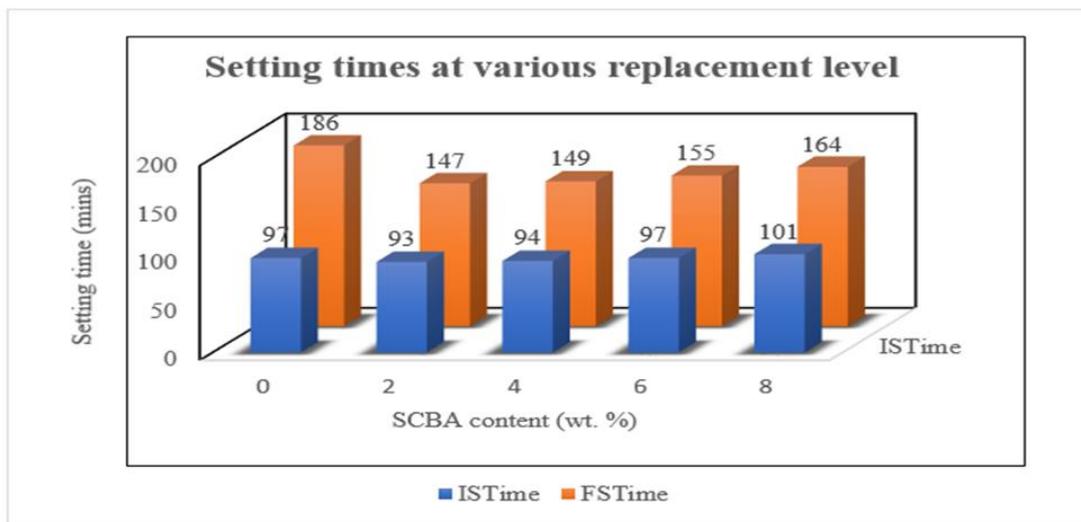


Figure 3: Effect of SCBA on the setting times.

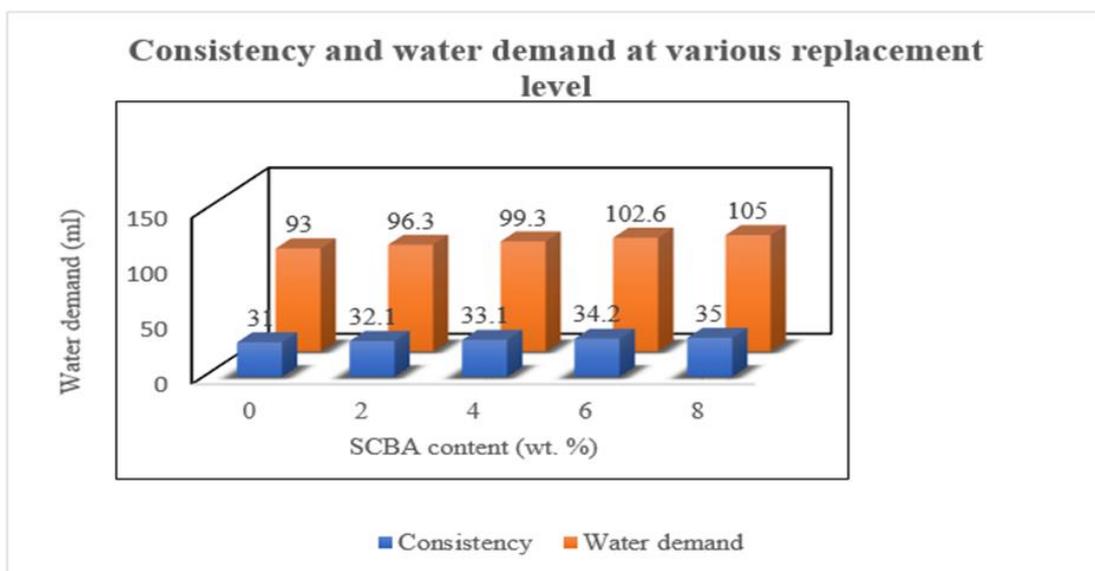


Figure 4: Effect of SCBA on the normal consistence and water demand.

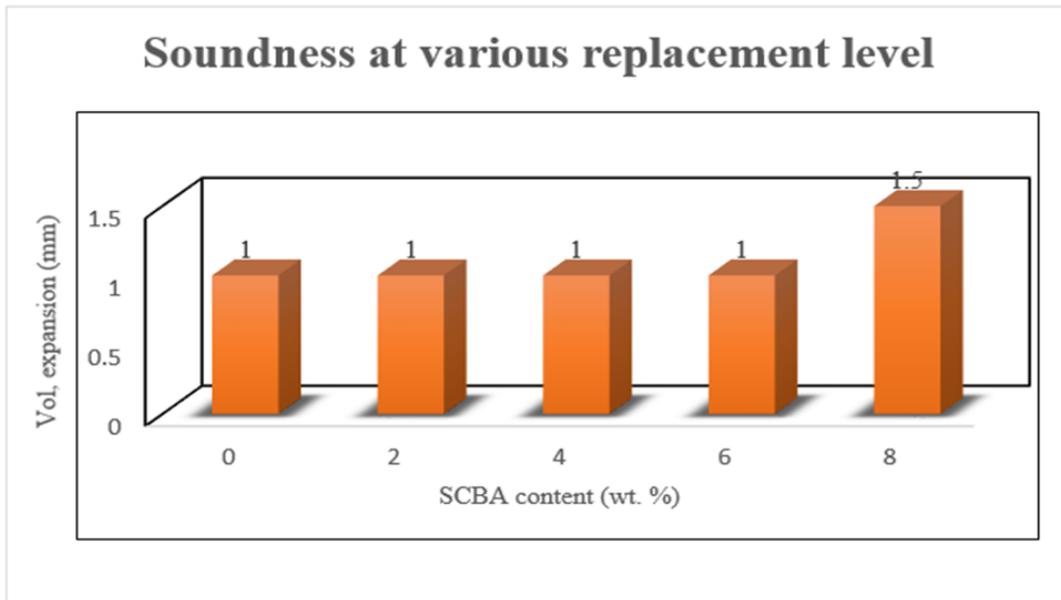


Figure 5: Effect of SCBA on the soundness of cement blends.

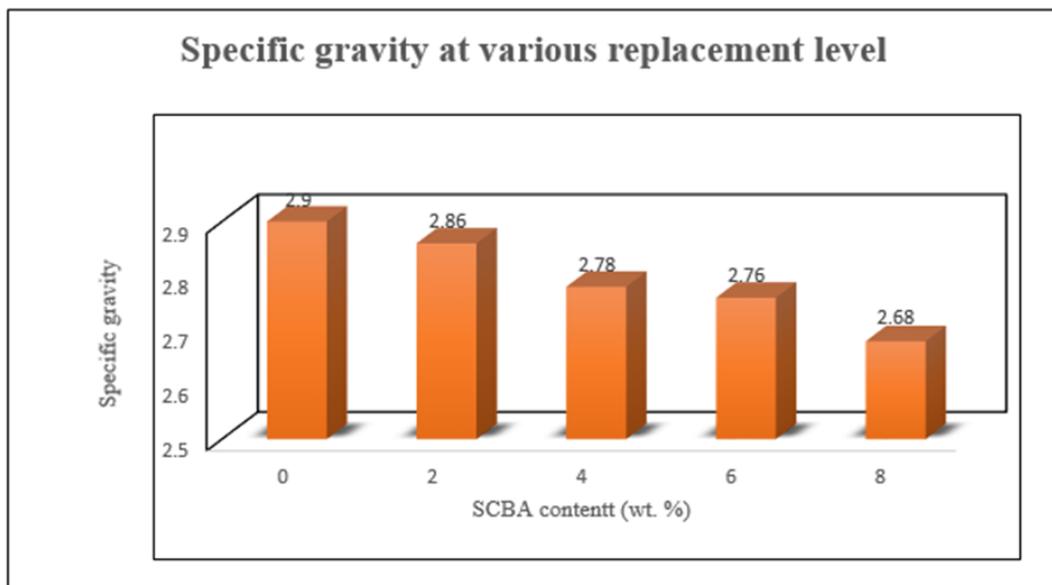


Figure 6: Effect of SCBA on the specific gravity of cement blends.

3.0 RESULTS AND DISCUSSION

3.1 X-Ray Fluorescence Results

The sugarcane bagasse ash was burned at 600°C temperature for 2 hours (120m) with the intent of preventing crystalline phases (consequently increasing the pozzolanic activity) and using the silica and alumina contents for this research.

3.2 Discussion of Result

The chemical composition of calcined sugarcane bagasse was determined using X-ray fluorescence spectrometer at 600°C for 120 minutes and are tabulated in Table 1. The SCBA contains mainly oxides such as Silica, Iron, Alumina, Lime and Magnesium oxide. Chemical analysis revealed that Sugarcane bagasse calcined at 600°C for 120 minutes comprised of more than 60 wt.% of $\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$ (63.40 wt. %) while CaO content was 11.30 wt.%, hence the ash satisfies as a pozzolan according to ASTM C 618. SCBA had a loss on ignition of 32.19 wt.% which indicates a high degree of unburnt carbon of ash which is also responsible for increase in the water requirement due to the high porosity of SCBA particle resulting in mixture segregation.

3.2.1 Effect of SCBA Content on the Mortar Compressive Strength of PLC Blends

The effect of SCBA content on the mortar compressive strength of blended cement mortars are tabulated in Table 2. A moderate decrease in the mortar compressive strength of SCBA cement blends were observed especially at higher SCBA content. These reductions in their strengths could be linked to the high unburnt carbon in the ash coupled with dilution of Portland cement compounds.

Figure 1 illustrates the effect of cement replacement on the mortar compressive strength of various cement blends. It was observed that as the curing days progressed from 3 to 14 days, the control and SCBA-PLC blends experienced increments in their mortar compressive strengths by 98.08, 99.88, 45.18, 52.05 and 14.68% for 0, 2, 4, 6 and 8 wt.% respectively. Most of the cement blends at 3 days produced compressive strengths better than control and could be attributed to the presence of available lime from the SCBA which tends to accelerate the hydration assembly. Thus, favoring formation of ettringite at the expense of monosulfate, leading to early hydration rates especially at 3 days despite the clinker diminution. Similarly, most of the compressive strength of the cement blends were greater than 15% of the control's compressive strength at the various curing days. This enhanced strength experienced by the cement blends despite clinker diminution could be evident that pozzolanic reaction occurred. Whereas, on the other hand, a series of increase and decrease in its mortar compressive strengths were experienced as the cement replacement was increased from 0 – 8 wt.% at intervals of 2 wt.%.

Cement replacement of 2 wt.% SCBA produced a lower 3 days mortar strength compared to those of PLC. There was an enhanced strength from 25.21 to 40.17 N/mm² (59% of the control strength at 7 days) followed by a significant improvement to 50.39 N/mm² at 14 days respectively. The enhanced strength of 2 wt.% SCBA cement blend could be attributed to the pozzolanic activity resulting in formation of more CSH which adds to its strength despite clinker diminution. Whereas, at 4 wt.% SCBA-PLC blend produced an enhanced strength of 50.87 N/mm² at 14 days in comparison with control. At 6 and 8 wt.% cement replacement with SCBA produced the least compressive strength of 48.11 and 38.13 N/mm² at 14 days.

3.2.2 Effect of SCBA Content on the Water Absorption rate of SCBA-PLC Mortars

Figure 2 indicates the effect of SCBA content on the rate of water absorption of cement mortars. An increase in the rate of water absorption of the mortars were observed as the curing days progressed from 3 to 14 days. A significant increase in the rate of water absorption of the SCBA mortars was observed due to the high absorptive capacity of SCBA, thus as its content was increased, resulted in an increase in the rate of water absorptive capacity of the SCBA mortars especially at 7 and 14 days as compared with 3 days. On the other hand, a variation in the rate of water absorption of SCBA mortars was observed as SCBA content was gradually increased from 0 – 8 wt.% at given curing ages of 3, 7 and 14 days respectively.

3.2.3 Effect of SCBA Content on the Setting Times of SCBA-PLC Blends

The results of both setting times of the SCBA cement blends presented in Table 4 were within the limit as recommended by ASTM C 595, while Figure 3 illustrated the effect of cement replacement on the setting times of SCBA cement blends. The setting times of SCBA cement blends at various cement replacements were found to be lower than PLC. This elongation of the setting times of SCBA cement blends compared to PLC could be attributed to the diminution of clinker content as a result of a decrease in calcium silicate and high-water requirement owing to presence of unburnt carbon. The SCBA cement blend up to 8 wt.% replacement retarded the initial and final setting time by 54 and 63 minutes in comparison with PLC control. Another reason for the retarded setting times could be due to the increase in the potassium ion (5.94 wt.%) present in SCBA resulting in formation of muscovite which is considered a retarder.

3.2.4 Effect of SCBA Content on the Consistency/Water Demand of PLC Blends

Table 5 tabulates the effect of SCBA content on cement blend water consistency (water demand). The variation in SCBA content at different percentage levels on water consistency (water demand) for binary cement PLC-SCBA blends are illustrated in Figure 4. An increase in the water consistence of SCBA-PLC paste from 31.0 – 35.0 % was experienced as cement was gradually replaced by SCBA content from 0 - 8 wt.%. Similarly, the water demand experienced an increase from 93 to 105 ml (by 13%) as the SCBA content was increased. The water demand for SCBA-cement blends were observed to be higher compared with PLC control. This increase could be attributed to higher unburnt carbon content of SCBA which is evident by a high LOI value of 10.22% in comparison with ASTM C 618 standards. Another reason for the higher water requirement could be due to the high silica content, thus imparting on the workability of the cement blend.

3.2.5 Effect of SCBA Content on the Soundness (Volume Expansion) of PLC Blends

The effect of SCBA content on the volume expansion of various cement blends was tabulated in Table 6 were determined via Le Chatelier apparatus. It could be observed from Figure 5 that as the cement replacement with SCBA increased from 2 - 8 wt.%, the volume expansion gradually increased from 1 – 1.5 mm, owing to an increase in the available free lime. This gradual increase could be due to relatively moderate lime content (11.30 wt.%) present in the SCBA.

3.2.6 Effect of SCBA on the Specific Gravity

The effect of SCBA content on the specific gravity of SCBA-PLC cements are also presented in Table 7. The specific gravities of SCBA-PLC cements were found to be lower compared to those of PLC. The specific gravity of SCBA cement blend diminished by 7.59 % as SCBA content was increased from 0 -8 wt. % as illustrated in Figure 6 which could be attributed to PLC's specific density being higher than SCBA.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The following conclusions were made from the results obtained after careful analysis of the test results and comparing them with similar work.

Sugarcane bagasse ash was calcined at 600°C temperature after burning for 2 hours. The SCBA was characterized using X-Ray Fluorescence spectrometer. The strengths of the mortar kept increasing with an increase in curing age from 3 to 14 days, the control and SCBA-PLC blends experienced increments in their mortar compressive strengths by 98.08, 99.88, 45.18, 52.06 and 14.68 % for 0, 2, 4, 6 and 8 wt. % respectively. The compressive strengths of the mortar determined for each percentage substitution and for each curing age suggest that SCBA is a suitable replacement for cement up to the 4 % substitutions beyond which improvements in strength did not continue. It can be finally concluded that sugarcane bagasse ash is a suitable replacement for cement in mortar at substitutions of 6 and 8% (considering compressive strength and strength gain with curing age) and can be used for all applications where the 42.5R Portland cement is used at those substitutions only.

4.2 Recommendations

As stated in the results earlier obtained the 6% and 8% are the most suitable for applications similar to those of the 42.5R cement. The 2% and 4% substitution can be used in places where high compressive strength is required. Other substitutions are not recommended for oil well where high compressive strength is required. They should rather be used in other applications where they might not cause any problem.

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