

# The Cluny Priory of Castelletto Cervo (Biella, Italy): Archaeometric Study of Mortars

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**Abstract** – The Cluny Priory of Castelletto Cervo (Biella, Piedmont) was deeply investigated from 2006 to 2014, in a multidisciplinary project. This contribution deals with the methodological approach followed for the archaeometric study of mortars, and the results in term of material knowledge and reading of the building phases in a time interval of about a millennium.

Petrographic observations combined with microchemical data showed that the local raw materials were exploited during a very long time span: the aggregates are polygenic sands, with a high percentage of volcanic rock grains, coming from the hydric basins of the Cervo River, and its tributary Ostola; the binders are mainly Mg-bearing limes lime, with a strong hydraulic component due to the reaction between the binder and the volcanic grains of the aggregates. A good match between mortars composition and building phases was determined only for some of the earliest phases of the monastery.

## I. THE SITE AND THE ARCHAEOLOGICAL QUESTIONS

The Cluny Priory of Castelletto Cervo (Biella, Piedmont) has been the object of a long-term and multidisciplinary research Project (2006-2014), led by the Humanities Department of the Eastern Piedmont University (under the direction of Eleonora Destefanis). Results have been recently published in a volume [1], where the research is illustrated in many aspects. In this contribution some of them are highlighted, notably concerning the archaeometric study of mortars.

The complex is located at around 25 km north of Vercelli, on the edge of a relief that appears to be a few meters higher than the surrounding plain; the landscape is

still characterized by extended moorland areas, as it was in the past. Not so far, and just beneath the Priory, the water stream Ostola joins the river Cervo, that flows at the foot of the relief.

Firstly mentioned in 1092 as already established (likely founded in the last quarter of the 11<sup>th</sup> century), the St. Peter and Paul monastery developed and implemented his ownership at least until the first half of the 13<sup>th</sup> century.

Then, the whole region was marked by a long period of troubles and wars involving the monastery too, which the written sources attest as abandoned by monks, who left for the safer dependency in Carpignano (Sesia Valley).

Only from the end of the 14<sup>th</sup> century and above all in the 15<sup>th</sup>, the monastery's development recovered, but this lasted very shortly: in fact, over the 16<sup>th</sup> century, it was permanently abandoned by the religious community, and, at the end of the same century, converted into a parish church, a function that the site has been keeping up until the present days.

The complex counts several buildings (Fig. 1), which, according to the stratigraphic analysis carried out on the masonries in the framework of the research project, belong to different phases, all over the Middle Ages [2]. A quite wide archaeological excavation, alongside this work on the existent structures, has allowed archaeologists to identify the main construction periods and to find out the most important steps in the development of the complex.

The site was occupied and dwelled at least since the Early Middle Ages (Period I), as documented by a group of graves, dating from the later 9<sup>th</sup>-10<sup>th</sup> century, and a possibly more ancient workshop for metal production. In the monastic period, the church, the first building realized, displays two main phases (Period I, phases 1a and 1b).

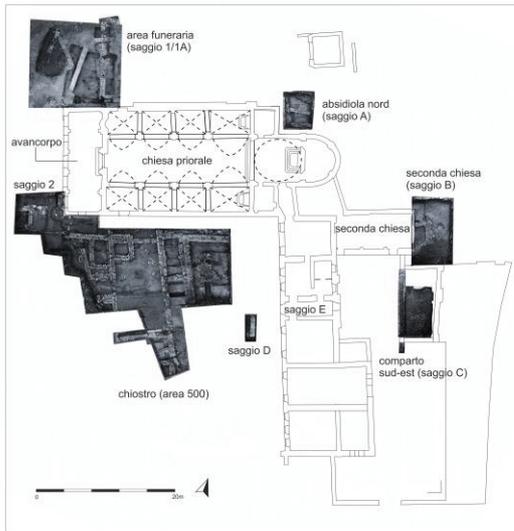


Fig. 1. Plan of the complex with the excavated areas. (after [1])

The oldest part of this three-aisled and three apses building, is the Eastern one, while the Western one belongs to a later moment: it not necessarily deals with a different phase, but rather with a recovery in the framework of a long-time constructing work, which is very common in the architectural medieval practice.

The façade displays decorated single-lancet windows and an originally painted single portal placed at the center. A bell-tower rises on the last bay of the southern aisle.

In the area south of the main church, in the first half of the 12<sup>th</sup> century, a cloister was built (Period II, phase 2), of which the eastern and western walks are known: the former is still preserved, although very transformed, while the latter has been brought to the light during the excavation.

A further development of the monastery took place in the second half/final decades of the same century, when a second single-aisled church, which apse was found in the excavation, was built against the cloister's Eastern building (Period II, phase 3). This church, documented by later written sources as consecrated to St. Mary, represents an important moment in the monastery's history, bearing witness to a characteristic and widespread architectural feature in the Cluniac world, associated to specific liturgical functions, as recent studies are underlining.

Finally, at the beginning of the 12<sup>th</sup> century, the last special building for the Middle Ages was added to the complex: a westblock is built against to the church's façade (Period II, phase 4). It is originally a one stored building, but in the second half of the 14<sup>th</sup> century a new two-stored room was erected on it, which gave the church a new, monumental façade (Period III, phase 1).

Its original functions are so far unknown, even tough,

again, the inclusion of this site in the Cluny milieu might most probably suggest its use as location for liturgical station and an in-between space, sat between the cloister, reserved to the monks, the main church and the outside world.

Furthermore, in the same construction phase, at the beginning of Duecento, another still preserved store was added to the bell-tower (Period II, phase 4), having three-mullioned windows per each side, which open on the surrounding landscape.

The most ancient construction phases show a consistent use of pebbles as main component in the masonry, bound by abundant mortar [3]. The squared stonework is used in a very careful and selective way, limited to the mouldings elements (such as arches and piers) as well as, generally speaking, to the most important structures from the statics point of view.

The most ancient masonries, apart from a very few exceptions, are very rarely enhanced by the insertion of bricks, usually of reuse. Only with the construction of the westblock, the building technique changes significantly, and the association brick-squared stone becomes more and more evident. The latter, moreover, comes from different areas in relation to the previous period, as a possible result of a change in the workshops operating in the westblock's construction site.

The elaborated reconstruction of the several architectural phases as well as the use of different materials and building techniques open several avenues of research, for example, as mentioned above, with regard to quarries and places of stone's provenance, the organization of workshops and their relationships with the monastic patronage. The archaeometric study carried out on bricks (in the framework of the international research Project *Terres cuites architecturales et nouvelle méthodes de datation*), stones, mortars, platters, has provided a very consistent contribution to the studies on these topics.

In the present contribution, we will point out the importance or the archaeometric study of mortars in the interpretation of the stratigraphic analysis of masonry.

## II. MATERIALS AND METHODS

Sampling was done on different areas of the building complex, in order to include all the main building phases identified through the archaeological analysis of masonry. In total, 150 mortar samples were taken from the still preserved walls of the buildings, and the time span ranges from the 11<sup>th</sup> century to modern times. Each sample was accurately recorded, including a photographic documentation to individuate the actual location of the sample; a description of the building's portion pertaining the sampling; a description of macroscopic features of the sample.

Samples of a few centimeters in size were represented by bedding mortars taken from pebbles or bricks rows. All of

them were observed under the stereomicroscope, for a description of macroscopic characters (color, mineral composition, texture).

The cohesion was qualitatively evaluated on the basis of UNI 11176 (2006) recommendation, a guideline for mortars description. A selection of mortar samples was made for realizing thin sections for microscopic analyses and microchemical measurements, aiming at defining textural and compositional parameters of both aggregate and binder in relation to a specific building phase.

Petrographic analyses were carried out by using a Leitz Laborlux polarizing microscope, equipped with a digital camera. Petrographic observation were devoted to determine the binder/aggregate ratio, and to characterize the aggregate in term of abundance, grainsize, sorting, grain shape, rounding, texture, and mineralogical-petrographic composition. Specific attention was also focused on reaction rims on the aggregate grains, due to physico-chemical reaction between grains and binder.

Further analyses were done by Scanning Electron Microscopy (SEM). Thin sections were prepared by polishing with abrasive diamond pastes decreasing in grain size (6, 3, 1, 0.25 microns), then C-coated or Au-sputtered by using a sputter coater.

SEM observation allowed to investigate the microtextural features of the binder, and the Energy Dispersive Spectrometer, which the SEM is equipped with, completed textural information with microchemical compositions.

Details on the instrumentation and the methodological approach used in this research, as well as data, are reported in [4].

### III. RESULTS AND DISCUSSION

According to their macroscopic features, mortars displayed differences in the degree of cohesion, the majority of them resulting good, other brittle, and a few incoherent. All mortars are characterized by a very abundant aggregate, the nature of which composed by quartz-feldspar grains.

#### A. The aggregate

Petrographic characters of mortar samples were observed on thin sections under the polarizing microscope.

In all the analyzed samples, aggregates showed a similar modal composition, which may indicate a common origin. The aggregate density varies between 40-50% in almost all mortars (Fig. 2A-B), and grains have inorganic nature (e.g., minerals and rock fragments), except for sporadic carbon fibers. Rounding of grains goes from angular to sub-rounded, with angular and sub-angular grains highly represented. Shrinkage around grains is quite frequent, and is due to the volume reduction of the binder during the hardening.

The aggregate's sorting is little variable and ranges from moderately to poorly sorted, indicating the use of a low mature or an unselected sand as aggregate. Grainsize varies from fine to very coarse, in the range between 0.125 and 2mm, rarely higher than 3mm (Fig. 2B).

The aggregate is a polygenic assemblage, composed of a both minerals and rock fragments. The most represented mineralogical phases are, in order of frequency: alkali feldspars (orthoclase and microcline), plagioclase, micas; less represented result heavy minerals, as ilmenite and amphiboles. Very common are instead volcanic rock fragments, characterized by a microcrystalline porphyric

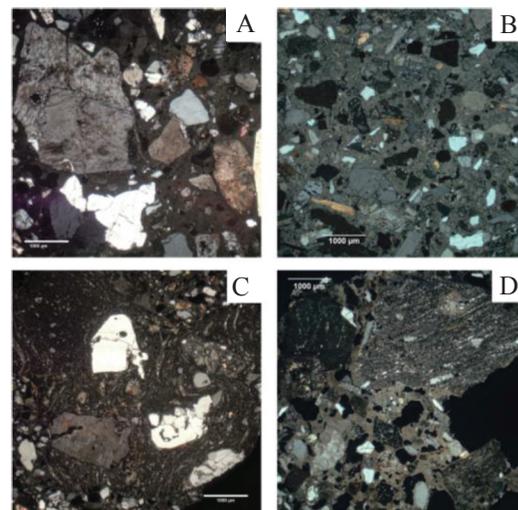


Fig. 2. Micrographs of mortar samples: A) typical texture of petrographic Group 2; B) texture of petrographic Group 3; C) volcanic rock fragment with porphyric microtexture; D) volcanic rock fragment with eutassitic microtexture. (after [4])

texture with phenocrysts (i.e., plagioclase and feldspars) (Fig. 2C), alongside volcanic rocks with eutassitic textures (Fig. 2D). Usually, volcanic fragments are heavily altered. Less frequent are coarse-sized acidic intrusive rocks, composed of quartz, biotite, feldspars and plagioclase, and metamorphic rock fragments, represented by schists, mainly composed of quartz and muscovite. A very few, large “cocciopesto” fragments have been also detected, but not as an intentional addition as pozzolanic materials.

According to mortars fabrics, four fabric groups were identified. Differences among the groups are subtle, and mostly related to aggregate grainsize abundance. No direct relations between groups and building phases were found, except for Group 1, which is represented by samples taken from the priory church, and hence representative of the oldest building phases.

What is interesting in term of the aggregate, is the use of materials determined on the basis of grains petrography. In fact, the petro-mineralogical assemblage has an alpine origin in all samples, from all building phases. Volcanic

rock fragments display common features with the Permian volcanic rocks associated to quartz porphyry outcropping north-west of Gattinara (Vercelli) [5]. Fragments of granitic rocks may be associated to the granites of the “Serie dei Laghi”, whereas the micaschists are related to the “Serie Sesia-Lanzo”, intruded by the Valle del Cervo pluton [6].

The variability in term of degree of roundness and petro-mineralogical composition indicate a local provenance, possibly from an area very close to the confluence between the Cervo River and their tributaries Ostola and Strona [5]. The Cervo River run through the gneiss and micaschists of the Unit Sesia-Lanzo, the granites and sienites of the Valle del Cervo pluton, and the rocks from the Dioritic-Kinzigitic formation. The Ostola and Strona streams run, respectively, through the Permian volcanic rocks of the quartz porphyry in the north-west, and the Permian granites of the “Serie dei Laghi”. The Cervo River and the Strona stream merges few kilometers north of the Cervo and Ostola confluence, explaining the simultaneous occurrence of intrusive and effusive rocks [7,8].

### B. The binder

The binder is extremely inhomogeneous even in a single mortar sample, in term of both microtexture and elemental composition analyzed by SEM-EDS (refer to [4] for analytic results). Lumps are scattered all over the binder, and they show different shapes, sizes, and optical features. The elemental composition of lumps was investigated with the intent of collecting information on the composition of the raw materials used to produce the binder, and the possible addition of additives enhancing the reaction binder/aggregate during hardening.

Observations under the polarizing microscope revealed that the binder is made of cryptocrystalline carbonate minerals, sometimes organized in aggregates. SEM-EDS analyses displayed that these minerals are very small particles, a few microns in size, of calcite ( $\text{CaCO}_3$ ) and magnesite ( $\text{MgCO}_3$ ), possibly associated with hydromagnesite ( $\text{Mg}_5(\text{CO}_3)_4(\text{OH})_2 \cdot 4\text{H}_2\text{O}$ ) (Fig. 3). Magnesium occurs in almost all the binder analyzed, but its content varies with respect to calcium values. The levels of magnesium seems to have also a role in determining the binder crystals morphology and their

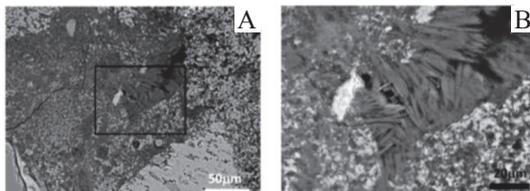


Fig. 3. BSE images of the binder's microstructure: A) microtexture showing the separation between calcium and magnesium mineral phases; B) detail of the needle-like magnesium phases (periclase). (after [4])

textural features. The peculiar microstructures observed might be represented by clusters of calcium and magnesium carbonates, with a low crystallinity index [9]. Where magnesium levels are higher, microtextures appear more compact increasing mechanical strength and durability of the mortar.

On the basis of CaO/MgO ratios calculated for lumps, three types of binder were determined:

- a. CaO/MgO~1
- b. CaO/MgO~2
- c. CaO/MgO~3

The majority of samples dating to Period II fall in types a and b, but a further distinction was done on the basis of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , and FeO contents. These elements in lumps can give some information on the contribution of a clayey component either naturally present in limestone or intentionally added. Considering the average sum of these three oxides, most of the samples showed values <20wt%, whereas a very few of them range between 24 and 37wt%.

Binder type c counts few samples, belonging to both Period II and III, with  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , and FeO contents variable in the range between 16.7 and 30.9wt%.

These data and the CaO/MgO ratio calculated according to lumps elemental composition, allowed us to hypothesize the use of a Mg-limestone as raw material for the production of binder. Binder and lumps compositions fall in the compositional field of Mg-limestone. The variability in the content of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , and FeO might be explained by the exploitation of limestone layers with a marl component. All these characteristics bring to the limestone outcropping in the area of Sostegno (Biella), in the Alpine foothills north/north-east of the monastery, where the Triassic dolomitic limestone were historically exploited for lime production [5].

It is worth to be noted that contents of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , and FeO seem to be significantly higher in binder rather than in lumps, giving the binder a strong hydraulic component. The increasing values in the binder can be explained by the formation of C-S-H phases [10] following the reaction between the volcanic grains in the aggregate and the carbonate binder, as demonstrated by their presence in the reactions rims around volcanic rock fragments. These phases are almost amorphous and strongly increase the strength properties of mortars.

The combination of Mg-bearing binder and aggregates with hydraulic properties play an essential role in the production of mortars with high mechanical strength, especially in a humid environment [11].

## IV. CONCLUSIONS

Given the high degree of inhomogeneity of mortars, grouping specimens collected by a systematic and accurate sampling may increase the degree of uncertainty. At the same time, however, this work highlights a methodological question.

Oldest building phases are well distinguished, with slight differences regarding textural features, which allow to well distinguish Period II, while after Period II data appear quite homogeneous, even on a long time interval. In Period II, the westblock appears to be very coherent with respect to the following phases in terms of building technique, materials (brick and squared stone), and mortars.

Particularly intriguing are the information about the exploitation of local raw materials (sands and limestones), inferred by material analyses. The ideal location of the Priory in an area marked by the presence of three water streams, bringing sands resulting by the erosion of different rocks, and at foot of the Alpine foothills, with precious limestone quarries, is totally reflected in the petro-chemical composition of mortars. The petro-mineralogical composition of the aggregate demonstrates a long-lasting persistence in the exploitation of the river basins, especially in term of sands for aggregates. This study highlights also working techniques (e.g., possible grinding of aggregate materials) and the ability of grainsize selection according to the specific use of mortars.

As for the binders, the exploitation of dolomitic limestones from the Sostegno area is plausible, and noteworthy, concerning a territory where land properties of the monastery are attested. This means that the monastery tended to collect quality supplying materials in location belonging to its patrimony, as it is equally well proved for the squared stones, coming from the Sesia Valley (notably in the Period II, phase 4: westblock). Besides, a transportation net was required for moving the materials from the quarry to the building site. Thus, the role played by the monastery in the transfer of the necessary construction materials was extremely important.

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