



Masonry Testing 101

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Thursday, April 12, 2018

Course Description

- Proper testing of masonry products is essential to ensure that materials meet project requirements. There are many mistakes that can be made during product testing, and most of these mistakes can lead to jobs being delayed or stopped, and usually require costly follow-up to determine if there are problems with the resulting construction. Proper testing procedures for masonry products will be covered here, and typical mistakes made will also be presented.

Learning Objectives

- Understand the common tests required by the building code for testing of masonry units, materials and assemblies.
- Understand the proper procedures for performing testing of masonry materials according to ASTM standards.
- Learn the requirements for masonry material testing equipment according to ASTM standards.
- Identify common errors that occur during testing and how to correct them.

Why Inspect/Test Masonry?

- Code requirements
- Structural design requirements
- **Quality control, quality assurance**
- Workmanship
- Aesthetics
- Economy

The Need for QA and QC

- Higher quality and better masonry performance
- Increased confidence that the project will be constructed correctly and as designed
- Confidence in design reduces over-design
 - More cost efficient

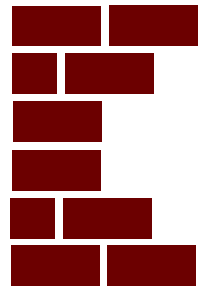
QA vs. QC

What is the difference?

- **Quality Assurance (QA):** the owner's or designer's efforts to determine project acceptability, accomplished through testing, field inspection, and QC
- **Quality Control (QC):** contractor's or manufacturer's efforts to ensure the final properties of the product in effort to achieve a specified goal

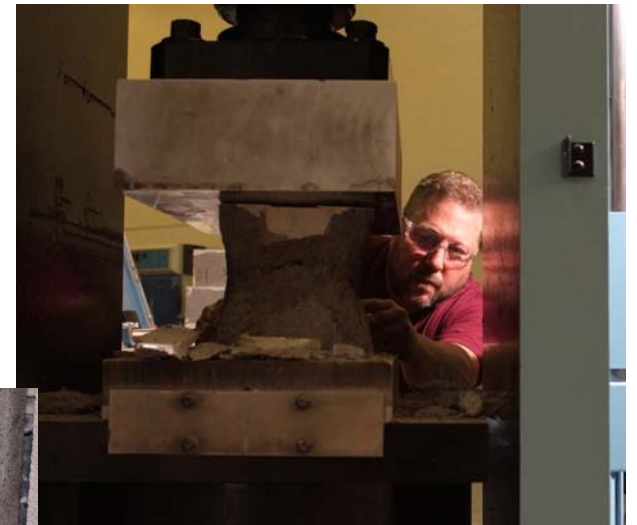
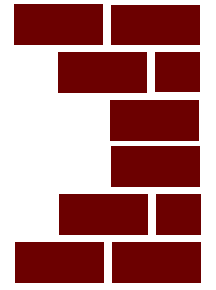
What Do We Test for Masonry?

	Strength	Workability	Absorption	Composition/ Proportions
Clay brick	✓	No	✓	No
Concrete block	✓	No	✓	No
Mortar	✓	✓	No	✓
Grout	✓	✓	No	✓
Prisms	✓	No	No	No



CONCRETE MASONRY UNITS

SAMPLING AND TESTING

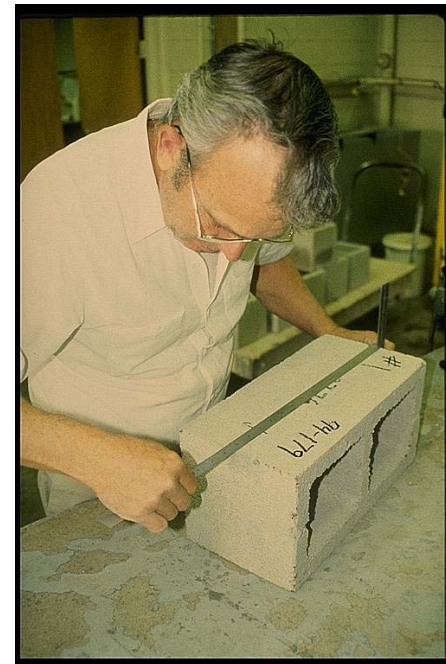
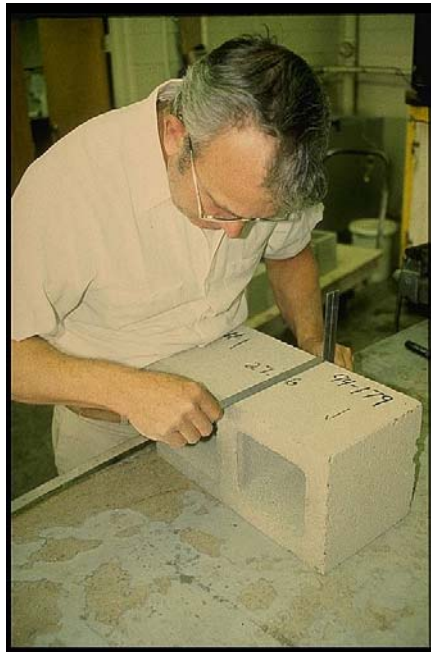
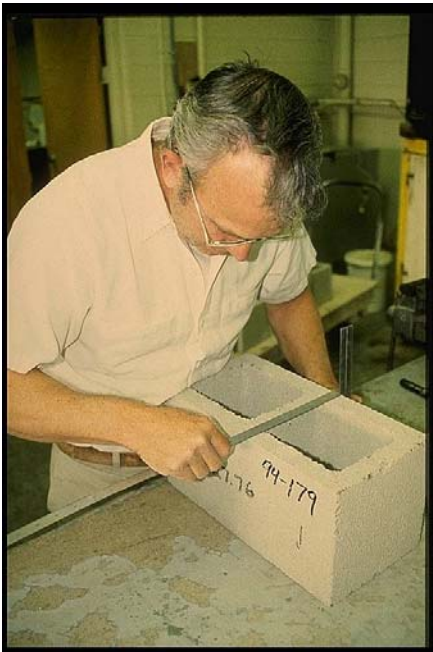


Concrete Masonry Units

- ASTM C140, *Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units*
- Used to determine compressive strength, water absorption, density, and dimensions of CMU
- Most common test performed on CMU

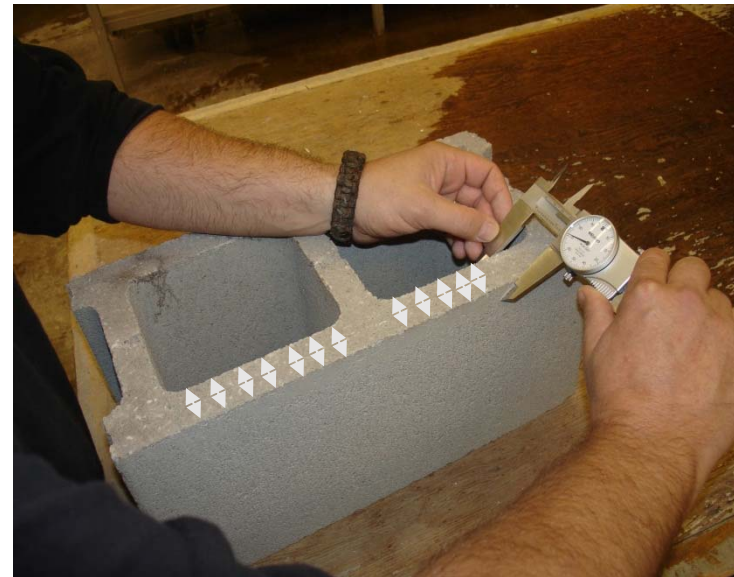
Dimensional Measurements

- Overall width measurements are taken at mid-length across top and bottom bearing surfaces
- Overall height measurements are taken at mid-length across each face
- Overall length measurements are taken at mid-height across each face



Dimensional Measurements

- Face Shell and Web thickness are taken $\frac{1}{2}$ inch down from the top surface as made (bottom surface as laid)
- Record minimum thickness of each element
- NEW – also measure web height



Web Height

- Measure and record the minimum height of each web.




Absorption Testing

- Four required weighings:
 - Received weight
 - Immersed weight
 - Saturated weight
 - Oven-dry weight
- Need to be in that order



Absorption Testing

- These four weights allow for calculation of many properties:
 - Absorption/Moisture Content
 - Density
 - Average Net Area  *More on this soon!*
 - Net Volume
 - Equivalent Thickness

Compressive Strength

- Compressive strength specimens must be capped (gypsum or sulfur) – Practice C1552
 - Pad caps not currently allowed!



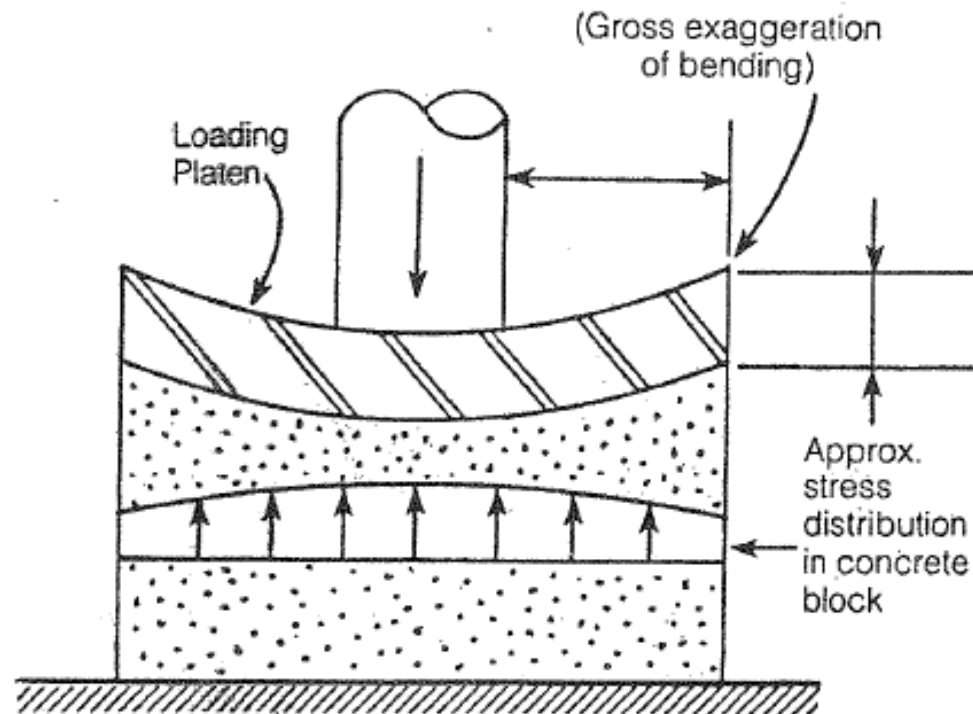
Compressive Strength

- Align centroid of test specimen with center of thrust of machine
- Apply $\frac{1}{2}$ of expected load at any convenient rate
- Apply second half in 1 to 2 minutes to failure



Testing Machine

- Thickness of bearing plate is important
- Too small and plate will bend – lowering compressive strength



Testing Machine

- Plate shall be at least equal to the distance from edge of from the edge of the spherical head to the most distant corner of the specimen

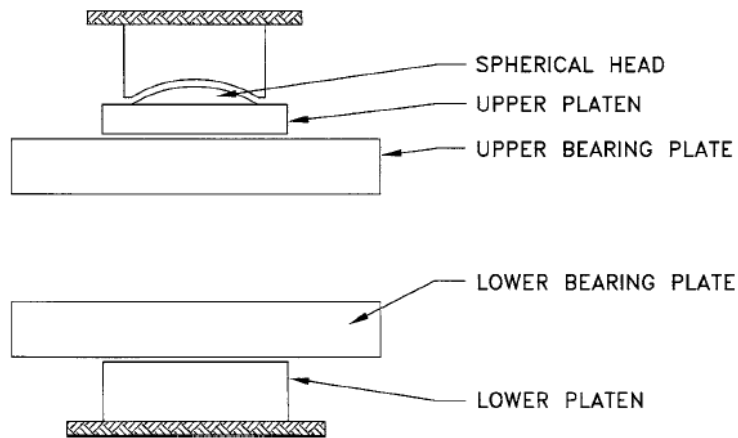


FIG. A8.1 Equipment Used for Compression Testing

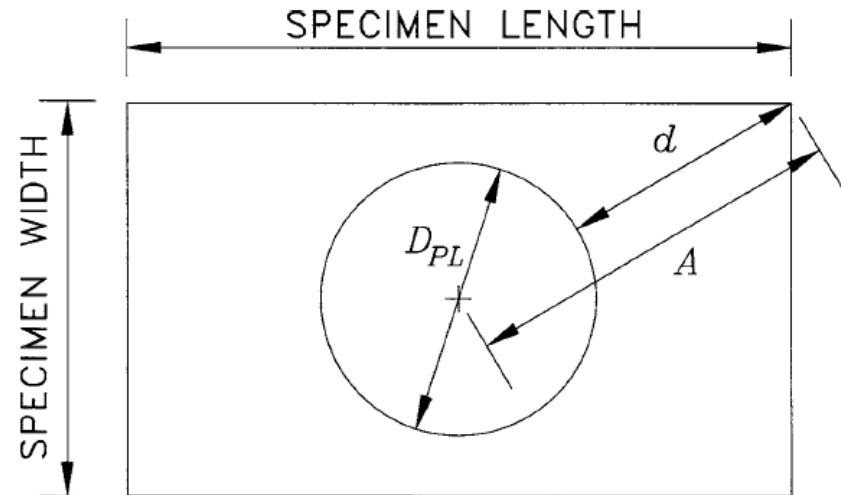


FIG. A8.3 Distance from Platen to Furthest Corner of Test Specimen

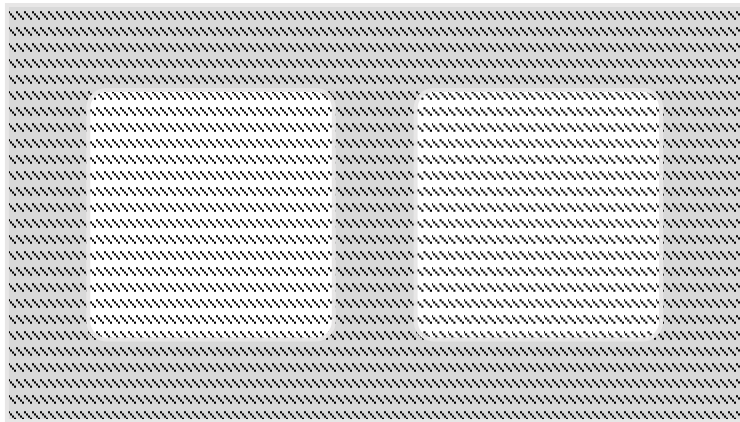
$$\text{Thickness} \geq d$$

Calculating Strength

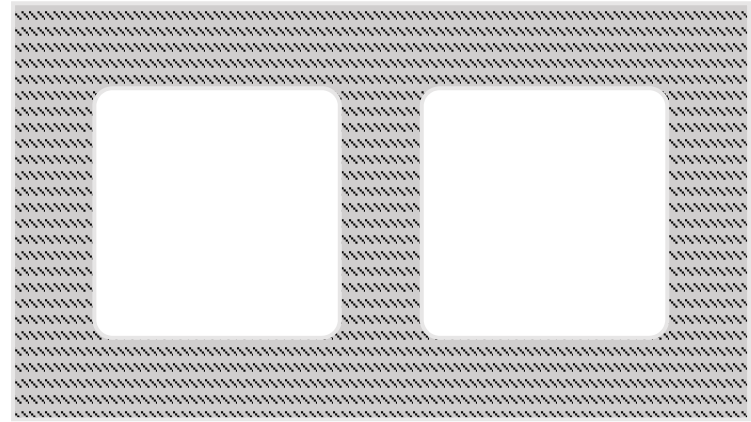
- A hollow CMU has both a net area and a gross area
- Gross area is simply length x width
- Net area is measure of solid area of concrete in the plane of bearing area of CMU (**determined through absorption testing**)
 - Compression and absorption units must be identical
 - Cannot test compression on units tested for absorption
- ASTM C90 minimum strength is **net area compressive strength**

Gross vs. Net Area

Gross Area

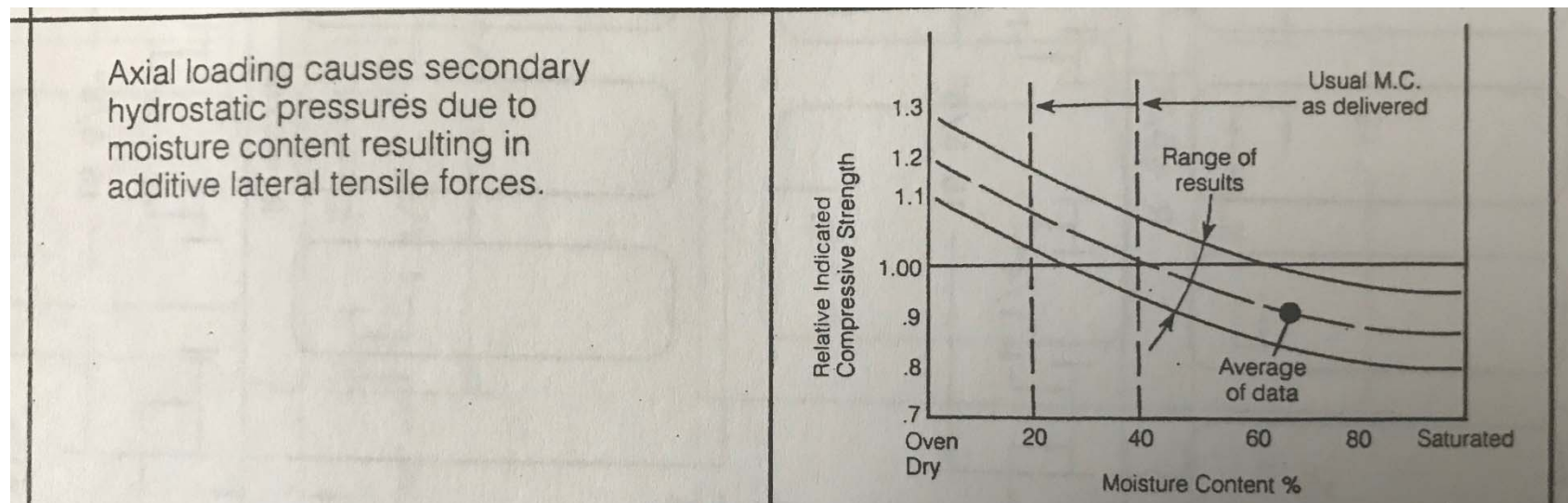


Net Area



Moisture Content

- CMU for compression testing must be in ‘equilibrium’ with environment
 - Not too wet, not too dry
- Defined as moisture content after 48 hours in lab air
 - $75 \pm 15^{\circ}\text{F}$ and $\text{RH} > 80\%$



Masonry Mortar

- Masonry mortar is used to:
 - Bond units together;
 - Accommodate unit irregularities;
 - Provide weather barrier; and
 - Enhance aesthetic finish.



Masonry Mortar

- ASTM C270
 - Specifying mortar
 - Laboratory testing
- ASTM C780
 - Preconstruction testing
 - Construction Evaluation
 - Evaluating mortar consistency during construction
- ASTM C1586
 - Practical guide for mortar testing



Specifying Masonry Mortar

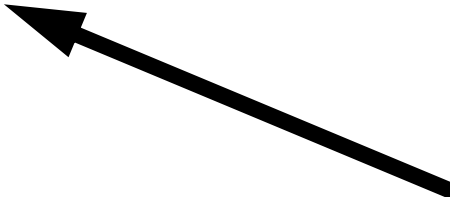
- Masonry mortars are specified to meet either the proportion or property requirements of ASTM C270.

Proportion Specification

--OR--

Property Specification

It makes no sense to specify both.



If neither is specified, the proportion specification governs.

C270 Property Specification

TABLE 2 Property Specification Requirements^A

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

These properties should not be applied to field sampled mortar

ASTM does not specify minimum physical requirements for field mortar

ASTM C780 – Field Evaluation

- Used to determine compliance with specified proportions
- Also used for quality control and uniformity
- For most methods, the absolute values are less important than variation between results
- Preconstruction testing is crucial
- **ASTM C270 Table 2 should not be used to evaluate field sampled mortars!**
- **NO FIELD REQUIREMENTS FOR MORTAR STRENGTH**



Differences in Testing

	ASTM C270	ASTM C780
Mixer Used	Hobart 5 qt bench top	Field Mixer
Sand Condition	Oven-dry	Moisture as is
Consistency	Mixed to specified flow (stiffer than field applications)	Mixed to workable field consistency
Compression Specimens	Cubes only	Cubes or Cylinders



ASTM C780

- Multiple Test Methods
 - Consistency by Cone Penetrometer
 - Consistency Retention
 - Mortar Aggregate Ratio
 - Air Content
 - Compressive Strength
- Mortar-Aggregate Ratio Testing best way to evaluate proper mortar proportions

ASTM C780 Mortar:Aggregate Ratio



- Can determine ratio of cementitious materials to aggregate used

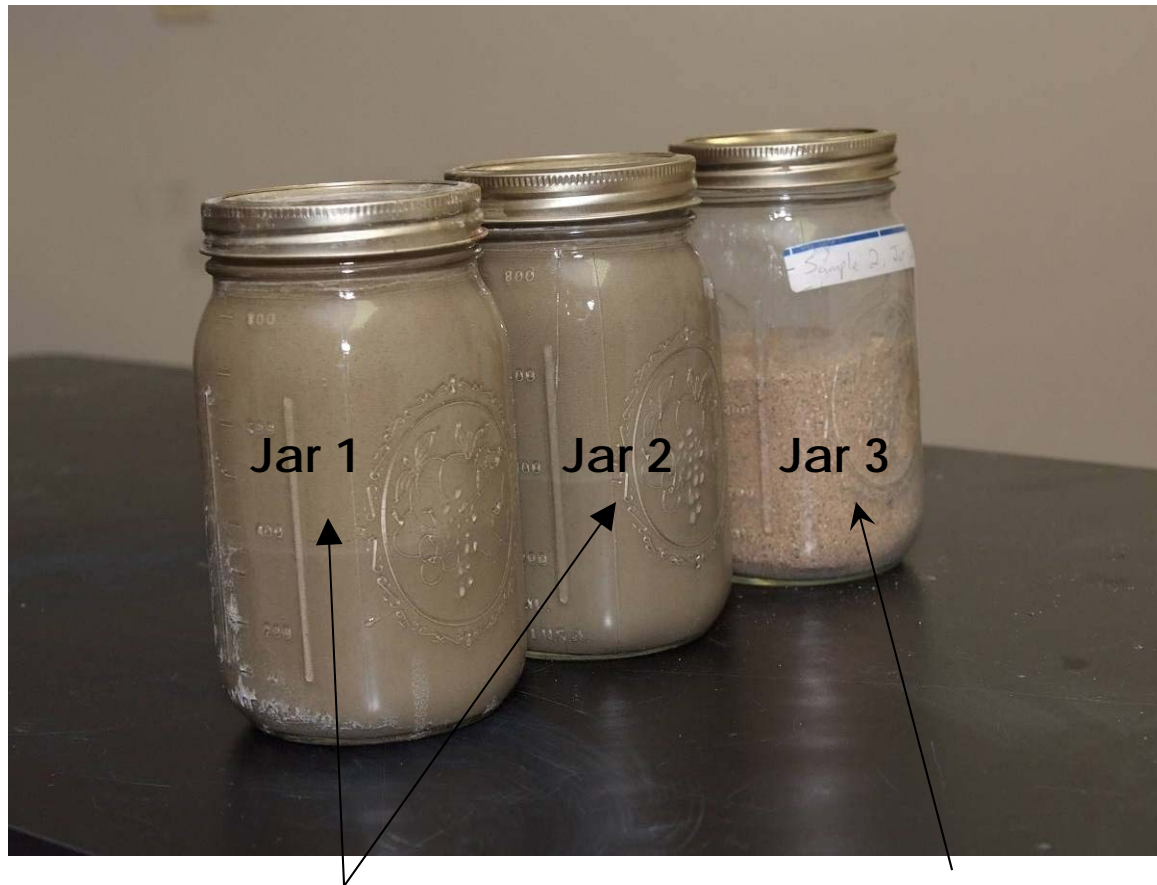


- Limits:
 - Provides ratio by weight
 - Cannot separate multiple cementitious materials

Mortar-Aggregate Ratio Sampling

- Before going to jobsite:
 - Add 250 mL isopropyl alcohol (91% preferred) to each of two mortar sample containers
 - Seal each and weigh, record to the nearest 1 g
- At jobsite
 - Take mortar samples directly from mixer (batch sampling)
 - Place 500 – 700 g of mortar in each container
 - Shake VIGOROUSLY!!!
 - Obtain sand sample (at least 500 g) and place in sand container

ASTM C780, Mortar-Aggregate Ratio



Mortar + Alcohol Sand

Mortar-Aggregate Ratio Sampling

- Why Alcohol?
 - Isopropyl alcohol stops the hydration reaction for cement and water
 - Keeps the cement from hardening...but not forever
 - Suggested to get samples back to the lab and complete testing within 24 hours (but sooner is always better)





Mortar-Aggregate Ratio Testing

- Back at the Lab...
 - Weigh each mortar container separately and record
 - Then....
- 

Mortar-Agg Ratio, Jar 1



- Pour Jar 1 into No. 100 sieve.
 - Option – use protection sieve
- Rinse to pass all fine material through.
- Oven-dry, weigh, and record the remaining material

Mortar-Agg Ratio, Jar 2



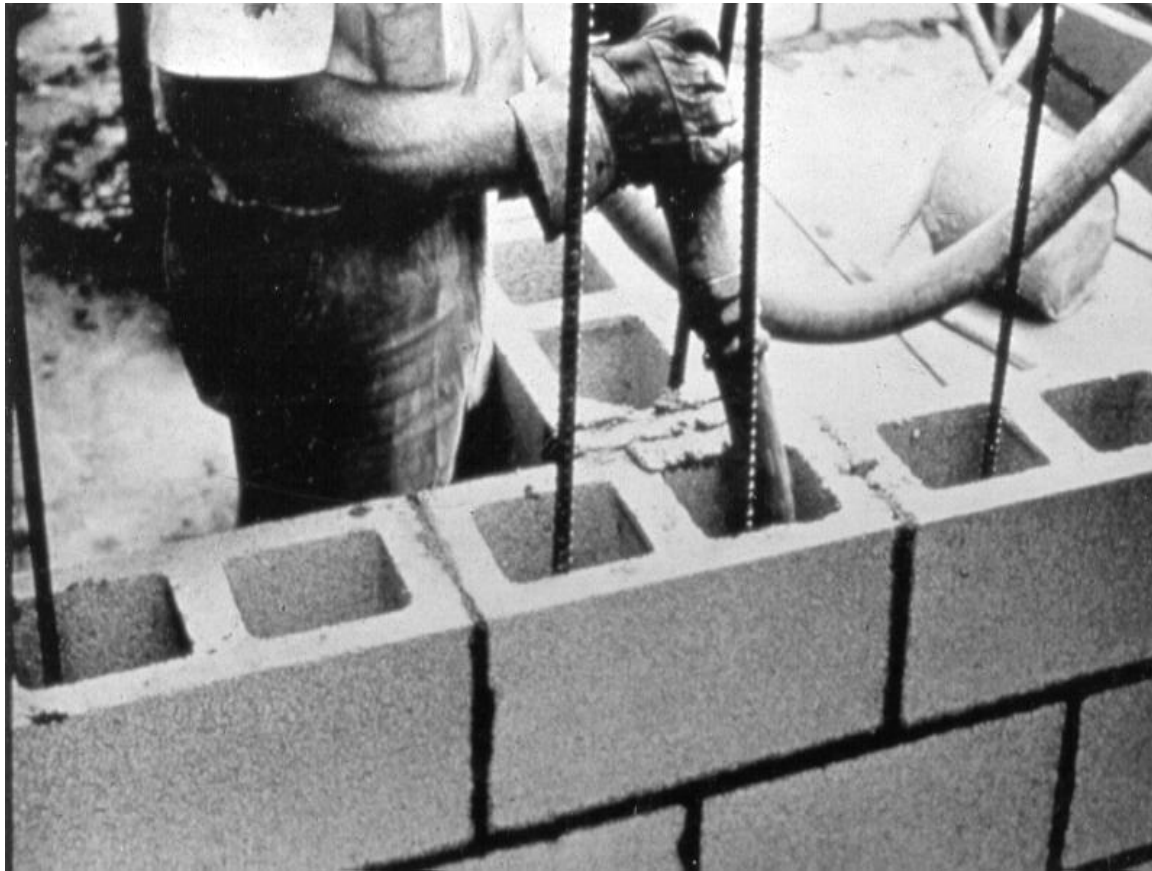
- Pour mortar and alcohol into pan
 - Use water or alcohol to transfer
- Ignite to burn off the alcohol.
- Place pan in oven.
- Oven-dry, weigh and record weight of remaining residue

Mortar-Agg Ratio, Sand



- Weigh sand as received
- Oven-dry, weigh, and record weight of sand from Jar 3.
- Pour dry sand into No.100 sieve and wet sieve to pass through fine particles.
(protection sieve)
- Oven-dry, weigh, and record weight of retained material to determine percent of fine aggregate.

Grout for Masonry Construction



Testing per ASTM C1019

Masonry Grout

- Masonry grout is a very fluid concrete placed within the cells of the masonry units to bond the reinforcement, units, and mortar into a single composite assembly.



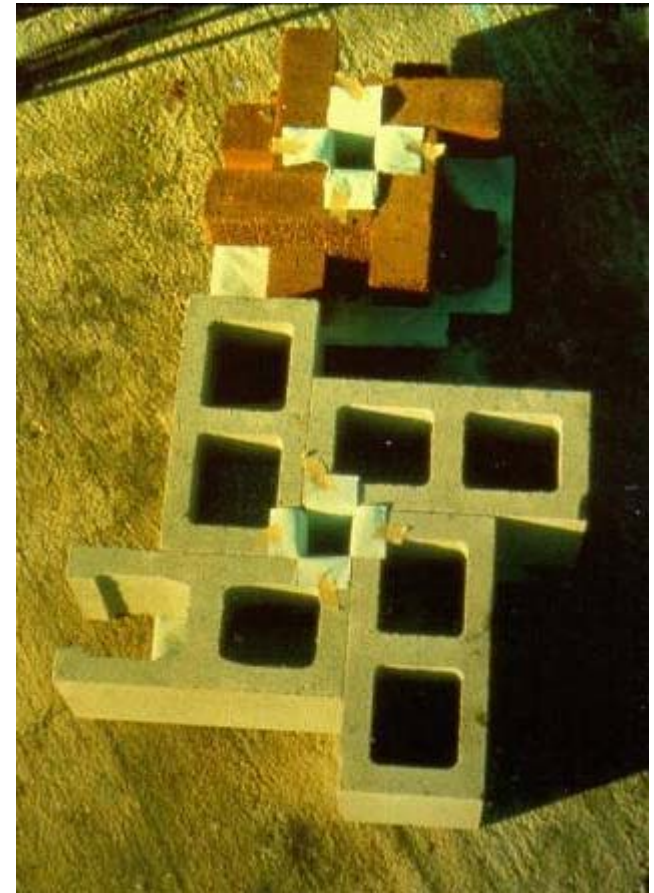
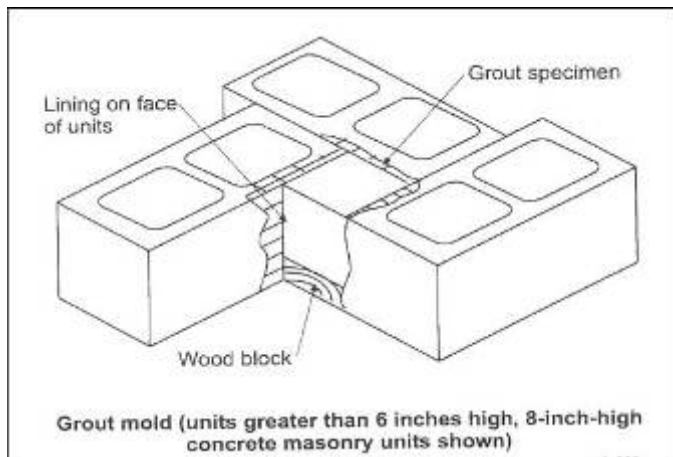
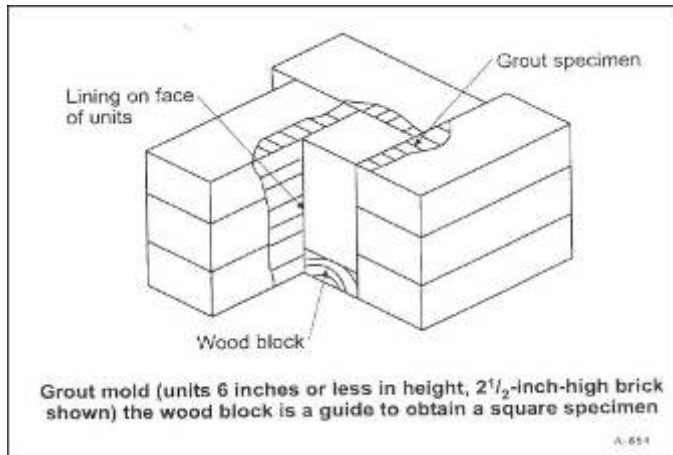
ASTM C1019 – Test Method Compressive Strength of Grout



Specimen Forming

- ‘Standard’ forming method is pinwheel using units from construction
- Other methods of forming grout specimens are available, and can be used
- These methods, however, must be correlated to “pinwheel” method
 - Correlation limited to grout design, units used, and method of forming
 - Developed by comparative testing (10 pairs)
 - Coefficient of variation for other forming methods must not be greater than pinwheel

Preparing Grout Compressive Strength Specimens



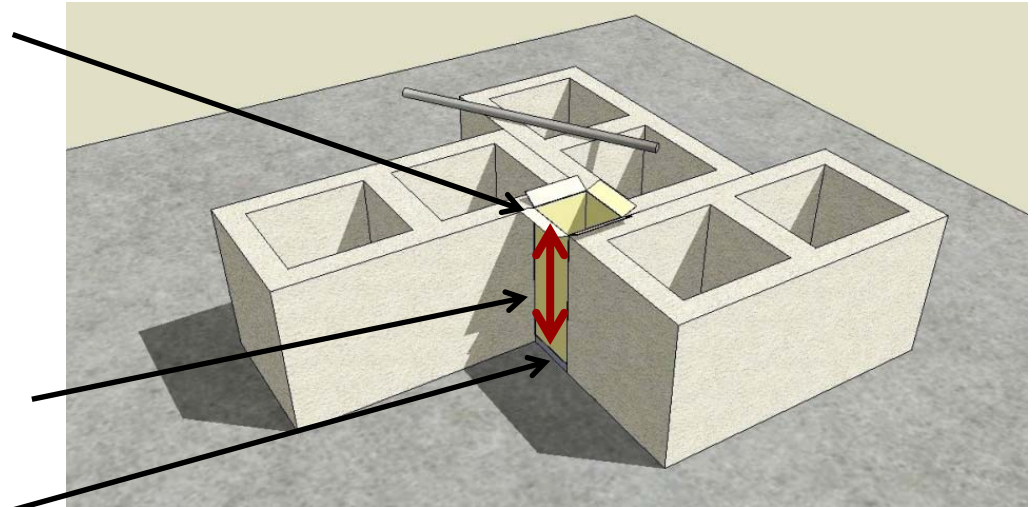
Mold Construction

- Select a level location where the molds can remain undisturbed for up to 48 hours
- Construct the mold space to replicate the grout location in the wall. If the grout is placed between two different types of masonry units, both types should be used to construct the mold



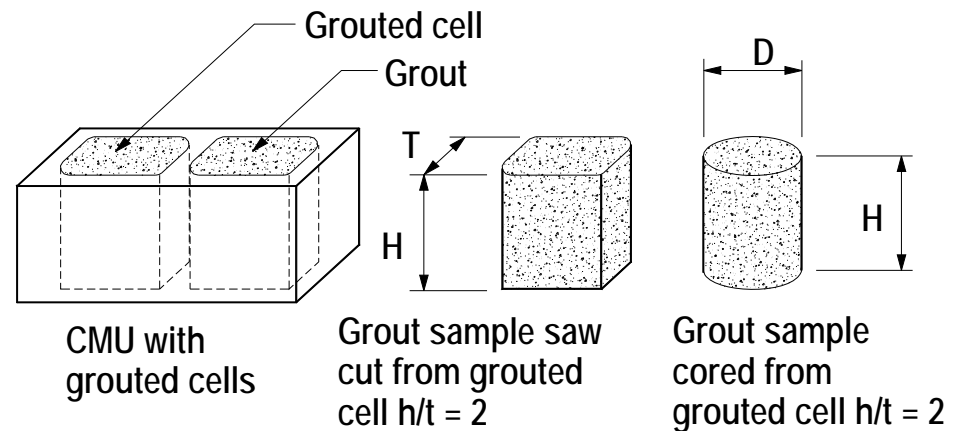
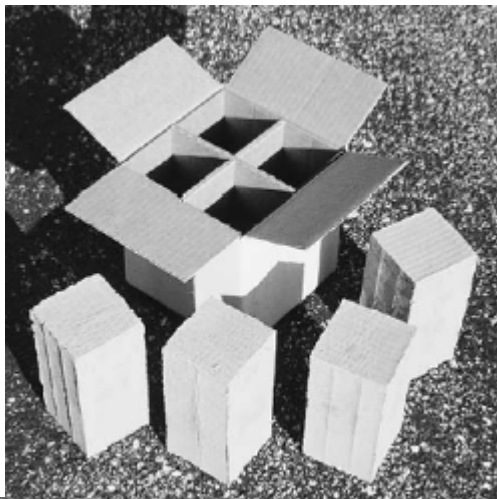
Grout Molds

- Square cross-section of 3 in. minimum
- Permeable liner material-paper (no plastic, building wrap, building felt)
- Twice as high as its width
- Nonabsorbent block at base
- Face in contact with grout not previously used to mold specimen



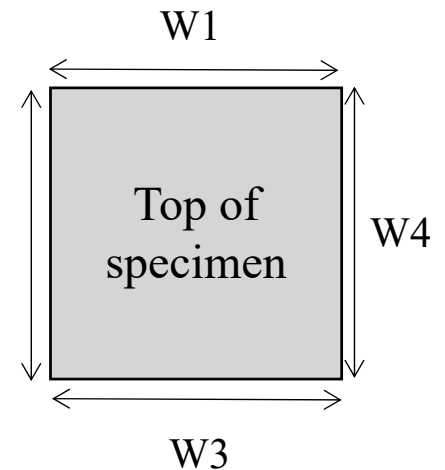
Alternate Grout Specimens

- Must be approved by the specifier
- Approval is based on comparative testing
 - COV of alternate method cannot be greater than standard method
- Limited to a single shape and size, a single forming method, a single grout mix, and a single masonry unit



Measuring Dimensions

- Measure width and length of specimens
- Width is measured on each face of specimen at mid-height
 - Calculate cross-sectional area by averaging the width of opposite faces, then multiplying the two averages
 - $A = ((W1 + W3)/2) * ((W2+W4)/2)$
- Length is measured on each face at mid-width
- Amount out of plumb is measured at mid-width of each face



Calculations

- Determine compressive strength by dividing maximum load by net cross-sectional area
- For alternative methods of forming:
 - Calculate average corrected compressive strength by dividing maximum load by cross-sectional area, and then multiplying the result by the conversion factor
- Conversion factor for alternative methods specific to specimen shape, method of forming, masonry units used, and grout mix
 - COV of alternative method cannot exceed COV of standard method.

Masonry Prism Testing



ASTM C1314

ASTM C1314

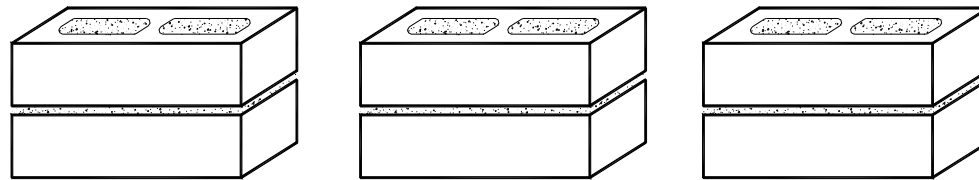
- Testing of prisms is one method for determining compliance with *specified compressive strength of masonry, f'_m*
- Construction, handling, and testing procedures are important



Figure C 1314-11: Positioning Specimen in Compression Machine

Number of Prisms Required?

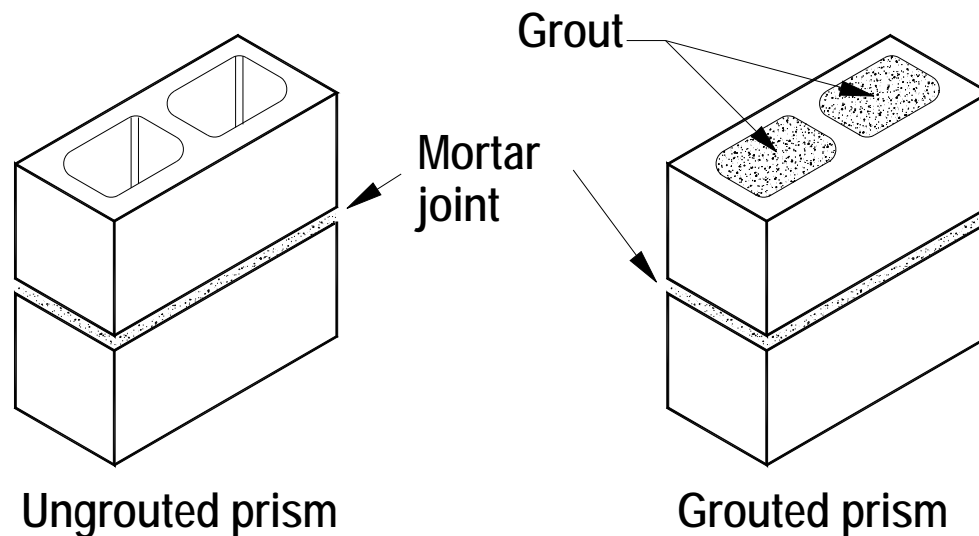
- If prisms are required for the job, remember that a set of prisms is composed of 3 prisms
- The resulting tested strength is an average strength from the 3 prisms
- Typically, a set of prisms is made and tested:
 - Prior to starting the work
 - For every 5,000 square feet of masonry construction*



A Set of Prisms is defined as 3 prisms !

Prisms for Partially Grouted Construction

- For partially grouted, construct two sets of prisms:
 - One set is grouted solid
 - One set is not grouted



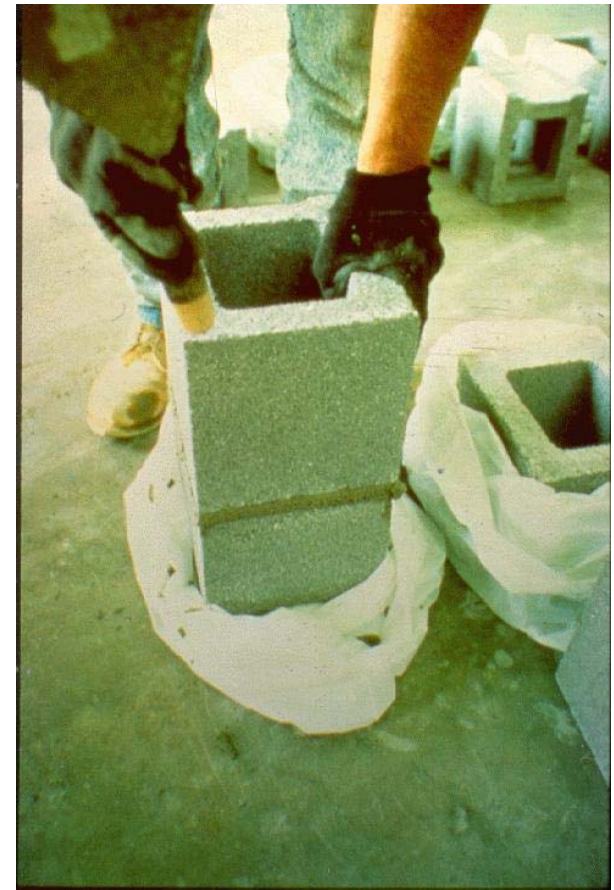
Construction

- Full mortar bed
- Stack bond
- Joints struck flush
- Cure in plastic bags



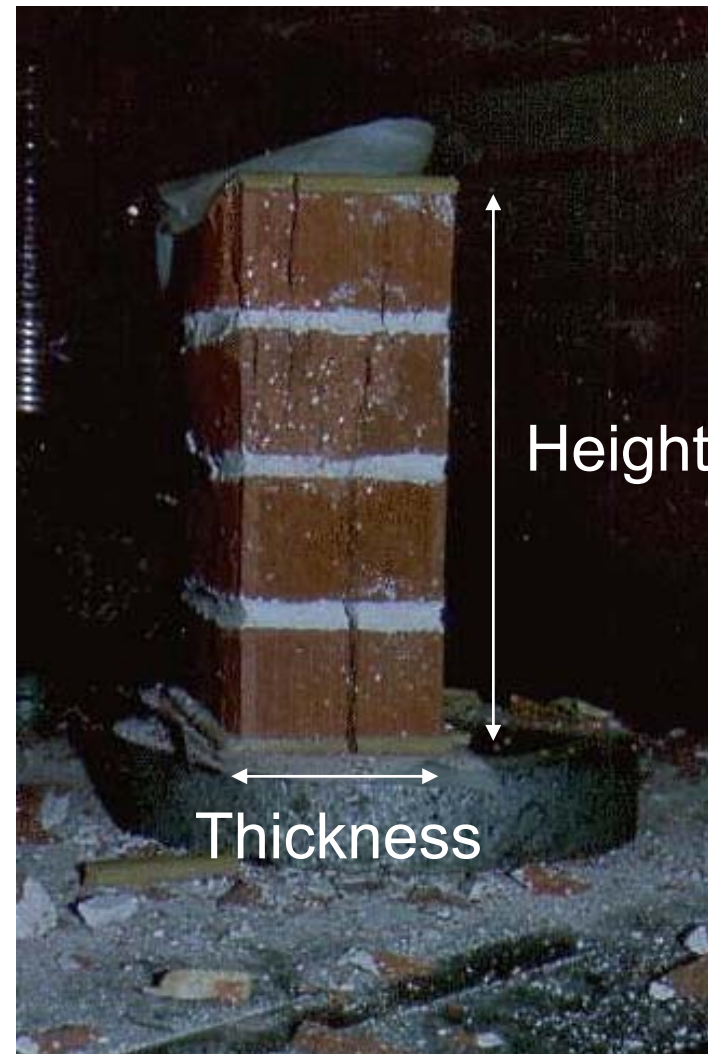
Prism Construction

- The length of prisms may be reduced by saw cutting, but:
 - Regular-shaped hollow units must have at least one complete cell with one full-width cross web either end
 - Irregular-shaped units must be cut to obtain a cross section as symmetrical as possible. The minimum length of saw-cut prisms is 4 in.



Prism Height

- Minimum height: two units
- Total height
 - Minimum = 1.3 times the least actual thickness
 - Maximum = 5.0 times the least actual thickness
- For CMU, prisms are typically 2 units tall
 - Stack Bond
 - Full mortar bed
 - Joints struck flush



Handling

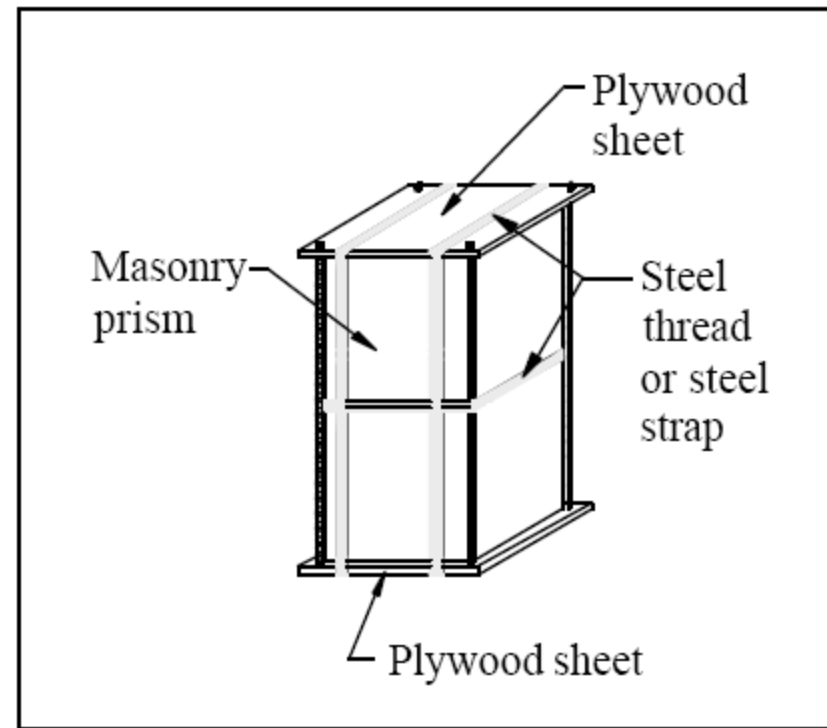


Figure C 1314-7: Prism Ready for Transport

Testing

- Prisms remain in plastic bags until 48 hours prior to testing
- Capping using gypsum or sulfur in accordance with ASTM C1552
- Testing provisions essentially the same as those in C140 – with two exceptions
 - Record failure mode
 - Correct strength for h/t ratio

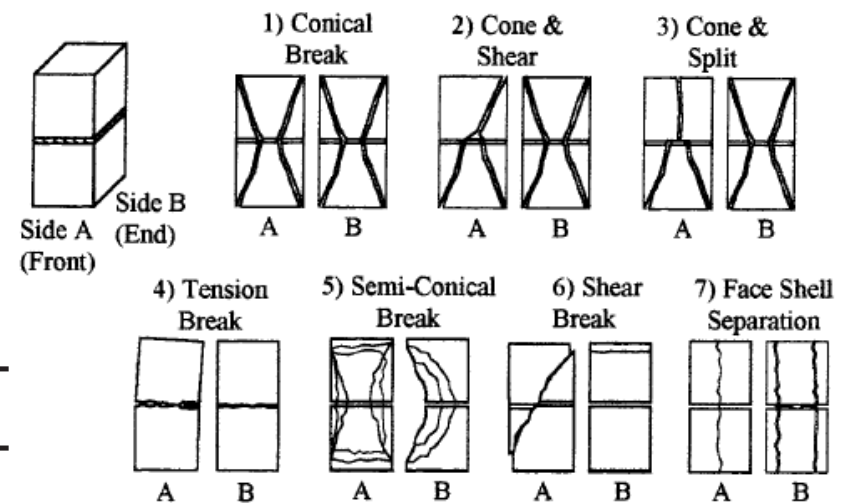


FIG. 4 Sketches of Mode of Failure

h_p/t_p^A	1.3	1.5	2.0	2.5	3.0	4.0	5.0
Correction Factor	0.75	0.86	1.0	1.04	1.07	1.15	1.22

^A h_p/t_p —Ratio of prism height to least lateral dimension of prism.

This concludes The American Institute of Architects
Continuing Education Systems Course



The Masonry Society

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