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CARACTERIZACIÓN DEL MORTERO DE REVESTIMIENTO Y ELEMENTOS CONSTRUCTIVOS DE MADERA USADOS EN LA EDIFICACIÓN TRADICIONAL CANARIA

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THE CHARACTERIZATION OF COATING MORTARS AND CARPENTRY ELEMENTS USED IN TRADITIONAL CANARIAN CONSTRUCTION

Abstract

This research presents a study regarding the characterization of the coating mortars and carpentry elements used in Traditional Canarian Buildings. Several techniques proposed in the relevant literature, which are based on the Thermogravimetric Analysis (TGA/DTG) and the Scanning Electron Microscopy (SEM), were used for the characterization and the identification of these building materials. The mapping obtained by the Energy Dispersive X-Ray (EDX) shows the presence of a low proportion of calcium in the coating mortar. On the other hand, the wood analysed by TGA/DTG shows the characteristic peaks of hemicellulose and cellulose, respectively. These peaks are within the normally expected temperature intervals, as reported in the literature for the identification of pitch wood (TEA, in Spanish).

Key words: *Traditional Canarian Architecture, coating mortars, Pitch wood, Preventive Conservation*

Resumen

Este trabajo presenta un estudio de caracterización del revestimiento y elementos de carpintería de la madera usada en una edificación tradicional canaria. Para esta caracterización e identificación se utilizan técnicas propuestas en la literatura que están basadas en el análisis termogravimétrico (TGA/DTG) y la microscopía electrónica de barrido (SEM). El mapeo obtenido mediante Energía Dispersiva de Rayos (EDX) muestra la presencia de calcio en el revestimiento en baja proporción. Por otra parte, la madera analizada mediante TGA/DTG presenta los picos característicos de la hemicelulosa y la celulosa, respectivamente. Estos picos se sitúan dentro de los intervalos de confianza de temperatura recogidos en la literatura para la identificación de la madera de TEA.

Palabras clave: *Edificación Tradicional Canaria, revestimientos, madera de TEA, Conservación Preventiva*

1. INTRODUCTION

Traditional Canarian Buildings are part of the rural landscape and urban space of the Canary Islands and constitute a relevant element of its architectural heritage, which must be preserved. The identification of the building materials of Canarian Architecture is essential for establishing strategies aimed at of preventive conservation and ensure the preservation of the original materials of the Canarian architectural model.

This research presents an example of practical application for the characterization of the coating mortars and elements of wood used in a Traditional Canarian Building known as: "The House of the *Sabandeños"* (Figure 1). This building was constructed in the 18th century and is located in San Cristobal de La Laguna and was declared a World Heritage City by UNESCO (United Nations, Educational, Scientific and Cultural Organization). San Cristóbal de La Laguna is located on the Island of Tenerife, which is part of the Autonomous Community of the Canary Islands in Spain. It was founded in the late 15th century on an inland plateau 550 m above sea level next to an insalubrious lagoon (http://whc.unesco.org/en/list/929)

The characterization of building materials from the architecture under study is absolutely necessary for a suitable intervention to the historical heritage. The preferential use of Pitch wood and coating mortars in the Traditional Canarian Building was due to the abundance of these materials. The original coating mortars were composed of lime and clay. The lime together with the clay is worked in the form of plaster.

Fig. 1: Main facade of the House of the Sabandeños (left) and an aerial view of La Laguna (right, image taken from website http://www.fotosaereasdecanarias.com/) indicating the situation of the House of the Sabandeños (a) and The Cathedral of San Cristóbal de La Laguna (b)

2. METHODOLOGY

The samples selected for this research come from *The House of the Sabandeños* and belong to three different elements of the building: wooden doorpost, wooden joist and coating mortar (Figure

2). The characterization of the wooden elements was performed by thermogravimetric analysis using a Perking Elmer thermogravimetric balance Pyris Diamond TGA/DTG. Sawdust obtained from the wooden samples with sizes less than 1 mm were used for thermogravimetric tests. To reduce the difference in heat transfer, the weight of the sample included in platinum crucible was less than 10 mg and all the wooden samples were heated at a constant heating rate of β=10 K/min. Pure nitrogen was used as a carrier gas to obtain an inert atmosphere during the test.

Furthermore, the chemical composition of the coating mortar was determined by energy-dispersed X-ray analysis (EDX) using a Scanning Electron Microscope JEOL JSM 6300 with a resolution of 3.5 nm and equipped with a microanalyzer X-ray Oxford INCA. For the EDX analysis of the sample, it is necessary to select an electron conductive coating material (target) that is not present in the sample. Silver was the target material for coating SEM samples using a sputtering. Carbon was not used because it is a component of calcium carbonate, which need to be analysed.

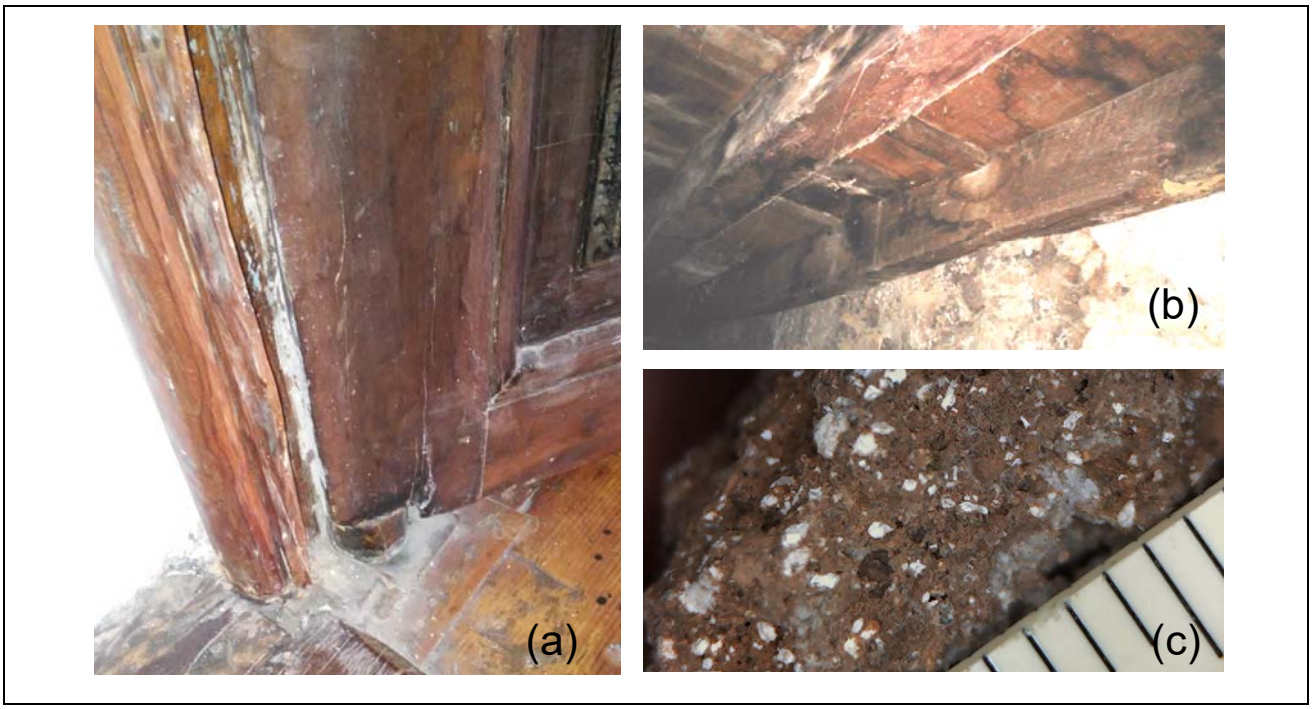


Fig. 2: Building elements selected for the study: (a) wooden doorpost, (b) wooden joist and (c) coating mortar, where the separation between the measurements of the ruler is 1 mm.

3. RESULTS AND DISCUSSION

3.1. Carpentry pieces of wood

The wooden samples were analysed by TGA/DTG. The loss of mass was determined during the pyrolysis process between 30ºC and 450ºC. The degree of conversion (α) for this process is defined as (Slopiecka, Bartocci, & Fantozzi, 2012):

$$\alpha = \frac{m_o - m}{m_o - m_f} \quad (1)$$

where m_o, m and m_f, expressed in grams, are the initial mass, instant mass and final mass, respectively. The thermogravimetric data obtained from the first derivate (*dm/dt*) can be expressed as:

$$\frac{d\alpha}{dt} = \frac{-1}{m_o - m_f}\frac{dm}{dt} \quad (2)$$

During the pyrolysis process, the wood of samples included in this study show dehydration before 100ºC. Figure 3 shows DTG curves for wood samples which belong to the doorpost and joist selected for the study.

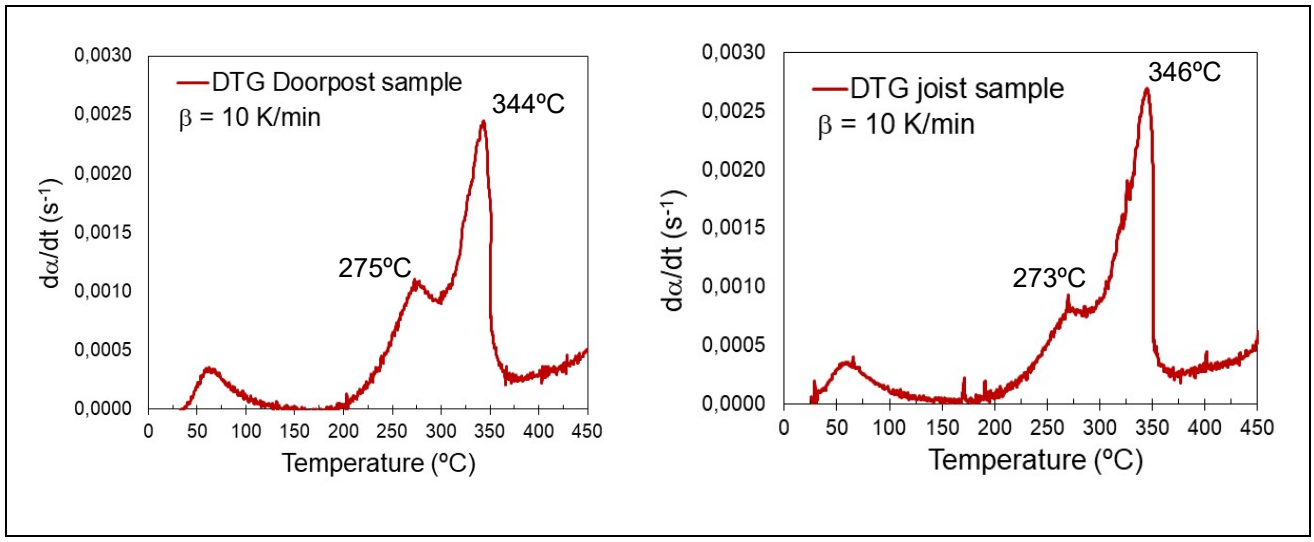


Fig. 3: DTG curves from wooden elements of The House of the Sabandeños.

The results of the thermogravimetric analysis (Figure 3) show a scheme of pyrolysis very similar for both samples: doorpost and joist. In both cases, pyrolysis scheme shown two peaks in DTG curves, which correspond to hemicellulose and cellulose decomposition, respectively. These peaks appear around 275ºC and 345ºC (Figure 3)

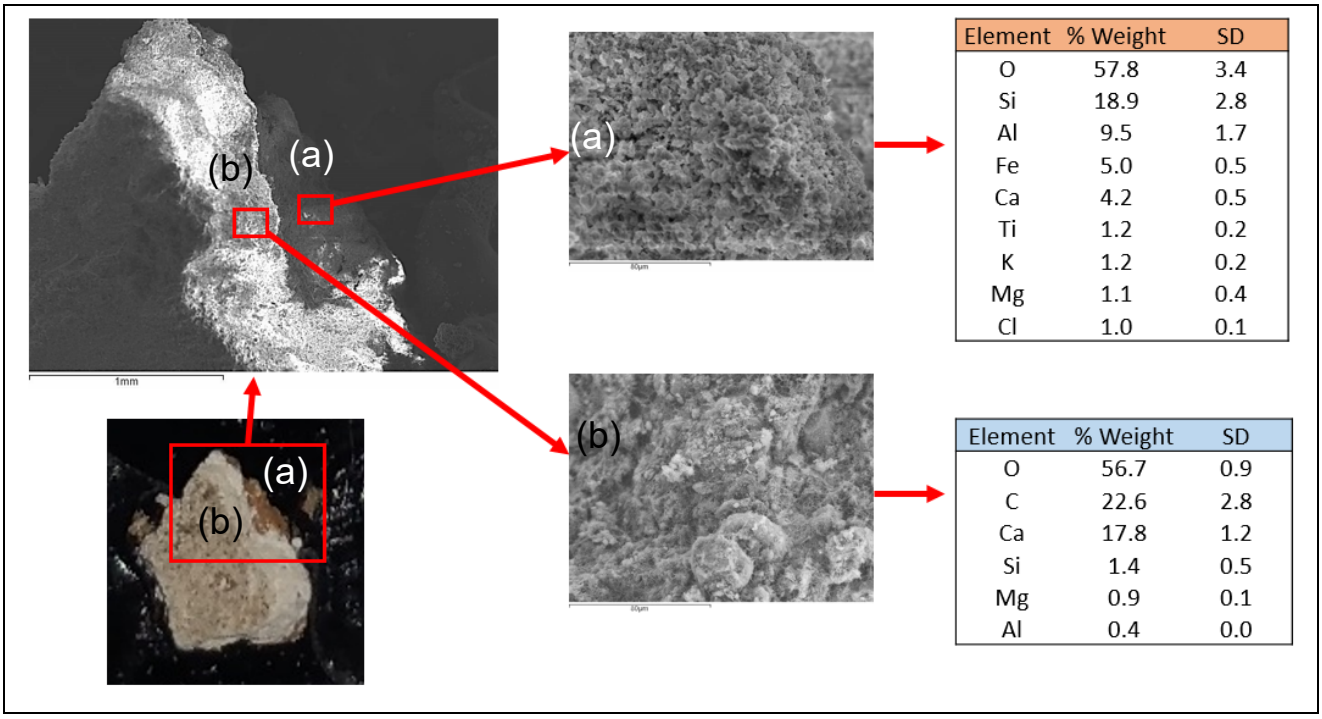
The previous research presented by (González-Díaz & Alonso-López, 2017) (González-Díaz, Alonso-López, & Fernández-Matrán, 2016) concluded that Pitch wood used in Canarian architectural heritage shows a first peak in the DTG curve between 269ºC and 289ºC with a confidence interval of 95%. This first peak corresponds to hemicellulose decomposition. Also for Pitch wood, a second peak appears due to cellulose decomposition. This second peak is located at temperatures between 342ºC and 362ºC with the same confidence interval of 95% (González-Díaz & Alonso-López, 2017)

The peaks of the maximum rate of hemicellulose and cellulose decomposition obtained for the wooden samples of The House of the *Sabandeños* are within the indicated range for Pitch wood used in Canarian architectural heritage. Therefore, it is possible to conclude that the wooden doorpost and joist were manufactured with Pitch wood (heartwood of *Pinus canariensis*)

3.1. Coating mortars

Coating mortars in Traditional Canarian Buildings are composed of mixtures of clay with a small proportion of lime (Quintana Andrés, 2008). This kind of coating mortar was the principal surface finish for Traditional Canarian Buildings until the nineteenth century. However, sometimes, cement mortars were used for this function during later interventions in these historical heritage sites. Cement mortars were not used as raw materials in the original building techniques. For this reason, the identification of the original materials is absolutely necessary in order to facilitate conservation and rehabilitation strategies in accordance with the original architecture.

The studied coating mortar shows areas perfectly different due to its colour: white and red areas. The red areas occupy a greater surface within the coating mortar (Figure 2c). Both areas were independently analysed. Figure 4 shows the chemical composition (% weight) and standard deviation (*SD)* for each area. The presented values within the tables of Figure 4 are average values of three different tests. The results show the presence of a high amount of calcium, carbon and oxygen within the white zone. It is due to the presence of $CaCO_3$, which was formed by carbonation of calcium hydroxide (lime). However, the red zones contain a most percentage of Si and Al. This fact is according with the composition chemical of clays. Clays are mainly composed by hydrous aluminium silicates and may also contain significant amounts of iron, alkali metals, or alkaline earth, such as show the table within Figure 4.



Element	% Weight	SD
O	57.8	3.4
Si	18.9	2.8
Al	9.5	1.7
Fe	5.0	0.5
Ca	4.2	0.5
Ti	1.2	0.2
K	1.2	0.2
Mg	1.1	0.4
Cl	1.0	0.1

Element	% Weight	SD
O	56.7	0.9
C	22.6	2.8
Ca	17.8	1.2
Si	1.4	0.5
Mg	0.9	0.1
Al	0.4	0.0

Fig. 4: SEM observation and chemical composition of two different areas of the coating mortar with different colour: red area (a) and white area (b).

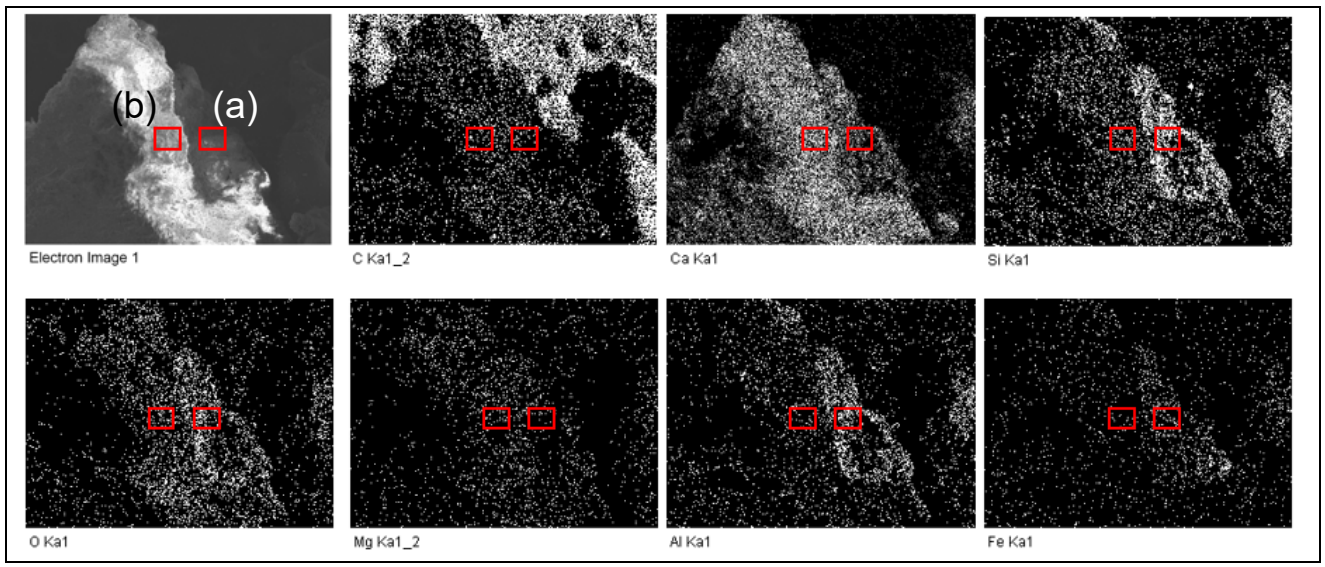
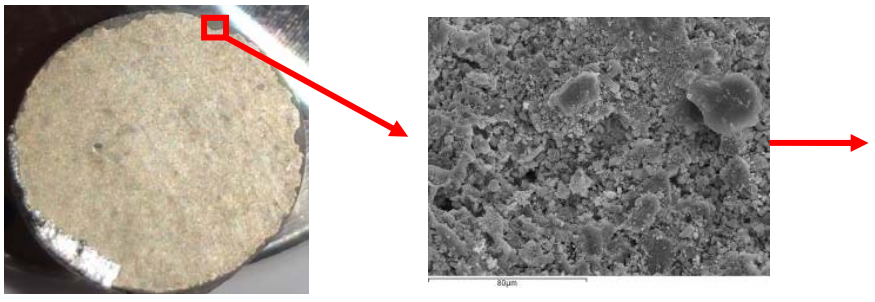


Fig. 5: Distribution of chemical elements (C, Ca Si, O, Mg, Al and Fe) for the coating mortar sample

Figure 5 shows the distribution of chemical elements (C, Ca Si, O, Mg, Al and Fe) obtained by mapping. The white points represent presence of the chemical element indicated below each image. Many points mean that there is a great amount of that element in that area of the sample. For example, there are a great number of points corresponding to silicon and aluminium in the area designated as "*a*" in Figure 5. However, there are numerous points corresponding to calcium in the white area designated as "*b*". This fact is in agreement with the previously indicated regarding chemical composition of clays and limes. Thus, the white areas, designated as "*b*", correspond mainly to the lime and the red areas, designated as "*a*", correspond to the clay. The findings correspond to similar results in studies performed on coating mortars in Traditional Canarian Buildings (Quintana Andrés, 2008).

The studied mortars of The House of the *Sabandeños* are not made of cement, since the cement contains less percentage of aluminium than that found in the red areas and more than that found in the white areas. In addition, the cement contains sulphur because the calcium sulphate is used as setting regulator during its manufacture. Figure 6 shows the chemical composition of a cement paste obtained by EDX, which evidence the presence of sulphur. The presented values in the table within Figure 6 are average values of three different tests. The samples of mortar belonging to The House of the Sabandeños do not contain sulphur (Figure 4).



Element	% Weight	SD
C	3.8	0.3
O	42.6	1.3
Na	1.7	0.2
Al	3.0	0.2
Si	11.8	1.2
S	1.7	0.2
K	1.8	0.4
Ca	31.8	1.2
Fe	1.7	0.3

Fig. 6: SEM observation and chemical composition of a Portland cement paste used as control sample.

4. CONCLUSIONS

The carpentry elements studied in The *House of the Sabandeños* correspond to a wooden doorpost and a wooden joist. Both wooden elements show two peaks in the curves DTG, which appear around 275°C and 345ºC. Those results of the thermogravimetric analysis indicate that those wooden elements were manufactured with Pitch wood (heartwood of *Pinus canariensis*).

The results also show that the studied coating mortars of the *House of the Sabandeños* are composed by a mixture of clays and lime mortars. The findings in terms of chemical composition and proportion clay/lime indicate that they correspond to original lining mortars of traditional Canarian buildings. These coating mortars does not contain cement in the mixture.

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This paper is dedicated to the memory of Clinton Peter Taylor, who was unable to finish the language revision of this work.

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