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Incorporation of industrial wastes as raw materials in brick's formulation

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ABSTRACT

This article presents a case study conducted as an experiment with the incorporation of different types of industrial waste in brick manufacturing process in laboratory scale. The main objective of this work is to incorporate large amounts of different types of waste as raw material in brick's formulation. Three types of wastes were mixed with clay: automotive industry waste sludge containing heavy metal concentrations; glass waste, from a galvanic plant, mainly consisting of glass microspheres; and wood ash, from the ceramic burning furnace. The formulation's materials were analyzed by X-ray diffraction, X-ray fluorescence and electronic microscopy. The dried samples were milled separately and then dry mixed. Water was added to the mixture in order to contribute to the compaction process. The samples were dried and then burned at temperatures similar to those used for brick firing furnace. The obtained ceramics were analyzed for their retraction and then submitted to flexural strength testing. Samples obtained value above 4 MPa were approved. Among the samples tested, the formulation that showed higher flexural strength was chosen. It was prepared sufficient sample to perform the solubilization and leaching tests. For tests, the samples were reduced to dust. The results of such analyzes did not identify the presence of elements described in the initial samples' formulation. Morphological analysis was performed using scanning electron microscopy. Tested sample showed glassy characteristic of material that has been sintered during the firing process. This effect is also a proof that the waste identified in initial sample's formulation were inerted. Obtained results characterizes that the tested formulation can be considered as an alternative for bricks manufacturing with incorporation of industrial waste and an activity non-hazardous to the environment.

1. Introduction

The quest for continuous improvement has provided the industry in general, the development of its production processes in condition to make them ever more robust, but with lower investments. This allows to say that these processes are increasingly controlled and have higher incomes, if evaluated primarily from a financial perspective, development focused on reducing costs (Wiemes, 2013). The objective of solid waste recycling is to reduce raw material consumption, thus minimizing pollution problems and treatment costs (Mymrin et al., 2016).

The application of ISO 9000/14000 also greatly contributed to the development of industrial processes, favoring the continued increase in production. Evaluating this scenario in a broader perspective, there is an increase in consumption globally, driven by supply products that provide comfort, agility and speed, among other characteristics, to meet increasing demands from costumers. Although contradictory, considering the facts mentioned above, the situation is critical and many industries are contrary to what can be named sustainable performance or environmentally friendly company. The waste generation resulting from manufacturing processes is quite considerable and the destination is usually applied the provision in landfills or co-processing in cement ovens.

In a strategic context and considering an approach where environmental problems are treated as such, Barbieri (2007) states that a company should take advantage of market opportunities and neutralize threats arising from environmental issues. The

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development of cleaner processes has advantages, among which may be mentioned: reduction in waste generation, lower impact on the environment, improving company's image in supervisory bodies and reducing of costs manufactured helps organizations to develop preventive actions.

Fired clay bricks are construction materials, which have been used since ancient times and currently display different states of deterioration in numerous historic buildings (Cultrone et al., 2005). Nowadays, bricks are still being used for the same purpose (Karaman et al., 2006). Reducing waste is not the only reason to investigate the addition of certain residues into a clay matrix, although traditionally it has been the main purpose of research on this topic (Velasco et al., 2014). The current trend in bricks manufacturing has major emphasis on the use of post-consumer wastes and industrial by-products in the production process (Shakir and Mohammed, 2013). According to Reinosa et al. (2010), the building industry is the most suitable technological activity sector to consume solid wastes. Clay can also be used to immobilize harmful heavy metals ions (Churchman et al., 2006; Addy et al., 2012). Furthermore, clay minerals are silicate phases that can incorporate considerable amounts of metals in their structures. Therefore, the ceramic industry is one of the best candidates to consume large amounts of industrial wastes, such as combustion ashes, granite cutting sludge and wastewater sludges (Torres et al., 2004; Reijnders, 2007; Martínez-García et al., 2012, Mymrin et al., 2014b).

Vitrification is one of the techniques that has aroused great interest by many researchers. Mymrin et al. (2014a) define glazing as a common method of burning to the traditional pottery clay base. The vitrification process simulates the natural phenomenon of the glassing from volcanic rocks (ex. Basalt). These natural glasses contain toxic materials in their structure that have shown environmental inert as the time (Silva and Mello Castanho, 2004). As mentioned by Kim et al. (2005), this technology is implemented for processing radioactive waste and studied for inerting various types of waste. Pisciella et al. (2000) show that this technique is a viable solution to the environmental impact of various industrial activities and opens opportunities to assign value to waste.

An initial composition and heat treatment conditions, as described by Erol et al. (2007), are the most important parameters affecting the kind of crystalline phases occurred in the glass-ceramic and the final properties of the materials. These same authors also emphasize that glass-ceramics having desirable properties to meet many applications can be produced from waste materials through the application of appropriate heat treatments.

This paper presents the analysis carried out with the incorporation of three types of industrial waste in large quantities, with clay in brick formulation. In addition, the important point of the study considers the application of these formulations at similar temperatures those already applied in brick-making process. The structure of the work is based on the Cleaner Production methodology consisting eliminating pollution during the production process, after the generation of waste.

2. Methods

2.1. Materials and preparation of test samples

Raw materials used in this study are automotive waste sludge (AWS), glass waste (GW) from metal cleaning before galvanic process, wood ash (WA) and mixture of red pottery clay with sand (RPC), all provided by local industrial enterprises of Paraná state, Brazil.

Ceramic samples of various compositions are presented in Table 1. They involve homogenizing a mixture of the initial components (water contents of 12–15%), compressing at 3 MPa (wet samples are rectangular, 60 × 20 × 10 mm in size), drying to constant weight at 100 °C, sintering for 6 h (temperatures of 800, 850, 900 or 1000 °C), and cooling by natural convection. Testing conditions correspond to real ranges applied at local brick plants.

Table 1
Formulation of ceramic samples.

Sample	Composition (%)			
	AWS	GW	WA	RPC
ETE-B1	50	20	0	30
ETE-B2	40	20	0	40
ETE-B3	40	10	10	40
ETE-B4	50	10	10	30
ETE-B5	4	0	10	86
ETE-B6	6	0	10	84
Clay	0	0	0	100

2.2. Methods

Raw materials and final ceramic were characterized according to their mineralogical and chemical composition by X-ray diffraction (XRD), X-ray fluorescence (XRF) and scanning electron microscope (SEM). Mineral composition (XRD) were studied by PANalytical brand, model Empireo with X'Celerator detector copper tube; chemical compositions (XRF) on PANalytical XRF equipment brand, Axios Max model with Rhodium 4kv tube; chemical micro analyses – by method of energy dispersive spectroscopy (EDS) on Oxford (Penta FET-Precision) X-ACT; morphological structures by SEM on FEI Quanta 200LV; solubility and leaching of metals from liquid extracts – by method of atomic absorption analysis (AAA) on Perkin Elmer 4100 spectrometer; mechanical resistance – by three-point flexural strength (FS) on EMIC universal testing machine; linear shrinkage (LS) – on Mitutoyo. Fire loss (FL) - calcined for 2 h in muffle furnace at 1000 °C. Values of mechanical properties were obtained as an average of 10 samples' measurements.

Samples were fired in laboratory furnace (Linn Elektro-Therm, thermocouple Pt-Pt/Rh and ranging from 5 °C), applying temperatures between tracks 800–1000 °C allowing to simulate the same conditions identified in a furnace a pottery. The firing temperature cycling and time adopted for each test burns were programmed to operate automatically, as represented in Fig. 1:

- Initiate the process until temperature 600 °C, with heating rate of 10 °C per minute.
- Temperature of 600 °C was kept constant for 30 min.
- Heating to desired temperature (800 °C for example), with heating rate 10 °C per minute.
- Operating temperature fixing (800 °C, for example.) for 6 h (360 min).

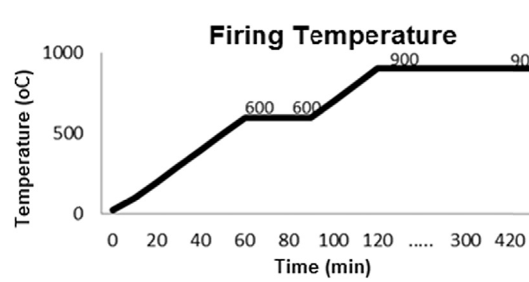

Fig. 1. Schematic representation of firing temperature applied to different samples tested.

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