Standard Specification for Mortar for Unit Masonry[1]

This standard is issued under the fixed designation C270; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers mortars for use in the construction of non-reinforced and reinforced unit masonry structures. Four types of mortar are covered in each of two alternative specifications: (*1*) proportion specifications and (*2*) property specifications.

NOTE 1—When the property specification is used to qualify masonry mortars, the testing agency performing the test methods should be evaluated in accordance with Practice C1093.

1.2 The proportion or property specifications shall govern as specified.

1.3 When neither proportion or property specifications are specified, the proportion specifications shall govern, unless data are presented to and accepted by the specifier to show that mortar meets the requirements of the property specifications.

1.4 The text of this specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.5 The terms used in this specification are identified in Terminologies C1180 and C1232.

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 The following safety hazards caveat pertains only to the test methods section of this specification: *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C5 Specification for Quicklime for Structural Purposes
C91 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
C128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate
C144 Specification for Aggregate for Masonry Mortar
C150 Specification for Portland Cement
C188 Test Method for Density of Hydraulic Cement
C207 Specification for Hydrated Lime for Masonry Purposes
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 Specification for Blended Hydraulic Cements
C780 Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry
C952 Test Method for Bond Strength of Mortar to Masonry Units
C979 Specification for Pigments for Integrally Colored Concrete
C1072 Test Method for Measurement of Masonry Flexural Bond Strength
C1093 Practice for Accreditation of Testing Agencies for Masonry
C1157 Performance Specification for Hydraulic Cement
C1180 Terminology of Mortar and Grout for Unit Masonry

[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.

***A Summary of Changes section appears at the end of this standard.**

C1232 Terminology of Masonry
C1324 Test Method for Examination and Analysis of Hardened Masonry Mortar
C1329 Specification for Mortar Cement
C1357 Test Methods for Evaluating Masonry Bond Strength
C1384 Specification for Admixtures for Masonry Mortars
C1489 Specification for Lime Putty for Structural Purposes
C1506 Test Method for Water Retention of Hydraulic Cement-Based Mortars and Plasters
C1586 Guide for Quality Assurance of Mortars
E72 Test Methods of Conducting Strength Tests of Panels for Building Construction
E514 Test Method for Water Penetration and Leakage Through Masonry
E518 Test Methods for Flexural Bond Strength of Masonry

2.2 *Masonry Industry Council:*[3]

Hot and Cold Weather Masonry Construction Manual, January 1999

3. Specification Limitations

3.1 Specification C270 is *not* a specification to determine mortar strengths through field testing.

3.2 Laboratory testing of mortar to ensure compliance with the property specification requirements of this specification shall be performed in accordance with 5.3. The property specification of this standard applies to mortar mixed to a specific flow in the laboratory.

3.3 The compressive strength values resulting from field tested mortars do not represent the compressive strength of mortar as tested in the laboratory nor that of the mortar in the wall. Physical properties of field sampled mortar shall not be used to determine compliance to this specification and are not intended as criteria to determine the acceptance or rejection of the mortar (see Section 8).

4. Materials

4.1 Materials used as ingredients in the mortar shall conform to the requirements specified in 4.1.1 to 4.1.4.

4.1.1 *Cementitious Materials*—Cementitious materials shall conform to the following ASTM specifications:

4.1.1.1 *Portland Cement*—Types I, IA, II, IIA, III, IIIA, or V of Specification C150.

4.1.1.2 *Blended Hydraulic Cements*—Types IS(<70), IS(<70)-A, IP, IP-A of Specification C595.

4.1.1.3 *Hydraulic Cements*—Types GU, HE, MS, HS, MH, and LH of Specification C1157.

4.1.1.4 *Portland Blast-Furnace Slag Cement (for Use in Property Specifications Only)*—Types IS(≥70) or IS(≥70)-A of Specification C595.

4.1.1.5 *Masonry Cement*—See Specification C91.

4.1.1.6 *Mortar Cement*—See Specification C1329.

4.1.1.7 *Quicklime*—See Specification C5.

4.1.1.8 *Hydrated Lime*—Specification C207, Types S or SA. Types N or NA limes are permitted if shown by test or performance record to be not detrimental to the soundness of the mortar.

4.1.1.9 *Lime Putty*—See Specification C1489.

4.1.2 *Aggregates*—See Specification C144.

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

4.1.4 *Admixtures*—Admixtures shall not be added to mortar unless specified. Admixtures shall not add more than 65 ppm (0.0065 %) water soluble chloride or 90 ppm (0.0090 %) acid soluble chloride to the mortar's overall chloride content, unless explicitly provided for in the contract documents.

4.1.4.1 *Classified Admixtures*—Admixtures which are classified as bond enhancers, workability enhancers, set accelerators, set retarders, and water repellents shall be in accordance with Specification C1384.

4.1.4.2 *Color Pigments*—Coloring pigments shall be in accordance with Specification C979.

4.1.4.3 *Unclassified Admixtures*—Mortars containing admixtures outside the scopes of Specifications C1384 and C979 shall be in accordance with the property requirements of this specification and the admixture shall be shown to be non-deleterious to the mortar, embedded metals, and the masonry units.

4.1.4.4 *Calcium Chloride*—When explicitly provided for in the contract documents, calcium chloride is permitted to be used as an accelerator in amounts not to exceed 2 % by weight of the portland cement content or 1 % of the masonry cement content, or both, of the mortar.

NOTE 2—If calcium chloride is allowed, it should be used with caution as it may have a detrimental effect on metals and on some wall finishes.

5. Requirements

5.1 Unless otherwise stated, a cement/lime mortar, a mortar cement mortar, or a masonry cement mortar is permitted. A mortar type of known higher strength shall not be indiscriminately substituted where a mortar type of anticipated lower strength is specified.

5.2 *Proportion Specifications*—Mortar conforming to the proportion specifications shall consist of a mixture of cementitious material, aggregate, and water, all conforming to the requirements of Section 4 and the proportion specifications' requirements of Table 1. See Appendix X1 or Appendix X3 for a guide for selecting masonry mortars.

5.3 *Property Specifications*—Mortar conformance to the property specifications shall be established by tests of laboratory prepared mortar in accordance with Section 6 and 7.2. The laboratory prepared mortar shall consist of a mixture of cementitious material, aggregate, and water, all conforming to the requirements of Section 4 and the properties of the laboratory prepared mortar shall conform to the requirements of Table 2. See Appendix X1 for a guide for selecting masonry mortars.

5.3.1 No change shall be made in the laboratory established proportions for mortar accepted under the property specifications, except for the quantity of mixing water. Materials with

[3] Available from the Mason Contractors Association of America, 1910 South Highland Avenue, Suite 101, Lombard, IL 60148.

TABLE 1 Proportion Specification Requirements

NOTE—Two air-entraining materials shall not be combined in mortar.

Mortar	Type	Proportions by Volume (Cementitious Materials)								Aggregate Ratio (Measured in Damp, Loose Conditions)
		Portland Cement or Blended Cement	Mortar Cement			Masonry Cement			Hydrated Lime or Lime Putty	
			M	S	N	M	S	N		
Cement-Lime	M	1	. . .	. . .	. . .	. . .	. . .	. . .	¼	
	S	1	. . .	. . .	. . .	. . .	. . .	. . .	over ¼ to ½	
	N	1	. . .	. . .	. . .	. . .	. . .	. . .	over ½ to 1¼	
	O	1	. . .	. . .	. . .	. . .	. . .	. . .	over 1¼ to 2½	
Mortar Cement	M	1	. . .	. . .	1	. . .	. . .	. . .	. . .	Not less than 2¼ and not more than 3 times the sum of the separate volumes of cementitious materials
	M	. . .	1	. . .	. . .	. . .	. . .	. . .	. . .	
	S	½	. . .	. . .	1	. . .	. . .	. . .	. . .	
	S	. . .	. . .	1	. . .	. . .	. . .	. . .	. . .	
	N	. . .	. . .	. . .	1	. . .	. . .	. . .	. . .	
	O	. . .	. . .	. . .	1	. . .	. . .	. . .	. . .	
Masonry Cement	M	1	. . .	. . .	. . .	. . .	. . .	1	. . .	
	M	. . .	. . .	. . .	. . .	1	. . .	. . .	. . .	
	S	½	. . .	. . .	. . .	. . .	. . .	1	. . .	
	S	. . .	. . .	. . .	. . .	. . .	1	. . .	. . .	
	N	. . .	. . .	. . .	. . .	. . .	. . .	1	. . .	
	O	. . .	. . .	. . .	. . .	. . .	. . .	1	. . .	

TABLE 2 Property Specification Requirements[A]

Mortar	Type	Average Compressive Strength at 28 days, min, psi (MPa)	Water Retention, min, %	Air Content, max, %[B]	Aggregate Ratio (Measured in Damp, Loose Conditions)
Cement-Lime	M	2500 (17.2)	75	12	
	S	1800 (12.4)	75	12	
	N	750 (5.2)	75	14[C]	
	O	350 (2.4)	75	14[C]	
Mortar Cement	M	2500 (17.2)	75	12	Not less than 2 ¼ and not more than 3 ½ the sum of the separate volumes of cementitious materials
	S	1800 (12.4)	75	12	
	N	750 (5.2)	75	14[C]	
	O	350 (2.4)	75	14[C]	
Masonry Cement	M	2500 (17.2)	75	18	
	S	1800 (12.4)	75	18	
	N	750 (5.2)	75	20[D]	
	O	350 (2.4)	75	20[D]	

[A] Laboratory prepared mortar only (see Note 4).
[B] See Note 5.
[C] When structural reinforcement is incorporated in cement-lime or mortar cement mortar, the maximum air content shall be 12 %.
[D] When structural reinforcement is incorporated in masonry cement mortar, the maximum air content shall be 18 %.

different physical characteristics shall not be utilized in the mortar used in the work unless compliance with the requirements of the property specifications is reestablished.

NOTE 3—The physical properties of plastic and hardened mortar complying with the proportion specification (5.1) may differ from the physical properties of mortar of the same type complying with the property specification (5.3). For example, laboratory prepared mortars batched to the proportions listed in Table 1 will, in many cases, considerably exceed the compressive strength requirements of Table 2.

NOTE 4—The required properties of the mortar in Table 2 are for laboratory prepared mortar mixed with a quantity of water to produce a flow of 110 ± 5 %. This quantity of water is not sufficient to produce a mortar with a workable consistency suitable for laying masonry units in the field. Mortar for use in the field must be mixed with the maximum amount of water, consistent with workability, in order to provide sufficient water to satisfy the initial rate of absorption (suction) of the masonry units. The properties of laboratory prepared mortar at a flow of 110 ± 5, as required by this specification, are intended to approximate the flow and properties of field prepared mortar after it has been placed in use and the suction of the masonry units has been satisfied. The properties of field prepared mortar mixed with the greater quantity of water, prior to being placed in contact with the masonry units, will differ from the property requirements in Table 2. Therefore, the property requirements in Table 2 cannot be used as requirements for quality control of field prepared mortar. Test Method C780 may be used for this purpose.

NOTE 5—Air content of non-air-entrained portland cement-lime mortar is generally less than 8 %.

6. Test Methods

6.1 *Proportions of Materials for Test Specimens*—Laboratory mixed mortar used for determining conformance to this property specification shall contain construction materials in proportions indicated in project specifications. Measure materials by weight for laboratory mixed batches. Convert proportions, by volume, to proportions, by weight, using a batch factor calculated as follows:

$$\text{Batch factor} = 1440/(80 \text{ times total sand volume proportion}) \quad (1)$$

Determine weight of material as follows:

$$\text{Mat. Weight} = \text{Mat.Volume Proportion} \times \text{Bulk Density} \times \text{Batch Factor} \quad (2)$$

NOTE 6—See Appendix X4 for examples of material proportioning.

6.1.1 When converting volume proportions to batch weights, use the following material bulk densities:

Material	Bulk Density
Portland Cement	Obtain from bag or supplier
Blended Cement	Obtain from bag or supplier
Hydraulic Cement	Obtain from bag or supplier
Slag Cement	Obtain from bag or supplier
Masonry Cement	Obtain from bag or supplier
Mortar Cement	Obtain from bag or supplier
Lime Putty	80 pcf (1280 kg/m^3)
Hydrated Lime	40 pcf (640 kg/m^3)
Sand	80 pcf (1280 kg/m^3)

NOTE 7—All quicklime should be slaked in accordance with the manufacturer's directions. All quicklime putty, except pulverized quicklime putty, should be sieved through a No. 20 (850 µm) sieve and allowed to cool until it has reached a temperature of 80°F (26.7°C). Quicklime putty should weigh at least 80 pcf (1280 kg/m^3). Putty that weighs less than this may be used in the proportion specifications, if the required quantity of extra putty is added to meet the minimum weight requirement.

NOTE 8—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 the materials used for purposes of air content calculations. It is not necessary for the purposes of this specification to measure the unit weight of the dry sand. Although the unit weight of dry sand will typically be 85–100 pcf (1360–1760 kg/m^3), experience has shown that the use of an assumed unit weight of 80 pcf (1280 kg/m^3) for dry sand will result in a laboratory mortar ratio of aggregate to cementitious material that is similar to that of the corresponding field mortar made using damp loose sand. A weight of 80 lb (36 kg) of dry sand is, in most cases, equivalent to the sand weight in 1 ft^3 (0.03 m^3) of loose, damp sand.

6.1.2 Oven dry and cool to room temperature all sand for laboratory mixed mortars. Sand weight shall be 1440 g for each individual batch of mortar prepared. Add water to obtain flow of 110 ± 5 %. A test batch provides sufficient mortar for completing the water retention test and fabricating three 2-in. cubes for the compressive strength test.

6.2 *Mixing of Mortars*—Mix the mortar in accordance with Practice C305.

6.3 *Water Retention*—Determine water retention in accordance with Specification C1506, except that the laboratory-mixed mortar shall be of the materials and proportions to be used in the construction.

6.4 *Air Content*—Determine air content in accordance with Specification C91 *except* that the laboratory mixed mortar is to be of the materials and proportions to be used in the construction. Calculate the air content to the nearest 0.1 % as follows:

$$D = \frac{(W_1 + W_2 + W_3 + W_4 + V_w)}{\frac{W_1}{P_1} + \frac{W_2}{P_2} + \frac{W_3}{P_3} + \frac{W_4}{P_4} + V_w}$$

$$A = 100 - \frac{W_m}{4D} \quad (3)$$

where:
D = density of air-free mortar, g/cm^3,
W_1 = weight of portland cement, g,
W_2 = weight of hydrated lime, g,
W_3 = weight of mortar cement or masonry cement, g,
W_4 = weight of oven-dry sand, g,
V_w = millilitres of water used,
P_1 = density of portland cement, g/cm^3,
P_2 = density of hydrated lime, g/cm^3,
P_3 = density of mortar cement or masonry cement, g/cm^3,
P_4 = density of oven-dry sand, g/cm^3,
A = volume of air, %, and
W_m = weight of 400 mL of mortar, g.

6.4.1 Determine the density of oven-dry sand, P_4, in accordance with Test Method C128, except that an oven-dry specimen shall be evaluated rather than a saturated surface-dry specimen. If a pycnometer is used, calculate the oven-dry density of sand as follows:

$$P_4 = X_1 / (Y + X_1 - Z) \quad (4)$$

where:
X_1 = weight of oven-dry specimen (used in pycnometer) in air, g,
Y = weight of pycnometer filled with water, g, and
Z = weight of pycnometer with specimen and water to calibration mark, g.

6.4.1.1 If the Le Chantelier flask method is used, calculate the oven-dry density of sand as follows:

$$P_4 = X_2 / [0.9975\,(R_2 - R_1)] \quad (5)$$

where:
X_2 = weight of oven-dry specimen (used in Le Chantelier flask) in air, g,
R_1 = initial reading of water level in Le Chantelier flask, and
R_2 = final reading of water in Le Chantelier flask.

6.4.2 Determine the density of portland cement, mortar cement, and masonry cement in accordance with Test Method C188. Determine the density of hydrated lime in accordance with Test Methods C110.

6.5 *Compressive Strength*:

6.5.1 Determine compressive strength in accordance with Test Method C109/C109M. The mortar shall be composed of materials and proportions that are to be used in the construction with mixing water to produce a flow of 110 ± 5.

6.5.2 *Alternative Molding Procedure*—Immediately after determining the flow and mass of 400 mL of mortar, return all of the mortar to the mixing bowl and remix for 15 s at the medium speed. Then mold the test specimen in accordance with Test Method C109/C109M, except that the elapsed time for mixing mortar, determining flow, determining air entrainment, and starting the molding of cubes shall be within 8 min.

6.5.3 *Specimen Storage*—Keep mortar cubes for compressive strength tests in the molds on plane plates in a moist room or a cabinet meeting the requirements of Specification C511, from 48 to 52 h in such a manner that the upper surfaces shall be exposed to the moist air. Remove mortar specimens from the molds and place in a moist cabinet or moist room until tested.

6.5.4 *Testing* —Test specimens in accordance with Test Method C109/C109M.

7. Construction Practices

7.1 *Storage of Materials*—Cementitious materials and aggregates shall be stored in such a manner as to prevent deterioration or intrusion of foreign material.

7.2 *Measurement of Materials*—The method of measuring materials for the mortar used in construction shall be such that the specified proportions of the mortar materials are controlled and accurately maintained.

7.3 *Mixing Mortars*—All cementitious materials and aggregate shall be mixed between 3 and 5 min in a mechanical batch mixer with the maximum amount of water to produce a workable consistency. Hand mixing of the mortar is permitted with the written approval of the specifier outlining hand mixing procedures.

NOTE 9—These mixing water requirements differ from those in test methods in Section 6.

7.4 *Tempering Mortars*—Mortars that have stiffened shall be retempered by adding water as frequently as needed to restore the required consistency. No mortars shall be used beyond 2½ h after mixing.

7.5 *Climatic Conditions*—Unless superseded by other contractual relationships or the requirements of local building codes, hot and cold weather masonry construction relating to mortar shall comply with the Masonry Industry Council's "Hot and Cold Weather Masonry Construction Manual."

NOTE 10—*Limitations*—Mortar type should be correlated with the particular masonry unit to be used because certain mortars are more compatible with certain masonry units.

The specifier should evaluate the interaction of the mortar type and masonry unit specified, that is, masonry units having a high initial rate of absorption will have greater compatibility with mortar of high-water retentivity.

8. Quality Assurance

8.1 Compliance to this specification is verified by confirming that the materials used are as specified, meet the requirements as given in Section 2.1, and added to the mixer in the proper proportions. Proportions of materials are verified by one of the following:

8.1.1 Implementation and observation of appropriate procedures for proportioning and mixing approved materials, as described in Section 7.

8.1.2 Test Method C780 Annex 4, Mortar Aggregate Ratio to determine the aggregate to cementitious material ratio of mortars while they are still in a plastic state.

8.2 Guide C1586 is suitable for developing quality assurance procedures to determine compliance of mortars to this standard.

8.3 Test Method C780 is suitable for the evaluation of masonry mortars in the field. However, due to the procedural differences between Specification C270 and C780, the compressive strength values resulting from field sampled mortars are not required nor expected to meet the compressive strength requirements of the property specification of Specification C270, nor do they represent the compressive strength of the mortar in the wall.

8.4 Test Method C1324 is available to determine the proportions of materials in hardened masonry mortars. There is no ASTM method for determining the conformance of a mortar to the property specifications of Specification C270 by testing hardened mortar samples taken from a structure.

NOTE 11—The results of tests using Test Methods C780 Annex 4 and C1324 can be compared with Specification C270 proportion requirements; however, precision and bias have not been determined for these test methods.

NOTE 12—The results of tests done using Test Method C1324 can be compared with the Specification C270 proportion requirements, however, precision and bias have not been determined for this test method.

NOTE 13—Where necessary, testing of a wall or a masonry prism from the wall is generally more desirable than attempting to test individual components.

NOTE 14—The cost of tests to show initial compliance are typically borne by the seller. The party initiating a change of materials typically bear the cost for recompliance.

Unless otherwise specified, the cost of other tests are typically borne as follows:

If the results of the tests show that the mortar does not conform to the requirements of the specification, the costs are typically borne by the seller.

If the results of the tests show that the mortar does conform to the requirements of the specification, the costs are typically borne by the purchaser.

9. Keywords

9.1 air content; compressive strength; masonry; masonry cement; mortar; portland cement-lime; water retention; water retentivity

APPENDIXES

(Nonmandatory Information)

X1. SELECTION AND USE OF MORTAR FOR UNIT MASONRY

X1.1 *Scope*—This appendix provides information to allow a more knowledgeable decision in the selection of mortar for a specific use.

X1.2 *Significance and Use*—Masonry mortar is a versatile material capable of satisfying a variety of diverse requirements. The relatively small portion of mortar in masonry significantly influences the total performance. There is no single mortar mix that satisfies all situations. Only an understanding of mortar materials and their properties, singly and collectively, will enable selection of a mortar that will perform satisfactorily for each specific endeavor.

X1.3 *Function*:

X1.3.1 The primary purpose of mortar in masonry is to bond masonry units into an assemblage which acts as an integral element having desired functional performance characteristics. Mortar influences the structural properties of the assemblage while adding to its water resistance.

X1.3.2 Because portland cement concretes and masonry mortars contain some of the same principal ingredients, it is often erroneously assumed that good concrete practice is also good mortar practice. Realistically, mortars differ from concrete in working consistencies, in methods of placement and in the curing environment. Masonry mortar is commonly used to bind masonry units into a single structural element, while concrete is usually a structural element in itself.

X1.3.3 A major distinction between the two materials is illustrated by the manner in which they are handled during construction. Concrete is usually placed in nonabsorbent metal or wooden forms or otherwise treated so that most of the water will be retained. Mortar is usually placed between absorbent masonry units, and as soon as contact is made the mortar loses water to the units. Compressive strength is a prime consideration in concrete, but it is only one of several important factors in mortar.

X1.4 *Properties*:

X1.4.1 Masonry mortars have two distinct, important sets of properties, those of plastic mortars and those of hardened mortars. Plastic properties determine a mortar's construction suitability, which in turn relate to the properties of the hardened mortar and, hence, of finished structural elements. Properties of plastic mortars that help determine their construction suitability include workability and water retentivity. Properties of hardened mortars that help determine the performance of the finished masonry include bond, durability, elasticity, and compressive strength.

X1.4.2 Many properties of mortar are not quantitatively definable in precise terms because of a lack of measurement standards. For this and other reasons there are no mortar standards wholly based upon performance, thus the continued use of the traditional prescription specification in most situations.

X1.4.3 It is recommended that Test Method C780 and assemblage testing be considered with proper interpretation to aid in determining the field suitability of a given masonry mortar for an intended use.

X1.5 *Plastic Mortars*:

X1.5.1 *Workability*—Workability is the most important property of plastic mortar. Workable mortar can be spread easily with a trowel into the separations and crevices of the masonry unit. Workable mortar also supports the weight of masonry units when placed and facilitates alignment. It adheres to vertical masonry surfaces and readily extrudes from the mortar joints when the mason applies pressure to bring the unit into alignment. Workability is a combination of several properties, including plasticity, consistency, cohesion, and adhesion, which have defied exact laboratory measurement. The mason can best assess workability by observing the response of the mortar to the trowel.

X1.5.2 Workability is the result of a ball bearing affect of aggregate particles lubricated by the cementing paste. Although largely determined by aggregate grading, material proportions and air content, the final adjustment to workability depends on water content. This can be, and usually is, regulated on the mortar board near the working face of the masonry. The capacity of a masonry mortar to retain satisfactory workability under the influence of masonry unit suction and evaporation rate depends on the water retentivity and setting characteristics of the mortar. Good workability is essential for maximum bond with masonry units.

X1.5.3 *Flow*—Initial flow is a laboratory measured property of mortar that indicates the percent increase in diameter of the base of a truncated cone of mortar when it is placed on a flow table and mechanically raised ½ in. (12.7 mm) and dropped 25 times in 15 s. Flow after suction is another laboratory property which is determined by the same test, but performed on a mortar sample which has had some water removed by a specific applied vacuum. Water retention is the ratio of flow after suction to initial flow, expressed in percent.

X1.5.3.1 Construction mortar normally requires a greater flow value than laboratory mortar, and consequently possesses a greater water content. Mortar standards commonly require a minimum water retention of 75 %, based on an initial flow of only 105 to 115 %. Construction mortars normally have initial flows, although infrequently measured, in the range of 130 to 150 % (50–60 mm by cone penetration, as outlined in the annex of Test Method C780) in order to produce a workability satisfactory to the mason. The lower initial flow requirements for laboratory mortars were arbitrarily set because the low flow mortars more closely indicated the mortar compressive strength in the masonry. This is because most masonry units will remove some water from the mortar once contact is made. While there may be some discernible relationship between bond and compressive strength of mortar, the relationship between mortar flow and tensile bond strength is apparent. For most mortars, and with minor exceptions for all but very low suction masonry units, bond strength increases as flow increases to where detectable bleeding begins. Bleeding is defined as migration of free water through the mortar to its surface.

X1.5.4 *Water Retention and Water Retentivity*—Water retention is a measure of the ability of a mortar under suction to retain its mixing water. This mortar property gives the mason time to place and adjust a masonry unit without the mortar stiffening. Water retentivity is increased through higher lime or air content, addition of sand fines within allowable gradation limits, or use of water retaining materials.

X1.5.5 *Stiffening Characteristics*—Hardening of plastic mortar relates to the setting characteristics of the mortar, as indicated by resistance to deformation. Initial set as measured in the laboratory for cementitious materials indicates extent of hydration or setting characteristics of neat cement pastes. Too rapid stiffening of the mortar before use is harmful. Mortar in masonry stiffens through loss of water and hardens through normal setting of cement. This transformation may be accelerated by heat or retarded by cold. A consistent rate of stiffening assists the mason in tooling joints.

X1.6 *Hardened Mortars*:

X1.6.1 *Bond*—Bond is probably the most important single physical property of hardened mortar. It is also the most inconstant and unpredictable. Bond actually has three facets; strength, extent and durability. Because many variables affect bond, it is difficult to devise a single laboratory test for each of these categories that will consistently yield reproducible results and which will approximate construction results. These variables include air content and cohesiveness of mortar, elapsed time between spreading mortar and laying masonry unit, suction of masonry unit, water retentivity of mortar, pressure applied to masonry joint during placement and tooling, texture of masonry unit's bedded surfaces, and curing conditions.

X1.6.1.1 Several test methods are available for testing bond strength of mortar to masonry units, normal to the mortar joints. These include Test Methods C952, C1072, C1357, E518, and E72. Test Method C952 includes provisions for testing the flexural bond strength of mortar to full-size hollow masonry units, constructed in a prism. It also contains a crossed brick couplet method for testing direct tensile bond of mortar to solid masonry units. Loading of the specimens in Test Method C952 is such that a single joint is tested in tension. Test Method C1072 tests the flexural bond strength of hollow and solid units and mortar, constructed in prisms. Individual joints of the prisms are tested for tensile bond strength. Test Method C1072 is becoming more widely used to test the flexural bond strength than the others, due to the large amount of data produced by relatively small amounts of material. Test Method C1357, which incorporates Test Method C1072, has two distinct methods. The first method, for laboratory prepared specimens, is intended to compare bond strengths of mortars using a standard solid concrete masonry unit constructed in a prism. The second method, for field prepared specimens, is intended to evaluate bond strength of a particular unit/mortar combination. Test Method E518 provides a method for testing a masonry prism as a simply supported beam to determine flexural strength. While individual joints are not loaded in the Test Method E518 procedure, the resulting strength is determined as the prism behaves in flexure. The flexural strength of masonry walls is perhaps best indicated by testing full-scale wall specimens with Test Method E72 with lateral uniform or point loading applied to the specimen. Research[4,5] on concrete masonry indicates the flexural bond strength of concrete masonry walls, using Test Method E72, may be correlated with results of flexural bond strength of concrete masonry prisms, tested in accordance with Test Method C1072 and Test Method E518.

X1.6.1.2 Extent of bond may be observed under the microscope. Lack of extent of bond, where severe, may be measured indirectly by testing for relative movement of water through the masonry at the unit-mortar interface, such as prescribed in Test Method E514. This laboratory test method consists of subjecting a sample wall to a through-the-wall pressure differential and applying water to the high pressure side. Time, location and rate of leakage must be observed and interpreted.

X1.6.1.3 The tensile and compressive strength of mortar far exceeds the bond strength between the mortar and the masonry unit. Mortar joints, therefore, are subject to bond failures at lower tensile or shear stress levels. A lack of bond at the interface of mortar and masonry unit may lead to moisture penetration through those areas. Complete and intimate contact between mortar and masonry unit is essential for good bond. This can best be achieved through use of mortar having proper composition and good workability, and being properly placed.

X1.6.1.4 In general, the tensile bond strength of laboratory mortars increase with an increase in cement content. Because of mortar workability, it has been found that Type S mortar generally results with the maximum tensile bond strength that can practically be achieved in the field.

X1.6.2 *Extensibility and Plastic Flow*—Extensibility is maximum unit tensile strain at rupture. It reflects the maximum elongation possible under tensile forces. Low strength mortars, which have lower moduli of elasticity, exhibit greater plastic flow than their high moduli counterparts at equal paste to aggregate ratios. For this reason, mortars with higher strength than necessary should not be used. Plastic flow or creep will impart flexibility to the masonry, permitting slight movement without apparent joint opening.

X1.6.3 *Compressive Strength*—The compressive strength of mortar is sometimes used as a principal criterion for selecting mortar type, since compressive strength is relatively easy to measure, and it commonly relates to some other properties, such as tensile strength and absorption of the mortar.

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[4] Thomas, R., Samblanet, P., and Hogan, M., "Research Evaluation of the Flexural Tensile Strength of Concrete Masonry," *Seventh Canadian Masonry Symposium*, June 1995.

[5] Melander, J. and Thomas, R., "Flexural Tensile Strength of Concrete Masonry Constructed with Type S Masonry Cement Mortar," *Eighth Canadian Masonry Symposium*, June 1998.

X1.6.3.1 The compressive strength of mortar depends largely upon the cement content and the water-cement ratio. The accepted laboratory means for measuring compressive strength is to test 2 in. (50.8 mm) cubes of mortar. Because the referenced test in this specification is relatively simple, and because it gives consistent, reproducible results, compressive strength is considered a basis for assessing the compatibility of mortar ingredients. Field testing compressive strength of mortar is accomplished with Test Method C780 using either 2 in. (50.8 mm) cubes or small cylindrical specimens of mortar.

X1.6.3.2 Perhaps because of the previously noted confusion regarding mortar and concrete, the importance of compressive strength of mortar is overemphasized. Compressive strength should not be the sole criterion for mortar selection. Bond strength is generally more important, as is good workability and water retentivity, both of which are required for maximum bond. Flexural strength is also important because it measures the ability of a mortar to resist cracking. Often overlooked is the size/shape of mortar joints in that the ultimate compressive load carrying capacity of a typical ⅜ in. (9.5 mm) bed joint will probably be well over twice the value obtained when the mortar is tested as a 2 in. (50.8 mm) cube. Mortars should typically be weaker than the masonry units, so that any cracks will occur in the mortar joints where they can more easily be repaired.

X1.6.3.3 Compressive strength of mortar increases with an increase in cement content and decreases with an increase in lime, sand, water or air content. Retempering is associated with a decrease in mortar compressive strength. The amount of the reduction increases with water addition and time between mixing and retempering. It is frequently desirable to sacrifice some compressive strength of the mortar in favor of improved bond, consequently retempering within reasonable time limits is recommended to improve bond.

X1.6.4 *Durability*—The durability of relatively dry masonry which resists water penetration is not a serious problem. The coupling of mortars with certain masonry units, and design without exposure considerations, can lead to unit or mortar durability problems. It is generally conceded that masonry walls, heated on one side, will stand many years before requiring maintenance, an indication of mortar's potential longevity. Parapets, masonry paving, retaining walls, and other masonry exposed to freezing while saturated represent extreme exposures and thus require a more durable mortar.

X1.6.4.1 Mortar, when tested in the laboratory for durability, is subjected to repeated cycles of freezing and thawing. Unless a masonry assemblage is allowed to become nearly saturated, there is little danger of substantial damage due to freezing. Properly entrained air in masonry mortar generally increases its resistance to freeze-thaw damage where extreme exposure (such as repeated cycles of freezing and thawing while saturated with water) exists. Air content within the specification limits for mortar, however, may be above the amount required for resistance to freeze-thaw damage. Durability is adversely affected by oversanded or overtempered mortars as well as use of highly absorbent masonry units.

X1.7 *Composition and Its Effect on Properties*:

X1.7.1 Essentially, mortars contain cementitious materials, aggregate and water. Sometimes admixtures are used also.

X1.7.2 Each of the principal constituents of mortar makes a definite contribution to its performance. Portland cement contributes to strength and durability. Lime, in its hydroxide state, provides workability, water retentivity, and elasticity. Both portland cement and lime contribute to bond strength. Instead of portland cement-lime combinations, masonry cement or mortar cement is used. Sand acts as a filler and enables the unset mortar to retain its shape and thickness under the weight of subsequent courses of masonry. Water is the mixing agent which gives fluidity and causes cement hydration to take place.

X1.7.3 Mortar should be composed of materials which will produce the best combination of mortar properties for the intended service conditions.

X1.7.4 *Cementitious Materials Based on Hydration*—Portland cement, a hydraulic cement, is the principal cementitious ingredient in most masonry mortars. Portland cement contributes strength to masonry mortar, particularly early strength, which is essential for speed of construction. Straight portland cement mortars are not used because they lack plasticity, have low water retentivity, and are harsh and less workable than portland cement-lime or masonry cement mortars.

X1.7.4.1 Masonry cement is a proprietary product usually containing portland cement and fines, such as ground limestone or other materials in various proportions, plus additives such as air entraining and water repellency agents.

X1.7.4.2 Mortar cement is a hydraulic cement similar to masonry cement, but the specification for mortar cement requires lower air contents and includes a flexural bond strength requirement.

X1.7.5 *Cementitious Materials Based on Carbonation*—Hydrated lime contributes to workability, water retentivity, and elasticity. Lime mortars carbonate gradually under the influence of carbon dioxide in the air, a process slowed by cold, wet weather. Because of this, complete hardening occurs very slowly over a long period of time. This allows healing, the recementing of small hairline cracks.

X1.7.5.1 Lime goes into solution when water is present and migrates through the masonry where it can be deposited in cracks and crevices as water evaporates. This could also cause some leaching, especially at early ages. Successive deposits may eventually fill the cracks. Such autogenous healing will tend to reduce water permeance.

X1.7.5.2 Portland cement will produce approximately 25 % of its weight in calcium hydroxide at complete hydration. This calcium hydroxide performs the same as lime during carbonation, solubilizing, and redepositing.

X1.7.6 *Aggregates*—Aggregates for mortar consist of natural or manufactured sand and are the largest volume and weight constituent of the mortar. Sand acts as an inert filler, providing economy, workability and reduced shrinkage, while influencing compressive strength. An increase in sand content increases the setting time of a masonry mortar, but reduces potential cracking due to shrinkage of the mortar joint. The special or standard sand required for certain laboratory mortar tests may produce quite different test results from sand that is used in the construction mortar.

X1.7.6.1 Well graded aggregate reduces separation of materials in plastic mortar, which reduces bleeding and improves workability. Sands deficient in fines produce harsh mortars, while sands with excessive fines produce weak mortars and increase shrinkage. High lime or high air content mortars can carry more sand, even with poorly graded aggregates, and still provide adequate workability.

X1.7.6.2 Field sands deficient in fines can result in the cementitious material acting as fines. Excess fines in the sand, however, is more common and can result in oversanding, since workability is not substantially affected by such excess.

X1.7.6.3 Unfortunately, aggregates are frequently selected on the basis of availability and cost rather than grading. Mortar properties are not seriously affected by some variation in grading, but quality is improved by more attention to aggregate selection. Often gradation can be easily and sometimes inexpensively altered by adding fine or coarse sands. Frequently the most feasible method requires proportioning the mortar mix to suit the available sand within permissible aggregate ratio tolerances, rather than requiring sand to meet a particular gradation.

X1.7.7 *Water*—Water performs three functions. It contributes to workability, hydrates cement, and facilitates carbonation of lime. The amount of water needed depends primarily on the ingredients of the mortar. Water should be clean and free from injurious amounts of any substances that may be deleterious to mortar or metal in the masonry. Usually, potable water is acceptable.

X1.7.7.1 Water content is possibly the most misunderstood aspect of masonry mortar, probably due to the confusion between mortar and concrete requirements. Water requirement for mortar is quite different from that for concrete where a low water/cement ratio is desirable. Mortars should contain the maximum amount of water consistent with optimum workability. Mortar should also be retempered to replace water lost by evaporation.

X1.7.8 *Admixtures*—Admixtures for masonry mortars are available in a wide variety and affect the properties of fresh or hardened mortar physically or chemically. Some chemical additions are essential in the manufacture of basic mortar materials. The inclusion of an additive is also necessary for the production of ready mixed mortars. Undoubtedly there are also some special situations where the use of admixtures may be advantageous when added at the job site mixer. In general, however, such use of admixtures is not recommended. Careful selection of the mortar mix, use of quality materials, and good practice will usually result in sound masonry. Improprieties cannot be corrected by admixtures, some of which are definitely harmful.

X1.7.8.1 Admixtures are usually commercially prepared products and their compositions are not generally disclosed. Admixtures are functionally classified as agents promoting air entrainment, water retentivity, workability, accelerated set, and so on. Limited data are available regarding the effect of proprietary admixtures on mortar bond, compressive strength, or water permeance of masonry. Field experience indicates that detrimental results have frequently occurred. For these reasons, admixtures should be used in the field only after it has been established by laboratory test under conditions duplicating their intended use, and experience, that they improve the masonry.

X1.7.8.2 Use of an air entraining admixture, along with the limits on air content in a field mortar, still continues to create controversy. Most masonry cements, all Type “A” portland cements and all Type “A” limes incorporate air entraining additions during their manufacture to provide required minimum as well as maximum levels of air in a laboratory mortar. Such materials should never be combined, nor should admixtures which increase the entrained air content of the mortar be added in the field, except under the most special of circumstances.

X1.7.8.3 The uncontrolled use of air entraining agents should be prohibited. At high air levels, a definite inverse relationship exists between air content and tensile bond strength of mortar as measured in the laboratory. In general, any increase in air content is accompanied by a decrease in bond as well as compressive strength. Data on masonry grouts indicate that lower bond strength between grout and reinforcing steel is associated with high air content. Most highly air entrained mortar systems can utilize higher sand contents without losing workability, which could be detrimental to the masonry if excessive sand were used. The use of any mortar containing air entraining materials, where resulting levels of air are high or unknown, should be based on a knowledge of local performance or on laboratory tests of mortar and masonry assemblages.

X1.7.8.4 Air can be removed from plastic mortar containing air entraining material by use of a defoamer, although its use in the field is strongly discouraged.

X1.7.8.5 Color can be added to mortar using selected aggregates or inorganic pigments. Inorganic pigments should be of mineral oxide composition and should not exceed 10 % of the weight of portland cement, with carbon black limited to 2 %, to avoid excessive strength reduction of the mortar. Pigments should be carefully chosen and used in the smallest amount that will produce the desired color. To minimize variations from batch to batch it is advisable to purchase cementitious materials to which coloring has been added at the plant or to use preweighed individual packets of coloring compounds for each batch of mortar, and to mix the mortar in batches large enough to permit accurate batching. Mortar mixing procedures should remain constant for color consistency.

X1.8 *Kinds of Mortars*:

X1.8.1 *History*—History records that burned gypsum and sand mortars were used in Egypt at least as early as 2690 B.C. Later in ancient Greece and Rome, mortars were produced from various materials such as burned lime, volcanic tuff, and sand. When the first settlements appeared in North America, a relatively weak product was still being made from lime and sand. The common use of portland cement in mortar began in the early part of the twentieth century and led to greatly strengthened mortar, either when portland cement was used alone or in combination with lime. Modern mortar is still made with from portland cement and hydrated lime, in addition to mortars made from masonry cement or mortar cement.

X1.8.2 *Portland Cement-Hydrated Lime*—Cement-lime mortars have a wide range of properties. At one extreme, a straight portland cement and sand mortar would have high compressive strength and low water retention. A wall containing such a mortar would be strong but vulnerable to cracking and rain penetration. At the other extreme, a straight lime and sand mortar would have low compressive strength and high water retention. A wall containing such a mortar would have lower strength, particularly early strength, but greater resistance to cracking and rain penetration. Between the two extremes, various combinations of cement and lime provide a balance with a wide variety of properties, the high strength and early setting characteristics of cement modified by the excellent workability and water retentivity of lime. Selective proportions are found in this specification.

X1.8.3 *Masonry Cement*—Masonry cement mortars generally have excellent workability. Microscopic bubbles of entrained air contribute to the ball bearing action and provide a part of this workability. Freeze-thaw durability of masonry cement mortars in the laboratory is outstanding. Three types of masonry cement are recognized by Specification C91. These masonry cements are formulated to produce mortars conforming to either the proportion or the property specifications of this specification. Such masonry cements provide the total cementitious material in a single bag to which sand and water are added at the mixer. A consistent appearance of mortar made from masonry cements should be easier to obtain because all the cementitious ingredients are proportioned, and ground or blended together before being packaged.

X1.8.4 *Portland Cement-Masonry Cement*—The addition of portland cement to Type N masonry cement mortars also allow qualification as Types M and S Mortars in this specification.

X1.8.5 *Mortar Cement*—Three types of mortar cements are recognized by Specification C1329. These mortar cements are formulated to produce mortar conforming to either the proportion or property requirements of this specification. Mortar cement mortars have attributes similar to those of masonry cement mortars while satisfying air content and bond strength requirements of Specification C1329.

X1.8.6 *Prebatched or Premixed*—Recently, prebatched or premixed mortars have been made readily available in two options. One is a wet, ready mixed combination of hydrated lime or lime putty, sand, and water delivered to the construction project, and when mixed with cement and additional water is ready for use. The other is dry, packaged mortar mixtures requiring only the addition of water and mixing. Special attention should be given to the dry system, in that resulting mortars may have to be mixed for a longer period of time to overcome the water affinity of oven dry sand and subsequent workability loss in the mortar. The use of ready mixed mortar is also on the increase. These are mixtures consisting of cementitious materials, aggregates, and admixtures, batched and mixed at a central location, and delivered to the construction project with suitable workability characteristics for a period in excess of 2½ h after mixing. Systems utilizing continuous batching of mortar are also available.

X1.8.7 *Portland Cement—Mortar Cement*—The addition of portland cement to Type N mortar cement mortars also allow qualification as Types M and S Mortars in this specification.

X1.9 *Related Items That Have an Effect on Properties*:

X1.9.1 The factors influencing the successful conclusion of any project with the desired performance characteristics are the design, material, procedure and craftsmanship selected and used.

X1.9.2 The supervision, inspecting and testing necessary for compliance with requirements should be appropriate and predetermined.

X1.9.3 *Masonry Units*—Masonry units are absorptive by nature, with the result that water is extracted from the mortar as soon as the masonry unit and the mortar come into contact. The amount of water removal and its consequences effect the strength of the mortar, the properties of the boundary between the mortar and the masonry units, and thus the strength, as well as other properties, of the masonry assemblage.

X1.9.3.1 The suction exerted by the masonry unit is a very important external factor which affects the fresh mortar and initiates the development of bond. Masonry units vary widely in initial rate of absorption (suction). It is therefore necessary that the mortar chosen have properties that will provide compatibility with the properties of the masonry unit being used, as well as environmental conditions that exist during construction and the construction practices peculiar to the job.

X1.9.3.2 Mortar generally bonds best to masonry units having moderate initial rates of absorption (IRA), from 5 to 25 g/min·30 in.^{2} (194 cm^2), at the time of laying. More than adequate bond can be obtained, however, with many units having IRA's less than or greater than these values.

X1.9.3.3 The extraction of too much or too little of the available water in the mortar tends to reduce the bond between the masonry unit and the mortar. A loss of too much water from the mortar can be caused by low water retentivity mortar, high suction masonry units, or dry, windy conditions. When this occurs, the mortar is incapable of forming a complete bond when the next unit is placed. Where lowering the suction by prewetting the units is not proper or possible, the time lapse between spreading the mortar and laying of a masonry unit should be kept to a minimum. When a very low suction masonry unit is used, the unit tends to float and bond is difficult to accomplish. There is no available means of increasing the suction of a low suction masonry unit, and thus the time lapse between spreading the mortar and placing the unit may have to be increased.

X1.9.3.4 Mortars having higher water retentivity are desirable for use in summer or with masonry units having high suction. Mortars having lower water retentivity are desirable for use in winter or with masonry units having low suction.

X1.9.3.5 Shrinkage or swelling of the masonry unit or mortar once contact has been achieved affects the quality of the mortar joint. Protection should be provided to prevent excessive wetting, drying, heating or cooling, until the mortar has at least achieved final set.

X1.9.3.6 Mortar bond is less to surfaces having an unbroken die skin or sanded finish than it is to roughened surfaces such as a wire cut or textured finish.

X1.9.4 *Construction Practice*—Careful attention to good practice on the construction site is essential to achieve quality. Cementitious materials and aggregate should be protected from rain and ground moisture and air borne contaminants.

X1.9.4.1 Proper batching procedures include use of a known volume container (such as a one cubic foot batching box) for measuring sand. When necessary, sand quantities should be adjusted to provide for bulking of the sand. Shovel measuring cannot be expected to produce mortar of consistent quality. Alternatively, a combination volumetric measure calibration of a mixer followed by full bag cementitious additions and shovel additions of sand to achieve the same volume of mortar in the mixer with subsequent batches, should prove adequate.

X1.9.4.2 Good mixing results can be obtained where about three-fourths of the required water, one-half of the sand, and all of the cementitious materials are briefly mixed together. The balance of the sand is then charged and the remaining water added. The mixer should be charged to its full design capacity for each batch and completely emptied before charging the next batch.

X1.9.4.3 Mixing time in a paddle mixer should usually be a minimum of 3 and a maximum of 5 min after the last mixing water has been added, to insure homogeneity and workability of the mortar. Overmixing results in changing the air content of the mortar. Worn paddles and rubber scrapers will greatly influence the mixing efficiency. Concern for quality suggests use of an automatic timer on the mixing machine. Mixing time should not be determined by the demand of the working force.

X1.9.4.4 Since all mortar is not used immediately after mixing, evaporation may require the addition of water, retempering the mortar, to restore its original consistency. The addition of water to mortar within specified time limits should not be prohibited. Although compressive strength of the mortar is reduced slightly by retempering, bond strength is usually increased. For this reason, retempering should be required to replace water lost by evaporation. Because retempering is harmful only after mortar has begun to set, all site prepared mortar should be placed in final position as soon as possible, but always within 2½ h after the original mixing, or the mortar discarded.

X1.9.4.5 Weather conditions also should be considered when selecting mortar. During warm, dry, windy, summer weather, mortar must have a high water retentivity to minimize the effect of water lost by evaporation. In winter, a lower water retentivity has merit because it facilitates water loss from the mortar to the units prior to a freeze. To minimize the risk of reduced bond in cold weather, the masonry units being used as well as the surface on which the mortar is placed should both be brought to a temperature at least above 32°F (0°C) before any work commences. (For more inclusive suggestions, see "Recommended Practices for Cold Weather Masonry Construction" available from the International Masonry Industry All Weather Council.)

X1.9.5 *Workmanship*—Workmanship has a substantial effect on strength and extent of bond. The time lapse between spreading mortar and placing masonry units should be kept to a minimum because the flow will be reduced through suction of the unit on which it is first placed. This time lapse should normally not exceed one minute. Reduce this time lapse for hot, dry and windy conditions, or with use of highly absorptive masonry units. If excessive time elapses before a unit is placed on the mortar, bond will be reduced. Elimination of deep furrows in horizontal bed joints and providing full head joints are essential. Any metal embedded in mortar should be completely surrounded by mortar.

X1.9.5.1 Once the mortar between adjacent units has begun to stiffen, tapping or otherwise attempting to move masonry units is highly detrimental to bond and should be prohibited. The movement breaks the bond between the mortar and the masonry unit, and the mortar will not be sufficiently plastic to reestablish adherence to the masonry unit.

X1.9.5.2 Tooling of the mortar joint should be done when its surface is thumb-print hard utilizing a jointer having a diameter slightly larger than the mortar joint width. Joint configurations other than concave can result in increased water permeance of the masonry assemblage. Striking joints with the same degree of hardness produces uniform joint appearance.

TABLE X1.1 Guide for the Selection of Masonry Mortars[A]

Location	Building Segment	Mortar Type	
		Recommended	Alternative
Exterior, above grade	load-bearing wall	N	S or M
	non-load bearing wall	O[B]	N or S
	parapet wall	N	S
Exterior, at or below grade	foundation wall, retaining wall, manholes, sewers, pavements, walks, and patios	S[C]	M or N[C]
Interior	load-bearing wall	N	S or M
	non-bearing partitions	O	N
Interior or Exterior	tuck pointing	see Appendix X3	see Appendix X3

[A] This table does not provide for many specialized mortar uses, such as chimney, reinforced masonry, and acid-resistant mortars.
[B] Type O mortar is recommended for use where the masonry is unlikely to be frozen when saturated, or unlikely to be subjected to high winds or other significant lateral loads. Type N or S mortar should be used in other cases.
[C] Masonry exposed to weather in a nominally horizontal surface is extremely vulnerable to weathering. Mortar for such masonry should be selected with due caution.

Finishing is not only for appearance, but to seal the interface between mortar and masonry unit, while densifying the surface of the mortar joint.

X1.9.5.3 The benefits of the finishing operation should be protected from improper cleaning of the masonry. Use of strong chemical or harsh physical methods of cleaning may be detrimental to the mortar. Colored mortars are especially susceptible to damage from such cleaning. Most chemicals used in cleaning attack the cementitious materials within the mortar system, as well as enlarge cracks between mortar and masonry unit.

X1.9.5.4 With very rapid drying under hot, dry and windy conditions, very light wetting of the in-place masonry, such as fog spray, can improve its quality. Curing of mortar by the addition of considerable water to the masonry assemblage, however, could prove to be more detrimental than curing of mortar by retention of water in the system from its construction. The addition of excess moisture might saturate the masonry, creating movements which decrease the adhesion between mortar and masonry unit.

X1.10 *Summary*:

X1.10.1 No one combination of ingredients provides a mortar possessing an optimum in all desirable properties. Factors that improve one property generally do so at the expense of others. Testing of mortars in the laboratory by this specification's referenced methods, and in the field by Test Method C780 is beneficial. Some physical properties of mortar, however, are of equal or greater significance to masonry performance than those properties commonly specified. When selecting a mortar, evaluate all properties, and then select the mortar providing the best compromise for the particular requirements.

X1.10.2 Bond is probably the most important single property of a conventional mortar. Many variables affect bond. To obtain optimum bond, use a mortar with properties that are compatible with the masonry units to be used. To increase tensile bond strength in general, increase the cement content of the mortar (see X1.6.1.4); keep air content of the mortar to a minimum; use mortars having high water retentivity; mix mortar to the water content compatible with workability; allow retempering of the mortar; use masonry units having moderate initial rates of absorption when laid (see X1.9.3.2); bond mortar to a rough surface rather than to a die skin surface; minimize time between spreading mortar and placing masonry units; apply pressure in forming the mortar joint; and do not subsequently disturb laid units.

X1.10.3 Table X1.1 is a general guide for the selection of mortar type for various masonry wall construction. Selection of mortar type should also be based on the type of masonry units to be used as well as the applicable building code and engineering practice standard requirements, such as allowable design stresses, and lateral support.

X2. EFFLORESCENCE

X2.1 Efflorescence is a crystalline deposit, usually white, of water soluble salts on the surface of masonry. The principal objection to efflorescence is the appearance of the salts and the nuisance of their removal. Under certain circumstances, particularly when exterior coatings are present, salts can be deposited below the surface of the masonry units. When this cryptoflorescence occurs, the force of crystallization can cause disintegration of the masonry.

X2.2 A combination of circumstances is necessary for the formation of efflorescence. First, there must be a source of soluble salts. Second, there must be moisture present to pick up the soluble salts and carry them to the surface. Third, evaporation or hydrostatic pressure must cause the solution to migrate. If any one of these conditions is eliminated, efflorescence will not occur.

X2.3 Salts may be found in the masonry units, mortar components, admixtures or other secondary sources. Water-soluble salts that appear in chemical analyses as only a few tenths of 1 % are sufficient to cause efflorescence when leached out and concentrated on the surface. The amount and character of the deposits vary according to the nature of the soluble materials and the atmospheric conditions. A test for the efflorescence of individual masonry units is contained within ASTM standards. Efflorescence can occur with any C270 mortar when moisture migration occurs. There is no ASTM test method that will predict the potential for efflorescence of mortar. Further, there is no ASTM test method to evaluate the efflorescence potential of combined masonry materials.

X2.4 The probability of efflorescence in masonry as related directly to materials may be reduced by the restrictive selection of materials. Masonry units with a rating of "not effloresced" are the least likely to contribute towards efflorescence. The potential for efflorescence decreases as the alkali content of cement decreases. Admixtures should not be used in the field. Washed sand and clean, potable water should be used.

X2.5 Moisture can enter masonry in a number of ways. Attention must be paid to the design and installation of flashing, vapor barriers, coping and caulking to minimize penetration of rainwater into the masonry. During construction, masonry materials and unfinished walls should be protected from rain and construction applied water. Full bed and head joints, along with a compacting finish on a concave mortar joint, will reduce water penetration. Condensation occurring within the masonry is a further source of water.

X2.6 Although selection of masonry construction materials having a minimum of soluble salts is desirable, the prevention of moisture migration through the wall holds the greatest potential in minimizing efflorescence. Design of masonry using the principle of pressure equalization between the outside and a void space within the wall will greatly reduce the chances of water penetration and subsequently efflorescence.

X2.7 Removal of efflorescence from the face of the masonry can frequently be achieved by dry brushing. Since many salts are highly soluble in water, they will disappear of their own accord under normal weathering processes. Some salts, however, may require harsh physical or even chemical treatment, if they are to be removed.

X3. TUCK POINTING MORTAR

X3.1 *General*:

X3.1.1 Tuck pointing mortars are replacement mortars used at or near the surface of the masonry wall to restore integrity or improve appearance. Mortars made without portland cement may require special considerations in selecting tuck pointing mortars.

X3.1.2 If the entire wall is not to be tuck pointed, the color and texture should closely match those of the original mortar. An exact match is virtually impossible to achieve.

X3.2 *Materials*:

X3.2.1 Use cementitious materials that conform to the requirements of this specification (C270).

X3.2.2 Use sand that conforms to the requirements of this specification (C270). Sand may be selected to have color, size, and gradation similar to that of the original mortar, if color and texture are important.

X3.3 *Selection Guide*—Use tuck pointing mortar of the same or weaker composition as the original mortar. See Table X3.1.

X3.4 *Materials*—Mortar shall be specified as one of the following:

X3.4.1 The proportion specification of C270, Type ____.

X3.4.2 *Type K*—One part portland cement and 2½ to 4 parts hydrated lime. Aggregate Ratio of 2¼ to 3 times sum of volume of cement and lime.

TABLE X3.1 Guide for Selection of Tuck Pointing Mortar[A]

Location or Service	Mortar Type	
	Recommended	Alternate
interior	O	K,N
exterior, above grade exposed on one side, unlikely to be frozen when saturated, not subject to high wind or other significant lateral load	O	N,K
exterior, other than above	N	O

[A] In some applications, structural concerns may dictate the use of mortars other than those recommended. This table is not applicable to pavement applications.

NOTE X3.1—Type K mortar proportions were referenced in this specification (C270) prior to 1982.

X3.5 *Mixing*:

X3.5.1 Dry mix all solid materials.

X3.5.2 Add sufficient water to produce a damp mix that will retain its shape when pressed into a ball by hand. Mix from 3 to 7 min, preferably with a mechanical mixer.

X3.5.3 Let mortar stand for not less than 1 h nor more than 1½ h for prehydration.

X3.5.4 Add sufficient water to bring the mortar to the proper consistency for tuck pointing, somewhat drier than mortar used for laying the units.

X3.5.5 Use the mortar within 2½ h of its initial mixing. Permit tempering of the mortar within this time interval.

X4. EXAMPLES OF MATERIAL PROPORTIONING FOR TEST BATCHES OF MORTAR

X4.1 *Example A*—A mortar consisting of one part portland cement, 1¼ parts lime, and 6¾ parts of sand is to be tested. The weights of the materials used in the mortar are calculated as follows:

$$\text{Batch factor} = 1440/(80 \times 6.75) = 2.67 \qquad \text{(X4.1)}$$

Weight of portland cement = $1 \times 94 \times 2.67 = 251$
Weight of lime = $1\frac{1}{4} \times 40 \times 2.67 = 133$
Weight of sand[A] = $6\frac{3}{4} \times 80 \times 2.67 = 1440$

	Portland Cement	Lime	Sand
Proportions by volume	1	1 ¼	6¾
Unit weight (lb/ft^3)	94	40	80
Batch factor	2.67	2.67	2.67
Weight of material[B] (in g)	251	133	1440

[A] Total sand content is calculated as: (1 volume part of portland cement plus 1¼ volume parts of hydrated lime) times three = 6¾ parts of sand.
[B] Weight of material = volume proportion times unit weight times batch factor.

X4.2 *Example B*—A mortar consisting of one part masonry cement, three parts sand is to be tested. The weights of the materials used in the mortar are calculated as follows:

$$\text{Batch factor} = 1440/(80 \times 3) = 6.00 \qquad \text{(X4.2)}$$

Weight of masonry cement = $1 \times 70 \times 6.00 = 420$
Weight of sand[A] = $3 \times 80 \times 6.00 = 1440$

	Masonry Cement	Sand
Proportions by volume	1	3
Unit weight (lb/ft^3) (Weight printed on bag for masonry cement)	70	80
Batch factor	6.00	6.00
Weight of material[B] (in g)	420	1440

[A] Total sand content is calculated as: (1 volume part of masonry cement) times three = 3 parts of sand.
[B] Weight of material = volume proportion times unit weight times batch factor.

SUMMARY OF CHANGES

Committee C12 has identified the location of selected changes to this standard since the last issue (C270 – 08a) that may impact the use of this standard. (Approved June 1, 2010.)

(*1*) An alternative method of forming compressive strength cubes was added.