SUGARCANE BAGASSE ASH AS A PARTIAL-PORTLAND-CEMENT-REPLACEMENT MATERIAL

CENIZA DE BAGAZO DE CAÑA DE AZÚCAR COMO MATERIAL DE SUSTITUCIÓN PARCIAL DEL CEMENTO PORTLAND

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Received for review August 6 th, 2008, accepted March 19 th, 2009, final version March, 20 th, 2009

ABSTRACT: This investigation is focused on the evaluation of the effects of the partial replacement of Portland cement by sugar cane bagasse ash (CBC) in mortars. The main objective wasto find a suitable destination for an agricultural residue generated in an increasing amount in Brazil, as the use of CBC as a mineral admixture in mortars and concretes, contributes to decrease the environmental impact of these materials related to cement production. Experimental techniques were applied both for the CBC characterization and for the evaluation of its use as a mineral admixture in mortars, based on mechanical and physical tests. The results from tests with mortars indicated the viability of the partial substitution of cement by up to 20% of the CBC considered.

KEYWORDS: solid waste management, building materials, sugar cane bagasse, Portland cement, sustainable development

RESUMEN: Esta investigación se centra en la evaluación de los efectos de la sustitución parcial del cemento Portland por cenizas de bagazo de caña de azúcar (CBC) en morteros. El objetivo principal fue encontrar un uso adecuado para este residuo agrícola que es generado en una cantidad cada vez mayor en Brasil, ya que el uso de CBC como un mineral mezclado en morteros y concretos, contribuye a disminuir el impacto ambiental de estos materiales relacionados con la producción de cemento. Técnicas experimentales fueron aplicadas tanto para la caracterización del CBC, como para la evaluación de su uso como una mezcla de minerales en los morteros, basados en pruebas físicas y mecánicas. Los resultados de las pruebas con morteros indicaron la viabilidad de la sustitución parcial del cemento por CBC, hasta en un 20%.

PALABRAS CLAVE: Manejo de residuos sólidos, materiales de construcción, bagazo de caña de azúcar, cemento Pórtland, desarrollo sostenible.

1. INTRODUCTION

Initiatives are emerging worldwide to control and regulate the management of subproducts, residuals, and industrial waste in order to preserve the environment from the point of view of environmental contamination as well as the preservation and care of natural areas [11].

A good solution for the problem of recycling agroindustrial residues would be to burn them in a controlled environment, and use the ashes for more noble means [6]. The use of residues such as biomass in the co-generation of electric energy is an interesting point, since when it is burned, the CO2 that is let out into the atmosphere returns to the carbon cycle of the biosphere, able to be absorbed by plants in the process of photosynthesis [12].

It is observed that a wide variety of residues are being used in the construction industry as mineral additives such as sugarcane bagasse ash [7], sugarcane chaff ash, swine waste ash and ash from swine bedding with a base of rice shells [5].

Beyond the economic and environmental aspects, one cannot overlook the technical advantages that come from the incorporation of mineral additives to cement. Various researches indicate benefits of reology, on the mechanical properties, and on the durability commensurated by the employment of mineral additives in mortar and concrete [9].

However, in the construction sector the incorrect characterization of these industrial residues can bring about the fault or loss of performance. For this reason, rigorous studies of the aspects related to the characterization, evaluation, and use of the residues is so important [10]. Thus variations in temperature and duration of burn, size of the particles, composition (chemical, morphological and mineralogical, and cristalinity among others); result in ash of completely different chemical constituents, which influences the way in which the material behaves like pozzolan when mixed with the cement [8].

In view of this, the aim of this research was to evaluate the potential of sugarcane bagasse ash as a partial substitution material of Portland cement.

2. METHODOLOGY

The experiment was conducted in the Department of Agricultural Engineering at the Federal University of Viçosa, in Viçosa State of Minas Gerais Brazil. The work was divided into two phases:

Phase 1

The CBC was obtained from sugarcane bagasse (BC), from the Usina Jatiboca (Urucânia, City State of Minas Gerais). The BC was collected and burned for 6 hours at 600ºC using a stove. After the burn, a layer of light colored ash was observed on the surface and then an ash of black color and heterogeneous composition was observed, consisting of leftovers of the sugarcane bagasse that was not burned as well as charcoal particles, making another burn necessary for the homogenization of the sample. The second burn of CBC lasted for 3 hours at 700ºC. After this reburn, the CBC was cooled naturally determining the C level of the ash using a ball mill for the grinding. Six samples of ash were collected and dried in the oven for 24 hours at 70ºC. The chemical characterization of the CBC was made using tests from an X-ray fluorescence spectroscopy and X-ray diffraction. The physical characterization was made using tests of granulometric distribution and specific surface area using 9 samples at different grind times (0; 30; 60; 120; 180; 300; 420; 540 and 660 min).

Phase 2

The following combinations of Portland cement (type CVC ARI PLUS made by Barroso) and sugarcane bagasse ash were used: 100-0(C1), 90-10(C2), 80-20(C3), 70-30(C4) (% of cement - % of ash), in mortar proportion 1:3, using normal Brazilian sand. To evaluate the influence of the addition of CBC on the mortar, tests were done to figure out initial and final set time, compressive strength, pozzolanic activity, specific mass, water absorption by immersion, and index of porous. The experiment was developed experimental an experimental design entirely randomized, being: 3 levels of CBC addition and a control (100% cement) with 3 repetitions. The best levels of CBC addition were evaluated using Tukey´s test for all the combinations at 7 and 28 days.

3. RESULTS AND DISCUSSION

The results show that the sugarcane bagasse presents an output of 10% CBC. The chemical compositions are given in Figure 1. The CBC consisted 5% carbon and was light gray in color.

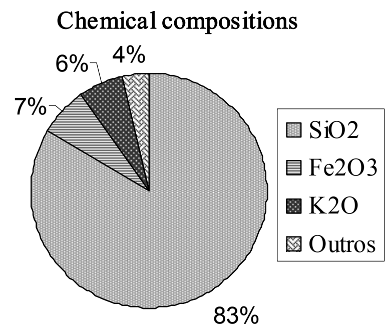

Figure 1. Chemical composition of the CBC, conducted by fluorescence spectrometry X-ray

According to reference [5], the presence of up to 20% carbon in the ash does not significantly affect the compressive strength. The diffraction spectrum of CBC is shown in Figure 2, where the intensity of the phases, in countings a second (CPS) is given in function of the angle of diffraction, 2θ.

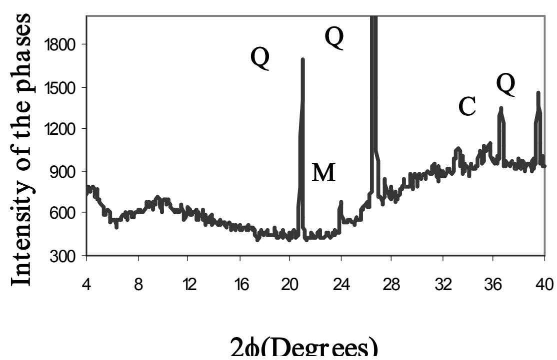

Figure 2. Analysis of X-Ray diffraction of CBC

Analyzing to Figure 2, a halo can be observed between 2θ = 06 and 18º and another one between 24 and 40º, which characterizes the amorphous phase. The peaks (2θ = 21º and 2θ = 27º) indicate that the structure of CBS presents the crystalline phases of silica, cristobalite (C) and quartz (Q), as well as muscovite crystals by washing the bagasse or with a layout in an appropriate place; or with.

(M). The presence of SiO_2 in the quartz phase could have occured because of the following factors [8]:

a) Contamination of the bagasse by sand once it was cleared off the patio of the industry. In this case, the presence of quartz can be avoided

b) inadequate burn time; The parameters can be adequate (from an empirical standpoint) when a predominantly amorphous ash is obtained.

The results found for the granulometric composition and surface area show that the ash being studied is composed by particles with size between 1 and 14µm and with surface area of the order of $24m^2/g$.

The additions of 10%, 20%, and 30% of CBC did not either speed up or slow down the initial set time, which was expected, being that the pozzolanic reaction occurs_in a more advanced stage of the hydration of cement (between 7 and 15 days after the mixture). Thus, the set time would not detect an influence in the pozzolanic activity. It was observed that the material does not interfere with the setting (which could occur in materials with high level of carbon). The additions of 10%, 20%, and 30% of CBC had delays of 10 minutes in the time period between the set times. This delay is due to the reduction of the proportion of cement in the combinations. The tests of the compressive strength of the mortar were conducted according to reference [2] of the ABNT NBR 7215 (1991).

The resistance of the mortar was determined at 7 and 28 days, with 3 test specimens of each of the different combinations of cement-ash being broken, in order to find out: C1 (100-0), C2 (90-10), C3 (80-20), C4 (70-30) [% of cement - % of ash, in weight]. It was noticed that the addition of CBC in the test specimens resulted in a gradual darkening of color. The Figure 3 illustrates the results of compressive strength conducted in the test specimens, in function of the interaction between the proportion of the substitution of cement for CBC ash at 7 and 28 days.

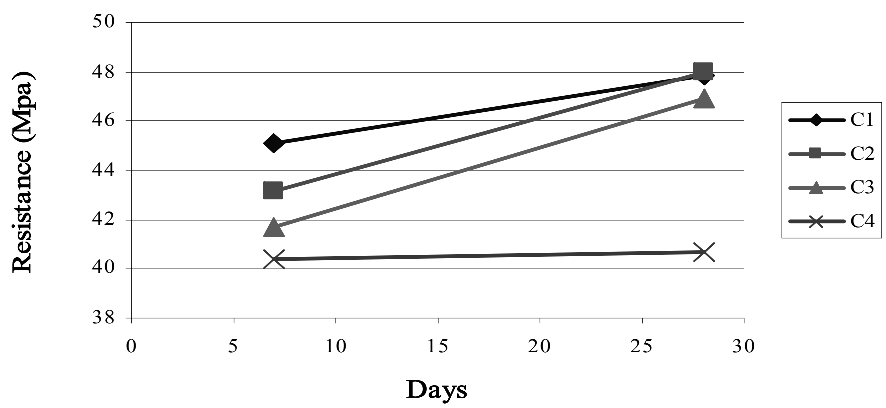

Figure 3. Resistance to compression at 7 and 28 days in mortar with different concentrations of cement and sugarcane bagasse ash: 100-0(C1), 90-10(C2), 80-20(C3), 70-30(C4) (% of cement - % of ash)

The analysis of the variance applied to the compressive strength data showed, at a level of 5% of probability by Tukey´s test, a high degree of significance for combinations at 7 and 28 days. Applied to the data of compressive strength at 7 and 28 days in the cement mortar with an addition of CBC, Tukey´s test showed that at 7 days, independent of the addition of the considered CBC, treatment C1 presented itself statistically different with respect to the other ones. Combinations C2 and C3 showed no differences between themselves, and neither did combinations C3 and C4. It was observed that the compressive strength of the mortar at 7 days is inversely proportional to the proportion of ash added. Considered at 28 days, the statistical analysis showed that the greatest values of resistance were reached by combinations C2, C1, and C3, which were all statistically equal, show in the Table 1. This similarity of resistance at 28 days proves that the pozzolanic reaction has its start between 7 and 15 days after the mixture, when the hydration of the cement is at an advanced state, also observed by reference [8]. Such results indicate the possibility of substituting up to 20% of Portland cement with sugarcane bagasse ash, without hurting the compressive strength.

The results found for the indices of pozzolanic activity (IAP) (Table 1).

Table 1. Average compression resistance in Mpa of mortar at 28 days and respective indices of pozzolanic activity (IAP) for the different mixtures of cement and sugarcane bagasse ash

Mixtures	Average Resistance* (MPa) at 28 dayy	Pozzolanic Activity (%)
C1	47,8	100
C2	48,0	100
C3	46,9	99
C4	40,7	86

* Average of 3 test bodies

The activity of CBC, since all the combinations resulted with IAP values greater than the minimum value of 75% established by NBR 5752 (1992) [1]. From the exposure to CBC it can be classified as pozzolanic.

The absorption tests by immersion, index of emptiness, and specific mass of the mortar test were conducted using reference [3] of the ABNT (1987) as a base. The results are presented in Figures 4, 5, and 6, as function of the substitution level at 28 days of age, in function of the proportion of substitution of cement for CBC ash at 28 days.

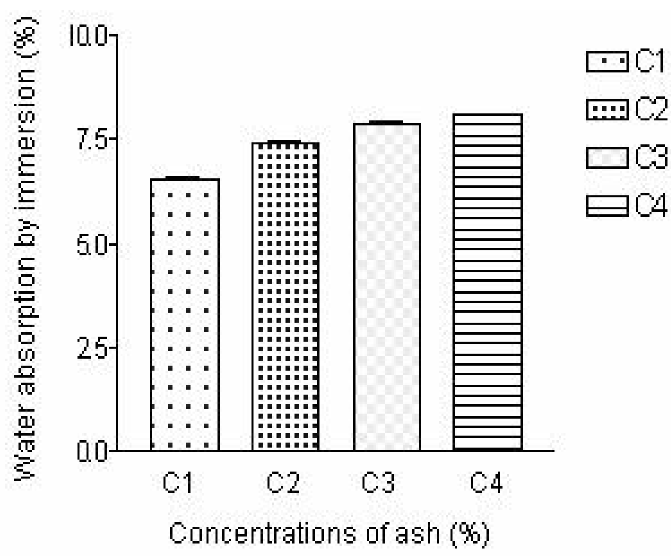

Figure 4. Water absorption by immersion at 28 days in the mortar made with different concentrations of cement and sugarcane bagasse ash

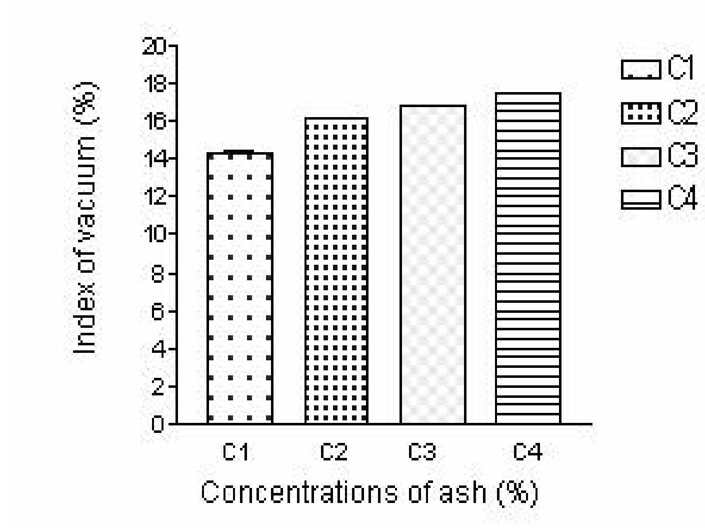

Figure 5. Index of Flow in the mortar at 28 days made with different concentrations of cement and sugarcane bagasse

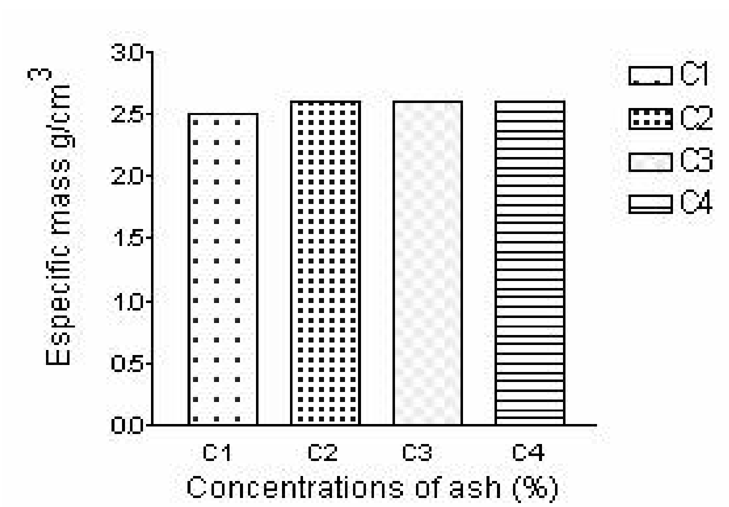

Figure 6. Specific mass in mortar at 28 days made with different concentrations of cement and sugarcane bagasse ash

It was observed that for both the absorption of water by immersion and the index of emptiness, the graphs resulted in a growing function, where it was concluded that the mortar with the greatest proportions of ash tended to be more porous, which justifies the greater values of absorption.

According to reference [4], this fact can be settled controlling the water/cement factor of each of the studied combinations. With respect to specific mass, it was observed that there was a small increase with the addition of CBC (0.5%). The partial substitution of Portlant cement for up to 30% of ash in the mixture does. not bring about any significant modification to the values of specific mass.

4. CONCLUSION

Based on the conducted experiment and according to the results obtained, it can be concluded that: The sugarcane bagasse used presented a yield of sugarcane bagasse ash (CBC) of 10% with a proportion of 84% SiO2 and 5% carbon; the silica in CBC is present both in the amorphous phase as well as the crystalline phases of Cristobalite and Quartz; the ash that was studied is composed of particles with sizes between 1 and 14μm and with a surface area of the order of $24m^2/g$; the additions of 10%, 20%, and 30% of CBC resulted in a delay of 10 minutes in the time period between the set times; the indexes of pozzolanic activity prove the pozzolanicity of CBC; the mortar with the greatest proportions of ash tended to be more porous, which justifies the greater values of absorption found; the partial substitution of Portland cement by up to 30% of ash in the mixture did not bring about any significant modification in the specific mass of the mortar; the mortar with proportions of CBC in substitution with cement between 0 and 30%, at 7 and 28 days, indicate the possibility to substitute up to 20% of cement by CBC without hurting its resistance; the addition of 30% of cement by CBC is viable, as long as a resistance of the material equal to that found in the test specimens of 100% cement is not demanded; and it is important to highlight that the obtained results are specific for the sugarcane bagasse ash obtained. Different burn procedures can be employed to obtain ash without crystalline phases. That being said, a pre-treatment of the sugarcane bagasse would prevent possible contamination by quartz.

5. ACKNOWLEDGEMENTS:

To the Federal University of Viçosa, especially to the Department of Agricultural and Environmental Engineering. To FAPEMIG for financing the project and to CAPES for awarding the Master´s studies scholarship.

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