Bottom Ash from Mineral Coal as Aggregate in Mixtures for Ceramic Products

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Keywords: Bottom ash, reuse, ceramics.

Abstract. The objective of this work is to analyze ashes from a thermal power plant with the aim of determining its environmental aptitude for reutilization as aggregates in clay mixtures for ceramics production. To achieve this objective the waste material was characterized by different techniques: optical microscopy, scanning electronic microscopy, conductivity, pH, among others. Clay samples with bottom ash addition, up to 50%, were prepared. These samples were thermally treated at 950ºC and then characterized with diverse techniques in order to determine their behaviour in service. The obtained results show the high feasibility of reutilization of the studied waste as raw material in the production of ceramic products.

Introduction

The industrial wastes accumulation due to the production increase is a subject that causes great concern. The construction industry uses a huge volume of materials that can incorporate high quantities of residues.

Bottom ash is a coarse granular material produced as a waste of coal combustion. One of the most common uses of bottom ash is as structural fill [1]. For this use, leaching characteristics have been studied [2, 3]. Many researchers have shown that there is a strong possibility to use coal bottom ash as replacement of fine aggregate in concrete [4 - 8]. Other studies have been carried out to evaluate the utilization of bottom ash as coarse aggregates in high-strength concrete [9].

The objective of this work is to analyze bottom ashes from a thermal power plant in order to determine their environmental aptitude for reutilization as aggregates in clay mixtures for ceramics production.

Experimental

Compacted samples were prepared using common clay, soil, and adding up to 50% bottom ash from a thermal power plant. These samples were prepared, adding 8% H_2O, in 70 mm x 40 mm moulds, obtaining tiles with 20 mm thickness. The compaction pressure was 25 MPa.

The samples were thermally treated at 950ºC for 3 hours with heating velocity of 1ºC/min, with 15 hours of heating ramp and 17 hours of cooling.

Raw materials were characterized by several techniques: optical microscopy and scanning electron microscopy (SEM), chemical analysis by energy dispersive X-ray, conductivity and pH. The sintered products were characterized to deduce their service behaviour. Among the techniques porosity and density, permanent volumetric variation and loss on ignition, can be mentioned.

The optical observations were made with Zeiss-Axiotech equipment with a Donpisha 3CCD camera and image scanner.

The scanning electron microscopy (SEM) analyses were carried out through a Phillips 515 scanning electronic microscope with an X-ray detector (EDAX-Phoenix).

The porosity of the samples was determined according to the IRAM 12510 Standard.

The mechanical essays were carried out with a Cific Universal Testing Machine, 294 kN.

Results and Discussion

Bottom ash is mainly composed of silica and alumina. The chemical analysis of the studied ash and clay is shown in Table 1. The values are expressed as weight percentage of the elements considering neither C nor O. The C contents are 24.5% and 20.2% for clay and ash respectively.

Table 1. Chemical composition of the studied powders.

Materials	Mg	Al	Si	K	Ca	Fe	Ti
Clay	3.2	22.5	67.1	4.0	1.1	2.1	---
Ash	3.5	34.8	49.8	1.1	4.8	4.4	1.6

The pH and conductivity values, obtained with 2 hours stirring in distilled water, are 7.46 and 301μS, respectively.

The samples were prepared with the bottom ash as received, without milling, selecting particles sizes smaller than 2 mm. The particle size distribution of the powders is shown in Fig. 1.

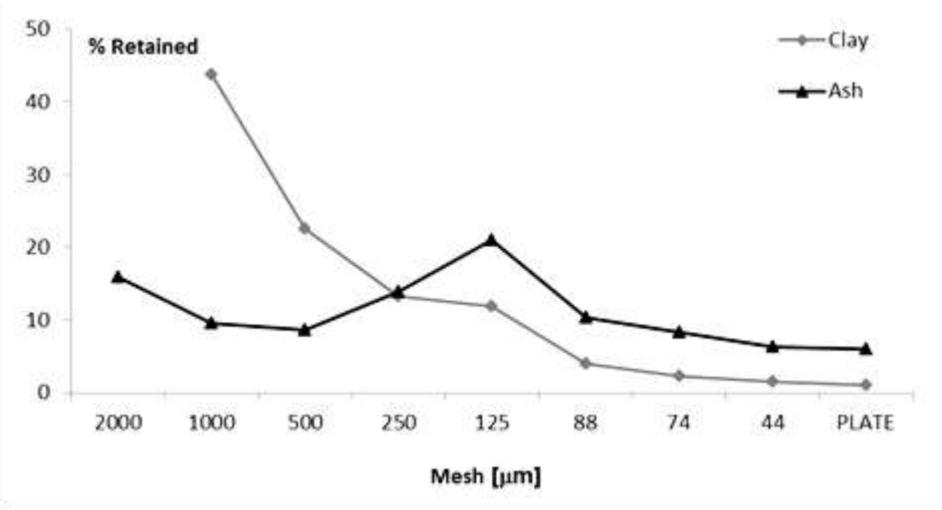

Figure 1. Particle size distribution of the raw materials

Figure 2 shows the optical micrographs of the ash, revealing the presence of very small particles. Figure 3 shows the corresponding SEM micrographs. Spherical particles, typically present in fusion processes, are observed.

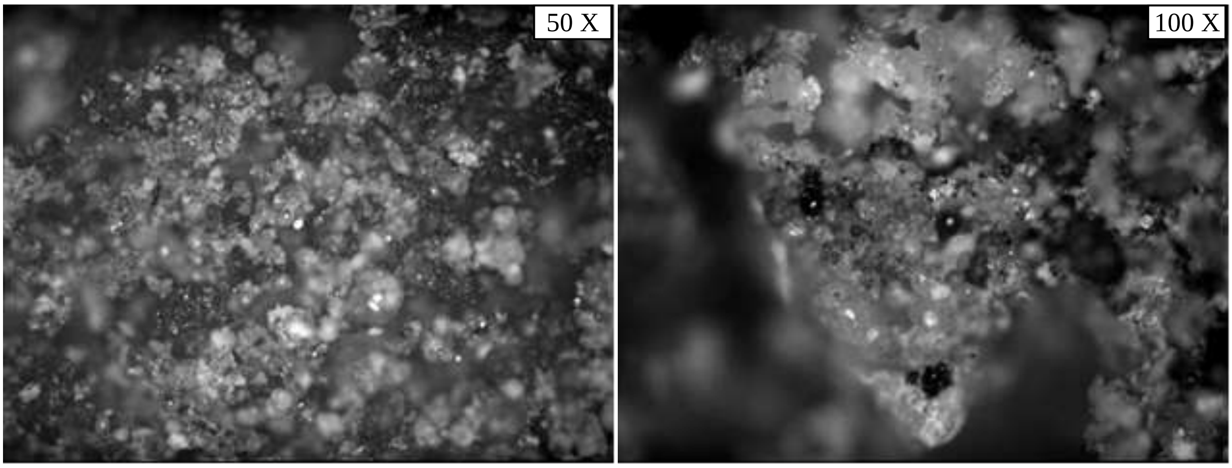

Figure 2. Optical microphotographs of the ash.

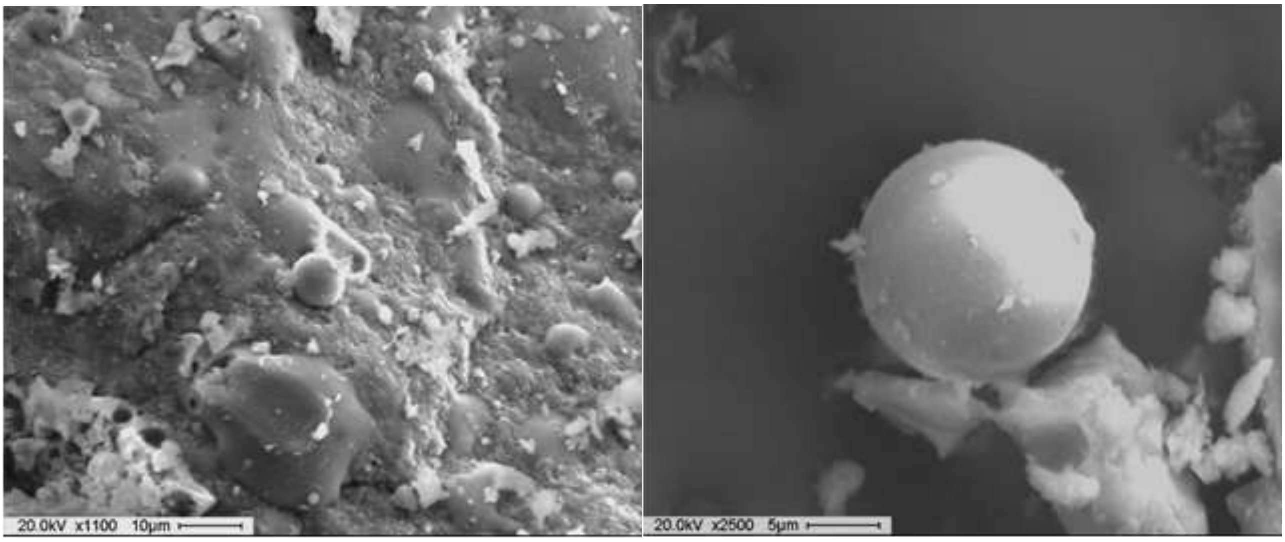

Figure 3. SEM microphotographs of the ash.

Figure 4 shows the obtained bricks. Most of these samples have good external characteristics, with defined edges, without losing edges or corners and a reddish coloration. However, in the samples with 40% and 50% of ashes, shelling in the edges and rough irregular surfaces can be observed.

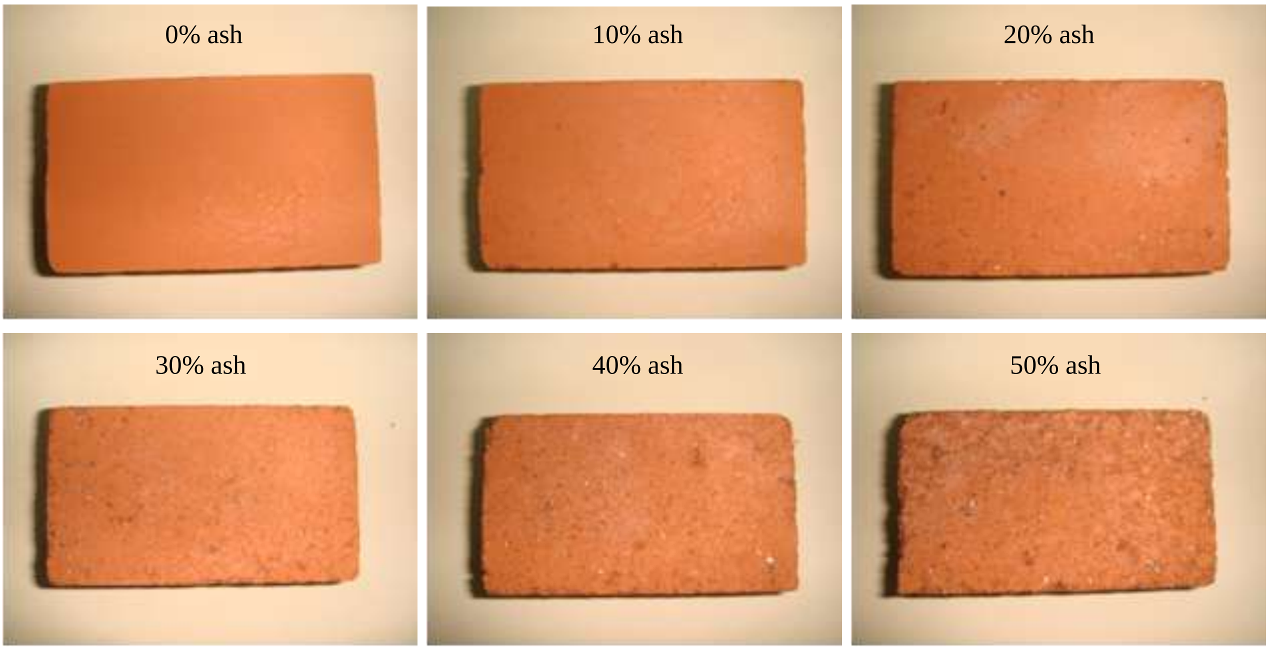

Figure 4. Bricks obtained with bottom ash addition.

The porosity of the samples is shown in Fig. 5. As the waste content increases, the porosity of the samples increases as well. These values are in the required range for commercial products. The bricks with 40% ash content are in the limit of the requirements for masonry, and the 50% ones can be considered in the lowest limit for lightweight products range.

Figure 6 shows the SEM microphotographs of the bricks with the addition of different amounts of bottom ash. For comparison, the photograph of a brick without aggregates is also shown. It is observed that, samples with low contents of ash up to 30% exhibit good sintering of particles. Samples with higher contents present loose particles within the structure bricks, specially identified by the presence of spherical particles not bounded to the clay matrix of the brick.

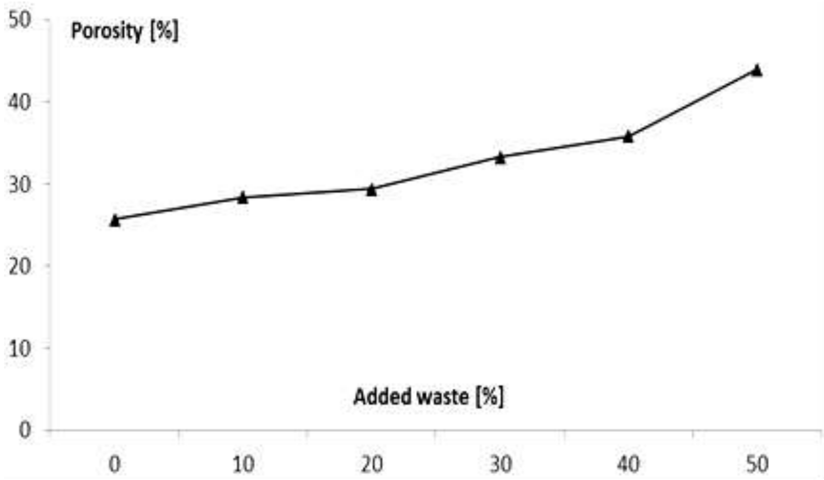

Figure 5. Porosity of the samples

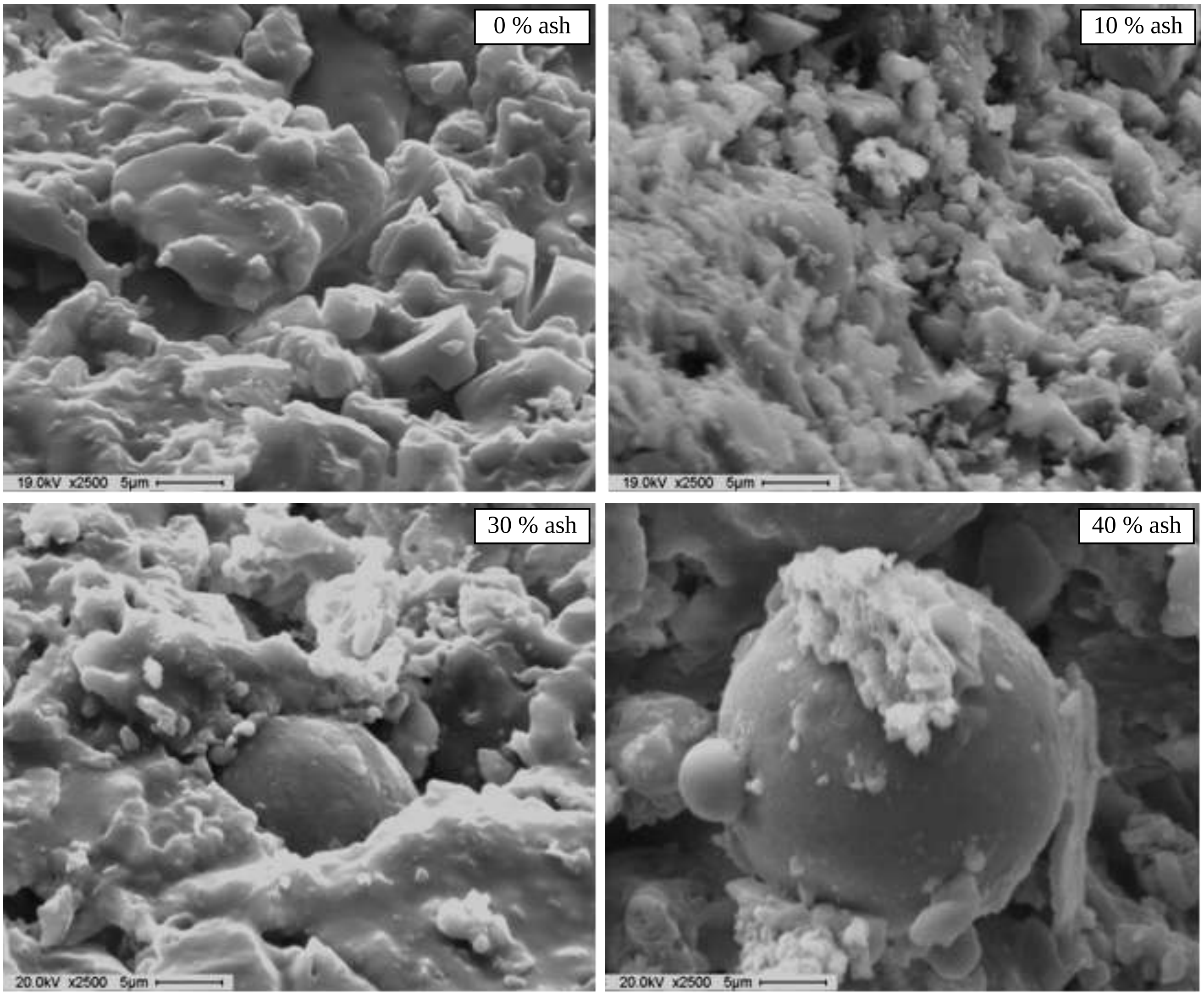

Figure 6. SEM microphotographs of the bricks.

The permanent volumetric variation (PVV) and loss on ignition (LOI) of the samples is shown in Fig. 7. The PVV of the samples with waste addition is smaller than the obtained for the clay samples. This is usually beneficial for the products, avoiding cracks in materials, but it may also indicate a lesser sintering degree.

The LOI, instead, behaves in inverse sense; higher percentages of ashes in the samples produce higher LOI values. This is in accordance with porosity and water absorption measured values which increase with the percentage of added waste.

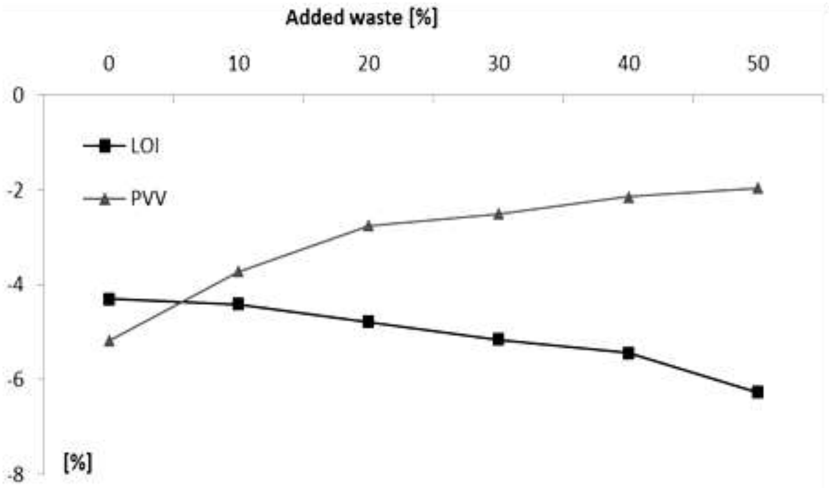

Figure 7. Permanent volumetric variation and loss on ignition of the samples

The compression resistance values of the samples with ash are within the standard for commercial bricks with low environmental requirements. The required values for clay masonry bricks are C_{Res}[MPa] > 10.3, 17.2 and 20.7 for environmental requirement (humidity and temperature) scarce, moderate and severe, respectively, following ASTM C62-04. Spanish standards establish a value higher than 10 MPa for these ceramic pieces (NSE FL90-Real Decree 1723/1990).

To use these materials as masonry, minimum values of flexural resistance are not required in the Argentine market. However, this essay has been performed on the obtained products in order to determine if these mixtures can be used for producing tiles. Figure 8 shows that the values of the samples with 40 and 50% ash are below the commercial requirements for tiles (required value 5.5 MPa).

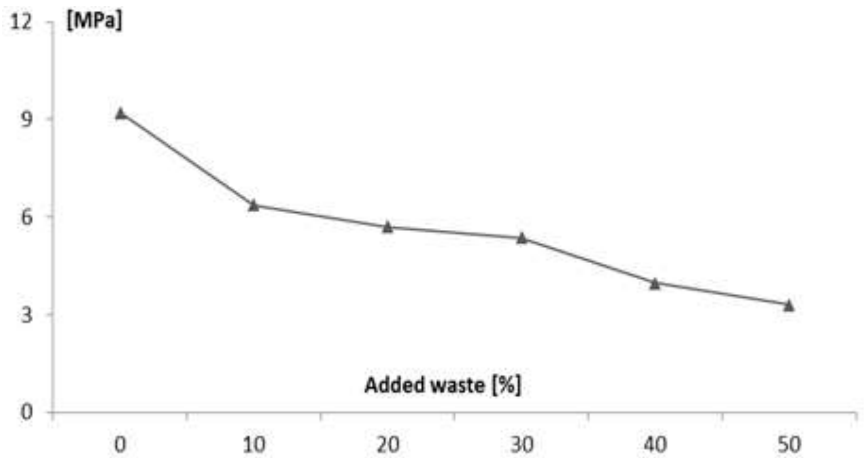

Figure 8. Flexural resistance of the samples.

From the obtained results, it can be concluded that these residual materials can be used as replacement of traditional raw materials up to 30% of content, in the ceramic material production.

Conclusions

In this paper the properties of clay based ceramic bodies with the addition of bottom ash from the coal burning in a thermal power plant are determined.

The thermal treated compact bodies with ash addition up to 30% have adequate physical and mechanical properties, with porosity, mechanical resistance, permanent volumetric variation and loss on ignition values in the range required by these products market.

The obtained results allow determining the high feasibility of reutilization of the studied waste as raw material in the production of ceramic products for the construction industry.

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