Designation: C 270 – 00

Standard Specification for Mortar for Unit Masonry[1]

This standard is issued under the fixed designation C 270; 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.

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 standard 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 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:*

C 5 Specification for Quicklime for Structural Purposes[2]
C 91 Specification for Masonry Cement[2]
C 109 Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens)[2]
C 110 Test Methods for Physical Testing of Quicklime, Hydrated Lime, and Limestone[2]
C 128 Test Method for Specific Gravity and Absorption of Fine Aggregates[3]
C 144 Specification for Aggregate for Masonry Mortar[4]
C 150 Specification for Portland Cement[2]
C 188 Test Method for Density of Hydraulic Cement[2]
C 207 Specification for Hydrated Lime for Masonry Purposes[2]
C 305 Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency[2]
C 511 Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes[2]
C 595 Specification for Blended Hydraulic Cements[2]
C 780 Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry[4]
C 979 Specification for Pigments for Integrally Colored Concrete[4]
C 1157 Performance Specification for Hydraulic Cement[2]
C 1324 Test Method for Examination and Analysis of Hardened Masonry Mortar[4]
C 1329 Specification for Mortar Cement[2]
E 514 Test Method for Water Penetration and Leakage Through Masonry[4]
E 518 Test Methods for Flexural Bond Strength of Masonry[4]

2.2 *International Masonry All Weather Council:*[5]

Recommended Practices and Guide Specifications for Cold Weather Masonry Construction; Section 04200, Article 3 of the Guide Specifications, Sixth Edition, July 1977

3. Specification Limitations

3.1 Specification C 270 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 5.2. 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

[1] This specification is under the jurisdiction of ASTM Committee C-12 on Mortars for Unit Masonry and is the direct responsibility of Subcommittee C12.03 on Specifications for Mortars.

Current edition approved March 10, 2000. Published April 2000. Originally published as C 270–51T. Last previous edition C 270–99b.

[2] *Annual Book of ASTM Standards*, Vol 04.01.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

[4] *Annual Book of ASTM Standards*, Vol 04.05.

[5] Available from the International Masonry All Weather Council, 823 Fifteenth Street, NW, Washington, DC 20005.

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, or IIIA of Specification C 150.

4.1.1.2 *Blended Hydraulic Cements*—Types IS, IS-A, IP, IP-A, I(PM) or I(PM)-A of Specification C 595.

4.1.1.3 *Blended Hydraulic Cements*—Types GU, HE, MS, HS, MH, and LH of Specification C 1157.

4.1.1.4 *Slag Cement (for Use in Property Specifications Only)*—Types S or SA of Specification C 595.

4.1.1.5 *Masonry Cement*—See Specification C 91.

4.1.1.6 *Mortar Cement*—See Specification C 1329.

4.1.1.7 *Quicklime*—See Specification C 5.

4.1.1.8 *Hydrated Lime*—Specification C 207, 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.

4.1.2 *Aggregates*—See Specification C 144.

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 such as coloring pigments, air-entraining agents, accelerators, retarders, water-repellent agents, antifreeze compounds, and other admixtures shall not be added to mortar unless specified. Coloring pigments shall conform to Specification C 979. Calcium chloride, when explicitly provided for in the contract documents, is permitted to be used as an accelerator in amounts not exceeding 2 % by weight of the portland cement content or 1 % by weight of the masonry cement content, or both, of the mortar.

NOTE 1—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 *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.

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

5.2 *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.

5.2.1 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 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 2—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 (5.2).

NOTE 3—The required properties of the mortar in Table 2 are for laboratory prepared mortar mixed with a quantity of water to produce a

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 3).
[B] See Note 4.
[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 %.

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 C 780 may be used for this purpose.

NOTE 4—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:

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

NOTE 5—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	94 pcf (1505 kg/m^3)
Blended 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 6—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 7—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 C 305.

6.3 *Water Retention*—Determine water retention in accordance with Specification C 91, except that the laboratory-mixed mortar shall be of the materials and proportions to be used in the construction.

6.4 *Compressive Strength*—Determine compressive strength in accordance with Test Method C 109. 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.

6.4.1 *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 C 511, 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 *Air Content*—Determine air content in accordance with Specification C 91 *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:

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

$$A = 100 - \frac{W_m}{4D} \quad (2)$$

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.

6.5.1 Determine the density of oven-dry sand, P_4, in accordance with Test Method C 128, 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:

$$P_4 = X_1 / (Y + X_1 - Z) \quad (3)$$

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.

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

$$P_4 = X_2 / [0.9975 (R_2 - R_1)] \quad (4)$$

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.

6.5.2 Determine the density of portland cement, mortar cement, and masonry cement in accordance with Test Method C 188. Determine the density of hydrated lime in accordance with Test Methods C 110.

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 8—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, cold weather masonry construction relating to mortar shall comply with the International Masonry All-Weather Council's "Guide Specification for Cold Weather Masonry Construction, Section 04200, Article 3."

NOTE 9—*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 Test Method C 780 is acceptable for preconstruction and construction evaluation of mortars for plain and reinforced unit masonry.

8.2 Compliance with Specification C 270 is obtained in the field by verifying that the required proportions of the specified materials are added to the mixer.

8.3 *Tests of Hardened Mortars*—Test Method C 1324 is available for determination of the proportions of components in hardened masonry mortars. There is no ASTM method for determining the conformance or nonconformance of a mortar to the property specifications of Specification C 270 by tests on hardened mortar samples taken from a structure.

NOTE 10—The results of tests done using Test Method C 1324 can be compared with the Specification C 270 proportion requirements, however, precision and bias have not been determined for this test method.

NOTE 11—Where necessary, testing of a wall or a masonry prism from the wall is generally more desirable than attempting to test individual components.

NOTE 12—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

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 C 780 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 retentivity 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 C 780) 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 Retentivity*—Water retentivity 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 The test method for flexural bond strength of masonry as prescribed in Test Methods E 518 is presently the most common method for evaluating this property of mortar. Test Methods E 518 consists of loading to failure a stack-bond, mortar and unit masonry prism, tested as a simple beam. Test Methods E 518 replaced a crossed-brick couplet test. Research on new test methods is currently underway. Presently the bend wrench method of test is under scrutiny as an alternative to Test Methods E 518.

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 E 514. 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.

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 C 780 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.