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Petrographic characteristics of the mortars from the Pisa's Cathedral apse

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***Abstract* – The archaeometric study of several mortar samples of the Pisa's Cathedral apse allows us to identify eight types of aerial and hydraulic binding materials, containing cocciopesto, fluvial sand, pozzolana, calcarenite and marble in various proportions bound by both aerial and hydraulic lime. The binder fraction is dirty snow-white in colour, with inhomogeneous structure due to the presence of millimetric lumps, in the cases in which only aerial lime is present and more or less whitish, reddish, pinkish or brownish in colour when binder is showing an hydraulic character.**

I. INTRODUCTION

Mortars are common bonding material that were produced by mixing binding materials (aerial or hydraulic binder) and fine aggregates with water. Their characteristics depended on raw materials and production technology available in a given historical period [1-5].

Studying ancient mortars with an archaeometric approach it was possible to obtain useful information on technology [6-8], construction phases [9-12], ancient recipes [13-19] and raw materials [20-25].

The ancient mortars characterization is usually performed by combining chemical, mineralogical and petrographic analyses [26-27]. Undoubtedly naked eye observations and an in deep petrographic study on thin section are able in many cases to provide interesting information for a characterization of the binding materials and of their raw materials [28-37].

Within the framework of a multidisciplinary study in the field of art history and restoration of the Pisa's Cathedral masonry, a comprehensive characterization of the building materials, including stones, marbles and mortars, was made [38].

In this paper, a petrographic characterization of several mortar samples coming from the Pisa's Cathedral in the Miracles Square (Italy) is reported, with a particular interest in determining the macroscopic and microscopic characteristics useful for determining the ancient recipes.

II. MATERIALS AND METHODS

About 200 mortars were sampled from the apsidal area of the Pisa's Cathedral (Fig. 1). In particular, samples were taken from the apse (I, II and III orders), the core (I, II and III orders) and the clerestory of the cathedral.

Macroscopic and microscopic features of the samples were observed by both a stereomicroscope (up to 200×) and a polarising microscope, working on polished thin sections.

Figure 1. The Cathedral of Pisa with scaffolding in the apse area.

RESULTS AND DISCUSSION

Based on both the macroscopic observation of hand samples and the study of thin sections, all the analysed samples have been divided into eight groups (Table 1):

- Group 1: 23 samples are made up of hydraulic binder and cocciopesto;
- Group 2: 18 samples are made up of hydraulic

binder and cocciopesto + river sand;

- Group 3: 2 samples are made up of hydraulic binder and cocciopesto + river sand + pozzolana in trace;
- Group 4: 134 samples are made up of aerial/hydraulic binders with river sand as aggregate fraction;
- Group 5: 5 samples are made up of aerial/ hydraulic binders with river sand as aggregate fraction;
- Group 6: 6 samples are made up of aerial/hydraulic binders with white marble as aggregate fraction;
- Group 7: 2 samples are made up of hydraulic binders with river sand + pozzolana + marble;
- Group 8: 3 samples are made up of gypsum + river sand.

Table 1 - Macroscopic features of the mortar samples coming from the apse of Pisa's Cathedral.

Group	n.	Binder*	Aggregate fraction				
			Cocciopesto	Sand	Pozzolana	Calcarenite	Marble
1	23	H	X				
2	18	H	X	X			
3	2	H	X	X	tr		
4	134	A/H		X			
5	5	A/H		X		X	
6	6	A/H					X
7	2	H			X		X
8	3	G		X			

* A = aerial lime; H = hydraulic lime; G = gypsum.

With the exception of the Group 4 samples, whose mortars are present in all the apse orders (G) as well as in all the core orders (C) and in the clerestory (F), about a third of the analysed mortars are almost exclusive of single sampled areas (Table 2).

Table 2 - Distribution of different types of mortars in the apse (G), core (C) and clerestory (F) of the Pisa's Cathedral.

Group	1G	2G	3G	1C	2C	3C	F
1	X	X		X			
2	X						X
3	X						
4	X	X	X	X	X	X	X
5		X					
6		X	X				
7					X		
8				X			X

The mortar samples differ from reddish (Group 1) to reddish/whitish (Groups 2 and 3), whitish/light grey (Groups 4, 5 and 6), dark pink (Group 7) up to black (Group 8) in colour.

As an example of the texture of the most representative analysed samples, the Figures 2-6 report the mortar samples of Groups 1, 2, 4 and 6.

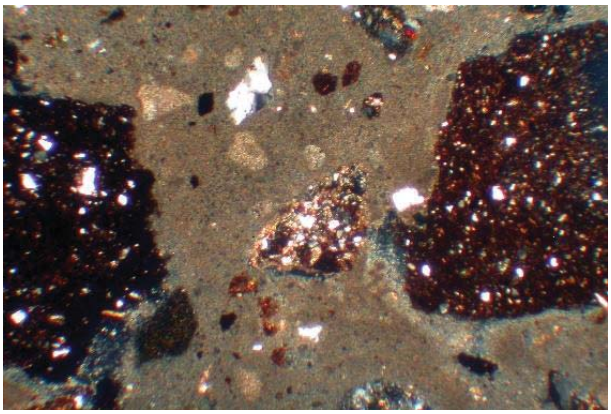

Figure 2. Mortar sample of Group 1 consisting of hydraulic binder and cocciopesto.

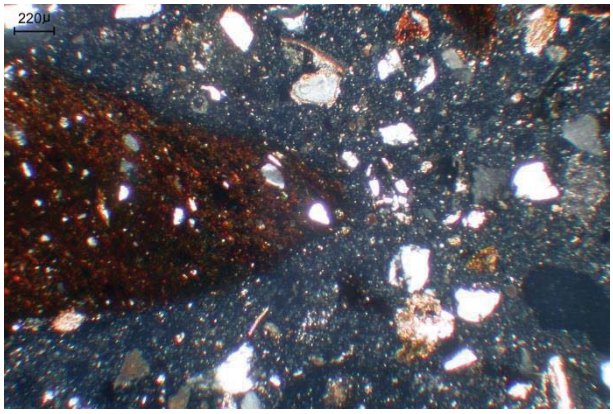

Figure 3. Mortar sample of Group 2 characterised by the presence of hydraulic binder, cocciopesto and fluvial sand.

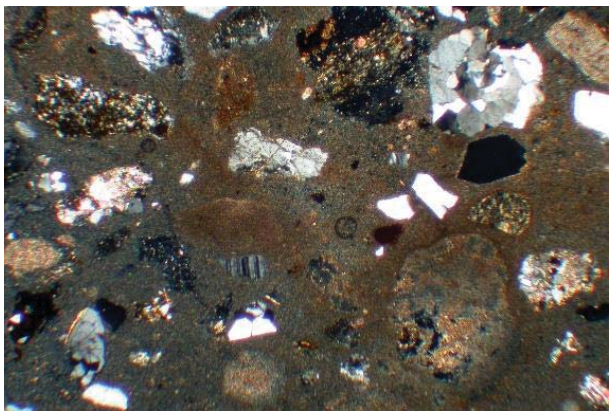

Figure 4. Mortar sample of Group 4 in which aerial/hydraulic binder and river sandy aggregate are present.

As regard to the cohesion, the samples are hard mortars (Groups 1-3 and 5), from hard to moderately hard mortars (Group 4), from moderately hard to soft and friable mortars (Groups 6 and 7), up to soft and friable mortars (Group 8).

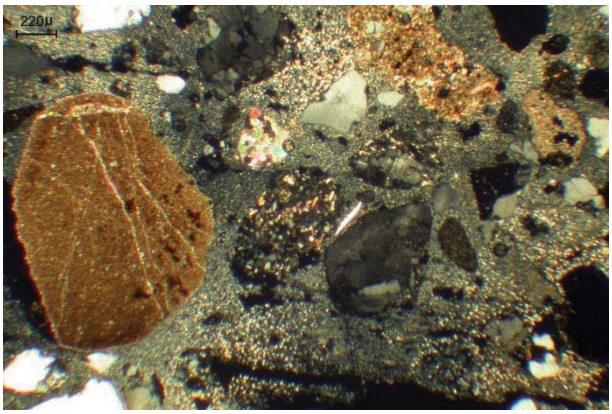

Figure 5. Mortar sample of Group 5 in which aerial/hydraulic binder and calcarenite aggregate are present.

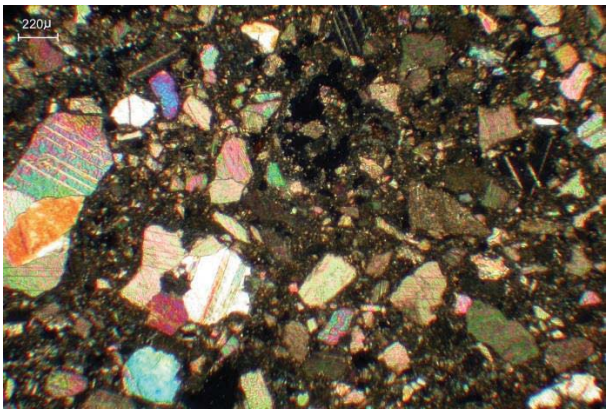

Figure 6. Mortar sample of Group 6 in which marble grains were used as aggregate.

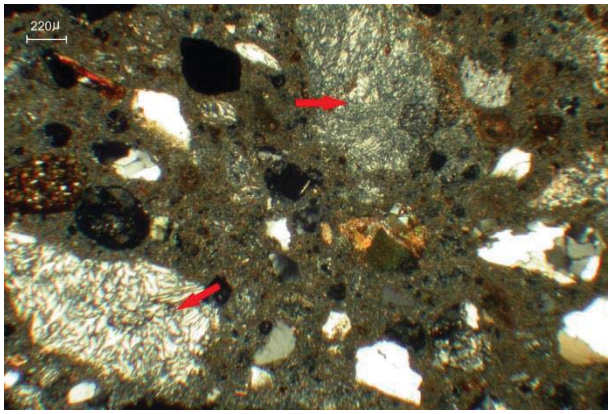

Figure 7. Mortar sample of Group 8 in which gypsum and sand grains were used as aggregate.

All the mortar samples are characterised by the presence of lumps. These lumps have various sizes: < 1 mm, for Groups 2, 3 and 6 mortars; < 4 mm, for Group 4 mortars and < 7 mm, for Group 5 mortars.

III. CONCLUSIONS

Macroscopic and microscopic observations of mortar samples are often useful for identifying raw materials used to produce these binding materials and to evaluate their mix proportions.

Three main different binder materials have been identified: hydraulic limes, aerial limes and gypsum. Those binders have been coupled with different material as aggregate: cocciopesto, river sand, pozzolana, calcarenite and marble.

In the case of the apse of the Pisa's Cathedral the petrographic characteristics highlighted the presence of eight groups of mortars that are related to different constructive phases and to restoration works occurred several times over the centuries and they often reflect the working building techniques used at the time.

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