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Review paper

Study of the recovery and recycling of tailings from the concentration of iron ore for the production of ceramic

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Abstract

The ceramic industry is the one that stands out in the use of industrial tailings, replacing pure raw materials by part these materials. Both technologically and economically, this segment is a good option for the recycling of solid waste. This work aims to study the feasibility and sustainability, from the economic and technological points, for the use of iron ore tailings as additives in the ceramic industry. To study the chemical, physical, morphological and optical properties of the tailings and clay, chemical, mineralogical and granulometric analysis were carried out. Specimens were formulated with different ceramic compositions at levels of 0 and 5% of tailings added in commercial clay and sintered at a temperature of 950 °C. The ceramics were characterized for color and mechanical properties. Results indicated that the addition of tailings from concentration of iron ore for the production of red ceramics was highly feasible both technically and environmentally.

Keywords: D. Clay; Ceramic; Tailings; Iron ore; Recycling

Contents

1. Introduction

The proper disposal of tailings has become crucial for environmental preservation, emerging the need to develop mechanisms to promote the awareness and find solutions to the deployment of capable technologies of minimizing the arising impacts from the disposal of these tailings in the environment and also to reduce the costs involved in this activity. Tailings generated by industrial activities have grown in importance in the environmental scene since they are produced by many kinds of industries as mining, metallurgical, etc. [1]. The tailings from iron ore concentration – despite being usually inert – have very distinct chemical composition and particle size from the original soil, which demands other destinations in order to reduce their impact on the environment [2,3]. The volume of the tailings produced varies according to the type and content of the extracted ore and of the used process [4].

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Thus, the low grade ores, as the itabirites, which are banded iron formations with relatively high silica content, contribute to tons of fine tailings that are generally deposited in tailings dams.

In the case of iron ore, the concentration tailings are fine materials, containing mostly silica, together with some fines of iron oxides, alumina and other minor minerals. This constitution puts those tailings such as potential aggregated materials of mortar and concrete, in the civil construction industry [5].

Many studies show that the ceramic industry can be largely indicated to absorb solid tailings in ceramic production [5,6]. The iron ore tailings in this study have particle sizes and particle shapes, which become easy to substitute other materials in the ceramic mass, as the clay used traditionally as a prime material is constituted of hydrated alumino-silicates with high contents of SiO_2 and Al_2O_3, and commonly with some contamination of Fe_2O_3, all of these constituents present in low particle sizes [5,6]. The raw material particle size interferes in many aspects as, for instance, the ceramic mass plasticity, sintering taxes, final porosity and density [7]. Hence, the use of low particle size tailings and the chemical characteristics similar to the clay present an excellent alternative to produce ceramics. Ceramic floor and wall tiles are some of such products where industrial wastes can be used as raw materials [8,9]. Oliveira et al. [10] reported the results of a study on the incorporation of solid tailings from the steelmaking industry in the formulation of a clay mass used in the production of red ceramics that indicate that the addition of tailings modify the physical and chemical characteristics of the clay mass in such a way that it improves properties of the test specimens and also that the ceramic masses containing steelmaking tailings could be used in the production of red ceramic for civil construction.

In the case of the iron ore industry, which concerns this paper, the wastes of the concentration processes are fine materials composed mostly by silica, together with some fines of iron oxides, alumina and other minor minerals, in a composition that is similar to the clays used in the ceramic industry. The fact that only in Brazil, iron ore concentration tailings are generated in excess of 120 million metric tons per year makes it fundamental that a proper destination is given to these wastes, and the ceramic industry, because of its volume, is an ideal candidate to absorb those materials [11].

2. Materials and methods

Iron ore concentration tailings were separated by type and origin together with one specific clay, for an initial characterization, in order to determine the best ways of recycling them. The particle size characterization was made by sieving down to 44 μm and below that value by cyclosizer. The structural density of the materials selected for this study was determined by helium pycnometry. Density analysis by helium pycnometry is used to obtain information on the true density or real density of solids. Helium, which can enter even the smallest voids or pores, is used to measure the unknown volume of a material with a known weight. The chemical and mineralogical compositions of the iron ore concentration tailings and clay were determined by Inductively Coupled Plasma/Optical Emission Spectrometry (ICP-OES) and X-ray diffraction.

The percentages of tailings from iron ore concentration added to the clay were of 0% and 5% of the mass. The blends were done with an industrial mixer for 15 min for each composition, with the clay's natural humidity. Each composition had 10 test specimens pressed in a hydraulic press with the pressure of 20 MPa, in the dimensions $60 \times 20 \times 6\ mm^3$ – 10 specimens were also made from the pure clay. The specimens were dried at 110 °C for 16 h and were measured and weighted before and after drying. After drying they were fired in an electric oven, with a heating rate of 3 °C/min reaching the temperature of 950 °C. After firing, the samples were measured, weighted and analyzed for their mechanical and ceramic properties.

3. Results and discussion

Three types of iron ore tailings were selected for this study, floatation tailings (FT), fine magnetic separation tailings (FM)

Table 1
Chemical composition of iron ore concentration tailings.

	Mass (g)	SiO_2 (%)	Al_2O_3 (%)	CaO (%)	TiO_2 (%)	MgO (%)	K_2O (%)	Fe (%)	P (%)	Mn (%)	Fe_2O_3 (%)	LOI %	FeO (%)
Floatation tailings (FT)	56	84.4	0.45	0.07	0.02	< 0.1	0.03	10.9	0.024	0.02	15.1	0.09	0.52
Fine tailings from magnetic separation (FM)	64	47.9	5.61	0.13	0.07	< 0.1	0.22	29.8	0.214	0.33	42.4	2.77	0.27
Coarse tailings from magnetic separation (CM)	74	90.4	0.43	0.06	< 0.01	< 0.1	0.01	6.07	0.035	0.06	8.38	0.22	0.28

Table 2
Chemical composition of clay.

SiO_2 (%)	Al_2O_3 (%)	CaO (%)	TiO_2 (%)	MgO (%)	K_2O (%)	Na_2O (%)	Fe (%)	P (%)	Mn (%)	Cr_2O_3 (%)	PF (%)
443.9	32.2	0.09	1.11	0.68	1.73	< 0.1	3.65	0.124	< 0.008	0.01	15.05