PREVIOUS STUDIES FOR THE RESTORATION OF THE CORDOBA DOOR OF CARMONA, (SEVILLE, SPAIN).

Espinosa Gaitán, Jesús; Ontiveros Ortega, Esther; Villegas Sánchez, Rosario

Instituto Andaluz del Patrimonio Histórico, Isla de la Cartuja, 1. 41071 Sevilla (Spain)

SUMMARY

As a previous part of the conservation-restoration project, the characterization of the materials from the Door and their state of conservation have been carried out. The stone is a biocalcarenite very porous, with little quantities of gypsum and clay minerals and very heterogenous. These compounds condition greatly the state of conservation and the weathering indicators of the Door. The ultrasonic velocity vary greatly, related inversely with the porosity.

1. INTRODUCTION

The Cordoba Door of Carmona is situated at the end of the old town, on an ancient water-way flanked by two borders of the Alcor. Its origin is roman, and its original structure is almost entirely preserved, with two lateral octagonal towers, and also exist later works arab and christian.

The Door has suffered several interventions, the first recorded information is dated on the XVIIth century, the most important one was that carried out during the reign of Carlos II. The exterior structure that is visible today corresponds to a reform made between 1790 and 1800.

Nowadays a restoration/conservation project is being carried out, due to the high degree of deterioration of the Door. On a first phase an archaeological study has been made, from which very interesting historical results have been obtained. The second phase consists on the characterization of the materials used on the Door and the determination of their state of conservation.

The Door is built mainly with stone blocks, that are covered, on several zones, with plasters of different compositions. The stone used comes from the geological formation of Los Alcores, constituted by calcarenites, sandstones and yellow muds; the stone from the Door is a calcarenite, with a yellow-orange colour, a grain size of gross sand very heterogeneous. It is mainly constituted by bivalves of fine shell.

Nowadays the Door is in an advanced state of deterioration, with loss of materials and phenomenons of alveolization, arenization, fissures and contour scaling on the stone.

The study carried out has been focused mainly on:
- Mineralogical-petrographical study
- Chemical analysis
- Physico-mechanical analysis

Its objectives have been to know the nature of the materials, their state of conservation, and to
determine the mechanisms and factors of weathering, to try to act directly on them.

2. METHODS

To characterize the materials, the following techniques have been used.

2.1. X-Ray diffraction

With powder method the main mineralogical composition of the stone has been determined, both from the Door and from the historical quarries of the Alcor.

The clay fraction has been identified by means of aggregated oriented and treatments (EG, DMS and thermic).

2.2. Optical microscopy

It has been used to make the petrographical analysis of the stone from the Door and the quarries. This technique allows to obtain data on the existence of minor mineral compounds not detected by X-Ray diffraction, as well as to study textural aspects of the material.

2.3. Chemical analysis

Samples preparation has been carried out by alkaline disgregation and later extraction on acid mean. Quantitative analysis have been made following Berzosa and Martin methodology (1-3), using: gravimetric volumetry, atomic absorption spectroscopy, and UV spectroscopy.

2.4. Ultrasonic velocity

This technique allowed to detect defects, unhomogeneities and structural problems, as well as to evaluate the degree of alteration of the stone from the building by comparing with that from the quarry.

2.5. Water saturation under vacuum

This test allows to determine saturation coefficient and the open porosity, i.e. accessible to water (4).

3. QUARRIES CHARACTERIZATION

There is a great quantity of quarries distributed on the zone of Los Alcores, near Carmona, due that this area has been a very propitious situation for human settlement.
The quarries studied correspond to roman exploitations, some of them being reused on later periods. The selection has been made following archaeological criteria:

- Little roman quarries on El Alcor beside Carmona
- La Batida, exploitation of XVth and XVIth centuries, but probably used on roman age
- Roman necropolis quarry (3)
- Puerto del Judío, is the most important roman quarry situated in this area (4)

4. RESULTS

4.1. X-Ray diffraction

Tables 1 and 2 show the mineralogical semiquantitative composition of the stones studied, both from the Door and from the quarries. These data have been obtained by dust method.

Table 1. Mineralogical composition of the material from the Door

<table>
<thead>
<tr>
<th>SAMPLES</th>
<th>PCC-2</th>
<th>PCC-3</th>
<th>PCC-19</th>
<th>PCC-20</th>
<th>PCC-21</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUARTZ</td>
<td>5</td>
<td>10</td>
<td>27</td>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>CALCITE</td>
<td>93</td>
<td>72</td>
<td>60</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>GYPSUM</td>
<td>5</td>
<td>17</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>DOLOMITE</td>
<td>5</td>
<td>5</td>
<td>-</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 2. Mineralogical composition of the material from quarries

<table>
<thead>
<tr>
<th>QUARRY</th>
<th>ALCOR</th>
<th>BATIDA</th>
<th>3*</th>
<th>4*</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUARTZ</td>
<td>27</td>
<td>61</td>
<td>38</td>
<td>21</td>
</tr>
<tr>
<td>CALC.</td>
<td>73</td>
<td>39</td>
<td>62</td>
<td>79</td>
</tr>
<tr>
<td>DOLOM.</td>
<td>&lt;5</td>
<td>&lt;5</td>
<td>&lt;5</td>
<td>&lt;5</td>
</tr>
<tr>
<td>GYPSUM</td>
<td>&lt;5</td>
<td>&lt;5</td>
<td>&lt;5</td>
<td>&lt;5</td>
</tr>
</tbody>
</table>

3. Quarry of the Neocropolis
4. Quarry of the Judío

These data make evident that the qualitative composition of the material from the Door and from the different quarries is the same, but semiquantitative composition varies greatly. It has to be notice the presence of gypsum as an intrinsic component of the stone, although its proportion is not very high, specially in the quarries samples.

The average composition of the stone from the Door and the quarries appear on Table 3.
Table 3. Average mineralogical composition of the stone

<table>
<thead>
<tr>
<th>SAMPLES</th>
<th>DOOR</th>
<th>ALCOR</th>
<th>BATIDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUARTZ</td>
<td>23</td>
<td>21</td>
<td>39</td>
</tr>
<tr>
<td>CALCITE</td>
<td>67</td>
<td>79</td>
<td>59</td>
</tr>
<tr>
<td>GYPSUM</td>
<td>7</td>
<td>traces</td>
<td>traces</td>
</tr>
<tr>
<td>DOLOMITE</td>
<td>traces</td>
<td>traces</td>
<td>traces</td>
</tr>
</tbody>
</table>

Although with this technique it has not been possible to detect the presence of clay minerals due to their low proportion, the aspect of the stone showed clearly its existence. By means of aggregated oriented method it has been possible to verify that this clay fraction is formed mainly by illite and smectite.

Smectite is an expansive clay that can duplicate its interlinear space easily in presence of water, fact that can explain partially the severe alteration that appears some times. This could be due to disruptive mechanical phenomenon caused by cyclic alternacy of relative humidity on the environment, that produces contractions and dilatations of the structure of smectite.

4.2. Optical microscopy

Six thin sections of stone have been studied, two from the Door and four from the quarries.

In general, it could be considered that all of them are the same lithotype, although there are some mineralogical and petrographical differences between the samples.

The stone is mainly forms by a framing of bioclasts of carbonatic nature (essentially bivalves, and in a minor quantity bryozoans and nummulites) that are fracture in their major part. These bioclasts are inserted in a fine grained matrix, also of carbonatic nature mainly, although there are also iron oxides and occasionally some clay nodules (Figure 1).

It is evident, on almost all the samples, the dissolution both of the fine carbonatic fraction and of the bioclasts. This diluted carbonate has reprecipitated on the open spaces of the stone (pores, fissures and original zones of the matrix) in the form of sparitic crystals as "mosaic" (Figure 1). On the most disfavourable cases, samples from the Door, recrystallization inside the stone is more limited, remaining some areas formed practically by the framing of clasts, suffering the stone an increment in porosity and an appreciable loss of compacity.

Besides the carbonatic components there is also, with variable proportions (10-20%), a terrigenous fraction formed by quartz grain of different sizes and with rounded and subrounded forms.

It is common for all the samples the presence of gypsum filling some pores, being its abundance variable, but, in general, on higher quantities on the Door samples. However, on one sample from the Alcor quarry the content of gypsum can be comparable with that of the Door. This fact suggests that, very probably, this gypsum is intrinsic to the stone, although the high contents
found on some samples from the Door (PCC3) besides the different crystallization habitude - more fibrous on the Door samples - indicate that this gypsum could comes from in part from joint mortars, some of them having it.

4.3. Chemical analysis

Chemical analysis have been carried out to confirm the data obtained by X-Ray diffraction. Two samples from the Door have been analyzed. On Table 4 appear the quantitative results.

<table>
<thead>
<tr>
<th>Samples</th>
<th>Ignit. loss</th>
<th>SiO₂</th>
<th>CaO</th>
<th>MgO</th>
<th>Fe₂O₃</th>
<th>Al₂O₃</th>
<th>SO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCC-2</td>
<td>38.10</td>
<td>9.09</td>
<td>48.87</td>
<td>0.32</td>
<td>0.98</td>
<td>0.26</td>
<td>3.23</td>
</tr>
<tr>
<td>PCC-3</td>
<td>31.49</td>
<td>9.07</td>
<td>44.37</td>
<td>0.55</td>
<td>0.74</td>
<td>0.31</td>
<td>12.52</td>
</tr>
</tbody>
</table>

It has to be remark that high content of sulphate, that would be as gypsum, fact confirmed by the other techniques.

4.4. Ultrasonic velocity

Measurements of ultrasonic velocity have been carried out on samples both from the Door and from the quarries, with values ranging from 800 to 2800 m/s, which makes evident the heterogeneity of the material. There is not appreciable differences between the material from the quarries and from the Door.

4.5. Water saturation under vacuum

With this method an average value of porosity of 34% has been obtained, a value quite high. With the aim of determine if there is a relation between ultrasonic velocity and porosity, the data have been represented graphically (Figure 1).
5. CONCLUSIONS

The stone used to construct The Door belongs all to the same lithotype, a calcarenite. Beside this stone is mineralogically and petrographically very similar to the samples from the quarries studied, so, with the analysis carried out it is not possible to discriminate the exact origin.

Recrystallization of sparry calcite have been observed both in the stone from the quarries and from the Door, which indicates that this fact took place before the stone was place in work. On some zones of the Door samples this sparry cement has been lost, together with fine matrix, what makes evident that later dissolution processes have been occurred.

The presence of gypsum is minority on quarries samples, but on the Door samples very high quantities have been detected, so that, partially at least, this gypsum proceeds from the joint mortar (the pollution levels at Carmona are very low).

The high degree of deterioration of some zones (mainly lower parts with rising damp) could be attributed to high contents of humidity with cyclic changes and the presence of expansive clays and gypsum (and probably other soluble salts) coming from the mortars.

The ultrasonic measurements do not reveal appreciable differences between those of the Door and those of laboratory. Being a rock with a high textural and structural heterogeneity, the values range in a wide margin depending on the compacity of the material. It has to be noticed that the values measured on blocks very deteriorated are lower, logically. From the relation between ultrasonic velocity and porosity, appears clearly that the velocity decreases when the volume of voids increases.

REFERENCES


Relationship porosity-ultrasonic velocity.

![Graph showing relationship between porosity and ultrasonic velocity.](image)

**Figure 1.**

Photomicrograph 1. Stone used in the door (several parts).