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Physico-chemical characterisation of bricks all through the manufacture process in relation to efflorescence salts

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Abstract

Due to the high competitiveness of the ceramic product market, quality and technical requirement are increasing. The efflorescence problem is a phenomenon that affects the aesthetic quality of brick facades and which is not easily dealt with. The aims of this work are to study the key physical and chemical parameters for this phenomenon in all activities of the brick manufacturing process and to evaluate the influence of the additives employed on the appearance of the efflorescence phenomenon. Porosity and specific surface, mineralogical analysis, total chemical content and soluble salts were determined on green, dried and fired brick, both when no additives were added to the manufacturing process and also when ammonium lignosulphonate and barium carbonate were used as additives. The main mineralogical phases and water soluble salts in the efflorescence phenomenon have been obtained. In some cases, relationships between soluble salts in the end product and soluble salts in the efflorescence have been established. From the obtained results, the use of a mixture of ammonium lignosulphonate and barium carbonate together with the control of the firing process variable is recommended in order to prevent this phenomenon.

Keywords: Efflorescence; Brick; Soluble salts; Ammonium lignosulphonate; Barium carbonate

1. Introduction

Coarse ceramic industry products, brick and roof tiles, are produced in large quantities and are used as materials in numerous branches of building and contracting. For the most part, brick and tiles are not designated according to the shaping technique used, but according to the intended application: building bricks (e.g. clay blocks, facing bricks, clinker bricks and lightweight bricks); roof tiles (e.g. extruded tiles, pressed tiles); paving bricks and chimney bricks. In 2003, the European clay brick and roof tile industry had total sales of around EUR 6800 million and a work force of around 50,000.[1]

Characteristic properties of ceramic products include high strength, wear resistance, long service life, chemical inertness and non-toxicity, resistance to heat and fire, (usually) electrical resistance and sometimes also a specific porosity. However one of the most frequent anomalies to be detected in the façade of bricks is the appearance of the efflorescence phenomenon, which consists in crystallised salts accumulating on the surface of the brick. Efflorescence is not only an aesthetic problem but can also cause serious microstructural damage[2]; it is a pathology that affects the quality of the product. Although damage from salts has been intensively investigated for several decades,[3–5] the mechanisms and factors that control the formation of salt crystals in porous building materials and the development of damage by crystal growth are poorly understood. Efflorescence appearance is also influenced by external agents such as climatic and land conditions.[6] Although numerous studies have been carried out to elucidate the causes of efflorescence, it is such a complex phenomenon that is still a permanent problem. Specifically, there have been many attempts to make the salts inside the brick non soluble, so that no migration to the surface can occur. Traditionally, barium compounds, like barium carbonate.[7,8] are used for this purpose, but the dosage of this additive must be optimum otherwise its use can have a self-defeating effect. Other kinds of additives have been investigated, such as alkaline and alkaline-earth chlorides, ammonium chloride and tricalcium aluminate,[9] the most interesting ones, from an economical point of view, being the low cost additives, as long as they do not cause corrosion and environmental problems. On the other hand, the use of

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lignosulphonate[10–14] as an additive due to its dispersant properties in building materials has also been studied and can be considered as usual additive in brick manufacturing.

In order to successfully prevent efflorescence, the chemical clay composition, the use of additives and the manufacturing process must all start to be controlled and the transport and storage operations must also be taken into account. Furthermore, the soluble salts content in bricks has been recently regulated by the European EN 771-1.[15] Some authors have evaluated the chemical composition of the clay and the soluble salts content,[9,16,17] the firing conditions such as temperature and kiln atmosphere[18] and, more recently, a greater effort to establish a relation between the efflorescence and the microstructure of the material and pore morphology has been made.[19–21] However, these parameters all through the manufacturing process have not been studied yet. In this study a physico-chemical characterisation of the raw material, the intermediate products, the end products and the efflorescence salts when two different kind of additives, barium carbonate and ammonium lignosulphonate and a mixture of both have been used, is presented. The aim of this research is to study the influence of the physical and chemical parameters, porosity, specific surface and mineralogical analysis, chemical content and soluble salts, in relation to the efflorescence phenomenon throughout the manufacturing process.

2. Materials and methods

2.1. Materials

Bricks analysed in this work have been manufactured on industrial scale at a plant located in Cantabria (Northern Spain). Fig. 1 shows a flowchart of the brick manufacturing process where material sampling strategy is detailed. The raw material, clay (R), the intermediate manufacturing products such as green product (GP) and dried product (DP) and the end-product (EP) have been analysed. Samples of efflorescence salts (EF) have been collected from the brick surface after efflorescence phenomenon appearance. The bricks have been manufactured with and without the use of two traditional additives, barium carbonate and ammonium lignosulphonate as additives.

2.2. Methods

Mineralogical analysis was evaluated by X-ray diffraction (DRX) using a Siemens D-500 diffractometer of Bragg–Brentano geometry. Specific surface and pore volume were analysed as physical parameters through BET surface using Micromeritics ASAP 2000 and Micromeritics Poresizer 9310 equipment respectively. Total chemical content was determined using Atomic Emission Spectrometer with Mass Spectrometry by an external laboratory (Activation Laboratories in Canada). Soluble salts were analysed after extraction following the standard method UNE-EN 772-5[22]; in the extracts, chlorides, sulphates and carbonates were measured by DX-120 Ion Chromatograph and Warder volumetric method. Calcium, magnesium and vanadium were analysed by Atomic Emission Spectrometer with Inductively Coupled Plasma Perkin Elmer 400 and sodium and potassium by Atomic Absorption Spectrometer Perkin Elmer 1100B. All the determinations were carried out in triplicate.

3. Results and discussion

3.1. Mineralogical analysis

High reproducibility in the mineralogical analyses is obtained from the analysed samples, which have been performed in triplicate. The main mineralogy species identified in the samples of raw material, green, dried and end-product, together with the efflorescences in all studied samples are collected in Table 1 and Fig. 2. The minerals, Illite and Kaolinite are the main components in clay used in manufacturing of bricks, and, as non-clayey

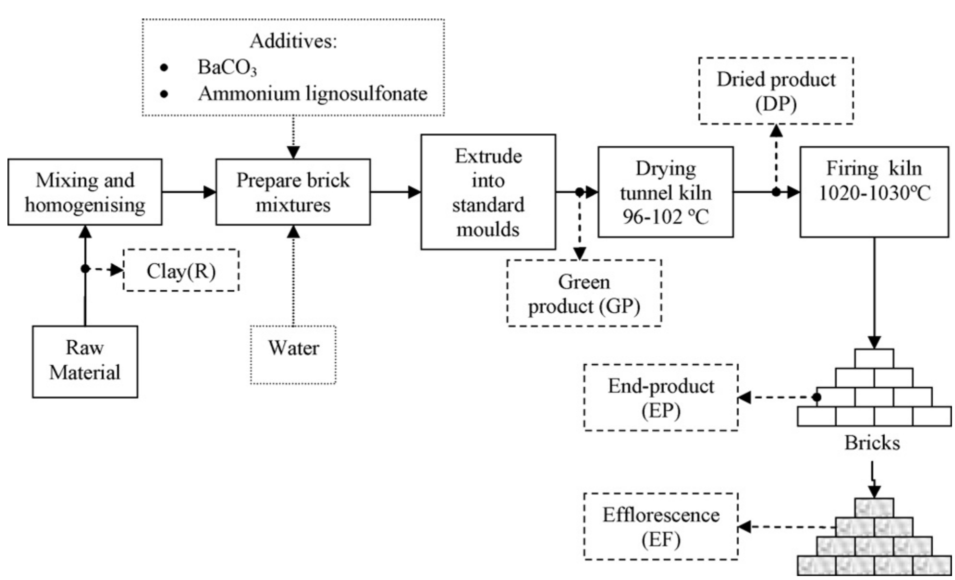

Fig. 1. Flowchart of the brick manufacturing process.