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Study and restoration of the Seville City Hall façade

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HIGHLIGHTS

- Characterisation of compounds added to and formed on the stone surface.
- Determination of damage processes and the state of decay.
- Use of modern and traditional experimental methods.
- Proposal for restoration materials based on experimental results.
- Enrichment of the field's knowledge of historical construction techniques.

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ABSTRACT

Before restoring the Seville City Hall façade, a study of the original materials and the compounds added or formed was performed. The stone is fine-grained carbonate rock. Gypsum and mortars were used to restore stone fragments. A black crust was also found the wall was covered with an acrylic resin. A layer of lime on the surface was also detected. The restoration was intended to preserve the artistic quality and uniqueness of this building. The cleaning, reinforcing and innovatively consolidating and protecting the stone using suitable materials similar to those used in the original construction are described in this study.

1. Introduction

The Seville City Hall is one of the more striking examples of the plateresque style of architecture in Andalusia. The building's construction was begun in 1526 by Diego de Riaño, who was commissioned to design a stone building with a façade facing the city's major plaza. After Diego de Riaño's death, Juan Sanchez directed the building's construction. This building is notable for its singularity, its grace, its proportionality, the perfection of its sculptures, its opulence, its elegance and its beauty.

This building is constructed entirely of stone obtained from several nearby quarries. To achieve the City Hall's exceptional plateresque façade, a soft stone was chosen that could be easily carved. However, this carved stone is highly vulnerable to the external agents that cause deterioration. Over the centuries it has undergone several stages of restoration with varying degrees of success. Though the building is entirely made of stone, it is necessary to distinguish the uncarved from the carved stone. Because of its smooth surface, the ashlar stone has suffered less deterioration than the carved stone.

The stone of the façade has been studied previously, and its mineralogy and structure are well understood. Guerrero Montes [1] diagnosed the current condition of the monumental façades of Seville City Hall. This author authoritatively identified the composition of the stone used in the original construction and examined the alteration of these materials. Several other studies examining this stone have been carried out [2–9].

Before beginning the restoration of the City Hall's façade, it was necessary to complete a study of the stone surface. This study supplied information about the environmental factors affecting the stone and the restoration methods that had been used in previous interventions.

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The surfaces of the ornamental features of monuments and historic buildings are altered by the interaction of the original materials with environmental pollutants. The grime covering the surfaces of such buildings is the result of both dry and wet deposits. These substances remain on the building's surface for an extensive period of time and are primarily responsible for the alteration processes, producing a black crust on exposed stone surfaces [10].

Several studies have shown that the surfaces of ornamental architectural features may be covered by environment pollutants and/or by substances produced during the alteration processes [11–16]. The main constituent of these crusts is gypsum, with a lower proportion of silicate minerals, iron oxyhydroxides, alkanes, soot, particles from car tires, asphalt, various ions, etc. Six groups of microspherules have also been found [17].

Mechanical and chemical cleaning methods are also responsible for the alteration of stone surfaces. The stone surface may also be affected by consolidation treatments or by the application of mortars or other materials and adhesives. These treatments and the effects of environmental pollution are primarily responsible for the formation and deposition of chemical compounds on the surfaces of historical monuments.

Prevention and restoration can be successfully accomplished only after a careful diagnosis of the building's damage. The kinetics of decay must be understood to develop treatments and preventative measures to slow deterioration [18]. It is also necessary to assess the mechanical properties of the materials, to establish constitutive laws for decayed materials, to develop methods for analysing damaged structures and to improve reliability criteria. Of these directives, the most important step is the material characterisation. An accurate material characterisation improves knowledge of the building's materials and construction phases, increases understanding of its structural behaviour and facilitates the development of successful intervention techniques [19].

Consolidation and water repellent treatments are frequently applied to the stonework at cultural heritage sites. Consolidation treatments are necessary only when the stone has lost cohesion. Water repellent prevents the entry of liquid water into the stone but allows water vapour to escape, maintaining the breathability of the material. In both cases, the treatments are applied to the surface of the stone.

The restoration of Seville City Hall's plateresque façade has proven difficult because of the stone's alteration and the meticulous detail of the stonework. The challenge posed is to clean, reinforce and innovatively consolidate and protect the stone with the appropriate materials.

This study aimed, first, to examine the surface of the City Hall's façade and report the effects on the stone of environmental factors and previous restoration treatments. Second, the façade was restored to preserve the artistic quality and uniqueness of the building. This was accomplished by cleaning, reinforcing and innovatively consolidating and protecting the stone using suitable materials similar to those used in the original construction of the building.

2. Experiment

2.1. Materials

Forty samples were taken from the City Hall's façade (Fig. 1). Stone fragment samples: 2–4, 10, 12 14–28, 30–32; mortar samples: 5 and 6; gypsum mortar samples: 9 and 29; façade protection samples: 1, 7 and 8; wall paintings: 11, 13, 33 and 34; black crust samples 40, 41 and 42. The resin, wall paintings and black crust was taken using a cuter. Mortars and small pieces of rocks were taken using a scalpel or small pliers. Small fragments from separate rocks were also taken. Fig. 2 shows plans to restore the façade. The deterioration of the façade is shown in Fig. 3. Descriptions and photos of selected samples examined in this study are shown in Fig. 4.

2.1.1. Mortars used in this study

2.1.1.1. Lime micro-mortar for injection; internal consolidation of mortar. This mortar is composed of lime, aggregate and water.

- Lime: slaked lime with a $Ca(OH)_2$ content greater than 90% and composing 40–50% of the total mixture weight content.
- Aggregate: 50–60% marble powder with high purity and small crystals. The grain size distribution must range between 0 and 0.8 mm (or between 0 and 0.4 mm depending on the crack and syringe size); 10% of the material content must be less than 7 μm.
- Water: after mixing the lime and aggregate, water is added until it constitutes 15% of the mixture. The pH must be between 5 and 8, and the ratio of dissolved chemicals cannot exceed 0.015 kg/l. Sulphates cannot exceed 0.001 kg/l and chlorides 0.006 g/l. Carbohydrates must not be present.

Similar micro-mortars have been applied to strengthen comparable historical buildings with satisfactory results, including good crack penetration [20,21,5]. This procedure is a derivative of ancient techniques used to protect stone structures [22].

It is proposed that grout be used to repair areas in the walls, vaults, and central core where the bricks and the mortar are damaged but appear consistent.

2.1.1.2. Mortars for reconstruction of the most deteriorated areas. This mortar is composed of lime, aggregate, mineral pigments (when required) and water.

- Lime: slaked lime with a $Ca(OH)_2$ content greater than 80% and composing 15–20% of the total mixture weight content.
- Aggregate: 50–60% silica–calcareous aggregate with a grain size distribution from 0 to 3.5 mm on a continuous size distribution curve.

The geometric characteristics and chemical specifications of the mortar should also be considered. Aggregates must be derived from hard, compact and durable rocks. Aggregates composed of tender and friable rocks should be avoided. To reduce shrinkage, the size of the aggregate particles must be controlled. To avoid reduced strength, excessively fine-grained sand must be avoided because it does not allow the lime to be properly distributed. To increase adherence, well-graded sharp sand is preferable to rounded grains.

- Mineral pigments (when required).
- Water: water is added to the lime and aggregate until it comprises 15% of the mixture. The pH must be between 5 and 8, and the ratio of dissolved chemicals should not exceed 0.015 kg/l. Sulphates, specifically SO_4, must not exceed 0.001 kg/l, and chlorides should not exceed 0.006 kg/l. Carbohydrates must not be present.

The new mortars will be used to repair the areas in the walls and central core where the mortar has experienced extreme damage.

2.2. Methods

A petrographic Leica DMLP (polarised light) microscope was used for the mineralogical study. Thin sections of the samples were prepared and partially stained with alizarin, an organic compound used in geology to indicate the presence of calcium carbonate minerals. The cross-sections were prepared following the methodology described by Khandekar and Duran et al. [23–25]. The cross-sections were observed and photographed using a Nikon OPTIPHOT (×25, ×50 and ×100) optical microscope and a non-destructive portable X-ray fluorescence (XRF) instrument designed and constructed in the C2RMF (Centre de Recherche et de Restauration des Musees de France) laboratory at the Louvre Museum. A 4 mm beam from a copper another source was used. The elemental analysis was performed using a Silicon Drift Detector (SDD) [26-29]. X-ray powder diffraction (XRD) was performed using an X'Pert Pro MPD PANalytical diffractometer. A Cu Kα radiation source operating at 40 kV and 40 mA was used. Diffraction data were collected over a 2θ range of 3–60°, with a step width of 0.02° and acquisition time of 240 s. X'Pert HighScore Plus software version 3.0 (2009) was used to analyse the diffraction patterns obtained. Minerals were identified by comparing the observed patterns with the standards published in the International Centre for Diffraction Data, Powder Diffraction File 2 database (ICDD PDF2 database). The morphology of the samples was observed with a HITACHI S-4800 scanning electron microscope (SEM). Samples were coated with a carbon film prior to SEM analysis. Thermoanalytical studies were performed using a TA Instruments simultaneous differential and thermogravimetric (DTA/TG) apparatus. Measurements were conducted under an airflow heated to 1000 °C at a linear heating rate of 10 °C/min. Fourier transform infrared spectroscopy (FTIR) was performed using a Jasco FTIR 6200. A PIKE MIRACLE-ATR was used to perform attenuated total reflectance (ATR) to examine the surface of the films independent of the rock surface.

This cleaning was performed manually to achieve greater efficiency, perfection and neatness. It was performed using tap water and green soap that would not harm the stone. Green soap is neutral and contains no harmful acids.