International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.39

Consistency, Setting Times and Chemical Properties of Sugar Cane Bagasse Ash Cement

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Abstract: ***This research work aims at determining the physical and chemical properties of sugar cane bagasse ash cement (SCBAC). The physical properties investigated in this research were initial and final setting times, consistency tests and chemical analysis tests using X-ray Florescence Spectral analysis test. These tests were carried out to compare the properties of the Sugar cane bagasse ash cement with the normal cement. The SCBA were replaced at 0%, 5%, 10%, 15% and 20% proportions of cement content. From the test results, the consistency was found to increase as the Sugar Cane Bagasse Ash(SCBA) proportion increased from 32.5% for the pure cement to 40% for 20% sugar Cane Bagasse Ash replacement with cement. This showed that the more the proportion of the SCBA in cement, the higher the amount of water required to get the right consistency. The initial setting time increased as the proportion of SCBA increased from 2.25 hours at 0% to 3.42 hours for 20% replacement but was within the acceptable range of less than 30 minutes. The final setting time however decreased from 8.33 hours to 7.5 hours for the same proportions of replacements but fell within the acceptable limit of not more than 10 hours. Finally, the elemental composition like Silicon Dioxide (*** SiO_2***), Alumina (*** Al_2O_3***) and Ferric Oxide (*** Fe_2O_3***) of the various samples containing the blend of SCBA and cement showed that the elements gradually decreased as the proportion of the SCBA increased in the mixes.***

Keywords: Sugar Cane Bagasse Ash Cement, Setting Time, Consistency, X-Ray Florescence Spectral Analysis, Vicat Apparatus

1. Introduction

Sugarcane bagasse is an industrial and agricultural waste which is fibrous in nature obtained from industrial processes of sugar mills as by-product after the juice is extracted from the sugarcane. The utilization of this by-product has been the focus from waste reduction point of view. Ordinary Portland cement is the most extensively used construction material in the world. Since the early 1980's, there has been an enormous demand for the mineral admixture and in future this demand is expected to increase even more.

In this modern age every structure has its own intended purpose, safety and construction requirements as well as cost limitations, hence to meet this purpose, modification in traditional cement concrete has become essential. This situation has led to the extensive research on concrete resulting in mineral admixture to be partly used as cement replacement to increase workability in most structural application. For this reason, Sugar Cane Bagasse Ash (SCBA) is one of the main by-product that can be used as mineral admixture due to its high content in silica (SiO_2) with the aim of replacing cement by weight, in concrete, then bringing the cost of concrete and subsequently cost of construction down without compromising on the concrete quality. According to U.R Kawade et al (2013), sugar cane bagasse consists of approximately 50% of cellulose, 25% of hemicelluloses and 25% of lignin. Each ton of sugarcane generates approximately 26% of bagasse (at a moisture content of 50%) and 0.62% of residual ash. The residue after combustion presents a chemical composition dominates by silicon dioxide (SiO_2) at 66.89%, Alumina(Al_2O_3) and Ferric Oxide (Fe_2O_3) at 29.18%, Calcium Oxide (CaO) at 1.92%, Magnesium Oxide (MgO) at 0.83%, Sulphur Trioxide (SO_3) at 0.56% and Loss of Ignition at 0.26%. U.R. Kawade et al (2013) found out in their study on effect of use of bagasse ash on strength of concrete that the strength of concrete increases up to 15% sugar cane bagasse ash replacement with cement.

A few studies have been carried out in the past on the utilization of bagasse ash obtained directly from the industries to study pozzolanic activity and their suitability as binders by partially replacing cement. P.O. Modani and M. R. Vyawahare (2012) in their study on the use of bagasse ash as a partial replacement of fine aggregates in concrete found out that, bagasse ash had lower specific gravity, bulk density and fineness modulus than the normal fine and coarse aggregates as shown in the table below: -

Table 1: Physical properties of aggregates

Physical tests	Coarse Aggregates	Fine aggregates	
		River sand	Bagasse ash
Specific gravity	2.83	2.64	1.25
Fineness modulus	3.08	3.08	2.12
Bulk density (Kg/M^3)	1428	1428	837

The same study found out that 10% to 20% fine aggregates replacement by sugar cane bagasse ash in concrete gave good results without a considerable loss of workability and strength properties i.e. the compressive strength results showed that, the strength of the mixes with 10% and 20% bagasse ash increased at later days (28 days) as compared to7 days that may be due to pozzolanic properties of bagasse ash. Also Sorptivity test result showed that the sorptivity coefficient increased with increase in percentage of bagasse ash which indicates more permeable concrete that is due to porous nature of SCBA and the impurities in it.

The main purpose of this research is to determine the physical and chemical properties of Sugar Cane Bagasse Ash Cement SCBAC and compare them with the normal Ordinary Portland Cement.

2. Materials and Methodology

2.1 Materials

The partial replacement material of cement, that is, Sugar Cane Bagasse Ash was obtained from Muhoroni Sugar company, Western Kenya. Also Nguvu CEM IV/B(P) 32,5N was obtained from licenced local cement vendors in Juja town, Central Kenya.

2.2 Methodology

4000 grams of Sugar Cane Bagasse Ash was sun dried from dampness and sieved to ensure that only particles passing 0.075mm were collected for this study. Cement was replaced with sugar cane bagasse ash at 0, 5, 10, 15 and 20% intervals per given sample. For each replacement, the following tests will be carried out: -

2.2.1 Consistency Test for Sugar Cane Bagasse Ash Cement

The standard consistency of a cement paste is defined as that consistency which will permit the vicat plunger to penetrate to a point 5 to 7mm from the bottom of the vicat mould. The standard procedure as stipulated in IS: 4031 (Part 4) 1988 was followed. The apparatus required were; Vicat Apparatus Conforming to IS: 5513-1976, weighing balance and a trowel and 1200g of cement and 300g of sugar cane bagasse ash was also be required to enable four runs of the experiment. The consistency cement paste was expressed as a percentage by weight of dry cement and is usually this percentage varies from 26% to 33% for Ordinary Portland Cement.

2.2.2 Initial and Final Setting Times for Sugar Cane Bagasse Ash Cement

Once the consistency tests of the various replacements are obtained, the results were used to determine the initial and final setting times of the sugar cane bagasse ash cement as per the standard procedure as stipulated in IS: 4031 (Part 5) 1988. Initial setting time is that time period between the time water is added to cement and time at which 1 mm square section needle fails to penetrate the cement paste, placed in the Vicat's mould 5 mm to 7 mm from the bottom of the mould. Final setting time is that time period between the time water is added to cement and the time at which 1 mm needle makes an impression on the paste in the mould but 5 mm attachment does not make any impression. The required apparatus will be weighing balance, vicat apparatus, stop watch and measuring cylinder.

Plate 1: Initial and Final Setting Time Test

2.2.3 Chemical Analysis for Sugar Cane Bagasse Ash Cement

This was done to determine the chemical composition of the different samples of SCBAC (Sugarcane Bagasse Ash Cement) based on BS12: 1992 for chemical analysis of Portland cement. The exercise was conducted using XRF technology (X-Ray Florescence Spectral Analysis) in the Ministry of Mining, Mines and Geological Department-Nairobi.

3. Results

3.1 Consistency of Sugar Cane Bagasse Ash Cement

The consistency test was carried out according to IS: 4031 (Part 4) 1988 using two samples in two vicat apparatus and the average results were tabulated as indicated in table 2, below: -

Table 2: Consistency test for Sugar Cane Bagasse Ash Cement

% of SCBA in cement	Weight of Cement (g)	Weight of SCBA (g)	W/C (ml)	Res. (mm)	Consistency (mm)
0	400	0	153	6	**38.25**
5	380	20	155	5	**38.75**
10	360	40	158	5	**39.5**
15	340	60	158	5	**39.5**
20	320	80	160	5	**40**

The table above shows that the consistency for Cement sample with 0% SCBA was 38.25%, for sample with 5% SCBA was 38.75%, for sample with 10% and 15% SCBA was 39.50% and for sample with 20% SCBA was 40.0%. The variation in the consistencies was plotted in a line graph as shown below: -

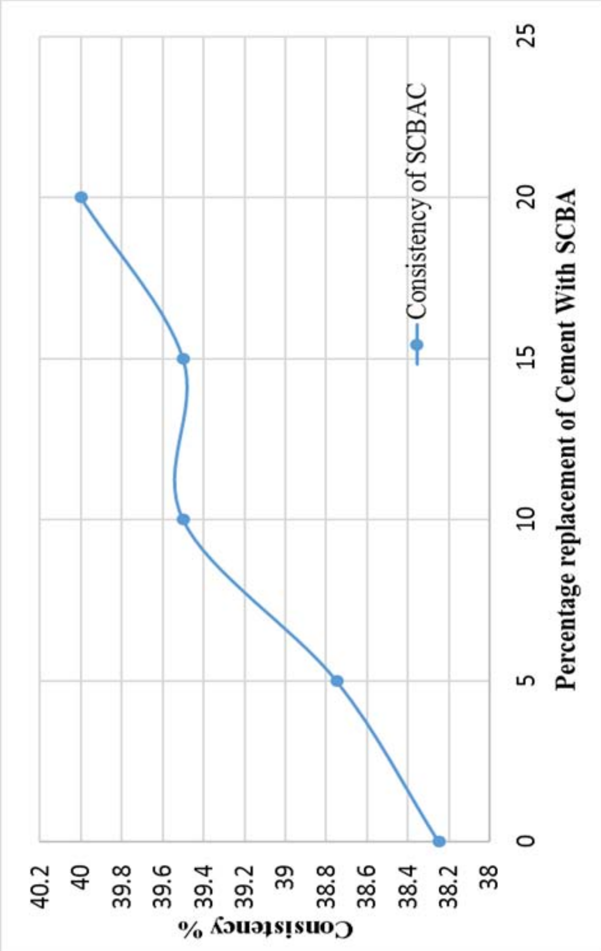

Figure 1: Consistency of Sugar Cane Bagasse Ash Cement

3.2 Initial and Final Setting Time of Sugar Cane Bagasse Ash Cement

Table 3 and Figure 2 show the initial and final setting times behavior of SCBA. From the results, it is noted that the initial and final setting times for Sugar Cane Bagasse Ash Cement, the initial setting times for SCBAC with 0%, 5%, 10%, 15% and 20% SCBA are 2.25 hours, 2.67 hours, 2.83 hours, 3.08 hours and 3.42 hours respectively. Also, the final setting times for SCBAC with 0%, 5%, 10%, 15% and 20% SCBA are 8.33 hours, 7.92 hours, 7.83 hours, 7.58 hours and 7.5 hours respectively.

Table 3: Initial Setting and Final Setting Time Tests for SCBA Cement

% of Bagasse in Cement	Average Initial Setting Time (Hours)	Average Final Setting Time (Hours)
0	2.25	8.33
5	2.67	7.92
10	2.83	7.83
15	3.08	7.58
20	3.42	7.5

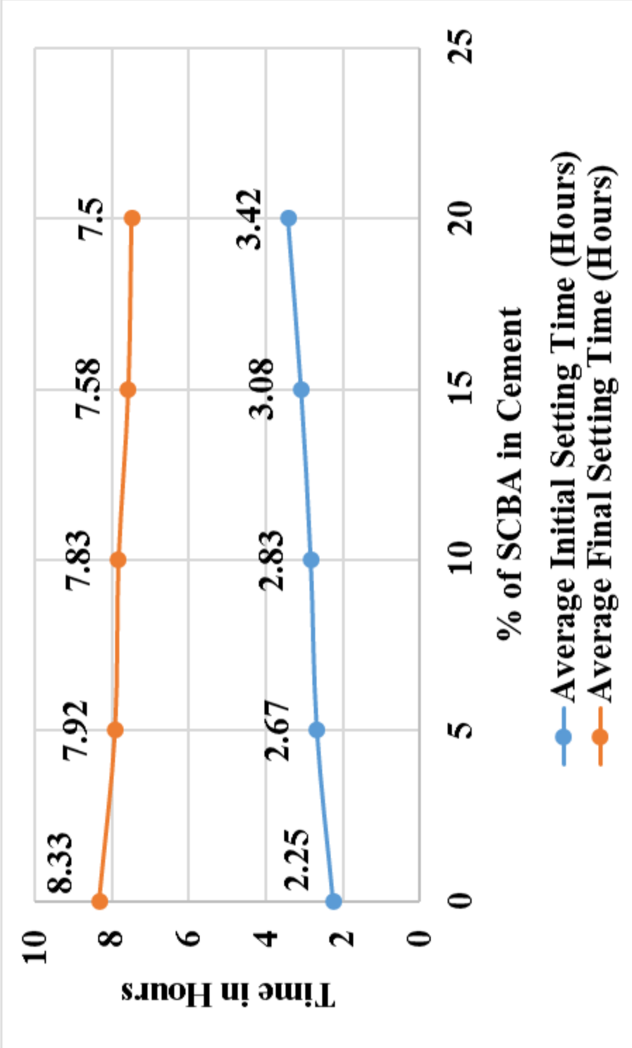

Figure 2: Setting Times of Sugar Cane Bagasse Ash Cement

3.3 Chemical Composition of Sugar Cane Bagasse Ash Cement

Tables 4A and 4B shows the chemical composition of SCBAC. The results for the chemical analysis of the Sugar Cane Bagasse Ash cement done using the X-Ray Florescence Spectral Analysis technology and are as shown below: -

Table 4A: Chemical Composition of Sugar Cane Bagasse Ash Cement-Part 1

% of SCBA in Cement	Aluminium Oxide (Alumina)-Al_2O_3	Silicon Dioxide (Silica)-SiO_2	Phosphorus Oxide-P_2O_5	Potassium Oxide-K_2O
0 Pure Cement	4.8	32	0.76	2.31
5	4.5	32.68	0.85	2.66
10	4.65	33.38	0.85	2.82
15	4.59	34.57	0.93	2.98
20	4.38	35.29	1.08	3.32
100 (Pure SCBA)	3.53	69.33	2.66	10.09

Table 4B: Chemical Composition of Sugar Cane Bagasse Ash Cement- Part 2

% of SCBA in Cement	Calcium Oxide -CaO	Titaniun-Ti	Iron-Fe	Sulphur-S	Others
0 Pure Cement	52.16	0.38	4.39	2.88	<1
5	51.02	0.42	4.63	2.89	<1
10	49.72	0.51	4.89	2.79	<1
15	48.32	0.58	4.98	2.67	<1
20	47.07	0.7	5.17	2.61	<1
100 Pure SCBA	5.15	1.21	6.6	0.73	<1

The results showed that, in the pure Sugar Cane Bagasse Ash, all the components of the pure cement were present having the oxides of Silicon, Potassium, Iron and Calcium being the most being the most prominent by 69.33% (SiO_2), 10.09% (K_2O), 6.6% (Fe), and 5.155% (CaO), respectively. But, for the pure cement, the most prominent oxides were Calcium, Silicon, Aluminium and Iron by 52.16% (CaO), 32% (SiO_2), 4.8% (Al_2O_3) and 4.39% (Fe) respectively. Graphically, the variations of the proportions are as shown in figures 3A and 3B below.

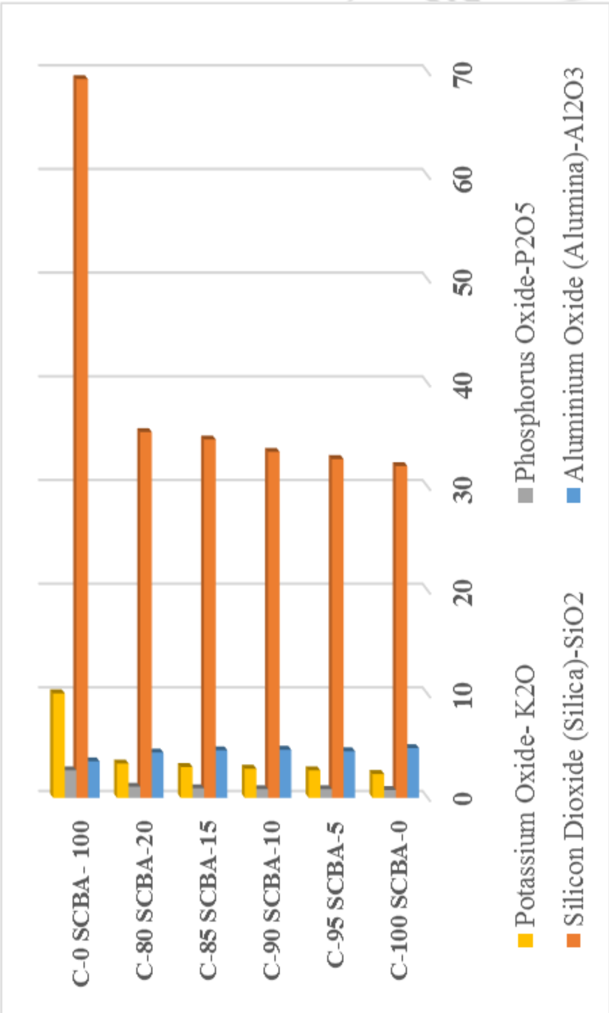

Figure 3A: Chemical Composition of Sugar Cane Bagasse Ash Cement- Part 1

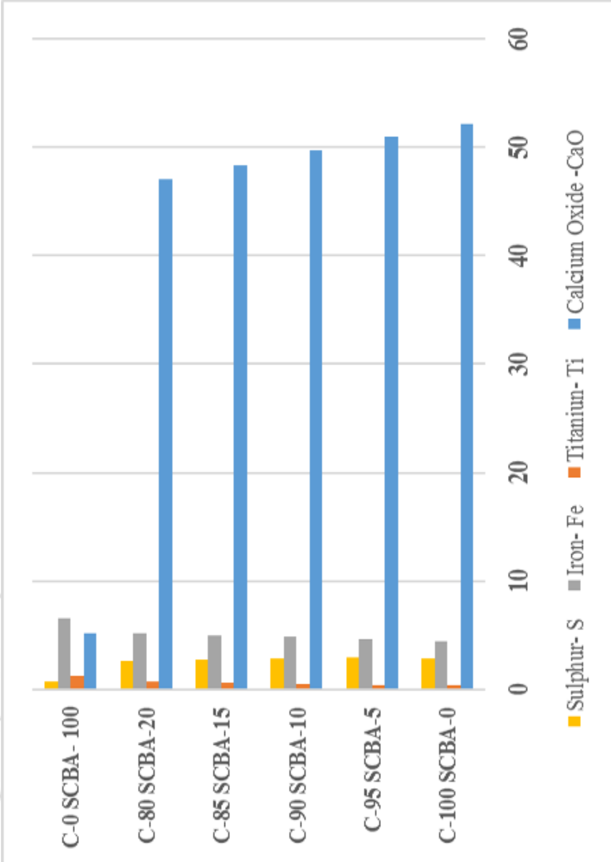

Figure 3B: Chemical Composition of Sugar Cane Bagasse Ash Cement- Part 2

4. Discussion

Sugar Cane Bagasse Ash (SCBA), to be qualified as a suitable replacement candidate for cement at some proportions for some specific uses, it has to meet some thresholds. These minimum requirements are the ones set by the generally accepted standards like the British Standard Codes.

From Table 2, the consistency results showed that the consistency was increasing as the amount of SCBA content increased in the mix sample. Even though, the required consistency varies from 26% to 33% for Ordinary Portland Cement, the samples never fell within the range. This is explained by the fact that Nguvu CEM IV/B(P) 32,5N is a blended cement and in addition, by adding Sugar Cane Bagasse Ash to Nguvu CEM IV/B(P) 32,5N cement has the effect of increasing the amount of water required to achieve the required consistency. Hence the more the amount of SCBA in cement, the higher the amount of water required to achieve a certain consistency. For the research done, the consistency of the SCBAC can be limited to 40% for up to 20% cement (Nguvu CEM IV/B(P) 32,5N) replacement as compared to pure Ordinary Portland Cement.

From Table 3, the initial setting time is seen to increase as the amount of SCBA proportion increases in cement but still within the acceptable limit of not less than 30 minutes. Also, the final setting time is seen to decrease as the SCBA content in the cement increased but still within the acceptable limit of not more than 10 hours. Hence, in the initial stages, SCBA can be seen as a retarder due to the sufficient amount of water it holds, as indicated by the consistency tests. In the long run, it may be seen as an accelerator, as the more the content in cement, the less the time it takes before it finally sets. This can be explained by the fact that most of the water has been used in the initial strength development stages, hence finally, the setting is speeded up by less water available.

From Tables 4A and 4B, compared to the control experiment of the pure cement, all the elements in the control experiment are present in the pure SCBA and subsequent mixes. Elements

Aluminum Oxide (Al_2O_3), Calcium Oxide (CaO) and Sulphur elements are generally seen to be decreasing with increase in the Sugar Cane Bagasse Ash proportion in the SCBAC, but all the other elements are seen to be increasing with increase in the SCBA content. This is because, the increase in the SCBA proportion in the cement increases its blending effect hence

Generally, the pattern of the element proportion per mix sample is seen to be maintained and also the range of mineral composition of pure cement and the various mixes were within the standard range of BS12-1996 and were within the acceptable limit of 5%.

5. Conclusion

From the results and discussion above, it is concluded that: -

1) SCBA is hygroscopic, as the higher the content in cement, the higher the amount of water required for standard consistency to be achieved.
2) For SCBAC, the consistency has been found to cap at 40% for up to 20% SCBA replacement in Nguvu CEM IV/B(P) 32,5N.
3) SCBAC is a retarder at initial setting time with up to 3.42 hours for 20% replacement in Nguvu CEM IV/B(P) 32,5N cement, but an accelerator with up to 7.5 hours final setting time at 20% Nguvu CEM IV/B(P) 32,5N cement replacement.
4) The highest component of SCBA is SiO_2 at 69.33% as compared to pure Nguvu CEM IV/B(P) 32,5N cement with 32% of the same compound mineral.
5) The highest component of pure Nguvu CEM IV/B(P) 32,5N cement is CaO at 52.16% as compared to pure SCBA with 5.15% of the same compound mineral.
6) All the mineral components of the SCBAC don't vary with more than 5% from the composition of pure cement, and are within the acceptable limits as per BS12-1996 hence the replacement up to 20% is generally acceptable within 95% confidence interval.

6. Acknowledgements

I am anxious to testify my gratitude to the African Union Commission to have given me the scholarship, the Pan African University to have given me the opportunity to access to this scholarship program and the African Development Bank for funding the research program. Also my gratitude goes to Jomo Kenyatta University of Agriculture and Technology, Structures and Materials Engineering Laboratory for the best environment in carrying out my laboratory work.

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