THE USE OF SUGARCANE BAGASSE ASH AS AN ALTERNATIVE LOCAL POZZOLANIC MATERIAL: STUDY OF CHEMICAL COMPOSITION

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ABSTRACT

The sugarcane bagasse ash is used as fuel in the boilers of the Kinana sugar factory in Sudan. The field observation and qualitative study of the ash revealed that it consisted of major amounts of carbon and organic materials; this is due to the incomplete combustion of bagasse fibers in boilers. Therefore, it became necessary to recondition the samples for use as pozzolana by re-ashing it. The study of chemical composition of the ash revealed that such byproducts are likely to be pozzolanic. Comparison between chemical compositions of Kinana sugarcane bagasse ash and the pulverized coal fly ashes (ASTM C 618 1999) shows that the composition of bagasse resembles that of Class F Coal Fly Ash, as the total of alumina, silica, and ferric oxide content is about 72 %. It may, therefore, behave like Class F Fly Ash, in its engineering properties.

Keywords: *Sugarcane, Bagasse ash, Pozzolana, Fly ash.*

1. INTRODUCTION

In the Republic of the Sudan, there are five operational sugar factories that utilize sugarcane. These factories are located at New Halfa in Kassala State; Guenied in Gezira State; Sinnar in Sinnar State, and Kinana and Assalaya in White Nile State. Some of these factories are generating electric power by using the sugarcane bagasse fibres. Bagasse is the fibrous leftover after sugarcane stalks are crushed to extract their juice. Bagasse is now used as a biofuel – as a renewable resource in the manufacture of pulp and paper products, and building materials. Bagasse is often used as a primary fuel source for sugar mills; when burned in quantity, it produces sufficient heat energy to supply all the needs of a typical sugar mill, with energy to spare. To this end, a secondary use for this waste product is in co-generation. The use of a fuel source to provide (i) heat energy, used in the mill, and (ii) electricity, which is typically sold to the consumer electricity grid. The combustion yields ashes containing high amounts of unburned matter, Silicon and Aluminum oxides as main components (Paya, J. et al., 2002).

The demand for building materials has been continuously rising with the increasing consumption of buildings, both in rural and urban areas. It has been seen that materials that were being used about a century back are still very popular. Commercial exploitation of traditional building materials by various industries has aggravated the situation. It has, therefore, become necessary to think over this problem seriously and to provide some sustainable solution to make the alternative materials available to solve this problem. Hence, the use of an alternative and cheaper local building material to substitute the ones being traditionally used may facilitate solving the acute problems relating to building materials (Ballerino, 2002).

Recently, a variety of alternative building materials are available. The use of these new materials may provide better, efficient, durable and cost-effective construction-material resources with reduced degradation of environment. Some of the materials are manufactured by using waste materials, such as fly ash (the ashen byproduct of burning coal), or agricultural waste ash as the raw material for their production (ASTM C 618, 1999).

Among other properties, pozzolanic activity is the main property that the researchers seek in industrial waste material of mineral nature. The pozzolanas are materials containing reactive silica and/or alumina, which on their own have little or no binding property, but when mixed with lime in the presence of water will set and harden like a cement (Lea, 1956). They are important ingredients in the production of an alternative cementing material to ordinary Portland cement. Nowadays, a wide variety of siliceous or aluminous materials of both natural and artificial origins are being used for producing pozzolanas, the common material being calcined clays; pulverized fly ash; volcanic ash; diatomaceous earth and ash from agricultural residues; such as rice husks (Oyetola, and Abdullahi, 2006); and sugarcane bagasse ash (Hernandez, Middendorf, Gehrke, and Budelmann, 1998). The industrial byproducts, including clays and wastes with an elevated silica content, are used as pozzolanas partially in place of Portland cement. This is due to their capacity for reacting with Calcium hydroxide ($Ca(OH)_2$), produced during the hydration of the Portland cement. Hydrated compounds formed during pozzolanic reactions commonly improve the performance of new cements (Massazza, 1976; Taylor, 1997; Metha, 1998; Frý´as, Sa´nchez de Rojas, and Urý´a, 2002; and Frý´as, and Sa´nchez de Rojas, 2004). The recycling of industrial wastes from

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the agricultural sector is increasingly encouraged, particularly in developing countries, e.g., Cuba, India and Brazil. For use as pozzolanas, the agricultural wastes need prior calcination but pozzolanic activation can vary substantially as a result of the calcining conditions and the nature of the source materials. However, there are contradictory reports about the pozzolanic effectiveness of agricultural waste ashes, possibly due to the use of different calcining temperatures (Martirena, Middendorf, and Budelman, 1998; Baguant, 1995; Paya, et al., 2002; and Singh, Singh, and Rai, 2000).

Since the beginning of the 20th century, sugarcane bagasse has been used as fuel in the boilers of the sugar factories. The sugarcane 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. In 2003, approximately 95 % of the sugarcane bagasse produced in Brazil was burnt to generate energy resulting in about two million tons of residual ash (Cordiero, et al., 2004). Table-1 illustrates the basic composition of different bagasse fibres, studied by various authors.

can be used in many construction applications where they have advantages, e.g. as mortars, renders and non-structural concretes (Markopoulos, and Triantafyllon, 2004).

Pozzolanic cements additionally have numerous other technical advantages to the user, such as improved workability, water retention/reduced bleeding, sulphate resistance, resistance to alkali and lowered heat of hydration. Therefore, in many large civil engineering projects involving mass concrete works, Portland cement-pozzolana mixes are specified due to these technical advantages (Eljack, 2008).

The objective of this paper is to describe the chemical nature of some of these resources and to emphasize the fundamental properties of this class of material so that it can be best utilized in an appropriate manner.

2. MATERIALS AND METHODS

A total of six samples (three each from Kinana and Guenaid Sugar companies) of sugarcane bagasse ash obtained after combustion of the bagasse fibres, for power generation were chemically analyzed. The field observation and qualitative studies of sugarcane

Table-1: Basic Composition of Bagasse Fibres (% by mass)

Cellulose	Hemicellulose	Lignin	Ashes	Reference
37	28	21	unreported	Bon, E.S.B., 2007
26 - 47	19-33	14-23	1-5	Paturua, J.M., 1989
38	33	22	3	Trikett, R.C., and Neytzell-de Wilde F.G., 1982
50	25	25	0.62	Cordiero, G.C., et al., 2004

The residue after combustion presents a chemical composition dominated by Silicon dioxide (SiO_2), Aluminium oxide (Al_2O_3) and Ferric oxide (Fe_2O_3). In order to be used as a mineral admixture, the residual sugarcane ash must have appropriate physical and chemical properties. The research work of Hernandez, Middendorf, Gehrke, and Budelmann (1998), emphasizes the similarity between the chemical composition of the rice husk residual ash and the residual bagasse ash (Metha, 1998 and Malhotra, (Ed.), 1996). The study of the mineralogical composition of different wastes of sugar industry, mainly sugarcane bagasse ash and sugarcane straw ash, have shown that such byproducts are likely to be pozzolanic (Hernandez, Middendorf, Gehrke, and Budelmann, 1998); their use in lime-pozzolana binders could become an interesting alternative to Portland cement. The alternative cements are not capable of replacing Portland cement totally, but they

bagasse ash revealed that it consists of a major amount of carbon and organic materials. This is due to the incomplete combustion of bagasse fibres in boiler's system (Eljack, Mohamed and Ibrahim, 2009; and Scheetz, et al., 1997). Thereof, it became necessary to recondition the samples for use as pozzolanic material by re-ashing again at 700°C in the laboratory to exclude the high carbon content. It was then pulverized to pass 150-micron sieve and the resulting ash was chemically analyzed. Table-2 shows the results of chemical analysis of bagasse ash from Kinana and Guenaid sugar companies.

3. RESULTS AND DISCUSSION

The results of the chemical analyses are presented in Table-2, which shows that the amount of silicon dioxide varies from 56.70 % in Guenaid sugar factory bagasse ash to 58.03 % in Kinana bagasse ash; and

Table-2: Average Chemical Composition of Sugarcane Bagasse Ash from Kinana and Guenaid

Oxide	Guenaid sugar factory (%)	Kinana sugar factory (%)
SiO_2	56.70	58.03
Fe_2O_3	15.52	4.56
Al_2O_3	6.81	9.69
CaO	9.30	13.71
MgO	4.50	5.85
LOI	6.40	8.66

iron oxide content ranges between 15.52 % in Guenaid to 4.56 % in Kinana. Aluminum, Calcium and Magnesium oxides and loss on ignition (LOI) also showed significant variations in contents.

Those variations may be due to the difference in soil type from one area to another. The significant increments of CaO values from 9.30% in Guenaid sugarcane bagasse ash to13.71% Kinana bagasse ash may be due to the presence of the lime nodules that are very common in the sediments of the White Nile area, where Kinana sugar factory is situated. These nodules include various forms of calcium carbonate, like calcite nodules and crystals, fossil shells as well as Ankerite (mixed carbonate of Ca, Mg, Fe and Mn) (Eljack, 2008), due to the different fertilizer treatments applied, to improve the cane production.

The chemical composition of the sugarcane bagasse ash produced in the laboratory showed that it is a non-volatile, incombustible, thermally altered mineral matter that was contained in sugarcane. The principal component of those ashes is certain mineral oxides dominant mineral phase in sugarcane. These minerals will undergo dehydroxylation in a fluidized bed combustion facility and melt to form glass in a bagasse combustion unit (Howard, 1989).

When the chemical composition of the sugarcane bagasse ash is compared with the chemical composition of pulverized coal fly ashes, classified by ASTM (ASTM C 618, 1999) by their aggregate Alumina, Silica, and Ferric oxide content into Class F or C. Class F coal ashes are generally produced by higher rank coals and typically have lower calcium content. Class F contains a total of at least 70% of these three oxides and Class C contains greater than 50% of the three oxides (ASTM C 618, 1999). Table-3 summarizes the average bulk composition of a Class F ash based on some analyses (Scheetz, et al., 1997; and Scheetz, and Earl, 1998).

Table-3: Average Bulk Composition of a Class F Fly Ash

Oxide	Wt. %
SiO_2	52.5±9.6
Fe_2O_3	7.5±4.3
Al_2O_3	22.8±5.4
CaO	4.9±2.9
MgO	1.3±0.7
LOI	2.6±2.4

From Table-2, the chemical composition of the sugarcane bagasse ash from Kinana sugar factory is seen to resemble that of Class F coal fly ash (Table-3), especially in terms of the total of Alumina, Silica, and Ferric oxide content. Therefore, it may also behave like Class F fly ash in its engineering properties. Table-4 shows the range of chemical composition of fly ash and a comparison between chemical compositions of Kinana sugarcane bagasse ash and the pulverized coal fly ashes (ASTM C 618, 1999) classification.

The major advantages of the bagasse ash is that it is cheaper to produce, needs much lower or even negligible capital inputs to get started, and requires far fewer imported technological equipment because it is produced by already existing facilities. They can also be produced on a small scale to supply a local market resulting in greatly reduced transportation costs and a much greater degree of local accountability in the supply of building materials.

There are five sugar factories in the Republic of the Sudan. According to the estimates of the Sudan Sugar Company officials, they were delegated to produce a total of 7 million tons of sugarcane stems annually. Each ton of sugarcane stems yields 26% bagasse fibres, i.e. 1.82 million tons of bagasse fibres annually.

Table-4: Comparison between Chemical Compositions of Kinana Sugarcane Bagasse Ash, Guenaid Sugarcane Bagasse Ash and the Pulverized Coal Fly Ashes ASTM C 618 Classification

Oxide	Guenaid sugarcane bagasse ash (%)	Kinana sugarcane bagasse ash (%)	Class F fly ash (%)	Class C fly ash (%)
SiO_2	56.70	58.03	40 - 63	32 - 42
Al_2O_3	15.52	4.56	17 - 28	15 - 20
Fe_2O_3	6.81	9.69	3 - 12	5 - 7
MgO	9.30	13.71	0.6 - 2	4.1 - 6.1
CaO	4.50	5.85	2 - 8	15 - 35
LOI	6.40	8.66	0 - 5	0 - 0.5

Most of the factories are used to burning bagasse fibres for power generation; the burning of one ton of bagasse leads to the production of 0.62% of residual ash (Cordiero, et al., 2004). So, theoretically, the burning of 1.82 million tons of bagasse fibres is going to produce 11,284 tons of residual ash.

4. CONCLUSIONS AND RECOMMENDATIONS

The recent average results of the chemical analyses of the sugarcane bagasse ash from Kinana and Guenaid sugar factories revealed that sugarcane bagasse combustion products (ash) resembles pozzolana in chemical nature. Therefore, it should be considered as an important mineral resource in Sudan. It might be successfully used as an engineering material for a wide variety of applications. The chemical investigations on the bagasse ash carried in this study indicated that it has had more or less the same chemical composition of other artificial pozzolanic material, like fly ash or any other conventional pozzolana.

The author considers that the material may be used for preparing lime ash (pozzolana) mixture for local use as a mortar; and other low cost building material, such as blocks and bricks, especially in the sugar production areas where its availability is high. Therefore, more detailed work to explore the physical and mineralogical characteristics of these materials will enable expansion of engineering and useful applications for environment conservation.

As should be done for all mineral resources, it is strongly recommended to exercise the applications of bagasse ash to avoid potential replacing of one environmental problem with another.

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