Masonry Detailing and Construction

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Masonry Institute of America
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Masonry Detailing and Construction

• What’s More Important?

[Scale with labels: Design, Construction]

Masonry Detailing and Construction

WHY???

- Designer Doesn’t Understand Contractor Complaints
- Contractors Don’t Understand the Design
- Codes Getting More Complicated
- Other Field Personnel (Inspectors, Suppliers) Caught in the Middle

WHAT HAPPENED TO COMMON SENSE?

Masonry Detailing and Construction

Outline

- Background—The Complicated Part
- The Players—Communication
- Vision to Reality
- Design Issues
  - The Right Specification
  - Moving Forward

Masonry Detailing and Construction

Outline—Design Issues

- Design Communication Issues
- What Needs to be in the Masonry Wall
  - Structural Integrity and Other Stuff
  - Congestion
- Reinforcement and Splices
- Grouting
- When Things Go South
- Finding Help—Industry Resources
BACKGROUND

The Complicated Part

- You Didn’t Make This Stuff Up

\[
\begin{align*}
\epsilon & = 0.152 \frac{f_y}{E_y} \\
\epsilon & = 1.0 \cdot \left( \frac{3.85}{\sqrt{2}} \right) \\
\sigma & = (0.357)^{0.5} \left( \frac{2.26}{A_c} \right) \\
\sigma & = 0.80 \left( \frac{3.80}{\sqrt{2}} \right) \\
\sigma & = 0.80 \left( \frac{\pi^2}{4} \right) \\
\sigma & = 0.80 \left( \frac{\pi^2}{4} \right) + 0.25 \epsilon
\end{align*}
\]
UNDERSTAND THE DESIGN

A MESSAGE TO THE CONTRACTOR

• How about the ‘plastic hinge zone’?

ASCE 7 Section 14.4, Masonry Detailing Requirements
Lap splices shall not be used in plastic hinge zones of special reinforced masonry shear walls. The length of the plastic hinge zone shall be taken as at least 0.15 times the distance between the point of zero moment to the point of maximum moment.

- Applies to Special Reinforced Masonry Shear Walls
- SDC D-Participating Element
• How about the ‘plastic hinge zone’?

– TMS 402-11, Sec 1.18.4.4.2 ➔ Sec. 1.18.3.2.6
– ASCE 7-10 Modification Sec. 18.4.4.2.2

• Maximum Design Moment

• RFI from Masonry Contractor to SE

Requirement For Block Strength of 3,750 PSI. Which is Classified Ultra High Strength by CMU Manufacturers, whom has Supplied CMU for A Dozen or so CVS’s This Year and This Would be the First One Using U.H.S. Masonry Units. I think The Question is Worth asking Because the Block Production time will be reduced with normal strength Units. The reason is that Once the Block is Manufactured they must cure and reach design strength before they Leave CMU Manufacturer and Obviously the Curing time Is reduced with Normal strength Units. We may need to Consult an Engineer as the overall Masonry assembly Design Strength is Stated At $F'M = 2,500$ PSI. (Page 5-0.1 masonry note # 4) Request Reduction to Typical $F'M = 1,500$ PSI.

UNDERSTAND THE CONSTRUCTION

A MESSAGE TO THE DESIGNER
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• How much can fit into a small space?

CALIFORNIA BUILDING CODE
2114.6 Grouted masonry.
2114.6.1 General conditions...

Reinforcement and embedded items shall be clean properly positioned and securely anchored against moving prior to grouting. Bolts shall be accurately set with templates or by approved equivalent means and held in place to prevent dislocation during grouting. Reinforcement, embedded items and bolts shall be solidly embedded in grout.

CRITICAL COMPONENTS

• Critical Components
  – Acceptable Foundation
  – Grout Space at Base of Wall
  – Location of Reinforcement
  – Grout
  – Connections, Including Anchor Bolts
Critical Components

- What’s really important?

Preparation of Foundation
First Course Layout

Reinforcement Placement
Grouting

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Inside the Wall

- What’s Inside the Masonry Wall?
  - Reinforcement
  - Grout
  - But Don’t Forget
    - Electrical
    - Plumbing
    - Penetrations (HVAC)
    - Embeds

DESIGN ISSUES

Inside the Wall

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Inside the Wall

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CODE

1.20.2.1 Conduits, pipes, and sleeves shall not be considered to be structural replacements for the displaced masonry. The masonry design shall consider the structural effects of this displaced masonry.

CONDUCTIVITY

1.20.2.1 Conduits, pipes, and sleeves not identified in the code may be embedded within the masonry, but the masonry member strength should not be less than that required by design. Effects of reduction in section properties in the areas of conduit, pipe, or sleeve embedment should be considered.

For the integrity of the structure, conduit and pipe fittings within the masonry should be carefully positioned and assembled. The coupling size should be considered when determining sleeve size.

Aluminum should not be used in masonry unless it is effectively coated or covered. Aluminum reacts with ions, and may also react electrolytically with steel, causing cracking and/or spalling of the masonry. Aluminum electrical conduits present a special problem since stray electric current accelerates the adverse reaction.

Pipes and conduits placed in masonry, whether surrounded by mortar or grout or placed in unfilled spaces, need to allow unrestrained movement.

- Maximum Bar Area
  - 5 in. x 6 in. = 30 in² x 4% = 1.2 in²
- Maximum Bar Size
  - #8 bar = 0.78 in²
- Most Reinforcement in Cell
  - 5 - #7 bars = 1.2 in²
  - 4 - #5 bars = 1.24 in²
• What the Code (TMS 402-11) Says:

3.3.3 Reinforcement requirements and details

3.3.3.1 Reinforcing bar size limitations

Reinforcing bars used in masonry shall not be larger than No. 9 (M#29). The nominal bar diameter shall not exceed one-eighth of the nominal member thickness and shall not exceed one-quarter of the least clear dimension of the cell, course, or collar joint in which the bar is placed. The area of reinforcing bars placed in a cell or in a course of hollow unit construction shall not exceed 4 percent of the cell area.

The limit of using a No. 9 (M#29) bar is motivated by the goal of having a larger number of smaller diameter bars to transfer stresses rather than a fewer number of larger diameter bars. Some research investigations have concluded that in certain applications masonry reinforced with more uniformly distributed smaller diameter bars performs better than similarly configured masonry elements using fewer larger diameter bars. While not...

DESIGN ISSUES

Reinforcement and Splices

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Reinforcement

Congestion

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Reinforcement

• Location

Tolerances for placement of reinforcing bars in a CMU cell

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Reinforcement

• Congestion
Reinforcement

- **Congestion**

**Masonry Detailing and Construction**

**Lap Splices**

- **How Long Should a Lap Splice Be?**

\[
L = 0.002 f_y d_{ef} 
\]

- **How Much Contact is Required for a Lap Splice to be Effective?**

\[
L = \frac{f_y}{f_y} \left( \frac{L}{L_{ef}} \right) 
\]

\[
L = \frac{0.13 f_y d_{ef}^2}{f_y} \left( \frac{L}{L_{ef}} \right) \quad \text{but} \quad \varepsilon = 1.0 - \frac{2.34}{0.6 \varepsilon} \leq 1.0 
\]

\[
L = \frac{0.13 f_y d_{ef}^2}{f_y} \left( \frac{L}{L_{ef}} \right) \quad \text{for when transverse bars cross lap splice} 
\]

\[
L = 0.0025 f_y d_{ef} \left( \frac{L}{L_{ef}} \right) \quad \text{for when transverse bars cross lap splice} 
\]

**ACI 318-11 Building Code Requirements for Structural Concrete (2011) - 12.4.2.3** Bars spliced by noncontact lap splices in flexural members shall not be spaced transversely farther apart than the smaller of one-fifth the required lap splice length, and 6 in.
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Lap Splices

• How Much Contact is Required for a Lap Splice to be Effective?

TMS 402-11 Building Code Requirements for Masonry Structures (2011) – Sections 2.1.7.7.1.3 and 3.1.3.3.1 Bars spliced by noncontact lap splices shall not be spaced transversely farther apart than one-fifth the required length of lap nor more than 8 in. (203 mm).

TMS 602-11 Specification for Masonry Structures (2011) – Article 3.4 B.9 Noncontact lap splices – Position bars spliced by noncontact lap splices no farther apart transversely than one-fifth the specified length of lap nor more than 8 in. (203 mm).

Available at www.cmacn.org

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Lap Splices

• How Much Contact is Required for a Lap Splice to be Effective?

TMS 602-08 Specification for Masonry Structures (2008) – Article 3.4 B.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 Specification for Masonry Structures (2011) – Article 3.4 B.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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Lap Splices

• Keep it simple and consistent
• Class of splice (ACI 318) NOT Required
• Try to Limit Congestion
• Tying Splices is Not a Code Requirement
• Consider Staggering Splices for Highest Seismic Applications

CRITICAL COMPONENTS

ANCHOR BOLTS
Anchor Bolts

- A Real Dilemma
  - Anchor Bolts Should Be Embedded as Deep as Possible for Maximum Efficiency
  - There isn’t Much Room Inside the Cell

3.4 D. Anchor bolts...

3. For anchor bolts placed through the face shell of a hollow masonry unit... maintain a clear distance between the bolt and the face of masonry unit and between the head or bent leg of the bolt and the formed surface of grout of at least ¼ in. (6.4 mm) when using fine grout and at least ½ in. (12.7 mm) when using coarse grout.

NOTES:

1. MINIMUM BOLT SPACING SHALL BE 16 BOLT DIAMETERS WITH A MINIMUM EDGE DISTANCE OF 12 DIAMETERS, UNLESS NOTED OTHERWISE.

2. PROVIDE AN ADDITIONAL 2" OF EMBEDMENT FOR ANCHOR BOLTS LOCATED IN THE TOP OF COLUMNS.

3. ANCHOR BOLTS SHALL BE HEX HEADED WITH THE DIMENSIONS OF THE HEX CONFORMING TO ANSI ASME B18.2.1. BENT BAR ANCHORS SHALL NOT BE USED.

4. PARTIAL CORE CMU FACE SHELLS ARE REQUIRED TO ATTAIN PROPER ANCHOR BOLT EMBEDMENT.

DESIGN ISSUES

Grouting

2013 CBC Section 2114.10 Bent bar anchor bolts shall not be allowed.
Grouting

- Cells should be reasonably clean

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Grouting

- Placement of Grout

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Masonry Grout is like Concrete, but……
- A lot of water is NOT a bad thing (up to 11” slump)
- Aggregates must be smaller

Masonry Grout is like Concrete, but……
- A lot of water is NOT a bad thing (up to 11” slump)
- Aggregates must be smaller
- Not Too Much Cement
- Fly Ash and Slag are Good (Longer Strength Gain)
- No Plasticizers as Water Replacement
- Masonry Grout has a unique ASTM Standard
Communication Between the Structural Engineer and Masonry Contractor

Mortar – A Thorn in the Side

Design Issues

- The Root of the Problem
  - ASTM C270 - Standard Specification for Mortar for Unit Masonry
  - ASTM C780 - Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry
  - ASTM C1586 - Standard Guide for Quality Assurance of Mortars
The compressive strength values resulting from field tested mortars do not represent the compressive strength of mortar as tested in the laboratory nor that of the mortar in the wall.

### ASTM C270, TABLE 1: PROPORTION SPECIFICATION REQUIREMENTS

<table>
<thead>
<tr>
<th>MORTAR TYPE</th>
<th>Mortar cement</th>
<th>Mortar cement</th>
<th>Aggregate measured in a damp loose condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>M</td>
<td>M</td>
<td>Over 5% to 15%</td>
</tr>
<tr>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Over 15% to 25%</td>
</tr>
<tr>
<td>O</td>
<td>O</td>
<td>O</td>
<td>Over 25%</td>
</tr>
</tbody>
</table>

For Field Mortar

### ASTM C270, TABLE 2: PROPERTY SPECIFICATION REQUIREMENTS

<table>
<thead>
<tr>
<th>Mortar Type</th>
<th>Avg. Compressive Strength at 28 Days, Min psi</th>
<th>Water Retention Min. %</th>
<th>Air Content Max. %</th>
<th>Aggregate Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement-Lime</td>
<td>2500 (17.2) SMALL</td>
<td>75</td>
<td>12</td>
<td>Not less than 2% and not more than 3% times the sum of the separate volumes of cementitious materials</td>
</tr>
<tr>
<td>Mortar Cement</td>
<td>2500 (17.2) SMALL</td>
<td>75</td>
<td>12</td>
<td>Not less than 2% and not more than 3% times the sum of the separate volumes of cementitious materials</td>
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<tr>
<td>Masonry Cement</td>
<td>2500 (17.2) SMALL</td>
<td>75</td>
<td>18</td>
<td>Not less than 2% and not more than 3% times the sum of the separate volumes of cementitious materials</td>
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</table>

Laboratory prepared mortar only

### ASTM C270, TABLE 2: PROPERTY SPECIFICATION REQUIREMENTS

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Laboratory prepared mortar only

### The Root of the Problem – ASTM C270

1.2 The proportion or property specifications shall govern as specified. When neither proportion or property specifications are specified, the proportion specifications shall govern.

3.1 Specification C270 is not a specification to determine mortar strengths through field testing.

3.3 The compressive strength values resulting from field tested mortars do not represent the compressive strength of mortar as tested in the laboratory nor that of the mortar in the wall.

### The Root of the Problem – ASTM C780

1.4 The test results obtained under this test method are not required to meet the minimum compressive values in accordance with the property specifications in Specification C270.

5.2.6 Mortar compressive strength test values are not representative of the actual compressive strength of mortar in the assembly and are not appropriate for use in predicting the compressive strength that would be attained by the mortar in the masonry assembly.

A6.1.1 Strength values for mortars obtained through these testing procedures are not required, not expected, to meet strength requirements of laboratory Specification C270 mortars.
4.1 Use Specification C270 to specify masonry mortar by either the Proportion or Property Specifications of that standard, but not both. If neither the Proportion nor Property specification is given, Specification C270 the Proportion specification to be used.

4.2 Proportion Specifications—These Specifications direct the mason to produce the masonry mortar using designated volumetric proportions of cementitious materials and aggregate as set forth in Table 1, Proportion Specifications, of Specification C270 for the Type of mortar specified. This procedure of specifying mortar requires no sampling and testing of mortar, and hence, no measurement of mortar properties in the laboratory or the field is required. All that is necessary is field confirmation of the proper proportions of the mixes used in construction.

4.3.2 Do not use the Specification C270 Property Specifications requirements to evaluate construction site-produced mortars. Due to the higher amount of water necessary for actual masonry construction, mortar produced and sampled in the field will typically have lower compressive strength than that produced in the laboratory per Specification C270.

5.5.3 Measurement of construction site masonry mortar compressive strength using Test Method C780, Annex A7, is not the appropriate test method to determine the compliance of the mortar with the compressive strength requirements of Specification C270; however it may have some value in the determination of mortar uniformity.

THE BAD STUFF

When Things Go South

• Coordination with Penetrations
  – Multiple Openings Interrupting Reinforcement

• Coordination with Penetrations
  – Multiple Openings Interrupting Reinforcement
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• Coordination with Penetrations
  – Penetrations at Beam Supports

• Coordination with Penetrations
  – Penetrations at Beam Supports

• Coordination with Underground
  – Base Wall Conditions

• Coordination with Underground
  – Interface with Dowels, Conduits, Piping

• Difficult Grouting Conditions
  – Top of Wall

• Difficult Grouting Conditions
  – Top of Wall
Difficult Grouting Conditions
– Top of Wall

Confusion on Both Sides

Frequency of Inspection
– How Much is Enough?

Periodic Inspection—How Much?

Not much help

(2012 IBC) Code Definition

Special inspection. Inspection of construction requiring the expertise of an approved special inspector in order to ensure compliance with this code and the approved construction documents.

Continuous special inspection. Special inspection by the special inspector who is present when and where the work to be inspected is being performed.

Periodic special inspection. Special inspection by the special inspector who is intermittently present where the work to be inspected has been or is being performed.

Need to Quantify ‘Periodic’ – TMS 602 Commentary

Quality Assurance Tables 3.1.2 and 3.1.3 require inspection tasks to be performed on a continuous or periodic basis. The Architect/Engineer should define the required timing of periodic inspections so that they are sufficient to verify a representative sample of the materials and workmanship. The frequency of periodic inspection varies depending on the size and complexity of the project.
Bad Test Reports? – Don’t Panic

- Case where prisms were capped out-of-tolerance

THE GOOD STUFF

Masonry Dimensioning

- Masonry Dimensioning

...
**Masonry Dimensioning**
- Masonry Dimensioning
- Reinforcing Steel Must be spaced in 8 inch increments
  - Vertically and Horizontally
- Any wall dimension is possible, but...
  - Things look best when designed in 8 inch modules
- You can hide stuff (electrical, plumbing) inside wall, but...
  - Be careful not to compromise the structural integrity
- When All is Said and Done
  - ASTM C90 says look at the wall from 20 feet away

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**Finding Help**

**Industry Resources**

- NCMA TEK Notes
- MasonrySystems.org
  - Google Sketchup
  - BIM-M
  - Local Resources

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**Masonry Dimensioning and Construction**

- National Concrete Masonry Association
  - www.ncma.org
  - TEK Notes

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**Masonry Dimensioning and Construction**

- www.MasonrySystems.org
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• BIM-M [www.BIMforMasonry.org]

  - Building Information Modeling for Masonry [BIM-M.org]

  - BIM-M Banners.png

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• Local Resources
  - Masonry Institute of Hawaii
    [www.masonryhawaii.com]
  - Cement and Concrete Products Institute
    [www.ccpihawaii.org]

  - Cement & Concrete Products Industry of Hawaii - Non Profit I Honolulu.png

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• Other Valuable Resources
  - Masonry Institute of America
    [www.masonryinstitute.org]

  - Concrete Masonry Association of CA and NV
    [www.cmacn.org]

  - Concrete Masonry Association of California and Nevada.png

Masonry Detailing and Construction

• Reinforced Masonry Engineering Handbook

• Design of Reinforced Masonry Structures

• Masonry Designers Guide

• Direct Design Handbook

Masonry Detailing and Construction

• Common on Structural Notes
  - Specifying Mortar by Properties and Proportion
  - Listing Grades and Types for CMU
  - Confusion about $f_m$
  - Not Understanding the Difference Between Grout Lift and Grout Pour
  - Conflicts Between Architectural Specifications and Structural Notes

THE RIGHT SPECIFICATION
5.1 BLOCK MASONRY UNITS SHALL BE SINGLE OR DOUBLE OPEN-ENDED BOND BEAM UNITS CONFORMING TO ASTM C90, LATEST REVISION, TYPE I.

5.2 MINIMUM f’m, UNO: 8” CMU = 1500 psi
12” CMU = 2000 psi

**Example:**

**5.5** MINIMUM LAP OF REINFORCING STEEL SHALL BE PER C5.03.

5.6 THE FIRST COURSE OF BLOCK FOR BLOCK LiftS EXCEEDING 5'-0" SHALL HAVE CLEANOUTS CONSISTING OF DOUBLE OPEN END BOND BEAM BLOCK. SEE DETAIL NS.03.

**Example:**

**5.7** GROUT POURS SHALL BE TO THE FULL HEIGHT OF THE BLOCK Lift. MAXIMUM GROUT Pour HEIGHT SHALL COMPLY WITH TABLE 1.19.1 OF ACI 530-08. GROUT POURS EXCEEDING 5'-0" IN HEIGHT SHALL CONSIST OF MULTIPLE GROUT LiftS OF 5'-0" OR LESS IN HEIGHT. CONSOLIDATE AND RECONSOLIDATE EACH GROUT Lift BY MEANS OF MECHANICAL VIBRATION IN COMPLIANCE WITH ACI 530.1 SECTION 3.5.E. A GROUT Lift SHALL NOT BE PERMITTED TO SET PRIOR TO PLACEMENT AND CONSOLIDATION OF SUBSEQUENT GROUT Lift.

**Example:**

5.8 HORIZONTAL CONSTRUCTION JOINTS BETWEEN GROUT POURS SHALL BE LOCATED 1" + 1/2" BELOW A MORTAR JOINT.

5.9 MINIMUM GROUTING: FILL ALL CELLS.

5.10 ALL BOLTS IN MASONRY SHALL BE CENTERED IN CELLS ± 2 INCHES.

**Example:**

**5.11** GROUT shall be made using specified materials, proportions, and admixtures. The compressive strength of the grout shall be determined by testing in accordance with ASTM C109, C120, or C496, and shall be in accordance with the ACI Building Code Requirements for Structural Concrete. The specified compressive strength of grout shall be at least 3000 psi for all grouts used below grade or under water and at least 2000 psi for all other grouts, unless otherwise specified.

**Example:**

**5.12** The height of masonry to be grouted prior to erection of structural slabs shall not exceed 12 inches, unless in accordance with ACI 530.1. In no case shall the grout height exceed 24 inches. Grout shall be consolidated until the height of the grouted course is established.

**Example:**

**5.13** Grout shall be placed in lifts not exceeding 12 inches in height, unless in accordance with ACI 530.1. The height of grout lifts shall not exceed 24 inches. Grout shall be consolidated until the height of the grouted course is established.

**Example:**

**5.14** Grout shall be placed in lifts not exceeding 12 inches in height, unless in accordance with ACI 530.1. The height of grout lifts shall not exceed 24 inches. Grout shall be consolidated until the height of the grouted course is established.

**Example:**

**5.15** Grout shall be placed in lifts not exceeding 12 inches in height, unless in accordance with ACI 530.1. The height of grout lifts shall not exceed 24 inches. Grout shall be consolidated until the height of the grouted course is established.

**Example:**

**5.16** Grout shall be placed in lifts not exceeding 12 inches in height, unless in accordance with ACI 530.1. The height of grout lifts shall not exceed 24 inches. Grout shall be consolidated until the height of the grouted course is established.

**Example:**

**5.17** Grout shall be placed in lifts not exceeding 12 inches in height, unless in accordance with ACI 530.1. The height of grout lifts shall not exceed 24 inches. Grout shall be consolidated until the height of the grouted course is established.
Cleanouts relate to grout pours, not grout lifts. The grout key is intended to be a minimum dimension, not an exact dimension.

The term f'c is a design strength, not an actual strength. The designer needs a verification that the actual masonry strength meets or exceeds the design strength to assure that the installed product is safe.

When grout pours do not exceed 5'-0" (low-lift grouting) the grout must set and consolidate prior to placement and consolidation of subsequent grout lift.

When grout pours exceed 5'-0", a grout lift shall not be permitted to set prior to placement and consolidation of subsequent grout lift.

When grout pours do not exceed 5'-0" (low-lift grouting) the great must set prior to the erection of additional masonry.

Concrete masonry units (CMUs) shall develop the following minimum 28 day prism compressive strengths in accordance with the building code.

<table>
<thead>
<tr>
<th>Unit Type</th>
<th>f'c (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All CMU UNITS</td>
<td>1500 psi</td>
</tr>
<tr>
<td>Type 5 Mortar</td>
<td>2000 psi</td>
</tr>
</tbody>
</table>

The code is clear that verification of the compressive strength is to be by the prism test method or the unit strength method, not both.
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What is the Strength of Masonry?

- Methods of Determination
  - Prism Test Method OR
  - Unit Strength Method
  - Testing Prisms from Constructed Masonry

- What About Mortar?
  - (Implication) Stronger is Not Better
  - Less Cement = Better Bond = Better Performance

Masonry Detailing and Construction

Masonry Prism

Unit Strength

Moving Forward

- Masonry Unit Strength Table Recalibration
  - (2013 TMS 402)
- Based on Unrecognized Strength of Masonry
- ASTM C90 Standard Specification for Loadbearing Concrete Masonry Units
  - C90-13 – Compressive Strength 1,900 psi
  - C90-14 – Compressive Strength 2,000 psi
Masonry Detailing and Construction

Moving Forward

ASTM C90-14, Table 2 Strength, Absorption and Density Classification Requirements

<table>
<thead>
<tr>
<th>Density Classification</th>
<th>Oven-Dry Density of Concrete, lb/ft³ (kg/m³)</th>
<th>Maximum Water Absorption, %</th>
<th>Minimum Net Area Compressive Strength, psi</th>
<th>Average of 3 Units</th>
<th>Individual Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lightweight</td>
<td>Less than 105 (1680)</td>
<td>18 (288)</td>
<td>2000 (13.8)</td>
<td>13 (208)</td>
<td>1800 (12.4)</td>
</tr>
<tr>
<td>Medium</td>
<td>105 to less than 125 (1680)</td>
<td>15 (240)</td>
<td>2000 (13.8)</td>
<td>15 (240)</td>
<td>1800 (12.4)</td>
</tr>
<tr>
<td>Normal Weight</td>
<td>125 (2000) or more</td>
<td>13 (208)</td>
<td>2000 (13.8)</td>
<td>15 (240)</td>
<td>1800 (12.4)</td>
</tr>
</tbody>
</table>

Masonry Unit Strength Recalibration

- Verification of masonry compressive strength
  - Prism test method
  - Unit strength method
  - Testing prisms from constructed masonry
    - (Masonry prism test record—No longer available)
      - Uniform Building Code exclusive
      - At least 30 historic prisms required
      - Test record results required to be at least 1.33 $f'_{cm}$

1973 Uniform Building Code

1973 UBC Table 24—Assumed Compressive Strength of Masonry, $f'_{cm}$ psi

<table>
<thead>
<tr>
<th>Specified Strength of Clay Masonry Units (psi)</th>
<th>Specified Compressive Strength of Masonry, $f'_{cm}$ psi of Specified Strength of Concrete Masonry Units (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type M or S Mortar (psi)</td>
<td>Type N Mortar (psi)</td>
</tr>
<tr>
<td>14,000 or more</td>
<td>5,000</td>
</tr>
<tr>
<td>12,000</td>
<td>4,000</td>
</tr>
<tr>
<td>10,000</td>
<td>3,000</td>
</tr>
<tr>
<td>8,000</td>
<td>2,000</td>
</tr>
<tr>
<td>6,000</td>
<td>1,000</td>
</tr>
<tr>
<td>4,000</td>
<td>2,000</td>
</tr>
<tr>
<td>Specified Strength of Concrete Masonry Units (psi)</td>
<td>Specified Compressive Strength of Masonry, $f'_{cm}$ psi of Specified Strength of Concrete Masonry Units (psi)</td>
</tr>
<tr>
<td>Type M or S Mortar (psi)</td>
<td>Type N Mortar (psi)</td>
</tr>
<tr>
<td>4,800 or more</td>
<td>3,000</td>
</tr>
<tr>
<td>3,750</td>
<td>2,500</td>
</tr>
<tr>
<td>2,800</td>
<td>1,500</td>
</tr>
<tr>
<td>1,900</td>
<td>1,000</td>
</tr>
<tr>
<td>1,250</td>
<td>950</td>
</tr>
</tbody>
</table>

2013 TMS 602, Specification for Masonry Structures

Table 2—Compressive strength of masonry based on the compressive strength of concrete masonry units and type of mortar used in construction

<table>
<thead>
<tr>
<th>Net area compressive strength of concrete masonry units, psi</th>
<th>Type M or S mortar</th>
<th>Type N mortar</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,900</td>
<td>1,350</td>
<td>1,350</td>
</tr>
<tr>
<td>1,850</td>
<td>1,300</td>
<td>1,300</td>
</tr>
<tr>
<td>1,800</td>
<td>1,250</td>
<td>1,250</td>
</tr>
<tr>
<td>1,750</td>
<td>1,200</td>
<td>1,200</td>
</tr>
<tr>
<td>1,700</td>
<td>1,150</td>
<td>1,150</td>
</tr>
<tr>
<td>1,650</td>
<td>1,100</td>
<td>1,100</td>
</tr>
<tr>
<td>1,600</td>
<td>1,050</td>
<td>1,050</td>
</tr>
<tr>
<td>1,550</td>
<td>1,000</td>
<td>1,000</td>
</tr>
<tr>
<td>1,500</td>
<td>950</td>
<td>950</td>
</tr>
</tbody>
</table>

Masonry Detailing and Construction

2011 TMS 602, Specification for Masonry Structures

Table 2—Compressive strength of masonry based on the compressive strength of concrete masonry units and type of mortar used in construction

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</tr>
<tr>
<td>1,550</td>
<td>1,000</td>
<td>1,000</td>
</tr>
<tr>
<td>1,500</td>
<td>950</td>
<td>950</td>
</tr>
</tbody>
</table>
### Table 2—Compressive strength of masonry based on the compressive strength of concrete masonry units and type of mortar used in construction

<table>
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<td>Type N mortar</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>1,900</td>
<td>1,900</td>
</tr>
<tr>
<td>2,400</td>
<td>2,400</td>
</tr>
<tr>
<td>2,500</td>
<td>2,500</td>
</tr>
<tr>
<td>4,800</td>
<td>4,800</td>
</tr>
</tbody>
</table>

- **Net area compressive strength of concrete masonry units, psi**
  - 1,700
  - 1,900
  - 2,000
  - 2,250
  - 2,500
  - 2,750
  - 3,000

- **Net area compressive strength of masonry, psi**
  - 1,900
  - 2,350
  - 2,650
  - 3,400
  - 4,350
  - 4,500
  - 4,500

- **Type M or S mortar**
  - Averages of Test Data

- **Type N mortar**
  - Summary of All Test Data
Background

Masonry Detailing and Construction

ASTM C90 Modification

• In concert with ASTM C90
  • There is a new change in ASTM C90-14 - Raise minimum average CMU strength requirement from 1,900 psi to 2,000 psi
  • Original Unit Strength change proposal assumed ASTM C90 change would be published
  • Unit Strength Table accommodates both 1,900 psi and 2,000 psi block strength during transition

Benefits

• Design – 2,000 psi, up from 1,500 psi
• Material – Recognized for improved manufacturing methods and increased quality control
• Verification – Moves results of two verification methods somewhat closer together while maintaining implied requirement for Prism Test Method on higher strength masonry

Strength Verification Method

• Unit Strength Verification is easily applied for design strengths of up to 2,500 psi, maybe 3,000
• Prism Test Verification may be applied for any strength masonry, but is the reasonable choice for higher design strength and the only choice for very high design strength

Many thanks to our Task Group

Russ Brown, Chair
Dick Bennett
John Chrysler
Rich Klingner
Art Schultz
Jason Thompson
Diane Throop
• Base design of masonry (f’m) has been 1,500 psi – Why? – Verification of design strength (f’m) – Low value on Unit Strength Table is 1,500 psi

<table>
<thead>
<tr>
<th>Net area compressive strength of concrete masonry units, psi (MPa)</th>
<th>Type M or S Mortar</th>
<th>Type N Mortar</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1,900 (13.10))</td>
<td>2,150 (14.82)</td>
<td>2,000 (13.79)</td>
</tr>
<tr>
<td>(2,800 (19.31))</td>
<td>3,050 (21.03)</td>
<td>2,500 (17.24)</td>
</tr>
<tr>
<td>(3,750 (25.86))</td>
<td>3,700 (25.86)</td>
<td>3,000 (20.69)</td>
</tr>
<tr>
<td>(4,800 (33.10))</td>
<td>4,050 (27.92)</td>
<td>3,000 (20.69)</td>
</tr>
</tbody>
</table>

Masonry Detailing and Construction

• Changes coming — increase in CMU strength — ASTM C90-14 requires CMU to be 2,000 psi

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</tbody>
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Masonry Detailing and Construction

• Not so fast—not everything gets increased by ⅓rd
• For example—Reinforcement development length

\[ l_d = \frac{0.13d_{re}f_yK}{\sqrt{\frac{f_m}{K}}} = 23 \text{ in. (for 2000 psi), 20 in for (1,500 psi)} \quad + 15\% \]

And ASD in-plane shear stress

\[ 1.5 \sqrt{f_{tm}} = 58 \text{ psi (for 2000 psi), 67 psi for (1,500 psi)} \quad + 15.5\% \]

Masonry Detailing and Construction

Moving Forward

• Some Thoughts to Ponder
  1. If a low bidder is really low, a higher level of QA verification may be required
  2. Many contractors are willing to go the extra mile if they know where that extra mile is
  3. Communication leads to Quality

Thank You

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(800) 221-4000
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