Bricks and mortars from the “Patio de Santo Tomás”, Alcalá University (Madrid, Spain): a combined study of fabric characterization and building morphology

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ABSTRACT: A combined study of fabric characterization and building geometry and morphology has been undertaken at the “Patio de Santo Tomás, Colegio Mayor de San Ildefonso” from the Alcalá University (Madrid, Spain). A set of bricks and their associated mortars from different chronology and locations has been selected to carry out fabric characterization, which were accomplished by using observation and analytical conventional techniques, such as thin section polarized light microscopy, scanning electron microscopy (SEM), X-ray diffraction (XRD), energy dispersive X-ray spectrometry (EDS), and thermogravimetric-differential thermal analysis (TG-DTA). Resulting data have enabled the recognition of three groups of bricks with their associated mortars in the five constructive phases of the building. Each group showed compositional and technological differences which can be correlated with their chronology and location in the building. This combined study has provided outstanding data which can be useful for future conservation and restoration strategies.

1 INTRODUCTION

Cardinal Cisneros founded the University of Alcalá in 1495 whose main building was the “Colegio Mayor de San Ildefonso”. This building has undergone many transformations and changes throughout the history since its construction in early sixteenth century. A recent restoration of the building has allowed the identification of up to five constructive phases (Barluenga et al. 2012). The first one begins with the construction of the “Colegio Mayor de San Ildefonso” between 1501 and 1508 under the direction of the architect Pedro de Gumiel. The second phase refers to the construction of the main façade of the building, between 1537 and 1553, whose works were undertaken by the master Rodrigo Gil de Ontañón. A clock tower was later added to the south wall between 1599 and 1615 which is the third constructive phase. At the beginning the clock tower was ordered to Juan de Ballesteros. However, several building troubles make Juan de Ballesteros left the work, which was finally ended by Juan García Atienza.

An important element of the building is the courtyard known as “Patio de Santo Tomás” which was originally made of bricks, even though bricks were later covered with granite during the construction of the cloister that can be nowadays seen. The cloister was built between 1656 and 1670 by José de Sopeña and constitutes the fourth constructive phase.

At late eighteenth century the University of Alcalá entered a period of decadence which ended with its move to Madrid in 1836. After some years, the building was occupied from 1850 by the army. The late phase identified is the period comprised from 1865 to 1868 in which the “Patio de Santo Tomás” was reconditioned. The modern University of Alcalá was created in 1977 and, from then, the “Colegio Mayor de San Ildefonso” was recovered for academic use. The building is a masterpiece of the Spanish Renaissance. Along with the rest of the historic city of Alcalá de Henares, in 1998 it was declared World Heritage Site by the UNESCO.

Due to recent rehabilitation of the building, accomplished during 2010 and 2011, a research program combining historic, graphic, morphological, geometrical, and materials characterization was started. This contribution presents the results derived from the combined study of fabric characterization and building geometry and morphology. The study was carried out when wall sections were exposed, for the first time, during rehabilitation works. The main goal of the study was the characterization of some building materials, such as bricks and mortars, to look for differences or similarities in the five constructive phases of the “Patio de Santo Tomás”.

2 EXPERIMENTAL

To undertake fabric characterization a set of bricks and their associated mortars was selected. These samples were taken in different locations of the building and encompassed either the four façades of the “Patio de Santo Tomás” or the five constructive phases. Table 1 shows the classification of the eight samples selected, as well as the types of bricks employed.

Table 1. Classification of the samples analyzed.

Sample	Constructive phase	Type of brick (high x length x width in cm)
A	4	ii (4 x 24-26 x 12-14)
B	4	ii (4 x 24-26 x 12-14)
C	2	ii (4 x 24-26 x 12-14)
D	1	i (4 x 16-18 x 8-10)
E	5	iii (5 x 24 x 12)
F	5	iii (5 x 24 x 12)
G	3	i (4 x 16-18 x 8-10)
H	1	i (4 x 16-18 x 8-10)

The following observation and analytical conventional techniques were used to carry out fabric characterization: thin section polarized light microscopy, scanning electron microscopy (SEM), X-ray diffraction (XRD), energy dispersive X-ray spectrometry (EDS), and thermo-gravimetric-differential thermal analysis (TG-DTA).

Polarized light microscopy was undertaken through examinations of thin sections by means of a Kyowa Bio-Pol 2 microscope. Micrographs from thin sections were recorded with a Moticam 2500 camera. SEM observations were accomplished by a Philips XL30 equipment, using acceleration voltages of 20 kV. Powder XRD analyses were carried out with a PANalytical X’Pert-MPD unit using Kα of copper radiation (1.54056 Å), under set conditions of 45 kV and 40 mA. Diffractograms were obtained between $2\theta = 5\text{-}60°$. Powder samples for XRD analyses were prepared by grinding the body of bricks and mortars selected in an agate mortar. The EDS equipment used was a DX4i spectrometer attached to the SEM microscope already mentioned. Finally, TG-DTA recordings were undertaken by a SDT Q600 equipment using a platinum cell holder under air atmosphere, at a heating rate of 10°C/min ranging from room temperature up to 1200°C.

3 RESULTS AND DISCUSSION

Fabric characterization determined three groups of bricks. Group 1 is formed by the following five samples: A, B, C, D, and H, which correspond to constructive phases 1, 2, and 4, from sixteenth and seventeenth century. Thin sections of this group (Fig. 1a) show a fine textured calcareous clay with a high degree of birefringence. Inclusions composed of quartz, feldspar, and mica appear disseminated throughout the clay matrix. Quartz and feldspar inclusions are rounded to sub-angular in shape and not higher than 500 µm in size, while mica is in general small needle-shape and between 500 and 600 µm in length. The most outstanding feature of this group is the presence of relatively abundant inclusions of grog or chamotte (crushed fragments of ceramic) which was, in all probability, deliberately added to the clay matrix to improve mechanical properties of these bricks (Rice 1987). The size of grog fragments reach up to 1 mm in length.

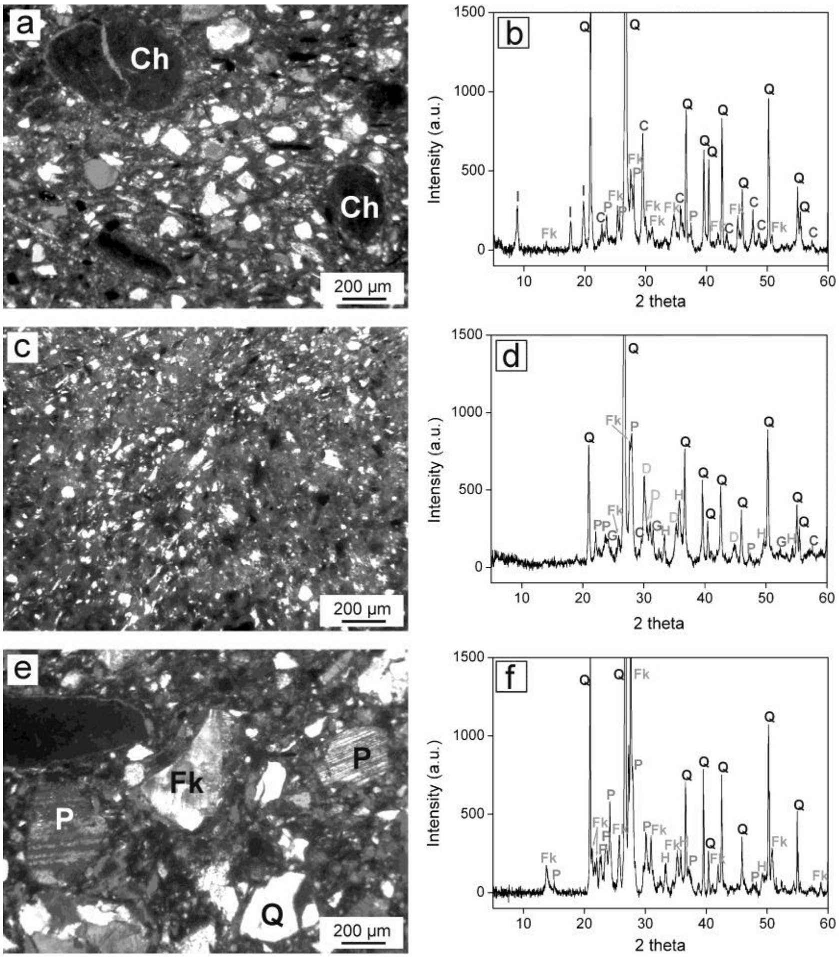

Figure 1. Thin section micrographs and diffractograms from representative brick samples of the three groups. a) Sample B. b) Sample A. c-d) Sample G. e-f) Sample F. Inclusions and phases: C calcite, Ch chamotte, D diopside, Fk K-feldspar, G gehlenite, H hematite, I illite, P Na-feldspar, Q quartz.

XRD data (Fig. 1b) confirm the presence of quartz and two kinds of feldspars: plagioclase (Na-rich feldspar) and microcline (K-rich feldspar). In addition, they also determine reflections corresponding to illite, calcite, hematite, and gehlenite. Illite decomposes from 850 to 900°C and calcite from approximately 750°C, while hematite is usually neo-formed from 700-750°C and gehlenite from 800°C (García-Heras et al. 2006). Based on the joint presence of these four phases a low firing temperature of 800-850°C can be estimated. A shrunken microstruture of non-vitrification is observed by SEM, while TG-DTA curves, not included due to space constrains, agree with the firing temperature estimated by diffractograms. Group 2 consists only in sample G, which corresponds to the constructive phase 3 from seventeenth century. The petrographic thin section (Fig. 1c) shows a very sorted calcareous clay with low birefringence and signs of vitrification. Small mainly rounded inclusions not higher than 300 µm of quartz and feldspars appear disseminated throughout the clay matrix. Apart from quartz and two kinds of feldspars: plagioclase (Na-rich feldspar) and microcline (K-rich feldspar), the X-ray diffraction (Fig. 1d) determines reflections of hematite, gehlenite, and diopside. Due to the presence of both gehlenite and diopside, which approximately crystallize from 800°C; and the absence of illite, whose full dehydroxilation occurs nearly 900°C (Rice 1987), it can be estimated a relatively high firing temperature, between 900 and nearly 950°C, for this brick sample. The starting of a vitrification microstructure is observed by SEM, while TG-DTA curves display neither endothermic nor exothermic effects as a result of the high firing temperature. Group 3 is formed by samples E and F, which correspond to the last constructive phase dated at mid nineteenth century. Thin sections of this group (Fig. 1e) show a poor sorted and birefringent non-calcareous clay in which a feldspathic sand, characterized by highly angular and sub-angular grains of quartz and feldspars, was added.

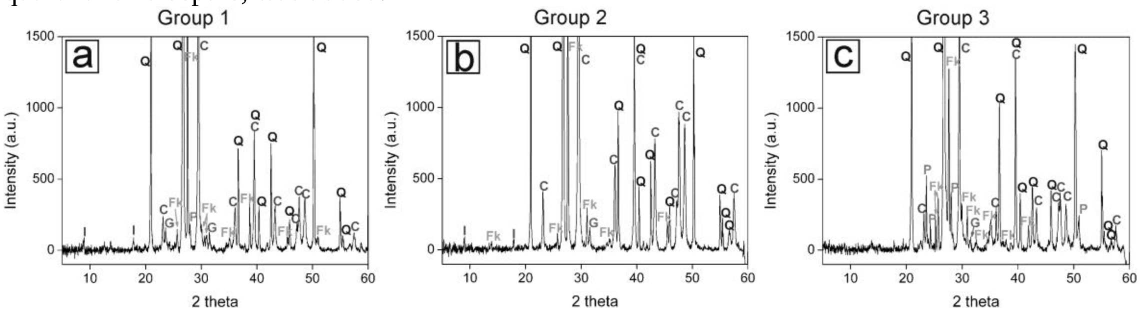

Figure 2. Diffractograms from representative mortar samples of the three groups. a) Sample A. b) Sample G. c) Sample E. Phases: C calcite, Fk K-feldspar, G gehlenite, I illite, P Na-feldspar, Q quartz.

X-ray diffractograms (Fig. 1f) confirm the presence of quartz and both feldspars. They also display reflections assigned to hematite. However, those reflections corresponding to illite and calcite are not present, which indicate an intermediate firing temperature that can be estimated roughly from 850 to 900°C. As far as the associated mortars are concerned, fabric characterization mainly undertaken by XRD data also determined three groups of mortars (Fig. 2), which are in conjunction with the three groups of bricks. All the groups are formed by lime mortars (reflections of calcite and gehlenite) with show small differences probably due to the raw materials employed. In all cases a feldspathic sand was used as aggregate. Such differences are as follows. Group 1 (Fig. 2a): Na-K feldspar sand with traces of illite. Group 2 (Fig. 2b): K-feldspar sand also with traces of illite. And Group 3 (Fig. 2c): Na-K feldspar sand without traces of illite.

4 CONCLUSIONS

The combined study of fabric characterization and building geometry and morphology has enabled the recognition of three groups of bricks and their associated mortars in the five constructive phases of the “Colegio Mayor de San Ildefonso”. Each of the three groups displayed compositional and technological differences, which can be correlated with their chronology and location in the building. Construction materials from sixteenth and seventeenth century can be easily distinguished to those from nineteenth century. In this sense, it must be noted the high quality of the brick (sample G) from the clock tower, which was probably made in the period of Juan García Atienza after the building troubles occurred during the work directed by Juan de Ballesteros.

This exploratory study has thus provided, for the first time, outstanding data on bricks and mortars employed in the different historic constructive phases of the “Patio de Santo Tomás”.

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