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Microstructure and chemical degradation of adobe and clay bricks

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Abstract

The environmental degradation of adobe and fired clay brick was studied. Leaching media based on $Na_2S_2O_5$ solution and deionized water were used. The microstructure of the samples was evaluated by X-ray powder diffraction, nitrogen adsorption–desorption (BET method), Fourier transform infrared spectroscopy and scanning electron microscopy. The predominant phases detected were kaolinite and quartz for both the adobe and fired brick samples. The high surface reactivity, associated with a large amount of OH groups, contributes to the significant degradation of adobe. The fired clay brick showed a significant decrease in the average pore diameter after the first day of the leaching process; its specific surface area exhibited a reduction of about three orders of magnitude. The results of the present investigation contribute to a better understanding of the correlation between structure and leaching behaviour in adobe and clay brick, attending the renewed interest in these materials as environmentally attractive building blocks.

Keywords: B. Microstructure; B. Porosity; D. Clays; E. Structural applications; Adobes

1. Introduction

Although red ceramics (structural clay products) have been in use since ancient times, knowledge about the quantitative correlations between microstructure, properties and performance in actual applications is still limited [1].

Adobe is an ancient form of brick which consists of earth (mud, silt and sand) and water. Occasionally, straw is also present in the structure to enhance mechanical resistance. Adobe does not go through a firing process; instead, it is submitted to a prolonged period of drying, usually carried out by exposing the material to the sunlight. An adobe building can last hundreds of years and it is totally recyclable [2,3]. This explains the current interest in adobe as environmental friendly material for sustainable construction [4]. Adobe is a porous material and acts as humidity regulator; it is capable of accumulating up to 30 times more humidity than a regular fired brick. It is permeable and it can function as an air filter, fresh air comes inside, while used air escapes out through the walls [2]. Hence, the amount, size and distribution of pores are directly related to these properties. Porosity is one of the factors that influence the chemical reactivity of solids and the physical–chemical interaction between the solids and the gases and liquids that may percolate the material; porosity also determines the resistance to degrading agents and, therefore, it influences the structural integrity and durability of materials [3].

In particular, in adobe, water sorption occurs in direct relation to its porosity. The pore size and pore distribution determine the degree of water sorption [1,5]. The capillary effect, due to the presence of pores in the microstructure, has remarkable importance when it comes to degradation by humidity, which is a limiting factor for a wider use of adobe [6,7]. When a solution contacts a clay surface, an ion exchange mechanism is established which is dependant on the ion concentration, pH and presence of other ions [8]. In acid solution, hydration of repulsive forces present in the clay surfaces are removed due to diffusion of H^+ ion in the inner layers, which neutralizes the hydroxyl groups. The chemical attack starts with the sorption of the acid on the solid surface, causing the substitution of exchangeable cations by protons. A chemical reaction takes place and the products of the reaction solution are desorbed into the liquid phase [9,10].

The overall goal of the present investigation is to increase knowledge about the behaviour of clay brick and adobe under

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different environmental conditions. The study of porosity is particularly relevant because, as mentioned above, porosity directly influences the material durability and performance during its useful lifetime, having impact on the technical, economic and aesthetical aspects. Thus, the specific objective of this study was to evaluate and compare the behaviour of adobe and fired brick submitted to leaching processes, and to correlate the processing characteristics, properties and microstructure of both materials.

2. Experimental procedure

2.1. Materials

We used in this investigation adobe, fired brick and clay from Minas Gerais (Brazil). Clays are denominated A and B, which were used to fabricate adobe and fired brick, respectively.

Clay A has as major components (wt%): SiO_2 (33.8%), Al_2O_3 (26.7%), Fe_2O_3 (21.5%). The chemical composition of clay B is: SiO_2 (86%), Al_2O_3 (9.2%), Fe_2O_3 (3%). The adobe was fabricated by drying the material under sunlight while the fired brick was heat treated at around 600 °C. In the case of fired brick, local producers are usually located close to a source of clay. The clay mass to produce the fired brick is normally mixed with water and sand and the mixture is then used in an extrusion machine to shape the blocks. Subsequently the bricks are heat treated in ovens for a period of about 1 day at temperatures of ~600 °C. The blocks are then dried in air. The typical process for adobe manufacturing is much simpler: the mud mass (water and clay) is prepared and shaped manually. After shaping the blocks, these are placed on a planar surface and left to dry under the sunlight. For the present investigation commercial fired bricks (Cerâmica Abelha, Minas Gerais, Brazil) of dimensions 23 cm × 10 cm × 5 cm were used while the dimensions of the adobe used were 24 cm × 13 cm × 13 cm.

2.2. Characterization

Fourier transform infrared spectroscopy (FTIR) was used to identify organic and inorganic groups. The equipment employed was a PerkinElmer (model Paragon-1000). The method used was diffuse reflectance and the samples were prepared as powders. In order to obtain the infrared spectra, 0.002 g of the material (fired brick or adobe) and 0.2 g of KBr (potassium bromide) were used. They were dried at 100 °C for about 4 h.

The instrument used for scanning electron microscopy (SEM) was a JEOL, model JSM-5410. Fired brick and adobe samples were prepared by ceramography and coated with a gold film.

X-ray diffraction (XRD) analyses were carried out using a Phillips diffractometer, model PW-3710, with Cu Kα radiation.

For physical nitrogen sorption analysis (Autosorb-1, Quantachrome) samples were powdered after crushing. Initially, the material was degassed at 120 °C. The BET method (nitrogen sorption at 77 K) was used to obtain the specific surface area, specific volume and pore size distribution of adobe and fired brick samples.

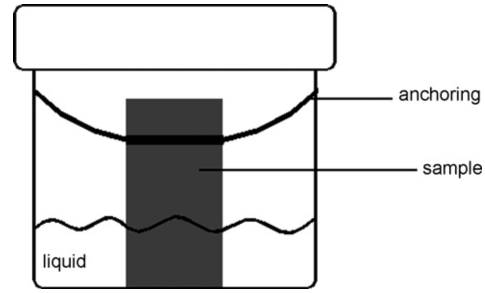

Fig. 1. Schematic diagram showing the set up used for the degradation (leaching) experiment.

2.3. Degradation evaluation

A 0.001 M $Na_2S_2O_5$ solution (from now on referred to as ''Na–S solution'') was prepared in order to obtain an aggressive medium (with a similar effect of acid rain) to investigate degradation of the materials. The sodium metasulphite ($Na_2S_2O_5$) is commonly used as a sulphur standard [11]. According to literature the pH of acid rain lies between 5 and 5.6 [12], while the measured pH of our solution was 5.

The prepared test bodies (fired clay brick and adobe) had a rectangular shape of about 2 cm × 1 cm × 1 cm. The simulation itself was made by using two degrading media: the first one containing 7 mL $Na_2S_2O_5$ and the second one with 7 mL of deionized water. They were kept in separate recipients and submitted to an ''anchorage'' to prevent them from tumbling inside the recipient, as shown schematically in Fig. 1. After the experiment, the liquid was removed by simple filtration and the leached material was dried in air at 60 °C for at least 2 days.

3. Results and discussion

3.1. Phase identification

Figs. 2 and 3 show the XRD patterns of the materials investigated showing a predominance of quartz and kaolinite for the clays A and B and for the fired brick and adobe samples. Clay A was used to fabricate adobe, while clay B was the raw-material for the fired brick. The XRD spectrum of the fired

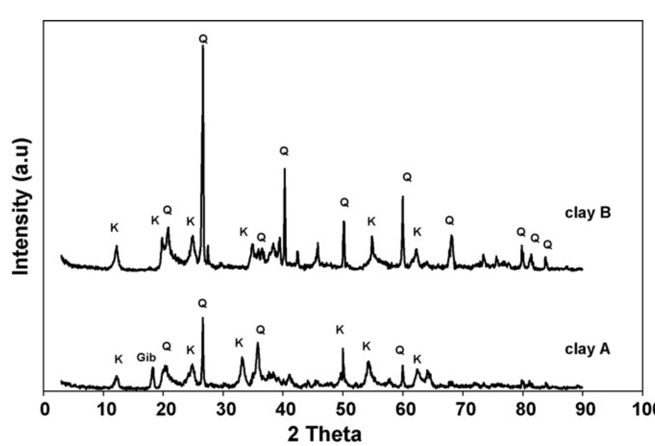

Fig. 2. X-ray powder diffraction patterns for clays A and B. The detected predominant crystalline phases are: kaolinite (K), quartz (Q) and gibbsite (Gib).