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# Standard Test Methods for Measurement of Masonry Flexural Bond Strength[1]

This standard is issued under the fixed designation C1072; 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 U.S. Department of Defense.*

ε[1] NOTE—Editorially corrected Table X1.1 in March 2014.

## 1. Scope*

1.1 These test methods evaluate the flexural bond strength, normal to the bed joints, of masonry built of manufactured masonry units. Sampling and testing procedures are referenced, and terms are defined. Three different specimen fabrication methods are specified, each for a different purpose:

1.1.1 The first method is the "Test Method for Laboratory-Prepared Specimens." Its purpose is to compare the bond strengths (under the given conditions) of masonry mortars. It could be used, for example, to check the quality of mortar products after production, or to indicate the bond strength (under the given conditions) of a mortar product without requiring the product to be tested in combination with many different units. It is not intended to represent field conditions. It uses standard concrete masonry units. Mortars are batched by weight equivalents of volume proportions and are mixed to a prescribed flow. Prisms are constructed using a jig and are bag-cured.

1.1.2 The second method is the "Test Method for Field-Prepared Specimens." Its purpose is to evaluate the bond strength (under the given conditions) of a particular unit-mortar combination, either for preconstruction evaluation of materials or for quality control purposes during construction. Mortars are batched conventionally, and the flow is not prescribed. Prisms are constructed conventionally (no jig) and are bag-cured.

1.1.3 The third method is the "Test Method for Prisms Removed from Existing Masonry." Its purpose is to evaluate the bond strength of unit-mortar combinations of prisms cut from existing walls.

1.1.4 The three methods are not consistent, nor are they intended to be. They are intended to be used for three different purposes. To make this clear, the three methods are presented separately.

1.1.5 Appendix X1 suggests two possible criteria for assessing the bond strength values obtained using these test methods. These possible evaluation criteria are given for illustration only and are not mandatory.

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

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

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

C67 Test Methods for Sampling and Testing Brick and Structural Clay Tile

C140 Test Methods for Sampling and Testing Concrete Masonry Units and Related Units

C230/C230M Specification for Flow Table for Use in Tests of Hydraulic Cement

C270 Specification for Mortar for Unit Masonry

C780 Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry

C1232 Terminology of Masonry

C1437 Test Method for Flow of Hydraulic Cement Mortar

C1532 Practice for Selection, Removal, and Shipment of Manufactured Masonry Units and Masonry Specimens from Existing Construction

2.2 *Other Documents:*

TMS 402/ACI 530/ASCE 5 Building Code Requirements for Masonry Structures[3]

[1] These test methods are under the jurisdiction of ASTM Committee C15 on Manufactured Masonry Units and are the direct responsibility of Subcommittee C15.04 on Research.

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

[3] Available from the Masonry Standards Joint Committee, http://www.masonrystandards.org.

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

NBS Handbook 91[4]

## 3. Terminology

3.1 *Definitions:*

3.1.1 *lot, n*—material of a given quantity of a single type, grade, class, and brand and practically of the same nominal size, color range, texture, and composition produced by a single source by virtually the same process and under essentially the same conditions.

3.2 For additional terms used in this test method, refer to Terminology C1232.

[4] Natrella, M. G.,*Experimental Statistics*, National Bureau of Standards Handbook 91, U.S. Government Printing Office, Aug. 1, 1963, pp. 2–14.

# TEST METHOD FOR LABORATORY-PREPARED SPECIMENS

## 4. Summary of Test Method

4.1 This test method is for evaluating the flexural bond strength (under the given conditions) of masonry built of standard masonry units. It uses standard concrete masonry units. Mortars are batched by weight equivalents of volume proportions and are mixed to a prescribed flow. Prisms are constructed using a jig and are bag-cured.

NOTE 1—Standard fired clay masonry units are under development but are not now available. When their development is complete, they will be incorporated into these test methods.

## 5. Significance and Use

5.1 This test method is intended for use in comparing the bond strengths (under the given conditions) of masonry mortars.

5.2 This test method could be used, for example, to check one aspect of the quality of mortar products after production, or to indicate the bond potential of a mortar product without requiring the product to be tested in combination with many different units.

5.3 This test method uses controlled conditions of fabrication and curing that are not intended to represent field conditions.

5.4 This test method uses standard concrete masonry units. Mortars are batched by weight equivalents of volume proportions and are mixed to a prescribed flow. Prisms are constructed using a jig and are bag-cured.

5.5 Flexural bond strength determined by this test method shall not be interpreted as the flexural bond strength of a wall (because standard units are not used for wall construction), nor shall it be interpreted as an indication of extent of bond for purposes of water permeability evaluation.

## 6. Apparatus

6.1 *Prism Alignment Jig,* as described in Annex A2 and shown in Fig. A2.1.

6.2 *Mortar Joint Template,* as described in Annex A2 and shown in Fig. A2.2.

6.3 *Drop Hammer,* as described in Annex A2 and shown in Fig. A2.3.

6.4 *Mechanical Paddle-Type Mortar Mixer,* of no less than 0.6 $ft^3$ (18 L) capacity.

6.5 *Flow Table, Flow Mold, and Caliper,* conforming to the requirements of Specification C230/C230M.

6.6 *Cone Penetrometer, Unit Measure, Straightedge, Spatula, Tapping Stick, and Spoon,* conforming to the requirements of Test Method C780.

6.7 *Bond Strength Test Apparatus,* conforming to the requirements of Annex A3.

## 7. Materials

7.1 Select representative samples of each lot of mortar materials. Each sample of material shall be of sufficient quantity to build a set of test prisms. Use standard concrete masonry units meeting the requirements of Annex A1.

7.2 Mortar materials (including water) shall be at an equilibrium temperature with laboratory air (see Section 8).

## 8. Temperature and Humidity

8.1 Maintain the temperature of laboratory air in the vicinity of mixing of mortar, fabrication of specimens, curing, and testing of specimens at 75 ± 15°F (24 ± 8°C).

8.2 Maintain the relative humidity of laboratory air in the vicinity of mixing of mortar, fabrication of specimens, and testing of specimens between 30 and 80 %.

## 9. Procedure

9.1 Fabricate a set of stack-bonded test prisms (any convenient number of prisms) containing a total of not less than 15 mortar joints. Each prism shall have no more than 5 joints.

9.1.1 Proportion mortar materials by weights equivalent to volume proportions to be used in prism construction. Use unit weights for individual materials as given in Specification C270. Sand shall be permitted to be used in a damp loose condition, provided that moisture content of sand is determined with reference to the oven-dried condition and batch proportions are adjusted accordingly. Record weight of ingredients (including water) added to the batch of mortar.

9.1.2 Mix mortar in a mechanical paddle-type mortar mixer. Time periods referenced below are measured from when water and cementitious materials are combined.

9.1.2.1 For standard concrete masonry units, add an estimated amount of water to the mortar to achieve a flow of 127 ± 3 determined in accordance with Test Method C1437. Mix mortar for 3 min and determine flow. Once flow is recorded,

return the material used to measure flow to the mixer. If the flow is 127 ± 3, continue mixing the batch for an additional 2 min. If the flow is less than 124, add water to the batch, mix for 1 min, and determine flow. Once flow is recorded, return the material used to measure flow to the mixer. If the flow is 127 ± 3, continue mixing the batch for 1 min.

9.1.2.2 If after the one-time addition of water the flow is not 127 ± 3, discard the batch.

9.1.2.3 If the measured flow exceeds 130 at any time, discard the batch.

9.1.3 Immediately after mixing the mortar, determine its initial cone penetration in accordance with Test Method C780. Determine the cone penetration of the mortar every 15 ± 5 min. If the cone penetration is less than 80 % of its initial value, discard the remaining portion of the mortar without constructing additional mortar joints.

9.1.4 Use standard concrete masonry units as defined in Annex A1. Clean the bed surface of units of dirt, loose sand, or other contaminants.

9.1.5 Fabricate prism specimens as described in Annex A2.

9.1.6 Cure prism specimens in accordance with Annex A2.

9.2 Conduct bond-wrench tests on prism specimens.

9.2.1 Test the prisms in the same facility where they were built.

9.2.2 Test masonry prisms in accordance with Annex A3. Determine the flexural tensile strength of each mortar joint tested, as described in Annex A3.

NOTE 2—When test ages other than 28 days are specified, the general relationship between the strength at the specified test age and that at 28 days is generally established by test. That relationship may vary with different materials and curing conditions.

## 10. Report

10.1 Report the following information:

10.1.1 Identify mortar materials and units tested, including as applicable the manufacturer's name, brand name, type, grade, source of sample, date sampled, and date tested.

10.1.2 List unit and prism dimensions to the nearest 0.05 in. (1.0 mm), number of joints per prism, and number of prisms per set of specimens and prism weight.

10.1.3 Include the following in the report:

10.1.3.1 Weight of ingredients (including water) added to the batch of mortar.

10.1.3.2 Flow or cone penetrometer reading of mortar used to construct prisms.

10.1.3.3 Flexural bond strength test results for each joint of the test specimens. Mean, standard deviation, and test age for each set of test specimens to the nearest psi.

10.1.3.4 If one or more mortar joints break during the handling of the specimen and tightening of the loading clamps but before additional load is applied by the testing apparatus, report which joints broke prematurely but do not include them in the calculation of the flexural tensile strength average and standard deviation. The top mortar joint shall be designated joint Number 1, the second, Number 2, etc. Measured loads and calculations shall also be included.

10.1.3.5 Description of failure, especially indicating whether failure occurred at the top or bottom of the mortar joint, or both.

## 11. Precision and Bias

11.1 *Precision*—Published data are not available for within-laboratory variability of this test method. Published data (Hedstrom,[5] Melander[6]) obtained under conditions almost identical with those of this test method show within-batch coefficients of variation varying between 10 % and 25 % for 30-joint samples of selected portland cement-lime mortars and masonry cement mortars. Because only one sample of each mortar was tested in each laboratory, sufficient data are not available to establish repeatability for this test method. Inter-laboratory testing is now planned to determine the reproducibility of this test method. It is the intent of this committee to develop precision values within five years from the date of issuance of this test method.

11.2 *Bias*—No information can be presented on the bias of this test method because no test having an accepted reference value is available.

[5] Hedstrom, E. G., Tarhini, K. M., Thomas, R. D., Dubovoy, V. S., Klingner, R. E., and Cook, R. A., "Flexural Bond Strength of Concrete Masonry Prisms Using Portland Cement and Hydrated Lime Mortars," *Masonry Society Journal*, Vol 9 , No. 2, February 1991.

[6] Melander, J. M., Ghosh, S. K., Dubovoy, V. S., Hedstrom, E. G., and Klingner, R. E., "Flexural Bond Strength of Concrete Masonry Prisms Using Masonry Cement Mortars," *Masonry: Design and Construction, Problems and Repair, ASTM STP 1180*, ASTM, 1993.

# TEST METHOD FOR FIELD-PREPARED SPECIMENS

## 12. Summary of Test Method

12.1 This test method is for evaluating the flexural bond strength (under the given conditions) of masonry built of conventional masonry units. Mortars are batched conventionally, and their flow is not prescribed. Prisms are constructed conventionally (no jig) and are bag-cured.

## 13. Significance and Use

13.1 This test method is intended for evaluation of flexural bond strength (under the given conditions) between mortar and units.

13.2 The purpose of this test method is to evaluate the bond strength (under the given conditions) of a particular unit-mortar combination, either for preconstruction evaluation of materials or for quality control purposes during construction. Preconstruction field tests may be used to provide information on the potential performance of a mortar-unit combination under field conditions of fabrication and workmanship (but not curing). Construction field tests may be used as a quality control measure to ensure that performance criteria established in preconstruction tests are being met.

13.3 Flexural bond strength determined by this test method shall not be interpreted as the flexural bond strength of a wall constructed of the same material, nor shall it be interpreted as an indication of extent of bond for purposes of water permeability evaluation. However, if effects of construction conditions, specimen size, workmanship, and curing conditions are taken into account, the results may be used to estimate the flexural strength of a wall.

## 14. Apparatus

14.1 *Mechanical Paddle-Type Mortar Mixer,* of no less than 0.6 $ft^3$ (18 L) capacity.

14.2 *Cone Penetrometer, Unit Measure, Straightedge, Spatula, Tapping Stick, and Spoon,* conforming to the requirements of Test Method C780.

14.3 *Bond Strength Test Apparatus,* conforming to the requirements of Annex A3.

## 15. Sampling

15.1 Select representative samples of each lot of masonry materials intended for use in construction. Each sample of material shall be of sufficient quantity to build a set of test prisms. A lot of each material shall consist of not less than the following quantities:

15.1.1 4000 of each type of masonry unit,

15.1.2 15 bags of each type of cement (or the equivalent bulk quantity),

15.1.3 15 bags of lime (or the equivalent bulk quantity),

15.1.4 3 $yd^3$ of sand, and

15.1.5 If mortar is delivered in bulk, 3 $yd^3$ of mortar.

## 16. Procedure

16.1 Prepare and mix mortar in accordance with the construction contract specifications. If no construction contract specifications exist, use the mortar preparation procedures of Test Method C780, modifying them as appropriate when proprietary materials are added to the mortar or when prebatched materials are used. Use sufficient water to achieve optimum workability.

NOTE 3—Workable consistency of mortar for concrete masonry construction generally requires an initial cone penetration reading of 55 ± 5 mm or a flow of 125 ± 5 %. Workable consistency of mortar for clay masonry construction generally requires an initial cone penetration reading of 65 ± 5 mm or a flow of 135 ± 5 %. Optimum consistency for a specific mortar-unit combination may differ from these values.

16.2 Fabricate a set of any convenient number of stack-bonded prisms, containing a total of at least 15 mortar joints. Each prism shall have no more than 5 joints and a minimum width *(b)* of 3.5 in. (see Note 4). Do not fabricate more prism specimens than can be constructed within 30 min.

NOTE 4—It is recommended that a width *(b)* of 1 full masonry unit be used. When conducting construction field tests for quality control, one set of test prisms for each 5000 $ft^2$ of masonry in the structure has been traditionally specified.

16.2.1 Sample and test mortar in accordance with Test Method C780 to determine initial consistency by cone penetrometer or flow table and air content.

16.2.2 Clean the bed surface of the units of dirt, loose sand, or other contaminants. Sample and test clay units in accordance with Test Methods C67 to determine initial rate of absorption (Field Test).

16.2.3 Keep handling of the prisms to a minimum and handle in such a way that the joints will not be subjected to detrimental tensile stresses.

16.2.4 Set the first unit of each prism on a firm, horizontal surface without the use of mortar.

NOTE 5—An alignment device may be used to ensure plumbness and joint thickness uniformity.

16.2.5 Place a full or face shell mortar bed on all units without furrowing unless the effect of furrowing is being studied.

16.2.6 Immediately place the next unit on the mortar bed and tap it to proper level and joint thickness. One face of each prism shall be in a nearly true plane.

16.2.7 Repeat 16.2.5 and 16.2.6 until the prisms are the desired height. Identify all specimens using a water-resistant marker.

16.2.8 Depending upon the desired test conditions, strike flush or tool the mortar joints. If tooling is required, tool only the joints on one face of each prism.

16.2.9 Unless specified otherwise, construct specimens in an open moisture-tight bag large enough to contain the completed prism (see Annex A2). After fabrication, draw and seal the bag around the specimen and cure for 28 days. Record and report the daily high and low temperatures in the area where specimens are stored for curing. If other curing conditions (for example, no moisture-tight bag) are specified, record and report all details of the curing.

NOTE 6—Workmanship during fabrication, temperature of the materials during fabrication, curing conditions, time between removal from moist curing test, and other factors may affect the bond strengths measured by this test. Standardized specimen fabrication curing procedures that attempt to control these variables are prescribed in the Test Method for Laboratory-Prepared Specimens, above.

16.2.10 Do not disturb or move specimens for the first 48 h after construction. Unless specified otherwise, keep specimens in the moisture-tight bags. Keep specimens at essentially the same temperatures as those experienced by the masonry that the specimens are intended to represent. At 24 ± 4 h prior to test age, remove bag and place specimens in laboratory air with a temperature of 75 ± 15°F (24 ± 8°C) and a relative humidity between 20 % and 80 %.

NOTE 7—Carefully package prisms and transport them to a laboratory in accordance with Practice C1532 for testing.

16.2.11 If specimens are transported for testing, strap them tightly first. Prepare plywood boards at least ¾-in. thick, cut to the size of the bed area of the unit. Place these boards under the bottom unit and on the top unit of the prism prior to strapping. During transport, cushion the specimens from vibration and from direct contact with each other.

16.2.12 Test specimens at an age of 28 days unless otherwise specified. Do not test specimens at an age of less than 3 days.

16.3 *Testing Specimens*—Test masonry prisms in accordance with the requirements of Annex A3 except as otherwise provided in this test method. Determine the flexural tensile strength of each mortar joint tested, as described in Annex A3.

NOTE 8—When test ages other than 28 days are specified, the general relationship between the strength at the specified test age and that at 28 days is generally established by test. That relationship may vary with different materials and curing conditions.

## 17. Report

17.1 Report the following information:

17.1.1 Identify mortar materials and units tested, including as applicable the manufacturer's name, brand name, type, grade, source of sample, date sampled, and date tested.

17.1.2 List number of prisms per set of specimens, number of joints per prism, unit dimensions, and joint thicknesses.

17.1.3 Average prism dimensions to the nearest 0.05 in. (1.0 mm) including width, depth, and height.

17.1.4 Weight of specimen, lbf (N).

17.1.5 Individual and average gross or net area flexural tensile stress calculated to the nearest psi (MPa), standard deviation, and position of the joint tested within the specimen. If one or more mortar joints break during the handling of the specimen and tightening of the loading clamps but before additional load is applied by the testing apparatus, report which joints broke prematurely but do not include them in the calculation of the flexural tensile strength average and standard deviation. The top mortar joint shall be designated joint Number 1, the second, Number 2, etc. Measured loads and calculation shall also be included.

17.1.6 Description of failure, especially indicating whether failure occurred at the top or bottom of the mortar joint, or both.

17.1.7 Sketch or photo of masonry unit showing core configuration and mortar bedded area, full or face shell.

17.1.8 Description of bonding pattern, joint tooling, location of tooled joint during test, and joint thickness.

17.2 Include the following in the report of preconstruction evaluation and construction field test results:

17.2.1 Volume proportions of mortar ingredients used in test mortar batch. Note whether mortar was prepared under the proportion or the property specification requirements of Specification C270.

17.2.2 Whether report is of preconstruction evaluation test or construction field tests. If field tests, identify building area represented by set of specimens.

17.2.3 Length of mixing time, time at which mixing was completed, and time at which specimen fabrication was completed.

17.2.4 Initial consistency as determined by flow or cone penetration, mortar water content, mortar aggregate ratio, air content and compressive strength determined in accordance with Test Method C780.

17.2.5 Initial rate of absorption (Field Test) of fired clay masonry units, as determined in accordance with Test Methods C67.

17.2.6 Ambient temperature and humidity at time specimens were fabricated.

17.2.7 Daily high and low temperatures in area where specimens were stored for curing.

17.2.8 Date and time when curing bags were removed from specimens.

17.2.9 Description of strapping procedure, if applicable.

17.2.10 Date and time specimens were delivered to laboratory, if applicable.

17.2.11 Condition of specimens as received from transport, if applicable.

17.2.12 Length of time specimens were exposed to laboratory air prior to testing.

## 18. Precision and Bias

18.1 *Precision*—Because this test method can be applied to many different combinations of units and mortar, and because workmanship is not controlled in fabricating field-prepared specimens, it is not possible to establish repeatability and reproducibility values that would be universally correct.

18.2 *Bias*—No information can be presented on the bias of this test method because no test having an accepted reference value is available.

# TEST METHOD FOR SAMPLES OBTAINED FROM EXISTING MASONRY

## 19. Summary of Test Method

19.1 This test method is for evaluating the flexural bond strength of masonry assemblies removed from existing masonry.

## 20. Significance and Use

20.1 This test method is intended to provide a simple and economical means to evaluate the bond strength of unit-mortar combinations of prisms cut from existing walls.

20.2 The flexural bond strengths determined by this method are influenced by such factors as masonry unit and mortar properties, workmanship, curing conditions, coatings on masonry units, and the procedures used to cut, transport and prepare the specimens for testing.

20.3 Flexural bond strength determined by this test method should not be interpreted as the flexural bond strength of a wall constructed of the same material. Nor should it be interpreted as an indication of extent of bond for purposes of water permeance evaluation. However, results may be used to predict the flexural strength of a wall.

## 21. Apparatus

21.1 *Bond Strength Test Apparatus,* conforming to the requirements of Annex A3.

## 22. Test Specimen

22.1 Select, remove, document, and transport the sample from existing masonry in accordance with Practice C1532.

22.2 The sample shall have at least five bed joints. The sample shall contain one or more prisms. Each prism in the sample shall have not more than five joints and a minimum width *(b)* of 3.5 in. (see Note 9) as shown in Fig. X2.1.

NOTE 9—It is recommended that a width *(b)* of 1 full masonry unit be used where possible. Typical specimens cut from walls laid in running bond have courses consisting of one full-unit alternating with courses consisting of two half-units.

22.3 Where mortar fins and extrusions project from the specimen to the extent that they may interfere with the attachment of the bond wrench, they shall be removed without causing damage to the specimen. Remove only enough material to enable proper attachment of the bond wrench.

## 23. Procedure

23.1 Test masonry assemblies in accordance with the requirements of Annex A3. Determine the flexural tensile strength of each mortar joint tested as described in Annex A3.

## 24. Report

24.1 In addition to the information required to be reported by Practice C1532, report the following information:

24.1.1 Identification number of prism.

24.1.2 Average prism dimensions to the nearest 0.05 in. (1.0 mm) including width, depth, and height.

24.1.3 Weight of specimen, lbf (N).

24.1.4 Individual and average gross or net area flexural tensile stress calculated to the nearest psi (MPa), standard deviation, and position of the joint tested within the specimen. If one or more mortar joints break during the handling of the specimen and tightening of the loading clamps but before additional load is applied by the testing apparatus, report which joints broke prematurely but do not include them in the calculation of the flexural tensile strength average and standard deviation. The top mortar joint shall be designated joint Number 1, the second, Number 2, etc. Measured loads and calculation shall also be included.

24.1.5 Description of failure, especially indicating whether failure occurred at the top or bottom of the mortar joint, or both.

24.1.6 Sketch or photo of masonry unit showing core configuration and mortar bedded area, full or face shell.

24.1.7 Description of bonding pattern, joint tooling, location of tooled joint during test, and joint thickness.

## 25. Precision and Bias

25.1 *Precision*—Because this test method can be applied to many different combinations of units and mortar, and because workmanship is not controlled, it is not possible to establish repeatability and reproducibility values that would be universally correct.

25.2 *Bias*—No information can be presented on the bias of this test method because no test having an accepted reference value is available.

## 26. Keywords

26.1 assemblies; bond wrench; flexural bond strength; flexure; masonry

# ANNEXES

**(Mandatory Information)**

## A1. STANDARD CONCRETE MASONRY UNITS[7]

A1.1 Standard concrete masonry units are special concrete units selected for the purpose of determining the flexural bond strength properties of mortars. The standard concrete masonry unit shall conform to the following requirements:

A1.1.1 Dimensions of units shall be 3⅝ in. (92 mm) wide by 2¼ in. (57 mm) high within a tolerance of ±⅛ in. (3 mm). The units shall have a single length not less than 7 in. nor more than 7⅝ in. (not less than 178 mm nor more than 194 mm) within a tolerance of ±⅛ in. (3 mm). Units shall be 100 % solid.

NOTE A1.1—When the performance of mortar is being studied, it is recommended that units of consistent length be used.

A1.1.2 The unit material shall be concrete masonry manufactured with the following material proportions by volume: 1 part portland cement to 8 parts aggregate.

A1.1.3 Aggregate used in the manufacture of the unit shall be as follows:

[7] The sole source of supply of the units known to the committee at this time is National Concrete Masonry Association (NCMA), 13750 Sunrise Valley Dr., Herndon, VA 22071-4662. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

| Bulk Specific Gravity 2.6 to 2.7 | |
|---|---|
| Sieve Designation | Percent Retained by Weight |
| ⅜-in. sieve | 0 |
| No. 4 sieve | 0 to 5 |
| No. 8 sieve | 20 to 30 |
| No. 16 sieve | 20 to 30 |
| No. 30 sieve | 15 to 25 |
| No. 50 sieve | 5 to 15 |
| No. 100 sieve | 5 to 10 |
| Pan | 5 to 10 |

A1.1.4 Density of the unit shall be 125 to 135 lb/ft$^3$ (2000 to 2160 kg/m$^3$).

A1.1.5 During manufacturing of the standard masonry unit, prevent contamination of the surfaces of the unit by mold-release agent.

A1.1.6 After manufacturing, cure units for 10 to 20 h at a relative humidity of 100 %, a temperature of 140 ± 10°F (160 ± 5°C), and atmospheric pressure. Continue curing in a roofed structure under ambient temperature and relative humidity for at least 28 days. Units shall be free of visible surface moisture at the time they are cubed for storage or shipping.

A1.1.7 Upon delivery, protect the units from outside contamination. Wet units only to meet the requirements of A1.1.8. Do not surface-treat the units prior to or during prism fabrication.

A1.1.8 When the prisms are fabricated, units shall have a moisture content of between 25 % and 35 % of total absorption, as determined in accordance with Test Methods C140.

## A2. FABRICATION OF LABORATORY-PREPARED TEST SPECIMENS

A2.1 Fabricate the test specimens as follows:

A2.1.1 Each stack-bonded prism shall be built in an opened moisture-tight bag that is large enough to enclose and seal the completed prism. Set the first unit of each prism on a plywood block in an alignment jig, as shown in Fig. A2.1.

NOTE A2.1—The purpose of the alignment jig is to align the prism perpendicular to the surface on which the prism is constructed, to within a tolerance of ±5° in each direction (length and width of the prism). A sample alignment jig, constructed of steel plate and using flat-head machine screws for adjustment, is shown in Fig. A2.1. That jig has a base that is L-shaped rather than rectangular, thereby permitting the jig to sit beside the prism rather than under it, so that the jig can be moved away from the prism immediately after construction. Other types of jigs of other materials are acceptable provided that they align the prism and provided

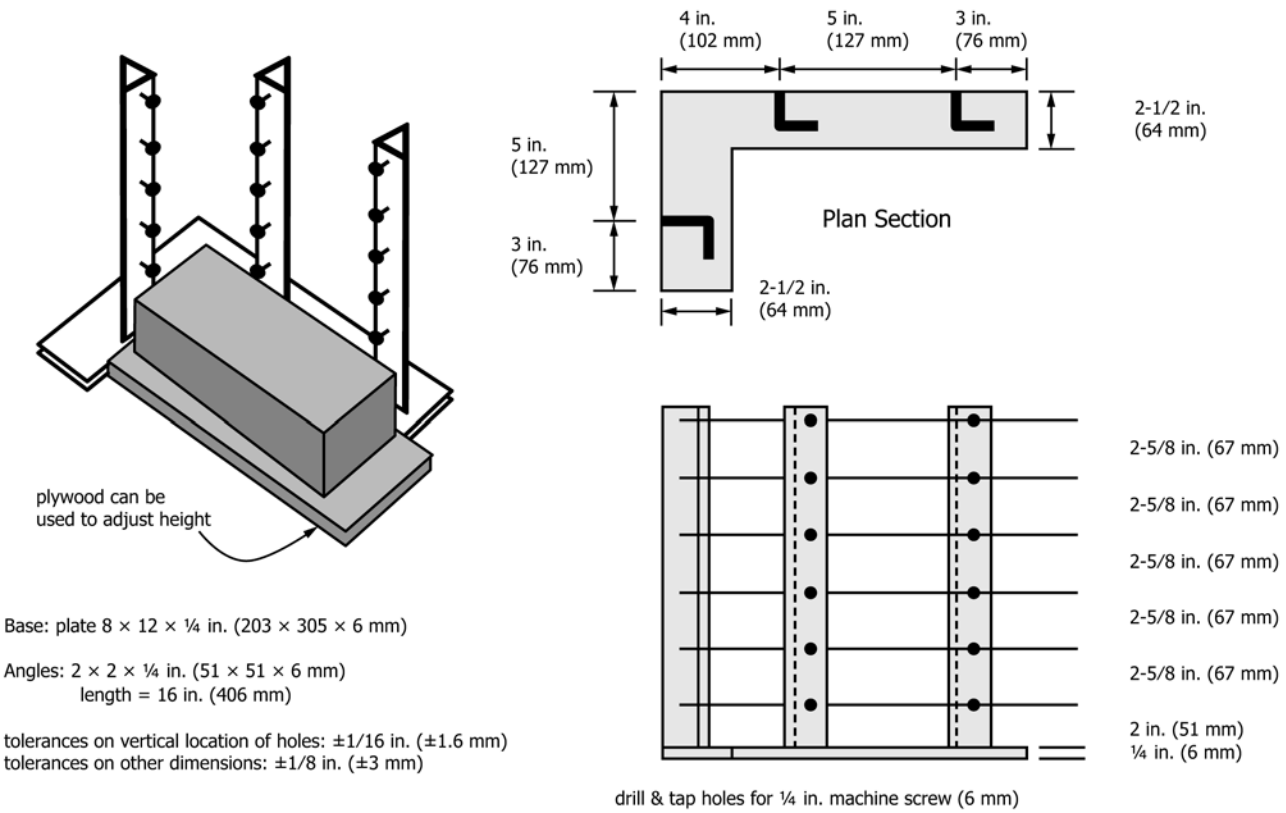



**FIG. A2.1 Schematic of Alignment Jig Used in Prism Construction**

that the samples can be left undisturbed as specified in A2.1.8. With some types of jigs, it may be necessary to adjust the elevation of the base of the prism. This can be done with blocks about as big as the bed face of the units and made of any convenient material that will maintain uniformity of thickness when wet. Plywood blocks, commonly about ½ in. (13 mm) thick, are acceptable for this purpose; other materials are also acceptable.

A2.1.2 Place the mortar template on the unit so that the mortar bed depth prior to compaction is ½ in. (12 mm). Place the mortar in the template, and strike off excess mortar with a straight edge.

NOTE A2.2—The purpose of the mortar template is to facilitate the creation of a uniform-thickness mortar joint on top of the most recently laid unit. A sample mortar template, made of poly(methyl methacrylate) (PMMA) and resting on four machine screws, is shown in Fig. A2.2. Other convenient materials that will maintain the template's dimensions when wet are also acceptable. Other means of support on the previously laid unit, such as two tightly stretched wires, are also acceptable.

A2.1.3 Remove the template, and immediately place the next unit on the mortar bed in contact with the three machine screws used to align that course, using a bulls-eye level to ensure uniform initial contact of the unit surface and bed mortar. Carefully position the drop hammer shown in Fig. A2.3 on top of the unit, and drop its 4-lb (1.8-kg) steel rod, round end down, once from a height of 1.5 in. (38 mm).

NOTE A2.3—The purpose of the drop hammer is to deliver a prescribed impact to the current topmost unit of the prism. The drop hammer shown in Fig. A2.3 consists of a plastic tube fixed to a plywood base. A cylindrical steel rod is allowed to drop inside the tube, striking the base. The purpose of the tube is to guide the steel rod and also to permit the operator to hold the drop hammer on top of the prism during this operation. Provided that those purposes are achieved, other designs and materials are permitted for the drop hammer.

A2.1.4 Repeat the steps given in A2.1.2 and A2.1.3 until the prisms are complete.

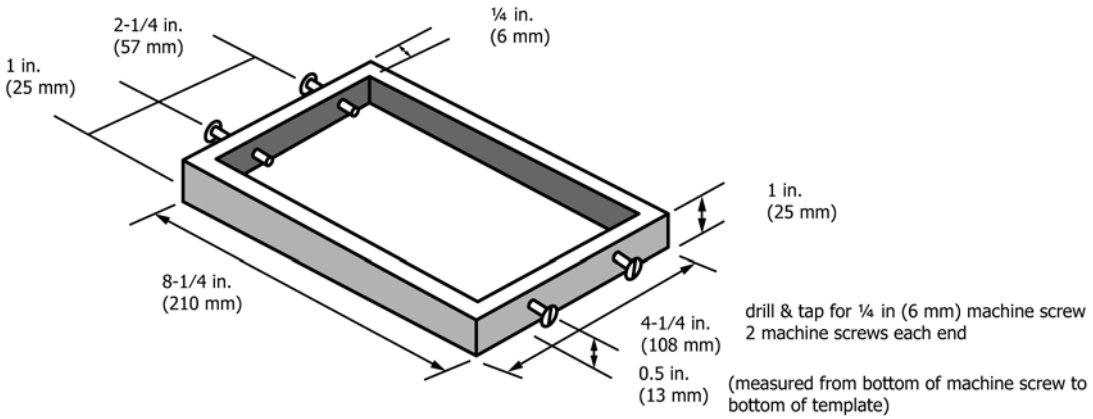
A2.1.5 Joints shall be cut flush after the prism is completely built. The joints shall not be tooled.

A2.1.6 Identify all test specimens using a water-resistant marker.

A2.1.7 Draw and seal the moisture-tight bag around the prism within 10 min of placing the last unit.

A2.1.8 Do not disturb the specimens for at least 24 h.

A2.1.9 Cure all prisms for 28 days unless otherwise required.




tolerances on horizontal dimensions of template: +1/2 in. (13 mm), −0 in. (0 mm)
tolerances on vertical distance from bottom of machine screw to bottom of template: ±1/16 in. (±1.6 mm)
tolerances on other dimensions: ±1/8 in. (±3 mm)

**FIG. A2.2 Schematic of Mortar Joint Template Used in Prism Construction**

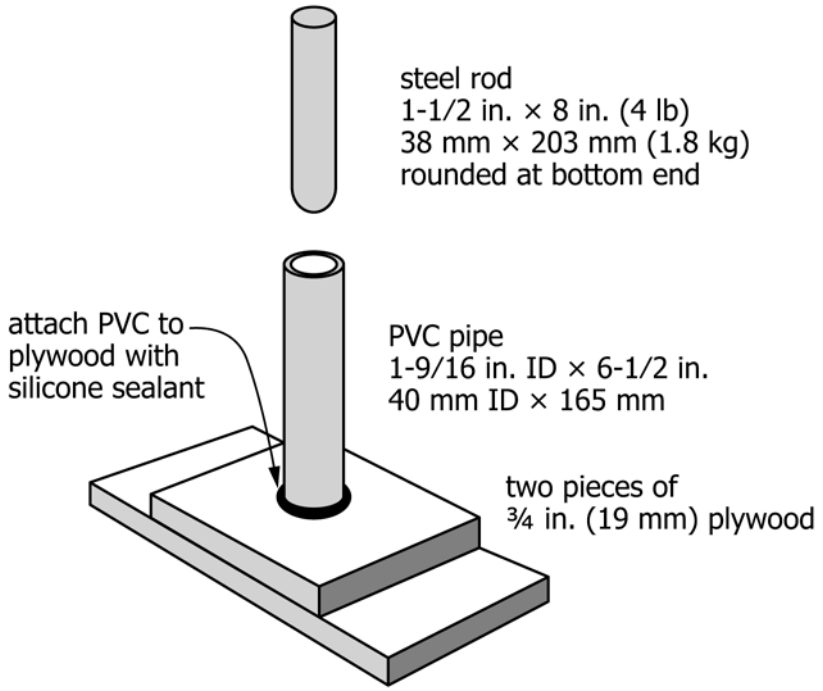



**FIG. A2.3 Schematic of 4-lb Drop Hammer Used in Prism Construction**

## A3. BOND STRENGTH TESTING APPARATUS AND PROCEDURES

### A3.1 Apparatus

A3.1.1 The test apparatus is shown in Figs. A3.1-A3.4. The upper and lower clamping mechanisms shall be constructed as shown, except that the hex head bolts are permitted to be

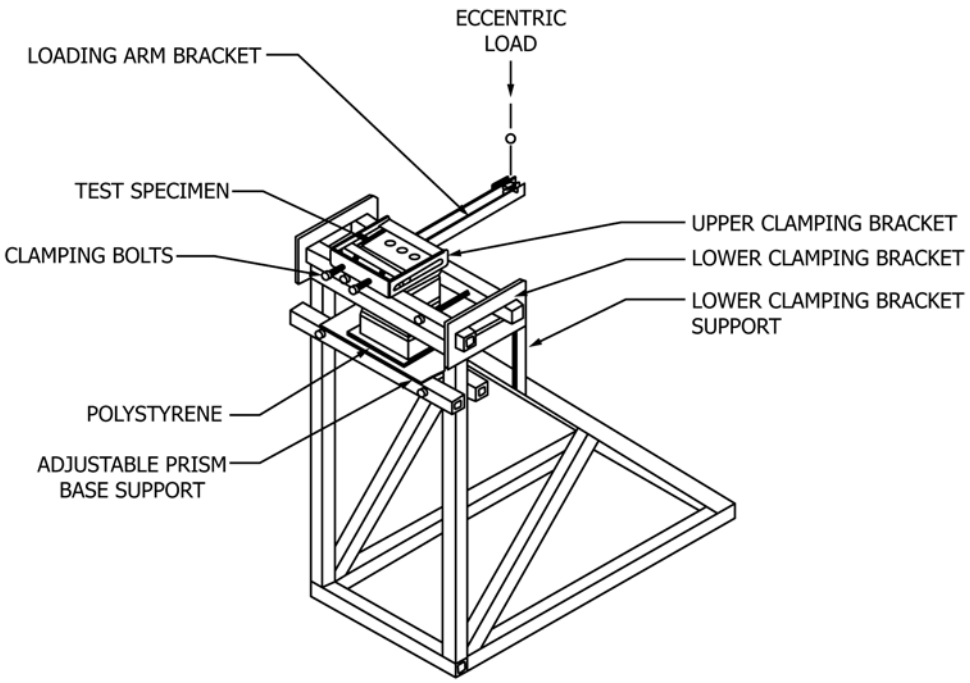



**FIG. A3.1 Bond Wrench Testing Apparatus**

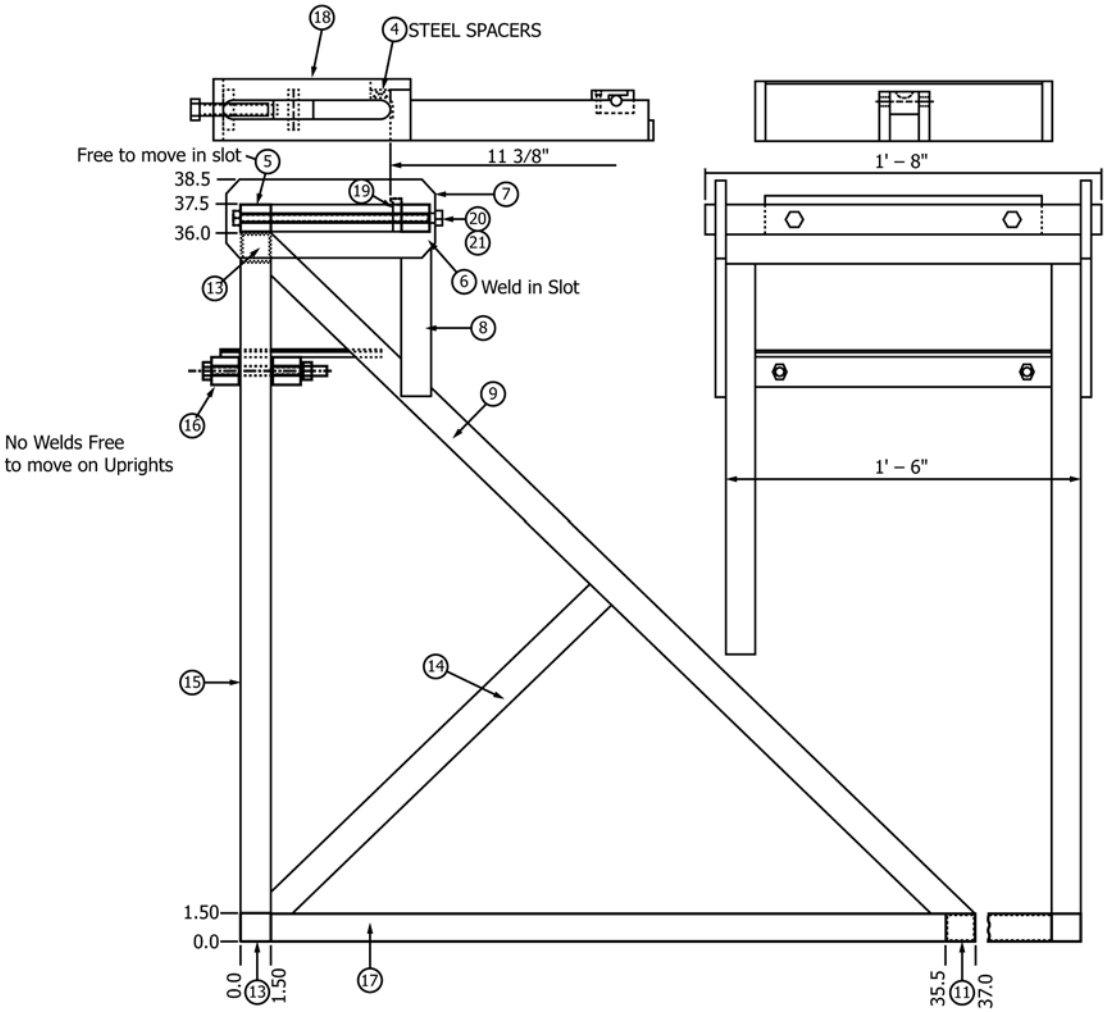



**FIG. A3.2 Bond Wrench Frame and Elevation**

NOTES:

1. ALL PARTS TO BE SECURELY ARC WELDED AS SHOWN. USE A MIN. OF 1/4" FILLET WELD ALONG LONG SIDES OF PARTS EXCEPT AS SHOWN USE E–70–XX ELECTRODES.
2. PAINT FRAME BLUE DUR–A–GRAIIN STANDARD HS59BE253
3. NUMBERS IN BRACKETS INDICATE DIMENSIONS IN (MM)
4. ALL STEEL A 36 GRADE MINIMUM
5. ALL FASTENERS A307 GRADE MINIMUM
6. ALL NEOPRENE MINIMUM 70 DUROMETER HARDNESS

| ITEM | PART | REQ. | SPEC. |
|---|---|---|---|
| 4 | STEEL SPACER | 2 | 1" × 1" × 3/8" FLAT BAR STOCK |
| 5 | SLIDING TUBE | 1 | 20" × 1 1/2" × 0.08 STL. SQ. TUBE |
| 6 | LOWER CLAMP BRT. | 1 | ASSEMBLY |
| 7 | SUPPORT | 2 | 10 1/2" × 4" × 1/4" FLAT BAR STOCK |
| 8 | BRACE | 2 | 5 1/2" × 1/4" × 1/4" FLAT BAR STOCK |
| 9 | BRACE | 2 | 50" × 1 1/2" × 0.08 STL. SQ. TUBE |
| 10 | NEOPRENE INSERT | 1 | 12" × 3/4" × 1/8" |
| 11 | TUBE | 1 | 15" × 1 1/2" × 0.08 STL. SQ. TUBE |
| 12 | NEOPRENE INSERT | 1 | 12" × 1" × 1/8" |
| 13 | TUBE | 2 | 18" × 1 1/2" × 0.08 STL. SQ. TUBE |
| 14 | BRACE | 2 | 23 13/16" × 1 1/2" × 0.08 STL. SQ. TUBE |
| 15 | TUBE | 2 | 34 1/2" × 1 1/2" × 0.08 STL. SQ. TUBE |
| 16 | PRISM BASE SUPPORT | 1 | ASSEMBLY |
| 17 | TUBE | 2 | 35 1/2" × 1 1/2" × 0.08 STL. SQ. TUBE |
| 18 | UPPER CLAMP BRT. | 1 | ASSEMBLY |
| 19 | NEOPRENE INSERT | 1 | 10" × 1–1/2" × 1/8" |
| 20 | 1/2"–13 × 10" HEX SCREW | 2 | STEEL Z.P |
| 21 | 1/2" FLAT WASHER | 4 | STEEL Z.P 9701–0039 |
| 22 | PLATE | 1 | 14 5/8" × 8" × 1/4" |
| 23 | TUBE | 2 | 18" × 1 1/2" × 0.080 SQ. STL. TUBE |
| 24 | 1/2" – 13 HEX NUT | 2 | |
| 25 | 1/2" – 13 × 8" HEX BOLT | 2 | 9601–0045 |
| 26 | 5/8"–18 × 6 HEX SCREW | 2 | MACHINE THREADS OFF LAST 1/2" TO 0.55Ø |
| 27 | SIDE | 1 | 14" × 3" × 1/2" BAR STOCK |
| 28 | FLOATING PLATE | 1 | 7 1/2" × 2" × 1/2" BAR STOCK |
| 29 | ROLL PIN | 2 | 1/2" DIA. × 2" |
| 30 | SLIDE | 1 | 15" × 2" × 1" ALUMINUM BAR |
| 31 | SIDE | 2 | 9 7/8" × 3" × 1/2" FLAT BAR STOCK |
| 32 | TOP PLATE | 1 | 14" × 2" × 1/2" FLAT BAR STOCK |
| 33 | SIDE | 1 | 14" × 2 1/8" × 1" FLAT BAR STOCK |
| 34 | PLATE | 2 | 12" × 2" × 1/2" FLAT BAR STOCK |
| 35 | SHCS | 2 | 1/4" – 20 × 1" |
| 36 | HOLDER | 2 | 2" × 1/2"× 1/2" STEEL BAR |
| 37 | LOADING BLOCK | 1 | STEEL |
| 38 | JOINT | 1 | 2" × 1" × 1/4" |

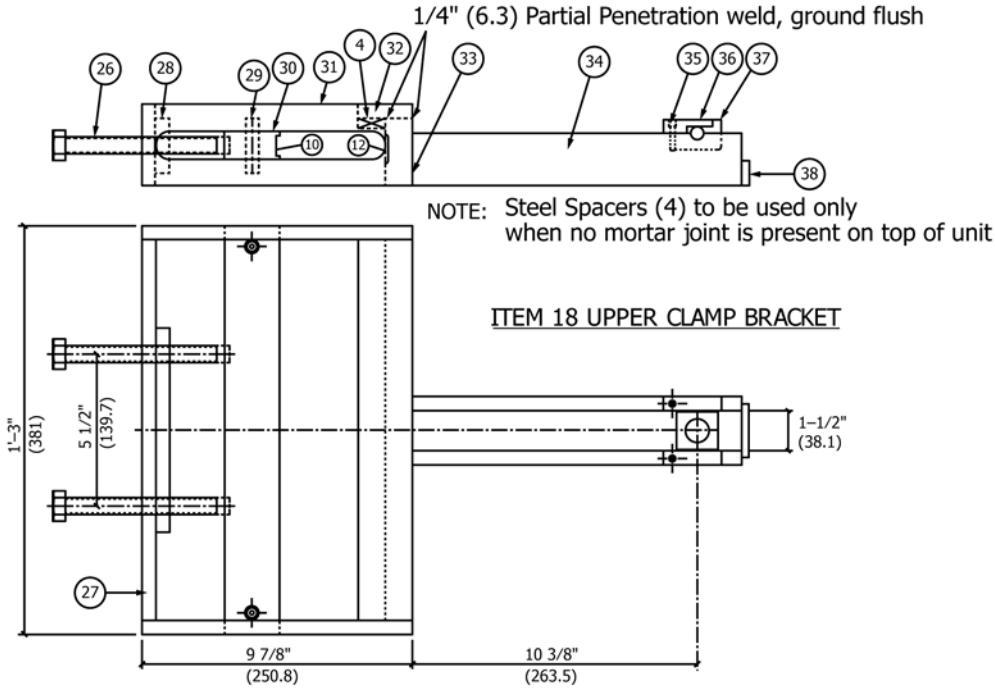
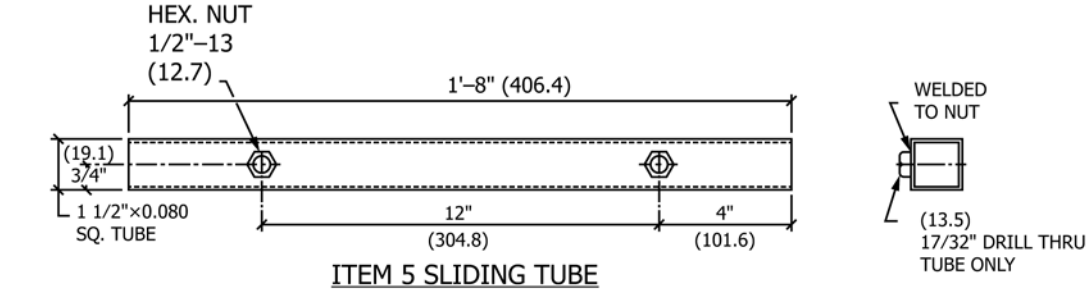
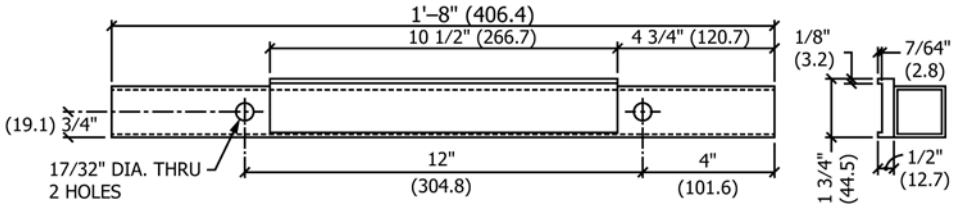


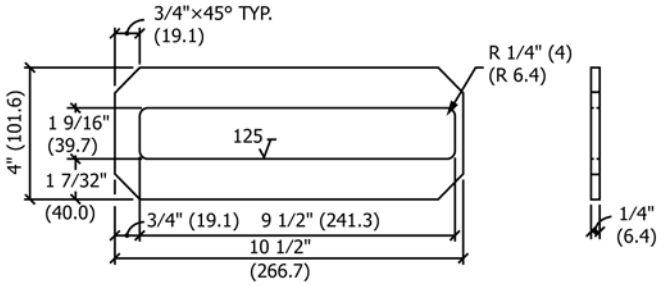

**FIG. A3.3 Material List and Detail Drawings**



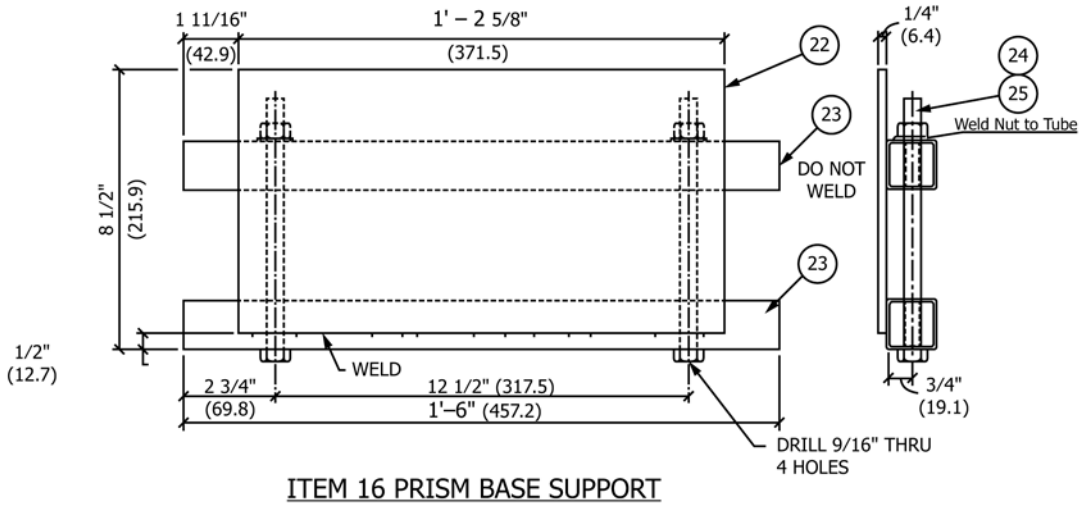

ITEM 5 SLIDING TUBE




ITEM 6 LOWER CLAMP BRACKET
WELDED AROUND IN SLOT IN SUPPORT




ITEM 7 SUPPORT




ITEM 16 PRISM BASE SUPPORT

**FIG. A3.4 Detail Drawings of Bond Wrench**

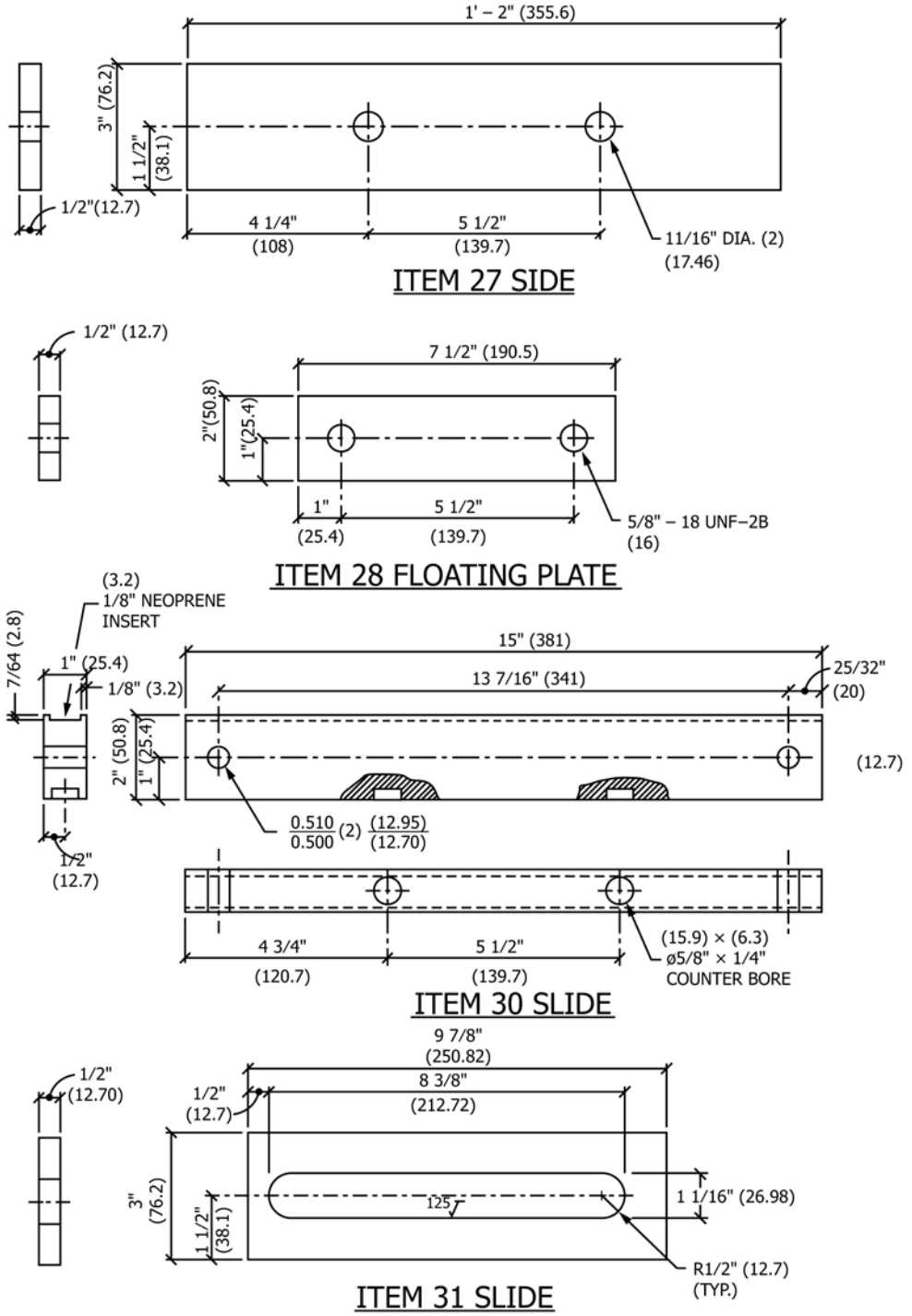



**FIG. A3.4 Detail Drawings of Bond Wrench** *(continued)*

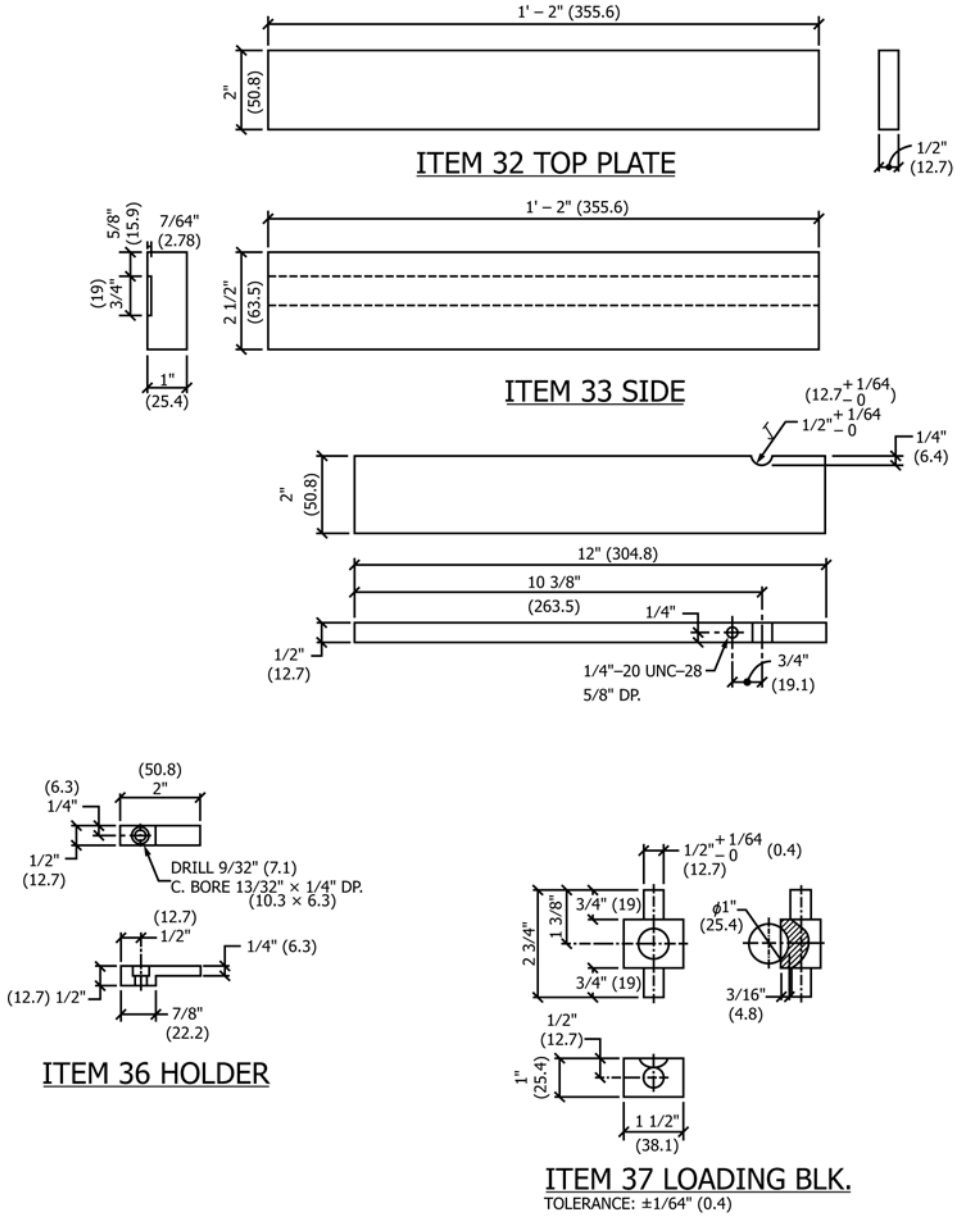



**FIG. A3.4 Detail Drawings of Bond Wrench** *(continued)*

replaced by other tightening devices of equal, or greater, strength and stiffness. The support frame shall be constructed as shown or shall be constructed using configurations and materials of equal, or greater, strength and stiffness. The testing apparatus shall be constructed to apply the load vertically downward on the upper clamping system in such a manner that the upper and lower clamp do not come in contact during the tests. The prism support system shall be able to accommodate the size of the prism to be tested.

### A3.2 Test Procedures

A3.2.1 Place the prism vertically in the support frame as shown in Fig. A3.1, and clamp firmly into a locked position using the lower clamping bracket. Orient the prism so that the face of the joint intended to be subjected to flexural tension is on the same side of the specimen as the clamping bolts. The prism shall be positioned at the required elevation that results in a single brick projecting above the lower clamping bracket.

A3.2.2 Attach the upper clamping bracket to the top unit as shown in Fig. A3.1. Tighten each clamping bolt using a torque not greater than 50 lbf·in. (5.7 N·m).

A3.2.3 Lower base support away from the bottom of the prism so that no contact occurs during testing.

A3.2.4 Apply the load at a uniform rate so that the total load is applied in not less than 1 min or more than 3 min. Measure load (see Note A3.1) to an accuracy of ±2 % with maximum error of 5 lbf (22 N).

NOTE A3.1—The load indicated in Fig. A3.1 may be applied by any means, such as a testing machine, hydraulic jack, dead weights, etc. but must be within ±3° of vertical. Load may be measured using the testing machine indicator, proving ring, load cell, or any device capable of the prescribed precision. Special attention must be given to non-recording load measuring devices. Since failure of the specimen is sudden, the device must be continuously monitored or the failure load will be lost.

### A3.3 Calculations

A3.3.1 For specimens built of solid masonry units (at least 75 % net area), calculate the gross area flexural strength as follows:

$$F_g = \frac{6(PL + P_l L_l)}{bd^2} - \frac{(P + P_l)}{bd} \qquad (A3.1)$$

where:

$F_g$ = gross area flexural tensile strength, psi (MPa),
$P$ = maximum applied load, lbf (N),
$P_l$ = weight of loading arm, lbf (N), (see Appendix X2),
$L$ = distance from center of prism to loading point, in. (mm),
$L_l$ = distance from center of prism to centroid of loading arm, in. (mm) (see Appendix X2),
$b$ = cross-sectional width of the mortar-bedded area, measured perpendicular to the loading arm of the upper clamping bracket as determined in A3.3.3 (see Fig. A3.5), and
$d$ = cross-sectional depth of the mortar-bedded area, measured parallel to the loading arm of the upper clamping bracket as determined in A3.3.4 (see Fig. A3.5).

A3.3.2 For prisms built with hollow masonry units (less than 75 % net area), calculate the net area flexural tensile stress as follows:

$$F_n = \frac{PL + P_l L_l}{S} - \frac{P + P_l}{A_n} \qquad (A3.2)$$

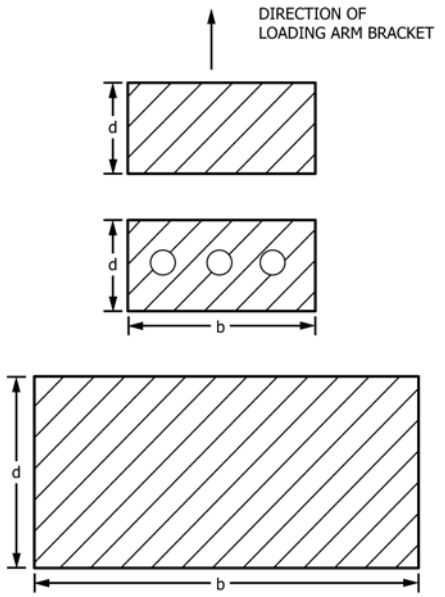
where:

$F_n$ = net area flexural tensile strength, psi (MPa),
$S$ = section modulus of the net bedded area of the prism, in.$^3$ (mm$^3$), and
$A_n$ = net bedded area of the prism, in.$^2$ (mm$^2$).

A3.3.2.1 If hollow masonry prisms are constructed using face shell mortar bedding in which opposing face shells are equal in thickness (within ⅛ in. (3 mm)) and are symmetrical about the centroidal axis of the prism, calculate the section properties of the prism as follows:

$$A_n = 2b\,(t_{fs}) \qquad (A3.3)$$

$$S = \frac{I}{c}$$




NOTE 1—All void areas are less than or equal to 25 %.

**FIG. A3.5 Example Cross-Section of Solid Masonry Units**

$$c = \frac{d}{2}$$

$$I = 2\left[\frac{b \times (t_{fs})^3}{12} + (b \times t_{fs}) \times \left(c - \frac{t_{fs}}{2}\right)^2\right] = \frac{b(t_{fs})^3}{6} + \frac{bt_{fs} \times (d - t_{fs})^2}{2}$$

where:

$A_n$ = net bedded area of the prism, in.$^2$ (mm$^2$),
$S$ = section modulus of the net bedded area of the prism, in.$^3$ (mm$^3$),
$I$ = moment of inertia of the net bedded area of the prism, in.$^4$ (mm$^4$),
$c$ = distance from the centroid to the most extreme tension fiber of the mortar bedded area, in. (mm),
$b$ = cross-sectional width of the mortar-bedded area, measured perpendicular to the loading arm of the upper clamping bracket as determined in A3.3.3 (see Fig. A3.6),
$d$ = cross-sectional depth of the mortar-bedded area, measured parallel to the loading arm of the upper clamping bracket as determined in A3.3.4 (see Fig. A3.6), and
$t_{fs}$ = minimum face shell thickness of unit (determined in accordance with Test Methods C140), in. (mm) (see Fig. A3.6).

A3.3.3 Determine the cross-sectional width of the mortar-bedded area, measured perpendicular to the loading arm of the upper clamping bracket, $b$, as follows:

A3.3.3.1 For clay masonry units, determine the length of the unit using Test Methods C67. This length shall be considered as the cross-sectional width of the mortar-bedded area, $b$, as defined in this test method.

A3.3.3.2 For concrete masonry units, determine the length of the unit using Test Methods C140. This length (referred to as $L$ in Test Methods C140) shall be considered as the cross-sectional width of the mortar-bedded area, $b$, as defined in this test method.

A3.3.4 Determine the cross-sectional depth of the mortar-bedded area, measured parallel to the loading arm of the upper clamping bracket, $d$, as follows:

A3.3.4.1 For clay masonry units, determine the width of the unit using Test Methods C67. This width shall be considered as the cross-sectional depth of the mortar-bedded area, $d$, as defined in this test method.

A3.3.4.2 For concrete masonry units, determine the width of the unit using Test Methods C140. This width (referred to as $W$ in Test Methods C140) shall be considered as the cross-sectional depth of the mortar-bedded area, $d$, as defined in this test method.

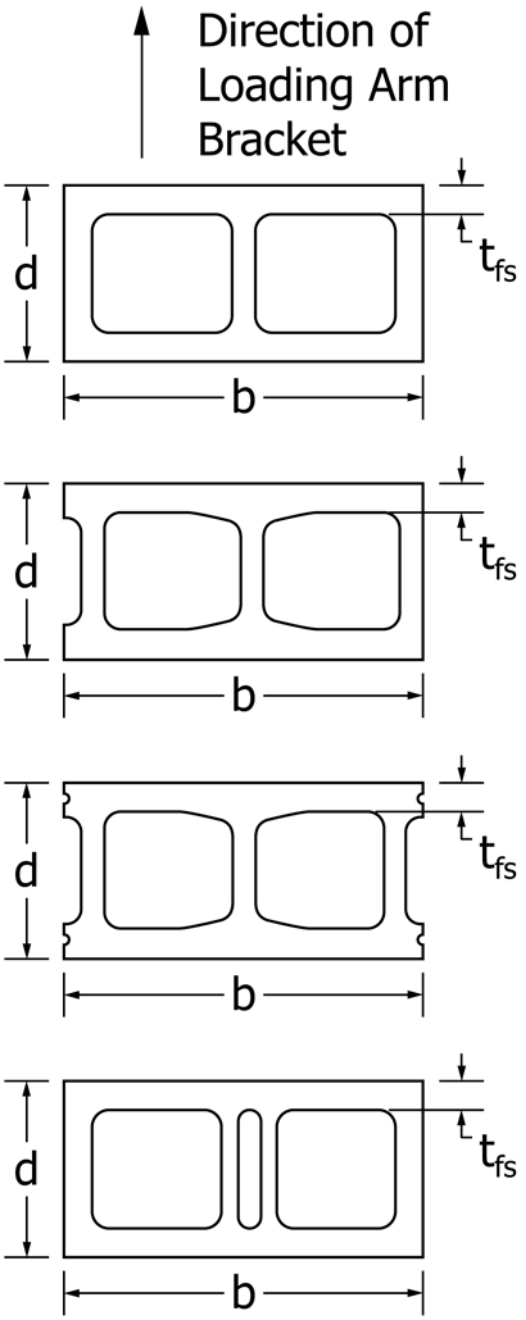



**FIG. A3.6 Example Dimensions of Hollow Masonry Units Used to Determine Section Properties**

# APPENDIXES

**(Nonmandatory Information)**

## X1. POSSIBLE CRITERIA FOR EVALUATING TEST RESULTS

### X1.1 Introduction

X1.1.1 This standard is a test method only. Its mode of application is left to the discretion of the user. The purpose of Appendix X1 is to suggest two possible criteria for evaluating the results obtained from these test methods. These criteria are included for illustrative purposes only and are not mandatory.

X1.1.2 Many criteria are available for evaluating test results. One simple criterion would be to require that the minimum value be not less than some target value. Another would be to require that the average value be not less than some target value. However, each of these simple criteria has the disadvantage of being insensitive to the scatter of the test results. Clearly, test results with smaller scatter are more reliable; this increased reliability ought to be reflected in the evaluation criteria. For this purpose, two such criteria are discussed here. The first criterion uses a lower characteristic value. The second criterion uses a one-sided tolerance limit.

### X1.2 Possible Acceptance Criterion Using a Lower Characteristic Value

X1.2.1 This possible criterion involves comparing a lower characteristic value of the tensile bond strength with a target value. This criterion has previously been used for statistical comparisons in the masonry industry. It is appropriate for use when so many joints are tested (usually at least 30) that the sample of joints closely approximates the entire population of joints. Specifically, the objective of this example criterion would be to establish a lower 10 % characteristic value (also referred to as a "10 % fractile") for the test data and to ensure that this lower characteristic value would exceed some target value.

X1.2.2 Determine and report the acceptability of the flexural bond strength of the masonry by the following calculation:

$$[X - (1.28 \times s)] \geq A \qquad \text{(X1.1)}$$

where:

$X$ = mean flexural tensile strength of masonry sample, psi (MPa),
$s$ = standard deviation in flexural tensile strength of masonry sample, psi (MPa), and
$A$ = target value, psi (MPa).

NOTE X1.1—The value of 1.28, excerpted from standard statistical tables, is based on the properties of the normal distribution. In such a distribution, 90 % of the values will lie above the mean minus 1.28 standard deviations.[4]

X1.2.3 If Eq X1.1 is satisfied, the masonry bond strength is acceptable. If Eq X1.1 is not satisfied, the masonry bond strength is not acceptable.

### X1.3 Possible Acceptance Criterion Using One-Sided Tolerance Limits

X1.3.1 This possible criterion involves establishing a lower tolerance limit (based on the sample size) to the tensile bond strength target value. The lower tolerance limit is selected so that a certain percentage of the time (the so-called "confidence"), no more than the desired percentage of the entire population will fall below the target value. This statistical technique is referred to as a "one-sided tolerance limit." It is more complex than the lower characteristic value approach of X1.2. It is appropriate for use when relatively few joints are tested, and the sample of joints may not closely approximate the entire population of joints. It is also appropriate for use when the scatter of results is small, so that the required number of specimens is less than for the criterion of X1.2. Specifically, the objective of this example criterion is to establish a 90 % probability that 90 % of the masonry in the entire population will have a flexural bond strength, perpendicular to the bed joints, equaling or exceeding the target value.

X1.3.2 Determine and report the acceptability of the flexural bond strength of the masonry by the following calculation:

$$[X - (K \times s)] \geq A \qquad \text{(X1.2)}$$

where:

$X$ = mean flexural tensile strength of masonry sample, psi (MPa),
$K$ = factor determined from Table X1.1,
$s$ = standard deviation in flexural tensile strength of masonry sample, psi (MPa), and
$A$ = target value.

NOTE X1.2—The target value in Eq X1.2 might be the allowable stress in flexural tension perpendicular to bed joints in unreinforced masonry, psi (MPa). If no other building code is used to select the allowable stress referred to above, the allowable stress might be that specified in TMS 402/ACI 530/ASCE 5. The allowable tensile stress would be that perpendicular to bed joints in unreinforced masonry. It might also be some other value, determined by project design requirements.

NOTE X1.3—The values of $K$ given in Table X1.1, excerpted from standard statistical tables, are obtained based on the properties of the normal distribution. These values of $K$ correspond to a 90 % probability that 90 % of the masonry population will have a flexural tensile strength equal to or greater than the corresponding target value.[4]

X1.3.3 If Eq X1.2 is satisfied, the masonry bond strength is acceptable. If Eq X1.2 is not satisfied, the masonry bond strength is not acceptable.

**TABLE X1.1 Factors for One-Sided Tolerance Limits for Normal Distributions**

| Number of Mortar Joints Tested | $K$ |
|---|---|
| 15 | 1.87 |
| 18 | 1.80 |
| 24 | 1.71 |
| 30 | 1.66 |
| 35 | 1.62 |
| 40 | 1.60 |
| 45 | 1.58 |
| 50 | 1.56 |

## X2. DETERMINATION OF WEIGHT AND CENTROID OF UPPER CLAMPING BRACKET

X2.1 Side and plan views of the upper clamping bracket are illustrated in Fig. X2.1. The weight (*P*) of the upper clamping bracket including the loading arm, is determined by weighing to the nearest 25 g or oz. A brick weighing within 0.1 lbf (0.44 N) and having a thickness (*d*) within 0.25 in. (6 mm) of those being tested must be clamped into the position shown for the brick in Fig. X2.1 before determining the weight and centroid of the upper clamping bracket. The centroid of the upper clamping bracket is located by positioning the bracket upside down upon a knife edge balance. Using a trial and error method, vary the position of the frame upon the knife edge balance. The location of the frame centroid is the point where the frame balances upon the knife edge.

X2.1.1 Determine *L* for use in Eq A3.1 and Eq A3.2 by the following expression:

$$L_l = r + d/2 \quad \text{(X2.1)}$$

where:

*r* is shown in Fig. X2.1.

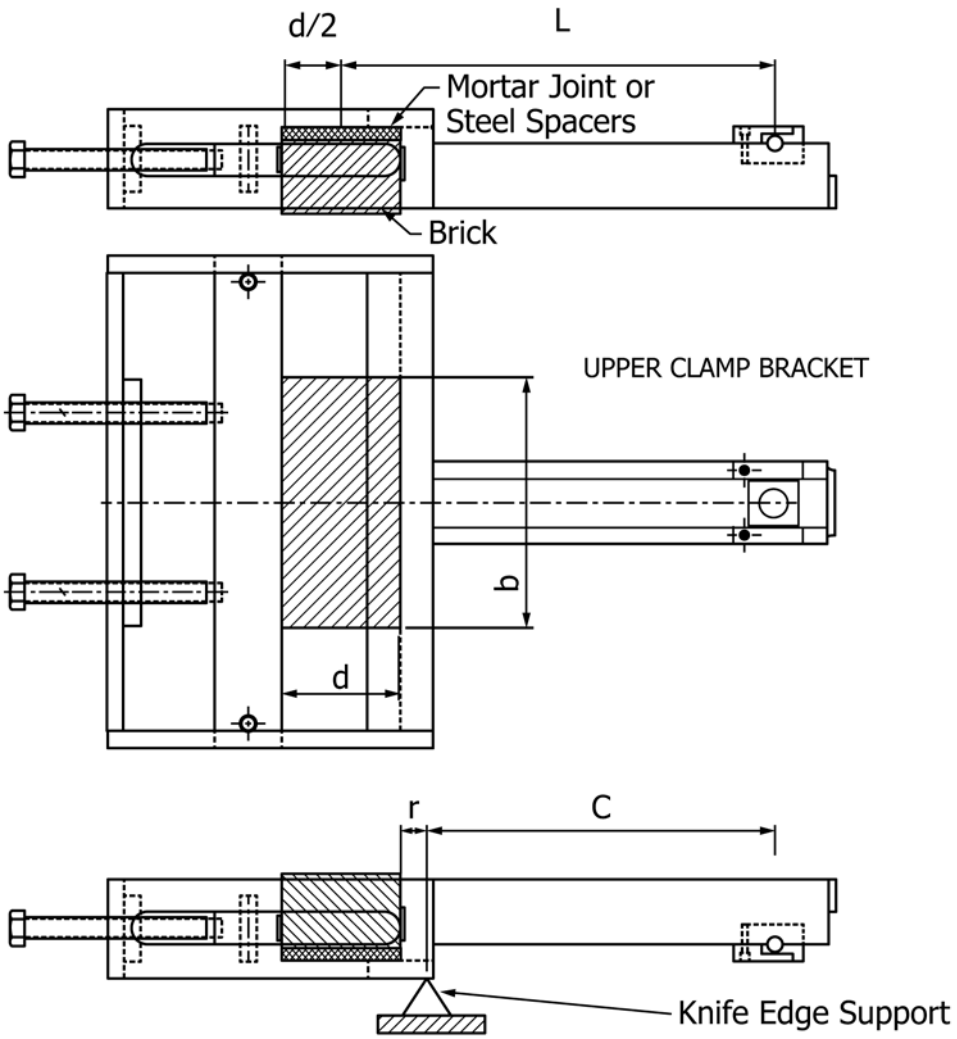



FIG. X2.1 Upper Clamping Bracket

## SUMMARY OF CHANGES

Committee C15 has identified the location of selected changes to this standard since the last issue (C1072 – 12) that may impact the use of this standard. (Approved April 15, 2013.)

*(1)* Changes have been made to 22.1 and 22.2 to clarify that multiple prisms are allowed.

Committee C15 has identified the location of selected changes to this standard since the last version (C1072 – 11) that may impact the use of this standard. (Approved Dec. 1, 2012.)

*(1)* Changes have been made to Section 26 to update the keywords.