AN INTERDISCIPLINARY APPROACH FOR THE HISTORICAL AND TECHNICAL CHARACTERIZATION OF MEDIEVAL AND MODERN MORTARS

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1. Introduction

Historical masonries are normally affected by a process of more or less deep natural weathering, but a further process of mechanical deterioration can occur if the masonries are located within a geologically seismic context or an area affected by tectonic instability. In this case, great care has to be taken in choosing the most suitable restoration interventions only after a detailed analysis of the historic materials to be repaired has been made. It is known that, owing to its geological history, almost all of Italy has a medium-high level of seismic hazard which may result in severe damage to its abundant and rich archeological heritage.

The study, in progress from April 2019, concerns Italian masonries and focuses on the historical, medieval and modern mortars in the Piedmont region, Po Valley, Latium, Umbria-Marche areas, and Apulia and Sardinia. The project (Progetto Grande di Ateneo 2018 – Sapienza University of Rome[1]) aims at improving our understanding of historical mortars in order to learn more about how to conserve the historical mortars used in built heritage, especially in seismic risk zones, together with their hydraulic characteristics. To achieve these results, we will perform analyses on selected samples to investigate to what extent different mechanical and cohesion properties affect the vulnerability of the ruined or collapsed structures.

Thanks to this information it will be possible to make advances in preventive measures, maintenance, protection and the preservation of historical buildings by:

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1. Improving the study of historical technical know-how on how to build complex structures, and on their vulnerability and maintenance.
2. Discerning material deterioration processes and instabilities caused by the masonry itself.
3. Identifying suitable tests and procedures for verifying statics.
4. Recognizing effective techniques for consolidation and conservation, prevention and degradation deceleration.
5. Planning a multidisciplinary analytical protocol for the characterization of masonries and mortars.
6. Organizing survey-derived information and other results in an open GIS database system.

Further details will concern the history of construction techniques, with particular regard to the relationship between local resources and construction sites. Another important topic will be the role of different components and additives used in the preparation of the mortars and their level of hydraulicity.

The materials will be studied both in situ and in laboratory, on different observation scales: the territory, the buildings, and the materials. All the information will be aimed at studying the construction materials and their areas of provenance, analyzing different building and executing techniques, including different degradation processes in historical structures. These mechanical and chemical-physical analyses, combined with an aesthetic and conservative assessment of surface finishes, are fundamental in identifying the mechanical properties of masonries and mortars in order to carry out their conservation and restoration.

2. The aim of the project

The project consists in collecting, producing, organizing and disseminating – through scientifically controlled sharing – the data related to the multiple components which characterize traditional medieval and modern mortars. The aim is to highlight the differences between the ways of crafting and using mortars depending on the raw materials available. The study will be carried out on both poor and rich architectures belonging to different regional areas. The comparison will allow – also through scientific investigations – to better recognize the specificities and the different features that have significant consequences, firstly on structural behaviour, with reference to the tensile strength, and secondly, on the cohesion capacity of the mortar [1-5].

Special attention will be given to samples taken from ruins which were damaged or collapsed after the seismic events of 2012 and 2016, in order to contribute to further the study of mortars in areas of risk and to test if and how the different characteristics and mechanical properties of the aggregates and binders (by controlling their performance) could influence the vulnerability of structures located within the same geological setting.

This operation will make it possible to identify specific chronological indicators useful for recognizing masonry techniques and will have obvious repercussions on the history of construction techniques, local resources, and construction sites. This research will contribute to better define the history of the territory, to clarify the role of organic additives (proteins, fats, etc.) and to assess the hydraulic characteristics of mortars according to the different components (fillers, lime, etc.) [6-14]. On a practical and operational level, the research will provide useful information for the prevention, maintenance, protection and conservation of historic buildings.

The methodological structure of the project is laid out primarily in the bibliographic and documentary research and metric and material survey with analyses of the masonries of specific study cases to be performed with direct and indirect surveys. The surveys will allow the reading of components, size and position of the elements and wall-unit organization; the ingredients and meshes of the mortars; potential re-used parts; surface treatments and decay. The study will focus mainly on the interaction between organic and inorganic materials, with particular attention given to the presence of additives and mortar composition.

The innovative features of the research consist in providing and sharing information of a highly scientific and historical content. Decoding the information contained in the buildings – in their constitutive materials and executive techniques – is a fundamental process that broadens the historical-technical knowledge itself and leads to the awareness that every element, such as a fragment of plaster or trace of colouring, will provide further knowledge about building techniques and a guide to conservation and restoration actions both in prevention and in intervention. The acquired knowledge will subsequently be collected in guidelines or in a compendium of the consolidation and preventive restoration interventions, according to an analysis of the damage and the definition of a list of priorities. Firstly, the design of compatible materials for the rehabilitation or improvement of performance, and subsequently, the development of new 'sustainable' mortars, produced with low energy impact and high performance.

Although a vast historical and contemporary bibliography exists, it can be added to and improved, both in the field of historical technical literature, regarding the most recent updates in archaeometry and in understanding different ways of processing, disseminating and exploiting the specific technical knowledge in the territories under examination.

3. Description of the project in progress

In the Umbria and Marche regions, we started by classifying the types of masonries with low lime mortars and earthen-clay components. The study includes the late-medieval brick structures recently excavated in the archaeological area of the abbey of Santa Croce di Sassovivo in Foligno and the masonries of the crypt and basement of the church of Santa Maria di Plestia in Colfiorito. Other case studies have been identified in the cities of Assisi, Foligno, Gubbio, Narni, Sangemini, Spello and Spoleto and in the localities of Massa Martana and Montecastrilli, in Umbria. In the Marche region, near Ascoli Piceno (Arquata del Tronto and hamlets), the samples show a low-lime mortar with components of terrigenous and/or clayey origin, which degrades over time, losing cohesion and binding capability. In the regions of Lazio and Apulia (Salento area), the study will focus on mortars with aggregates made mostly of *pozzolana*, *cocciopesto* and *bolo* ('red soil'), and mortars with aggregates deriving from the grinding of local stone.

3.1. A case study: the mortars of the abbey of Santa Maria di Cerrate (Lecce, Apulia)

The interdisciplinary study on the Cerrate complex masonry structures represents a tentative analytical approach which could become a standard procedure for the knowledge, restoration and conservation of historic buildings (Figure 1)[2]. The study includes techniques ranging from a macroscopic reading of the type of masonry, and architectonic and construction characteristics, to a microscopic, petrographic, and chemical reading of the composition of the mortars.

Figure 1. The Santa Maria di Cerrate complex.

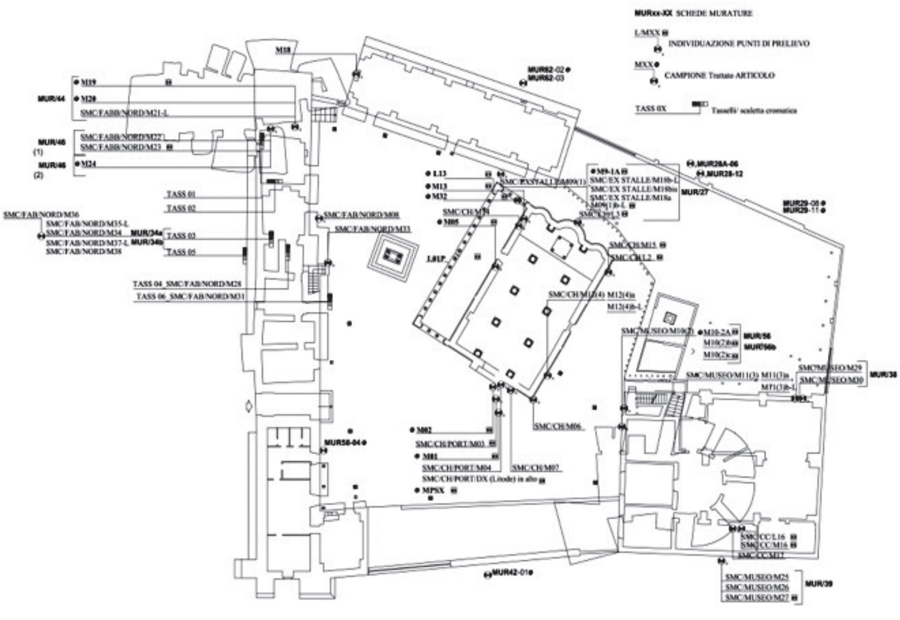

Figure 2. Topographic sketch map of the complex of Santa Maria di Cerrate.

3.1.1 Macroscopic reading

A macroscopic reading may contribute to the scientific knowledge of ancient mortars in terms of mechanical characteristics and the historical background of their production. Analyzing mortars from different historical periods helps to identify the various types of mixture and production techniques, and to evaluate their state of preservation.

The masonry of the medieval buildings of Cerrate is characterized by the use of square blocks of local limestone of different quality (*calcarenite*). The medieval mortars display a predominantly carbonate binder with aggregates consisting mostly of carbonate bioclasts and lithoclasts.

The mortars that make up the wall structures of the church (12^{th} and 13^{th} century) and of the *masseria* (16^{th} century) are generally composed of lime and red siliceous soil or *bolo*. Therefore, the composition and the mixtures used for the mortars often constitute important chronological indicators (Figure 2).

3.1.2. Optical microscopy

Optical microscopy is the preliminary approach to studying historic mortars. It is used to observe the texture and structure of the binder (i.e. drying, shrinkage, cracks), the mineralogical composition and character of the aggregate, the binder-to-aggregate ratios and the possible occurrence of fragments of brick, re-used mortar or pozzolanic additives.

Based on the proportion of aggregate and binder, the analyzed mortars were gathered into two main groups which were further split into sub-groups based on the composition and character of the aggregate. The aggregate constituents are represented by silicate grains (mostly quartz and K-feldspar) or carbonate grains (bioclasts, benthonic and planktonic foraminifera, fragments of underburned limestones and occasionally re-used mortar fragments); lime lumps also occur that have been related to either incorrect slaking or incomplete calcination, or poor mixing of lime binder and aggregates (Figure 3).

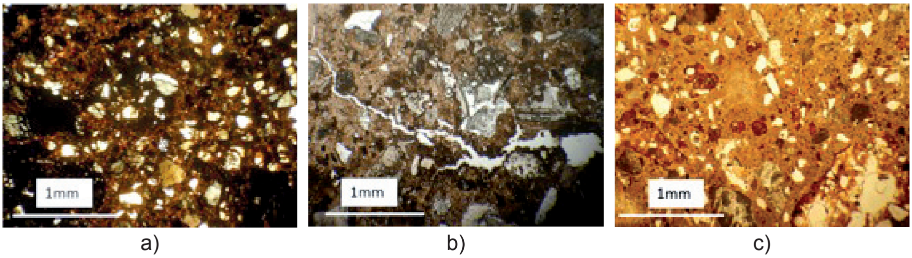

Figure 3. Microphotographs of some analyzed mortars. a) mortar showing siliciclastic aggregate (crossed polars, scale bar 1 mm); b) mortar showing carbonate aggregate (plane polars, scale bar 1 mm.); c) small-sized lumps of silicate material (plane polars, scale bar 1 mm).

An interesting feature is the occurrence of lumps of silicate material on which further investigations are still in progress. The formation of lumps is probably due to an incomplete or incorrect mixture of lime binder and fine-grained silicate phases; their characterization could shed light on the important problem of the hydraulic properties of the mortars.

Based on the chemical-mineralogical composition of aggregates and binder, it was possible to discriminate the medieval mortars (12th-13th centuries) from the post-medieval ones.

3.1.3. Scanning electron microscopy and energy-dispersive spectrometry

Scanning electron microscopy (SEM) coupled with energy dispersive spectroscopy (EDS) provides details on morphologies, microstructures and aggregate components. Moreover, the acquisition of X-ray maps contributes to a better understanding of the elemental composition of the mortar, making it possible to evaluate the more or less homogeneous elemental distribution and abundance, both of binder and aggregate components.

Based on the SEM analyses, it was possible to discriminate a first group of mortars, represented by the medieval mortars, which were characterized by a homogeneous, predominantly carbonate binder, well mixed with a clay-sized silicate fraction and an overall well-distributed carbonate aggregate. The second group, including the post-medieval mortars, was characterized by a prevalently carbonate binder containing a more or less abundant clay-sized silicate component mostly represented by Al-silicates (Figure 4a). This second group, by elemental abundance (Ca*vs* Si) and elemental distribution (Al-silicate material scattered within the binder *vs* gathered as lumps), observable on the X-ray maps, was further subdivided into two sub-groups. The first sub-group includes mortars dated between the 16th and 17thcenturies and exhibits a mixed siliciclastic-carbonate binder containing a scattered clay-sized Al-silicate component whereas the second, represented by mortars dated approximately to the 19th and 20th centuries, displays a predominantly carbonate binder with the subordinate Al-silicate fraction mostly gathered as lumps (Figures 4b and 4c). Our findings suggest that this unusual analytical technique should represent a further discriminating tool.

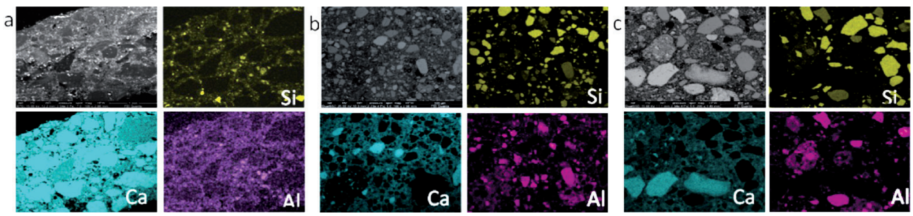

Figure 4. Image and X-ray maps showing elemental distribution.

Figure 4 shows: a) medieval mortars with aggregates composed mostly by calcareous bioclasts (bright turquoise) and a siliciclastic component, definitely subordinate, consisting of fine to very fine grains (mostly represented by quartz) and a clay-sized silicate fraction mixed within the binder (the yellow color represents Si and bright magenta represents Al); b) mortars of the 16th and 17th centuries with the aggregates mostly represented by quartz (bright yellow) and Al-silicates (bright magenta) and subordinate carbonate fragments (bright turquoise color represents Ca). The binder appears to be predominantly carbonate (light turquoise) with a clay-sized silicate fraction, scattered within the binder, mostly constituted by Al-silicates (light magenta color); c) mortars of the 19th and 20th centuries with the aggregates dominantly composed by quartz (bright yellow) and Al-silicates; carbonate fragments (bright turquoise color represents Ca) are subordinate. The binder appears to be predominantly carbonate (light turquoise) with a clay-sized silicate fraction, gathered as lumps, mostly constituted by Al-silicates (light magenta color).

3.1.4. X-ray diffraction

This technique allows the identification of crystalline material on powdered samples; it is essentially used to interpret the mineralogical composition of mortar binders. The choice of Cerrate mortars to be analyzed by XRD technique focused on mortars with a higher silicate content and a more evident reddish coloring, in order to characterize the mineral composition of the red silicate component. However, one difficulty we encountered was the dominance of the carbonate component which almost completely obscured the other phases, as well as the presence of amorphous or non-crystalline materials which can obscure small peaks in certain ranges of the scan. To highlight the detection of silicate material, the carbonate component was first removed from the selected samples by dissolution with hydrochloric acid.

This allowed the small peaks to stand out, making them faintly visible in a certain range of the scan, referable to phyllosilicates of the illite-smectite group and occasionally chlorite. Such a subordinate silicate component probably represents the part of the silicate that was added to the lime binder, together with the aggregate particles, in order to enhance mortar performance. This last assumption is consistent with the qualitative composition shown by the SEM-EDS spectra of the mixed carbonate-silicate binder and of the silicate lumps we frequently observed in the mortars.

Although the XRD method does not allow aggregates and binder to be differentiated, by coupling the OM and SEM observations with the XRD analyses it is possible to make the distinction.

As regards the aggregate composition, XRD data supported our petrographic interpretation showing the strongest peaks for quartz and K-feldspar.

3.1.5. X-ray fluorescence

X-ray fluorescence, historically used in the study of mortars, consists of the quantitative chemical analysis of major and minor elements on pellets of pressed powdered samples to create a more homogeneous representation of the mortar compositions.

Chemical data resulting from the Cerrate mortars are in general agreement with petrographic and diffractometric data. Mortars with silicate, or mixed silicate-carbonate aggregate, display a higher content of SiO_2 and K2O (chemical formulas are SiO_2 and $KAlSi_3O_8$ respectively). A high content of CaO, on the contrary, was detected in mortars with a predominantly carbonate binder and in mortars with carbonate aggregate in which, as expected, the highest concentration of CaO was detected (about 95 wt%), due both to the aggregate grains and to the predominantly carbonate binder as well.

3.1.6. Mössbauer spectrometry

^{57}FeMössbauer spectrometry provides quantitative information on the magnetic and structural properties of Fe-bearing materials. Mössbauer spectra are useful for quantitative phase analyses or determination of the Fe^{2+}/Fe^{3+} ratio in different phases, even when the phases are nanostructured or amorphous [15 -17].

Using this technique, quite unusual for the characterization of historical mortars, a considerable amount of amorphous and/or nanostructured material was detected within the studied mortars and is probably responsible for the hydraulic properties. In order to investigate the origin of this amorphous material, the bauxite from local red soils cropping out as lenses and horizons within the local sedimentary successions, and the bauxite from the Otranto quarry (Apulia) were analyzed and compared. Preliminary results suggest a significant similarity between the studied mortars and the local red soils (G.B. Andreozzi, personal communication).

3.1.7. Thermal analysis

This analysis includes a variety of techniques providing information about the properties of materials measured through a predetermined temperature profile.

In the case of our study, thermal analysis – differential scanning colorimetry (DSC), was additionally performed. This technique is ongoing and is currently being employed to determine the chemical character of the studied mortars and to assess the possible presence of hydraulic compounds within the mortars and so learn more about their nature and characteristics. This technique should enable us to discriminate the presumable source area of the clay-sized fraction which was artificially added and mixed to give it the proper hydraulicity.

3.1.8. Remarks

Study of the Cerrate masonries:

- petrographic results showed a possible discrimination between mortars of different production periods, based on textural features and the mineralogical composition of binder and aggregate;
- SEM-EDS analyses coupled with X-ray diffraction provided information about the texture and composition of the binder, aggregates and the artificially added clay-sized fraction; further discrimination between mortars dated between the 16th and 17th centuries and mortars dated approximately to the 19th and 20th centuries was made possible through X-ray maps, on the basis of elemental abundance and the different degree of mixing of the clay-sized silicate component within the binder;
- the ongoing Mössbauer and thermal analyses are currently providing interesting results about the properties of the original mortars and the possible raw materials used in their production.

Considering the complexity and the difficulties in studying mortars and, in general, historical buildings, the significant results reached in our study of the Cerrate complex have allowed us to delineate a preliminary analysis protocol. The protocol consists of analytical procedures which will help gain further knowledge of historical masonries and their characterization. More in general the systematic physico-chemical characterization of the original historical mortars is essential for conservative and repair purposes and useful in selecting the most compatible restoration materials. This methodology, verified on Cerrate, is also applicable to other sites.

It is important to emphasize that this framework of analyses should be considered only a preliminary step and, as yet, incomplete. Further testing needs to be carried out in other contexts for it to be fine-tuned.

Table 1 shows the samples examined and the analytical investigations carried out.

Table 1.
Summary of the macroscopic-microscopic observations (texture, type and composition of aggregate, total elemental composition, binder composition) and of the analyses performed on the studied mortars. In the XRD column, minerals are listed in order of abundance. Plain-type = more abundant minerals; bold-type = minor abundance; bold italic type = minerals in traces. Kf = K-feldspar; plg = plagioclase. XRF chemical composition is given in wt% oxides.

				Aggregate more than 50 %
AGGREGATE COMPOSITION	SAMPLE	CENTURY	COLOUR	OPTICAL MICROSCOPE ANALYSIS: AGGREGATE COMPOSITION AND TEXTURE
silicate aggregate	M24	20th	pinkish red	Medium to very fine-grained silicate grains, 0.05-0.5 mm, mostly quartz and K-feldspar, subordinate bioclasts, carbonate lithoclast and a reused mortar fragment containing quartz.
	MUR42-01	12th-17th	pinkish red	Medium to very fine-grained silicate grains, 0.05-0.4 mm, mostly quartz and K-feldspar, rare bioclasts and lithoclasts including crystalline limestone and fragments of pietraleccese, presence of lime lumps.
	MUR62-02	(≤ 16th) ???	pinkish white	Inhomogeneously distributed aggregate represented by medium to very fine grains, 0.05-0.35 mm of quartz and K-feldspar and Na-feldspar, sub-angular to sub-rounded in shape. Subordinate bioclasts (red algae, planktonic and benthonic foraminifera with phosphate filling) are concentrated in a small sector of the mortar.
	MUR58-04	20th	pinkish white	Poorly sorted aggregate consisting of fine to very fine grains, 0.05-0.25 mm of quartz and K-feldspar, sub-angular to sub-rounded in shape and subordinate bioclasts (red algae and echinoids). A fragment of a reused mortar, about 2 mm in size, was detected, displaying a mixed carbonate and silicate aggregate in a carbonate binder. A large lime lump is also present.

	MUR29-11	19th-20th	red	Inhomogeneously distributed aggregate with silicate grains, mostly quartz and K-feldspar, medium to very fine in size. A large lime lump is present displaying typical shrinkage fractures.
	M16	19th	pinkish white	Silicate grains, very fine to medium in size, predominantly represented by quartz, K-felspar and silicate of Al, Mg, and Fe, from sub-angular to sub-rounded in shape; K-feldspar appear more rounded. Rare bioclasts (red algae).
	M23	16th-18th	pinkish red	Silicate grains, 0.05-0.7 mm, subordinate bioclasts (red algae, bryozoans, bivalves, benthonic foraminifera, worm tubes (> 1mm), underburned carbonate lithoclasts.
	M19	16th-18th	red	Aggregate mostly represented by grains of quartz and K-feldspar, 0.05-0.5 mm, and subordinate silicates rich in Fe. A large lime lump (up to 1 cm) was detected, with shrinkage fractures containing very small angular fragments of quartz.
	M18	16th	red	Inhomogeneously distributed aggregate with silicate grains, mostly quartz, K-feldspar and Na-felspar, medium to very fine in size (0.05-0.35 mm); sub-angular to sub-rounded in shape. A fragment of a previous mortar was observed, displaying a mixed bioclastic and subordinately silicate aggregate scattered in a carbonate binder.
	M27	19th	red	Poorly sorted and inhomogeneously distributed aggregate with predominant silicate grains of quartz and K-feldspar,0.05-0.35 mm in size, from angular to sub-rounded and subordinate bioclasts. A large lime lump is also present.
	MUR29-08	19th-20th	red	Scialbo + mortar finishing: bioclastic calcarenite with abundant fragments of red algae (rhodoliths ≥ 2mm), echinoids, worm tubes, benthonic foraminifera and rare planktonic foraminifera. Subordinate grains of quartz and K-feldspar. The finishing mortar exhibits a silicate aggregate consisting of quartz and K-feldspar grains (grainsize: 0.06-0.25 mm) from sub-rounded to sub-angular and rare bioclasts.
	M9-1A	17th-18th	pinkish white	This sample is represented by a very thin layer of mortar on lithoid material. Aggregate consists of quartz and K-felspar grains of 0.05-0.3 mm, sub-angular in shape.

carbonate aggregate	M22	16th	pinkish white	Aggregate dominated by carbonate bioclasts, variable in size up to 1 mm. The subordinate silicate fraction, absolute, consists of rare grains of quartz and K-feldspar, 0.05-0.25 mm. A thin superficial layer with a silicate composition was observed.
	MUR30-07	19th	pinkish white	Bioclasts (mostly red algae) and lithoclasts), rare silicate grains of quartz. K-feldspar and Na-feldspar, 0.08-0.2 mm, commonly sub-angular in shape. A thin external layer (about 1 mm) of silicate material containing abundant grains of quartz and K-felspar) was also observed.
	M02	12th	pinkish white	Abundant medium to coarse-grained bioclasts, up to1.5 mm (red algae and worm tubes); dolomitic lithoclasts are also present. The subordinate silicate fraction is mostly represented by quartz grains (<0.1 mm in size) and silicates of Mg, Al, K and Fe
	MPSX	12th	pinkish white	Abundant medium to coarse-grained bioclasts, up to 2 mm (red algae, benthonic foraminifera and echinoids). The subordinate silicate fraction mainly consists of quartz grains, 0.05-0.2 mm.
	M10-2A	19th	pinkish white	Abundant medium to coarse-grained bioclasts, up to 1 mm (red algae, benthonic foraminifera and echinoids, bryozoans, bivalves). The fine-grained, 0.01-0.3, silicate fraction is very poor and mostly represented by quartz. Irregular and unusual porosity and fractures (10-15%) are also present.
	M13	13th	pinkish white	Abundant medium to coarse-grained bioclasts (red algae, serpulids, balanids, bryozoans, echinoids). The subordinate silicate fraction (0.02 - 0.2 mm) mostly consists of quartz.
	M10-2B	19th	pinkish white	Sample very similar to M10-2A.
mixed carbonate-silicate aggregate	M01	12th	pinkish white	Abundant medium to coarse-grained bioclasts (red algae, echinoids, bivalves and benthic foraminifera). The subordinate silicate fraction is represented by quartz, subordinate K-Feldspar and rare apatite grains. Silicate grains (less than 0.25 mm in size) are sub-angular to sub-rounded in shape.

	M32	13th	pinkish red	Inhomogeneously distributed aggregate with portions characterized by bioclasts (mostly red algae) more than 1.5 mm in size mixed with medium to very fine silicate grains (quartz and subordinate K-Feldspar). Other portions of the sample exhibit rare silicate grains.
	L13		pinkish white	Very abundant aggregate consisting of medium to coarse-grained bioclasts (mostly echinoids and red algae), benthonic foraminifera (locally phosphatized) and rare planktonic foraminifera. The silicate fraction is mostly represented by fine-grained, 0.1 mm in size, quartz (sub-rounded to sub-angular in shape) and subordinate K-Feldspar and micas).
				Aggregate less than 50 %
silicate aggregate				
	MUR62-03	pre-16th	pinkish white	Medium to fine-grained grains of quartz and K-feldspar, 0.05-0.5 mm, and silicate lumps. Rare bioclasts and fragments of underburned crystalline limestone are also present.
	MUR28-12	16th	pinkish red	This sample is an extremely weathered mortar consisting of reddish powder containing a limestone fragment (corresponding to sample Mur 28A-06).
	MUR28A-06	16th	pinkish red	Limestone fragment included within the sample MUR28-12. It consists of bioclastic calcarenite with red algae and echinoids (even more than 1.5 mm in size), serpulids and bivalves, surrounded by a film of reddish dust.
carbonate aggregate				
	FN 44-M20	17th	pinkish red	Aggregate constituted by bioclasts, up to more than 1 mm, of red algae, bryozoans, echinoids. Underburned limestone particles are also present. The silicate fraction, consisting of quartz and K-feldspar grains, 0.1 mm in size, is scarce.
	M05	12th	pinkish red	Aggregate mostly constituted by bioclasts, up to more than 1 mm, (red algae, echinoids, benthonic and rare planktonic foraminifera). Underburned lithoclasts are also present. The silicate fraction, showing a mostly bimodal particle-size distribution, around 0.5-0.7 mm and 0.1-0.2 mm, consists of Qz and more rarely Al-silicate

mixed carbonate-silicate aggregate				
	M15	16th or 19th	pinkish white	Aggregate constituted by quartz and feldspar grains, less than 0.25 mm in size, phosphates and bioclasts (red algae). Underburned lithic fragments, around 1 mm in size were detected. A large silicate lump, more than 2 mm in size, containing quartz grains, is also present.

4. Conclusions

As part of a wider ongoing project, the study on the Santa Maria di Cerrate complex offers a framework of analyses and methodologies which are relevant and promising for studying historic masonries. These methodologies, presented here as a case study, will be tested on other samples from different archeological contexts with the purpose of creating a background of knowledge useful for evaluating technical properties and the performance of historical mortars also in relation to local construction techniques.

In detail, studies will be carried out on the history of construction techniques and the relationship between local resources and construction sites, thus contributing to a more accurate history of the territory. The analytical aspect, specific analyses on organic additives (proteins, lipids, etc.) and the use of quicklime will contribute to understanding their role in the properties of the mortars.

The path the project will follow, starting from the experiences of the single researchers, aims to integrate historical, technical and scientific knowledge at international level, also through bibliographic research, for a better understanding of cultural heritage [18-21].

Notes

[1] The "Progetto Grande di Ateneo" (2018), *Historical and technical characterization of medieval and modern mortars. Methods for study and conservation* (scientific coordinator Prof. Daniela Esposito) is being carried out by the interdisciplinary research group composed of Professors M. Asciutti, L. Barelli, F. De Cesaris, R. Mancini, M.L. Santarelli, L. Sorrentino with the collaboration of L. Corda of the Sapienza University of Rome, the Laboratory AStRe-LabMat (Architettura Storica e Restauro-Laboratorio Materiali) (E. Giorgi) and the CNR of Milan, Rome and Lecce (A. Sansonetti, A. M. Conte, E. Scopinaro, A. Monte), the Politecnico of Milan (G. Landi), the Università di Roma Tre (S. Passigli), the University of Camerino (E. Petrucci), Pavia (M.P. Riccardi), Parma (F. Ottoni), the Politecnico of Turin (C. Tosco) and Ph.Ds of the Sapienza University of Rome (S. Cirulli, V. Montanari, L. Ninarello, M.G. Putzu)

[2] The abbey (founded in the12th century) became a *masseria* ('manor farm') from the 16th century and the church was gradually abandoned. The manor farm carried out its agricultural activity until the postwar period, when it was purchased by the Biancos. In 1965, they ceded the complex to the Province of Lecce. In the 1970s, restoration interventions of the complex were started, designed by Franco Minissi. Some adaptations were made in 1986, and other interventions followed in 2006, on the initiative of the provincial administration. The restoration project is supported by FAI (Fondo Ambiente Italiano) and its technical office (and architects Paola Candiani, Roberto Segattini, Giacomo Sosio et al.) in 2012-2014.

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Elisabetta Giorgi is an architect and expert in conservation of historical-building materials, surfaces and finishes. A consultant and teacher at ICCROM for the conservation of mural painting and historical constructions; a researcher in many worksites for testing hydraulic mortar for conservation plaster and mural painting (Pompei, and other sites with the scientific support of Prof. G. Torraca). A consultant for IsCR (Istituto Superiore per la Conservazione ed il Restauro, formerly ICR) in didactic worksites with the coordination of data and lectures on graphic documentation. She is currently the Technical-Head of AsTRE-LabMat, Architettura Storica e Restauro-Laboratorio Materiali at the Sapienza University of Rome, Department for Architectural History, Design and Restoration. As an architect Elisabetta Giorgi is involved in many research activities and provides didactic support for post-graduates and thesis preparation on the Restoration of Architecture and history of Architecture.

Summary

The study concerns Italian masonries and focuses on historical, medieval and modern mortars. Within the context of the different regions under examination (Piedmont, the Po Valley area, Latium, the Umbria-Marche region, and Apulia and Sardinia) a wide variety of materials with different chemical-physical characteristics were used in masonry work, determining different structural behaviors. The project aims at improving our knowledge about historical mortars in order to further the conservation of Italian built heritage, especially in zones with seismic risk. To achieve these results, we took samples and carried out analyses to investigate the different mechanical and cohesion properties that influence the vulnerability of ruined or collapsed structures.

This information has enabled advances to be made in the prevention, maintenance, protection and preservation of historical buildings.

Further details will concern the history of construction techniques, with particular regard to the relationship between local resources and construction sites. Another important topic is the role of different components and additives during the preparation of the mortars and their level of hydraulicity.

Riassunto

Lo studio riguarda le strutture murarie in Italia e si concentra sulle malte storiche, medievali e moderne. Nei contesti regionali oggetto d'indagine (Piemonte e Pianura Padana, Lazio, Umbria-Marche, Puglia e Sardegna) è stata utilizzata una grande varietà di materiali, con caratteristiche chimico-fisiche diverse, e queste differenze determinano anche comportamenti strutturali diversi. Il progetto mira a migliorare la nostra conoscenza delle malte storiche per approfondire il tema della conservazione del patrimonio edilizio italiano, soprattutto nelle zone a rischio sismico. Per ottenere questi risultati, sono stati prelevati campioni sui quali sono state effettuate analisi per indagare quanto le diverse proprietà meccaniche e di coesione incidano sulla vulnerabilità delle strutture in rovina o collassate.

Grazie a queste informazioni è stato possibile contribuire alla prevenzione, manutenzione, protezione e conservazione dell'edilizia storica.

Ulteriori conoscenze hanno riguardato la storia delle tecniche di costruzione, con particolare riguardo al rapporto tra risorse locali e i cantieri. Un altro importante tema è stato il ruolo dei diversi componenti e additivi durante la preparazione delle malte e il loro livello di idraulicità.