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The ancient mortars, an attestation of the material culture: the case of Florence

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Abstract. — The aim of this paper is to describe and highlight the role of artificial stone materials used by man through history in order to further the understanding of history itself.

The study of artificial materials such as mortar, plaster, ceramics, etc. made and used over the centuries, augments our knowledge of the "Material Culture." It provides information about raw materials, technologies and processes as well as data that are important from the historical standpoint and for the restoration of works of art.

Specifically, the paper reviews some examples of ancient mortars used in the Florence area. Petrographic analysis alone was able to provide of data which permitted a detailed reconstruction of production methods. Scientific analyses, together with data obtained from historical sources, have brought to life materials which otherwise would have remained "dead." These methods make it possible to reconstruct specific details of the monuments reviewed and furthermore, they clearly reveal how much of this ancient knowledge and the methods have been completely lost to the detriment of "history" and the present.

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Riassunto. — Questo lavoro vuole illustrare e sottolineare l'importanza che hanno i materiali lapidei artificiali utilizzati nella storia dell'uomo, per la comprensione e la divulgazione della storia stessa. Lo studio dei materiali artificiali, come le malte, gli intonaci, le ceramiche ecc., confezionati dall'uomo, nel corso dei secoli, utilizzando materiali naturali, restituisce ad oggi, la storia dell'arte del suo confezionamento, le tecniche utilizzate, il materiale reperito per realizzarlo, fornendo una "Cultura del materiale" fondamentale per il "ruolo storico" e il recupero delle Opere d'Arte.

In questo caso specifico sono stati presi in considerazione alcuni esempi di malte storiche antiche utilizzate nell'area fiorentina. La sola analisi petrografica è stata in grado di fornirci una serie dettagliata di informazioni, tali da permettere una ricostruzione particolareggiata delle modalità di realizzazione. Le analisi scientifiche insieme ai dati ricavati dalle fonti storiche raccolte, hanno dato voce ai materiali che altrimenti sarebbero rimasti in silenzio. In questo modo è stato possibile ricostruire la storia dei monumenti presi in considerazione, mettendo in risalto inoltre, come ad oggi certe antiche conoscenze e metodologie siano andate completamente perdute a discapito della "storia" e del recupero di questa.

Key Words: *ancient mortars, characterisation, history, Material Culture.*

The importance of the material culture

There are many sources that give us the possibility to study the history of humanity: written texts, findings at archaeological excavations such as bones, pottery, the building structures etc. In particular the study of the findings like**,** bricks, building mortars, plasters are interesting because they still preserve not only their shapes but also the materials and the technologies developed by the early masons. The more the data we can obtain from these findings, the more we can learn about our past and acquire information useful for the conservation of our Cultural Heritage.

Issues concerning the conservation of building materials, is focus mainly on natural stone and Florence, with regard to this aspect, is surely very respectful. For instance unbelievable efforts are made to preserve (rather than replace) seriously decayed architectural and decorative elements in *Pietra Serena* (local sandstone), with very aesthetic good results.

On the other hand, artificial stone materials and particularly the mortars, are generally neglected or overlooked. In Florence this is borne out by the frequent practice of removing the lime renders and preparing them a new, even when their state of conservation is good.

That lack of care and interest in materials such as mortar may be due to the "humble" aspect, the fact that it is only an "auxiliary" in erecting a building, such as masonry mortars or a protective medium (like plaster). Actually the archaeometric analysis of these materials provides lot of interesting information about the technologies to produce them, their evolution over the centuries and more generally on the history of a given building. Removing or hiding them under new plaster has consequences that are even more serious than the replacement of stone ashlars or decorations, because a stone hardly contains the amount of information that can be obtained from a material made entirely by man and not only quarried, shaped and carved. The extreme consequence of this practice is the loss of the building's identity.

In some cases, for examples when the mortar joints of the masonry are removed or sealed, the image of the object is preserved but we lose the original material comprising the object. Concerning this, we should emphasise that the use of modern hydraulic binders can cause severe aesthetic and mechanical damage to the wall surfaces. In other cases the entire original image of a building is lost, for instance when a rendered façade is completely replastered or painted with products that form films; the end results are severe aesthetic damage and loss of information on the "Material Culture".

A negative aspect of the technological revolution of the XIX century was to consider as primitive, not reliable, everything that would be based only on the empirical experience without any scientific background. As a consequence of this way of thinking, the handicraft traditions were forgotten, with an interruption in transmission of the knowledge.

For instance recent studies (Beruto *et al*., 2003), have emphasized that the presence of water vapour inside the kiln, plays an important role in the quality of the lime itself. In fact air hardening limes of poor quality were produced from the beginning of the XX century, when the old wood-burning kilns were abandoned to "improve" the production cycle. The result was lime lacking the moisture that came from the fuel (wood). The moisture contributed to developing a microstructure that guaranteed good binding characteristics. However, water vapour is not the only variable because there are many other factors which play a role in the raw material-production-use cycle and that influence the ultimate quality of the lime binder.

Therefore, it is evident that studies on the good performance of some ancient mortars, as Tiziano Mannoni maintains, would not only answer historical question but would provide important information with respect to present needs: "*good lime mortars are basic for the maintenance, preservation and restoration of all pre-industrial buildings. Their production is actually less expensive, requires less energy and is less polluting compared to modern hydraulic binders"* (Mannoni, 2000).

The real challenge is to reproduce the old "recipes", and this will provide important scientific information about the old mortars, once made by skilled craftsmen.

The early raw materials used in the Florentine area

Past studies have characterised ancient mortars of historical buildings and statues in the Florentine area. The data showed that in the mixture preparation, the main factors were the choice of raw materials (Fratini *et al.*, 1994) and the production techniques.

Research in archive documents confirms that, in the Florentine area, limestone and sand were procured locally until the end of the XVIII century; the reason was obviously the economic advantage. Sometimes specific products, such as gypsum, were acquired from other areas (Giovannini, 1993).

The limestone used to prepare lime was quarried or was dredged as pebbles from the river beds, but quarried limestone was generally preferred because of its more homogeneous composition. In the second half of XVI century the use of dredged pebbles became more common and it is one of the reasons of the poor quality of the lime produced in Florence in that period.

A local limestone that was widely used to make lime and binder for mortar was the *Alberese* marly limestone that the naturalist Targioni Tozzetti identified as "*pietra da far calcina"* (stone to make lime) (Targioni Tozzetti I, 1768, 13). In Florence the oldest quarries were located in Oltrarno district on the hills between Scandicci and Pozzolatico and around Pistoia. It is important to note the use of different kinds of *Alberese*. The *Alberese* for *calcina forte* (hard lime) was a hard, very fine grained, ash- coloured, marly limestone that was utilised to produce a hydraulic lime. The *calcina dolce* (sweet lime) or lime for plaster, was generally obtained by calcination of pure or slightly marly limestone (Targioni Tozzetti, I, 1768, 14). The *Alberese* for sweet lime was quarried in the outskirts of Florence at Poggio a Querceto.

Targioni Tozzetti also speaks about *calcina per imbiancare* (lime for whitewashing) obtained by burning calcareous and sulphate rich evaporitic rocks, and *Bianchetto* (from Lunigiana) obtained from a stone called "white Marmorino", quarried in this province (Targioni Tozzetti, IX, 1776, 138; X, 1777, 270, 292). In southern Tuscany (Rapolano) *Bianco* was produced by calcinating the local travertine (Vasari, 1568 ed. 1878-1885, I, 1878, 192).

In addition to the *Alberese* quarried around Florence and Pistoia, other stones were used in Tuscany to produce lime, such as pure limestones from Garfagnana, dolomitic limestone from northern (eg. Apuan Alps) to southern Tuscany (eg. Montagnola Senese). Among these materials we should also mention the *Albazzano* from Montagnola Senese (Cavernoso limestone) with its mainly whitish colour and that was called *Spugnone,* in the Pisa quarries (Targioni Tozzetti, I, 1768, 13), still another kind of limestone was quarried near Pisa: *Pietra di Caprona* (Rodolico, 1956).

As to aggregates in Florence, the best and sufficiently clean, mud-free sand from the Arno, was only available upriver, between Nave a Rovezzano and Pontassieve. Because of its torrential regime the Mugnone guaranteed purer and selected materials all along its course.

The advantage of petrographic analyses in the study of ancient mortars

Mortars play an important role in the Florentine Cultural Heritage. They are the supports for frescos, mural paintings, the white renderings of Renaissance architecture, and the masonry mortars.

Some methods of studying ancient mortars, are often inherited from the archaeology (styles, chronotypologies, stratigraphic analysis of the layers) and/or from the archaeometry, other relevant information comes from chemical, mineralogical and petrographic analyses. For example, the mineralogical and petrographic study of the mortar's aggregate, tell us if sand was used rather than crushed stone and if this aggregate was sieved. Moreover, its mineralogical composition gives information on the supply zones. The petrographic and chemical study of the mortar binders gives information on the stone used to make the lime, on the technology used in the manufacturing phases (presence of lumps, charcoal, additives, etc.) and in the burning. Furthermore petrographic analyses makes it possible to evaluate the binder/aggregate ratio which is a relevant datum for many reasons: a large amount of aggregate reduces the shrinkage phenomena of the mixture but on the other hand, increasing the aggregate, decreases the workability,

creating difficulties in setting and a need to add water. This, in turn, leads to an increase in shrinkage and the formation of fissures.

Therefore, it is clear that every analysis (particularly in this case, petrographic analysis) can give us significant information about the manufacturing and compositional elements of an ancient mortar.

On the basis of the data obtained from petrographic analyses, the following section will discuss the defects, characteristics and peculiarities of some mortars from different periods, and used for different purposes.

The mortar used to build the dome of the *Santa Maria del Fiore Cathedral* (Fig. 1) (Brunelleschi 1420-1446) is a "fat mortar" with abundant binder (Fig. 2) where however, no shrinkage fissures can be observed. This means that particular care was devoted to the "curing", keeping the mortar wet throughout the setting reaction. Another fact that can be learned from the observation of the thin section is the care put in to the stirring and the size selection of the aggregate itself which consists of well sorted sand from the Arno river.

In the ancient mortars there are some "fragments" that can be considered and/or confused with the aggregate although their origin is completely different: the so called "white lumps" (Bugini & Toniolo, 1990; Bakolas *et al.,* 1995; Cantisani *et al*., 2002). These fragments are particularly useful with regard to the information we can get about the stone utilised to make the lime and more generally on the production process. In Figures 3 and 4 some white lumps considered as burning relict, namely fragments of limestone not sufficiently fired, can be observed. Their presence is evidence of a technological defect but, nevertheless, makes it possible to recognise that to produce mortar

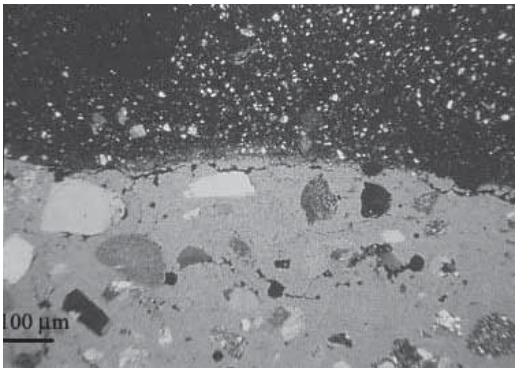

Fig. 2 – Image of the thin section of a masonry mortar from Brunelleschi's dome in the *Santa Maria del Fiore Cathedral* in Florence (25 x, nicol ⊥). Abundant binder, good selection of the aggregate, absence of shrinkage phenomena can be observed. The dark zone is a brick.

Fig.1 – The dome of the *Santa Maria del Fiore Cathedral* (Florence), built by Brunelleschi between 1420-1446.

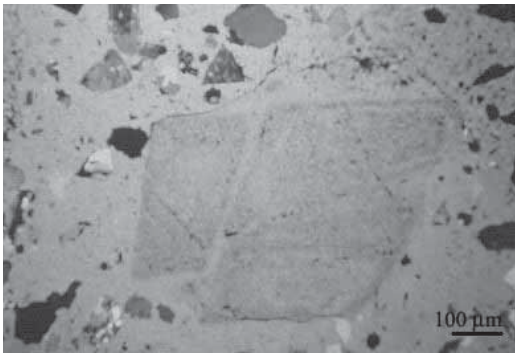

Fig. 3 – Image of the thin section of a masonry mortar from Brunelleschi's dome in the *Santa Maria del Fiore Cathedral* in Florence (25 x, nicol ⊥). Presence of a "burning relict" related to *Alberese* limestone.

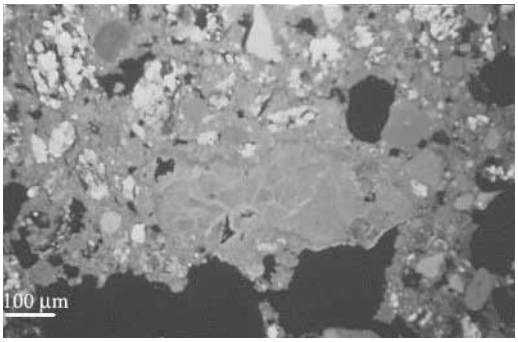

Fig. 4 – Image of the thin section of a masonry mortar from the bell tower of *Pietrasanta Cathedral* (Lucca) (25 x, nicol ⊥). Presence of a "burning relict" related to a marble.

(from Brunelleschi's dome - Fig. 3) the *Alberese* marly limestone was burned; while the lime used in the mortar (Fig. 4), from the bell tower of the *Pietrasanta Cathedral* (end XV-beginning XVI century - Fig. 5), was made by burning marble.

The mortar of a plaster coming from *Palazzo Davanzati* in Florence (XIV century - Fig. 6) shows a high amount of aggregate which nevertheless did not prevent the development of remarkable

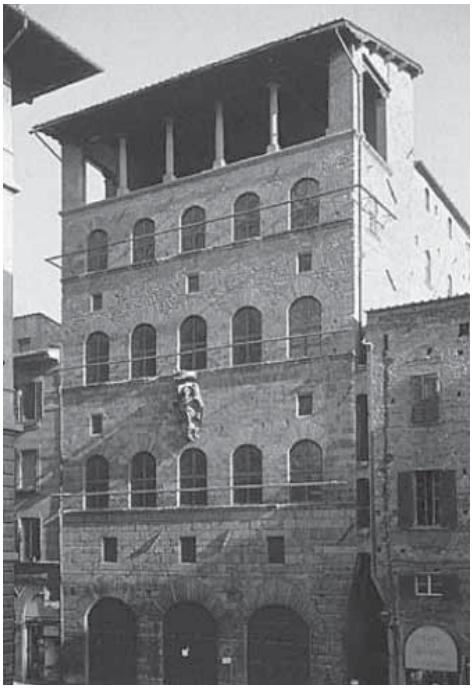

Fig. 6 – *Palazzo Davanzati* (Florence), XIV century.

Fig. 5 – *Pietrasanta Cathedral* (Lucca), built between the end of the XV and the beginning of the XVI century.

shrinkage fissuring (Fig. 7). This phenomenon can be explained by the lack of care in keeping the masonry wet during the setting. However poor quality lime perhaps obtained by burning too marly limestone and therefore lacking in sufficient binding properties, may also be a contributing fact.

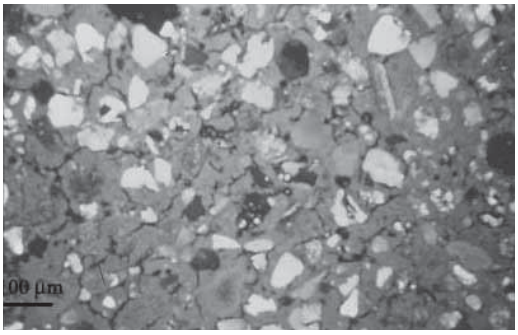

Fig. 7 – Image of the thin section of a plastering mortar from *Palazzo Davanzati* (Florence) (25 x, nicol ⊥): high amount of aggregate and the remarkable shrinkage fissuring.

The *Apennine's Statue* by Giambologna (second half of XV century, Fig. 8), an example of Florentine Mannerism in the park of *Villa Demidoff* in Pratolino, near Florence, is a huge statue made of bricks and covered by plaster and spongy limestones. In Figure 9, which shows a masonry mortar, a "lump of lime putty", namely a portion of slaked lime which hardened before the setting because it came in contact with the air, can be seen.

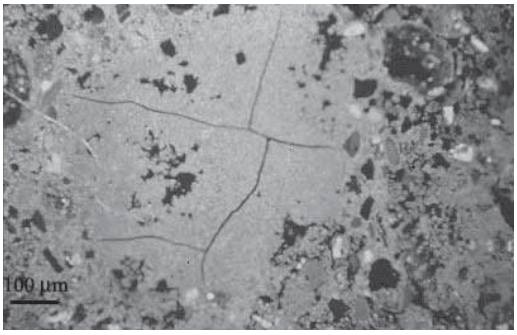

Fig. 9 – Image of the thin section of a masonry mortar from *Apennine's Statue* by Giambologna (25 x, nicol ⊥). Presence of a fissured "lump of lime putty".

In this case the petrographic study of the aggregate, also revealed how mortar debris was "recycled" and used as aggregate. In Figure 10, some fragments of old mortar are clearly visible.

The *Fortezza da Basso* (Fig. 11), designed by Antonio da Sangalllo the younger, with the help of Pier Francesco da Viterbo in the XV century, a monumental building with a pentagonal plan, is a splendid example of a brick Renaissance architecture. It is characterised by imposing ramparts with scattered turrets, narrow galleries, and hidden passages. From a masonry mortar of this building, it is possible to recognise the

Fig. 8 – The *Apennine's Statue* by Giambologna in the park of *Villa Demidoff* in Pratolino (Florence), second half of XV century.

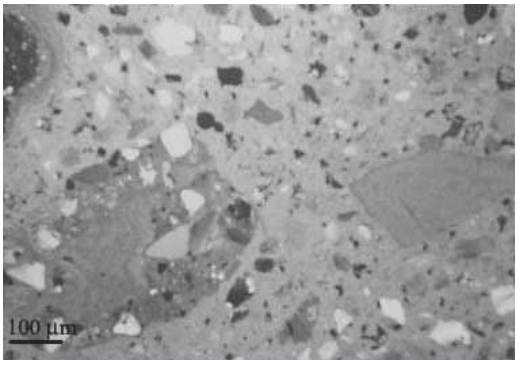

Fig. 10 – Image of the thin section of a plastering mortar from the *Apennine's Statue* by Giambologna (25 x, nicol ⊥): presence of a fragment of a reused mortar.

Fig. 11 – *Fortezza da Basso* (Florence, XV century).

presence of lumps (Fig. 12) derived from portions of lime hydrated and carbonated during the setting. Their presence can be dangerous for the masonry because the reaction takes place when the mortar is already hardened giving rise to strong stresses inside the material. This indicates a lack of care during the slaking of the lime perhaps due to overly big clods of lime.

The examples discussed, show two types of mortar present on the Florence dome Cathedral. The first is a mortar with abundant binder, a well sorted aggregate coming from river sand (Arno river), good manufacturing and state of conservation, typical of the handicraft traditions of the XV century. The second mortar is characterised by particular technological defect, namely the presence of burning relicts (not burned limestone fragments). These defects show that the raw material used to produce the lime was the *Alberese* marly limestone (*calcina forte,* hard lime), according to the Florentine tradition (Targioni Tozzetti I, 1768, 13).

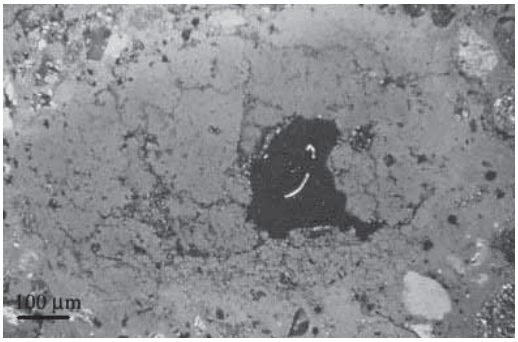

Fig. 12 – Image of the thin section of a masonry mortar from the *Fortezza da Basso* (Florence) (25 x, nicol ⊥). Presence of a lump derived from portions of lime hydrated and carbonated during the setting.

However the same defects present in the mortar of the bell tower of the *Pietrasanta Cathedral,* show that the stone used to make the lime, was a marble, from the Apuan Alps, used because it was available nearby and, hence, less expensive.

In the plaster mortar of *Palazzo Davanzati* poor manufacturing and poor quality of lime are clearly visible. With the regard to lime we have to recall that in the XVI century the use of dredged pebbles became common and not enough care was devoted to the selection of the limestone, both because limestone pebbles are not frequent in the Arno and Mugnone beds (therefore they took all the various kinds of limestone pebbles) and also because weathering makes it difficult to recognize the quality kinds of limestone materials. This is one of reason for the poor quality of the lime produced in Florence in that period.

The two mortars examined from Giambologna's statue show strong differences: a masonry mortar with lime lumps, the consequence of a lack of care during the setting, and in a poor state of conservation; a quite well-made plaster mortar with an aggregate consisting of reused fragments of old mortars (typical of the Renaissance period).

The masonry mortar of the *Fortezza da Basso* is characterised by lumps that can be referred to fragment of quick lime originating from a lack of care during the slaking of the lime itself. Indeed the presence of fragments of quick lime in the binder, is very dangerous because the reaction of hydration and carbonation in the hardened mortar, causes the disaggregation of the mortar itself.

Conclusion

The petrographic analysis of the ancient mortars can provide important information of historical interest, about technologies used in the past in their production, human skills, mistakes, and technical "tricks".

The skilled Florentine craftsmen of the XIV-XV centuries produced mortars with different

characteristics but always used *Alberese* marly limestone as the stone to make lime. Masons in other provinces used other materials, such as marble, from the Apuan Alps, in the mortar for the *Pietrasanta Cathedral*. The aggregate was often constituted of fluvial sand (Arno river) with a good granulometric selection, or sometimes fragments of old mortars. The dosage between aggregate and binder was the responsible cause of any shrinkage fissuring. White lumps of lime were often present due to a lack of care in manufacturing.

Some mortars (see Brunelleschi's dome of the *Santa Maria del Fiore Cathedral*) have reached to us in perfect conditions of conservation. Understanding their behaviour can be of practical interest for producing good traditional binders to be used in restoration and as well as also in the modern buildings according to the old traditions of the Material Culture. Other mortars, such as the mortar of *Palazzo Davanzati*, are in a poor state of conservation. They must be studied to understand the causes of the alterations.

In conclusion we must emphasize the importance of the study of the ancient mortars. Furthering our knowledge about their properties and characteristics, how they were produced and how they have withstood the centuries, in all old building- and not only monuments- will satisfy the historical curiosities and have significant, positive impact with respect to current need.

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