



TESTING OF CONCRETE MASONRY

Field Sampling and Laboratory Testing

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PREFACE

The information in this manual has been prepared to be of assistance to testing laboratories and field technicians/inspectors regarding procedures for sampling and testing of concrete masonry. It includes field preparation of specimens for laboratory testing, handling, curing, preparation, capping, testing and reporting of results.

Many individuals, companies and associations have participated in the preparation and review of the material presented.

This presentation does **not** include the quality assurance of the field construction details, nor is it intended to be used as a guide to quality assurance program. We sincerely hope that the material presented here finds its use in furthering the state of knowledge of testing of concrete masonry construction.

The original manual in 1992 was prepared by Merlyn Isaak, Consulting Engineer in California. Major credit in preparation of this manual goes to him. The current publication is significantly altered and revised from the 1992 manual.

Photographs were taken by Richard Carey, Angelus Block Company, Inc., and Dave Rainey, Davis Colors.

Facilities where the photos were taken were made available by Smith Emery and Testing Engineers.

Stuart R. Beavers, the first and longtime Executive Director of Concrete Masonry Association of California and Nevada, although retired, reviewed and proofread this manual, and provided valuable comments.

Robert Thomas, Vice President of Engineering for the National Concrete Masonry Association, also critiqued the manual.

Last, but not least, Donna Lazier of the Association Headquarters, typed, formatted and proofread the entire manuscript.

IV

Testing of Concrete Masonry

Field Sampling and Laboratory Testing

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COMMONLY USED STANDARDS

Portions Included in Annotated Form

ASTM	Title	UBC Standard
C 90-99a	Standard Specification for Load- Bearing Concrete Masonry Units	21-4
C 140-99b	Sampling and Testing Concrete Masonry Units	
C 270- 99b	Specification for Mortar for Unit Masonry	21-15
C 426-99	Test Method for Linear Drying Shrinkage of Concrete Masonry Units	(Portion of 21-4)
C 476-99	Standard Specification for Grout for Masonry	21-19
C 780-96	Method for Pre-construction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry	
C 1019-00b	Method of Sampling and Testing Grout	21-18
C 1314-00	Test Methods for Compressive Strength of Masonry Prisms	21-17
	Field Tests Specimens for Mortar, Test Standard of ICBO	21-16
	California Code of regulations, (CCR) Part I, Title 24; Amendments to UBC Chapter 21 (see also note, Pg. VIII)	

Note: 1 As UBC Standards are incorporated in 1997 UBC, the corresponding ASTM Standard may not be directly compatible as most ASTM Standards are dated later than 1997.

^{2.} It is essential that laboratories involved in performing tests governed by these Standards have a copy of the latest edition.

OTHER RELATED STANDARDS

ASTM	Title	UBC Standard
C 55-99	Specification for Concrete Building Brick	21-3
C 91-93	Specification for Masonry Cement	21-11
C 129-99a	Specification for Non-load Bearing Concrete Masonry Units	21-5
C 144-99	Specification for Aggregate for Masonry Mortar	
C 404-97	Specification for Aggregates for Masonry Grout	
C 1072-99	Test Method for Measurement of Masonry Flexural Bond Strength (Note substantial differences between ASTM and UB	21-20 C)
C1093-95	Standard Practice for Accreditation of Testing Agenc For Masonry Units	ies
C 1142-95	Specification for Extended Life Mortar for Unit Masonry	
C 1180-99	Standard Terminology of Mortar and Grout for Unit Masonry	
C1209-99a	Standard Terminology of Concrete Masonry Units an Related Units	d
C 1232-99b	Standard Terminology of Masonry	
C 1329-00	Mortar Cement, Test Standard of ICBO	21-14
C 1357-98a	Standard Test Methods for Evaluating Masonry Bond Strength	

Note: For schools, hospitals, and state-owned essential services buildings, the State of California has adopted, with certain **amendments**, the Uniform Building Code (UBC) as published by the International Conference of Building Officials (ICBO). These amendments are cited by the California Code of Regulations (CCR), Part I, Title 24, and are published as a separate "supplement" to the UBC Chapters. They bear a designation "A", e.g., the amended chapter for masonry is designated "21A". These amendments, wherever applicable herein, will be referred to with "Title 24" and/or "Calif. Amendments" in this manual.

1. SAMPLING CONCRETE MASONRY UNITS (CMU'S)

References: ASTM C 90-99a

ASTM C 140-99b ASTM C 426-99 UBC Standard 21-4

SCOPE

Sampling and testing of concrete masonry units for dimensions, compressive strength, absorption, unit weight (density), moisture content and shrinkage.

Sampling

Random sampling is essential to obtaining **representative** samples of CMU's in a lot*. They should be of the same size and configuration.

Sampling may be done on the jobsite, or in some cases, at the manufacturer's plant, where project time schedules permit or space limitations dictate. When sampling at the plant, obtain manufacturer's cooperation in identifying the lot for your specific project. Pallets in the lot must be marked so as to be identifiable when they arrive at the jobsite.

Number of specimens required:

- 6 units from each lot up to 10,000
- 12 units from lots of 10,000 to 100,000
- 6 units per 50,000 over 100, 000 or fraction thereof.

Exceptions

- Reduce number of specimens by 1/2 if compressive strength tests only based on gross area are required.
- 2. At least 3 additional units are required when also testing for shrinkage.

Identification

During sampling process, mark each unit so it can be identified at any time. Markings should not exceed 5% of surface.

Record weather conditions at time of sampling and recent days during rainy weather. Note also whether units are or are not protected against weather. Since rain or extreme humidity fluctuations affects moisture content/absorption test results, measuring relative humidity at time of sampling is highly recommended.

Weigh units for moisture content tests **immediately** after sampling and marking at the place of sampling and record received weight.

Units must be handled so that they are not damaged during transportation. If they are to be tested for moisture content or shrinkage, they shall be placed in a plastic bag and sealed to maintain their moisture content during transit.

A typical project usually involves units of more than one size or type (bond beam, open end, closed end, pilaster, "C"-block, etc). Sampling and testing of **each** type is not usually required as manufacturing processes and ingredients are identical for each. However, requirements should be verified for each specific project.

^{* &}quot;Lot" refers to any number of concrete masonry units of the size and dimension specified for your project that are manufactured by the producer using the same materials, concrete mix design, manufacturing process and curing method.

SAMPLING CHECKLIST Date: Project name and location: Inspector's name: Location of sampling: (jobsite, manufacturing plant, city, etc.) List types of tests required: Number of units sampled: (need to know job size and specifications requirement for number and type of tests required) Type of units sampled: (color, grade [is not applicable to ASTM C90-99a], weight, etc.; and number of each if more than one type) Identify/Mark the sampled units: Weigh each unit immediately after sampling: (if moisture content and/or shrinkage tests required) Bag and seal samples for transporting to laboratory: If at manufacturing plant, ensure that pallets for this project are identifiable/marked: Record weather conditions at time of sampling, and recent days. If during rainy weather, note relative humidity reading if available.

Note whether units are or are not protected against weather:

2. TESTS FOR CONCRETE MASONRY UNITS

The most commonly tested physical properties of masonry units are tabulated below. (See specifications for a list of tests required for a specific project.)

TABLE A

Property	Test Procedure	Specification
Measurements: Thickness of face shell and web at thinnest points		
 Average width, height, and length of specimen 	ASTM C 140-99b	ASTM C 90-99a, Table 2 UBC Std. 21-4, Table 21-4-C
• Equivalent web thickness (in/lin. ft.)		
Moisture Content	ASTM C 140-99b	ASTM C 90-99a, Table 1 UBC Std. 21-4, Table 21-4-A
Absorption	ASTM C 140-99b	ASTM C 90-99a, Table 3 UBC Std. 21-4, Table 21-4-B
Unit Compressive Strength (Within 72 hrs of delivery to lab, store in normal lab air)	ASTM C 140-99b	ASTM C 90-99a, Table 3 UBC Std. 21-4, Table 21-4-B
Shrinkage	ASTM C 426-99	ASTM C 90-99a, Table 1 UBC Std. 21-4, Table 21-4-A

a. MEASUREMENTS

References: ASTM C 140-99b UBC Standard 21-4

Three full-size units shall be used for measurements. Cored units shall also be measured for minimum thickness of face shells and webs. Read individual measurements of each unit to the nearest division of the scale (1/32-inch divisions) or caliper (1/100-inch divisions) and record the average.

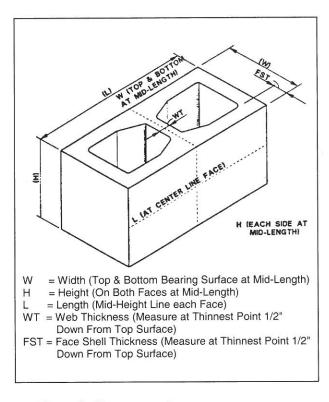


Figure 1 Measurements

Measure the length (L) in inches, at the midheight of each face; width (W) in inches across the top and bottom bearing surfaces at mid-length; and height (H) in inches on each face at mid-length. Measure face-shell thicknesses (FST) and web thicknesses (WT) at the thinnest point of each such element ½ inch down from the top surface of unit as manufactured. (The ½ inch below the top surface is stipulated so as to avoid potential influence on measurements as might be caused by minor chipping and erosion which occurs at the edges due to handling). Where opposite face shells differ in thickness by less

than 1/8 inch, average their measurements. Disregard sash grooves, dummy joints, and similar details.

- Under ASTM C 90-99a and UBC Standard 21-4, for split face units, a maximum of 10% of the split face shell area may have thickness less than shown, but not less than ¾ inch.
- Under ASTM C 90-99a, when units are solid grouted, the 10% limit does not apply.

Equivalent Web Thickness (inches)

Strictly speaking, this is a calculation, not a test.

- Equivalent web thickness (inches per linear foot of specimen) is the sum of measured thickness of all webs in the unit x 12, and divided by the length of unit (L).
- Equivalent web thickness does not apply to the portion of the unit to be filled with grout. The length of that portion shall be deducted from the overall L of the unit for the calculation.

ASTM C 90 and UBC Standard 21-4 allow a maximum 1/8 inch deviation from manufacturer's standards for L, W, and H. In addition, Table 2 in ASTM C 90 and Table 21-4-C in UBC Std. 21-4 stipulate minimum requirements for face-shell thickness (FST), web thickness (WT), and equivalent web thickness for non-grouted construction.

Although ASTM permits minimum face shell thickness to be 5/8 inch for solid grouted masonry construction of at least 6 inches nominal width, UBC Standard 21-4 does not allow face shell thickness to be less than 3/4 inch.

Equivalent Wall thickness (inches)

Equivalent wall thickness (**Te** = average thickness of solid material in the unit.)

Te = $1728 \text{ V}_0/(\text{L x H})$

where:

 V_n = net volume of unit (ft³);

and 1728 converts volume from ft³ to in³.

The requirement for **Te** originates in UBC Table 7-B "Rated Fire-resistive Periods for Various Walls and Partitions". Required values of **Te** vary from 2.1 to 6.2 depending upon type of aggregate used in manufacturing CMU and level of fire resistance required by the project design.

The equation shown above allows us to convert the net volume of the CMU to an equivalent wall thickness for fire resistance purpose.

Report

- Average L, W, & H of each specimen
- Minimum face-shell and minimum web thickness
- Equivalent web thickness as an average for the 3 specimens
- Equivalent thickness as an average for 3 specimens

b. ABSORPTION AND MOISTURE CONTENT

References: ASTM C 140-99b

UBC Standard 21-4

Three full size units shall be tested. Make sure that as-sampled weight has been recorded before proceeding. This is W_r.

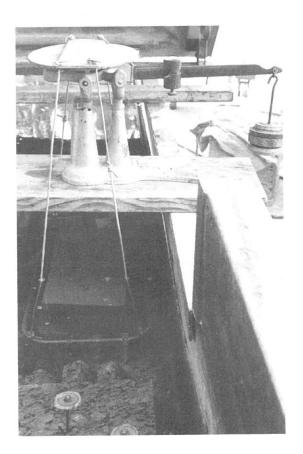


Figure 2 Weighing Sample While Suspended in Water

- Immerse each unit in water at 60°F to 80°F for 24 hours.
- Weigh each unit while suspended by a metal wire and completely submerged in water. This is the suspended immersed weight W_i.
- Remove from water and allow the unit to drain for 1 minute while placed on a 3/8 inch or coarser wire mesh and remove visible surface water with a damp cloth.
- Immediately weigh the unit. This is the saturated weight W_s.
- Dry each unit in ventilated oven at 212°F to 239°F for not less than 24 hours and until 2 successive weighings at intervals of 2 hours show loss not greater than 0.2% of last previous weight. This is the dry weight W_d.

Absorption (lb/ft³) = $[(W_s-W_d)/(W_s-W_i] \times 62.4$

Absorption (%) = $[(W_s-W_d)/W_d] \times 100$

where:

 W_s = saturated weight of unit, (lb)

 $W_d = dry$ weight of unit, (lb)

W_i = suspended immersed weight of unit, (lb)

 $(62.4 = weight of water in lb/ft^3)$

Moisture Content, (%)

 $= [(W_r-W_d)/(W_s-W_d)] \times 100$

where:

 W_r = sampled recorded weight of unit, (lb)

Report

- Results separately for each unit and as the average for the three units.
- For **absorption**, report to nearest 0.1 lb/ft³ or 0.1%.
- For **moisture content** report results to 0.1%.
- See ASTM C 90-99a (Tables 1 and 3) or UBC Standard 21-4 (Table 21-4-A and B) and project specifications for acceptance criteria.

(Note: Required accuracy of weigh balance per ASTM is, sensitivity to within 0.5% of the weight of lightest specimen tested).

c. LINEAR DRYING SHRINKAGE

References:

ASTM C 426-99 UBC 21-4 (Portions only)

Linear Drying shrinkage is defined by ASTM as "...the change in linear dimension of the test specimen due to drying from a saturated condition to an equilibrium weight and length under specified accelerated drying conditions."

Only key points of test procedure are reproduced here. For entire procedure see ASTM C426-99. **Exact** conformance to the test procedures is essential as precision measuring techniques and instruments are involved. Even minor deviations from the prescribed procedure have been shown to cause major discrepancies in final results.

If ingredients, manufacturing procedures, or mix proportions are changed, a new linear drying shrinkage test should be performed.

Apparatus

- 1. Dial micrometer, or equivalent measuring device, graduated in 0.0001-inch units (see also ASTM for accuracy requirements).
- 2. Strain gages and gage plugs.
- 3. Drying oven: Airtight, insulated cabinet with room for at least three test specimens, and capable of constant temperature at 122 ± 2° F., minimum 1" clearance on all sides of each specimen, electrical heat source, circulation within the oven, and a means of drying specimens to a condition of equilibrium with a relative humidity of 17 + 2%.
- Cooling chamber: Airtight and large enough for 3 whole specimens to cool to 73.4 ± 2° F.

- Immersion tank, to completely immerse 3 whole specimens simultaneously in water maintained at 73.4 ± 2° F.
- 6. Balance or scale shall be sensitive to within 0.1% of the weight of smallest specimen tested.

Test Specimens

Three whole units, representative of the lot and free of visible cracks or structural defects. Units previously subjected to tests involving temperatures exceeding 150° F shall not be used. Half-face shells may be used, subject to conditions outlined in ASTM.



Figure 3 Immersing Specimen

Procedure

- 1. Install gage plugs per ASTM.
- 2. Immerse specimens in water at 73.4 \pm 2°F for 48 \pm 2 hours.
- 3. Obtain initial-length reading with unit in water tank, still submerged to avoid any error due to cooling by evaporation.
- Obtain saturated surface-dry weight of units, by draining each specimen for 1 minute over 3/8" or larger mesh and removing visible surface water by blotting with a damp cloth.

- 5. Store specimens in drying oven for 5 days.
- Remove and cool specimens to 73.4 ± 2° F. After cooling, obtain specimen-length reading and weight and length reading of standard reference bar. (See ASTM for specifications of the cooling chamber.)
- 7. Return specimens to drying oven for a second period of drying (48 hours); then repeat cooling, length readings, and weight determinations as above.



Figure 4 Removing Visible Surface Water

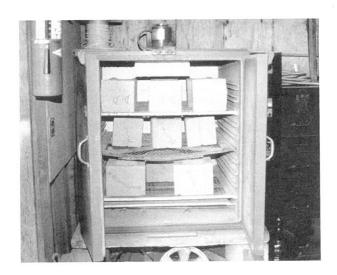


Figure 5 Drying Oven

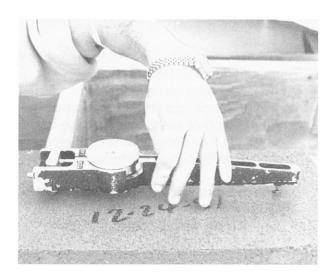


Figure 6 Obtaining Specimen Length Reading

 Continue the 48-hour periods of drying/cooling cycles (with length and weight measurements) until an equilibrium condition of the shrinkage specimens has been reached. (See ASTM for details of equilibrium condition).

Calculations and Report

See ASTM for details of calculations and any adjustments required for reference bar length changes and temperature corrections.

Report shall include

- Identification of kind of product
- number of specimens
- source of specimens
- aggregate type
- cement type
- method of producing the product
- condition of curing and drying prior to test
- · age of specimens at start of test
- total length of drying period prior to each length measurement
- · weight of test specimens as received
- saturated, and at time of each length measurement total linear drying shrinkage in percent, from saturation to each length measurement

d. UNIT COMPRESSIVE STRENGTH

References: ASTM C 140-99b UBC Standard 21-4

Three specimens shall be tested within 72 hours after delivery to the laboratory, during which time they shall be stored continuously in normal room air. These specimens shall **not** be used for determining absorption or moisture content.

1. Equipment

Testing Machine and Steel Bearing Block Requirements:

Must meet requirements of ASTM E-4, for calibration and capacity, and requirement for spherically seated block. The error for loads within the loading range of the testing machine shall not exceed \pm 1.0%. When load applied to specimen is less than 10% of the capacity of the range of machine, then special stricter criteria apply (See ASTM E-4 for details).

If the bearing blocks of the testing machines are not large enough to cover the bearing area of the masonry specimen, steel bearing plates shall be used (See ASTM C 140).

See Appendix Table C for a tabulated representation of the platen thickness requirements. It has been found by several researchers that rigidity (thickness) of the loading plates is **extremely** important in achieving accurate and consistent results.

For small specimens such as mortar cubes, mortar cylinders, and CMU coupons, a testing machine with a low capacity load range is important.

2. Sample Preparation

Samples shall be full sized units, except as modified below:

Sawcutting is required for the following conditions:

- (1) Unsupported projections with a length greater than the thickness of the projection shall be removed.
- (2) Units with recessed webs: Cut that portion of the face shell off which projects above the web, in order to achieve full bearing over total cross section. If this reduces height of specimen by more than 1/3, the unit shall be coupon tested.

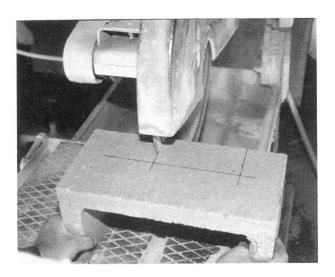


Figure 7 A Diamond Blade is Required for Sawcutting

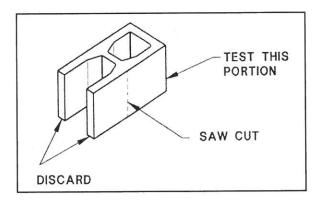


Figure 8 Standard Open Ended Block

(3) If full sized units are too large for testing machine bearing blocks or beyond load capacity of the machine, cut the units to properly size them to conform to test machine capability. Resultant specimen shall have no face-shell projections or irregular webs, and shall have fully enclosed four-sided cell or cells.

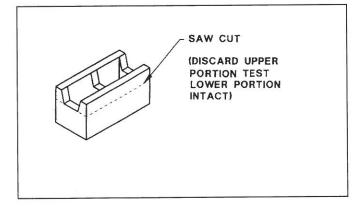


Figure 9 Bond Beam Unit



Figure 10 Compression Testing a Coupon

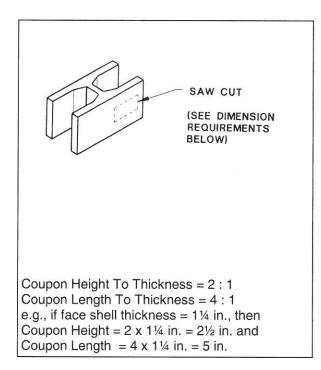


Figure 11 Double Open Ended Block

(4) For unusual size or shape, if 4-sided cell(s) is not achievable, e.g. double open-ended unit, cut a coupon from face-shell. Coupon height to thickness ratio shall be 2 to 1, and length to thickness ratio shall be 4 to 1. These ratios are before capping the coupon. As double open-ended unit face shells taper in thickness along the length, as well as along the height, coupon shall be cut where the thickness is not less than 1.25 in.

Caution

- When sawing is required minimize vibration
- Use diamond blade
- If specimen is wetted during sawing, dry to equilibrium in normal room air before testing
- Minimize amount of sawing

- Avoid sawing the face shell at the web
- Discard specimens with chips or defects

3. Calculation of Net Area

After cutting, but **before** capping, obtain measurements per ASTM, as described under "MEASUREMENTS" above.

For coupons:

Net Area = $L \times W$, where length (L) and width (W) are measured at mid-height of coupon.

For other than coupons:

The net area is determined as follows:

Net volume V_n , $(ft^3) = W_d/D$ Density D $(lb/ft^3) = [W_d/(W_s-W_i)] \times 62.4$

Net area = $1728 \times V_n/H$

4. Capping

Capping of bearing surfaces may be achieved by sulfur or gypsum cement. See ASTM C 140-99b for capping material requirements.

- Capping surface plate shall be plane within 0.003 inches in 16 inches (see Figure 33, page 32). (Plate must be thick enough to **remain flat** with repeated usage; especially critical if hot sulfur is used for capping. Hot sulfur can cause warping of capping plates).
- The cap shall be at least as strong as the unit.
- Strength of capping material shall be determined on receipt of a new lot and at intervals not exceeding 3 months.
- Planeness tolerance should be checked frequently.

- When gypsum cement is used as capping material, it shall have a compressive strength of not less than 3500 psi at age 2 hours when tested as 2-inch cubes.
- Average thickness of gypsum cement cap shall not exceed 1/8 inch.
- · Patching of caps is not permitted.
- Allow minimum of 2 hours for cap to age/cure.
- Caps must be perpendicular to the vertical axis of the unit. Capping requires care in order to maintain vertical alignment. Custom-built capping jig is recommended.

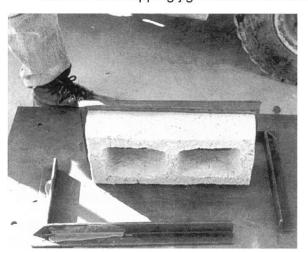


Figure 12 Flat plate is Required for Capping Material

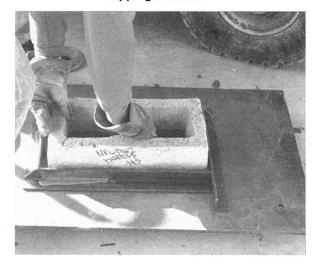


Figure 13 Capping Plate



Figure 14 Pouring Sulfur Capping Material

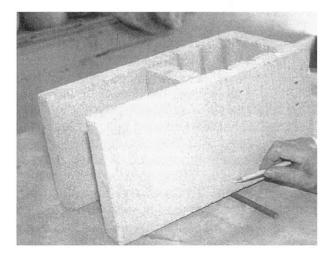


Figure 15 Locate and Mark Centroid

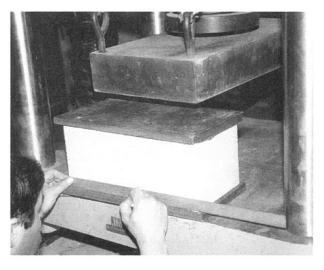


Figure 16 Position centroid with Respect to Center of Spherically seated Block

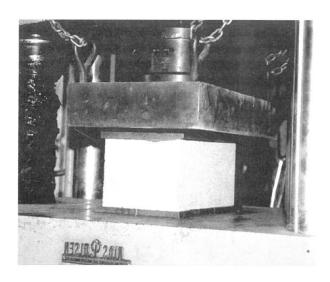


Figure 17 Capped CMU positioned on clean flat testing machine. Ready for compression test

5. Positioning Test Specimens

When testing full units, centroid of specimen must be aligned vertically with center of thrust of spherically seated bearing block of testing machine. Determine centroid (center of gravity) by balancing on a rod or pipe. Position CMU's with their cores vertical (see Figure 32, page 32). Careful positioning and clean, flat surfaces are essential. Coupons must also be centered on the center of the spherically seated bearing block.

6. Speed of Testing (Rate of Loading)

The load is applied at a convenient rate for 1/2 the expected maximum load. The remaining load is applied in not less than 1 nor more than 2 minutes with a uniform rate of travel of moving head. Therefore, the test technician must know before start of test the approximate strength of the unit to be tested (or use 1/2 of design required strength for the first 1/2 of load).

Record the Maximum compressive load in P_{max} (lbs).

7. Compressive Strength

Calculate the compressive strength as follows:

Gross area compressive strength (psi) = Maximum compressive load divided by gross area of unit.

 $= P_{max}/A_g$

where $A_g = gross$ area for unit (in²)

Net area compressive strength (psi) = Maximum compressive load divided by net area of unit.

 $= P_{max}/A_n$

where A_n = average net area of unit (in²)

Report

Compressive strength (nearest 10 psi) for each specimen and average of three specimens. (Net area strength is required for both ASTM C-90 and UBC 21-4).

NOTE:

For required unit strength based on specified f'_m , see Table 21-D of UBC.

PRISMS - PREPARATION AND COMPRESSIVE STRENGTH TESTING

References: ASTM C 1314-2000

UBC Standard 21-17 Calif. Amend. (Title 24)

2105 A.3.2 2105 A.3.5

a. GENERAL REQUIREMENTS

Please note:

ASTM E447-97 "Test Method for Compressive Strength of Laboratory constructed Prisms" is intended for use as a research tool only.

UBC Section 2105.3.2.2

To prove conformance with specified compressive strength of masonry f'_m when full allowable stresses are used in design based on testing at age 28 days, unless relationship for other ages has been established prior to start of construction.

Before Construction: A set of 5 masonry prisms should be built and tested prior to start of construction. Materials used for construction of the prisms shall be taken from those specified to be used on the project. Prisms shall be constructed under the observation of the engineer or special inspector or an approved agency, and tested by an approved agency.

During Construction: A set of 3 prisms is required for each 5000 square foot of wall area, but not less than one set of three masonry prisms for the project.

- **EXCEPTIONS:** 1) Using unit strength method per UBC Sec. 2105.3.4, prism tests are not required (but unit tests and grout tests are required during construction. Mortar tests are also required for California Amendment Section 2105.A3.4.) Prism testing may be used as an alternate to unit and grout testing required per UBC Section 2105 3.4.4.
 - 2) When using one-half of allowable stresses, tests are not required on units or for grout. Mortar shall conform to mortar type required in Table 21-D.

b. PRISM TEST RECORD

UBC Section 2105 3.3

- Allows verification of compressive strength by prism test records.
- A cumulative record of at least 30 masonry test prisms built and tested per UBC Standard 21-17 is required.
- Prisms shall be representative of corresponding construction constructed under the observation of an engineer or special inspector or an approved agency.

- The test record average compressive strength shall equal to or exceed 1.33 f'_m
- **During construction**, a set of three prisms required for each 5,000 square feet of wall area, but not less than one set of three prisms for the project.

c. CONSTRUCTED MASONRY

UBC Section 2105.3.5

On approval of building official, when masonry does not meet the requirements of UBC 2105.3.2 (Prism Testing), 2105.3.3 (Prism Test Record) or 2105.3.4 (Unit Strength Method), acceptance shall be permitted based on tests of prisms cut from the masonry construction.

- 1. Saw cut a set of three prisms for each 5,000 square foot of wall area that is in question. Not less than one set of three prisms for the project is required.
- 2. Masonry shall be at least 28 days old.
- 3. Calculated compressive strength shall be based on net mortar bedded area of the prism
- 4. If compressive strength equals or exceeds specified compressive strength, masonry is considered to comply.

d. COMBINATON OF UNITS

Section 2105A.6 (State of California Amendment)

This section is applicable to public schools, community colleges, hospitals, and essential services buildings that are state owned or leased.

When different kinds or grades of units or materials are used in a structural member, a full-scale test panel before construction of masonry is required.

Panel shall be cored and cores shall be tested for bond strength between materials.

TABLE B

PRISM REQUIREMENTS

GENERAL

Authority	Subject
ASTM	Build in protected location with flat, level base; use moisture tight bag large enough to seal the completed prism; avoid being disturbed for minimum 48 hours; use same materials and workmanship as for project; stack bond pattern.
UBC, and Title 24	In addition to above, prisms shall be constructed under the observation of the engineer or special inspector or an approved agency.
	SIZE
	Minimum length of prism shall be 4 inch
	 Height to least actual dimension ratio to be between 1.3 and 5
	Use minimum two units in height
	 Length may be reduced from that of an individual unit by saw-cutting
	 Prism composed of closed cells must have one full width cross web on either end
	Caution: Where cutting CMU's is performed using water lubricated/cooled blade, it should be done well ahead (1 or 2 days minimum) of laying up the units, so that the water can evaporate. The moisture content of the test units should be as close as possible to those used in the project.
	MORTAR BED
UBC AND Title 24	Use full mortar bed (mortar bed face shells <u>and</u> webs); mortar shall be same as for construction project; joint thickness, tooling and method of positioning and aligning units shall be same as the construction project.
ASTM	In addition to the above requirements, mortar joints shall be cut flush; remove "fins" that protrude into grout space if prisms are to be grouted.

GROUT

UBC AND Title 24

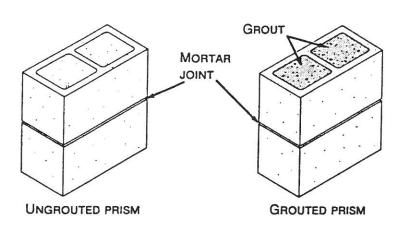
- Grout shall be same as that in the construction.
- Place grout not before 1 day nor later than 2 days after construction of prism.
- Consolidate, reconsolidate, and add to make up for settlement due to water loss, but before grout sets. (Use same consolidation procedure as will be used in the construction).
- Screed to level surface of top of prism.
- If open-ended units are used for prism, use additional units for end form to confine the grout during placement.
- Brace forms during grouting to prevent displacement during grouting. (It
 is recommended that prisms be built with closed end units of similar
 manufacture if acceptable).
- Where the construction is to be partially grouted, 2 sets of prisms shall be constructed, one set shall be grouted and the other set shall be un-grouted.
- Immediately after grouting, reseal the moisture tight bag around the prism.

ASTM

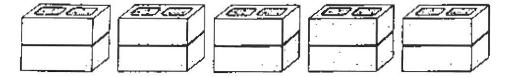
In addition to above requirements, remove mortar droppings from grout space prior to grouting.



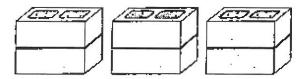
Figure 18 Preparing a Prism



MASONRY PRISM CONSTRUCTION FOR UBC STANDARD NO. 21-17 AND ASTM C 1314



FOR QUALIFYING TEST PRIOR TO CONSTRUCTION, FIVE SPECIMENS ARE REQUIRED FOR ONE TEST.



FOR FIELD CONTROL AS THE PROJECT IS BEING CONSTRUCTED, THREE SPECIMENS ARE REQUIRED FOR ONE TEST.

NUMBER OF SPECIMENS FOR A PRISM TEST

Figure 19 Reprinted with permission from the Reinforced Concrete Masonry Construction Inspector Handbook, Published by the Masonry Institute of America and International Conference of Building Officials.

CURING

Prisms shall be left undisturbed for at least 48 hours after construction. Prisms shall remain in moisture tight bag until 2 days prior to testing, then remove the bag and cure at lab with air temperature at 75 ± 15 °F.

TRANSPORTATION

Handling of prisms is difficult due to their size and weight. **Caution and care** are required to avoid damage in handling, especially during transportation, while they are still relatively weak. Recommend plywood top and bottom, wired, strapped or clamped during transit, cushioning material under the specimens, and restraints to prevent movement during transit.

MEASUREMENT

ASTM

Measure length and width at top and bottom faces of the prisms to nearest 0.05 inch. Average the four measurements of each dimension.

Measure height at center of each face to nearest 0.05 inch. Average the four measurements.

UBC

Measure length and width at center and quarter points of the height to the nearest 0.01 inch. Average the three measurements.

Measure the height (including caps) to the nearest 0.1 inch.

e. LOADING PLATEN

Capping, testing machine, and rate of loading are covered under "Compressive Strength Testing."

ASTM

ASTM requires a minimum 6" diameter of upper platen.

UBC

UBC allows a minimum 5"diameter of upper platen.

Loading platen thickness influences the test results of compressive strength of masonry units. Specifically, using a thinner platen thickness creates non-uniform stress concentrations resulting in lower indicated strength (see Figure 31, page 32).

It is important that thicknesses of platens specified in UBC Standards and ASTM specifications be adhered to for accurate and consistent results (see Table C, page 31).

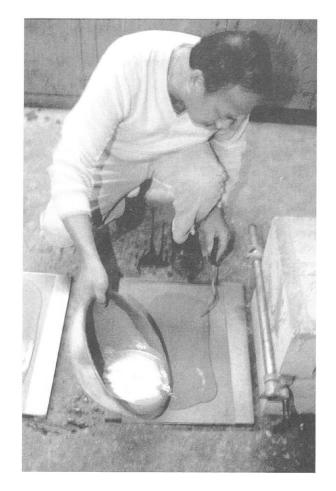






Figure 21 Moving a Prism

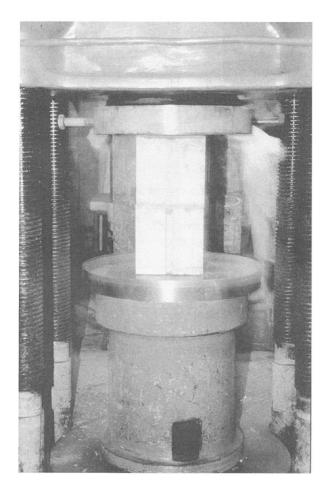


Figure 22 Compression Testing a Prism

f. CALCULATION OF TEST RESULTS

ALL

For each **solid grouted prism**, divide maximum compressive load by net cross-sectional area of prism ${}^{L}A_{n}$ (where A_{n} = average length x average width of prism).

For $ungrouted\ prisms$, 'An' is to be taken as the net cross-sectional area of masonry units determined from a representative sample of units.

PRISM STRENGTH

Compressive strength of each prism is determined by maximum compressive load sustained by the net cross sectional area of the prism.

q. COMPRESSIVE STRENGTH OF MASONRY

UBC

The compressive strength of masonry (psi) for each set of prisms shall be the lesser of the average strength of the prisms in the set, or 1.25 times the least prism strength multiplied by the prism height to thickness correction factor (h/t_p) from Table No. 21-17-A, reproduced below.

Where a set of grouted and non-grouted prisms are tested, the compressive strength of masonry shall be determined for the grouted set and for the non-grouted set separately.

ASTM

Calculate h/t_p ratio for each prism. Using the correction factor from table below, multiply masory prism strength by the correction factor. Compressive strength is average of a set of prism values as calculated.

Prism *h/t_p 1.30 1.50 2.00 2.50 3.00 4.00 5.00

Correction factor 0.75 0.86 1.00 1.04 1.07 1.15 1.22

 $^*h/t_p = ratio$ of prism height to least actual lateral dimension of prism.

PRISM TEST REPORT

Following items shall be reported:

ASTM

- Name of testing laboratory
- Description of prism including height, width, and length, h/tp ratio, mortar type, grout, and masonry unit used in construction
- Maximum and minimum temperature experienced by the prism during the first 48 hours after construction and grouting
- Age of prism at time the of test
- Maximum compressive load sustained by each prism in lbs.
- Net cross-sectional area of each prism in in² and method used to calculate net area
- Compression machine spherical head diameter, required upper bearing plate thickness
- · Upper bearing plate thickness used
- Compressive strength of each prism (nearest 10 psi)
- Average compressive strength of masonry for each set of prisms (nearest 10 psi)

UBC

Same as above and

 Description of mode of failure, including details of any unusual circumstances or defects. Include photographs if necessary

Title 24

Same as above and

• Name of professional engineer responsible for the tests

4. MORTAR

a. Proportioning and Property Specifications

References:

ASTM C 270-99b UBC Standard 21-15

SCOPE

Proportioning, property, specimen preparation and testing

NOTES:

- 1. Masonry Cement and Plastic Cement for mortar are **not** permitted for structural resistance in seismic zones 3 and 4 (UBC).
- 2. Maximum percentage of Fly Ash is 15 for mortar cement for buildings in California regulated by the Division of the State Architect.
- Mortar shall attain a minimum compressive strength of 1500 psi. at 28 days for field test specimens prepared according to UBC Standard 21-16. (Specimen are 2 inch X 4 inch cylinders).
- 4. When compressive strength of mortar is specified, tests are conducted in the laboratory. Average of three tests on 2 inch cubes shall not be less than that given in Table 21-15-A, modified.

TABLE 21-15-A MORTAR PROPERTY SPECIFICATIONS¹ (MODIFIED)

MORTAR	TYPE	AVERAGE COMPRESSIVE STRENGTH OF 2-INCH (51 mm) CUBES AT 28 DAYS (Min., psi)	WATER RETENTION (Min., percent)	AIR CONTENT (Max., percent) ²	AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION
Cement-lime	M	2,500	75	12	
or					
Mortar Cement	S	1,800	75	12	Not less than 2¼ and not more than 3½ times the sum of the separate volumes of cementitious materials.

NOTES:

- 1. Laboratory prepared mortar only
- 2. Determined in accordance with applicable standards
- 3. When reinforcement is incorporated in mortar, the maximum air content shall be 12%

TABLE 21-15-B MORTAR PROPORTIONS FOR UNIT MASONRY (MODIFIED)

		PROPOF	RTIONS	BY VOL	UME (C	EMENTITIOUS MATER	RIALS)
MORTAR	TYPE	PORTLAND CEMENT OR BLENDED CEMENT	MORT	AR CEN	1ENT ¹	HYDRATED LIME OR LIME PUTTY	AGGREGATE MEASURED IN A DAMP, LOOSE CONDITION
			М	S	N		
Cement-lime	М	1	_	_	9.22	1/4	
	S	1	_	_	-	over 1/4 to 1/2	Not less than 21/4 and
Mortar	M	1		_	1	_	not more than 3 times
Cement	M		1	_	0	_	the sum of the
	S	1/2	_	_	1		separate
	S		_	1			volumes of cementitious materials.

NOTE:

5. A mortar with specified proportions of ingredients that differ from the mortar proportions of Table 21-A may be approved for use when it is demonstrated by laboratory or field experience that this mortar with the specified proportions of ingredients, when combined with the masonry units to be used in the structure will achieve the specified compressive strength (f_m). Water content shall be adjusted to provide proper workability under existing field conditions. When the proportions of ingredients is not specified, the proportions by mortar type shall be used as given in Table No. 21-A of UBC.

b. Evaluation (Sampling and Testing)

References:

UBC Standard 21-15

UBC Standard 21-16

Mortar sampling and testing is **not** required except when property is specified.

Title 24, Section 2105 A.3.4.2

At the beginning of all masonry work, at least one test sample (3 cylinders minimum) of mortar and grout shall be taken on 3 successive working days and at least at one-week intervals thereafter.

- The samples shall be continuously stored in moist air until tested.
- Minimum strength shall meet requirements per Sec. 2103 A.3.2.

- Additional samples shall be taken whenever changes in materials or job conditions occur, or
- Whenever in the judgment of the architect, structural engineer, or the enforcement agency, such tests are necessary to determine the quality of the material.

Specimen Preparation (UBC Std. 21-16)

- Spread mortar on the masonry units 1/2 inch to 5/8 inch thick, and allow to stand for one minute.
- Remove mortar and place in 2 inch x 4 inch cylinder in two layers, compressing the mortar into the cylinder using a flat end stick or fingers.
- Lightly tap mold on opposite sides, level off.

¹ Mortar cement conforming to the requirements of UBC Standard 21-14

- Immediately cover molds and keep them damp until taken to laboratory.
- Protect against drying and damage during transit.
- After 48 hours set, have laboratory remove molds and place them in the fog room until tested in damp condition.

Testing

Each mortar test specimen shall have a minimum ultimate compressive strength of 1500 lbs/in².

Note: Mortar samples, due to their small size are fragile and sensitive to deviations in procedure and mishandling. Therefore, care is required to avoid misleading or erroneous results.

Other Methods

Since the predominant method in the Western United States is UBC Standard, the ASTM methods will not be covered here, but are provided for reference.

ASTM C 780-00 "Pre-construction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry." This standard, and especially its accompanying Annex A7, deals with compressive strength and contain detailed requirements for molds (size, tolerance, rigid vs. non-reusable), specimen preparation, field storage, transportation, curing, capping, testing, and reporting).

ASTM C 1142-95: "Standard Specification for Extended Life Mortar for Unit Masonry"; requires 3 specimens per batch to be tested at 28 days age; includes provision for discarding faulty specimens and results deviating ± 10% from average (therefore, allowing for a 7-day test and possibly one discard, suggests a minimum of 5 specimens per sample).

ASTM C 109-99, "Test Method for Compressive Strength of Hydraulic Cement Mortars" using 2" cubes.

NOTE:

Field sampling and testing methods are different than laboratory testing methods. Field tests should not be used to demonstrate requirements to meet C-270 specification.

5. GROUT

a. Specifications

References:

ASTM C 476-99 UBC Standard, 21-19 (Based on ASTM

C 476-91)

These references include provisions for coarse and fine grouts. They include materials, proportions, measurements, and mixing, but do **not** cover field sampling or testing.

SCOPE

Sampling, testing, and Code requirements

b. Code Testing Requirements

UBC, Section 2105.3.4.4

When *full stresses* are used in design and the unit strength method is used for verification of compressive strength of masonry, grout shall be tested for each 5000 sq. ft. of wall area, (minimum one test per project), to show compliance with compressive strength required in Table 21-D, Footnote 4; which states " - compressive strength of grout shall be equal to or greater than the compressive strength of the concrete masonry units."

UBC, Section 2105.3.5

When one half the allowable stresses are used in design, testing is not required for the grout. A letter of certification from the supplier of the grout shall be provided at the time of, or prior to, delivery of the grout to the jobsite to assure the grout complies with the compressive strength required in Table 21-D, Footnote 4, which states " - Compressive strength of grout shall be equal to or greater than the compressive strength of the concrete masonry units."

c. Sampling and Testing

References:

ASTM C 1019-00b

UBC Standard, 21-18

Sampling

Collect a minimum, 1/2 cubic foot size sample in the middle portion of batch delivery.

Three test specimens are required for each sample at specified test age.

Procedure for Sample Construction

- Simulate construction using same CMU's.
- Line cavity with permeable material such as paper towel to prevent bond to CMU's.
- Construct a square prism, size of each prism shall be nominal 3" or larger on each side with a height twice its width.
- ASTM recommends using an absorbent material at the bottom of mold blocks as an aid to uniform mold sizing (maximum 5% tolerance on dimensions) and ease of mold set-up). See Figure 23.

The reason for using the same CMU's as the structure, along with permeable liner, is to simulate the absorption of water from the grout, as this affects compressive strength. Therefore, it is very important to use CMU's with same moisture content (i.e. same site storage conditions). See Figure 19.

Location of the mold shall be flat and level and undisturbed for 48 hours.

- Measure and record slump.
- Fill mold with grout in two layers.
- Rod each layer 15 times with tamping rod penetrating ½ inch into lower layer. See Figure 20.

- Distribute strokes uniformly over the cross section of mold Level with straightedge and cover immediately with damp absorbent material such as a paper towel or cloth and keep damp for 48 hours.
- Protect sample from freezing or major temperature variations. See Figure 22.
- Measure and record width of each face at mid-height and height of each face at mid-width to the nearest 0.01 inch for width, and nearest 0.1 inch for height (including cap).
- Measure and record the amount out of plumb at mid-width of each face.
 See Figure 27.
- After 48 hours, carefully transport to laboratory, protect against drying or handling damage, keep it damp and in a protective container, and stored in a moist room conforming to ASTM Standards.

Testing

- Cap specimens as per applicable portion of UBC Std 21-17.
- Take care to ensure that axis of prism is vertical and caps are parallel.
- Maximum cap thickness shall be 1/8 inch average.
- Allow cap to age at least 2 hours before testing.
- Test specimens in damp condition as soon as practicable after removal from storage.

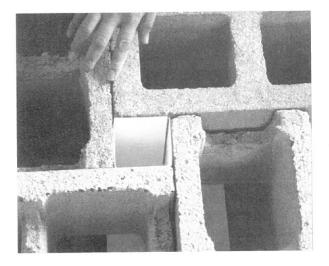


Figure 23 Mold for a Grout Sample

d. Report

- Include mix design, slump, type and number of units used to form mold.
- Dates cast and transported to laboratory, dimensions, percent out of plumb.
- Curing history, including max/min temperature in field.
- Maximum load, actual compressive strength.
- Required compressive strength.

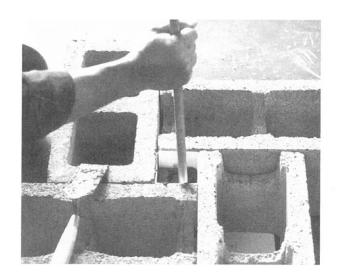


Figure 24 Placing Grout in the Mold



Figure 26 Protecting the Grout Sample

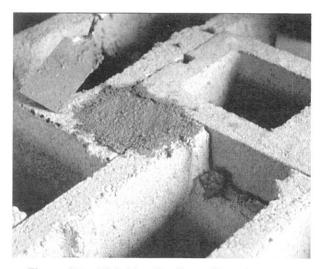


Figure 25 Finishing the Grout Sample

SAMPLE CONSTRUCTION

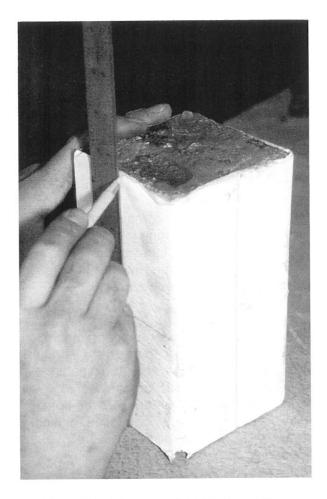


Figure 27 Measuring the Grout Sample



Figure 29 Capping the Grout Sample

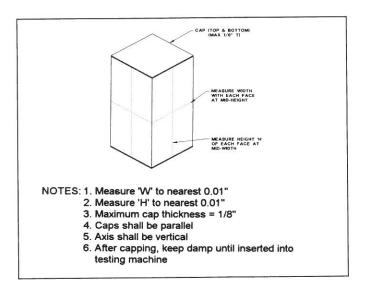


Figure 28 Grout Specimen Measurements

GROUT SAMPLE

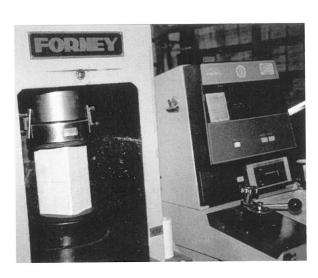


Figure 30 Compression Testing the Grout Sample

6. CORE TESTS

References:

1998 California Building

Code

Chapter 21A(DSA/SS)

Section 2105A.3.1.

Applies only to those structures regulated by the above amendments, typically *public* schools, hospitals, community colleges, State of California-owned or leased essential services buildings.

- Minimum two cores per project are required
- Two cores per building for each 5000 sq. ft. floor area, or masonry wall area, which ever is greater
- The project inspector should designate core locations
- Diameter of cores shall be 6 inches

- Report total number of cores, location, and condition of cores
- Do not soak cores prior to testing
- Transportation and handling at all stages must be done with care, as bond of face shells to grout can be fragile

Testing

One half the number of cores taken shall be tested in shear to test bond joints between grout core and outside faces of masonry units. Compression test remainder of cores and report per ASTM procedures.

Caution: Obtaining a representative sample requires careful alignment of coring machine and firm mounting so as to minimize vibration. Avoid coring into CMU webs. Avoid cutting rebar (use of a magnetic locator is recommended). Wastewater from the core cutting operation must be controlled to avoid staining the CMU's (especially critical in exposed or architectural surfaces).

TABLE C

Minimum Platen Thickness For Testing Commercial Units For Various Bearing Block Diameters

Test		Bearing	6" Dia.	Platen *T Bearing		(inches) Bearing		Bearing	Min. Bearing Block Diameter
Standard	8 x 16 Unit	ock 12 x 16 Unit	8 x 16 Unit	12 x16 Unit	8 x 16 Unit	12 x 16 Unit	8 x 16 Unit	12 x 16 Unit	(inches)
97 UBC 21-17 Prisms	6.19	7.23	5.69	6.74	4.69	5.74	3.69	4.74	5
ASTM C140-99b	**np	**np	5.69	6.74	4.69	5.74	3.69	4.74	6

^{*} Platen is defined as the steel plate between the spherically seated upper bearing block of the testing machine and the test specimen.

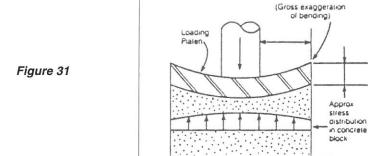
NOTE:

Recognizing the influence of thickness of platen or bearing plate, ASTM C140-99b has been revised to conform to 97 UBC, Standard 21-17, except that ASTM requires a minimum bearing block diameter of 6 inches, whereas UBC permits a 5 inch diameter bearing block.

^{**} np: not permitted

TABLE D

Influence of Major Testing Variables on the Indicated Compressive Strength of Concrete Masonry.



Thickness of Loading Platen (Plate too Thin)

May indicate lower compressive strength than actual, due to non-uniform stress distribution.

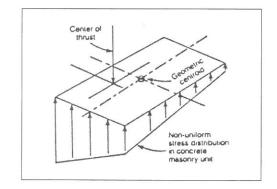
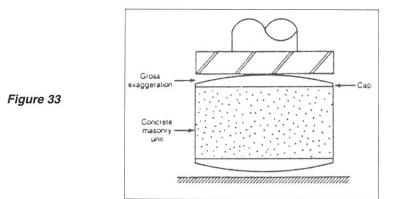


Figure 32

Center of Thrust Not Aligned with Geometric Centroid

Excessively loaded faces or corner may indicate lower strength than actual.



- ASTM C140 stipulates planeness within 0.003 inches in 16 inches.
- Max. thickness of cap 1/4" with sulfur, 1/8" with gypsum cement.

Non-Uniform Thickness of Capping

May provide erratic non-consistent results.

