Designation: C 780 – 08a

Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry[1]

This standard is issued under the fixed designation C 780; 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.

INTRODUCTION

This test method provides a standard procedure for sampling and testing mortars for composition and plastic and hardened properties, either before or during actual construction. The procedures outlined in the Annexes are considered applicable for evaluating various combinations of portland cement, lime, and masonry cement for mortars common to plain and reinforced unit masonry construction.

The test procedures describe methods for the measurement of mortar composition and mortar properties. No attempt is made to claim or substantiate specific correlations between the measured properties and mortar performance in the masonry. However, data from these test methods can be combined with other information to formulate judgments about the quality of the masonry.

Testing using these procedures is limited to the preconstruction evaluation of masonry mortars within the laboratory, to the evaluation of masonry mortars at the construction site, and in establishing the degree of quality control exercised during mortar production at the construction site.

1. Scope*

1.1 This test method covers procedures for the sampling and testing of mortars for composition and for their plastic and hardened properties, either before or during their actual use in construction.

NOTE 1—Guide C 1586 provides guidance on evaluating mortar and clarifies the purpose of both this test method and Specification C 270.

NOTE 2—The testing agency performing this test method should be evaluated in accordance with Practice C 1093.

1.2 *Preconstruction Evaluation*—This test method permits comparisons of mortars made from different materials under simulated field conditions. It is also used to establish baseline values for comparative evaluation of field mortars.

1.3 *Construction Evaluation*—Use of this method in the field provides a means for quality assurance of field-mixed mortar. It includes methods for verifying the mortar mix proportions, comparing test results for field mortars to preconstruction testing, and determining batch-to-batch uniformity of the mortar.

1.4 The test results obtained under this test method are not required to meet the minimum compressive values in accordance with the property specifications in Specification C 270.

1.5 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.

1.6 *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.* For specific hazards statements, see Section 8.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

[1] This test method is under the jurisdiction of ASTM Committee C12 on Mortars and Grouts for Unit Masonry and is the direct responsibility of Subcommittee C12.02 on Research and Methods of Test.

Current edition approved Dec. 15, 2008. Published January 2009. Originally approved in 1974. Last previous edition approved in 2008 as C 780 – 08.

[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.**

C 128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate
C 173/C 173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
C 187 Test Method for Normal Consistency of Hydraulic Cement
C 231 Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
C 270 Specification for Mortar for Unit Masonry
C 470/C 470M Specification for Molds for Forming Concrete Test Cylinders Vertically
C 496/C 496M Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens
C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes
C 1093 Practice for Accreditation of Testing Agencies for Masonry
C 1586 Guide for Quality Assurance of Mortars
E 11 Specification for Wire Cloth and Sieves for Testing Purposes

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 Terms peculiar to testing masonry mortar are indicated and defined below:

3.1.2 *disturbed sample*—any plastic mortar test sample which is taken at some time after mixing and bulk sampling, that is further remixed or molded immediately prior to test, or both.

3.1.3 *undisturbed sample*—any plastic mortar test sample molded immediately after mixing and sampling that sits on a vibration-free surface until tested.

3.2 During sampling, the following descriptions will identify sample locations:

3.2.1 *Batch mixer samples* are those obtained during or immediately after the discharge of the mortar from the batch mixer.

3.2.2 *Mortar board samples* are those obtained from the mortar board after some established time period from the end of mixing, and before retempering. Retempered mortar board samples are those obtained from the mortar board after retempering. Since mortar on a mason's mortar board is disturbed by the activity of the mason, samples from a mason's mortar board shall be so identified to differentiate them from samples taken from a mortar board used exclusively for test purposes.

4. Summary of Test Method

4.1 Preconstruction evaluation of mortar systems involves the preparation of one or more trial batches which are mixed in the laboratory using mechanical batch mixers. These trial batches are sampled and used in establishing the plastic and hardened properties of the mixtures. Because all the trial mixtures are prebatched by weight, additional characteristics of the mortars may be calculated and used in an analysis of mortar performance.

4.2 During actual construction, evaluation of masonry mortars is possible by sampling the mortar at various stages of construction, and performing tests on both its plastic and hardened properties. The test results permit further verification of preconstruction testing, and reflect batch-to-batch variations introduced during mortar production and use at the construction site. More immediate corrective action for the mixing procedure is thereby attainable.

4.3 The following test methods may be singly or collectively incorporated into the testing to establish mortar composition, and mortar plastic and hardened properties:

4.3.1 Annex A1—Consistency by Cone Penetration Test Method,

4.3.2 Annex A2—Consistency Retention of Mortars for Unit Masonry,

4.3.3 Annex A3—Initial Consistency and Consistency Retention or Board Life of Masonry Mortars Using a Modified Concrete Pentrometer,

4.3.4 Annex A4—Mortar Aggregate Ratio Test Method,

4.3.5 Annex A5—Mortar Air Content Test Method,

4.3.6 Annex A6—Compressive Strength of Molded Masonry Mortar Cylinders and Cubes, and

4.3.7 Annex A7—Splitting Tensile Strength of Molded Masonry Mortar Cylinders.

5. Significance and Use

5.1 During preconstruction and construction evaluations, use of these test methods establishes specific and overall performance characteristics for the mortar system.

5.2 Preconstruction testing of mortars prebatched by weight provides information for the selection of the individual mortar system best suited for the masonry to be constructed. The recommended tests and their significance are as follows:

5.2.1 Consistency determinations by cone penetration allow gaging the water additions for all mortars included in the preconstruction test series. Even if the mortar consistency as measured at the construction site is at a different penetration value than those measured during the preconstruction tests, the cone preparation test serves to standardize water additions for mortars being considered as alternatives before construction. Additional testing of mortar water content-consistency relationships (Annex A4) will allow relating these two factors to batch-to-batch variations at the construction site.

5.2.2 Consistency retention by cone penetration using disturbed or undisturbed mortar samples provides a means of establishing the early-age setting and stiffening characteristics of the mortars. Because laboratory testing is conducted under static climatic conditions, consistency retention test results reflect the relative performance of the mortar systems under test. The same general relationships are expected to hold during testing at the construction project, except as they are influenced by jobsite weather conditions.

5.2.3 Mortar water-content determinations (Annex A4) allow measurement of the water content of the mortar mixture. Mortars prebatched using moist masonry sand may be mathematically analyzed for mortar water content; however, this test, when used for preconstruction evaluation, establishes the effectiveness of the test method and serves as the control or base for tests performed at the construction site.

5.2.4 Mortar aggregate ratio testing provides a method for determining the ratio of aggregate-to-cementitious materials.

The sieving operation employed during this test is incapable of separating an individual cementitious material when more than one such material is used, but can accurately establish the aggregate-to-cementitious materials ratio of the mixture.

5.2.5 Mortar air-content testing is useful in establishing the value of this component of the mortar. This test is of particular importance in evaluating mortars that contain air-entraining portland cement, air-entraining lime, masonry cement or any combination thereof.

5.2.6 Compressive strength testing of molded mortar cylinders and cubes establishes one of the characteristics of hardened mortar. Mortar compressive strength test values are not representative of the actual compressive strength of mortar in the assembly and are not appropriate for use in predicting the compressive strength that would be attained by the mortar in the masonry assembly. The measured compressive strength of a molded mortar specimen is almost always lower than the strength of the same mortar in the wall, primarily as a result of differences in mortar water content and specimen shape. Mortar compressive strength is influenced by mortar water content at the time of set. Because molded mortar specimens are not in contact with absorptive masonry units and are not subjected to other mechanisms of water loss, they have higher water contents than mortar in the wall. Higher water contents almost always result in lower strengths. Specimen size and shape also affect compressive strength. Cylinders and cubes exhibit different strengths even when made from the same mortar mix. Both of these specimen configurations yield lower strengths than what would be attained if a specimen having the same size and configuration of a typical mortar joint could be reliably tested.

NOTE 3—When cube and cylinder test specimens from like mixtures are to be compared, the cylinder compressive strength is approximately 85 % of the cube compressive strength.

5.2.7 Splitting tensile strength of molded mortar cylinders provides a method for determining the splitting tensile strength developing characteristics of the mortar. The measured strength is dependent upon the mortar water content at the time of set, along with other factors, and reflects the general strength attainable by the mortar in the masonry. The measured value, however, is not representative of the actual strength of the mortar in the masonry.

5.3 Testing during the actual construction may employ one or more of the test methods described in 4.2. Repetitive testing using these test methods on consecutive or intermittent batches provides a method for measurement of batch-to-batch variations in the mortar production. Testing during actual construction may be referenced to laboratory testing and used to predict later age mortar characteristics. In addition to the comments in 5.2, the following test meanings may be obtained from construction project testing:

5.3.1 Consistency by cone penetration is used as a quick reference for indicating batch-to-batch variations in mix ingredients and mixing time. Erratic consistency readings indicate poor control during batching and mixing, but they do not indicate if cement, sand, or water additions are improper. Other test methods must be used to isolate and identify the unsatisfactory proportioning or mixing procedure, for example, cement to aggregate, mortar water, or air content tests.

5.3.2 Consistency retention by cone penetration tests establishes the early-age setting and stiffening characteristics of the mortar. These properties are influenced by mix proportions and ingredients, weather conditions, effects of chemical additives, and mixing time.

5.3.3 Individual and repeated evaluations of mortar water content (Annex A4) show the ability of the mixer operator to properly and consistently add water to the mixer.

5.3.4 Individual and repeated tests for mortar aggregate ratio show the ability of the mixer operator to properly and consistently add the cementitious material and sand to the mixer, and will establish batch-to-batch variations in the composition of the mortar.

5.3.5 Individual and repetitive tests for mortar air content show the changes caused by variations in mixing time, mixing efficiency and other factors.

5.3.6 Comparison of compressive strength tests of field batched mortars to preconstruction mortar compression tests, each conducted in accordance with this test method, can be used to identify variations in mortar mix constituents and/or proportions. Variations in compressive strength values typically indicate changes in mix water content, mixing procedures, mix materials, material proportions, and environmental conditions.

NOTE 4—Variations in the measured compressive strengths of field-sampled mortar and between the measured compressive strengths of construction and pre-construction mortar samples should be expected. Many of these variations result from sampling mortar from the mixer or mortarboard and do not necessarily translate into significant mortar strength variations in the wall. Unit suction will remove water from the mortar in the wall and the curing conditions are different. However, significant variation between measured compression strength values should prompt evaluation of probable causes of this variation. Conducting companion mortar aggregate ratio tests would assist in determining if changes in mix constituents and proportions are the likely cause. (See 5.2.6 for additional information).

5.3.7 Splitting tensile strengths of molded cylinders stored in accordance with the test method reflect the approximate strength of the masonry mortar because lower water-cement ratio mortars are found in the wall than are typically measured for mortars from the mixer.

6. Test Method Limitations

6.1 During mortar aggregate ratio testing, no attempt has been made to establish the proportions of either portland cement to lime or portland cement to masonry cement in the mixture. Additional testing could establish this proportioning, however, batching operations should be supervised to ensure the correct proportioning of these ingredients.

6.2 Due to the greater ability to weigh materials accurately, mix on a precise schedule, and control other factors relating to the production and testing of mortar under laboratory conditions as compared to field conditions, the principal purpose of this test method is to provide a means to identify, measure, evaluate, and control differences that exist between laboratory and jobsite mortars.

6.3 There is no ASTM standard method for measuring the composition or physical properties of hardened mortars removed from a structure.

7. Apparatus

7.1 The apparatus required for this test, along with the apparatus for sampling (see Section 9) are given in the individual tests included in the annexes.

8. Hazards

8.1 During any period that the alcohol used in the mortar aggregate ratio test is exposed to the atmosphere, and particularly when the test sample is being dried, the tester should be aware that alcohol is a very flammable material. Prior to drying the sample in an oven, place the sample in a shallow pan and flash off the alcohol by intentional ignition in an open, well-ventilated area.

9. Sampling

9.1 This section deals with the sampling of individual mortar ingredients and of the mortar itself for preconstruction evaluation in the laboratory and construction evaluation at the jobsite.

9.2 Complete the sampling of materials as follows:

9.2.1 Bagged material, such as portland cement, lime, and masonry cement, shall be of the type and brand that will be used or is being considered for use in the actual construction. Obtain full-bag lots in sufficient quantity for completing the desired tests.

9.2.2 Aggregate for test purposes shall be from the same source and of the same description as will be used or is being considered for use in the actual construction. Obtain a representative sample of sufficient quantity to complete the desired tests.

9.2.3 Water for test purposes need not be the same as that to be used in construction, except when it is known or suspected that the properties of the water available for mortar production at the construction site will have a measurable effect upon the mortar properties. In normal testing, clean, potable water shall be acceptable for test purposes.

9.3 Obtain plastic mortar samples both in the laboratory and at the construction project by taking uniformly distributed incremental samples, and mixing them to form a bulk sample from which the quantity of mortar required for a specific test or specimen can be randomly taken.

9.3.1 Take batch mixer samples immediately after mixing, either during the discharge of the mixer or after the mortar has been discharged into the mortar boat, buggy, or other receptacle. If samples are taken during the discharge of the mixer, they shall be taken at any time except for the first and last 10 % of the batch. Samples of the mortar taken after discharge from the mixer shall be representative of the entire batch.

9.3.2 Take mortar for mortar board tests in accordance with 9.3.1, and place upon mortar boards typical of those used or to be used at the project. For construction site testing, expose the test mortar on the board(s) to climatic conditions typical of those on the jobsite. When mortar from a mason's mortar board is used for test purposes, identify it further to reflect this exception for proper data interpretation. Thoroughly hand-mix mortar selected for testing with a trowel immediately before sampling for tests or specimens. Record the lapsed time from the end of mixing as part of the test data.

9.3.3 Take retempered mortar board samples from the mason's mortar board at recorded time periods after mixing and retempering. Thoroughly hand-mix all mortar on the board with a trowel before sampling.

9.4 Record sampling procedures to include the date, time, place, and method of sampling. When applicable, note and record the climatic conditions.

10. Test Specimens

10.1 During preconstruction evaluation of masonry mortars, measure plastic mortar properties using a single test specimen for each part of the tests. For determining hardened mortar properties, prepare three test specimens for each test age and property.

10.2 During construction evaluation of masonry mortars, measure plastic mortar properties using a single test specimen for each part of the method of test. For determining hardened mortar properties, prepare three test specimens for each test age and property.

10.3 During actual construction evaluation of masonry mortars, and when batch-to-batch variations are to be established, sample three consecutive batches and test for plastic and hardened properties.

11. Procedure

11.1 *Mortar Preparation*—Prepare and mix the mortar for preconstruction evaluation in the laboratory using the materials (see 9.2.3, regarding water) and proportions intended for use in construction. Use a mechanical batch mixer similar to that intended for use in construction.

11.1.1 Use masonry sand in the damp, as-received condition, and handle in such a manner as to prevent segregation. Correct the water added to the mortar as free water in sands above the saturated, surface-dry condition, in accordance with Test Method C 128. Report the total water used in the mix.

11.1.2 Prebatch the mortar materials, by weight, to meet the desired volume proportions.

11.1.3 *Mixing*—Mix the mortar following this sequence:

11.1.3.1 When two or more cementitious materials are to be used in preconstruction evaluation tests, pre-blend the materials so that they may be charged into the mixer as one ingredient.

11.1.3.2 Charge the mixer for preconstruction evaluation tests as follows:

(1) approximately ½ the estimated mixing water required,

(2) sand,

(3) cementitious material, and

(4) the balance of the mixing water required to produce the desired consistency. Inasmuch as laboratory procedures permit a more rapid combination of materials than is generally achieved under actual construction conditions, time delays between the various mixing sequences must be made to approximate jobsite situations.

11.1.3.3 Mix the mortar for preconstruction evaluation tests at normal speed for a total of 5 min after the completion of the charging sequence. Water additions must be made during the first 4 min of this mixing period if the mix appears too dry.

11.1.3.4 Determine the cone penetration value of the mortar for preconstruction evaluation tests in accordance with Annex A1.

NOTE 5—There is some disagreement regarding the relative values of the cone penetration test versus the flow table test. The cone penetration test is selected for this procedure since a flow table mounted in accordance with applicable ASTM specifications is not practically portable, and correlation between laboratory and field would be lost if one procedure used the flow table and the other the cone penetrometer.

11.2 Complete the preconstruction and construction evaluation in accordance with the test methods appended, Annex A1-Annex A7.

12. Report

12.1 Report the following information:

12.1.1 Include the test results and all pertinent data relating to the conduct and conditions of the tests in the test report. The data sheet in Annex A8 is suggested as a general format for the development of report forms.

13. Keywords

13.1 aggregate ratio; air content; compressive strength; concrete penetrometer; cone penetrometer; consistency; consistency retention; mortar; tensile strength

ANNEXES

(Mandatory Information)

A1. CONSISTENCY BY CONE PENETRATION TEST METHOD

A1.1 Scope

A1.1.1 This test method covers a procedure for determining the consistency of mortars for unit masonry by measuring the penetration of a conical plunger into a mortar sample.

A1.2 Apparatus

A1.2.1 *Unit Measure*—A cylindrical measure having an inside diameter of 3 ± 1⁄16 in. (76 ± 1.6 mm) and a depth of approximately 3 15⁄32 in. (88.1 mm), adjusted by standardization with water to contain 400 ± 1 ml at 73.4°F (23°C). For purposes of this test, the capacity of the measure in millilitres is the weight of the water content of the measure, in grams, divided by 0.998. The measure shall have a uniform wall thickness. The thickness of the wall and bottom shall not be less than 0.115 in. The total weight of the empty measure shall not be more than 900 g. The measure shall be made of a metal not attacked by the cement mortar. The 400-mL measure can be calibrated readily by filling with distilled water at 73.4°F (23°C) to a point where the meniscus extends appreciably above the top of the measure, placing a clean piece of plate glass on the top of the measure, and allowing the excess water to be squeezed out. The absence of air bubbles as seen through the glass ensures that the measure is completely full. Care should be taken that the excess water is wiped from the sides of the container before weighing.

A1.2.2 *Straightedge*—A steel straightedge not less than 4 in. (101.6 mm) long and not less than 1⁄16 in. (1.59 mm) nor more than 1⁄8 in. (3.2 mm) in thickness.

A1.2.3 *Tamper*—In accordance with Test Method C 109/C 109M. The tamping face shall be flat and at right angles to the length of the tamper.

A1.2.4 *Tapping Stick*—A maple wood rod, having a diameter of 5⁄8 in. (15.9 mm) and a length of 6 in. (152.4 mm).

A1.2.5 *Spoon*, metal, kitchen-type, with the handle cut off to make the overall length approximately 9 in. (228.6 mm) and with the bowl of the spoon being approximately 4 in. (101.6 mm) long, 2½ in. (63.5 mm) in width at the widest portion, and ½ to ¾ in. (12.7 to 19.05 mm) deep.

A1.2.6 *Cone Penetrometer*—A Vicat apparatus, conforming to the physical requirements of Test Method C 187, shall be modified to allow reading cone penetrations to a depth of 89 mm. The frame shall be raised 2 in. (50.8 mm) to accommodate the unit measure and the plunger in the raised position. The indicator scale shall be extended to allow measuring a full drop of 89 mm. The plunger shall be an aluminum cone, 1⅝ in. (41.3 mm) in diameter by 3⅝-in. (92.08-mm) long, blunted to a hemisphere a distance of ⅛ in. (3.2 mm) making the overall length 3½ in. (88.9 mm). The base of the cone shall be drilled and tapped on the centerline for threading to a stainless steel tube of proper size and able to slide freely in the guides of the apparatus. The weight of the tube shall be adjusted so that the combined weight of the cone, tube and index pointer is 200 ± 2 g.

A1.3 Procedure

A1.3.1 Immediately after the mortar is sampled, fill the unit measure. Using the spoon, place the mortar gently into the measure in three layers of equal volume, tamping each layer 20 times with the tamper in one complete revolution around the inner surface of the measure. Consider one complete up-and-down motion of the tamper held in a vertical position as one tamping. In tamping the first layer, do not strike the tamper forcibly against the bottom of the measure. In tamping the second and third layers, each layer is tamped in one complete revolution (rotation) with only sufficient pressure to adequately fill the measure and eliminate voids within the mortar. After the measure has been filled and tamped in the above prescribed manner, tap the sides of the measure lightly with the side of the tapping stick once each at five different points at approximately equal spacing around the outside of the measure in order to preclude entrapment of extraneous air. Take care that no space is left between the mortar and the inner surface of the measure as a result of the tamping operation. Then cut the mortar off to a plane surface flush with the top of the measure, by drawing the straightedge with a sawing motion across the top of the measure, making two passes over the entire surface, the second pass being made at right angles to the first. Take care in the striking-off operation that no loose sand grains cause the straightedge to ride above the top surface of the measure. Complete the entire operation of filling and striking off the measure within 1½ min. Wipe off all mortar and water adhering to the outside of the measure.

A1.3.2 Raise the penetration plunger and slide the unit measure underneath the plunger until the point of the plunger rests on the edge of the container. Tighten the set screw just enough to hold the plunger and move the indicator opposite the zero point of the scale.

A1.3.3 Center the container under the plunger and release the plunger with a swift, definite turn of the set screw while holding the entire apparatus firmly with the other hand.

A1.3.4 Read the depth of penetration in millimetres or at the end of 30 s.

A1.4 Report

A1.4.1 Report the depth of cone penetration to the nearest 1 mm.

A2. CONSISTENCY RETENTION OF MORTARS FOR UNIT MASONRY

A2.1 Scope

A2.1.1 This method describes a procedure for determining the consistency retention of mortars after various time intervals by the cone penetration test method. Both disturbed and undisturbed sample testing are included in the method. Unless otherwise stipulated, only the disturbed sample testing will be required.

A2.2 Apparatus

A2.2.1 In addition to the apparatus required for completing the cone penetration test in Annex A1, extra unit measures and glass cover plates are required when using the undisturbed sample test procedure for each test time to be included in the determination of consistency retention. No additional equipment is necessary using the disturbed mortar sample test procedure.

A2.3 Procedure

A2.3.1 *Disturbed Samples*—When testing disturbed mortar samples, sample and use the mortar in filling the mortar test container immediately prior to conducting the test. Sample the mortar as it is discharged from the mixer, and place on a mortar board reserved for test purposes. This mortar shall not be used by the mason, or disturbed until immediately prior to testing. Just before the test, remix the mortar sample with a trowel until it is of uniform consistency. Then agitate or handle the mortar just enough to allow proper consolidation of the mortar in the test container. After the mortar sample has been consolidated in the mold as described in Annex A1, immediately complete the test. The normal interval between tests is 15 min.

A2.3.2 *Undisturbed Samples*—When testing undisturbed mortar samples, prepare the test specimens for all test ages immediately after the mortar is discharged from the mixer. Prepare one test specimen in accordance with Annex A1 for each test age. One test container will be required for each test. Immediately after filling the test container, cover the sample with a cover plate and invert the entire assemblage and place upon a firm, level surface. Immediately prior to testing, turn the assemblage upright and remove the cover plate. The normal interval between tests is 15 min. Two options are available under this test procedure. The method given for undisturbed samples in A2.3.2 minimizes, by the use of the cover plate, the effects of surface moisture evaporation on the consistency of the mortar. Although a mason seldom uses a board of mortar which has sat undisturbed for some time without mixing it with his trowel first, some mortar study programs may wish to include determinations of these surface effects. If this is desired, vary the procedure by not covering and not inverting the test molds for the interval between their preparation and testing. The test report must note the use of this alternate procedure when it is employed.

A2.3.3 Determine the penetration of the cone into the mortar sample as described in Annex A1.

A2.4 Report

A2.4.1 The report shall include the following:

A2.4.1.1 Depth of penetration to the nearest 1 mm,

A2.4.1.2 Notation as to whether the data refers to disturbed or undisturbed samples, and

A2.4.1.3 Test time.

A3. INITIAL CONSISTENCY AND CONSISTENCY RETENTION OR BOARD LIFE OF MASONRY MORTARS USING A MODIFIED CONCRETE PENETROMETER

A3.1 Scope

A3.1.1 This method allows determination of initial consistency and board life of masonry mortars. The method is sufficiently restrictive to be used as a basis for acceptance of mortars. Results correspond to pounds per square inch of pressure required to penetrate a sample of mortar 1 in. with a disk of a given size and weight. English units of measure will be used throughout the method.

A3.2 Terminology

A3.2.1 *Definitions:*

A3.2.1.1 *board life*—the time period during which penetration resistance stays below a given value (P_f).

A3.2.1.2 P_o—the initial penetration resistance or consistency of a masonry mortar as measured, using this method.

A3.2.1.3 P_f—the penetration resistance or consistency of a masonry mortar when the mortar is too stiff for use.

A3.2.1.4 *rate of stiffening*—the ratio of the difference between P_o and P_f per time interval.

A3.2.1.5 T_o—the time when the initial penetration resistance measurement was made.

A3.2.1.6 T_f—the time when P_f was reached, obtained by interpolation.

A3.3 Significance and Use

A3.3.1 Data obtained from this method are used to determine consistency of a mortar, as well as board life of a mortar. The method is also useful for determining when a mortar is or is not acceptable for use due to stiffness. When penetration resistance is outside the desired range (P_o to P_f) the mortar is retempered or discarded.

A3.4 Apparatus

A3.4.1 *Concrete Penetrometer*, spring activated with calibration markings from 20 to 700 psi.

NOTE A3.1—The penetrometer shall be modified by the attachment of a 1 in. thick steel disk 2.70 in. in diameter with a horizontal cross sectional area of 5.75 ± 0.10 in. to the shaft. The overall weight shall be 2.1± 0.5 lb.

NOTE A3.2—Pocket-sized concrete penetrometers are available in different configurations. The disk modification of this method prevents direct use of the scale provided on the penetrometer shaft. Disk material other than steel may be used providing the alternate material is abrasion resistant, rigid and resistant to chemical attack by mortars. Other disk materials require calibration, also.

A3.4.2 *Trowel*—A mason's trowel.

A3.4.3 *Shovel*—A square nosed shovel.

A3.4.4 *Ring*—A 16-in. inside diameter ring made of steel or other rigid, chemical and abrasive resistant material, 3 in. high with exterior, opposing handles.

A3.4.5 *Mortar Board*— A nominal 2 ft by 2 ft by ¾ in. mortar board of exterior grade plywood.

A3.4.6 *Straightedge*—A wooden straightedge of nominal dimensions, 2 in. by 4 in. and 24 in. in length (optional).

A3.5 Sampling, Test Specimens, and Test Units

A3.5.1 At least one specimen shall be prepared for each mortar.

A3.5.2 Test condition shall be either actual climatic conditions and construction practices at the construction site or simulated conditions considering temperature, humidity, wind, sand, water, mixing equipment, handling, mixing procedure, etc.

A3.6 Calibration and Standardization

A3.6.1 Calibrate the penetrometer by placing it on a weigh scale with a capacity of 30 lb and accurate to 0.05 lb. Place the penetrometer on the weigh scale platform and tare to zero. Push downward on the handhold of the penetrometer until the weigh scale registers 1 lb. This pressure shall be applied within for three seconds. Read and record penetrometer scale pressure. Repeat applications of downward force in increments of 1 lb from 1 to 30 lb and record each incremental penetrometer scale reading. Divide the total applied load plus the weight of the penetrometer by the cross sectional area of the disk. These values represent pressure at the face of disk. Prepare a calibration chart to allow converting penetrometer scale reading to penetration resistance, in psi. See Table A3.1.

A3.7 Procedure

A3.7.1 Mortar to be tested for board life shall be prepared so the initial penetration resistance (P_o) is either 0.94 ± 0.05 psi for mortar to be used with *brick sized units* or 1.24 ± 0.05 psi for mortar to be used with *heavier units requiring less plastic mortars for proper bedment*. Water additions to the mortar decrease penetration resistance. Prepare comparison mortars with varied composition and proportions controlling equipment and procedures.

A3.7.2 Place the mortar in the circular ring, previously centered on the damp mortar board. Spade the mortar with the square-nosed shovel. Screed the top surface of the specimen to the surface of the ring using either the straightedge or trowel. Remove mold within three min after mortar mixing was completed. Immediately take three penetration readings. Position the disk of the penetrometer on the surface of the mortar

TABLE A3.1 Penetrometer Calibration (5.67 in.^{2} Disk, 2.47 lb of Penetrometer and Disk)

NOTE—The pressure exerted on the specimen is the measured weight plus the weight of the penetrometer and disk divided by the area of the disk. For example, the disk weighs 2.47 lb and the area of the disk is 5.67 in.^{2}; 1 lb of measured weight + 2.47 lb weight of penetrometer and disk (tare)/5.67 in.^{2} = 0.61 psi.

Measured Weight, lb	Scale Readings	psi
1	20	0.61
2	40	0.79
3	60	0.96
4	80	1.14
5	100	1.32
6	120	1.49
7	140	1.67
8	160	1.85
9	180	2.02
10	200	2.20
11	220	2.38
12	240	2.55
13	260	2.73
14	280	2.90
15	300	3.08
16	320	3.26
17	340	3.43
18	360	3.61
19	380	3.79
20	400	3.96
21	420	4.14
22	440	4.32
23	460	4.49
24	480	4.67
25	500	4.84
26	520	5.02
27	540	5.20
28	560	5.37
29	580	5.55
30	600	5.73

at least one disk diameter from both the edge and previous test areas. Apply uniform pressure within three seconds so the disk penetrates the mortar a distance of 1 in., the disk thickness. Read the penetrometer scale to the nearest 5 psi and record penetrometer scale reading and time of readings. Reset scale marker to zero. Average the three readings and convert to applied pressure, in psi, using the calibration curve. Record this result as P_o, psi, and the time as T_o, min.

A3.7.3 Within two minutes after completing the three initial penetration readings, thoroughly remix the mortar using mason's trowel. Position ring, screed, and remove ring. Allow mortar to remain undisturbed for 15 min since T_o. Read and record three additional penetrations and time, using the procedures of A3.7.2. Repeat this procedure every 15 min till the average penetration resistance is either 1.74 psi for mortars to be used with brick sized units or 2.44 psi for mortars to be used with heavier units. (Note A3.3)

NOTE A3.3—Uniformly spaced measurements other than 15 min may be desirable for research and other testing needs.

A3.8 Report

A3.8.1 Report the following information:

A3.8.1.1 Plot data of penetration resistance, in psi, with elapsed time until P_f is reached.

A3.8.1.2 Calculate and report the rate of stiffening as:

$$\text{Rate of stiffening} = (P_f - P_o)/T_f, \text{ psi per min} \quad (A3.1)$$

where:

P_f and P_o are as indicated:

Mortar for Brick Sized Units[A]	Mortar for Heavier Units
$P_f = 1.74$	$P_f = 2.44$
$P_o = 0.94$	$P_o = 1.24$

[A] The size, weight and bedding area of the unit should be considered in selecting the appropriate values of P_f and P_o.

$$T_f = \text{ interpolated time when } P_f \text{ obtained.} \quad (A3.2)$$

(see Note A3.4)

NOTE A3.4—For graphic illustration, see Fig. A3.1.

A3.8.2 Report T_f as board life, in minutes. P_f is approximately equal to the consistency when mortars are judged too stiff to be used properly.

A3.8.3 Report all penetration resistance data in psi and associated times in minutes.

A3.9 Precision and Bias

A3.9.1 The precision of the procedure in Test Method C 780, Annex A3, for measuring consistency and board life is being determined.

A3.9.2 The procedure in Test Method C 780, Annex A3, for measuring the consistency and board life of masonry mortars has no bias because the value of consistency and board life can be defined only in terms of a test method.

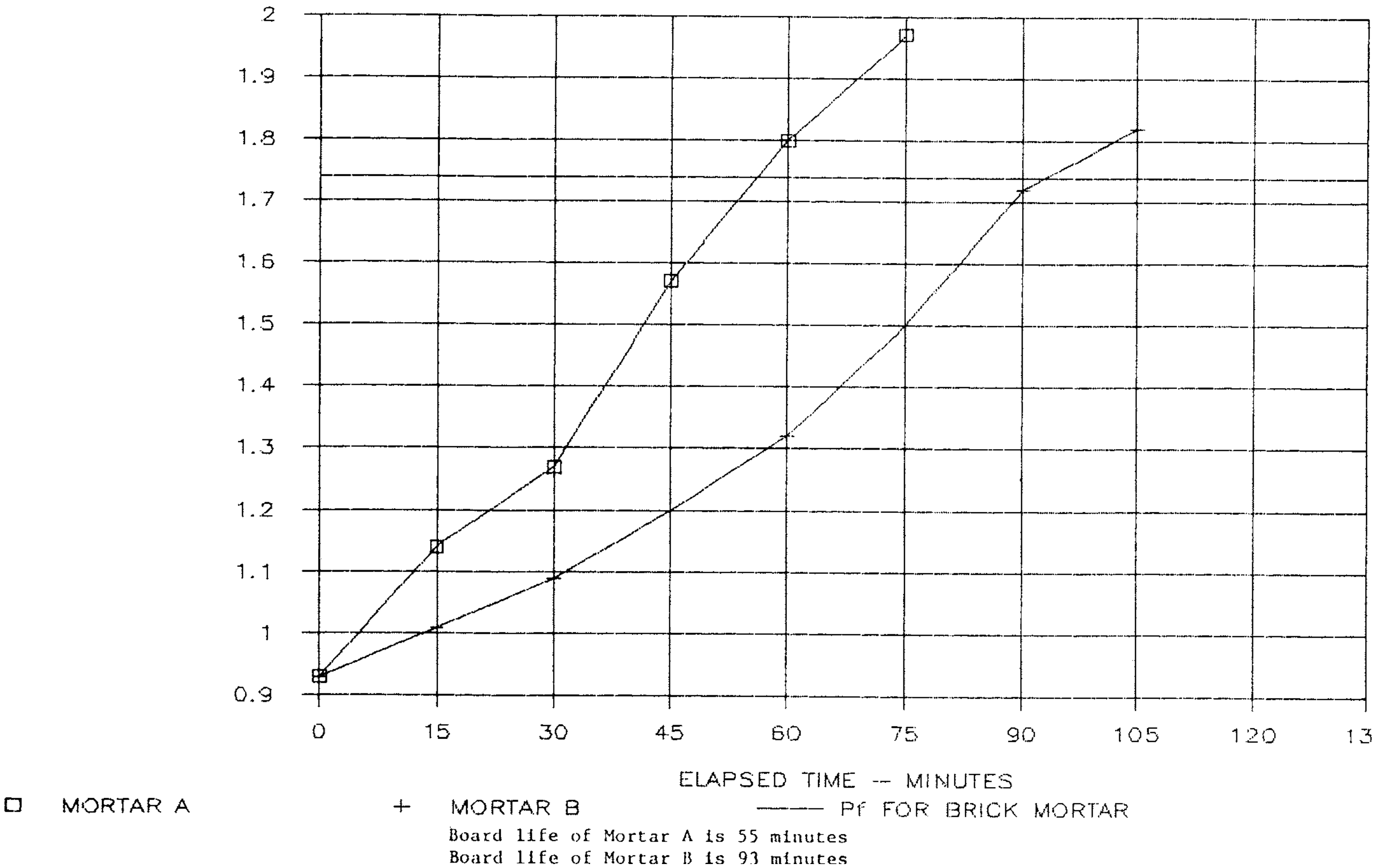

FIG. A3.1 Penetration Resistance Versus Elapsed Time

A4. MORTAR AGGREGATE RATIO TEST METHOD

A4.1 Scope

A4.1.1 This test method describes a procedure for determining the aggregate-to-cementitious materials ratio of mortars for unit masonry by determining the mortar fraction coarser than a No. 100 (150-µm) sieve and correcting for the sand finer than the No. 100 sieve. This test method also includes a procedure for determining the water content of mortar.

NOTE A4.1—Previous editions of this standard included a stand-alone method for determining water content of mortars. That method and the mortar aggregate method were so interrelated that they have been combined into one method. This method retains methods for calculating and reporting mortar water contents and can be performed with a single sample of mortar without determination of the ratio of aggregate to cementitious materials.

A4.1.2 This test method determines the aggregate-to-cementitious materials ratio by weight. For mortars specified by volume proportions, guidance for converting the ratio by weight to a ratio by volume is located in Note A4.3.

A4.2 Apparatus

A4.2.1 *Sand Sample Container*—A clean 1-qt (1 L) wide-mouth clear glass or plastic watertight container or waterproof sand bag.

A4.2.2 *Mortar Sample Container*—Two clean 1-qt (1 L) wide-mouth clear glass or plastic watertight containers with sealable lids.

A4.2.3 *Spoon*—A stainless steel tea or soup spoon.

A4.2.4 *Sieve*—A No. 100 (150-µm) sieve (8 in. (203.2 mm) in diameter and 2 in. (50.8 mm) from the top of the tram to the cloth), conforming to the requirements of Table 1 of Specification E 11 as follows:

Sieve Designation:	
Standard	150 µm
Alternative	No. 100
Nominal sieve opening, in.	0.0059
Allowable variation of average opening from the standard sieve designation	±8 µm
Maximum opening size for not more than 5 % of openings	174 µm
Maximum individual opening	192 µm
Nominal wire diameter, mm	0.110

NOTE A4.2—The average diameter of the warp and of the shoot wires, taken separately, of the cloth of any sieve shall not deviate from nominal values by more than the following:

Sieves 600 to 125 µm	7½ %

A4.2.5 *Oven*—An oven capable of maintaining a constant temperature of 110 ± 5°C (230 ± 9°F).

A4.3 Procedure

A4.3.1 Prior to going to the construction site, label one of the mortar sample containers as "H" and the other as "a," add

250 ml of isopropyl or methyl alcohol to both mortar sample containers, and determine and record the combined weight of each container and alcohol to the nearest 1 g. Tightly seal the containers to prevent evaporation.

A4.3.2 At the construction site, place 500 to 700 g of mortar into each mortar sample container with the alcohol, as rapidly as is practical. Tightly reseal the lids to minimize evaporation, then agitate the containers until no lumps are visible. Take care to minimize any loss of alcohol during mortar sampling and agitation. Record and report the time the mortar is mixed and the time the sample is placed in alcohol. Identify where that mortar is being installed on the project.

A4.3.3 At the construction site, obtain a representative sand sample in excess of 500 g. Place the sand sample in the sand sample container.

A4.3.4 Upon returning to the laboratory, using the container labeled "H," determine and record as "I" the combined weight of the mortar sample, alcohol, and container to the nearest 1 g. Then, using water, transfer the entire mortar sample to the No. 100 (150-µm) sieve for wet sieving. Wash the mortar with a gentle flow of water accompanied by a slight tilting of the screen in various positions until the wash water is clear and contains no visible particles of sand or cementitious material when viewed against a background of contrasting color such as a white sink basin. Dry the + 100-mesh fraction in the oven to constant weight without removing the material from the screen at 110 ± 5°C (230 ± 9°F). The sample is at constant weight when drying for an additional 15 min results in a weight change of less than 0.1 %. Determine the oven-dry weight of the + 100 fraction and record as "Y" to the nearest 1 g.

A4.3.5 Weigh the sand sample, dry in the oven to constant weight at 110 ± 5°C (230 ± 9 ºF), and record the weight as "R" to the nearest 1 g. Wet-sieve as described in A4.3.4, dry in the oven to constant weight at 110 ± 5°C (230 ± 9 ºF), weigh, and record as "W" the + 100 sand fraction to the nearest 1 g.

A4.3.6 Using the container labeled "a," determine and record as "b" the combined weight of the mortar sample, alcohol, and container to the nearest 1 g. Then, using water, transfer the entire mortar sample to a weighing pan. Ignite the alcohol within the sample following the safety precautions of Section 8 of this test method, and then bring the partially dried sample in the oven at 110 ± 5°C (230 ± 9 ºF) to constant weight. Record as "d" the oven-dry weight of the mortar to the nearest 1 g.

A4.4 Calculation

A4.4.1 Calculate the moisture content of the mortar, expressed on the wet and dry basis as follows:

$$\text{Mortar water content, wet basis, } \% = [(b - a - d) / (b - a)] \times 100 \quad \text{(A4.1)}$$

$$\text{Mortar water content, dry basis, } \% = G = [(b - a - d)/d] \times 100$$

where:
- a = weight of the container and alcohol, g,
- b = weight of the container, alcohol, and mortar, g, and
- d = weight of the oven-dry mortar sample, g.

A4.4.2 Calculate the ratio of the aggregate-to-cementitious materials as follows:

$$\text{Weight of wet mortar} = J = I - H \quad \text{(A4.2)}$$

$$\text{Weight of dry mortar} = K = J//[1 + (G/100)]$$

$$\text{Weight of } + 100 \text{ mortar, dry, corrected } = Q = (Y \times R/W)$$

$$\text{Weight of } - 100 \text{ mortar, dry, corrected } = P = K - Q$$

$$\text{Aggregate-to-Cementitious Materials ratio} = Q/P \text{ to } 1$$

where:
- H = weight of container and alcohol,
- I = weight of container, alcohol and mortar,
- G = mortar water content, dry basis, from A4.4.1,
- Y = weight of + 100 fraction, dry,
- R = weight of sand, oven dry, and
- W = weight of the + 100 sand, dry.

NOTE A4.3—This test method does not differentiate between multiple cementitious materials, simply the total cementitious content as compared to the aggregate content. This method yields the aggregate-to-cementitious materials ratio by weight, yet aggregate-to-cementitious material ratios are typically specified by volume.

If the specified volume ratio is known, it can be converted to a weight ratio, which can then be compared with the result of this test method. Alternatively, if only one cementitious material is used in the mortar, the results of this method can be converted to a volume ratio, which can then be compared to the specified ratio. This method cannot be reliably used to convert the test result of mortar with multiple cementitious materials into a volume ratio.

When converting ratios, use the following material bulk densities:

Cementitious Material	Bulk Density
Portland Cement	94 lb/ft^3(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 lb/ft^3(1280 kg/m^3)
Hydrated Lime	40 lb/ft^3(640 kg/m^3)

Aggregate	Bulk Density
Sand	80 lb/ft^3(1280 kg/m^3)

Example 1—To convert a cement and lime mortar specified to contain 1 part by volume of portland cement, 1¼ parts by volume of hydrated lime and 6¾ parts by volume of damp, loose sand (this represents a volume ratio of aggregate-to-cementitious material of 3 to 1) to a weight ratio, perform the following:

$$\text{Aggregate-to-Cementitious Ratio (by wt)*}$$

$$= \frac{6.75 \text{ parts aggregate (by vol)} \times 80 \text{ lb/ft}^3}{[1 \text{ part portland cement (by vol)} \times 94 \text{ lb/ft}^3] + [1.25 \text{ parts hydrated lime (by vol)} \times 40 \text{ lb/ft}^3]}$$

$$= \frac{540}{94 + 50}$$

$$= \frac{540}{144}$$

$$= 3.75 \text{ or } 3.75 \text{ to } 1$$

Example 2 (convert weight ratio as tested to volume ratio)—This conversion can only be performed on mortars in which the bulk density of the combined cementitious material is known. Consider a sample mortar in which the measured weight ratio using this method was determined to be 3.4 parts aggregate to 1 part cementitious material. Inspection of the mortar materials at the time of sampling shows a masonry cement (with a bulk density of 70 lb/ft^3 as shown on the bag) was the only cementitious material used. To convert this weight ratio to a volume ratio, perform the following:

$$\text{Aggregate-to-Cementitious Ratio (by vol)*} = \frac{\frac{3.4 \text{ parts aggregate}}{80 \text{ lb/ft}^3}}{\frac{1 \text{ part masonry cement}}{70 \text{ lb/ft}^3}}$$

$$= \frac{3.4 \text{ parts aggregate}}{80 \text{ lb/ft}^3} \times \frac{70 \text{ lb/ft}^3}{1 \text{ part cement}}$$

$$= \frac{238}{80}$$

$$= 2.98 \text{ or } 2.98 \text{ to } 1$$

*Values shown in examples use English units. If English units are replaced with SI units, the resulting calculated proportions by weight would be identical to those shown here.

A5. MORTAR AIR CONTENT TEST METHOD

A5.1 Scope

A5.1.1 This test method covers a procedure for determining the air content of mortars for unit masonry using either the pressure meter method or the volumetric method.

A5.2 Apparatus

A5.2.1 Depending on the test method selected, the apparatus requirements and calibration procedures are given in Test Methods C 231 (See Note A5.1) and C 173.

A5.3 Procedure A—Pressure Method (Test Method C 231)

A5.3.1 Place a representative sample of the mortar in the measuring bowl in three equal layers. Consolidate each layer by 25 strokes of the tamping rod, evenly distributed over the cross section, followed by tapping the sides of the bowl smartly 10 to 15 times with the mallet until the cavities left by rodding are leveled out and no large bubbles of air appear on the surface of the rodded layer. In rodding the first layer, do not forcibly strike the rod against the bottom of the bowl. In rodding the second and final layers, use only enough force to cause the rod to penetrate the surface of the previous layer. Slightly overfill the bowl with the third layer and, after consolidation, remove the excess mortar by sliding the strike-off bar across the top flange with a sawing motion until the bowl is just level-full.

A5.3.2 Thoroughly clean the flanges of the bowl and conical cover so that a pressure-tight seal will be obtained when the cover is clamped in place. Assemble the apparatus and add water into the tube until the water rises to about the halfway mark in the water column. Incline the apparatus assembly about 30° from the vertical and, using the bottom of the bowl as a pivot, describe several complete circles with the upper end of the column, simultaneously tapping the conical cover lightly to remove any entrapped air bubbles above the mortar sample. Return the apparatus assembly to its vertical position and fill the water column slightly above the zero mark, while lightly tapping the sides of the bowl. Remove foam on the surface of the water column with a syringe or with a spray of alcohol in order to provide a clear meniscus. Bring the water level to the zero mark of the graduated tube before closing the vent at the top of the water column.

A5.3.3 Apply slightly more than the desired test pressure, P, (about 0.2 psi (1.38 kPa) more) to the mortar by means of the small hand pump. To relieve local restraints, tap the sides of the measure smartly and, when the pressure gage indicates the exact test pressure, P, read the water level, h_1, and record to the nearest division or half division (0.10 or 0.05 % air content) on the graduated precision bore tube or gage glass of the standpipe. For extremely harsh mixes, it will be necessary to tap the bowl vigorously until further tapping produces no change in indicated air content. Gradually release the air pressure through the vent at the top of the water column and tap the sides of the bowl lightly for about 1 min. Record the water level, h_2, to the nearest division or half division. The apparent air content, A_1, is equal to $h_1 - h_2$.

A5.3.4 Repeat the steps described in the preceding paragraph (without adding water to reestablish the water level at the zero mark). The two consecutive determinations of apparent air content should check within 0.2 % of air and shall be averaged to give the value A_1 to be used in calculating the air content, A, in A5.3.4.1.

A5.3.4.1 Calculate the air content of the mortar as follows:

$$A = A_1 - G \quad \text{(A5.1)}$$

where:

A = air content, percentage by volume of mortar,
A_1 = apparent air content, percentage by volume of mortar, and
G = aggregate correction factor, percentage by volume of mortar.

NOTE A5.1—The aggregate correction factor for any given source is usually constant. While using this procedure for comparing preconstruction and construction mortar properties and using the same aggregate, no significant errors will be produced if the correction factor is assumed to be 0. When absolute values are desired or mortars containing different aggregates are to be compared, determine the aggregate correction factor in accordance with Test Method C 231. Experience with aggregates from various geographical areas and sources indicates whether repeated determinations of the aggregate correction factor will produce significant variations in the measured air content. Ordinarily the factor remains reasonably constant for given aggregates, but a periodic check is recommended.

A5.4 Procedure B—Volumetric Method (Test Method C 173)

A5.4.1 Using the scoop, aided by the trowel if necessary, fill the bowl with mortar in three layers of equal depth. Consolidate each layer by 25 strokes of the tamping rod, distributed evenly over the cross section, followed by tapping the sides of the bowl smartly 10 to 15 times with the mallet until the cavities left by rodding are leveled out, and no large bubbles of air appear on the surface of the rodded layer. In rodding the first layer, do not forcibly strike the rod against the bottom of the bowl. In rodding the second and final layers, use only enough force to cause the rod to penetrate the surface of the previous layer. Slightly overfill the bowl with the third layer, and after consolidation, remove the excess mortar by sliding the strike-off bar across the top flange with a sawing motion until the bowl is just level-full. Wipe the flange of the bowl clean.

A5.4.2 Clamp the top section into position on the bowl, insert the funnel, and add water until it appears in the water column. Remove the funnel and adjust the water level, using the rubber syringe, until the bottom of the meniscus is level with the zero mark. Attach and tighten the screw cap. Invert and agitate the unit until the mortar settles free from the base. Then, with the neck elevated, roll and rock the unit until the air appears to have been removed from the mortar. Set the apparatus upright, jar it lightly, and let it stand until the air rises to the top. Repeat this operation until no further drop in the water column is observed. When all the air has been removed from the mortar and allowed to rise to the top of the apparatus, remove the screw cap. Add in 1-cup increments, sufficient isopropyl alcohol to dispel the foamy mass on the surface of the water.

A5.4.3 Estimate the liquid in the neck by reading to the bottom of the meniscus to the nearest 0.1%.

A5.4.4 Calculate the air content of the mortar in percent, by adding to the reading in A5.4.3 the amount of alcohol used in dispelling the bubbles.

A5.5 Report

A5.5.1 Determine the mortar air content and the aggregate correction factor, and calculate and report the net air content from these data. Also report the test method, the meter type, meter air content capacity, and the meter bowl size.

A6. COMPRESSIVE STRENGTH OF MOLDED MASONRY MORTAR CYLINDERS AND CUBES

A6.1 Scope

A6.1.1 This test method establishes testing procedures for determining compressive strength of preconstruction and construction mortars. Strength values for mortars obtained through these testing procedures are not required, nor expected, to meet strength requirements of laboratory Specification C 270 mortars. The values obtained from preconstruction testing are to be correlated with those of construction mortars made with the same materials, in the same proportions, and mixed to the same consistency.

A6.1.2 This method covers the procedure for determining the compressive strength of mortars for unit masonry using any of the following: 2 by 4-in. (50.8 by 101.6-mm) cylinders, 3 by 6-in. (76.2 by 152.4-mm) cylinders, or 2-in. (50.8-mm) three-compartment gang cubes. See A6.2 through A6.4 for cylindrical specimens and A6.5-A6.10 for cube specimens.

A6.1.3 *Tests of Hardened Mortars*—There is no accepted standard for measuring individual hardened mortar joint strengths.

A6.2 Preparation of Cylinder Specimens

A6.2.1 *Apparatus*:

A6.2.1.1 *Molds*—Cylinder molds for 2 by 4 in. (50.8 by 101.6 mm) cylinders, or 3 by 6 in. (76.2 by 152.4 mm) cylinders, shall be single-use or reusable molds and shall comply with Specification C 470.

A6.2.1.2 *Straightedge*—A steel straightedge not less than 7 in. (178 mm) long, and not less than 1⁄16 in. (1.59 mm) nor more than 1⁄8 in. (3.18 mm) in thickness.

A6.2.1.3 *Spoon*—A stainless steel tea or soup spoon.

A6.2.1.4 *Maximum-Minimum Thermometer*.

A6.2.1.5 *Tamper*, in accordance with Test Method C 109/C 109M. The tamping face shall be flat and at right angles to the length of the tamper.

A6.2.1.6 *Trowel*, with blade 4 to 6 in. (101.2 to 152 mm) in length, with straight edges.

A6.2.1.7 *Nonabsorbent Container*—A metal or plastic bowl or bucket suitable for collecting field mortar samples.

A6.2.1.8 *Testing Machine*—The testing machine shall conform to the requirements of Test Method C 39.

A6.3 Procedure

A6.3.1 Fabricate the test specimens immediately after the mortar has been sampled. Select the specimen casting area in close proximity to the area where the specimens will be stored for the first 24 ± 4 h. Coat reusable metal molds with a light coating of mineral oil to minimize mortar sticking to the molds.

A6.3.2 Using the spoon, place the mortar gently into the cylinder mold in three layers of approximately equal volume, tamping each layer 20 times with the tamper in one complete revolution around the inner surface of the mold. Consider one complete up-and-down motion of the tamper, held in a vertical position, as one tamping. In tamping the first layer, do not strike the tamper forcibly against the bottom of the mold. In tamping the second and final layers, each layer is tamped in one complete revolution (rotation) with only sufficient pressure to adequately fill the measure and eliminate voids within the mortar. Slightly overfill the top layer of the mold prior to and during the period the top layer is tamped. After the mold has been filled and the mortar tamped, tap the sides of the mold lightly in order to preclude the entrapment of extraneous air. Strike off the top surface of the specimen using the straightedge, so it is level with the top of the mold. After fabrication, cover the top surface of the mold, using either a cap or a plastic bag, to minimize evaporation.

NOTE A6.1—As far as possible, provide jobsite storage facilities which approximate laboratory storage conditions. Minimum facilities must include an insulated container, a vibration-free location and protection from temperature extremes. Store an indicating maximum-minimum thermometer with the test specimens, and record the maximum, minimum, and average temperatures at the time the specimens are taken to the laboratory. If storage temperatures are less than 40°F (4.4°C) or greater than 90°F (32.2°C) as shown by the thermometers, the specimens shall be discarded.

A6.3.3 At the age of 24 ± 4 h, transport the specimens to the laboratory, and store in a moist closet or moist room for the next 20 to 24 h prior to removing the specimens from their molds. Store the specimens until they are of test age in a moist closet or room in compliance with Specification C 511. Remove the specimens from the moist room 2 h prior to testing, and cap the cylinders with high-strength gypsum plaster or sulfur mortar. Square any cylinder ends that are very obviously uneven, convex, or concave before capping. Grind small irregularities and saw-cut major irregularities. Remove coatings or deposits of oily or waxy materials that would interfere with bonding of the cap from the ends of the specimen. Slightly roughen the end of the specimen with a steel file or a wire brush, as needed, to produce proper adhesion of the caps. Make caps as thin as practicable, generally, about ⅛ in. (3.2 mm) thick, and in no case more than 5⁄16 in. (7.9 mm) thick. Coat capping plates with a thin layer of mineral oil to prevent the capping material from adhering to the surface of the plate. Use high-strength gypsum plaster mixed with water, between 26 and 30 % by weight, for capping. Allow the cap to cure at least 1 h before compression testing. Prepare sulfur mortar by heating to about 265°F (130°C), as periodically determined by an all-metal thermometer inserted near the center of the mass. Empty the pot and recharge with fresh material at frequent intervals to ensure that the oldest material in the pot has not been used more than five times. Fresh sulfur mortar must be dry at the time it is placed in the pot as dampness can cause foaming. Keep water away from molten sulfur for the same reason. Slightly warm the capping plate or device before use to slow the rate of hardening and facilitate the production of thin caps. Oil the capping plate lightly and stir the molten sulfur immediately prior to pouring each cap. The ends of moist-cured specimens shall be dry enough at the time of capping to preclude the formation of steam or foam pockets under or in the cap larger than ¼ in. (6.35 mm) in diameter. To ensure that the cap shall be bonded to the surface of the specimen, prevent oil from contacting the end of the specimen prior to application of the cap. Restrict any reuse of capping material in order to minimize the loss of strength and pourability occasioned by contamination of the mortar with oil and miscellaneous debris, and the loss of sulfur through volatilization. Provide a capping jig of the proper size.

A6.3.4 Maintain moist-cured specimens in a moist condition between capping and testing by returning them to moist storage or wrapping them with a double layer of wet burlap. Do not immerse specimens with gypsum plaster caps in water nor store them in a moist room for more than 4 h. If stored in a moist room, protect the plaster caps against water dripping on their surfaces.

A6.3.5 Keep test specimens moist during the period between their removal from the moist room and testing, by using a wet burlap or blanket covering. Test them in a moist condition. Determine the diameter of the test specimen to the nearest 0.01 in. (0.25 mm) by averaging two diameters measured at right angles to each other at about midheight of the specimen. Use this average diameter for calculating the cross-sectional area. Measure the length of the specimen, including caps, to the nearest 0.1 in. (2.5 mm). Place the plain (lower) bearing block, with its hardened side face-up, on the table or platen of the testing machine directly under the spherically seated (upper) bearing block. Wipe the bearing faces of the upper and lower bearing blocks and the test specimen clean, and place the test specimen on the lower bearing block. Carefully align the axis of the specimen with the center of thrust of the spherically-seated block. As the spherically seated block is brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.

A6.3.6 Apply the load continuously and without shock. In testing machines of the screw type, the moving head shall travel at a rate of approximately 0.05 in. (1.3 mm)/min. In hydraulically-operated machines, apply the load at a constant rate within the range from 20 to 50 psi (0.14 to 0.34 MPa)/s. During the application of the first half of the anticipated load a higher rate of loading is permissible. Make no adjustment in the controls of the testing machine while a specimen is yielding rapidly immediately before failure. Apply the load until the specimen fails, and record the maximum load carried by the specimen during the test. Note the type of failure and the appearance of the mortar.

A6.4 Calculation

A6.4.1 Calculate the compressive strength of the specimen by dividing the maximum load carried by the specimen during the test by the average cross-sectional area, determined as described in 6.3.5 and express the result to the nearest 10 psi (0.07 MPa).

A6.5 Preparation of Cube Specimens

A6.5.1 *Apparatus*:

A6.5.1.1 *Nonabsorbent Container*—A metal or plastic bowl or bucket for collecting field mortar samples.

A6.5.1.2 *Spoon*—A stainless steel tea or soup spoon.

A6.5.1.3 *Specimen Molds*—Molds for 2-in. cubic specimens in accordance with Test Method C 109/C 109M.

A6.5.1.4 *Tamper*—Maintain style for molding specimens in accordance with Test Method C 109/C 109M.

A6.5.1.5 *Trowel*, with a blade 4 to 6 in. in length, with straight edges.

A6.5.2 *Number of Specimens*:

A6.5.2.1 A minimum of three specimens shall be made for each period of test specified.

A6.5.3 *Preparation of Cube Molds*—Thinly cover the interior face of the specimen molds with mineral oil or light cup grease. Thinly cover the contact surfaces of the halves of each mold with mineral oil. After assembling the molds, remove the excess oil or grease from the interior faces and the top and bottom surfaces of the mold. Set the molds on a plane, nonabsorptive base plate that has been thinly coated with mineral oil. Apply a wax similar to microcrystalline wax at the outside contact lines of the molds and base plates, so that watertight joints are affected between the molds and the baseplates.

A6.5.4 *Procedure*—Immediately after the mortar has been sampled, mold the test specimens in accordance with Test Method C 109/C 109M.

A6.6 Storing the Test Specimens

A6.6.1 Immediately on completion of the molding, place specimens in jobsite storage facility. Minimum facilities shall include an insulated container, a vibration free location, and a maximum-minimum thermometer shall be placed with each specimen that will record the maximum and minimum temperatures of the specimens until they are taken to the laboratory. by 12-in. (152.4 by 304.8-mm) concrete cylinder mold may be used for the storing of test specimens providing:

A6.6.1.1 The mold contains several thicknesses of wet paper towels underneath the molded specimens. The wet towels shall not touch the mortar specimen.

A6.6.1.2 The specimens are in a horizontal upright position at all times in the sealed mold when buried in the mortar sand pile. The spot of imbedment in the sand pile shall be marked properly to avoid any disturbance for the next following 24-h period.

A6.6.1.3 The storage temperatures are not less than 40°F (4.4°C) nor greater than 90°F (32.2°C) as measured by a maximum-minimum thermometer. If temperatures exceed these limits, the specimens shall be discarded.

A6.6.2 Remove the specimens from their stored position at the end of 24 h ± 4 h and carefully transport them to the laboratory. Place the test specimens in a moist closet or moist room for the next 20 to 24 h with their upper surfaces exposed to the moist air but protected from dripping water. Next, following the 20 to 24-h period, remove the specimens from the molds. The specimens shall be maintained in a moist cabinet with the relative humidity maintained at 90 % or more, up to the testing age for each 7 day or 28 day test.

A6.7 Test Procedure

A6.7.1 Test the cube specimens immediately after their removal from the moist cabinet. If more than one specimen at a time is removed from the moist closet for each test, cover these cubes with a damp cloth until the time of testing.

A6.7.2 Wipe each specimen to a surface dry condition, and remove any loose sand grains or incrustations from the faces that will be in contact with the bearing block of the testing machine. Check these faces by applying a straightedge. If there is appreciable curvature, grind the face or faces to plane surfaces or discard the specimen. Results much lower than the true strength will be obtained by loading faces of the cube specimens that are not truly plane surfaces. It is essential that specimen molds be kept scrupulously clean, as otherwise, large irregularities in the surface will occur. Instruments for cleaning molds shall always be softer than the metal in the mold. In case grinding of the specimen face becomes necessary, it can be accomplished best by rubbing the specimen on a piece of fine emery paper or cloth glued to a plane surface, using only a moderate pressure. Such grinding is tedious for more than a few thousandths of an inch. If more grinding than this is found necessary, the specimen must be discarded.

A6.7.3 Prior to the testing of each cube, it shall be ascertained that the spherically-seated block is free to tilt. No cushioning or bedding materials shall be used. The diagonal or diameter of the bearing surface shall be only slightly greater than the diagonal of the face of the 2-in. (50-mm) cube in order to facilitate accurate centering of the specimen. A diameter not greater than 2.9 in. (74 mm) shall be used, provided the lower bearing block has a diameter of 3⅛ in. (79.4 mm).

A6.7.4 Apply the load to the specimen faces that were in contact with the true plane surfaces of the mold. Carefully place the specimen in the testing machine below the center of the upper bearing block.

A6.7.5 An initial loading up to one half of the expected maximum load for specimens having expected maximum loads of more than 3000 lb shall be applied at any convenient rate. Apply no initial loading to specimens having expected maximum loads of less than 3000 lb.

A6.7.6 Adjust the rate of load application so that the remainder of the load (or the entire load in the case of expected maximum loads of less than 3000 lb) is applied, without interruption, to failure at such a rate that the maximum load will be reached in not less than 20 nor more than 80 s. Make no adjustments in the controls of the testing machine while a specimen is yielding rapidly immediately before failure.

A6.8 Calculation

A6.8.1 Record the total maximum load indicated by the testing machine, and calculate the compressive strength in pounds per square inch. If the cross-sectional area of a specimen varies more than 0.06 in.^{2} from 4 square in., use the actual area for the calculation of the compressive strength. The compressive strength of all acceptable test specimens (see A6.7) made from the same sample and tested at the same period shall be averaged and reported to the nearest pound per square inch.

A6.9 Faulty Specimens and Retests

A6.9.1 In determining the compressive strength, do not consider the specimens that are manifestly faulty, or that give strengths differing by more than 10 % from the average value of all test specimens made from the same sample and tested at the same period.

A6.9.2 After discarding specimens or strength values, if less than two strength values remain for determining the compressive strength at any given period, make a new test. Reliable strength results depend upon careful observance of all the specified requirements and procedures. Erratic results at a given test period indicate that some of the requirements and procedures have not been carefully observed; for example, those covering the testing of the specimens as prescribed in A7.2, A7.3, and A7.4. Improper centering of specimens resulting in oblique fractures or lateral movements of one of the heads of the testing machine during loading will often cause lower strength results. A specimen so broken shall be considered “manifestly faulty” if its strength differs by more than 10 % from the average of all test specimens made from the sample and tested at the same period.

A6.10 Report

A6.10.1 The report shall include the following:

A6.10.1.1 A description of the specimen by size, A6.10.1.2 The test mold material, and

A6.10.1.3 The curing procedure, dimensions, total load, and compressive strength of the individual specimen for each test age.

A7. SPLITTING TENSILE STRENGTH OF MOLDED MASONRY MORTAR CYLINDERS

A7.1 Scope

A7.1.1 This method covers a procedure for determining the splitting tensile strength of mortars for units using molded cylinders measuring 2 by 4 or 3 by 6 in. (50.8 by 101.6 or 76.2 by 152.4 mm).

A7.2 Apparatus

A7.2.1 *Molds*—Cylinder molds shall be single-use cardboard, individual or gang-metal molds.

A7.2.1.1 *Reusable Metal Molds*—for making test specimens shall be made of noncorrodible material and shall be sufficiently rigid to prevent spreading during molding. The molds shall have not more than three compartments, and shall be separable into not more than two parts (plus a baseplate). Single-compartment molds or gang molds with heavy rib reinforcement at the top, middle, and bottom, fitted with heavy, quick-acting yoke clamps, and with bolts or thumbscrews for locking the halves together shall be suitable. The specimen compartments shall be 2 ± 0.01 in. (50.8 ± 0.25 mm) in diameter by 4 ± 0.01 in. (101.6± 0.25 mm) in height for new molds (3 ± 0.01 by 6 ± 0.01 in. (76 ± 0.25 by 152 ± 0.25 mm) for 3 by 6-in. (76 by 152-mm molds), or 2 ± 0.02 in. (50.8 ± 0.64 mm) in diameter by 4 ± 0.02 in. (101.2 ± 0.64 mm) in height for molds in use (3 ± 0.02 by 6 ± 0.02 in. (76 ± 0.64 by 152 ± 0.64 mm) for 3 by 6-in. molds). The interior surfaces shall be smooth, and the top and bottom surfaces shall be plane and parallel. The baseplate shall be of metal or plate glass not less than ¼ in. (6.35 mm) thick and having a plane, smooth surface.

A7.2.1.2 *Single-Use Paper Molds*—The side walls of paper molds shall be made with a minimum of three plies having a combined thickness of not less than 0.07 in. (1.78 mm). Seams on the inside of the mold shall not be open by more than 1⁄32 in. (0.79 mm). The bottom cap of the mold shall be made of either metal or paper. If metal, it shall not be less than 0.009 in. (0.229 mm) in thickness. It shall be so designed that it will be flush with the bottom edge of the sidewall within a tolerance of 1⁄16 in. (1.59 mm), and the inside crimp, if any, shall produce an indentation of not more than 3⁄16 in. (4.76 mm) in the radial, and no more than 1⁄8 in. (3.18 mm) in the vertical direction. If made of paper, the bottom cap of the mold shall be of parchment-lined cap stock not less than 0.028 in. (0.71 mm) thick. It shall be glued to the outside of the walls by means of a flange not less than ¾ in. (19.05 mm) high. The glue shall be a water-insoluble type of resin adhesive that will not react with fresh mortar. Only the practical minimum amount of adhesive should be exposed on the inner side of the bottom of the mold. All interior surfaces of the molds shall be coated or impregnated with wax or other nonreactive sealer which will prevent both leakage and any reaction between the mortar and the mold.

A7.2.2 *Straightedge*—A steel straightedge not less than 7 in. (178 mm) long and not less than 1⁄16 in. (1.59 mm) nor more than 1⁄8 in. (3.18 mm) in thickness.

A7.2.3 *Spatula*—A spatula with a metal blade 8 in. (203 mm) in length and ½ in. (12.7 mm) in width, with straight edges and a wooden handle.

A7.2.4 *Spoon*—A stainless steel tea or soup spoon.

A7.2.5 *Maximum-Minimum Thermometer*.

A7.2.6 *Testing Machine*—The testing machine shall conform to the requirements of Test Method C 39, and shall be of sufficient capacity that will provide a uniform rate of loading within the range of 100 to 200 psi (0.69 to 1.38 MPa)/min splitting tensile stress until failure of the specimen.

A7.2.7 *Supplementary Bearing Bar or Plate*—A supplementary bearing bar or plate of machined steel shall be used when the diameter or largest dimension of the upper or lower bearing block is less than the length of the cylinder to be tested. The surfaces of the bearing bar or plate shall be machined to within ±0.001 in. (0.025 mm) of planeness, as measured on any line of a width of at least 2 in. (50.8 mm), and a thickness not less than the distance from the edge of the spherical or rectangular bearing block to the end of the cylinder. The bar or plate shall transmit the applied load uniformly over the entire length of the specimen.

A7.2.8 *Bearing Strips*—Two noncorrugated cardboard bearing strips, similar to tablet backs, approximately 1 in. (25.4 mm) wide and equal to or slightly longer than the specimen, shall be provided for each specimen. The bearing strips shall be placed between the specimen and both the upper and lower bearing blocks of the testing machine or between the specimen and supplemental bars or plates, if used. Bearing strips shall not be reused.

A7.3 Procedure

A7.3.1 After the mortar has been sampled, immediately begin the fabrication of the test specimens. Select the specimen casting area in close proximity to the area where the specimens will be stored for the first 48 h.

A7.3.2 Coat reusable metal molds with a light coating of mineral oil to minimize sticking of the mortar to the molds.

A7.3.3 Using the spoon, place the mortar gently into the cylinder mold in three layers of approximately equal volume, spading each layer 20 times with the spatula in one complete revolution around the inner surface of the mold. Consider one complete up-and-down motion of the spatula held in a vertical position as one spading. In spading the first layer do not strike the spatula forcibly against the bottom of the mold. In spading the second and final layers, use only enough force to cause the spatula to penetrate the surface of the previous layer. Slightly overfill the top layer of the mold prior to and during the period the top layer is spaded. After the mold has been filled and the mortar spaded, tap the sides of the mold lightly in order to preclude entrapment of extraneous air. Strike the top surface of the specimen level with the top of the mold using the straightedge. After fabrication, cover the top surface of the mold using either a cap or a plastic bag to minimize evaporation. As far as possible, provide jobsite storage facilities which approximate laboratory storage conditions. Minimum facilities include an insulated container, a vibration-free location, and protection from temperature extremes. Store an indicating maximum-minimum thermometer with the test specimens, and record the maximum, minimum, and average temperatures at the time the specimens are taken to the laboratory.

A7.3.4 At the age of 48 ± 4 h, bring the specimens to the laboratory where they will be demolded and stored in a moist room conforming to Specification C 511 until they are of test age. Keep the specimens moist during the period between their removal from the curing environment and testing, by using a wet burlap or blanket covering, and test in a moist condition.

A7.3.5 Draw diametral lines on each end of the specimen using a device that will ensure they are in the same axial plane.

NOTE A7.1—A jig design which can be fabricated with modifications to accommodate 2 by 4-in. (50 by 102-mm) and 3 by 6-in. (76 by 152-mm) specimens is described in Test Method C 496.

A7.3.6 Determine the diameter of the test specimen to the nearest 0.01 in. (0.25 mm) by averaging three diameters measured near the ends and the middle of the specimen and lying in the plane containing the lines marked on the two ends. Determine the length of the specimen to the nearest 0.1 in. (2.5 mm) by averaging at least two length measurements taken in the plane containing the lines marked on the two ends.

A7.3.7 Center one of the cardboard strips along the center of the lower bearing block. Place the specimen on the cardboard strip and align so that the cardboard strip is centered with the lines marked on the ends of the specimen when those lines are oriented vertically. Place a second cardboard strip lengthwise on the cylinder and centered on the lines marked on the ends of the cylinder. Position the assembly so that the projection of the plane of the two lines marked on the ends of the specimen intersects the center of the upper bearing plate, and the supplementary bearing bar or plate, when used, and the center of the specimen are directly beneath the center of thrust of the spherical-bearing block.

A7.3.8 Apply the load continuously and without shock, at a constant rate within the range of 100 to 200 psi (0.69 to 1.38 MPa)/min splitting tensile stress until failure of the specimen. Record the maximum applied load indicated by the testing machine at failure. Note the type of failure and appearance of the mortar.

A7.4 Calculation

A7.4.1 Calculate the splitting tensile strength of the specimen as follows:

$$T = 2P/\pi LD \qquad \text{(A7.1)}$$

where:

T = splitting tensile strength, psi (MPa),
P = maximum applied load indicated by the testing machine, lbf (N),
L = length, in. (mm), and
D = diameter, in. (mm).

A7.5 Report

A7.5.1 The report shall include descriptions of the specimen by size, test mold material, maximum, minimum and average temperatures, storage conditions, age, and the individual total load and splitting tensile strength for each test specimen.

A8. PRECONSTRUCTION AND CONSTRUCTION EVALUATION OF MORTARS FOR UNIT AND REINFORCED MASONRY

General information
- Project:
- Masonry: ....
- Contractor: ....
- Mortar specified:

Mixer:Mfgr.
- Type ....
- RPM ....
- Condition

Materials:
- Cement, portland ....
- Cement, masonry ....
- Lime ....
- Sand ....
- Water ....
- Admixture ....

Mixture:	Order	Vol	Wt
Cement, portland	....	....	....
Cement, masonry	....	....	....
Lime	....	....	....
Sand	....	....	....
Water	....	....	....
Admixture	....	....	....

Mixing information:
- Charging time ....
- Mixing time ....
- Time ....

Sampling information:
- Sample board ....
- Mortar board ....
- Sample time ....

Ambient conditions:
- Temperature ....
- Relative humidity ....
- Wind velocity ....

Plastic mortar properties
- Consistency, mm ....
- Consistency retention, mm — 15 min .... 30 min .... 45 min ....

Mortar water content:
- Wt. content, alcohol (A)..........
- Wt. content, alcohol, mortar (B)..........
- Wt. mortar, wet (C)..........
- Wt. mortar, dry (D)..........
- Wt. water (E)..........
- Mortar water content, wet, % (F)..........
- Mortar water content, dry, % (G)..........

Mortar aggregate ratio:
- Wt. content, alcohol (H)..........
- Wt. content alcohol, mortar (I)..........
- Wt. mortar, wet (J)..........
- Wt. mortar, dry (K)..........
- Wt. + 100 mortar, dry (Y)..........
- Wt. sand, blank, dry (R)..........
- Wt. + 100 sand, dry (W)..........
- Wt. + 100 mortar, dry, cor (Q)..........
- Wt. − 100 mortar, dry, cor (P)..........

Cement: aggregate ratio 1:..........

Mortar air content
- Method ....
- Gross air content, % ....
- Aggregate content, % ....
- Net air content, % ....

Job site curing temperatures
- Maximum F ....
- Average F ....
- Minimum F ....

Hardened mortar properties

Mortar compressive strength:
- Specimen: ....
- Mold:
- Cure: ....

Spec. No.	Test Age	Total Load	Strength psi(kPA)	Avg
1	3d	....	....	
2	3d	....	....	....
3	3d	....	....	....
4	7d	....	....	
5	7d	....	....	....
6	7d	....	....	
7	28d	....	....	
8	28d	....	....	....
9	28d	....	....	

Mortar splitting tensile strength:
- Specimen: ....
- Mold: ....
- Cure: ....

Spec. No.	Test Age	Total Load	Strength psi(kPa)	Avg
1	3d	....	....	
2	3d	....	....	....
3	3d	....	....	
4	7d	....	....	
5	7d	....	....	....
6	7d	....	....	
7	28d	....	....	
8	28d	....	....	....
9	28d	....	....	

Miscellaneous:
- Date: ....
- Testing Machine: ....
- Observer: ....

SUMMARY OF CHANGES

Committee C12 has identified the location of selected changes to this standard since the last issue (C 780 – 08) that may impact the use of this standard. (Approved Dec. 15, 2008.)

(*1*) Added subsection A4.1.2 to provide additional clarification that the method determines ratios by weight.

Committee C12 has identified the location of selected changes to this standard since the last issue (C 780 – 07a) that may impact the use of this standard. (Approved Aug. 1, 2008.)

(*1*) Language about compressive strength in 5.2.6 and 5.3.6 was improved to clarify the use of compressive strength.
(*2*) Added oven to apparatus section. Also made changes to A4.3.4 and A4.3.5 regarding drying to constant weight.
(*3*) Revised A4.2 and A4.3 to remove references to Mason jar.

Committee C12 has identified the location of selected changes to this standard since the last issue (C 780 – 07) that may impact the use of this standard. (Approved Nov. 15, 2007.)

(*1*) A comment was added to A4.3.2 about recording the time and location of taking the mortar sample.