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BAGASSE ASH YIELD OF DIFFERENT COMPONENTS OF SUGARCANE ANDTHEIR POZZOLANIC CHARACTERISTICS

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Abstract

Bagasse ash is the ash of the fibrous residue obtained from sugarcane after extraction of sugar juice,locally or at sugar mills. Three types of bagasse ash, obtained from different bagasse compositions, and from different components of sugarcane,were studied. Sample A was obtained from the brownish black cover of the sugarcane variety, sample B was made up of the inner whitish fibrous residue, while sample C was obtained from the combined mixture of the sugarcane crop. The sugarcane bagasse yield, sugarcane bagasse ash yield and the oxide compositions were determined to check for their pozzolanic characteristics. The results were then compared with the pozzolanic characteristics specified by ASTM C618-93. Though, the values obtained were lower than those specified, they could still be employed as pozzolanas, based on the high content of calcium oxide in the ashes.

Keywords:*Bagasse ash yield, Bagasse yield, Oxide composition, Pozzolana, Sugarcane.*

1.0 Introduction

Sugarcane, which has genetic name as *Saccharin spp*, and called *canne a sure* in French, *cana de acucar* in portuguse, *cana de azucar* in Spanish, has been cultivated and selected at village (local) level over thousands of years. The oldest cultivated species was *Saccharin Officinarum*, which was thick-stemmed juicy specie that includes many varieties [1]. According to Misari*et al.*[2], India is the birth place of sugarcane, but some other writers ascribed its origin to Guinea, from where it was reportedly taken to China, India and further east to the Pacific Islands. It was from these early centres of sugarcane cultivation that the crop spread to the rest parts of the world such that today, the crop is grown in about 200 countries[3], most lying between latitudes 40°N and 32°S, which encompasses nearly half of the world[4]. According to Wada *et al*. [3], the top worldwide producers of sugar cane are Brazil, India, China, Thailand, Pakistan and Mexico.

In all the countries where sugarcane is cultivated, including Nigeria, the consumed and commercial varieties are found. In developing countries, where the crop is produced, the consumed varieties are commonly chewed and the residue discarded, littering the environment, while the commercial varieties are commonly used in sugar producing factories for extraction of sugar juice, with the by-product also discarded. Misari*et al*.[2] and Ogbonyomi[5] stated that, between 600,000 and 720,000 tonnes of bagasse is generated annually in Nigeria, and there are potentials to increasethe production to about 3.5 million tonnes. Mansaneira*et al.* [6] stated that for each ton of processed sugarcane, 270 to 290 kg of bagasse is generated, and each ton of bagasse produces 23.8 kg of sugarcane bagasse ash. These translate to about 27 to 29 for bagasse yield and 2.38% for bagasse ash yield. However, regardless of the fact that the Federal Ministry of Housing in Nigeria has been scouting for readily available cheap construction materials for low-cost buildings, the World Bank continued to spend substantial amounts of money on research towards harnessing industrial and refined solid wastes for human usage. This has prompted many researchers into exploring the possibility of using some industrial by-products like fly ash, coal-bottom ash, rice husk ash etc,aspartial substitute to the common available binder (cement) in order to enhance the performance of the later. Laboratory trials by Osinubi [7], Abdullahi [8], Oyetola and Abdullahi [9], Alhassanand Mustapha [10],Alhassan[11], Abdulkadir *et al*. [12]and Tantawy[13]recorded successes at different levels of partial replacement of cement with ashes of some agriculturalwaste (mostly as pozzolanas), which were capable of enhancing performance of the cement in presence of the lime liberated by its hydration.

1.1 Pozzolanas

American Society of Testing and Materials (ASTM C618-93)[14]define pozzolana as a siliceous or siliceous and aluminous material which in itself possess little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with lime liberated by hydrating Portland cement at ordinary temperatures to form compounds possessing cementious properties. According to Neville [15], the original reason for using these materials are usually economic related: they existed as natural deposits requiring none or little processing, and sometime they are by-products or wastes from industrial processes. However, it is important that pozzolanas be in a finely divided form [15]. As it is only then that silica can combine with calcium hydroxide in the presence of water to form stable calcium silicate, which has cementitious properties.

Pozzolanas can be natural or artificial. Natural pazzolanas are mostly materials of volcanic origin but could include certain diatomaceous earth, which include volcanic tuff. The main artificial pazzolanas however, are burnt clays and shales, pulverized fuel ash etc[5]. The positive aspect of using agricultural waste for producing cementatious compounds in conjunction with lime, have recently been considered [16]. Many plants during growths pick up silica from the ground into the structure of their leaves, stalks and other parts. When residues of these plants are burnt, organic materials which are the largest proportions, are broken down and disappear as carbon dioxide and water vapour. The remaining ash contains mostly inorganic residue notably silica [16].

1.2 Bagasse ash

Bagasse ash later joined the group of the above mentioned pozzolanas as reported in Oversea Road Note 31 [17] and Ogbonyomi[5], etc with its pozzolanic activity increasing with specific surface area. Using oxide composition, various researchers have reported the pozzolanic potentials of this ash (Table 1).

	Reported composition (%)		
Author	SiO_2	Al_2O_3	Fe_2O_3
Ganesana*et al*. [18]	64.15	9.05	5.52
Osinubi *et al*. [19]	41.17	6.98	2.75%
Suliman and Almola [20]	56.7 - 58.3	4.56 - 15.52	6.81 - 9.69
Cordeiro*et al*. [21]	78.34	8.55	3.61
Modania*et al*. [22]	62.43	4.28	6.98
Srinivasan and Sathiya[23]	78.34	8.55	3.61
Otoko [24]	41.15	7.00	2.70
Usman *et al*. [25]	76.17 - 77.29	10.95 - 11.1	3.66 - 3.7
Hussein *et al*. [26]	77.25	6.37	4.21
Abdulkadir *et al*. [12]	72.85	1.08	6.96
Tantawy*et al*. [13]	50.69	13.56	11.78
Dhengare*et al*. [27]	87.59	0.51	0.67
Sadeeq*et al*. [28]	57.95	8.23	3.96
Dang *et al*. [29]	65.27	3.11	2.10
Priya and Ragupathy [30]	71.0	1.9	7.8
Shahnaz *et al*. [31]	66.28	15.10	3.40
Saranya*et al*. [32]	66.89	29.18	
Mansaneira*et al*. [6]	92.9-93.1	0.9-1.0	3.7
Maldonado-García*et al*. [33]	56.37	14.61	5.04

Some researchers likeOgbayomi[5], Mansaneira*et al*. [6], Tantawy [13], Smith [16], Ganesana*et al*. [18], Osinubi *et al.* [19], Suliman*et al*. [20], Otoko [24], Usman *et al.* [25], Dhengare*et al.* [27], Sadeeq*et al.*[28], Dang *et al*. [29], Priya and Ragupathy [30], Shahnaz *et al*. [31], Saranya [32], Osinubi and Stephen [34], Osinubi and Stephen[35], Osinubi and Stephen [36], Osinubi andAlhassan[37],Osinubi and Mustapha [38],Amu *et al.*[39],Kawade*et al.*[40],Sadeeq*et al.*[41] andAlhassan and Alhaji[42]used bagasse ash, obtained from different sources and from bagasse generated from both consumed and commercial varieties of the sugarcane to help solve their disposal problem. In developing countries like Nigeria, where sugar companies are very few, it is difficult to utilize the abundant sugarcane being cultivated. Furthermore, most of the cultivated sugarcanesare consumed varieties,which are chewed, and the fibrous residue discarded carelessly, and consequently littering the environment. Also in many Nigerian towns, there are sugarcane depots, where consumed sugarcane varieties, from cultivating centers are sold to retailers. The retailers, in turn prepare them by cutting off the unwanted parts and sometimes peeling off the brownish black cover before selling them to consumers. These depots also face disposal problems, which is also of concern to environmentalists. Proper understanding of the pozzolanic potentials of the various components of the disposed products can help in tackling the disposal problems. This work was therefore, aimed at evaluating the potentials of the ash from different components of the sugarcanebassageas pozzolana.

As mentioned earlier, most pozzolanasrely on lime from other sources (e.g lime liberated from hydration of cement) to develop compounds possessing binding properties except for some few pozzolanas that possess some substantialamount of lime on their own. Ogbonyomi[5], Abdullahi (2003) [8], Abdulkadir *et al*. [12], Srinivasan and Sathiya[23], Hussein *et al*. [26], Sadeeq*et al*. [28], Dang *et al*. [29] Priya and Ragupathy [30], Sadeeq*et al*. [41], Aigbodion*et al.*[43], Rafael *et al.*[44], Prakash and Nagakumar[45],used various percentages of differentpozzolanic materials that are by-products of agricultural waste (including bagasse ash)in conjunction with other additives (e.g. lime), either as partial substitute to cement in the production of sandcrete blocks or to improve the strength and durability of road base materials. These researchers recorded some level of success as regards the use of ashes from this material for soil improvement. Alhassan and Alhaji[42] reviewed advances that have been made in the improvement of deficient soils in Nigeria using bagasse ash. However, not much work has been reported on the yield and oxides composition(pozzolanic characteristics) of ashes from the various components of the sugarcane cropand method of their preparation.

2.0 Methodology

2.1 Samples Collection, Preparation and Testing

The sugarcanes used for this study were collected from a large consumed variety sugarcane plantation, encompassing several hectares of land at Wuya village along Bida-MokwaRoad, and from sugarcane deport in Minna, Niger State, Nigeria. The sugarcane collected from Wuya village were prepared and marked as samples A and B, while sample C was prepared from bagasse collected from thedeport in Minna.

13kg of the sugarcane collected from Wuya village was weighted and the dark brown cover of the weighted sample was peeled off and kept separately as sample A (Figure 1-a). The juice contained in the whitish internal part was sauced, squeezed out and the whitish fibrous residue was kept separately as sample B (Figure 1-b), taking care not to lose any part. These two separate compositions were air dried to constant weights, and were used to determine the bagasse yield of the sugarcane specie. Sample C (Figure 1-c) was a combination of all parts of the sugarcane crop (i.e. including the leaves, stalks, roots, tips and even some compositions of samples A and B). This made it relatively difficult to determine the bagasse yield value of this sample since it depended on the quantity and compositions of the various components present in the mixture. Consequently, bagasse yield value was determined using sugarcane of the same specie for samples A and B and the average sugarcane yield of the two results were obtained.

a b c

Figure 1: Sugarcane bagasse used: a) dark brown cover, b) inner whitish fibrous residue, c) combination of all parts of the sugarcane crop

Samples A and B were separately heated to char in a burner, taking care not to lose any part. Some specimen of the charcoal was then weighted for the two samples and placed in a crucible, which in turn was placed in a laboratory mini-furnace, where it was heated to ashing at a temperature of 525^{o}C for 3 hours. The bagasse ash yield of the sugarcane was also obtained as a percentage of the sugarcane bagasse.

The ash of sample C was prepared in a different manner. A substantial amount of the sample, dumped by a tipper, was set on fire in an open space. The mixture was allowed to burn for about 2 days during which a thermocouple was inserted to measure the temperature of ashing at intervals. All the bagasse mixture turned to ash after 2 days of burning except for the materials on the surface that contained some charcoal. This surface was removed and the real ash sieved through B.S. sieve with aperture size 75µm as specified in ASTM C618-93[14] for pozzolanic ashes. Ashes from samples A and B were tested as removed from the furnace without further grinding.

The chemical composition of the ashes from samples A, B and C were determined using x-ray florescence method, because it is fast and reproducible. The samples were first grounded into fine powder using a Siemen-milling machine, possessing a very high grinding speed. Care was taken to ensure that the samples contained no moisture. The grinded samples were collected and 20g of these was weigh using digital weighting balance. 0.4g of ascorbic acid was also weigh and added to the 20g of the individual samples. The quantity of ascorbic addedto the samples was relatively insignificant, because it served as a binder to hold the fine powdered particles together so that no particle was lost during compression of the particles of the samples together.

The grounded samples were placed on shallow cylindrical steel containers of about 50mm external diameter. The samples in the steel container were placed in a “Hazog” compression machine, which has a pressure range of 10 to 40kN/m^2. The machine was used to select a pressure of 10kN/m^2 to compress the particles of the samples together to form pellets. The formed pellets were in turn, mounted on either cadmium or iron source holder of pholic (model 1414) x-ray fluorescent equipment assessed by computer.A reset time of 3000 seconds for iron source for every sample was used. After counting, characteristics peaks were displayed and conversion to equivalent concentration values was done through appropriate software and printed out in hard copy.

Loss on Ignition of the ashes was also determined in accordance procedure outlined in ASTM D7348 - 13[46].

3.0 Results and Discussion

The result of the sugarcane bagasse yield values of the tested samples, as percentages of the sugarcane specimen is shown on Table 1.The chemical compositions of the bagasse samples are shown on Table 3. The total average bagasse yield of 12.22% (Table 1) and average bagasse ash yield of 1.015% (Table 2) are very low compared to values of 29.70 and 2.48%, respectively obtained by Ogbonyomi[5]. These values are also lower than those reported by Mansaneira*et al*. [6]. The low values could be due to the varieties of the sugarcane used in the study. The sugarcane commonly used in the production of sugar in factories, which is mostly used by researchers is the commercial variety. This commercial variety juicier and thinner than the consumed variety, which is thicker with more liquid,but not as juicy as the commercial variety. Result of the bagasse ash yield as a percentage of the total bagasse is also shown in Table 2.

2.36 recorded by Ogbonyomi[5],Sadeeq*et al*. [28], Sadeeq*et al*. [41] and Maldonado-García*et al*. [33] respectively, and could contribute to self-cementing action of the bagasse ash.

The values of the Fe_2O_3, Al_2O_3, S_iO_2 and C_aO obtained in this study compared to the values reported other researchers [5, 6, 13, 19, 20, 24, 25, 27, 31 and 33] can be attributed to the difference in varieties of the sugarcane and temperature at which the ashes were prepared.

Table 3: Oxide composition of the bagasse ash samples

Oxide	**Compositions (%)**		
	Sample A	**Sample B**	**Sample C**
S_iO_2	41.14	55.56	43.32
Al_2O_3	2.31	5.41	2.67
Fe_2O_3	0.77	1.16	1.17
C_aO	9.15	11.30	10.01
M_gO	1.48	1.32	1.85
SO_3	1.63	1.51	5.89
K_2O	14.73	10.66	17.41
Na_2O	0.04	0.04	0.04
LOI	9.21	11.28	10.37

Although, Mansaneira*et al*. [6] reported 0% Sodium oxide (Na_2O) in bagasse ash, the 0.04% recorded in this study for all the three samples, is relatively very low, and is as expected of a good pozzolana. However, there is an anomaly in the percent composition of potassium oxide with values of 14.73, 10.66 and 17.41% for samples A, B and C respectively. These values are relatively higher than 0.3, 0.49, 2.41, 3.46, 6.77, 8.2, 8.72 and 8.75% reported by Mansaneira*et al*. [6], Tantawy*et al*. [13], Sadeeq*et al*. [28], Sadeeq*et al*. [41], Cordeiro*et al*. [21], Abdulkadir *et al*. [12], Priya and Ragupathy[30], Osinubi *et al*. [19] and Otoko[24] respectively. This could be attributed to the sugarcane variety studied, or most likelydue to the quantity and type of fertilizer applied to the sugarcane during growth.

The Losson Ignition (LOI) values are 9.21, 11.21 and 10.37% for samples A,B and C respectively.These values, although are high,when compared with the 5.21% reported by Ogbnyomi[5], 6.4 and 8.7% reported by Suliman and Almola[20], 3.2 to 3.6% reported by Usman *et al*. [25], 0.72% reported by Kawade*et al*. [40], 5.0% reported by Sadeeq*et al*. [28] and Sadeeq*et al*. [41], but lower than 17.55 and 17.57% reported by Otoko[24] and Osinubi*et al*. [19] respectively, and the maximum value of 12% specified by ASTM C618-93 for pozzolanas.

Table 1:Bagasse yield value as percentage of sugarcane specimen

Trial	Bagasse yield (%)	
	Sample A	Sample B
First trial	5.43	5.54
Second trial	6.81	6.65
Average	6.12	6.10
Total	12.22	

Table 2: Bagasse ash yield value as percentage of total bagasse

Trial	Bagasse ash yield (%)	
	Simple A	Sample B
First trial	0.50	0.50
Second trial	0.52	0.51
Average	0.51	0.505
Total	1.015	

The oxide compositions of ashes of the studied bagasse are presented on Table 3. From the table, it is observed that although, the composition are generally lower, especiallyin ashes of samples A (sugarcane cover) and C (combined mixture of sugarcane crop) compared to ash from sample B (the whitish inner fibrous part of the sugarcane), the obtained values are within the range reported in literature. SiO_2 content of 41.17 and 41.15 were reported by Osinubi *et al*. [19] and Otoko[24] respectively, while as high as 93.1% SiO_2 content was reported by Mansaneira*et al*. [6]. The combined percentage composition of SiO_2, Al_2O_3 and $Fe_2O_3$for samples A, B and C (Table 3) are 44.22, 62.13 and 47.16% respectively.Although, these are generally lower than the 70% minimum specified by ASTM C618-93 [14]for class N, F and C pozzolanas, they are generally within the ranges reported in the literature.

Although, the Al_2O_3 contents of 2.31, 5.41and 2.67% for samples A, B and C respectively, are relatively low, the values are within the range reported in the literature. Fe_2O_3 content, which is as low as 0.5% was reported by Dhengare*et al*. [27], and a value, which is as high as 15.10% was reported by Shahnaz *et al*. [31]. Ogbonyomi[5] had earlier reported Al_2O_3 content 7.95%, while Al_2O_3 content of about 11% for bagasse ash, prepared at between 500 and 700^{o}C was also reported by Usman *et al*. [25]. Also, Fe_2O_3 content of 0.77, 1.16 and 1.17% in the studied bagasse ashes are relatively low compared to the values of 4.27 reported by Ogbonyomi[5] and 6.81 to 9.69% reported by Suliman and Almola[20]. Tantawy*et al*. [13] also reported a value of as high as11.78% for Fe_2O_3 content in bagasse ash. However, the calcium oxide content of 9.15, 11.3 and 10.01%, obtained for samples A, B and C respectively, are higher than 6.47, 4.52 and

4.0 Conclusion

The consumed variety of the sugarcane used in this study possesses some pozzolanic characteristics although, not as much as the commercial variety studied by Ogbonyomi [5], Usman *et al*. [25], Dhengare*et al*. [27], Shahnaz *et al*. [31], Mansaneira*et al*. [6], Maldonado-García*et al*. [33]. However, in developing countries like Nigeria were more of the consumed variety is cultivated, its ash could still be used as pozzlana. Also, where high percentages of silica, alumina and ferrous oxides are necessary, the inner whitish fibrous residue (sample B) of the variety should be considered. In situationswhere high percentages of silica, alumina and ferrous oxides are not necessarily required in a pozzolana, the combined mixture of the sugarcane crop (sample C) could be used, because of its ease of preparation.

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