MASONRY MATERIALS

August 13, 2021

Presented by:

MASONRY INSTITUTE OF AMERICA
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AIA CES Provider

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

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Learning Objectives

After this presentation, you should be able to:

- ***Understand and Specify*** the appropriate ASTM Material Standards for Masonry components.
- ***Learn how to Interpret*** the required Quality Assurance provisions that are required by the code and applicable for the specific project.
- ***Learn*** how project specifications and structural notes can conflict and how conflicts can be resolved.
- ***Recognize*** how project documents can be misunderstood by the contractor and ways to produce clear requirements.

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Outline

- Masonry as a System
- Concrete Masonry Units (CMU)
- Mortar
- Grout

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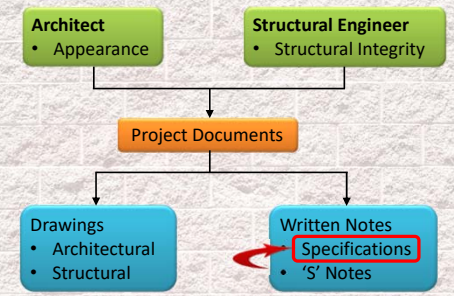
Outline



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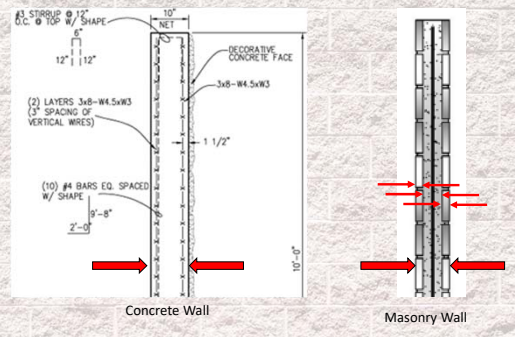
Masonry as a System



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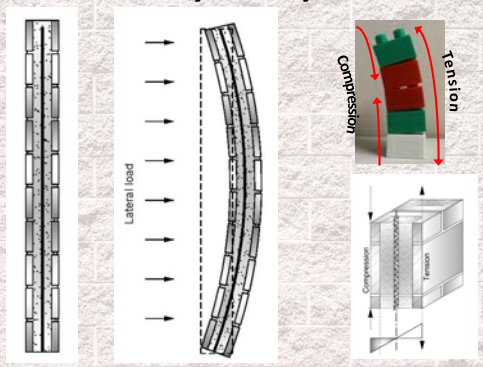
Masonry as a System



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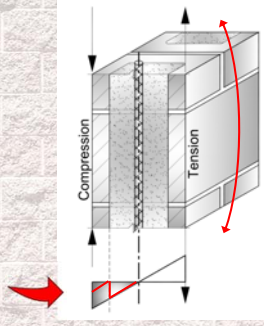
Masonry as a System



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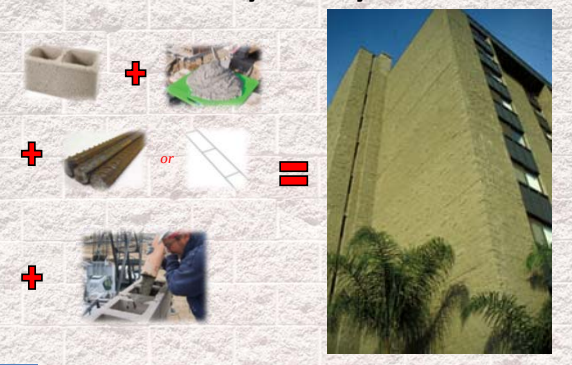
Masonry as a System



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Masonry as a System

- Masonry is Often Overspecified-Common Pitfalls
  - Concrete Masonry Units, ASTM C90
    - Grades and Types Specified—No Longer in Standard
    - f'_m = 1,500—Unit Strength is now 2,000, f'_m is design
  - Mortar, ASTM C270
    - Specified by Proportion and Property
    - Minimum Compressive Strength for Field Mortar Testing
  - Masonry Grout, ASTM C476
    - ASTM C94, Standard Specification for Concrete
    - Specified by Proportion and Property
    - Low slump (less than 8 in.) Specified

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Concrete Masonry Units

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Concrete Masonry Units

- Masonry Units are Structurally Flexible

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Concrete Masonry Units

- Masonry Units have a lot of color variety

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Concrete Masonry Units-ASTM C90

- Old minimum strength requirement – 1,900psi
- New minimum strength requirement – 2,000psi
- No "Equivalent Web Thickness" requirement
- Now "Normalized Web Area" and minimum "Web Thickness"
- No Type I (since 1990)
- No Grade N (since 2000)
- Producers should NOT certify that materials are Type I or Grade N

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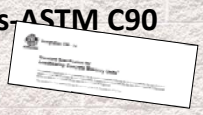
Concrete Masonry Units-ASTM C90



- What's in ASTM C90?
- ASTM C90 Covers
  - Compressive Strength
  - Dimension Tolerances
  - Density Definitions
  - Absorption
  - Linear Shrinkage
  - Visual Acceptance Criteria

Structural

- ASTM C90 Does Not Cover
  - Color
  - Texture
  - Fire Ratings (IBC T721.1(2)
  - Sound Properties (TMS 302)
  - Thermal Properties (CA Energy Code 120.7)
  - Water Repellency

Certified or Aesthetic

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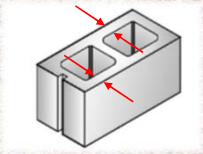
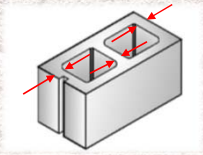
Concrete Masonry Units-ASTM C90

- Minimum Face Shell Thickness (8 inch unit) 1-1/4"
- Minimum Web Thickness (all units) 3/4"
- Normalized Web Area (all units) 6.5 in^2/ ft^2





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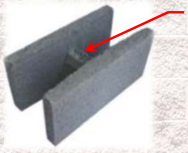
Concrete Masonry Units-ASTM C90

- Open-end units are virtually impossible to manufacture with 3/4" webs and 6.5 square inches of total web area per square foot (5.75 in^2/unit)
- Caution when reviewing specifications; some specifiers may ask for the "minimum" web area



Currently about 11½ in^2 of (web) connection

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Concrete Masonry Units-ASTM C90

Top of the block: as laid or made?

The top of the block as made:
- thinner webs and face shells
- rougher surface
- core bar indentations / cracks

The CMU is inverted before it is laid in a wall to:
- provide mason with better area for spreading mortar
- to allow mason to use hand holds

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Concrete Masonry Units-ASTM C90

Tapering face shells/webs

Top as made

Straight taper face shells

Top as laid

Straight taper webs

Flared center web as hand grip

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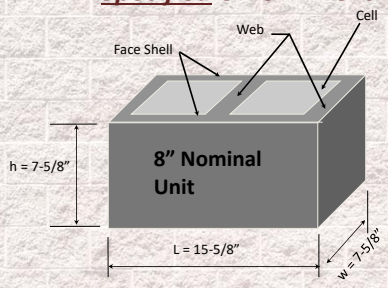
Concrete Masonry Units-ASTM C90

Specified CMU Dimensions



Dimensions will vary based on type of unit, manufacturer, tolerances, etc.

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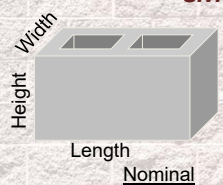
Concrete Masonry Units-ASTM C90

CMU Dimensions



Dimensions for CMU:
Width x Height x Length

Nominal Widths - 4", 6", 8", 10", 12"
Specified Dimensions = nominal - 3/8"

Nominal	Specified
4 x 8 x 16	
6 x 8 x 16	
8 x 8 x 16	for, e.g. 7-5/8 x 7-5/8 x 15-5/8
10 x 8 x 16	
12 x 8 x 16	

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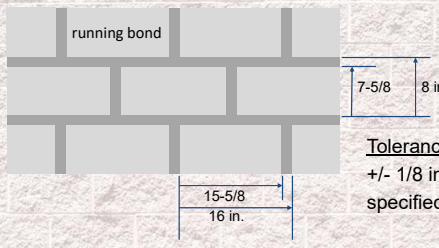
Concrete Masonry Units-ASTM C90

Nominal dimensions are equal to the specified dimensions plus the thickness of one mortar joint (typically 3/8 in.)



Tolerance Permitted:
+/- 1/8 in. from the specified dimensions

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Concrete Masonry Units-ASTM C90

ASTM C90 Loadbearing Concrete Masonry Units

- Density
  - Lightweight (less than 105 pcf)
  - Medium Weight (105 to less than 125 pcf)
  - Normal Weight (125 pcf and above)
- ~~Types I and II, Moisture controlled~~
- ~~Grades N and S~~

Type I and II units deleted!!

Grade N and S deleted!!

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Concrete Masonry Units-ASTM C90

- ASTM C90-09 Requirements
  - Table 2 - Compressive Strength (Minimum)
    - 1900 psi (min.) - average of 3 units
    - 1700 psi (min.) - individual unit
  - Moisture absorption
    - Measured in pounds per cubic foot
    - Varies for different density classifications

TABLE 2 Strength, Absorption and Density Classifcation Requirements

Density Classification	Oven Dry Density of Concrete, lb/ft³	Maximum Water Absorption, lb/ft³		Minimum Net Area Compressive Strength, lb/in²	
	Avg of 3 Units	Avg of 3 Units	Individual Units	Avg of 3 Units	Individual Units
Lightweight	Less than 105	18	20	1900	1700
Medium Weight	105 to less than 125	15	17	1900	1700
Normal Weight	125 or more	13	15	1900	1700

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Concrete Masonry Units-ASTM C90

- ASTM C90-14 Requirements
  - Table 2 - Compressive Strength (Minimum)
    - 2000 psi (min.) - average of 3 units
    - 1800 psi (min.) - individual unit
  - Moisture absorption
    - Measured in pounds per cubic foot
    - Varies for different density classifications

TABLE 2 Strength, Absorption and Density Classifcation Requirements

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	Avg of 3 Units	Avg of 3 Units	Individual Units	Avg of 3 Units	Individual Units
Lightweight	Less than 105	18	20	2000	1800
Medium Weight	105 to less than 125	15	17	2000	1800
Normal Weight	125 or more	13	15	2000	1800

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Concrete Masonry Units-ASTM C90

Previous ASTM C90-09 Requirements

TABLE 1 Minimum Thickness of Face Shells and Webs[A]

Nominal Width (W) of Units, in.	Face Sell Thickness (t_{fs}), min. in. [B,C]	Web Thickness (t_w)	
		Webs [B,C,D] min. in.	Equivalent Web Thickness, min. in./lin ft [E]
3	3/4	3/4	1-5/8
6	1	1	2-1/4
8	1-1/4	1	2-1/4
10 and greater	1-1/4	1-1/8	2-1/2

[A] Average of measurements on a minimum of 3 units when measured as described in Test Methods C140.
[B] When this standard is used for units having split surfaces, a maximum of 10 % of the split surface is permitted to have thickness less than those shown, but not less than 3⁄4 in. (19.1 mm). When the units are to be solid grouted, the 10 % limit does not apply and Footnote C establishes a thickness requirement for the entire faceshell.
[C] When the units are to be solid grouted, minimum face shell and web thickness shall be not less than 5⁄8 in. (16 mm).
[D] The minimum web thickness for units with webs closer than 1 in. (25.4 mm) apart shall be 3⁄4 in. (19.1 mm).
[E] 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 length of the unit for the calculation of the equivalent web thickness.

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Concrete Masonry Units-ASTM C90

Previous ASTM C90-14 Requirements

TABLE 1 Minimum Thickness of Face Shells and Webs[A]

Nominal Width (W) of Units, in.	Face Sell Thickness (t_{fs}), min. in. [B,C]	Web Thickness (t_w)	
		Web Thickness[C] (t_w), min. in.	Normalized Web Area (A_{nw}), min. in.²/ ft² [D]
3	3/4	3/4	6.5
6	1	3/4	6.5
8 and greater	1-1/4	3/4	6.5

[A] Average of measurements on a minimum of 3 units when measured as described in Test Methods C140.
[B] When this standard is used for units having split surfaces, a maximum of 10 % of the split surface is permitted to have thickness less than those shown, but not less than 3⁄4 in. (19.1 mm). When the units are to be solid grouted, the 10 % limit does not apply and Footnote C establishes a thickness requirement for the entire faceshell.
[C] When the units are to be solid grouted, minimum face shell and web thickness shall be not less than 5⁄8 in. (16 mm).
[D] Minimum normalized web area 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 length of the unit for the calculation of the minimum web cross-sectional area.

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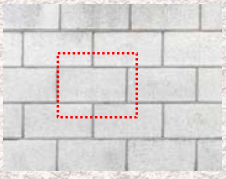
Concrete Masonry Units-ASTM C90

- **Normalized Web Area**
  - Literally, this requirement means that for every square foot of wall surface, no less than 6.5 in.² (5-3/4 in.² per unit) of web must connect the front and back face shells, with no web measuring less than 0.75 in. in thickness



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MORTAR

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Mortar is the Most Misunderstood Component of Masonry

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Mortar-ASTM C270

- What is mortar?
  - Definition (2021 IBC, ASTM C1180-18)
    - Cementitious Materials (Portland Cement & Lime, Masonry Cement, Mortar Cement)
    - Sand (Gradation important)
    - Water (Rule Of Thumb – drinkable)
    - Possible Admixtures

Mortar, *n*—a mixture consisting of cementitious materials, fine aggregate, water, with or without admixtures, that is used to construct unit masonry assemblies.

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Mortar-ASTM C270

- Cementitious Materials

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Mortar-ASTM C270

- Sand

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Mortar-ASTM C270

- Water

ASTM C270, 4.1.3 ***Water*****—**Water shall be clean and free of amounts of oils, acids, alkalies, salts, organic materials, or other substances that are deleterious to mortar or any metal in the wall.

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Mortar-ASTM C270

- Classified Admixtures C1384
  - Bond enhancers
  - Workability enhancers
  - Set accelerators, set retarders
  - Water repellents
- Color pigments C979

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Mortar-ASTM C270

- How should mortar be specified?
  - By Type
    - MaSoN WoRK
      - M-When very high compressive strength or durability resistance required
      - S-General use for higher seismic applications
      - N-General use for load-bearing masonry
      - O-For non-load bearing masonry
  - By Proportion ***OR*** Property
    - **This is significant since Specification Writers have a habit of listing BOTH!**

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Mortar-ASTM C270

- Mortar Specified by Proportion

ASM C270-19a TABLE 2 Proportion Specification Requirements

Mortar	Type	Proportions by Volume (Cementitious Materials)								Aggregate (Measured in Damp, Loose Conditions)
		Cement[A]	Mortar Cement			Masonry Cement			Hydrated Lime or Lime Putty	
			M	S	N	M	S	N		
Cement-Lime	M	1	-	-	-	-	-	-	¼	Not less than 2¼ and not more than 3 times the sum of the separate volumes of cementitious materials
	S	1	-	-	-	-	-	-	Over ¼ to ½	
	N	1	-	-	-	-	-	-	Over ½ to 1 ¼	
	O	1	-	-	-	-	-	-	Over 1 ¼ or 2 ½	
Mortar Cement	M	1	-	-	1	-	-	-	-	
	M	-	1	-	-	-	-	-	-	
	S	½	-	-	1	-	-	-	-	
	S	-	-	1	-	-	-	-	-	
	N	-	-	-	1	-	-	-	-	
	O	-	-	-	1	-	-	-	-	
Masonry Cement	M	1	-	-	-	1	-	1	-	
	M	-	-	-	-	-	-	-	-	
	S	½	-	-	-	-	-	1	-	
	S	-	-	-	-	-	1	-	-	
	N	-	-	-	-	-	-	1	-	
	O	-	-	-	-	-	-	1	-	

[A] Includes Specification C150, C595, and C1157 cements as described in 4.1.1.

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Mortar-ASTM C270

- Mortar Specified by Property

ASTM C270-14a TABLE 1 Property Specification Requirements[A]

Mortar	Type	Average Compressive Strength at 28 days, min. psi (MPa)	Water Retention min. %	Air Content, max. %	Aggregate Ratio (Measured in Damp, Loose Condition)
Cement-Lime	M	2500 (17.2)	75	12	Not less than 2¼ and not more than 3½ times the sum of separate volumes of the cementitious materials
	S	1800 (12.4)	75	12	
	N	750 (5.2)	75	14	
	O	350 (2.4)	75	14	
Mortar Cement	M	2500 (17.2)	75	12	
	S	1800 (12.4)	75	12	
	N	750 (5.2)	75	14	
	O	350 (2.4)	75	14	
Masonry Cement	M	2500 (17.2)	75	18	
	S	1800 (12.4)	75	18	
	N	750 (5.2)	75	20	
	O	350 (2.4)	75	20	

[A] Laboratory prepared mortar only (see Note 5)

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Mortar-ASTM C270

NOTE 5—The required properties of the mortar in Table 1 are for laboratory prepared mortar mixed with a quantity of water to produce a flow of 110 ± 5 %. This quantity of water is not sufficient to produce a mortar with a workable consistency suitable for laying masonry units in the field. Mortar for use in the field must be mixed with the maximum amount of water, consistent with workability, in order to provide sufficient water to satisfy the initial rate of absorption (suction) of the masonry units. The properties of laboratory prepared mortar at a flow of 110 ± 5, as required by this specification, are intended to approximate the flow and properties of field prepared mortar after it has been placed in use and the suction of the masonry units has been satisfied. **The properties of field prepared mortar mixed with the greater quantity of water, prior to being placed in contact with the masonry units, will differ from the property requirements in Table 1. Therefore, the property requirements in Table 1 cannot be used as requirements for quality control of field prepared mortar.** Test Method C780 may be used for this purpose.

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Mortar-ASTM C270

- Understanding mortar ASTM C270, Appendix X1.6.3.2

X1.6.3.2 Perhaps because of the previously noted confusion regarding mortar and concrete, the importance of compressive strength of mortar is overemphasized. Compressive strength should not be the sole criterion for mortar selection. Bond strength is generally more important, as is good workability and water retentivity, both of which are required for maximum bond. Flexural strength is also important because it measures the ability of a mortar to resist cracking. Often overlooked is the size/shape of mortar joints in that the ultimate compressive load carrying capacity of a typical 3⁄8 in. (9.5 mm) bed joint will probably be well over twice the value obtained when the mortar is tested as a 2 in. (50.8 mm) cube. Mortars should typically be weaker than the masonry units, so that any cracks will occur in the mortar joints where they can more easily be repaired.

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Mortar-ASTM C270

- Understanding mortar compressive strength requirements-ASTM C270
  - 1.4 "…not a specification to determine mortar strengths through field testing"
  - 3.2 "Property specification requirements…shall not be used to evaluate…"
  - Note 5 "…property requirements of Table 1 cannot be used…field prepared…"
  - 8.3 "..field sampled mortars are not required…to meet compressive strength…"

1. Scope
1.4 This standard is **not** a specification to determine mortar strengths through field testing (see Section 3).

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Mortar-ASTM C270

- Understanding mortar compressive strength requirements-ASTM C780
  - 1.4 "…test results…are not required to meet minimum compressive strength…"
  - 5.2.6 "Mortar compressive strength test values…not representative of actual…"
  - A6.1.1 "…values obtained through these testing procedures…not required…"
- Understanding mortar compressive strength requirements-ASTM C1586
  - 4.2 "…no measurement of mortar properties…is required…"
  - 4.3.2 "Do not use…Property Specifications…to evaluate construction mortars"
  - 5.5.3 "…site masonry mortar compressive strength…is not the appropriate test.."
  - 6.3 "…mortars measured …not required to meet the Property Requirements…"

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Mortar-ASTM C270

Excerpt from a Project Specification

2.02 G Mortar

1. Mortar shall be Type S in accordance with ASTM C270. Proportions (all parts by volume shall be one part, Type II Portland Cement; 1/2 part hydrated lime and 4 to 4-1/2 parts mortar sand. The mortar shall have a flow, after suction, of 70 percent or more when tested for water retention in accordance with ASTM C91 except mortar shall be mixed to an initial flow of 125 to 135 percent.
2. Minimum strength (psi at 28 days): 1800 p.s.i.

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Mortar-ASTM C270

- Mortar needs….
  - Workability
  - Strength
    - Bond strength
    - Compressive strength
  - Durability
  - Appearance
    - Color
    - Finish – Specified mortar joint

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Mortar-ASTM C270

- Workability
  - Unlike concrete, surplus water in mortar is a good thing
  - Trust the mason for how much is enough
  - Insufficient water will lead to a poor bond between mortar and masonry unit
    - Poor bond will lead to cracks between mortar and masonry unit
    - Cracks will lead to leaks
  - Surplus water will be absorbed by masonry unit
  - Absorption of water will assist bond between mortar and masonry unit

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Mortar-ASTM C270

- Strength
  - Bond Strength

Brick Industry Association (BIA) Tech Notes 8, *Mortars for Brickwork*
Flexural **bond strength** is perhaps the most important physical property of hardened mortar. For veneer applications, the bond strength of mortar to brick units provides the ability to transfer lateral loads to veneer anchors. For loadbearing applications, the bond influences the overall strength of the wall for resisting lateral and flexural loads.

  - Compressive Strength

Brick Industry Association (BIA) Tech Notes 8, *Mortars for Brickwork*
However, because **compressive strength** of masonry mortar is less important than bond strength, workability and water retention, the latter properties should be given principal consideration in mortar selection. The water/cement ratio of mortar as mixed in the field is reduced due to absorption of water by the adjacent brick.

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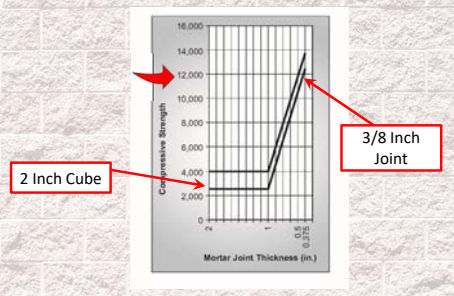
Mortar-ASTM C270

- How strong is a Mortar Joint?



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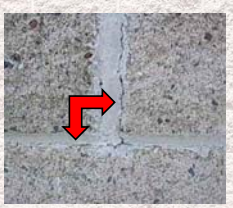
Mortar-ASTM C270

- Good bond between mortar and masonry unit minimizes cracking



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Mortar-ASTM C270

- Mortar is a plastic mixture of materials used to bind masonry units into a structural mass and is used for:
  - A bedding or seating material for the masonry units
  - Leveling and properly placing masonry units
  - Bonding the units together
  - Providing compressive strength
  - Providing shear strength, particularly parallel to the wall
  - Allowing some movement and elasticity between units
  - Sealing irregularities of the masonry units
  - Providing color to the wall by using color additives
  - Providing an architectural appearance by using various types of joints

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Mortar-ASTM C270

- Durability

Brick Industry Association (BIA) Tech Notes 8, *Mortars for Brickwork*
Portland cement, a hydraulic cement, is the principal cementitious ingredient for cement-lime mortar. It contributes to **durability**, high strength and early setting of the mortar.

The **durability** of mortar in unsaturated masonry is not a serious problem. The durability of mortar is shown in the number of masonry structures that have been in service for many years.
In general, mortar contains sufficient entrapped and entrained air to resist freeze-thaw damage.


University of Notre Dame (1879)


Monadnock Building
Chicago (1893)
17 Stories

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Mortar-ASTM C270

- Durability

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Mortar-ASTM C270

- Appearance
  - Color
  - Texture
  - Joint Finish
- Many factors affect mortar appearance, including the mix design, the water content of the mortar, the moisture content of the unit, the uniformity of the mix, and the tooling of the joints


Concave Tooled


Raked


Flush

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Mortar-ASTM C270

- Mortar Joints

Concave joint
Most common joint used, tooling works the mortar tight into the joint to produce a good weather joint. Pattern is emphasized and small irregularities in laying are concealed.

"V" joint
Tooling works the mortar tight and provides a good weather joint. Used to emphasize joints and conceal small irregularities in laying and provide a line in center of mortar joint.

Weather joint
Use to emphasize horizontal joints. Acceptable joint with proper tooling.

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Mortar-ASTM C270

- Mortar Joints

Raked joint
Strongly emphasizes joints. Poor weather joint – Not recommended if exposed to weather unless tooled at bottom of mortar joint.

Flush joint
Use where wall is to be plastered or where it is desired to hide joints under paint. Special care is required to make joint weatherproof.

Squeeze joint
Provide a rustic, high texture look. Satisfactory indoors and exterior fences. Not recommended for exterior building walls.

54

Mortar-ASTM C270

- Mortar Joints

Beaded joint
Special effect, poor exterior weather joint because of exposed ledge – Not recommended for exterior use.

Struck joint
Used to emphasize horizontal joints. Poor weather joint. Not recommended as water will penetrate on lower edge.

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Mortar-ASTM C270

- Methods of Preparation
  - Hand Mix
  - Traditional Mixer
  - Pre Blended Sack
  - Pre Blended Bulk

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Mortar-ASTM C270

- Mixing mortar

TMS 602, Article 2.6 A *Mortar*
1. Mix cementitious materials and aggregates between 3 and 5 minutes in a mechanical batch mixer with a sufficient amount of water to produce a workable consistency. Unless acceptable, do not hand mix mortar. Maintain workability of mortar by remixing or retempering. Discard mortar which has begun to stiffen or is not used within 2 1/2 hr after initial mixing.

ASTM C270, Section 7 Construction Practices
7.3 Mixing Mortars—All cementitious materials and aggregate shall be mixed between 3 and 5 min in a mechanical batch mixer with the maximum amount of water to produce a workable consistency. Hand mixing of the mortar is permitted with the written approval of the specifier outlining hand mixing procedures..

Paddle or Plaster Mixer

Drum or Concrete Mixer

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Mortar-ASTM C270

- What about retempering?

ASTM C270, Section 7 Construction Practices
7.4 Tempering Mortars—Mortars that have stiffened shall be retempered by adding water as frequently as needed to restore the required consistency. No mortars shall be used beyond 2 1/2 h after mixing.

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Mortar-ASTM C270

- Mixing mortar – Mortar color

TMS 602, Article 2.6 A.2		
Mortar Color Limit by Weight of Cement		
Pigment Type	Portland Cement-Lime Mortar	Masonry Cement or Mortar Cement Mortar
Mineral Oxide	10%	5%
Carbon Black	2%	1%

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Mortar-ASTM C270

- Inspecting Mortar

TMS 602, Table 3 – Minimum Verification Requirements			
Minimum Verification	**Required for Quality Assurance**		
	Level 1	**Level 2**	**Level 3**
Prior to construction, verification of compliance of submittals.	R	R	R
Prior to construction, verification of f'_m and f'_{AAC}, except where specifically exempted by the Code.	NR	R	R
During construction, verification of f'_m and f'_{AAC} for every 5,000 sq. ft. (465 sq. m).	NR	NR	R
During construction, verification of proportions of materials as delivered to the project site for premixed or preblended mortar, prestressing grout, and grout other than self-consolidating grout.	NR	NR	R

R = Required, NR = Not Required

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Mortar-ASTM C270

- Mortar - Inspection

Specified by Proportion

- Verify Volume of Materials
  - Pre-Blended Mortar
  - Site-Mixed Mortar

Specified by Property

- Verify (Test) Mortar Properties
  - Compressive Strength (psi)
  - Water Retention (%)
  - Air Content (%)

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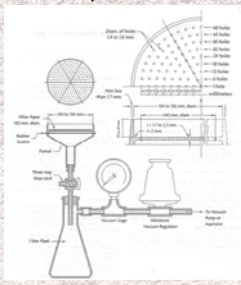
Mortar-ASTM C270

- Water Retention (ASTM C1506)



Apparatus Assembly for Water-Retention Test.

62

Mortar-ASTM C270

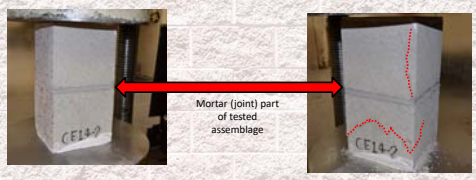
- Air Content (ASTM C270)
- $D = \frac{(W_1+W_2+W_3+W_4+V_w)}{\frac{W_1}{P_1}+\frac{W_2}{P_2}+\frac{W_3}{P_3}+\frac{W_4}{P_4}+V_w}$, $\quad A = 100 - \frac{W_m}{4D}$

Where:
D = density of air-free mortar, gm/cm³
W_1 = weight of Portland cement, g
W_2 = weight of hydrated lime, g
W_3 = weight of mortar cement or masonry cement, g
W_4 = weight of oven-dry sand, g
V_w = milliliters of water used, g
P_1 = density of Portland cement, g/cm³
P_2 = density of hydrated lime, g/cm³
P_3 = density of mortar cement or masonry cement, g/cm³
P_4 = density of oven-dry sand, g/cm³
A = Volume of air, %
W_m = weight of 400 ml. of mortar, g

63

Mortar-ASTM C270

- Note on mortar testing
  - When verifying f'_m by prism test, mortar is being tested (compression)



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Mortar-ASTM C270

- Mortar joint finish

TMS 602, Article 3.3 B *Placing mortar and units (Commentary)*
Normal construction practices can create mortar joints with minor imperfections and small voids that have no significant effect on the masonry assembly. Mortar joints on the face of masonry need to be filled to provide the specified mortar joint finish.

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Mortar-ASTM C270

- Mortar joint finish

Industry Definition
Pointing – Filling (troweling) mortar into a joint after the masonry unit is laid.

The Masonry Glossary, International Masonry Institute, 1981
Reinforced Concrete Masonry Construction Inspectors Handbook, Masonry Institute of America, 2017

- The difference between 'perfect' and acceptable'

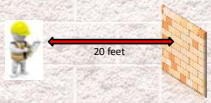
66

Mortar-ASTM C270

- What is reasonable acceptance?
  - Reasonable to use ASTM C90 or ASTM C216

ASTM C90 (CMU) Section 7, *Finish and Appearance*
7.2 Where units are to be used in exposed wall construction, the face or faces that are to be exposed shall not show chips or cracks, not otherwise permitted in 7.1.2 and 7.1.3, or other imperfections when viewed from a distance of not less than 20 ft (6.1 m) under diffused lighting.

ASTM C216 (Clay Brick) Section 10, *Finish and Appearance*
10.1.1 Other than chips, the face or faces shall be free of cracks or other imperfections detracting from the appearance of the designated sample when viewed under diffused lighting from a distance of 15 ft (4.6 m) for Type FBX and a distance of 20 ft (6.1 m) for Types FBS and FBA.



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GROUT

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Grout-ASTM C476

- What is Masonry Grout?
  - Grout is a high slump cementitious material (like concrete) concrete used to fill voids in the masonry unit cells or cavities to bind together the masonry units, mortar, and reinforcement into a single composite assemblage.
- Grout is – soupy concrete with small rocks (pea gravel)


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Grout-ASTM C476

- Why bother to grout masonry walls?
  - Plain masonry has been working just fine
  - Joint reinforcement works well
  - Grout and reinforcing steel make masonry too expensive


- As we evolve, we find that
  - Grouted masonry is becoming more of a code requirement
    - Seismic, Wind and Resilience
  - Grouted masonry walls can be thinner
  - Grouted masonry walls can be taller
  - Grouted masonry walls are safer

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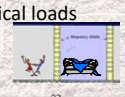
Grout-ASTM C476

- Why use masonry grout?
  - Ties reinforcement and masonry together
  - Provides more cross-sectional area for vertical loads
  - Increases Fire Rating
  - Increases Sound Transmission Coefficient
  - Adds mass for thermal efficiency
  - Adds weight to resist overturning
  - Increases shear resistance
  - Makes concealed masonry lintels possible



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Grout-ASTM C476

- Masonry Grout – Materials

Concrete	Masonry Grout
– Sand	– Sand
– Gravel (1” Rock)	– Gravel (3/8” Pea)
– Cement	– Cement
– Water (Minimum)	– Water (Maximum)
– Admixtures	– Admixtures


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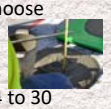
Grout-ASTM C476

- ASTM C 476, *Standard Specification for Grout for Masonry*
  - Types of Grout
    - Fine (Sand) Grout
    - Coarse (Pea gravel) Grout
  - Conventional Grout-Slump 8 to 11 inches (Choose one)
    - Specified by proportions of ingredients ***or***
    - Specified by compressive strength
  - Self-consolidating grout-Grout slump flow 24 to 30 inches, VSI = 0 or 1
    - Specified by compressive strength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Grout-ASTM C476

- Grout specified by strength-greater of:
  - At least 2,000 psi or
  - At least masonry design strength f'_m
- Grout specified by proportion – ASTM C476, Table 1

Type	Parts by volume of Portland Cement of Blended Cement	Parts by Volume of Hydrated Lime of Lime Putty	Aggregate Measured in a Damp, Loose Condition	
			Fine	Coarse
Fine grout	1	0 – 1/10	2 ¼ - 3 times the sum of the volume of the cementitious materials	---
Coarse grout	1	0 – 1/10	2 ¼ - 3 times the sum of the volume of the cementitious materials	1 - 2 times the sum of the volume of the cementitious materials

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Grout-ASTM C476

- Portland Cement *n.* - a hydraulic cement made by finely pulverizing the clinker produced by calcining to incipient fusion a mixture of clay and limestone or similar materials

75

Grout-ASTM C476

- Cementitious Materials – Cement Substitutes
  - Fly ash *n.* - fine solid particles of ashes, dust, and soot carried out from burning fuel (such as coal or oil) by the draft
  - Slag (Ground granulated blast furnace) *n.* - the dross or scoria of a metal


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Grout-ASTM C476

- Fly ash and Slag have been used as Portland cement substitute, but how much can we substitute?
- Actually, quite a bit


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Grout-ASTM C476

- Self Consolidating Grout

Preparing SCG for Testing

T50 Test
Spread Within 2 to 5 Seconds

Checking SCG Spread
And Visual Stability

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Grout-ASTM C476

- Self Consolidating Grout

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Grout-ASTM C476

- Visual Stability Index

VSI Rating	Properties	Stability
0	No Bleed Water Na Material Segregation	Stable
1	Slight Bleed Water No Material Segregation	
2	Bleed Water Present Slight Material Segregation	Unstable
3	Significant Bleed Water Material Segregation	

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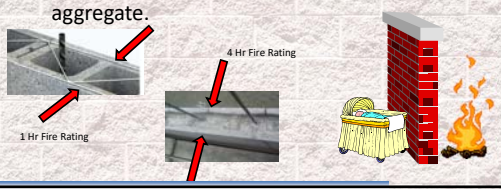
Grout-ASTM C476

- Increased Fire Rating
  - An ungrouted 8 in. hollow concrete block wall has a fire rating of approximately one hour, depending on the aggregate. A solid grouted wall 6 in. thick may have a four-hour rating, depending on the aggregate.



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Grout-ASTM C476

- Fire rating

IBC TABLE 721.1(2) – RATED FIRE-RESISTANCE PERIODS FOR VARIOUS WALLS AND PARTITIONS

MATERIAL	ITEM NUMBER	CONSTRUCTION	MINIMUM FINISHED THICKNESS FACE-TO- FACE (Inches)			
			4 hours	3 hours	2 hours	1 hour
3. Concrete Masonry Units	3-1.1	Expanded slag or pumice	4.7	4.0	3.2	2.1
	3-1.2	Expanded clay, shale or slate	5.1	4.4	3.6	2.6
	3-1.3	Limestone, cinders or air-cooled slag	5.9	5.0	4.0	2.7
	3-1.4	Calcareous or siliceous gravel	6.2	5.3	4.2	2.8

UL 618, Table 4A.1—Thickness, material and strength requirements

Type of aggregate	Manufacturing process	Equivalent thickness, Hourly rating		
		2 hr	3 hr	4 hr
Expanded clay, shale, slate	Rotary kiln process	3.6	4.4	5.1
Expanded clay, shale, slate	Sintered process	4.2	4.75	5.4
Expanded slag	Blast furnace	4.1	4.8	5.3
Natural by products		4.2	5.5	6.5

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Grout-ASTM C476

- Things to Consider About Masonry Grout
  - Grout Space
  - Grouting Height
  - Grout Strength
  - Grout Mix Design-Fluidity
  - Partially or Fully Grouted
  - Consolidation and Reconsolidation

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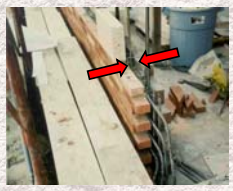
Grout-ASTM C476

- Grout Space
  - Grout Type – Fine or Coarse?



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Grout-ASTM C476

- Placement of reinforcing steel
  - Legacy codes required restraint at 112, 192 and 200 d_b

TMS 602-08, Article 3.6 B *Reinforcement*
1. Support and fasten reinforcement together to prevent displacement beyond the tolerances allowed by construction loads or by placement of grout or mortar.

TMS 602-11, Article 3.6 B *Reinforcement*
1. Support reinforcement to prevent displacement caused by construction loads or by placement of grout or mortar, beyond the allowable tolerances.



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Grout-ASTM C476

- Grout Method
  - Low Lift (Up to 5'-4"/No cleanouts)
  - High Lift (Up to 24' with cleanouts)

86

Grout-ASTM C476

- Low Lift or High Lift – Who Decides?
  - Code does not care
  - May be in the project documents
  - Contractor may have a preference
- What does the Code say?

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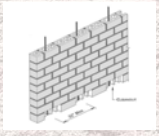
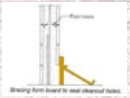
Grout-ASTM C476

- When high-lift grouting, cleanouts are required for grouted cell access
  - Solidly grouted-Maximum 32" o.c (Trick-Invert Bond Beam CMU for access)
  - Partially grouted-As needed



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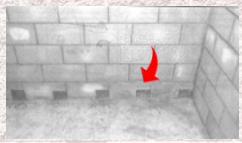
Grout-ASTM C476

- Even though cleanouts can be smaller, removing and replacing full face shells works well

TMS 602-08, Article 3.2 F *Cleanouts*
2. Construct cleanouts with an opening of sufficient size to permit removal of debris. The minimum opening dimension shall be 3 in. (76.2 mm).

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Grout-ASTM C476

- TMS 602, Table 6

Table 6 – Grout space requirements

Grout Type	Maximum grout pour height, ft (m)	Minimum clear width of grout space[3], in. (mm)	Minimum clear grout space dimensions for grouting cells of hollow units[3], in. x in. (mm x mm)
Fine	1 (0.30)	¾ (19.1)	1 ½ x 2 (38.1 x 50.8)
Fine	5.33 (1.63)	2 (50.8)	2 x 3 (50.8 x 76.2)
Fine	12.667 (3.86)	2½ (63.5)	2 ½ x 3 (63.5 x 76.2)
Fine	24 (7.32)	3 (76.2)	3 x 3 (76.2 x 76.2)
Coarse	1 (0.30)	1½ (38.1)	1 ½ x 3 (38.1 x 76.2)
Coarse	5.33 (1.63)	2 (50.8)	2 ½ x 3 (63.5 x 76.2)
Coarse	12.667 (3.86)	2½ (63.5)	3 x 3 (76.2 x 76.2)
Coarse	24 (7.32)	3 (76.2)	3 x 4 (76.2 x 102)

[3] Minimum clear width of grout space and minimum clear grout space dimension are the net dimension of the space determined by subtracting masonry protrusions and the diameters of horizontal bars from the as-built cross section of the grout space. Select the grout type and maximum grout pour height based on the minimum clear space.

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Grout-ASTM C476

- TMS 602, Article 3.5 D

3.5 D. *Grout lift height*
1. For grout conforming to Article 2.2 A:
   a. Where the following conditions are met, place grout in lifts not exceeding 12 ft 8 in. (3.86 m).
      i. The masonry has cured for at least 4 hours.
      ii. The grout slump is maintained between 10 and 11 in. (254 and 279 mm).
      iii. No intermediate reinforced bond beams are placed between the top and the bottom of the pour height.
   b. When the conditions of Articles 3.5 D.1.a.i and 3.5 D.l.a.ii are met but there are intermediate bond beams within the grout pour, limit the grout lift height to the bottom of the lowest bond beam that is more than 5 ft 4 in. (1.63 m) above the bottom of the lift, but do not exceed a grout lift height of 12 ft 8 in. (3.86 m).
   c. When the conditions of Article 3.5 D.l.a.i or Article 3 .5 D. l.a.ii are not met, place grout in lifts not exceeding 5 ft 4 in. (1.63 m).
2. For self-consolidating grout conforming to Article 2.2…….

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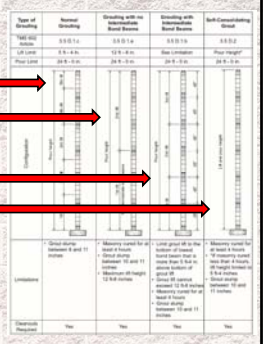
Grout-ASTM C476

- Traditional grouting
- 12’8” Lift Grouting
- 12’8” Lift Grouting-Modified
  - Intermediate Bond Beams
- Self Consolidating Grout



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Grout-ASTM C476

- Typical job specifications

D. Grouting: Fill in all cells with grout. Pour in 5 ft – 4 in. lifts, waiting about a-hour between lifts. Pour full height in each section of the wall in one work shift. Consolidate grout by puddling or internal vibration, then reconsolidate about 10 minutes later before plasticity is lost. Form horizontal construction joints by stopping the grout pour 1-1/2" below top of masonry units. High lift grout placement may be used at Contractors option as approved and according to Code.

F. Submit which method of grouting is to be used for masonry work: low-lift or high-lift.

I. Grouting:
4. Fill cells solidly with grout in lifts not to exceed 5’-4” unless clean-outs are provided.

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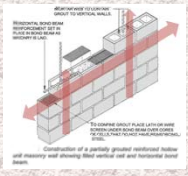
Grout-ASTM C476

- Walls may be partially or fully grouted
  - Fully grouted means fill all cells with grout
  - Partially grouted means fill only cells containing reinforcement



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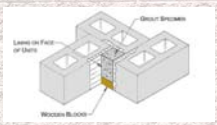
Grout-ASTM C476

- With all the water, how is grout tested?
  - Replicate grout as if it were in the wall
  - ASTM C1019 provides guidance



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Grout-ASTM C476

- Create mold
- Place grout in 2 layers
- Rod each layer 15 times
- Cover and keep moist
- Take to lab 24 to 48 hours

96

Grout-ASTM C476

- Lab keeps grout specimens in controlled environment
  - Cap and test at 28 days

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Grout-ASTM C476

- Unlike Concrete, Surplus Water is Essential

	Concrete	CMU	Mortar	Grout
Materials	Cement, Aggregates, Water, Admixtures, Lime			
Aggregate Size	< 1"	< 3/8"	< #8 Fine Masonry Sand	Coarse: <3/8" Fine: < #4 (Concrete Sand)
Consistency	3 - 6 in. Pourable, Stiff	No Slump	Sticky	8 -11 in. Pourable, Runny
Preparation	Barrell Mixer or Truck	Mixer, vibrated into form	Paddle Mixer	Barrell Mixer or Truck

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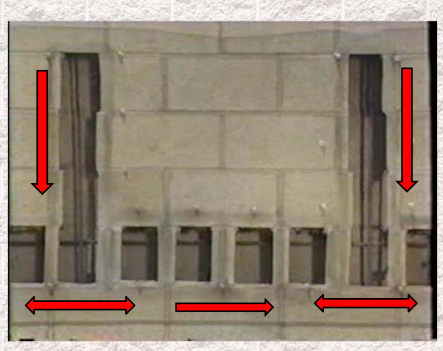
Grout-ASTM C476

- Unlike concrete, surplus water is needed so that grout can easily flow into restricted cells and cavities
- Excess water is immediately absorbed into masonry units

99

Grout-ASTM C476



100

Grout-ASTM C476

- Low-Lift Grouting
  - Maximum lift is 5 ft-4 in.
  - No cleanouts are required
  - Grout wall as it is built
  - The inspector can visually check to see that the bottom of the cells are clean and free of excessive mortar protrusions, and verify the reinforcing steel location, all before grouting since the height of the pour is 5 ft-4 in. or less. Low lift grouting walls gain strength as they are built and grouted.

101

Grout-ASTM C476

- High-Lift Grouting
  - Build masonry wall up to 24 feet before grouting
  - Cleanouts are required
  - Reinforcement must be positioned within tolerances
  - Place grout in lifts up to 5 ft-4 in.
    - Lifts up to 12 ft-8 in. allowed if no intermediate bond beams, 4 hr. cure & high slump
    - Up to full height for self consolidating grout if masonry has cured for at least 4 hours
  - Delay between lifts to allow water to be absorbed by the masonry unit. A minimum 5 minute delay is recommended

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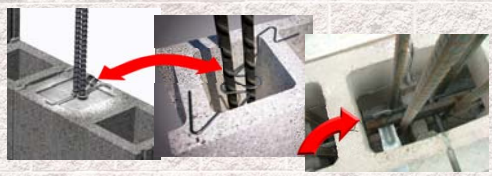
Grout-ASTM C476

- Securing reinforcement



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Grout-ASTM C476

- The key element to successful grouting
  - **Consolidate**
  - **Reconsolidate**
- To compact and solidify the grout
- To compact the grout after water is absorbed into the masonry
- To consolidate any cracks or pull away due to settlement of grout

104

Grout-ASTM C476

- Grout consolidation

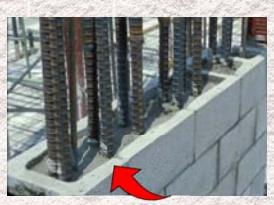
Use mechanical vibrator when grout lift is greater than 1 foot

May puddle with a stick for grout lift up to 1 foot

105

Grout-ASTM C476

- Grout will sink with loss of water



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Grout-ASTM C476

Inadequate Consolidation

- Serious bell-shape cracks

Correct Consolidation

- Uniform crack-free cross section

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Grout-ASTM C476

- Grouting Alternatives

TMS 402, Section 3.2 – Construction considerations

3.2.1 *Grouting, minimum spaces*

The minimum dimensions of spaces provided for the placement of grout shall be in accordance with Table 3.2.1. Grout pours with heights exceeding those shown in Table 3.2.1, collar joint widths, or cell sizes smaller than those permitted in Table 3.2.1 or grout lift heights exceeding those permitted by Article 3.5 D of TMS 602 are permitted if the results of a grout demonstration panel show that the grout spaces are filled and adequately consolidated. In that case, the procedures used in constructing the grout demonstration panel shall be the minimum acceptable standard for grouting, and the quality assurance program shall include inspection during construction to verify grout placement.

TMS 602, Section 1.6 Quality assurance

1.6 E. *Grout demonstration panel* — Prior to masonry construction, construct a grout demonstration panel if proposed grouting procedures, construction techniques, or grout space geometry do not conform to the applicable requirements of Articles 3.5 C, 3.5 D, and 3.5 E.

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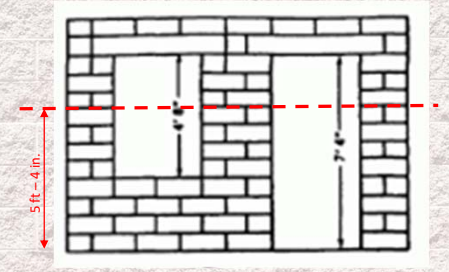
Grout-ASTM C476

- Grouting Alternatives



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Grout-ASTM C476

- Poor grouting can have disastrous results

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Summary

- Concrete Masonry Units
  - ASTM C90 – Increased Strength
  - Watch for Specified Grade/Type – NO!!
  - Watch for Specified Minimum Web Connection
- Clay Brick
  - Mostly Veneer Application
  - Veneer Not Considered Structural

Avoid Overspecifying

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Summary

- Mortar
  - Should be Specified by **ONE** of the Following
    - Proportion
    - Property
  - When by Proportion, Field Testing is not Appropriate Unless…….
    - Preconstruction Mortar is Tested and Only for Comparative Values, Not Absolute Values (Listed in ASTM C270, Table 2)

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Summary

- Grout
  - Masonry's 'Ace-In-The-Hole'
  - Can Substitute Much More Fly Ash and Slag than Concrete **Green-Green-Green**
    - Saves Energy with Less Portland Cement Required
    - Recycles Waste from Other Industries
    - May Need Extra Cure Time
  - SCG Properties without all the Chemistry

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