CHARACTERISATION OF MORTARS COMPATIBILITY USING MICROSCOPICAL AND XRD ANALYSIS

N. COBIRZAN, A.-A. BALOG
Faculty of Construction, Technical University of Cluj-Napoca, Baritiu 25, 4, Cluj-Napoca, Romania
E-mail: nicoleta.cobarzan@ccm.utcluj.ro, E-mail: ancabalog@dst.utcluj.ro

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The determination of the physical and mechanical properties or mineralogical composition of mortars from heritage buildings is often difficult to realize because the possibility of extracting samples is reduced, being necessary a large number collected from different area of structural and nonstructural elements (piers, walls, etc.). This study analyzes a few mortar samples taken from an existing building and compared with a Portland cement mortar made in laboratory. It was used thin sections analysis as destructive investigation method and X-ray diffractions as non-destructive analytical technique in order to compare the mineralogical content of the investigated mortars.

Key words: compatibility, mortar, thin sections, XRD analysis, alteration.

1. INTRODUCTION

Old masonry work is inhomogeneous and anisotropic building material, composed of masonry units and mortar whose mechanical and physical characteristics (porosity, permeability, unit weight, deformability and mechanical strengths) influences its behavior in time. Using higher-strength materials (such as cement mortar instead of lime mortar) in restoration of heritage buildings, can lead to appearance of inhomogeneous areas in masonry works and local stresses, which can cause high mechanical actions on materials with lower strength accelerating in this way the masonry decay [1, 2].

Weathering is responsible for other types of damages found in heritage buildings. Solubility, dissolution or sulphate attack, especially in case of limestone or sandstones masonry, appears due to different technical properties and mineralogical or chemical content as well, theirs effect having catastrophic consequences [3].

In order to avoid masonry degradation, the materials chosen for rehabilitation works should be in accordance to the type of intervention technique (reversible or irreversible). Irreversible interventions are those that take into account the compatibility of the new materials with the ones initially used, to ensure durability, sustainability and the desired architectural or aesthetical aspect [2, 4, 5].

Compatibility between new and existing building materials is an important aspect in case restoration stage of cultural heritage monuments. Van Hees (2000) suggested a definition of compatibility of mortars as follows: ‘the new mortar should be as durable as possible, without (directly or indirectly) causing damage to the original material’ [6].

Sustainability, in case of rehabilitation of heritage buildings is consisting in choosing durable materials, having reduced embodied energy, low thermal conductivity coefficient, free of toxic or diminished radioactivity [7, 8] in order to reduce the impact upon the environment and to protect the people’s health.

2. RESEARCH METHODOLOGY

2.1. PHYSICAL AND MECHANICAL CHARACTERISTICS

The determination of physical and mechanical characteristics by classical methods (destructive) require a large number of samples, taken from different places, depending on the height of the structural element, the degree of damage or orientation of buildings [4, 5]. In case of heritage building is not allowed to extract such a large number of samples, being almost impossible to determine their mechanical properties through destructive techniques.

To assess the compatibility between mortars samples, the results obtained by mechanical tests are often insufficient, requiring additional data on the microstructure of materials (obtained by XRD, EDX, SEM, DTG analyses). These methods has significant applications in rehabilitation/consolidation/restoration/projects [9, 10] and other fields [11] being preferred lately due to their many advantages (few grams of samples, short time needed for analysis, accuracy).

2.2. THIN SECTION ANALYSIS

Mineralogical examination can provide to technical experts useful and detailed information necessary to evaluate a construction. In thin sections can be determined mineralogical composition and quality of the original mortars; microscopic cracks formed in elements and the causes of their occurrence (crystallization under pressure, tensions between mortar and rock), porosity of materials, chemical or biological attack.

Mortars samples have been collected from a heritage building (samples S1 and S2), analysed and compared from mineralogical point of view with a sample of Portland cement mortar (S3) prepared into laboratory.

Samples have been analysed in thin sections with the dimensions of 0.02 mm (according to STAS 6200/3-81) [12] and treated with Canada balsam. Thin sections of mortar samples are presented in Figs. 1–3.
Fig. 1 – Thin sections of mortar S1:
1-feldspar, 2-claying mass, 3-alteration of muscovite, 4-pore, 5-quartz, 6-groundmass (with carbonate and clay), 7-fissured feldspar, scale bar= 1mm

Fig. 2 – Thin sections of mortar S2:
a)-b) 1-feldspar, 2-transformation of feldspar into clay, 3-sericite, 4-fissured feldspar, 5-groundmass (intensively altered), 6-opaque mineral c) sericite detail; scale bar= 1mm

Fig. 3 – Thin sections of Portland cement mortar S3:
a) 1- quartz, 2- feldspar, 3-mica, 4-reaction crown around the quartz, 5-opaque minerals in the groundmass, 6- carbonate groundmass, 7- biotite; scale bar 100 µm, N+
b) 1-pore, 2-corrosion of quartz, 3-criptocrystaline carbonate groundmass, 4- reaction crown around the quartz, 5-fine groundmass (carbonate and clay) scale bare 200 µm, N+

In the thin sections the analysed mortars, shows the following mineralogical composition:
– sample S1: contains clasts of quartz, feldspar, caught in a fundamental carbonate mass (calcite), with muscovite and mineral clay, probably formed due to feldspar;
– sample S2: contains a high percentage of quartz, calcites, claying due to feldspar and sericite. The appearance of sericite in the mass of mortar indicates a higher age of the mortar S2 than sample S1. Probably this mortar was used to realise the original masonry works while sample S1 it was used during one rehabilitation stage (buildings was rehabilitated for many times in the last 400 years);
– sample S3: contains quartz, feldspars biotite, mica, opaque mineral, iron oxy-hydroxide, carbonated fundamental groundmass. Mortars behavior was analyzed at 28, 56, 90 days; a development in the degradation processes was observed through: the appearance of a crown around the feldspars and quartz, the feldspar turning into zeolites, replacing of opaque minerals by iron hydroxides, intense chloritization of micelles and secondary recrystallizations of the fundamental groundmass.

2.3. XRD ANALYSIS

Mineralogical composition of mortars, have been determined on few grams of the sample using a diffractometer with Co-Kα radiation anticathode, λ = 1.790300 Å and 20θ/min from 100 to 700 (2theta).

XRD diffraction allows identification of the mortar mineralogical crystal composition (Figure 4, Table 1), as complementary data as those obtained in thin sections.
b.

c.

Fig. 4 – XRD analysis:
- mortar sample S1, b- mortar sample S2, c- Portland cement mortar S3
Table 1

Mineralogical composition by XRD

<table>
<thead>
<tr>
<th>Content</th>
<th>Mortars sample</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>S1</td>
</tr>
<tr>
<td>Quartz</td>
<td>58.7</td>
</tr>
<tr>
<td>Calcite</td>
<td>15.1</td>
</tr>
<tr>
<td>Muscovite</td>
<td>1.8</td>
</tr>
<tr>
<td>Anorthite</td>
<td>7.2</td>
</tr>
<tr>
<td>Orthoclase</td>
<td>6.6</td>
</tr>
<tr>
<td>Biotite</td>
<td>2.7</td>
</tr>
<tr>
<td>Chlorite</td>
<td>2.3</td>
</tr>
<tr>
<td>Mica</td>
<td>5</td>
</tr>
<tr>
<td>Anatase</td>
<td>0.6</td>
</tr>
<tr>
<td>Feldspar</td>
<td>-</td>
</tr>
</tbody>
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XRD analysis revealed the following:

– larger amount of calcite present in samples S1 (15.1%) and S2 (9.2%) is probably due to the use of lime in mortar recipe. Sample S3, made in the laboratory has a lower content of calcite (1.3%);

– high content of quartz in sample S2 (81.2%) can be the result of the removal of the binder due to environmental factors, which affected the mortar during the time or the result of the reduced aggregate / binder ratio used initial in the mortar. The presence of mica show an intense decline of feldspar due to which they were formed;

– cement mortar (S3) has a large amount of quartz (70.7%), feldspar (14.1%) and a low amount of calcite (1.3%). Quartz from mortar reacts with carbonate mass, which corrodes its margins (from 28 to 90 days); feldspars alteration is proportional to their quantity, breaking into pieces and forming more and more clay minerals; these are processes which in time may contribute to the degradation of mortars.

3. CONCLUSIONS

Replacement or reconstruction of destroyed or detached building materials from a heritage building requires finding mortars with similar properties not only from mechanical point of view (usually considered in rehabilitation works); in the same time being necessary to determine the mineralogical composition to prevent further damages caused by weathering.

In order to establish the compatibility of mortars analyzed in terms of behavior in time, the thin sections revealed that mortar created in the laboratory (S3) suffers different degradations from those taken from the building.
Old mortars present varying degrees of corrosion and degradation of feldspar and quartz in contact with carbonated fundamental groundmass which is influenced by the percentage of calcite in mortar.

High percentages of feldspar presented in S2 mortar sample leads to the appreciation of their age: this is a new mortar compared to mortar in sample S1, the justification being linked to the incomplete feldspar alteration.

Thin sections and XRD analyses can conclude that S1 and S2 mortars have almost similar percentages of quartz, calcite and mica, while S3 mortar has a high percentage of quartz, mica, feldspars and a low calcite percentage. Mineralogical content suggests that the first two mortars are based on lime and cement, being different from mineralogical point of view of Portland cement mortar.

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