

How the Masonry Code affects Design and Construction

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CULLEN COLLEGE OF ENGINEERING
CIVIL AND ENVIRONMENTAL ENGINEERING

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The Masonry Society - TMS

TMS-The Masonry Society

- Formed in 1977
- Not quite as well known
- Staff of 3
- Custodian of Masonry Standard
- ANSI Accredited



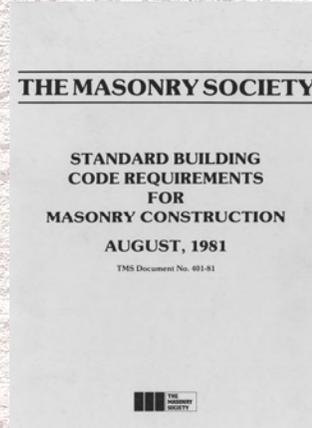
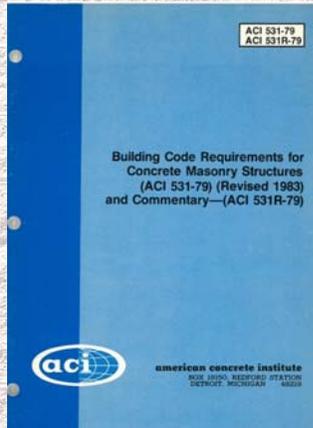
ACI-American Concrete Institute

- Formed in 1907
- Very well known
- Staff of 30
- Custodian of Concrete Standard
- ANSI Accredited



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Once Upon a Time

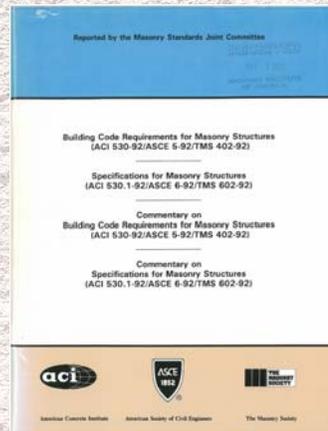
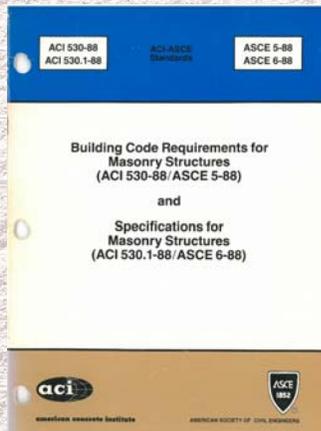


1979 – ACI Publishes a Concrete Masonry Standard

1981 – TMS Publishes a Masonry Standard

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Making Some Progress

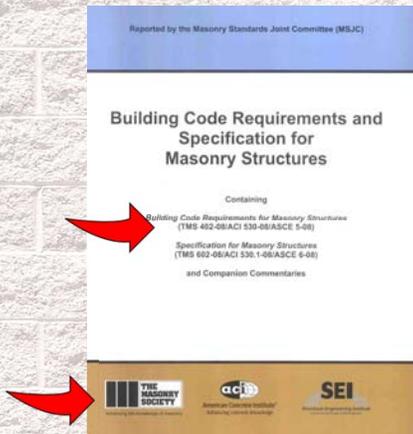


1988 – ACI/ASCE Masonry Standard-Still no TMS

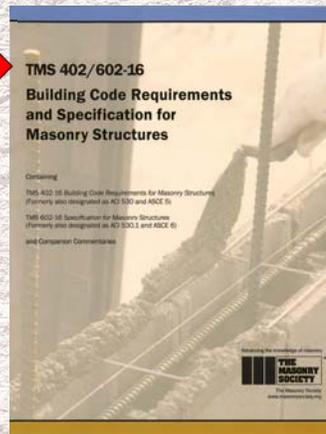
1992 – TMS Finally Recognized

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Then and Now



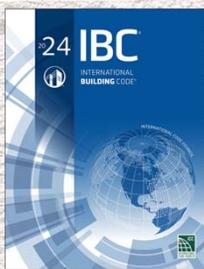
2008 – Big Break-TMS gets First Billing



2016 – BIGGER Break-ACI/ASCE Dropped Out

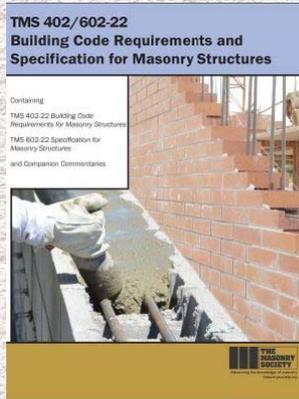
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Let's Start with the Building Code



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TMS 402/602 – What Is It?



Code – 402 (Designer)

Specification – 602 (Contractor)

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The Code Part (402-22)

- 1 – General Requirements
- 2 – Notations and Definitions
- 3 – Quality and Construction
- 4 – General Analysis and Design
- 5 – Structural Members
- 6 – Reinforcement and Metal
- 7 – Seismic Requirements
- 8 – Allowable Stress Design
- 9 – Strength Design
- 10 – Prestressed Masonry
- 11 – Autoclaved Aerated Masonry
- 12 – Masonry Infills
- 13 – Veneer
- 14 – Glass Unit Masonry
- 15 – Partition Walls
- A and B – Not Used
- C – Limit Design Method
- D – Glass Fiber Reinforced

Part 1

Part 2

Part 3

Part 4

Part 5

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The Specification Part (602-22)

TMS 602 Specification Format

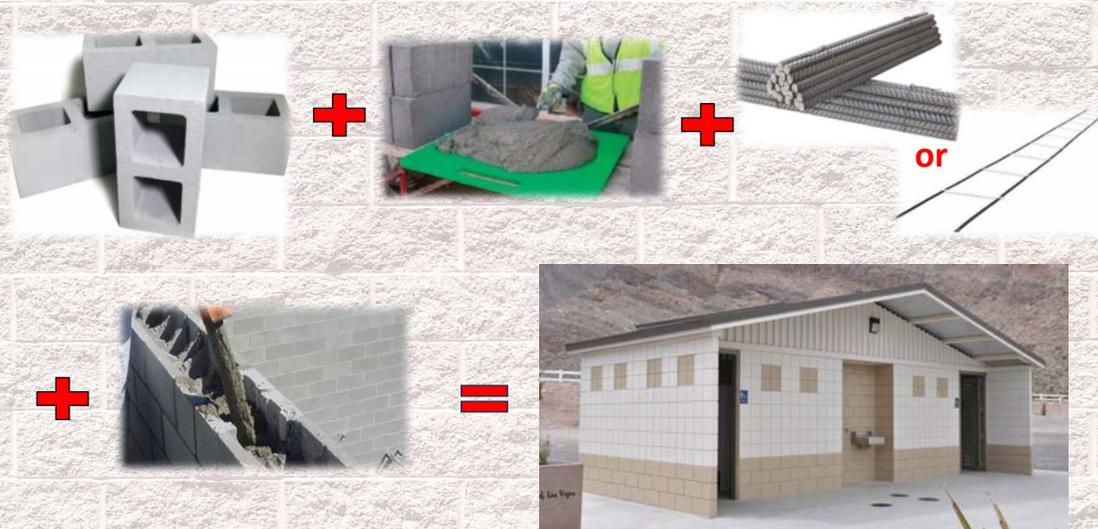
- Part 1 – General
- Part 2 – Products
- Part 3 – Execution

CSI Format

- Part 1 – General
- Part 2 – Products
- Part 3 – Execution

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The Materials



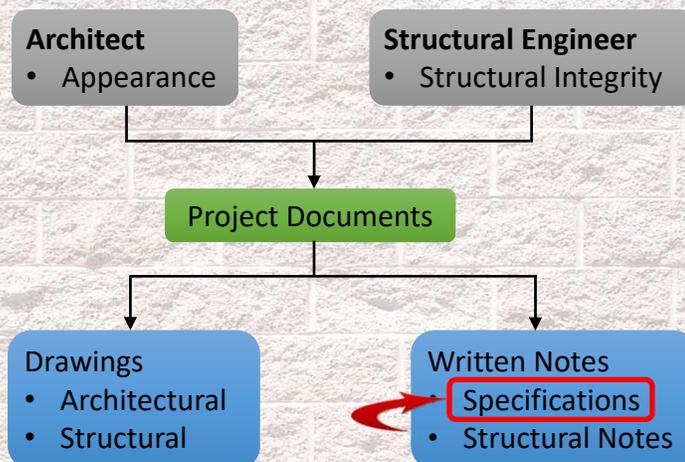
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Specification

- Why should Designer care?
 - Code reflects minimum design requirements (Quality Assurance)
 - Specification reflects minimum construction requirements (Quality Control)
 - Each needs to be NO LESS than Code/Specification requirements
- Designers want assurance that construction meets the minimum Specification requirements
- **Aesthetics**
- **Structural Performance**

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Quality Assurance Relationship

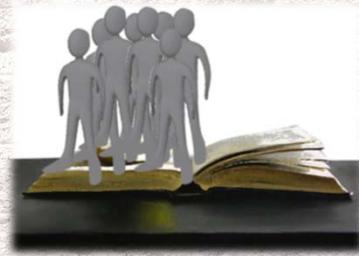


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Proactive Communication

- Preconstruction Meeting

- Architect
- Engineer
- General Contractor
- Subcontractor
- Testing Agency
- Inspection Agency
- Material Suppliers



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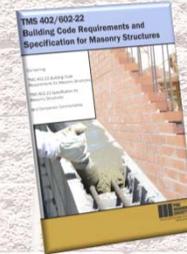
Quality Control

- What is the difference between Quality Assurance (from the Code) and Quality Control (from the Specification)?
- Why do we need either one?
- Assuming we do, how do we effectively implement a program?
- Will it cost?
- How does it help?

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Quality Assurance

- Code Requirements
 - (TMS 402 Code Section 2.2 and TMS 602 Specification, Article 1.2)
Quality Assurance—The administrative and procedural requirements established by the Contract Documents to assure that constructed masonry is in compliance with the Contract Documents



The Plan

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Quality Control

- Code Requirements
 - **Quality Control**—Not code-defined.
 - “A system for ensuring the maintenance of proper standards in manufactured goods, especially by periodic random inspection of the product.” (American Heritage Dictionary, 2006; www.thefreedictionary.com 2015)

Implementation of The Plan

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TMS 402/602 Code & Specification

- And Where are QA/QC Provisions?
Code (TMS 402-22)
 - CHAPTER 3 — Quality and Construction

Table 3.1 Minimum Quality Assurance Level

Designed in accordance with	Risk Category I, II or III	Risk Category IV ↓
Part 3 or Appendix C or Appendix D	Level 2	Level 3
Part 4	Level 1	Level 2

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TMS 402/602 Code & Specification

- And Where are QA/QC Provisions?
Specification (TMS 602-22)
 - ARTICLE 1.6 — Quality Assurance

Table 3: Minimum Verification Requirements

Minimum Verification	Required for Quality Assurance ↓			Reference for Criteria TMS 602
	Level 1	Level 2	Level 3	
Prior to construction, verification of compliance of submittals	R	R	R	Art. 1.5

(Table truncated)

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TMS 402/602 Code & Specification

- And Where are QA/QC Provisions?

Specification (TMS 602-22)

- ARTICLE 1.6 — Quality Assurance

Table 4: Minimum Special Inspection Requirements

MINIMUM SPECIAL INSPECTION					
Inspection Task	Frequency			Reference for Criteria	
	Level 1	Level 2	Level 3	TMS 402	TMS 602
1. As masonry construction begins, verify that the following are in compliance					
a. Proportions of site prepared mortar	NR	P	P		Art 2.1 & 2.6 A & C

(Table truncated)

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TMS 402/602 Code & Specification

- Assuming Design or Prescriptive Requirements are Satisfied, What is Structurally Important?
 - Materials (Quality/Conformance to Standards)
 - Proper Installation



Location of Reinforcing Steel and Joint Reinforcement

Grouting Process



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Tolerances

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Tolerances – ASTM C90

6. Permissible Variations in Dimensions

6.1 *Standard Units*—For standard units, no overall dimension (width, height, and length) shall differ by more than $\pm 1/8$ in. (3.2 mm) from the specified dimensions.

6.2 *Particular Feature Units*—For particular feature units, dimensions shall be in accordance with the following:

6.2.1 For molded face units, no overall dimension (width, height, and length) shall differ by more than $\pm 1/8$ in. (3.2 mm) from the specified standard dimension. Dimensions of molded features shall be within $\pm 1/16$ in. (1.6 mm) of the specified standard dimensions and shall be within $\pm 1/16$ in. (1.6 mm) of the specified placement of the molded feature.

NOTE 9—Molded features include, but are not limited to: ribs, scores, hex-shapes, and patterns.

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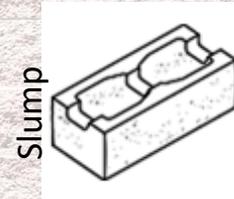
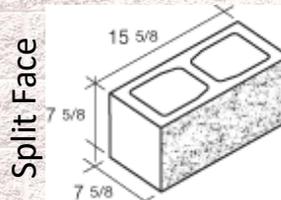
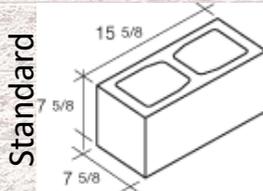
Tolerances – ASTM C90

6. Permissible Variations in Dimensions

6.2.2 For split-faced units, all non-split overall dimensions shall differ by not more than $\pm 1/8$ in. (3.2 mm) from the specified standard dimensions.

6.2.3 For slump units, no overall height dimension shall differ by more than $\pm 1/8$ in. (3.2 mm) from the specified standard dimension.

NOTE 10—On faces that are split or slumped, overall dimensions will vary. Consult with suppliers to determine achievable dimensional tolerances for products including these features.



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Tolerances – TMS 602

- Tolerances contained in TMS 602 Specification are based on structural requirements (eccentricities) for performance, not aesthetics. It is, however, reasonable to use these tolerance values for acceptance of the project. Consideration must also be given to the ASTM distance viewing requirements for aesthetic acceptance.

TMS 602 Specification, Article 3.3 G

3.3 G. Site Tolerances – Erect masonry within the following tolerances from the specified dimensions.

1. Dimension of elements

a. In cross section or elevation

..... $-1/4$ in. (6.4 mm), $+1/2$ in. (12.7 mm)

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Tolerances

TMS 602 Specification, Article 3.3 G

3.3 G. *Site Tolerances* – Erect masonry within the following tolerances from the specified dimensions.

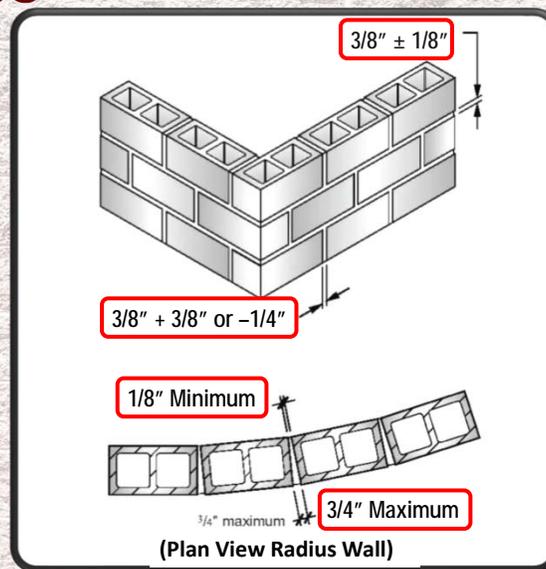
1. Dimension of elements

b. Mortar joint thickness

bed.....	$\pm 1/8$ in. (3.2 mm)
head.....	$-1/4$ in. (6.4 mm), $+ 3/8$ in. (9.5 mm)
collar.....	$-1/4$ in. (6.4 mm), $+ 3/8$ in. (9.5 mm)

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Tolerances



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Tolerances



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But Don't Forget ASTM C90

7. Finish and Appearance

7.1 No more than 5% of the units in the shipment shall exhibit one or more of the characteristics described in 7.1.1 through 7.1.4 and 7.2.

7.1.1 Units with dimensions not meeting the requirements of 6.1.

7.1.2 Units with finished face(s) containing chips larger than 1 in. (25.4 mm) in any direction.

7.1.3 Units with finished face(s) containing cracks wider than 0.02 in. (0.5 mm) and longer than 25 % of the nominal height of the unit.

7.1.4 Units that are broken.

NOTE 11—Units specified to have particular features or finishes, such as split-face and tumbled units, should not be evaluated for conformance of such features to the requirements of 7.1.2.

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.

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Tolerances

- Before we go on to Reinforcement tolerances, lets review visual acceptance?



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Tolerances

TMS 602, Article 3.3 G

3.3 G. Site Tolerances – Erect masonry within the following tolerances from the specified dimensions.

2. Elements

a. Variation from level:

bed joints

..... $\pm 1/4$ in. (6.4 mm) in 10 ft. (3.05 m)

..... $\pm 1/2$ in. (12.7 mm) maximum

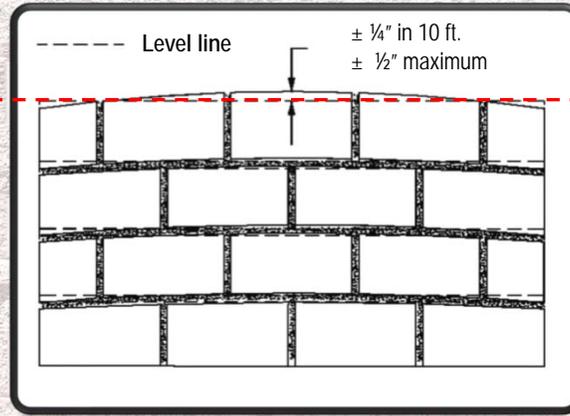
top surface of bearing walls

..... $\pm 1/4$ in. (6.4 mm) in 10 ft. (3.05 m)

..... $\pm 1/2$ in. (12.7 mm) maximum

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Tolerances



Permissible variation from level for bed joints.

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Tolerances

TMS 602, Article 3.3 G

3.3 G. Site Tolerances – Erect masonry within the following tolerances from the specified dimensions.

2. Elements

b. Variation from plumb

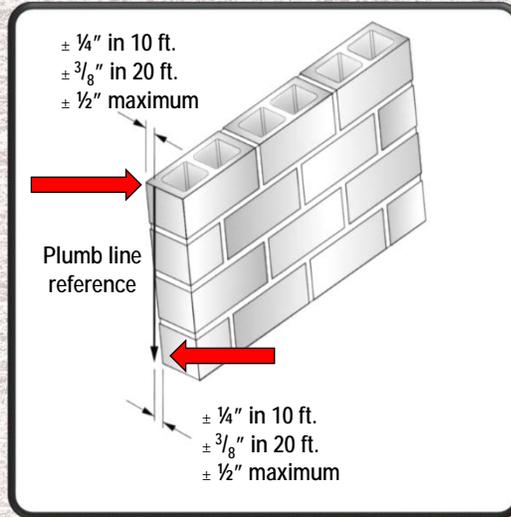
..... $\pm 1/4$ in. (6.4 mm) in 10 ft. (3.05 m)

..... $\pm 3/8$ in. (9.5 mm) in 20 ft. (6.10 m)

..... $\pm 1/2$ in. (13 mm) maximum

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Tolerances



Permissible variation from plumb.

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Tolerances

TMS 602, Article 3.3 G

3.3 G. Site Tolerances – Erect masonry within the following tolerances from the specified dimensions.

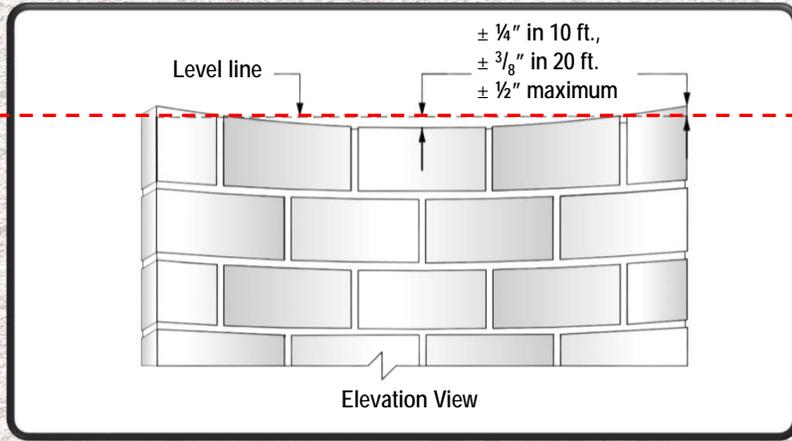
2. Elements

c. True to a line

- $\pm \frac{1}{4}$ in. (6.4 mm) in 10 ft. (3.05 m)
- $\pm \frac{3}{8}$ in. (9.5 mm) in 20 ft. (6.10 m)
- $\pm \frac{1}{2}$ in. (12.7 mm) maximum

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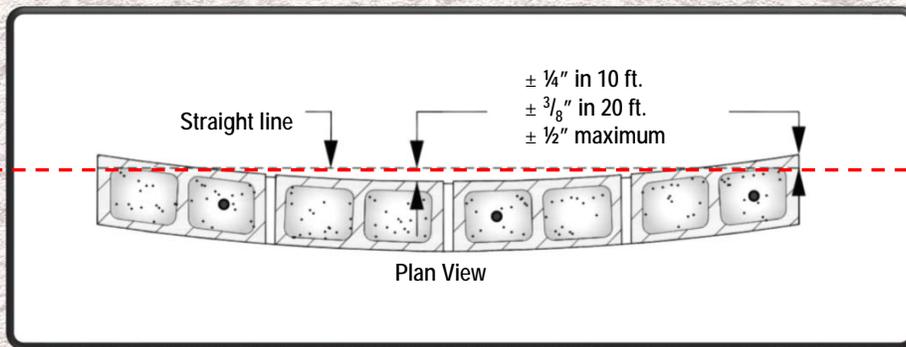
Tolerances



Permissible variation from true to line.

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Tolerances



Permissible variation from true to line.

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Reinforcement Tolerances

TMS 602, Article 3.4 B

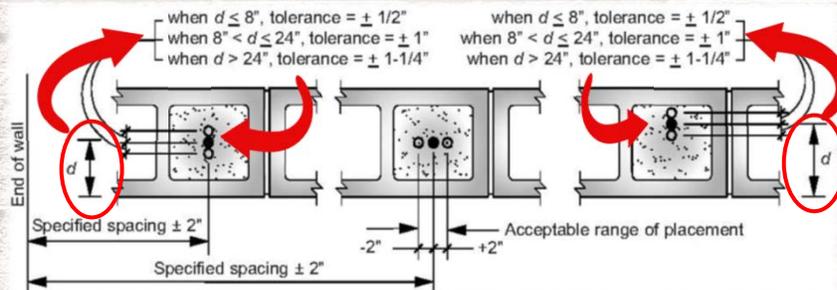
8. Placement tolerances

- a. Tolerances for the placement of reinforcing bars in walls and flexural elements shall be $\pm 1/2$ in. (12.7 mm) when the distance from the centerline of reinforcing bars to the opposite face of masonry, d , is equal to 8 in. (203 mm) or less, ± 1 in. (25.4 mm) for d equal to 24 in. (610 mm) or less but greater than 8 in. (203 mm), and $\pm 1 1/4$ in. (31.8 mm) for d greater than 24 in. (610 mm).
- b. Place vertical bars within 2 in. (50.8 mm) of the required location along the length of the wall.

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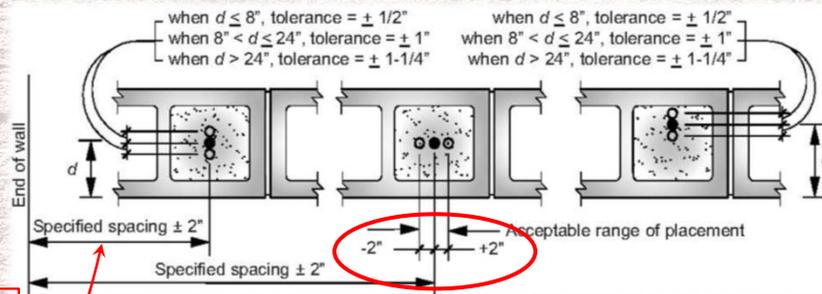
Reinforcement Tolerances

Distance (d) from face of CMU to center of reinforcing (in)	Allowable Tolerance (in)
$d \leq 8$	$\pm 1/2$
$8 < d \leq 24$	± 1
$d > 24$	$\pm 1-1/4$



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Reinforcement Tolerances

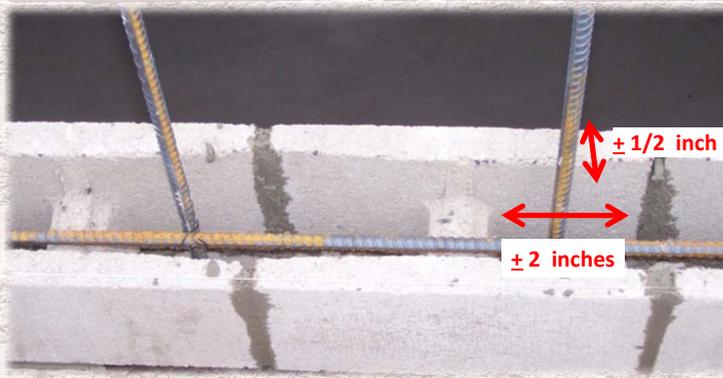


Within 24 inches
from end of wall,
 ± 1 inch



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Reinforcement Tolerances



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Grouting



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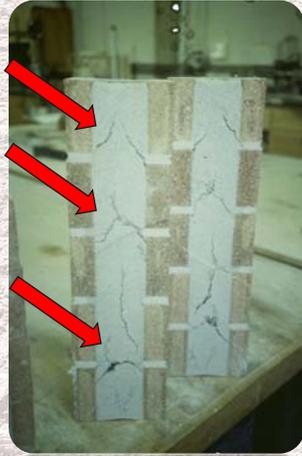
Grouting

- Vibrate
 - ...to compact and solidify the grout
 - ...to compact the grout after the water is absorbed into the masonry
 - ...to consolidate any cracks or pull away from the unit due to settlement of the grout



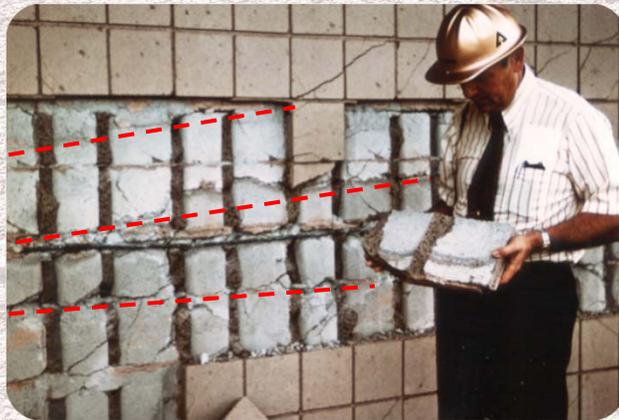
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Grouting



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Grouting



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Some considerations for Guidelines and Resources to Develop a Plan

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Guidelines and Resources

- General
 - Specify the Quality Assurance Level Required
 - Provide site access to the Testing and Inspection Agency
 - Advise the Testing Agency in advance to facilitate the required sampling of materials
 - Cooperate with the Testing and Inspection Agency for the appropriate level of inspection (Level 1, Level 2 or Level 3)
 - Who will be responsible for this?

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Guidelines and Resources

- Materials
 - Certificates of Compliance for Masonry Units, Mortar and Grout
 - Any material required for sampling and testing
 - Comply with the applicable requirements of Specification for Masonry Structures, Part 2, Products
 - Who will be responsible for this?

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Guidelines and Resources

- Installation
 - Install masonry units within the tolerances of Specification for Masonry Structures Article 3.3 G
 - Install masonry reinforcement within the tolerances of Specification for Masonry Structures, Article 3.4 B
 - Comply with the applicable requirements of Specification for Masonry Structures, Part 3, Execution
 - Who will be responsible for this?

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Guidelines and Resources

- Where else to go?
 - The Masonry Society (www.masonrysociety.org)
 - Inspection Checklist
 - Masonry Institute of America (www.masonry.pro)
 - Concrete Masonry Inspectors Handbook
 - Concrete Masonry Association of California and Nevada (www.cmacn.org)
 - Various Technical Resources
 - National Concrete Masonry Association (www.ncma.org)
 - Technical Notes Series 3 and 18

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Significant Issues

Some final thoughts

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Significant Issues

- What's Important?
 - Communicating the Intent of Contract Documents
 - Adequate Plans/Specifications
 - Correct Material
 - Reinforcement Placement
 - Reasonable Cleanliness of Cells
 - Grouting Process
 - Construction Extremes (Temperature)
 - Use these points to develop the QA Program

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Elements of a QC Program

- Materials
 - Provide Certificates of Compliance for masonry units, mortar, grout and any other required materials
 - Provide materials for sampling and testing
 - Comply with applicable requirements of Specification for Masonry Structures, Part 2

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Elements of a QC Program

- Installation
 - Install masonry units within tolerances of Specification for Masonry Structures, Article 3.3 F
 - Install masonry reinforcement within tolerances of Specification for Masonry Structures, Article 3.4 B
 - Comply with applicable requirements of Specification for Masonry Structures, Part 3, Execution

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Coastline Community College



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East Valley High School



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Digital Media, Santa Ana



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Orange County Fire Authority



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Cal State Fullerton



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East Anaheim Gymnasium



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Eleanor Roosevelt High School



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Rosemont High School



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Honolulu Auto Dealership



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*Thank you
for Listening!*

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