Selection of a mortar for repointing or other masonry repairs should be based on compatibility of the repair mortar with the existing mortar and with the existing masonry units and not based on minimum compressive strength. Masonry is a composite assembly of several materials, of which mortar is only one, and consideration of only one physical property of one of those materials while neglecting the properties of the others could lead to problems.

Why mortar compressive strength is of little importance
Matching the compressive strength of the original mortar is unimportant for at least two reasons. First, the magnitude of mortar compressive strength is relatively unimportant. A large percentage of modern masonry construction is as a masonry veneer, which is non-loadbearing. A veneer supports its self weight only, which typically results in axial stress of the magnitude of 2 to 8 psi per story. Even the weakest mortar is capable of supporting this level of axial stress.

In loadbearing masonry, the contribution of mortar compressive strength to compressive strength of the masonry assembly, $f_{m}^{'min}$, is small. According to the property specification requirements of ASTM C270, Type N mortar is required to achieve a minimum compressive strength of 750 psi and Type S mortar is required to have at least 1800 psi compressive strength. This is a 240% increase in compressive strength when changing from Type N to Type S.

Now, consider the tables used to estimate the compressive strength of the masonry assembly, as provided in the Masonry Standards Joint Committee’s (MSJC) “Specification for Masonry Structures,” ACI 530.1/ASCE 6/TMS 602, which are reproduced herein as Tables 1 and 2. For concrete masonry with units that have compressive strength of 1900 psi (minimum required by ASTM C90), the assembly compressive strength increases by only 11% if Type S mortar is used instead of Type N mortar. The increase in $f_{m}^{'min}$ is only 8.5% when 2400 psi compressive strength units are used and only 6.5% for 3000 psi compressive strength units. For clay masonry, the increase in assembly compressive strength is slightly higher when changing from Type N mortar to Type S mortar: about 20% when units of 6000 to 8000 psi compressive strength are used. However, a difference of 20% is still an order of magnitude smaller than the 240% difference in mortar compressive strengths (Type S to Type N).

Face brick, even those used for architectural veneer on homes, are currently manufactured to high compressive strengths; this author routinely sees test reports that record compressive strengths in the range of 12,000 to 18,000 psi, although ASTM C216 only requires a minimum compressive strength of 3000 psi. Some brick plants are manufacturing face brick units up to 35,000 psi compressive strength. According to the MSJC, the maximum assembly compressive strength is attained when the units have 13,200 psi compressive strength and Type S mortar.

The second reason that minimum mortar compressive strength should not be of major concern is that there is no standard test method to measure the compressive strength of in-place hardened mortar. In ASTM C270, mortar compressive strength is measured on 2” cubes molded from plastic mortar. In ASTM C780, the specimens used to evaluate compressive strength may be 2” cubes or cylinders that are 2” in diameter by 4” long or 3” in diameter by 6” long, each of which is
molded using plastic mortar. Mortar removed from an in-place joint cannot be evaluated for compressive strength using these standards. In fact, ASTM C780 specifically states the following relative to compressive strength of hardened mortar: “Tests of hardened mortars — There is no accepted standard for measuring individual hardened mortar joint strengths.”

Mortar compressive strength measured based on testing a thin section removed from a joint cannot be compared to the compressive strength of mortar based on testing a cube or cylinder. The aspect ratio of a test specimen (height to width) greatly influences the test results. That is why ASTM C1314, for example, requires that each test prism be fabricated with an aspect ratio no lower than 1.3 and no greater than 5. An aspect ratio of 2 is considered to be ideal, and correction factors are applied to the test results for prisms with aspect ratios other than 2. Prisms with aspect ratios outside this range are inappropriate for testing in accordance with ASTM C1314. The same issue exists with the aspect ratio of mortar specimens. Thin specimens (with low aspect ratio), such as those resulting from removing hardened mortar from an in-place joint, will produce inordinately high compression test results that cannot be compared to test results of standard specimens with standard aspect ratios.

**What compatibility aspects should be considered for repair mortar?**

There are two basic approaches to defining an appropriate repair mortar: defining the constituent materials and their relative proportions; and/or defining the relevant physical properties. In each approach, the existing mortar is analyzed to define the pertinent parameters and assure compatibility. The first approach is likely sufficient when repointing fairly contemporary masonry. The second approach, especially in combination with the first approach, should be used to define an appropriate repair mortar for a historic building.

Defining constituent materials and their proportions in an existing mortar is not adequate to define an appropriate repointing mortar for a historic building because the materials have changed over the years. Portland cement used in an 80-year-old mortar is not the same Portland cement that is currently manufactured. One of the differences is in the fineness with which Portland cement is ground. Modern cements are ground much finer than historic cements, resulting in mortars that are denser and harder. Repointing mortar that is denser and harder than the original mortar is not compatible because it will not have the same absorption and deformability characteristics. Use of a repointing mortar that is denser and harder than the original mortar will likely result in spalling of the masonry unit faces.

Constituent mortar materials and their proportions can be determined by evaluating the existing mortar in accordance with ASTM C1324. This test method requires the skills of both a petrographer (microscopist) and a chemist, who must work closely together. Each mortar sample to be analyzed should consist of a minimum chunk of 10 grams [ground-up mortar is not an acceptable sample].

Mortar analysis by ASTM C1324 begins with the petrographic examination, using a petrographic microscope and stereoscopic low power microscope. X-ray diffractometry and scanning electron microscopy may also be used. Visual observations of the mortar are followed by visually determining the rock and mineral composition of the aggregate used in the mortar. If the aggregate is determined to be acid-insoluble, aggregate gradation can be determined by dissolving the paste matrix, leaving only the aggregate particles that can be sieved. If some or all of the aggregate is acid-soluble, aggregate size definition must be performed by viewing sections of the sample under the microscope. The paste is then examined to identify whether the following materials are present: partially hydrated Portland cement particles, hydration products of Portland cement and their carbonated equivalents, hydrated lime, carbonated hydrated lime and finely ground mineral components such as limestone, dolomite, slag, fly ash, clay and pigments.

The petrographic examination includes characterization of the mortar for air void configuration and distribution. Non-spherical, non-uniformly dispersed air voids are typical of air that was entrapped during the mixing process. Spherical, uniformly distributed air voids indicate that an air entrainment additive or admixture was used in the mortar. Air entrainment is always used in masonry cement and mortar cement mortars, but only occasionally used in Portland cement/lime mortars. The petrographer is able to estimate the percentage of air voids by viewing the thin sections under the microscope.

**Beware of testing laboratories that perform petrographic and chemical mortar analysis independently rather than sequentially. Their test results are likely invalid.**

Upon conclusion of the petrographic examination, information is reported to the chemist. The chemical analysis cannot be performed without information provided by the petrographer. Because materials such as cement, lime and limestone have molecules in common, the chemist needs to know what to look for before the proportions of those materials can be quantified. Furthermore, the chemist needs to know whether the aggregate contains silica sand, since its presence will also affect the chemical analysis. Beware of testing laboratories that perform petrographic and chemical mortar analysis independently rather than sequentially. Their test results are likely invalid.

Upon conclusion of the chemical analysis in accordance with ASTM C1324, the mortar ingredients and their relative proportions will be defined. For contemporary construction [say, within the last 40 to 50 years], this information will likely be sufficient to define a compatible repointing mortar. For older construction, further testing should be performed. The additional testing should define properties such as density, porosity, absorption and water permeability for the original mortar and density, porosity,
CHOOSE A REPAIR MORTAR BASED ON COMPATIBILITY

water permeability and air content of the proposed repointing mortar.

The density is a measurement of the unit mass of the mortar. Density is affected by the fineness of the hydraulic components used to make up the mortar matrix. As mentioned previously, modern cements are more finely ground, resulting in a denser mortar. Denser mortars are harder, and should not be used to repoint a building with less dense original mortar. It is acceptable to use a repair mortar that is less dense than the original mortar.

Porosity is measured in accordance with ASTM C948. The test method should be applied to at least three 2" cube specimens of the proposed repointing mortar that are molded in accordance with ASTM C109. Three 2" cube specimens are also used to evaluate absorption in accordance with ASTM C67. The repointing mortar used to mold the cube specimens is made with sufficient water to obtain a Vicat Cone Penetrometer value of 15 mm plus or minus 5% (per ASTM C780). For mortars used for bedding units, the water addition should achieve a flow of 110 plus or minus 5% (a laboratory mix). Repair mortars should closely match the original mortar in porosity and absorption. Repair mortars that are substantially less porous and less absorptive than the original mortar could lead to damage in the masonry units. Repair mortars that are slightly more porous and more absorptive than the original mortar can perform well. Mortars that are too porous and absorptive will likely have poor durability, particularly in freeze-thaw climates.

Specimens used to evaluate water vapor transmission consist of assemblies of brick and mortar. The samples are generally formed in accordance with ASTM C1357, except that only two brick units are used, cheese cloth is used as a bond break and the mortar used to fabricate the specimens is mixed to a flow value of 120 plus or minus 5%. The samples are cut to fit over a testing cup that measures 2" (50 mm) plus or minus 1" (25 mm) on a side. The permeability is then determined in accordance with ASTM E96. The repair mortar should not be less permeable than the original mortar, but may be more permeable.

It is considered to be optional to specify a repair mortar based on additional physical properties, such as compressive strength or flexural bond strength. If compressive strength is specified, it is more important to specify a maximum compressive strength than a minimum compressive strength. Repair mortars with too high a compressive strength could cause unit masonry distress when used over existing weaker mortar and with relatively soft units.

Committee C12 of ASTM, specifically task group C12.03.03, is in the process of preparing a standard specification for mortars used in masonry preservation. That standard is expected to outline requirements similar to the recommendations contained herein.

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