Delaware Valley Association of Structural Engineers

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Cutting Edge Masonry Codes & Standards

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on behalf of the Delaware Valley & New Jersey Structural Coalitions

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Learning Objectives


✓ Understand the relationship between the IBC and the TMS 402/602.

✓ Review and understand select changes incorporated into the 2011, 2013, and 2016 TMS 402/602 and discuss the likely impact from these changes to masonry design & construction.

✓ Understand how to implement the new provisions to produce cutting edge masonry designs.
ICC, IBC, IRC

ICC - International Code Council (I-Codes)
- 3 year development cycle
- Multiple materials
- Structural, fire, etc.

IBC - International Building Code
- Chapter 14 Veneer
- Chapter 17 Special Inspection
- Chapter 21 Masonry

IRC – International Residential Code
- 1 and 2 family dwellings
TMS 402/602 (MSJC) Documents

TMS 402-11 /ACI 530-11 /ASCE 5-11 (MSJC)
TMS 402-13 /ACI 530-13 /ASCE 5-13 (MSJC)
TMS 402-16 (TMS 402)
Building Code Requirements for Masonry Structures

TMS 602-11 /ACI 530.1-11/ASCE 6-11 (MSJC)
TMS 602-13 /ACI 530.1-13/ASCE 6-13 (MSJC)
TMS 602-16 (TMS 602)
Specification for Masonry Structures

Commentary for each
Non-mandatory
TMS 402/TMS602 (MSJC)

- TMS 402 **Code** contains primarily structural design provisions but also a few Construction Requirements – Designer oriented

- Construction provisions are primarily found in the TMS 602 **Specification** – Contractor & Inspector oriented

- Companion **Commentary** to each – Non-mandatory
TMS 402/602 (MSJC) Development

- Mandatory language standards that provide minimum requirements for the design & construction of masonry
- Typically 3-year development cycle BUT changing to 6 year cycle for the TMS 402/602!
- Consensus process
  - balance, letter ballots, resolution of negatives, public comment
- Sponsoring society oversight & approval
  - TMS, ACI, SEI/ASCE
  - TMS is sole sponsor for 2016 edition! TMS 402/602
- Intended for adoption by Codes
How do they relate?

- **IBC**: Model code, legally adopted with or without local amendments

- **MSJC & TMS 402/602**: Reference documents
Companion Documents

- Check the dates
- MSJC & TMS 402/602 date will be one or two years PRIOR to its companion IBC
- ’12 IBC goes with ’11 MSJC
- ’15 IBC goes with ’13 MSJC
- Also check for local amendments & adoptions
The Code & Commentary and the Specification & Commentary are now shown in a side by side format for easier use by users.
2011 MSJC – Select Changes

- Updated to ASCE 7-10
  - Required major recalibration as a result of the change by ASCE 7 to base wind loads on a “strength” level versus a service level. As a result, wind “triggers” changed for:
    - Empirical Design
    - Veneer
    - Glass Unit Masonry
2011 MSJC – Select Changes

- Recalibration of stresses
  - Removal of 1/3 stress increase option that was formerly permitted for Allowable Stress Design (ASD) when considering wind or seismic loads
  - Harmonization of ASD and SD shear provisions
  - Some Allowable Stresses increased. Reduces impact of removal of 1/3 stress increase options
  - Conflict between the MSJC ASD loading provisions permitting the 1/3 stress increase and the ASCE 7-05 prohibition of the 1/3 stress increase has been eliminated.
Allowable Stresses - General

- Anchor Bolts: No change
  - Major Revision in 2008
  - 2008 Increased Allowables; Harmonized with Strength Design

- Bearing Stress
  - Increased from $0.25 f'_m$ to $0.33 f'_m$
  - Nominal strength also increased from $0.60 f'_m$ to $0.80 f'_m$
  - Changes based on comparison with other codes
Allowable Stresses – Unreinforced Masonry

- **Flexural tension**
  - Increased by 33% based on reliability analysis

- **Unchanged**
  - Axial compression
  - Combined flexural and axial compression
    \[(0.33 f_m')\]
  - Shear

Flexural tension usually controls with unreinforced masonry so impact of unchanged allowable stresses is minimal
Allowable Stresses – Reinforced Masonry

- Allowable stresses for axial compression not changed
- Allowable steel reinforcement stress increased to 32 ksi (Grade 60 steel)
  - Based on comparison to strength design
- Allowable masonry stress due to combined flexure and axial loads increased to $0.45f'_m$
  - Based on comparison to strength design
- Shear strength provisions now similar to strength design
  - Based on comparison to experimental data
  - Permitted to add masonry & steel shear strength
Impact of ASD Shear Design Provisions

- 2011 ASD shear provisions require approximately the same amount of reinforcement as strength design provisions.
- 2011 ASD shear provisions require significantly less reinforcement than the 2008 ASD provisions for ordinary shear walls.
- 2011 ASD shear provisions require approximately the same amount of reinforcement as the 2008 ASD provisions for special shear walls.
Example of the Benefits

- **Building perimeter:** $2(350') + 2(525') = 1,750$ LF of wall

- **2009 IBC / TMS 402:** #5 Rebar at 24” o.c. =
  - 875 rebar = 19,250 LF + lap splices
  - 124 CY of grout

- **2012 IBC / TMS 402:** #5 Rebar at 32” o.c. =
  - 657 rebar = 14,438 LF + lap splices
    - 25% reduction / 2009 code = 33% increase!
    - 4,812 LF less
    - 5,053 lbs. less
  - 93 CY of grout
    - 25% reduction using new codes / 33% increase using the 2009 code
    - 31 CY less = 4 to 5 trucks!
2011 MSJC – Select Changes

2 Updates - Lap Splices & Development Length

\[ l_d = \frac{0.13d_b^2 f_y \gamma}{K \sqrt{f'_m}} \]

- The beneficial effect of larger cover for computation of development length has been changed from \(5d_b\) to \(9d_b\)

- Option: Lap splices are permitted to be reduced where transverse reinforcement is placed within 8” of the end of the splice if it is fully developed in grouted masonry.
Deep Beam Provisions added. Apply to beams where the effective span-to-depth ratio, \( \frac{l_{eff}}{d_v} \), is less than:
- 3 for continuous span
- 2 for simple span

Requires additional analysis as well as minimum flexural and shear reinforcement (Code Section 1.13.2)
2011 MSJC – Select Changes

- New Appendix B for Masonry Infill
  - Unreinforced CMU and Clay units (work on AAC infill on the 2013 agenda)
  - Participating and non-participating infill
  - Prescriptive reinforcement required
New in the 2011 MSJC

- Anchor bolt installation requirements have been revised.
- Reference only to running bond or “not in running bond” rather than reference to stack bond or other bond patterns.
New in the 2011 MSJC

- Revised equation for walls with laterally restrained or laterally unrestrained unbonded prestressing tendons.

- Commentary guidance on seismic design coefficients for prestressed masonry shear walls. (Will be removed when included in ASCE 7)
2011 MSJC – Select Changes

- Empirical design restricted from use in structures located in Risk Category IV. (Essential Structures)
- Adhered dimension stone provisions are included.
- Single pintle ties are permitted for anchored veneer
- Clarification that drips are not permitted in wire anchors and joint reinforcement cross wires and tabs.
2011 MSJC – Select Changes

- AAC moves from an Appendix A to new Chapter 8
- Provisions for nominal sliding shear strength added at the interface of AAC and thin bed mortar.
- Quality assurance requirements for AAC masonry were expanded and clarified.
2011 MSJC – Select Changes

- **MSJC QA tables**
  - Direct reference in the IBC 2012
  - New column in the Tables includes reference to specific code/spec provisions

<table>
<thead>
<tr>
<th>Inspection Task</th>
<th>Frequency (a)</th>
<th>Reference for Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Continuous</td>
<td>TMS 402/ACI 530/ASCE 5</td>
</tr>
<tr>
<td>4. Verify during construction:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Size and location of structural elements</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>b. Type, size, and location of anchors, including other details of anchorage</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>of masonry to structural members, frames, or other construction</td>
<td></td>
<td>Sec. 1.16.4.3, 1.17.1</td>
</tr>
</tbody>
</table>
2011 MSJC – Select Changes

- Grout lift height changed to 5’-4” to accommodate modular construction.
- Prism testing provisions for specimens cut from construction were included.
2011 MSJC Select Changes

and many more...
SELECT CHANGES – 2013 MSJC
2013 MSJC - Reorganization

Part 1: General
- Chapter 1 – General Requirements
- Chapter 2 – Notations & Definitions
- Chapter 3 – Quality & Construction

Part 2: Design Requirements
- Chapter 4: General Analysis & Design Considerations
- Chapter 5: Structural Elements
- Chapter 6: Reinforcement, Metal Accessories & Anchor Bolts
- Chapter 7: Seismic Design Requirements

Part 3: Engineered Design Methods
- Chapter 8: ASD
- Chapter 9: SD
- Chapter 10: Prestressed
- Chapter 11: AAC

Part 4: Prescriptive Design Methods
- Chapter 12: Veneer
- Chapter 13: Glass Unit Masonry
- Chapter 14: Masonry Partition Walls

Part 5: Appendices & References
- Appendix A – Empirical Design of Masonry
- Appendix B: Design of Masonry infill
- Appendix C: Limit Design of Masonry
- References

User Friendly/Designer Input
5 Parts with smaller focused chapters
3 Appendices

Specification
2013 MSJC Code Reorganized

Part 1: General
- Chapter 1: General Requirements
- Chapter 2: Notations & Definitions
- Chapter 3: Quality & Construction

Part 2: Design Requirements
- Chapter 4: General Analysis & Design Considerations
- Chapter 5: Structural Elements
- Chapter 6: Reinforcement, Metal Accessories & Anchor Bolts
- Chapter 7: Seismic Design Requirements

Part 3: Engineered Design Methods
- Chapter 8: ASD
- Chapter 9: SD
- Chapter 10: Prestressed
- Chapter 11: AAC

Part 4: Prescriptive Design Methods
- Chapter 12: Veneer
- Chapter 13: Glass Unit Masonry
- Chapter 14: Masonry Partition Walls

Part 5: Appendices & References
- Appendix A: Empirical Design of Masonry
- Appendix B: Design of Masonry infill
- Appendix C: Limit Design of Masonry
- References
2013 MSJC - Limit Design

- Appendix C in 2013 MSJC
- Seismic design – Optional
- Sophisticated Analysis Method
- Perforated Walls

“This was a bold move for masonry and marks it as an even more serious structural material.”
Limit Design: Seismic Design of Reinforced Masonry Structures

- force-based design
  - (ASCE 7 - 10)
  - emphasizes strength

- displacement-based design
  - (no code provisions yet)
  - emphasizes deformation
Force-based Seismic Design Limitations

- uncoupled cantilever walls are easy to design
- coupled cantilever walls are more difficult to design
- walls with arbitrary openings may be impossible to design rationally
2013 MSJC - Empirical design

Past MSJC Codes
- Chapter 5: Empirical Design of Masonry

2013 MSJC Code
- Appendix A: Empirical Design of Masonry
  - Relocated from previous Code Chapter 5
  - Mandatory appendix
  - Checklist to make sure provisions are used correctly and appropriately.
Partition walls are ‘walls without structural function’

New requirements are similar to the partition wall requirements in previous empirical chapter but changes based on ASD analysis

Tables for 5 psf and 10 psf lateral load

Example – 5 psf table shown below

Maximum \( \ell/t^2 \) and \( h/t^4 \) Requirements from 2013 MSJC Table 14.3.1(5) when the Lateral Load does not exceed 5 psf (0.239 kPa)

<table>
<thead>
<tr>
<th>Unit and Masonry Type</th>
<th>Mortar types</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Portland cement/lime or mortar cement</td>
</tr>
<tr>
<td></td>
<td>M or S</td>
</tr>
<tr>
<td>Ungrounded and partially grouted hollow units</td>
<td>26</td>
</tr>
<tr>
<td>Solid units and fully grouted hollow units(^3)</td>
<td>40</td>
</tr>
</tbody>
</table>

\(^1\) \( t \) by definition is the nominal thickness of member
2013 MSJC - Select Changes

- Partially grouted shear walls were addressed with some refinement perhaps coming in future cycles.

- Moment magnifier provisions were added for concrete masonry, clay masonry and also for AAC masonry.

- Modulus of Rupture values were increased by approximately 33%
2013 MSJC - Select Changes

- Masonry Cement Mortar permitted for fully grouted participating elements in SDC D and higher

- AAC Infill provisions were added to Appendix B: Design of Masonry Infill
2013 MSJC – Select Changes

- Updating done for the requirements for:
  - mechanical splices in flexural reinforcement in plastic hinge zones;
  - joint reinforcement and seismic clips for anchored veneer in SDC D, E, and F.

- Joint reinforcement can be used as primary reinforcement in Strength Design.
### 2013 MSJC – Unit Strength Table

2013 MSJC 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, psi (MPa)</th>
<th>Net area compressive strength of ASTM C90 concrete masonry units, psi (MPa)</th>
<th>Type M or S Mortar</th>
<th>Type N Mortar</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,700 (11.72)</td>
<td>---</td>
<td>1,900 (13.10)</td>
<td></td>
</tr>
<tr>
<td>1,900 (13.10)</td>
<td>1,900 (13.10)</td>
<td>2,350 (14.82)</td>
<td></td>
</tr>
<tr>
<td>2,000 (13.79)</td>
<td>2,000 (13.79)</td>
<td>2,650 (18.27)</td>
<td>3050</td>
</tr>
<tr>
<td>2,250 (15.51)</td>
<td>2,600 (17.93)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2,500 (17.24)</td>
<td>3,250 (22.41)</td>
<td>4,350 (28.96)</td>
<td></td>
</tr>
<tr>
<td>2,750 (18.96)</td>
<td>3,900 (26.89)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3,000 (20.69)</td>
<td>4,500 (31.03)</td>
<td></td>
<td>5250</td>
</tr>
</tbody>
</table>

- Both unit strength tables reformatted to be more user friendly
- Values in Table 2 were recalibrated as shown above
- Generally higher masonry compressive strength tailing off at higher unit strengths
- Prism testing still an option
### TEST RESULTS

<table>
<thead>
<tr>
<th>Physical Properties</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight Dry (lbs)</td>
<td>33.60</td>
<td>33.55</td>
<td>33.60</td>
<td>33.58</td>
</tr>
<tr>
<td>Absorption (%)</td>
<td>6.99</td>
<td>6.86</td>
<td>7.14</td>
<td>7.00</td>
</tr>
<tr>
<td>Absorption (lbs/cu.ft.)</td>
<td>9.08</td>
<td>8.91</td>
<td>9.27</td>
<td>9.09</td>
</tr>
<tr>
<td>Compressive Strength (PSI)</td>
<td>3025</td>
<td>3101</td>
<td>3075</td>
<td>3067</td>
</tr>
<tr>
<td>Density (lbs./cu.ft.)</td>
<td>119.82</td>
<td>120.03</td>
<td>119.82</td>
<td>119.89</td>
</tr>
<tr>
<td>Linear Shrinkage (%)</td>
<td>0.036</td>
<td>0.041</td>
<td>0.041</td>
<td>0.039</td>
</tr>
</tbody>
</table>

The tests show compliance with ASTM C 90, “Specification for Loadbearing Concrete Masonry Units".
2013 MSJC – ASTM C90 Changes

- Changed the web requirements:
  - C90-11a and earlier:
    - Minimum thicknesses of ¾” for 3” and 4” units, 1” for 6” and 8”, and 1-1/8” for 10” and greater;
    - Equivalent Web Thickness values – greater than 2 webs, less than three...
  - Starting with C90-11b:
    - Minimum thicknesses of ¾” for all units;
    - Normalized Web Area values – 6.5 sq. in./sq. ft.
Starting with C90-11b – Equivalent web area replaces equivalent web thickness.

### TABLE 1 Minimum Thickness of Face Shells and Webs Requirements

<table>
<thead>
<tr>
<th>Nominal Width (W) of Units, in. (mm)</th>
<th>Face Shell Thickness ( (t_b) ), min. in. (mm)</th>
<th>Web Thickness ( (t_w) ), min. in. (mm)</th>
<th>Equivalent Web Thickness, min. in./linear ft ( ^2 ) (mm/linear m)</th>
<th>Web Area ( (A_w) ), min. in. (^2/\text{ft}^2 ) (mm(^2/\text{m}^2 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 (76.2) and 4 (102)</td>
<td>( \frac{3}{4} (19) )</td>
<td>( \frac{3}{4} (19) )</td>
<td>2-( \frac{1}{4} ) (136)</td>
<td>6.5 (45,140)</td>
</tr>
<tr>
<td>6 (152)</td>
<td>( 1 (25) )</td>
<td>( 1 (25) )</td>
<td>2-( \frac{1}{4} ) (188)</td>
<td></td>
</tr>
<tr>
<td>8 (203)</td>
<td>( 1 \frac{1}{4} (32) )</td>
<td>( 1 \frac{1}{4} (32) )</td>
<td>2-( \frac{1}{4} ) (188)</td>
<td>2-( \frac{1}{4} ) (209)</td>
</tr>
<tr>
<td>10 (254) and greater</td>
<td>( 1 \frac{1}{4} (32) )</td>
<td>( 1 \frac{1}{4} (32) )</td>
<td>2-( \frac{1}{4} ) (209)</td>
<td>2-( \frac{1}{4} ) (209)</td>
</tr>
</tbody>
</table>

Potential energy benefits, additional unit configuration options...design flexibility
2013 MSJC – ASTM C90 Changes

- Examples of unit configurations that comply with new ASTM C90 web area requirements

Figure 1—Examples of Web Configurations Permitted Under ASTM C90-11b

A Not all units are available in all areas. Consult local manufacturers.

B Note that 0.75 in. (19 mm) is the minimum web thickness. Thicker webs are permitted.

C 2.6 in. (66 mm) is the minimum web height that will meet the C90 normalized web area requirement for units with three 0.75 in. (19 mm) thick webs and nominal face dimensions of 8 in. x 16 in. (203 x 406 mm).

D The single web could be any combination of height and thickness that results in a web area of at least 6.5 in.² of web/ft² of wall area (45,140 mm²/m²).

NCMA TEK 2-5B
2013 MSJC - Select Changes

- ASTM C90-12 referenced in the 2013 MSJC triggering a requirement to check normalized web area:
  - ASD and SD – Min. normalized web area of 27 in$^2$/ft$^2$ (revised to 25 in$^2$/ft$^2$ in the 2016 TMS 402 Draft) or do a calculated web shear stress check.

- Partitions and Empirical – Min. normalized web area of 27 in$^2$/ft$^2$ (revised to 25 in$^2$/ft$^2$ in the 2016 TMS 402 Draft) required unless section is solidly grouted to use prescriptive provisions. This allows the web shear stress check to be avoided.
2013 MSJC - Select Changes

- **d distance** figures were added to the Specification to help illustrate tolerances based on d.

- Mortar joint tolerances at foundations and at flashings were clarified.
Clarification that bond beams may be stepped or sloped.

Figure SC-1: Sloped and Stepped Bond Beams
2013 MSJC Select Changes

and many more...
SELECT CHANGES – 2016 TMS 402/TMS 602
• Shear-friction and Shear-friction Strength provisions were added to both ASD (Section 8.3.6) and SD (Section 9.3.6.5)
  • Shear transfer across horizontal interfaces in walls subjected to in-plane loads.
  • When subjected to in-plane lateral loads, walls that have a low axial compressive load and a low shear-span ratio are vulnerable to shear sliding, which normally occurs at the base.
  • Function of the roughness at the base.
  • Separate equations for both ASD and SD but they are coordinated.
Reorganization efforts continued with a primary focus on moving common provisions into Chapter 6 - Reinforcement, Metal Accessories and Anchor Bolts.

Splice and development length requirements were consolidated into Chapter 6 and removed from the individual chapters. (No equation changes)

Nominal bar diameter requirement (Bar diameter shall not exceed one-eighth of the nominal member thickness) which applied only to SD in previous editions was moved to Chapter 6. It now applies to ASD and SD.
Previously tables for 5 psf and 10 psf lateral load for unreinforced masonry walls were included.
- Concern expressed for seismic loading
- Limited use for designers

New tables added for h/t and l/t lateral loadings from 5 psf to 50 psf
- Table 14.3.1 for ungrouted or partially grouted unreinforced walls.
- Table 14.3.2 for solidly grouted unreinforced walls.
- Some of the restrictions on use were removed.
### 2016 TMS 402/TMS 602

Table 14.3.1 Partition Walls – Ungrouted or Partially Grouted
(See Table 14.3.2 for solidly grouted walls)

<table>
<thead>
<tr>
<th>Maximum combined allowable stress level out-of-plane load acting on simple span partition wall</th>
<th>Mortar type</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Portland cement/lime or mortar cement</td>
<td>Masonry cement or air entrained portland cement/lime</td>
<td></td>
</tr>
<tr>
<td></td>
<td>M or S</td>
<td>N</td>
<td>M or S</td>
</tr>
<tr>
<td>5 psf (0.239 kPa)</td>
<td>26</td>
<td>24</td>
<td>22</td>
</tr>
<tr>
<td>10 psf (0.479 kPa)</td>
<td>18</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>15 psf (0.718 kPa)</td>
<td>15</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>20 psf (0.958 kPa)</td>
<td>13</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>30 psf (1.436 kPa)</td>
<td>10</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>40 psf (1.915 kPa)</td>
<td>9</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>50 psf (2.394 kPa)</td>
<td>8</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>

**Example:**

15 psf load. Partially grouted 8” wall. PCL mortar. Simple support.

\[
\frac{h}{t} = 15 \text{ (from table)} \quad t = 8'' \text{ (nominal dimension of an 8”CMU)}
\]

Solve for \(h\):

\[
h = \frac{(15 \times 8'')}{12} = 10' \text{ maximum height.}
\]
Loads terminology made consistent throughout the document. ‘Allowable stress level loads’ and ‘Strength level loads’ now are used rather than a mix of ‘nominal loads’ ‘service loads’ and more. Both terms are also defined to help with clarity:

- **Load, allowable stress level** – Loads resulting from allowable stress design load combinations.
- **Load, strength level** – Loads resulting from strength design load combinations.

Definitions were added for ‘Beam’, ‘Lintel’, ‘Pilaster’ and ‘Cavity’ as well as modification to the ‘Collar Joint’ and inconsistencies in the use of the terms were eliminated.
Tables, instead of written provisions, were incorporated in several locations to more clearly explain the requirements.

- Ease of use by the user
- Similar to ACI 318-14 formatting
- Highlighted underlying confusion in some cases which is now clarified.
This:

### TABLE 3.1 MINIMUM QUALITY ASSURANCE LEVEL

<table>
<thead>
<tr>
<th>DESIGNED IN ACCORDANCE WITH</th>
<th>RISK CATEGORY I, II OR III</th>
<th>RISK CATEGORY IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part 3 or Appendix B or Appendix C</td>
<td>Level 2</td>
<td>Level 3</td>
</tr>
<tr>
<td>Part 4</td>
<td>Level 1</td>
<td>Level 2</td>
</tr>
<tr>
<td>Appendix A</td>
<td>Level 1</td>
<td>Not permitted</td>
</tr>
</tbody>
</table>

**3.1.1 Level 1 Quality Assurance**

The minimum quality assurance program for masonry in Risk Category I, II, or III structures and designed in accordance with Part 4 or Appendix A shall comply with the Level 1 requirements of TMS 602 Tables 3 and 4.

**3.1.2 Level 2 Quality Assurance**

**3.1.2.1** The minimum quality assurance program for masonry in Risk Category IV structures and designed in accordance with Chapter 12 or 13 shall comply with the Level 2 requirements of TMS 602 Tables 3 and 4.

**3.1.2.2** The minimum quality assurance program for masonry in Risk Category I, II, or III structures and designed in accordance with chapters other than those in Part 4 or Appendix A shall comply with the Level 2 requirements of TMS 602 Tables 3 and 4.

**3.1.3 Level 3 Quality Assurance**

The minimum quality assurance program for masonry in Risk Category IV structures and designed in accordance with chapters other than those in Part 4 or Appendix A shall comply with the Level 3 requirements of TMS 602 Tables 3 and 4.

Not This:

DESIGNED IN ACCORDANCE WITH RISK CATEGORY I, II OR III RISK CATEGORY IV
Part 3 or Appendix B or Appendix C Level 2 Level 3
Part 4 Level 1 Level 2
Appendix A Level 1 Not permitted

3.1.1 Level 1 Quality Assurance
The minimum quality assurance program for masonry in Risk Category I, II, or III structures and designed in accordance with Part 4 or Appendix A shall comply with the Level 1 requirements of TMS 602 Tables 3 and 4.

3.1.2 Level 2 Quality Assurance
3.1.2.1 The minimum quality assurance program for masonry in Risk Category IV structures and designed in accordance with Chapter 12 or 13 shall comply with the Level 2 requirements of TMS 602 Tables 3 and 4.
3.1.2.2 The minimum quality assurance program for masonry in Risk Category I, II, or III structures and designed in accordance with chapters other than those in Part 4 or Appendix A shall comply with the Level 2 requirements of TMS 602 Tables 3 and 4.

3.1.3 Level 3 Quality Assurance
The minimum quality assurance program for masonry in Risk Category IV structures and designed in accordance with chapters other than those in Part 4 or Appendix A shall comply with the Level 3 requirements of TMS 602 Tables 3 and 4.


**TABLE 6.1.8**

**STANDARD HOOKS GEOMETRY AND MINIMUM INSIDE BEND DIAMETERS FOR REINFORCING BARS, STIRRUPS & TIES**

<table>
<thead>
<tr>
<th>Standard Hook Type and Use</th>
<th>Bar Grade</th>
<th>Bar Size</th>
<th>Min. Inside Bend Diameter</th>
<th>Extension</th>
<th>Standard Hook Figures</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 Degree Hook – Reinforcing Bars</td>
<td>40 (M280)</td>
<td>No. 3 - No. 7 (W610 - W22)</td>
<td>5(d_b)</td>
<td>12 (d_b)</td>
<td><img src="Diagram1" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td>50 or 60 (M350 or 420)</td>
<td>No. 3 - No. 8 (W610 - W25)</td>
<td>6 (d_b)</td>
<td>12 (d_b)</td>
<td><img src="Diagram2" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td>50 or 60 (M350 or 420)</td>
<td>No. 9 - No. 11 (W610 - W36)</td>
<td>8 (d_b)</td>
<td>12 (d_b)</td>
<td><img src="Diagram3" alt="Diagram" /></td>
</tr>
<tr>
<td>90 Degree Hook – Stirrups &amp; Ties</td>
<td>40, 50, 60 (M280, 350 or 420)</td>
<td>No. 3 - No. 5 (W610 - W16)</td>
<td>4 (d_b)</td>
<td>6 (d_b) but not less than 2-1/2 in. (64 mm)</td>
<td><img src="Diagram4" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td>40 (M280)</td>
<td>No. 6 and No. 7 (W610 - W22)</td>
<td>5 (d_b)</td>
<td>6 (d_b)</td>
<td><img src="Diagram5" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td>50 or 60 (M350 or 420)</td>
<td>No. 6 - No. 8 (W610 - W25)</td>
<td>6 (d_b)</td>
<td>6 (d_b)</td>
<td><img src="Diagram6" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td>50 or 60 (M350 or 420)</td>
<td>No. 9 - No. 11 (W610 - W36)</td>
<td>8 (d_b)</td>
<td>6 (d_b)</td>
<td><img src="Diagram7" alt="Diagram" /></td>
</tr>
<tr>
<td>135 Degree Hook – Stirrups &amp; Ties</td>
<td>40, 50, 60 (M280, 350 or 420)</td>
<td>No. 3 - No. 5 (W610 - W16)</td>
<td>4 (d_b)</td>
<td>6 (d_b)</td>
<td><img src="Diagram8" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td>40 (M280)</td>
<td>No. 6 and No. 7 (W610 - W22)</td>
<td>5 (d_b)</td>
<td>6 (d_b)</td>
<td><img src="Diagram9" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td>50 or 60 (M350 or 420)</td>
<td>No. 6 - No. 8 (W610 - W25)</td>
<td>6 (d_b)</td>
<td>6 (d_b)</td>
<td><img src="Diagram10" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td>50 or 60 (M350 or 420)</td>
<td>No. 9 - No. 11 (W610 - W36)</td>
<td>8 (d_b)</td>
<td>6 (d_b)</td>
<td><img src="Diagram11" alt="Diagram" /></td>
</tr>
<tr>
<td>180 Degree Hook – Reinforcing Bars</td>
<td>40 (M280)</td>
<td>No. 3 - No. 7 (W610 - W22)</td>
<td>5 (d_b)</td>
<td>4 (d_b) but not less than 2-1/2 in. (64 mm)</td>
<td><img src="Diagram12" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td>50 or 60 (M350 or 420)</td>
<td>No. 3 - No. 8 (W610 - W25)</td>
<td>6 (d_b)</td>
<td>4 (d_b) but not less than 2-1/2 in. (64 mm)</td>
<td><img src="Diagram13" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td>50 or 60 (M350 or 420)</td>
<td>No. 9 – No. 11 (W610 - W36)</td>
<td>8 (d_b)</td>
<td>4 (d_b)</td>
<td><img src="Diagram14" alt="Diagram" /></td>
</tr>
</tbody>
</table>

**Replaces language in multiple sections of the Code and consolidates into one table**
Anchored Veneer

- Distance between inside face of the veneer and the backing increased from $4\frac{1}{2}''$ to $4\frac{5}{8}''$ before tie analysis is required.

- Option to increase that space to $6\frac{5}{8}''$ with special anchoring provisions....
Anchored Veneer - 6\(\frac{5}{8}\)” max. space from inside of veneer to the backing requirements:

- Adjustable anchor with 2 or more W2.8 wires (min.)

- Barrel anchor, plate or prong anchor (min sizes required) to back-up with wood, steel or concrete or masonry backing.

- Masonry back-up can also use tab anchor with min. of 2 eyes.

- Inside face of veneer to end of the adjustable part of anchor – 2” max.
2016 TMS 402/TMS 602

- Quality Assurance Tables were rewritten and simplified.
  - Duplicate tables were deleted from the TMS 402 Code which now refers to the TMS 602 Tables.
  - Components of the change:
    - List current Inspection Requirement tasks for all levels into a single table.
    - Segregate Minimum Test Requirements from the Inspection Requirements.
    - Changed QA Levels A, B, C to QA Levels 1,2,3. (Consistent with IBC)
### 2016 TMS 402/TMS 602

- Quality Assurance Tables

**Table 3 — Minimum Verification Requirements**

<table>
<thead>
<tr>
<th>Minimum Verification</th>
<th>Required for Quality Assurance&lt;sup&gt;(a)&lt;/sup&gt;</th>
<th>Reference for Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level 1</td>
<td>Level 2</td>
</tr>
<tr>
<td>Prior to construction, verification of compliance of submittals.</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Prior to construction, verification of $f'<em>m$ and $f'</em>{AAC}$, except where specifically exempted by the Code.</td>
<td>NR</td>
<td>R</td>
</tr>
<tr>
<td>During construction, verification of Slump flow and Visual Stability Index (VSI) when self-consolidating grout is delivered to the project site.</td>
<td>NR</td>
<td>R</td>
</tr>
<tr>
<td>During construction, verification of $f'<em>m$ and $f'</em>{MAC}$ for every 5,000 sq. ft. (465 sq. m).</td>
<td>NR</td>
<td>NR</td>
</tr>
</tbody>
</table>

(a) R=Required, NR=Not Required

**Table 4 — Minimum Special Inspection Requirements**

<table>
<thead>
<tr>
<th>Inspection Task</th>
<th>Frequency&lt;sup&gt;(a)&lt;/sup&gt;</th>
<th>Reference for Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level 1</td>
<td>Level 2</td>
</tr>
<tr>
<td>1. As masonry construction begins, verify that the following are in compliance:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Proportions of site-prepared mortar</td>
<td>NR</td>
<td>P</td>
</tr>
<tr>
<td>b. Grade and size of prestressing tendons and anchorages</td>
<td>NR</td>
<td>P</td>
</tr>
<tr>
<td>c. Grade, type and size of reinforcement, connectors, anchor bolts, and prestressing tendons and anchorages</td>
<td>NR</td>
<td>P</td>
</tr>
<tr>
<td>d. Prestressing technique</td>
<td>NR</td>
<td>P</td>
</tr>
<tr>
<td>e. Properties of thin-bed mortar for AAC masonry</td>
<td>NR</td>
<td>C&lt;sup&gt;(b)&lt;sup&gt;(c)&lt;/sup&gt;&lt;sup&gt;(c)&lt;/sup&gt;</td>
</tr>
<tr>
<td>f. Sample panel construction</td>
<td>NR</td>
<td>P</td>
</tr>
<tr>
<td>2. Prior to grouting, verify that the following are in compliance:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Grout space</td>
<td>NR</td>
<td>P</td>
</tr>
<tr>
<td>b. Placement of prestressing tendons and</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Excerpt of Table 4 only
and many more...
IN CONCLUSION...
Code Adoption Time Lines - 2011 & 2013 MSJC and 2016 TMS 402/602

- 2011 MSJC Referenced in the 2012 IBC and IRC
- 2013 MSJC Referenced in the 2015 IBC and IRC
- 2016 TMS 402/ TMS 602 Completed and Referenced in the 2018 IBC and IRC.
- 2022 TMS 402/TMS 602 - **A six year cycle!**
  Work started Sept. 2016 for reference in the 2024 IBC

  Check for local adoption status and potential local amendments
Questions?

Contacting IMI is easy!
Just call...

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Delaware Valley Association of Structural Engineers

Wednesday, November 16, 2016 • Plymouth Meeting, PA

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Masonry Codes & Standards

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Walkowicz Consulting Engineers
on behalf of the Delaware Valley & New Jersey Structural Coalitions