Practice Points NUMBER 11

Mortar Analysis Part 3: Buying the Right Services

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In Practice Point Number 7, *Mortar Analysis Part 2: Analytical Methods*, the different methods for analyzing historic mortars were reviewed in detail.[1] Methods included (in the order presented):

- petrographic analysis, including polarized light microscopy
- X-ray diffraction (XRD) and scanning electron microscopy/energy dispersive spectroscopy (SEM/EDS)
- thermal analysis methods, including differential thermal analysis (DTA), differential scanning calorimetry (DSC), and thermogravimetric analysis (TG)
- Fourier-transform infrared spectroscopy (FTIR)
- chemical analysis, including acid digestion

Existing and proposed standard mortar-analysis procedures were also presented, including ASTM C 1324 "Standard Test Method for Examination and Analysis of Hardened Masonry Mortar," the protocol proposed by Elizabeth Goins, and the RILEM Technical Committee TC 167-COM proposed protocols for mineralogical and chemical characterization of mortars.

Given the many different analytical methods available and the different kinds of information they provide, the first step in buying the right services is to carefully consider and clearly articulate the information needed from a mortar analysis. The objectives of the analysis will determine the most appropriate method or methods. The next steps include developing an analysis program, sampling, performing the analysis, and interpreting the results.

Mortar-Analysis Objectives

Identifying the information needed from a mortar analysis is the first and most important step in obtaining the right services. The analytical objectives will determine not only the analysis method(s) to be used but also the size and number of samples that will be required and the most appropriate individual to perform the analysis. Because of the costs associated with any kind of materials analysis, the architectural conservator, architect, engineer, or other preservation professional in charge should establish the need for mortar analysis and define the analytical objectives at the earliest possible point in a project, preferably before any kind of work begins, so that appropriate funds can be allocated for the analysis. A preliminary field assessment of the masonry by an experienced preservation professional is always essential to the development of meaningful mortar-analysis objectives and a sensible sampling plan (Fig. 1).

Fig. 1. *Image of an historic brick masonry wall that has had a new mortar smeared over the existing original instead of being raked out and repointed properly. Preliminary field assessment by an experienced preservation professional is essential for defining a mortar-analysis program. An inexperienced preservation professional might mistake this construction as having different pointing and setting mortars. All illustrations by the author.*

There are four main reasons mortars are analyzed:

- to aid in developing mortar mixes for repointing and repair
- to clarify construction history
- to identify the cause of deterioration of the mortar and/or the masonry units[2]
- to meet the requirement of a regulatory agency

Developing mortar mixes for repointing and repair. A common reason for analyzing existing mortar is to aid in developing mortars for masonry repointing and repair. The importance of selecting a repointing mortar that matches the appearance of the existing mortar is generally well understood by preservation professionals. In order to develop an appropriate repointing mortar, all aspects affecting the appearance of the existing mortar should be determined. These include

- the size, distribution, color, shape, and surface luster of the aggregate grains
- the color of the binder
- the proportion of binder to aggregate

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Analysis of the mechanical and physical properties of existing mortar (strength, porosity, etc.) can be performed, but the utility of such testing is debatable. Obtaining intact samples of sufficient size to meet the requirements of the various analysis methods is often impossible, and the characteristics of the mortar can be highly variable depending upon how the mortar was placed in the wall. However, void content of the existing mortar, which is known to affect mortar durability, is easily assessed and should be considered when developing a replacement mortar. If the existing mortar has shown good durability, void content of the replacement should approximate that of the existing material. Otherwise, void content of the replacement should be designed to match the conditions of exposure.

When mortar analysis is conducted for the purpose of developing repair and repointing mortars, analyzing the mortar alone may not be enough. The masonry units themselves may need to be tested. The existing mechanical and physical properties of the weathered units are crucial indicators of appropriate repair and repointing mortar mixes. Matching the original composition of the existing mortar as determined by mortar analysis may be neither prudent nor desirable if the existing mortar has caused deterioration of the masonry units or was insufficiently durable for the exposure. Consideration of the masonry type, condition, and exposures may suggest the need for a repointing or repair mortar of different composition from the original. Depending upon the project, masonry evaluation might include strength testing (compressive, tensile, modulus of rupture), porosity and water-absorption tests, and determination of the water-vapor transmission rate.

Fig. 2.
Sample of brick with adherent original mortar. Mortar samples must have the right form for the analysis method selected. Sometimes intact samples of fairly large size, such as those shown here, are required.

Specifying mortar mixes for masonry repointing and repair is part of the design process, so if mortar analysis is needed to inform the process of developing specifications, then obtaining a mortar analysis is rightly the responsibility of the preservation professional responsible for preparing the construction documents. The requirement for obtaining the analysis should not normally be transferred to the contractor. Such a transfer of responsibility inappropriately places the analysis in the construction phase, rather than during design, where time constraints may unduly influence the methods selected. Also, the contractor may not have the experience to request a relevant analysis from an appropriate individual. Deferring mortar analysis may make sense in cases where sampling access is limited until construction is underway, but the responsibility for clearly articulating the reason for the analysis, defining the analytical methods to be used, selecting sample locations, and identifying professionals with the necessary skills to perform the analytical work is still that of the preservation professional in charge of the design work, not the contractor.

Clarifying construction history. Mortar is sometimes analyzed to determine construction history for a building or group of buildings, because it serves as a historical record of the construction period. Samples taken from different parts of a building or from different buildings on a site may have compositions and physical characteristics that typify construction practice during a particular time period or building campaign. When used in conjunction with a careful review of other historic documents, mortar-analysis data can sometimes prove useful in unraveling construction history of a building or site. Mortar analysis may sometimes be performed to confirm use of a specific mix documented in a specification or other historic document. In this type of study, the original composition of the binder may be the most relevant information, as sources of sand used for aggregate are typically local and therefore may not vary greatly over time.

Identifying causes of mortar deterioration. Even though mortar weathers and deteriorates over time, large-scale mortar failure is not necessarily normal for historic masonry. Although careful condition assessment will generally reveal causes of mortar failure, mortar analysis can verify initial conclusions from an assessment or provide additional data when causes of observed deterioration are not clear. Various analytical methods can be used to identify causes of accelerated mortar deterioration, such as soluble salts in the binder and reactions between alkali and aggregate. In order to diagnose causes of mortar deterioration, sam-

ples of both sound and unsound mortar are needed. Though mortar serves as a record of deterioration processes and can be used to help diagnose deterioration problems, when unusual or extensive mortar deterioration is observed, testing the masonry can also be helpful. For example, changes in the properties of the masonry units relative to water movement through either normal weathering or application of water-repellent coatings can cause widespread mortar deterioration and failure that would not be discernable from analyzing the mortar alone.

Regulatory requirement. Unfortunately, the overwhelming majority of mortar analyses are performed only because analysis is required by a regulatory agency for structures of a particular age or in a particular district or for projects receiving certain types of grants or tax credits. Within this context, the expressed objective of the mortar analysis is almost always to "determine the original composition of the mortar." Certainly the *Secretary of Interior's Standards* reinforce that objective when they recommend "duplicating old mortar in strength, composition, color and texture."[3] As has already been discussed, the nature of hardened mortar makes determining the original composition a daunting, if not impossible, task.

More importantly, determining the composition of the existing mortar may not be the critical objective of a mortar analysis. For example, when matching an existing pointing mortar, freeing the aggregate for characterization and comparison with locally available sands may be the most important objective. Determining the volume proportion of voids and soluble salt content may be important for understanding deterioration. Preservation professionals and regulatory agencies need to accept the spirit of the *Secretary of Interior's Standards* and obtain analysis of mortars as required to meet the needs of each project on an individual basis. Moreover, preservation professionals must take the responsibility to carefully consider what those needs are and to articulate them clearly enough to define achievable analytical objectives.

The Analytical Process

Once the reasons for mortar analysis are clearly articulated and the analytical objectives are defined, the next steps are developing an analytical program, including a sampling plan; obtaining samples; and performing the analysis and interpreting the results.

Each of these tasks requires particular skills, experience, and knowledge. The individual developing the analytical program must have a good knowledge of historic building practices and mortar-making materials and must also understand the available analysis methods well enough to select those that meet the analytical objectives. A sampling plan is a critical component of the analytical program because sample requirements vary depending on the analytical method. The need for random sampling and the ability to obtain enough samples to be representative of the existing masonry without exceeding the available budget must also be considered. When developing the analytical program and sampling plan, it is always good practice to first consult with the individual who will actually perform the analysis so that all parties understand the level of effort required and how the sampling will be performed.

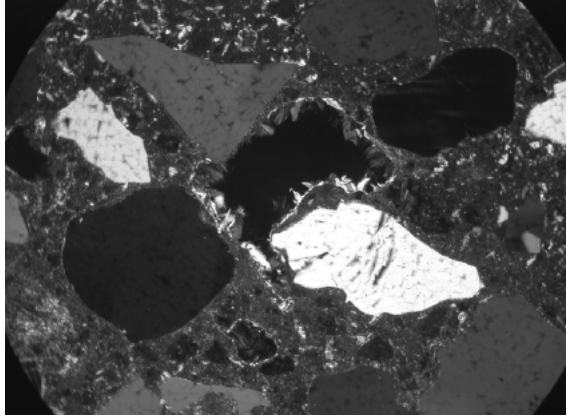

Fig. 3.
View of a mortar sample in thin section, crossed polars, 400x magnification. Experience with a particular analysis method is critical to selecting proper sample-preparation procedures. Without proper sample preparation, the material lining the void in this sample would have been lost.

The individual performing the sampling must have manual skills appropriate to the removal of the samples (Fig. 2). Samples of inadequate size or powdered samples where solid samples are needed will at best derail the analytical program and may necessitate obtaining more samples, with the additional associated costs. The person taking the samples must also have sufficient experience and understanding of historic buildings to know where to take samples that, when analyzed, will provide the information needed to meet the analytical objectives. For example, historic masonry was often constructed with one mortar used for setting the units and a second mortar of different composition used for pointing. A masonry-restoration contractor may be able to take samples if provided with appropriate guidance as to suitable sample locations and quantity and type of samples.

Finally, the individual actually performing the analysis and interpreting the results must have sufficient experience with the method to properly prepare and analyze the mortar samples (Fig. 3). The analyst should also provide input regarding the character of the required samples. To interpret the data, they must also understand the materials they are analyzing — knowledge of historic mortar-making materials is critical to accurate interpretation of the data.

Determining who will perform these three tasks is the challenge. An experienced preservation architect or engineer might feel confident performing the first two tasks, while an appropriately trained architectural conservator with the right experience could easily perform all three. Large testing laboratories may have appropriate equipment to perform certain types of analyses but may or may not have employees who are experienced in working with historic mortars. Independent architectural conservators often have extensive experience with historic materials and structures, and experienced conservators often expand their analytical capabilities by outsourcing some types of instrumental analyses. Regardless of who performs which tasks, clear articulation of the objectives of the analysis at the outset is the most critical factor in a satisfactory outcome of the work.

Circumstance often dictates that a preservation design professional or contractor is charged with the responsibility for obtaining mortar-analysis services when they have little or no knowledge of the information expected from such an analysis. In this case, the services of a individual who can perform all three tasks (program development, sampling, and analysis) should be sought. There are several ways to find such a person. The best way is by word of mouth, that is, consulting others in the field with masonry preservation experience. A second option is the American Institute for Conservation of Historic and Artistic Works (AIC) referral service, which can provide a list of Professional Associate or Fellow-level members.[4] A third option is the laboratory directory provided by ASTM International, which is searchable in a number of ways but particularly by ASTM standard number.[5] Of these three, word of mouth is likely to be the most effective.

Once you have identified one or more potential service providers, evaluate their services as you would those of any other professional. Ask about their experience and background and find out what equipment and methods they normally use for analyzing mortars when no specific method is requested. Asking why they use the methods they use can also be quite illuminating. Ask for references and a sample report. Most importantly, discuss your project with them and ask for their input about scope of services and sampling. An experienced individual will tailor their services to your analytical needs and will be eager to help you articulate your testing objectives. However, beware of "one size fits all" service providers. Responsible professionals will also be willing to refer you elsewhere if they cannot meet your needs.

Conclusions

Analysis of historic mortars is a complex problem, and no single analysis method is right for every situation. When the reasons for a mortar analysis are clearly articulated and the analytical objectives defined accordingly, the most economical analysis method that will meet the needs of the project can be selected. Mortar and masonry units work together to provide a weatherproof exterior wall envelope. Accordingly, in the development of a comprehensive masonry-conservation program, the need for mortar analysis must be considered as only one part of a masonry assessment. Analysis of the masonry units is also often needed to complement the information gained from mortar analysis in order to develop a suitable masonry-conservation program; consideration should be given to the routine assessment of the masonry as a part of any mortar analysis aimed at the development of mortars for repointing and particularly repair. Finally, buying mortar analysis services means understanding the knowledge, skills, and experience required for all the different steps in the process in order to identify the service provider with the right skill set for the project.

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Notes

1. Lorraine Schnabel, "Mortar Analysis Part 2: Analytical Methods," Practice Points Number 7, *APT Bulletin* 40, no. 2 (2009): 1–7.

2. The word "units" is used to simplify the discussion of the masonry elements being joined by mortar.

3. U.S. Dept. of the Interior with Kay D. Weeks and Anne E. Grimmer, *The Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring & Reconstructing Historic Buildings* (Washington, D.C.: National Park Service, Heritage Preservation Services, 1995), 24.

4. The AIC referral service is an online database available at www.conservation-us.org. The database is searchable by material and service and organized by locality.

5. The ASTM Laboratory Directory is an online database available at http://www.astm.org/LABS/search.html.

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