This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: C1713 – 23

Standard Specification for Mortars for the Repair of Historic Masonry[1]

This standard is issued under the fixed designation C1713; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers mortar for the repair of masonry constructed with methods and materials that pre-date the origination of current standards of construction. The mortar may be used for non-structural purposes such as repointing of the masonry, or for structural purposes such as, but not restricted to, re-construction or repair of mortar joints that contribute to the structural integrity of the masonry.

1.2 Masonry includes the following units laid in mortar: (*1*) cast stone, (*2*) clay brick and tile, (*3*) concrete masonry, (*4*) natural stone, (*5*) terra cotta, and (*6*) calcium silicate.

1.3 This specification may be used to pre-qualify mortar for a project.

1.4 Mortars tested using this specification are laboratory-prepared mortars and do not represent in-place, site mortars.

1.5 This specification provides a basis for the design of an appropriate mortar formulation based upon performance, material and aesthetic requirements. Use of this specification requires a thorough understanding of the function, maintenance, and repair requirements for the preservation and continued performance of the masonry assembly in the context of the assembly's structure, water management, and long-term performance.

1.6 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C5 Specification for Quicklime for Structural Purposes
C10/C10M Specification for Natural Cement
C61/C61M Specification for Gypsum Keene's Cement
C91/C91M Specification for Masonry Cement
C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50 mm] Cube Specimens)
C110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone
C136/C136M Test Method for Sieve Analysis of Fine and Coarse Aggregates
C141/C141M Specification for Hydrated Hydraulic Lime for Structural Purposes
C144 Specification for Aggregate for Masonry Mortar
C150/C150M Specification for Portland Cement
C207 Specification for Hydrated Lime for Masonry Purposes
C216 Specification for Facing Brick (Solid Masonry Units Made from Clay or Shale)
C270 Specification for Mortar for Unit Masonry
C305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency
C511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
C595/C595M Specification for Blended Hydraulic Cements
C780 Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry
C948 Test Method for Dry and Wet Bulk Density, Water Absorption, and Apparent Porosity of Thin Sections of Glass-Fiber Reinforced Concrete
C979/C979M Specification for Pigments for Integrally Colored Concrete

[1] This specification is under the jurisdiction of ASTM Committee C12 on Mortars and Grouts for Unit Masonry and is the direct responsibility of Subcommittee C12.03 on Specifications for Mortars.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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C1072 Test Methods for Measurement of Masonry Flexural Bond Strength
C1093 Practice for Accreditation of Testing Agencies for Masonry
C1157/C1157M Performance Specification for Hydraulic Cement
C1180 Terminology of Mortar and Grout for Unit Masonry
C1329/C1329M Specification for Mortar Cement
C1384 Specification for Admixtures for Masonry Mortars
C1400 Guide for Reduction of Efflorescence Potential in New Masonry Walls
C1403 Test Method for Rate of Water Absorption of Masonry Mortars
C1489 Specification for Lime Putty for Structural Purposes
C1506 Test Method for Water Retention of Hydraulic Cement-Based Mortars and Plasters
C1707 Specification for Pozzolanic Hydraulic Lime for Structural Purposes
E96/E96M Test Methods for Gravimetric Determination of Water Vapor Transmission Rate of Materials
E2260 Guide for Repointing (Tuckpointing) Historic Masonry

3. Terminology

3.1 The terms used in this specification are identified in Terminology C1180.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aggregate, n*—material as defined in Terminology C1180, but limited to the material groups listed under Section 4 of this specification.

3.2.2 *binder, n*—material as defined in Terminology C1180, but limited to the cementitious material groups listed under Section 4 of this specification to be mixed with potable water.

3.2.3 *curing, n*—process by which a mortar gains its long-term, final-state properties.

3.2.4 *curing time (CT), n*—number of days in which a hardened state sample is cured before testing.

3.2.5 *historic masonry, n*—masonry that may have been constructed with methods and materials that pre-date the origination of current standards.

3.3 *Properties*, as determined by Section 8 of this specification:

3.3.1 *absorption rate (AR), n*—a measure of the hardened mortar's ability to absorb water from a dry condition, measured as the initial flow of water into the mortar, as defined under Test Method C1403 and evaluated at the specified curing time (CT).

3.3.2 *air content, n*—cumulative volume of air in a mortar, as a percentage of the total volume of mortar in its plastic state.

3.3.3 *flexural bond strength (FBS), n*—maximum flexural tensile stress that causes failure of the bond between the mortar and masonry unit in a tested assembly at the specified curing time (CT).

3.3.4 *maximum compressive strength (Fcmx), n*—upper allowable limit on the ultimate strength of a hardened mortar sample subjected to compression measured as force per unit area at the specified curing time (CT).

3.3.5 *minimum compressive strength (Fc), n*—lower allowable limit on the ultimate strength of a hardened mortar sample subjected to compression measured as force per unit area at the specified curing time (CT).

3.3.6 *total porosity, n*—volume percentage of all pores or void space in the mortar at the specified curing time (CT).

3.3.7 *water retention, n*—as defined in Terminology C1180. Test shall be conducted on a sample in its plastic state.

3.3.8 *water vapor permeability (WVP), n*—ability of a mortar to pass water through it in vapor form at the specified curing time (CT).

4. Constituent Materials

4.1 *Binder Materials* shall be classified into the following groups:

4.1.1 *Group L*—Lime (non-hydraulic) shall conform to the following specifications:

4.1.1.1 Hydrated Lime shall conform to Specification C207, Types S or SA. Types N and NA hydrated limes are permitted if soaked or shown by test or performance record to be not detrimental to the mortar.

4.1.1.2 Lime putty shall conform to Specification C1489.

NOTE 1—Specification C5, Appendix 1, may be used, and the resulting putty should meet the requirements of Specification C1489.

4.1.2 *Group HL*—Hydraulic Lime shall conform to the following specifications:

4.1.2.1 *Hydraulic Hydrated Lime*—shall conform to Specification C141/C141M.

4.1.2.2 *Pozzolanic Hydraulic Lime*—shall conform to Specification C1707.

4.1.3 *Group HC*—Hydraulic Cements shall conform to the following specifications:

4.1.3.1 *Blended Hydraulic Cement*—shall conform to Specification C595/C595M.

NOTE 2—Blended hydraulic cement may not be appropriate for structures built before the second half of the 20th century.

4.1.3.2 *Performance Hydraulic Cement*—shall conform to Specification C1157/C1157M.

NOTE 3—Performance hydraulic cement may not be appropriate for structures built before the second half of the 20th century.

4.1.3.3 *Masonry Cement*—shall conform to Specification C91/C91M.

4.1.3.4 *Mortar Cement*—shall conform to Specification C1329/C1329M.

4.1.3.5 *Natural Cement*—shall conform to Specification C10/C10M.

4.1.3.6 *Portland Cement*—shall conform to Specification C150/C150M.

NOTE 4—For interior gypsum mortar based systems requiring gypsum cement refer to Specification C61/C61M and consult with the product manufacturer regarding exposure suitability.

4.2 *Aggregates*—Aggregate shall conform to Specification C144. Aggregates that conform to all aspects of Specification C144 except for the gradation limits are permitted if demonstrated by their history of performance under equivalent

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conditions and mortar formulation to be non-detrimental to the mortar. To determine aggregate gradation, use Test Method C136/C136M.

NOTE 5—The need to aesthetically match the color and texture of an existing mortar may be justification for deviating from the gradation limits of Specification C144.

4.3 *Water*—Water shall be clean and free of oils, acids, alkalies, salts, organic materials, or other substances that are deleterious to mortar or any metal used in the masonry.

4.4 *Admixtures:*

4.4.1 *Admixtures*—shall meet the requirements of Specification C1384. Calcium chloride is not permitted. Other admixtures that are outside the scope of Specification C1384 are permitted if they contain no more than 0.3 % water-soluble alkali and if demonstrated by their history of performance under equivalent conditions and mortar formulation to be non-detrimental to the mortar and items in contact.

4.4.2 *Pigments*—Pigments shall meet the requirements of Specification C979/C979M. Pigments which are not described by Specification C979/C979M are permitted if demonstrated by their history of performance under equivalent conditions and mortar formulation to be non-detrimental to the mortar. Pigment addition shall not exceed 10 % by weight of the binder materials except for carbon black which is limited to 2 % unless otherwise demonstrated by history of performance under equivalent conditions and mortar formulation to be non-detrimental to the mortar.

5. Mortar Proportioning

5.1 *Binder/Aggregate Ratio:*

5.1.1 Combine the mortars in volume ratios of 1 part total binder materials to 2 to 3½ parts aggregate.

5.1.2 Mortars specified outside volume ratios of 1 part total binder materials to 2 to 3½ parts aggregate shall be permitted if shown by history of use or by mortar testing per this specification to be not detrimental to the mortar.

NOTE 6—Most common mortars have total binder to aggregate ratios of 1 part total cementitious materials to 2½ to 3 part aggregate, whereas some earlier mortars may have ratios as high as 1 to 1.

5.2 *Air Entraining Binders*—Air entraining binders shall not be used in combination with other air entraining binders or with a separate air entrainment admixture.

6. Requirements

6.1 *Establishing Mortar Proportions:*

6.1.1 Specify mortars by (*1*) proportion specification, constituent materials and their respective volume proportions, or (*2*) property specification, constituent materials (or proprietary products names) and required properties, in accordance with Table 1.

6.1.1.1 Specifiers using the proportion specification shall select binder and aggregate proportions based upon an established history of performance or testing that documents satisfactory performance of the combinations and proportions specified, and in conformance with Section 5 of this specification.

NOTE 7—WVP of the mortar should be greater than that of the masonry units, and equal to or greater than that of the substrate mortar where present.

NOTE 8—Vapor permeability will generally decrease with increasing hydraulic constituents; however, aggregate gradation and admixtures can greatly influence the value.

7. Test Samples and Preparation

7.1 *Material Proportioning*—Laboratory mixed mortar specified by volume proportions shall contain the mortar materials as indicated in the mortar specification. Volume proportions shall be converted to weights using the batch factor calculated as follows:

7.1.1 *Material Proportioning for Test Batches of Mortar:*

7.1.1.1 Batch factor = 1440/ [1280 kg/m^3 (bulk density of aggregate) times total aggregate volume proportion].

NOTE 9—A batch size using 1440 g of aggregate will typically result in enough mortar for water retention testing and one set of three 2-in. cubes for compressive strength testing. Several batches with the same water to binder ratio may be necessary to complete all tests.

7.1.1.2 Oven dry and cool to room temperature all aggregate used for test mortars. Mortars preblended with aggregate require no proportioning.

7.1.2 Constituent materials shall have the bulk densities as noted in Table 2.

7.2 *Masonry Units for Use in Water Vapor Permeability and Bond Strength*—Masonry units shall be the actual masonry units to be used in the field, or if unavailable, a brick meeting Specification C216, Grade SW with absorption properties similar to the in-situ masonry units, if known.

7.3 *Mortar Mixing*—Mix the mortar in accordance with Practice C305 with the exception that for Group L and Group HL mortars and those combined mortars at or greater than 45 % lime by binder volume the initial (low speed) mixing time is extended to up to 2 minutes, the resting time is extended to 1.5 minutes, and the final (medium speed) mixing time is extended to up to 8 minutes, as best suits the formulation for complete intermixing of components without segregation or over entrapment of air.

NOTE 10—These time extensions allow for the full wetting of the mortar constituents.

7.4 *Mortar Test Sample Molding:*

7.4.1 For total porosity, absorption rate and compressive strength testing, mold the 2-in. (50-mm) cubes in accordance with Test Method C109/C109M, subsections on Specimen Molds and Molding Test Specimens. For mortars to be used as unit bedding, add enough water to obtain flow of 110 ± 5 %. For mortars to be used as repointing mortars, add enough water to obtain a Vicat Cone Penetrometer value (Test Method C780, Annex A1, Consistency by Cone Penetration Test Method) of 15 mm ± 5 %.

7.4.2 For vapor transmission and bond strength testing mold the samples according to Test Method C1072, with the exception that for the vapor transmission the specimen is two brick, and cheese cloth is to be used as a bond break, and mortar is to have flow values of 120 ± 5%. If the binder material to aggregate volume ratio has not been specified, use a value of 1:3 binder to aggregate ratio measured by volume with sand meeting Specification C144.

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TABLE 1 Specification Requirements

Requirement	Proportion Specification	Property Specification
Water Retention (%)—Water retention value shall not be less than 75 %.	Mandatory requirement for all mortar formulations in their plastic states	Mandatory requirement for all mortar formulations in their plastic states
Air Content (%)—When an air entraining admixture is used, the air content of the mortar shall not exceed 12 %, with the exceptions of mortar cement which shall not exceed 17 % and masonry cement mortar which shall not exceed 21 %.	Mandatory requirement for all mortar formulations	Mandatory requirement for all mortar formulations
Curing Time (CT, days)—Laboratory Test Samples shall be cured according to Section 7. The minimum CT for mortars with Group L and Group HL as binders, and those that combine Group HC with greater than or equal to 45 volume % Group L shall be 120 days. The minimum CT for mortars with Group HC as binder and those that combined Group HC with Group L with less than 45 volume % Group L shall be 28 days. Longer CTs or multiple CTs may be required at the discretion of the specifier. The above is for Laboratory Sample Testing Only.	Mandatory minimum curing requirement for all hardened state mortar test samples	Mandatory minimum curing requirement for all hardened state mortar test samples
Total Porosity (TP, %)—Where a target value has been established by the specifier or the manufacturer, the total porosity % shall not range more than 0.75 to 1.25 times the target value.	Report if specified.	Mandatory if specified. Previously determined TP values obtained using this specification within the last five years from at least five same mortar formulations are permitted to be used.
Water Vapor Permeability (WVP, perms)—Where a target value has been established by the specifier or the manufacturer the water vapor permeability value shall not range more than ±25 % of the target value.	Report if specified.	Mandatory to report. Previously determined WVP values obtained under this specification within the last five years for at least five samples from the same mortar formulation are permitted to be used.
Minimum Compressive Strength (Fc, psi)[A]	Report if specified.	Mandatory requirement.
Maximum Compressive Strength (Fcmx, psi)—Where needed to establish material quality control. Where minimum compressive strength is specified, the value shall not be more than 100 ± 20 % greater than the minimum compressive strength.[B]	Report if specified.	Mandatory if specified.
Flexural Bond Strength (FBS, psi)—Where bond strength of the mortar to masonry unit is critical. In mortars containing more than 50 % of Group HC binder, the FBS average shall be not less than 29 psi.	Report if specified.	Mandatory if specified.
Absorption Rate (AR, g/min/30 in.^{2}) , shall be appropriate for the masonry units employed.	Report if specified.	Mandatory if specified.

[A] This property can be critical to physical compatibility with the surrounding construction, and the structural safety and/or stability of the system.
[B] This property can be critical to physical compatibility with the surrounding construction, as limited by structural safety and/or stability of the system.

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7.5 *Sample Demolding*—Table 3 summarizes the demolding time required for different binder combinations.

7.6 *Specimen Storage and Curing*—The storage and curing conditions in Table 3 shall be maintained both before and after demolding, for the duration of the specified Curing Time (CT).

7.6.1 Test specimens stored at 70 ± 5 % RH shall be placed in a cabinet or environmental chamber where the relative humidity and ambient CO_2 level can be maintained and documented.

7.6.2 Test specimens stored at 100 % RH shall be placed in a moist room or cabinet following Specification C511.

8. Test Methods

8.1 *Water Retention*—Determine water retention in accordance with the Test Method C1506.

NOTE 11—Water retention cannot be determined for repointing mortars at low flow values. Enough water must be added to obtain a flow of 110 ± 5 %.

8.2 *Air Content*—Determine air content in accordance with Specification C270 or with the air meter technique of Test Method C110.

8.3 *Total Porosity*—Determine total porosity in accordance with Test Method C948, on a set of three 2-in. samples.

TABLE 2 Bulk Density of Constituent Materials

Binder/Aggregate	Material	Bulk Density
Group L Binder	Hydrated Lime	40 pcf (640 kg/m^3)
	Lime Putty	80 pcf (1280 kg/m^3)
Group HL Binder	Hydrated Hydraulic Lime	Obtain from manufacturer
Group HC Binder	Pozzolanic Hydraulic Lime	Obtain from manufacturer
	Portland Cement	Obtain from manufacturer
	Masonry Cement	Obtain from manufacturer
	Mortar Cement	Obtain from manufacturer
	Natural Cement	Obtain from manufacturer
	Blended Hydraulic Cement	Obtain from manufacturer
	Hydraulic Cement	
Pre-blended Binder	Any or all of the above	Obtain from manufacturer
Aggregate		80 pcf (1280 kg/m^3)[A]

[A]The sand is oven dried for laboratory testing to reduce the potential of variability due to sand moisture content and to permit better accounting of materials used for air content calculations. It is not necessary for the purpose of this specification to measure the unit weight of the dry sand. Although the unit weight of dry sand will typically be 85 to 100 pcf (1360 to 1760 kg/m^3), experience has shown the use of an assumed unit weight of 80 lb (1280 kg/m^3) for dry sand will result in a laboratory mortar ratio of aggregate to binder that is similar to that of the corresponding field mortar made using damp loose (bulked) sand.

TABLE 3 Storage Time in Molds

Binder Type	Time in Molds	Specimen Storage Conditions
Group L and Group HL only and combined mortars with 45 % or more lime by binder volume	Minimum 5 days or until the sample is sufficiently stable to demold	70 ± 5 % RH for Group L 90 ± 5 % RH for Group HL
Group HC only and combined mortars with less than 45 % lime by binder volume	2 to 5 days as needed	100 % RH

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8.4 *Absorption Rate*—Determine absorption rate in accordance with Test Method C1403 using three 2-in. cubes, performing weight measurements at 1 and 3 min in addition to the times specified therein, with reported units converted to g/min/30 in.^{2}.

8.5 *Water Vapor Permeability*—Determine in accordance with Test Method E96/E96M. The mortar shall be prepared according to 7.3. At the time of testing, samples will be cut to fit over a testing cup measuring 50 ± 2.5 mm on a side, in a manner so as not to adversely affect the result.

8.6 *Compressive Strength*—Determine in accordance with Test Method C109/C109M (using 2-in. or 50-mm cube specimens), except that samples shall be cured in accordance with 7.6 of this specification.

8.7 *Flexural Bond Strength*—Determine in accordance with Test Method C1072 using masonry units as described in 7.2. Assembly shall be cured in accordance with 7.6 of this specification.

9. Quality Assurance

9.1 Compliance of volume specified mortars to this specification shall be verified by:

9.1.1 Confirmation that the materials in Section 4 of this specification are used shall be verified by letters of certification or mill reports from the manufacturer.

9.1.2 Proportions of material shall be verified by weigh scale certificates or described procedures for proportioning and mixing the approved materials.

NOTE 12—The testing laboratories performing the testing specified herein should be evaluated in accordance with Practice C1093.

10. Keywords

10.1 absorption rate; air content; compressive strength; flexural bond strength; hydrated lime; hydraulic cement; hydraulic lime; lime putty; masonry; natural cement; portland cement masonry cement; preservation; repointing; total porosity; water retention; water vapor permeability

APPENDIXES

(Nonmandatory Information)

X1. EVALUATION, SELECTION AND USE OF MORTAR FOR REPAIR OF HISTORIC MASONRY

X1.1 *Scope*—This specification covers mortar for the repair of masonry that was constructed with methods and materials that pre-date the origination of current standards of construction. The mortar may be used for non-structural purposes such as repointing of the masonry, or for structural purposes such as, but not restricted to, reconstruction or repair of mortar joints that contribute to the structural integrity of the masonry. This appendix is a guide to the use of this specification and provides additional information for use in evaluating and specifying mortars for the repair of historic masonry. Repeated reference is made to the Appendix X1 of Specification C270, which provides nonmandatory information that can be used as a supplement to this appendix. The reader is encouraged to read all of Appendix X1 and X2 in Specification C270 as well as the other appendices in Specification C270 as they will provide helpful information beyond what is specifically referenced herein.

X1.2 *Significance and Use*—Masonry mortar is a versatile material capable of satisfying a variety of diverse requirements and significantly influences the performance of the masonry assembly as a whole. In the repair of existing masonry, it is critical that the mortar being used in the repair is both aesthetically and physically compatible with the existing mortar, as well as the masonry assembly as a whole. In many cases, this may be achieved with nearly equal success by a variety of different mortar types that all satisfy the same requirements. A thorough understanding of both existing mortar materials and those used in the repair and their properties, and their relation to the historic masonry assembly being repaired will enable selection of a mortar that will perform satisfactorily.

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X1.3 *Specifying Mortars for Repair of Historic Masonry*:

X1.3.1 *Understanding the Existing Masonry Assembly and Functional Requirements of Mortar for Repair*—In order to properly specify a mortar that is appropriate for the repair of an historic masonry assembly, the user of this specification (specifier) must first understand the materials and functional requirements of the existing masonry assembly, the way in which the assembly has and will behave, how well it has performed, and how appropriate the existing mortar and masonry units have been for the assembly's usage requirements and environment. Based upon this understanding, the specifier must then determine what materials and mortar properties are most appropriate for the mortar that will be used for the repairs.

X1.3.2 *Proportion vs. Property Specification*—This specification provides two ways of specifying mortars: (*1*) by proportion and (*2*) by property, whichever better suits the requirements of the work. The specifier may also designate or restrict allowed material types to be used in a property-specified mortar, and require verification of expected properties on a proportion-specified mortar. In all cases, the proportion-specifier must have a thorough understanding of the available materials, which include binders (cementitious materials), aggregate, water and sometimes admixtures, and their role in the mortar properties that will result. The property-specifier must have a thorough understanding of the properties that are required, as well as the properties that can be achieved with the available materials. The specifier is cautioned not to intermix the requirements of the proportion specification and the property specification in such a way as creates unachievable requirements for given formulations, but must rather, base the use of all overlapping requirements on a thorough understanding of the properties that will result from the specified proportions.

X1.3.3 *Proportion Specification* can be useful for projects where manufactured property-specified mortars are not available or may not best suit the requirements of the work, or where the size of the project is such that it is not expedient for a contractor or manufacturer to produce a pre-tested, prequalified mortar for the specific requirements of the job, as well as in cases where mortar formulations have been developed by the specifier for mixing on site.

NOTE X1.1—It is the intent of this specification to encourage the growth of a public domain repository of mortar formulations and their correlated properties that will be helpful in guiding the process for selection of mortar formulations that must satisfy the specific needs of the project.

X1.3.3.1 *Examples of Proportion Specification*—When using proportion specification, the specifier must list the constituent materials in the mortar with their relative proportions by volume. For example:

> "Mortar A and its constituents shall meet the requirements of ASTM C1713, and shall consist of 1 part portland cement, 3 parts hydrated lime and 12 parts bulked sand by volume."
> or:
> "Mortar B and its constituents shall meet the requirements of ASTM C1713 and shall consist of 2 parts natural cement, 1 part hydrated lime and 7 parts bulked sand by volume with an air content of 8 % plus or minus 2 %."
> or:
> "Mortar C and its constituents shall meet the requirements of ASTM C1713, and shall consist of 2 parts lime putty and 5 parts bulked sand by weight."

X1.3.3.2 Additional requirements can be put into the specification regarding sand gradation, additives and pigments for exposed applications, such as:

> "For architecturally exposed mortar, the aggregate type and gradation shall match the existing exposed original mortar sand and, where necessary, mineral oxide pigments may be added by up to ten percent by weight of binder to adjust the paste color to match the original."

X1.3.3.3 The specifier may also require certain properties to be attained or reported as verification of the formulation (but must allow a mechanism for adjustment of the proportions in order to meet required properties if the original formulation does not), such as:

"Mortar A shall have an Fc of 750 psi and an Fcmx of 1500 psi subject to verification by test in accordance with ASTM C1713. Constituent proportions may be adjusted by up to 25 percent to meet these property requirements, but only with written authorization of the [specifier]."

or:

"The water vapor permeability (WVP) of Mortars B and C shall be determined in accordance with ASTM C1713 and shall be reported in writing."

X1.3.4 *Property Specification* can be useful in projects where pre-blended mortars are available to suit the requirements of the work, or where the size of the project is such that it is expedient for a manufacturer or contractor to produce a pre-tested, prequalified mortar for the specific requirements of the job, as well as cases where the performance requirements of the project are so critical that the specific property requirements drive the design.

X1.3.4.1 *Example of Property Specification*—When using property specification, the specifier should state the allowed constituent types but not the proportions, leaving the determination of proportions to the contractor or manufacturer, to be verified by test (tests shall be batch specific in the case of custom designed mortars or where permitted from previous tests within the last five years for pre-manufactured pre-blended standardized mortars). For example:

"Mortar A and its constituents shall meet the requirements of ASTM C1713, and shall consist of a mix of Group HC and L binders and sand with the following properties as determined in accordance with ASTM C1713 at the required CT: air content of 8 % plus or minus 2 %, Fc=750 psi, Fcmx=1500 psi. The WVP shall be determined in accordance with ASTM C1713 and shall be reported in writing."

or, if more specificity is desired:

"Mortar B and its constituents shall meet the requirements of ASTM C1713 and shall consist of a mix of natural cement and hydrated lime binders and sand following properties as determined in accordance with ASTM C1713 at the required CT: Fc=2500 psi, FBS>50 psi. The WVP shall be determined in accordance with ASTM C1713 and shall be reported in writing."

or:

"Mortar C and its constituents shall meet the requirements of ASTM C1713 and shall consist of a mix of lime putty and sand with an Fc of 350 psi as determined in accordance with ASTM C1713 at the required CT. The WVP shall be determined in accordance with ASTM C1713 and shall be reported in writing."

X1.3.4.2 Additional requirements can be put into the specification regarding sand gradation, additives and pigments for exposed applications, such as:

"For architecturally exposed mortar, the aggregate type gradation shall match that of the existing exposed original mortar and where necessary, up to 10 percent mineral oxide pigment may be added to adjust the paste color to match the original."

X1.3.5 *Binder Materials and Historical Context*—The specification allows a wide range of binder materials because of the many time periods of construction it covers. Lime putty and, to a lesser extent, clay, hydraulic lime, and lime hydrate were the predominent binder materials used up until the mid- to late-19th century. Natural cement was first used in England in 1756 and then North America in 1818, and then became increasingly common throughout duration of the 19th century, particularly in large urban centers and in significant public works, transportation and industrial projects. Portland cement production began in England in the 1820s and began to be exported shortly thereafter, not being produced in North America until the 1870s. By the beginning of the 20th century, portland cement had gained market dominance, becoming one of the primary building materials of the modern industrialized world. Masonry cement was first introduced as a patented product in 1918 and generic masonry cements gained sufficient use in the marketplace to warrant issuing of ASTM , Tentative Specification for Masonry Cement in 1932. Much of this more recent, modern-era construction that was built during the first half of the 20th century, is now old enough that it too can be considered "historic".

X1.3.6 *Differences in Curing Times* in the specification were developed to account for the differences between carbonation-curing, which takes place in Group L and to some extent HL binders, and hydration curing which takes place in Goup HC and HL binders. In simplistic terms, carbonation-curing generally starts from the exposed surface of a mortar and slowly works its way inward (requiring sample testing at up to 120 days), while hydration curing takes place from within (requiring sample testing at only 28 days).

X1.3.6.1 The curing times in hydrating laboratory samples are generally analogous to the curing times that might be experienced in the field, whereas curing times in carbonating samples are usually not analogous to field curing times, because the actual time that it takes to cure a carbonating mortar is dependent upon the mode and pathway of carbon transport from the atmosphere. For example, mortar that is in the core of a granite faced wall with tight joints will carbonate more slowly than the same mortar used in pointing the exposed surfaces of the joints because it takes longer for sufficient carbon to reach the wall's core than the surface. Carbonation is promoted through repeated cycles of wet and dry where care is taken in the early stages to ensure the mortar is not allowed to completely dry out. The unit material, construction sequencing and joint detailing in a masonry assembly along with wetting and drying frequency of the completed work will affect the curing time. The geometric relationship of the mortar, the masonry units and the free air surface, however, will often have an even bigger effect on the in-situ curing time of the mortar, this being a function of the unexposed mortar volume multiplied by the distance from the surface divided by the surface-exposed area.

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X1.4 *Function of Mortar in Historic Masonry Assemblies*:

X1.4.1 The purposes of mortar in historic masonry are to bond masonry units together, provide for load-bearing support, weather resistance, vapor transport, architectural expression, and constructability as an integral element having the desired functional performance characteristics. Mortar influences the performance of the assembly in many ways.

X1.4.2 *Functional Requirements*—A masonry assembly may be subjected to numerous external conditions under which it must successfully perform. These include structural loading, induced strains and forced displacements, environmental abrasion, wetting and drying, freezing and thawing, and salt transport. The ability of an historic masonry assembly to perform under these conditions must be maintained or, if needed improved, with the proper selection of materials that will be used in their repair.