Selecting mortar for historic preservation projects

Follow these guidelines to determine the composition of a structure's existing mortar, and consider using a lime-based mortar for repointing if a lime mortar was used originally

By Lauren B. Sickels-Taves

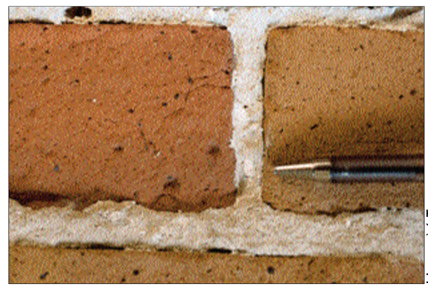
To an architectural preservationist, the worst scenario imaginable is a masonry wall where the mortar joints surround deep impressions, pockets of eroded brick or stone. This indicates that little or no consideration was given to compatibility when the wall was repointed. A dense mortar was used against softer masonry, and the stronger material dominated.

Mortar should be flexible enough to absorb movement due to temperature change, settlement or vibration. Lime mortars provide this flexibility. In contrast, when cement is the sole binder used in a mortar, the masonry is forced to absorb any movement and becomes subject to erosion, spalling or cracking. Portland cement lacks the key characteristics of a lime mortar—porosity and plasticity. Therefore, lime mortar should be considered for historic masonry preservation projects.

The use of lime as the sole and preferred binder in mortars dates back to ancient Rome, when Vitruvius expounded on the virtues of lime in his treatise *The Ten Books of Architecture* (Ref. 1). Though lime was available in different forms, such as powder or putty, and its quality varied according to local geology, it remained the key binder for masonry mortar until natural and portland cements were introduced in the United States in the 1820s and 1870s, respectively.

Only recently has the use of lime as the sole binder made a comeback, as the preservation movement gains ground. Hydrated lime generally is used for restoration; however, when early strength is required, hydraulic lime may be added (in lieu of portland cement).

To determine whether a mortar is lime-based, wipe a finger firmly across the mortar joint. White powder residue on the finger clearly indicates the presence of lime.



Henry V. Taves

The presence of free lime, or large chunks of undissolved lime, is another diagnostic feature of lime-based mortars. In this photograph, a large piece of free lime is visible at the end of the pen.

In *Introduction to Early American Masonry*, Harley J. McKee advocates that new materials never be stronger than the old materials to which they adhere (Ref. 2). Toward this end, a variety of preservation materials, methods and literature are available to ensure that a mortar for repointing is compatible in strength, adhesion, color and texture with a building's original materials.

Preservationists are strong proponents of reversibility—that is, the ability to undo changes and return a structure to its former state. Indeed, every repair should be predicated with this question: Is it reversible? Ideally, mortars should be replaced with the same kind; but in many cases, particularly in the United States, the ingredients are no longer available.

For example, in coastal areas without limestone, oyster shells used to be burned to obtain lime. Ash from the wood fire was mixed (inadvertently) with this lime to provide hydraulic qualities. Not only is this type of lime hard to reproduce today, but also vast supplies of oyster shells no longer are available.

Clues to compatibility

Examining the existing mortar is necessary to achieve the best possible match of the new with the old. Visual examination can yield an abundance of clues.

Test by rubbing. Rub a finger across an existing mortar joint. If the finger picks up white dust, lime is the binder. Also look for small dots of pure white in the mortar joints, typically no larger than ⅛ inch; these are pockets of pure lime and are typical of early hand-mixed mortars.

If the finger appears clean, cement is the binder; this is further verified if the joint is of a distinct gray color. General dirt and aging are distinguished by nonuniform smears across the finger that can easily be wiped off.

If this mortar test is inconclusive because not enough binder sticks to one's finger, try the same method on the brick (if the building is comprised of such). Red dust indicates an unfired, perhaps sun-dried, brick without a surface coatingof glaze.Checkotherbrick, particularly interior faces or core brick, since it is possible that the glaze coat was originally there but wore off—typically due to sandblasting. By far, most unglazed brick were used in combination with lime mortars.

Measure brick. Measuring brick sizes is another means of gaining clues to the mortar. Brick was not standardized in size until 1899 (Ref. 3). Before then, brick were made by hand, moldormachine, resultinginmany sizes. Though there are many factors to consider, the presence of nonstandardized brick generally should suggest the use of a lime mortar in a restoration project.

A significant relationship also exists between brick porosity and mortar plasticity. Generally, handmade brick are more porous than machined ones, and their salvation requires the use of softer, more plastic mortars, such as lime mortars.

Analyzing mortarcomposition

To supplement visual examination, one can analyze the composition of the existing mortar. These analyses range from simple onsite tests to laboratory studies—all in an effort to determine the type of binder and aggregate originally used.

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This photograph reveals evidence of a poor color match between new mortar and existing stonework and brickwork.

Use hydrochloric acid. One onsite technique involves placing a pulverized sample in diluted hydrochloric acid (muriatic acid). Vigorous bubbling and an amber hue indicate a lime binder. Weak agitation and a murky green color are characteristic of cements. After any aggregate left undissolved by the acid is washed and dried, additional tests may be run.

Examine color traits. One fairly simple test to identify binders is visual examination of the dried aggregate. The color of the binder often alters the color characteristics of the undissolved aggregate. For example, the dried residue of portland cement tends to be medium to dark gray, and clay produces a reddish to light tan color. Naturalcement residuesare brown but may be difficult to distinguish from clay additives (Ref. 4).

Assess sand-grain shape. Another test focuses on the sand grains in the remaining aggregate. The general characteristics of their shape can be determined by rubbing the particles between finger tips. Angular grains produce more of a "crackle" than rounded grains. More specific information about sand grains can be gained by examining them with a 5x hand lens, which yields the range of particle sizes, as well as an idea of the mortar's color.

Run through sieves. As an alternative to using a hand lens to determine particle size, aggregate can be run through a series of ASTM-compliant sieves, ranging from 5.00 mm to fines. This will clarify sand color and assess the quantity of fines present. Though fines generally should not exceed 10% of the total aggregate, the higher their percentage, the more hydraulic the qualities of the mortar.

Sieving also determines the grading curve or range of particle sizes. Selecting new aggregate with a similar curve further promotes compatibility.

Computer-assisted optical stereology. Should the need arise to precisely match the aggregate, computer-assisted optical stereology can be performed (Ref. 5). This is a simple, though high-tech, test whereby binary images are made of individual grains of sand. Comparing their angularity with grains from possible sources can help achieve a more exact match.

Petrographic analysis of the aggregate. Petrography, or mineralogical analysis of the aggregate, is another technique available. Though not astronomical in cost, these tests generally are used only on projects where precise matches are required, such as nationally significant historic structures.

Volume of binder required. A void-ratio test should be run to determine the volume of binder required to adequately fill all voids in a new mortar. Two cylindrical beakers are filled—one with dry sand and one with water, in equal volumes. Water is then poured into the sand only until it reaches the top of the sand. The

Drayton Hall in Charleston, S.C., provides an example of how the excessive application of new mortar to the original brick (upper-left quadrant of the closeup photograph) detracts significantly from the more carefully executed original mortar joints (shown on the right).

measurement of the remaining water is subtracted from the initial volume figure; the difference is the quantity of binder required to completely fill the voids in the measured quantity of dry sand (Ref. 6).

Compressive strength of units. Though extreme and irreversible, a single brick or stone can be sacrificed to obtain its compressive strength by crushing it in a laboratory. This data can be compared to the compressive strength of known mortar mixes, providing a rough idea of the proportions a new mix should *not* exceed (Ref. 7).

Armed with such a variety of data, one may more closely match a new mortar with the old. If these analyses determine that a lime mortar was used originally, the building should be repointed using a lime mortar, preferably made with lime putty.

A case for lime mortar

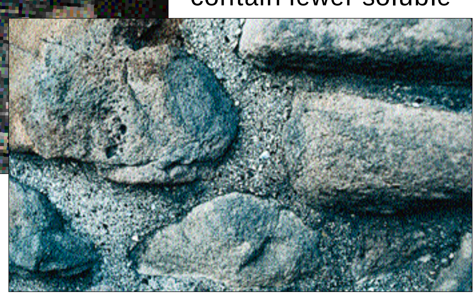
Recently, Scotland has seen a resurgence of lime mortar use and traditional craftsmanship. Professionals there, including master masons, have argued long and hard for lime mortars, and they have been heard. Their case is not just an aesthetic one but structural as well. To this end, the Edinburgh-based Scottish Lime Centre, a 10-year-old organization providing a range of preservation services, drafted a technical note titled *Preparation and Use of Lime Mortars* (Ref. 6). Prepared for another Edinburgh-based preservation organization, Historic Scotland, this document clearly shows universal support for lime-based mortars—from government, preservation organizations and industry professionals. According to the technical note, lime-based mortars "are more permeable and more flexible than cement mortars; they contain fewer soluble salts; and they are environmentally more friendly than cement mortars. They also look better." (Ref. 6)

The key to an excellent lime for use in lime mortars is in its slaking and carbonation. The best control can be achieved by using lime putty (aged quicklime that is run through a series of sieves and soaked in water). The prolonged storage of lime putty progressively reduces the size of its individual particles, which increases the quality of the material (Ref. 6). Although the particle size of dry lime is acceptable, the reduced particle size of lime putty increases the material's binding qualities. Lime putty merely needs to be "knocked up" (made workable) before use.

In contrast to other single-material binders, such as cement or hydraulic lime, lime putty repeatedly has proved itself in the Scottish building sector over the past 10 years. Lime putty performs so successfully because it is able to draw carbon dioxide from the surrounding atmosphere to achieve durability while maintaining its plasticity. The hydraulic quality of other binders ultimately creates a harder mortar with less permeability and flexibility (Ref. 6).

In an effort to achieve a single baseline mix that can be modified to meet the specific demands of a restoration project, various tests were conducted on different mortar mixes at the Natchitoches, La., laboratory of Raleigh-based Biohistory International, an environmental conservation organization. (See the author's information at the end of this article for more information.) A ratio of 1:2 or 1:3 lime:sand was determined as a benchmark. These are the same ratios cited by Vitruvius of ancient Rome in his treatise: 1:2 if river or sea sand was used; 1:3 if pit sand was the aggregate. Subsequent tests merely reconfirmed their value (Ref. 1).

Adjusting this basic recipe is acceptable; it can be gauged or combined with additives ranging



An excellent example of a lime-based mortar can be found in the walls of Edinburgh Castle in Edinburgh, Scotland.

from pozzolanic ingredients, such as ash and brick dust, to animal hair to air entrainers. Hydraulic lime, as a gauging agent, is preferred for use in damp or exposed locations.

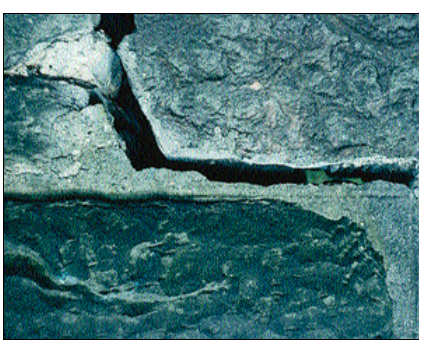
To further aid in the sympathetic matching of new lime mortars to old, the Society for the Protection of Ancient Buildings (SPAB) in London suggests replacing up to one-half of the quantity of coarse sand with the old mortar that is raked out (Ref. 8). The theory is that its inclusion provides the new mix with a better color match and added strength from years of carbonation.

Applicability in North America

Our building sector certainly can learn from the example set in Scotland, where the materials required to create lime mortars are readily available. The same cannot be said for North America. Few building supply stores carry lime putty, but it can be obtained from a couple of U.S. sources (see box at end of story). And some suppliers will place a special order for hydraulic lime.

Historical research

The key thrust of this article is to provide techniques that will yield information on historic mortars, thus allowing a sympathetic new mortar to be specified. If this data turns out to be insufficient, there is always the opportunity to delve into the written past. Historical research using courthouse (deed, tax and mortgage) records, Sanborn (late 19th-century fire) maps, county histories, etc., often can provide a definitive date of construction. Though not normally consulted in a typical masonry restoration project, such as a repointing job, this historical information can be very useful.


Lauren B. Sickels-Taves

The mortar used here is not stronger than the material to which it adheres, making repointing easier.


Lauren B. Sickels-Taves

A well-executed brick wall with lime-based mortar, gauged with portland cement, is represented here by the museum of the Old North Church in Boston.

Need for universal standards

In preservation, nothing is foolproof. Meticulously kept records and cutting-edge technology still may not yield the exact mortar ingredients and their sources. However, enough information can be gained to allow a sympathetic mortar to be used that will safely ensure the continued life of a historic masonry building.

There is a growing need to explore and establish universal preservation standards through international collaborative research. Following Scotland's lead in employing more lime mortars in masonry building restorations would be one step in the right direction. In addition, the availability of the necessary ingredients must improve. It is to be hoped that this day is not far off. However, until then, there are a variety of materials and methods available to ensure that future mortars are compatible and sympathetic with the old.

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References

1. Vitruvius The Ten Books of Architecture, translated by Morris H. Morgan, 1960, Dover Publications, 180 Varick St., New York, NY 10014.

2. Harley J. McKee, Introduction to Early American Masonry, 1973, The Preservation Press, 740-748 Jackson Pl., Washington, DC, 20006.

3. Mark London, Masonry: How to Care for Old and Historic Brick and Stone, 1988, page 61, The Preservation Press.

4. E. Blaine Cliver, "Tests for the Analysis of Mortar Samples," Association for Preservation Technology Bulletin, Vol. VI, No. 1, 1974, pages 68-73, Association for Preservation Technology, P.O. Box 351, Williamsburg, VA 23187.

5. Lauren B. Sickels-Taves, Michael S. Sheehan and Irwin Rovner, "Computer-Assisted Optical Stereology In Historic Preservation: Tabby, a Case Study," Association for Preservation Technology Bulletin, Vol. XXVIII, No. 2, 1997, pages 30-34.

6. Pat Gibbons, Preparation and Use of Lime Mortars, 1995, page 16, Historic Scotland, Salisbury Place, Edinburgh, Scotland EH9 1SH.

7. Lauren B. Sickels-Taves, "Creep, Shrinkage and Mortars in Historic Preservation," The Journal of Testing and Evaluation, Vol. 23, No. 6, 1995, pages 447-452, ASTM, 100 Barr Harbor Dr., West Conshohocken, PA 19428.

8. G.B.A. Williams, Pointing Stone and Brick Walling, 1983, Society for the Protection of Ancient Buildings, 37 Spital Square, London, England E1 6DY.

9. Jeanne Marie Teutonico, Iain McCaig, Colin Burns, et al, "The Smeaton Project: Factors Affecting the Properties of Lime-based Mortars," Association for Preservation Technology Bulletin, Vol. XXV, No. 3-4, 1994, page 35.

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