Movement Control
All materials in a building experience changes in volume
Movement

- Expansion
- Shrinkage
- Moisture
TMS 2013 Code

Section 1.2.1 (h)

Provisions for dimensional changes resulting from the following are required to be included on the Project Drawings:

- Elastic deformation
- Creep
- Shrinkage
- Temperature
- Moisture
<table>
<thead>
<tr>
<th>Section/Part/Article</th>
<th>Notes to the Architect/Engineer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PART 1 — GENERAL</strong></td>
<td></td>
</tr>
<tr>
<td>1.4 A Compressive strength requirements</td>
<td>Specify $f_{cu}$ and $f'<em>{cu}$, except for veneer, glass unit masonry, prescriptively designed partition walls, and empirically designed masonry. Specify $f</em>{cu}$ for prestressed masonry.</td>
</tr>
<tr>
<td>1.4 B.2 Unit strength method</td>
<td>Specify when strength of grout is to be determined by test.</td>
</tr>
<tr>
<td>1.5 Submittals</td>
<td>Define the submittal reporting and review procedure.</td>
</tr>
<tr>
<td>1.6 A.1 Testing Agency’s services and duties</td>
<td>Specify which of Tables 3, 4, or 5 applies to the project. Specify which portions of the masonry were designed in accordance with the prescriptive partition wall, empirical, veneer, or glass unit masonry provisions of this Code and are, therefore, exempt from verification of $f_{cu}$.</td>
</tr>
<tr>
<td>1.6 B.1 Inspection Agency’s services and duties</td>
<td>Specify which of Tables 3, 4, or 5 applies to the project. Specify which portions of the masonry were designed in accordance with the prescriptive partition wall, empirical, veneer, or glass unit masonry provisions of this Code and are, therefore, exempt from verification of $f_{cu}$.</td>
</tr>
<tr>
<td>1.6 D Sample panels</td>
<td>Specify requirements for sample panels.</td>
</tr>
<tr>
<td><strong>PART 2 — PRODUCTS</strong></td>
<td></td>
</tr>
<tr>
<td>2.1 Mortar materials</td>
<td>Specify type, color, and cementitious materials to be used in mortar and mortar to be used for the various parts of the project and the type of mortar to be used with each type of masonry unit.</td>
</tr>
<tr>
<td>2.3 Masonry unit materials</td>
<td>Specify the masonry units to be used for the various parts of the project.</td>
</tr>
<tr>
<td>2.4 Reinforcement, prestressing tendons, and metal accessories</td>
<td>Specify type and grade of reinforcement, tendons, connectors, and accessories.</td>
</tr>
<tr>
<td>2.4 A Reinforcing Steel</td>
<td>When deformed reinforcing bars conforming to ASTM A615/A615M or ASTM A996/A996M are required by strength design in accordance with Code Chapter 9 or Chapter 11, specify that the actual yield strength must not exceed the specified yield strength multiplied by 1.3.</td>
</tr>
<tr>
<td>2.4 C.1 Joint reinforcement</td>
<td>Specify joint reinforcement wire size and number of longitudinal wires when joint reinforcement is to be used as shear reinforcement.</td>
</tr>
<tr>
<td>2.4 C.3 Welded wire reinforcement</td>
<td>Specify when welded wire reinforcement is to be plain.</td>
</tr>
<tr>
<td>2.4 E Stainless steel</td>
<td>Specify when stainless steel joint reinforcement, anchors, ties, and/or accessories are required.</td>
</tr>
<tr>
<td>2.4 F Coating for corrosion protection</td>
<td>Specify the types of corrosion protection that are required for each portion of the masonry construction.</td>
</tr>
<tr>
<td>2.4 G Corrosion protection for tendons</td>
<td>Specify the corrosion protection method.</td>
</tr>
<tr>
<td><strong>PART 3 — EXECUTION</strong></td>
<td></td>
</tr>
<tr>
<td>3.3 D.2-4 Pipes and conduits</td>
<td>Specify sleeve sizes and spacing.</td>
</tr>
<tr>
<td>3.3 D.5 Accessories</td>
<td>Specify accessories not indicated on the project drawings.</td>
</tr>
<tr>
<td>3.3 D.6 Movement joints</td>
<td>Indicate type and location of movement joints on the project drawings.</td>
</tr>
<tr>
<td>3.4 B.11 Placement tolerances</td>
<td>Indicate $d$ distance for beams on drawings or as a schedule in the project specifications.</td>
</tr>
<tr>
<td>3.4 E Veneer anchors</td>
<td>Specify type of anchor required.</td>
</tr>
</tbody>
</table>
Clay Masonry

Expands
Clay Volume Changes

A brick unit is smallest in size when it cools after coming from the kiln.
Projected Moisture Expansion

Figure 2
Projected Moisture Expansion of Fired Brick vs. Time
Moisture & Thermal Movement

- **Coefficient of Moisture Expansion, in./in.**
  - 0.0003 for clay masonry (TMS 2013)
  - 0.0005 for clay masonry veneer (BIA 18, 2006)

- **Coefficient of Lineal Thermal Expansion, in./in./°F**
  - Use 0.000004 for clay masonry (TMS 2013)
Clay Wall Expansion

How much does this wall expand due to moisture and thermal differential?

Foundation provides some restraint to horizontal expansion

100’-0”

100’-1.1”
Clay Wall Expansion

Evidence of movement
Unrestrained Expansion (Veneer)

\[ m_u = (k_e + k_f + k_t \Delta T) L \] \hspace{0.5cm} \text{[Long Eqn]}

\[ w_{je_j} = (0.0005 + 0.0 + 0.000004 \times 100) \times S_e \]

\[ w_{je_j} = (0.0005 + 0.0004) \times S_e \]

\[ w_{je_j} = 0.0009 \times S_e \]

\[ S_e = \frac{w_{je_j}}{0.0009 \times 100} \]

\[ S_e = \frac{w_{je_j}}{0.09} \] \hspace{0.5cm} \text{[Short Eqn]}
Vertical Expansion Joints

- Size of sealant joint
  - BIA suggests 1/2”

- Compressibility of sealant
  - 50%
### Joint Sealant

#### Table 8.5.1 Common Sealant Material Movement Capacities

<table>
<thead>
<tr>
<th>Sealant Type</th>
<th>Movement Capacities, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylic</td>
<td>+7</td>
</tr>
<tr>
<td>Butyl</td>
<td>+5</td>
</tr>
<tr>
<td>Latex</td>
<td>+7</td>
</tr>
<tr>
<td>Polysulfide</td>
<td>+25</td>
</tr>
<tr>
<td>Polyurethane</td>
<td>+25</td>
</tr>
<tr>
<td>Low Modulus</td>
<td>+50</td>
</tr>
<tr>
<td>Silicone</td>
<td>+50</td>
</tr>
<tr>
<td>Low Modulus</td>
<td>+100, -50</td>
</tr>
</tbody>
</table>

+ is extension, - is compression
Types of Expansion Joints

- Premolded Foam Pad
- Neoprene Pad
- Sealant & Backer Rod

Figure 1
Example 1: *(spring, dark brick, south wall)*

\[
\frac{1}{2}" \times 50\% = [0.0003 + 0 + 0.000004(T_{\text{max}} - T_{\text{const}})] \times 12 \\
\frac{1}{2}" \times 50\% = [0.0003 + 0 + 0.000004(160-55)] \times 12 \\
0.25 = 0.00072 \times L \times 12 \\
0.25 = 0.00864 \times L
\]

1) [Long Eqn.] \(L = 28.9'\)
   
   *Use 29’ (0.0003, 105°F)*

2) [Short Eqn.] \(S_e = ((1/2"\times50)/12)/0.09 = 23.15'\)
   
   *Use 23’-4” (0.0005, 100°F)*

3) [Limit] \(L = 25’\) max. per BIA 18A (2006) w/o openings
Typical Locations of EJs

- Long Walls
- Corners
- Setbacks & Offsets
- Differences in height
- Different support conditions
- Beneath shelf angles
- Inside corners
- Openings
Typical Locations of EJs

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Typical Locations of EJs

- Long Walls
- Corners
- Setbacks & Offsets
- Differences in height
- Different support conditions
- Beneath shelf angles
- Inside corners
- Openings

**Figure 4**
Vertical Expansion Joints at Offsets
Typical Locations of EJs

- Long Walls
- Corners
- Setbacks & Offsets
- Differences in height
- Different support conditions
- Beneath shelf angles
- Inside corners
- Openings
Typical Locations of EJs

- Long Walls
- Corners
- Setbacks & Offsets
- Differences in height
- Different support conditions
- Beneath shelf angles
- Inside corners
- Openings
Typical Locations of EJs

- Long Walls
- Corners
- Setbacks & Offsets
- Differences in height
- Different support conditions
- Beneath shelf angles
- Inside corners
- Openings
Vertical Expansion

Subtotal concrete masonry contraction:
0.050 + 0.155 + 0.020 = 0.225 in.

Total differential movement = 0.339 (clay brick↑) + 0.234 (CMU↓) = 0.573 in.

If an expansion joint filler has a 50% compressibility, the minimum expansion joint filler thickness is:
0.573 in. / 50% = 1.15 in.
Typical Locations of EJs

- Long Walls
- Corners
- Setbacks & Offsets
- Differences in height
- Different support conditions
- Beneath shelf angles
- Inside corners
- Openings
Openings

Wall Segment Movement

25' w/o openings, \( \frac{1}{2}'' \) EJ

20' w/ openings, \( \frac{1}{2}'' \) EJ

Brick Expansion Joints and Wall Openings, J. Gregg Borchelt. PE, ME/SP Vol 38, No 4, 2007
Openings

Symmetrically place expansion joints at decreased spacing
EJ Color Matches Mortar

Improper sealant color
EJ Color Matches Brick

Proper sealant color
Concrete Masonry

Shrinks
Shrinkage Pattern

Bond to foundation
Concrete Volume Changes

Concrete masonry units are largest at time of manufacturing.
Anticipated Movement

- Crack Control Coefficient (CCC)
  - Carbonation
  - Linear Drying shrinkage
  - Thermal contraction

\[0.00063 - 0.00108 \text{ in/in}\]
Concrete Wall Shrinkage

How much does this wall shrink due to moisture and thermal differential?

Foundation provides some restraint to horizontal expansion.

99’-10 ¾”

100’-0”

99’-10 ¾”
Control Joint (CJ)

Evidence of movement
Control Joint (CJ)

Horizontal Joint Reinforcement
Control Joint (CJ)

Horizontal Joint Reinforcement

MIM Generic Wall Design Details
Control Joint (CJ)

No material should be continuous through a control joint unless for structural reasons.
Bond Beams

- Non-continuous (discuss with SER)
Bond Beams

- Continuous (discuss with SER)

- Continuous Horizontal Steel Reinforcement
- Grout Bond Beam Units Solid, Continuous
- Rake Joint, Backer Rod & Sealant (on interior face)
- Bond Beam Units (omit C.J. at bond beam)
- Joints to be struck flush on exterior face of CMU back-up

Masonry control joint @ 8C
Continuous bond beam detail A-1 (per structural requirements)
Types of Control Joints

- Pre-formed gasket
Types of Control Joints

- Michigan control joint
Intersecting Walls

- Shear Wall Locations (discuss with SER)
Intersecting Walls

- Hinged Joint
Table 1—Recommended Control Joint Spacing for Above Grade Exposed Concrete Masonry Walls

Distance between joints should not exceed the lesser of:

<table>
<thead>
<tr>
<th>Length to height ratio</th>
<th>or ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/2</td>
<td>25</td>
</tr>
</tbody>
</table>

Table values are based on the use of horizontal reinforcement having an equivalent area of not less than 0.025 in.2/ft (52.9 mm²/m) of height to keep unplanned cracks closed (see Table 2).
### Table 1—Criteria for Controlling Cracking in Reinforced Concrete Masonry Walls\(^a\)

<table>
<thead>
<tr>
<th>Maximum wall panel dimensions(^2)</th>
<th>Crack Control Coefficient in./in. (mm/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>length, ft (m)</td>
<td>0.0010</td>
</tr>
<tr>
<td></td>
<td>0.0015</td>
</tr>
<tr>
<td>length/height ratio</td>
<td>25 (7.62)</td>
</tr>
<tr>
<td></td>
<td>20 (6.10)</td>
</tr>
<tr>
<td>Minimum horizontal reinforcement ratio (A_s/A_n)</td>
<td>2 1/2</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>0.0007</td>
</tr>
<tr>
<td></td>
<td>0.0007</td>
</tr>
</tbody>
</table>

\(^a\) NCMA TEK 10-3 (2003)
## Table 2—Maximum Spacing of Horizontal Reinforcement to Meet the Criteria As > 0.0007An

<table>
<thead>
<tr>
<th>Wall thickness, in. (mm)</th>
<th>Maximum spacing of horizontal reinforcement, in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. 5 (M 16)</td>
</tr>
<tr>
<td>6 (152)</td>
<td>144 (3658)</td>
</tr>
<tr>
<td>8 (203)</td>
<td>144 (3658)</td>
</tr>
<tr>
<td>10 (254)</td>
<td>136 (3458)</td>
</tr>
<tr>
<td>12 (305)</td>
<td>120 (3048)</td>
</tr>
</tbody>
</table>

### Ungrouted or partially grouted walls

### Fully grouted walls

---

1. $A_n$ includes cross-sectional area of grout in bond beams

NCMA TEK 10-3 (2003)
## Engineered Method

### Table 3—Maximum Spacing of Horizontal Reinforcement to Meet the Criteria As > 0.002$A_n$

(Control joints may be eliminated)

<table>
<thead>
<tr>
<th>Wall thickness, in. (mm)</th>
<th>Maximum spacing of horizontal reinforcement, in. (mm)</th>
<th>Reinforcement size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. 6 (M19)</td>
<td>No. 5 (M16)</td>
</tr>
<tr>
<td><strong>Ungrouted or partially grouted walls</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 (152)</td>
<td>48 (1219)</td>
<td>48 (1219)</td>
</tr>
<tr>
<td>8 (203)</td>
<td>48 (1219)</td>
<td>40 (1016)</td>
</tr>
<tr>
<td>10 (254)</td>
<td>48 (1219)</td>
<td>32 (813)</td>
</tr>
<tr>
<td>12 (305)</td>
<td>48 (1219)</td>
<td>24 (610)</td>
</tr>
<tr>
<td><strong>Fully grouted walls</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 (152)</td>
<td>32 (813)</td>
<td>24 (610)</td>
</tr>
<tr>
<td>8 (203)</td>
<td>24 (610)</td>
<td>16 (406)</td>
</tr>
<tr>
<td>10 (254)</td>
<td>16 (406)</td>
<td>16 (406)</td>
</tr>
<tr>
<td>12 (305)</td>
<td>16 (406)</td>
<td>8 (203)</td>
</tr>
</tbody>
</table>

1. $A_n$ includes cross-sectional area of grout in bond beams
At maximum of one-half control joint spacing from corners

Between main and intersecting wall

At changes in wall height

At pilasters and changes in wall thickness

Adjacent to lintel and through opening if not crossing vertical reinforcement
Reinforced Wall

Maximum control joint spacing per Table 1

Lintel reinforcement

Sill

2c—Preferred strengthening of opening with reinforcement—extending lintel reinforcement and joint reinforcement under the sill

Advantages

■ Inherent arching action
■ Fewer control joints
■ No slip plane (no bearing plate)
■ No maintenance (no painting)
■ No cutting and anchoring of soaps
■ No lead time
■ No delays (material readily available)

Reinforced Opening
These details may also be used in unreinforced walls and walls utilizing steel lintels, since the area surrounding the opening is strengthened by the additional reinforcement.

Reinforced Opening

2d—Opening strengthened with joint reinforcement (first two courses over opening and under sill)
### Suggested Guidelines

**Multi-Wythe**

- **Exterior Clay Masonry Wythe (EJs)**

**Straight run walls with no openings**

<table>
<thead>
<tr>
<th>Jt size</th>
<th>$S_e$ (Short Eq.)</th>
<th>$m_u$ (Long Eq.)</th>
<th>No Openings</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8”</td>
<td>17’-4”</td>
<td>22’-0”</td>
<td>20’ max</td>
</tr>
<tr>
<td>1/2”</td>
<td>23’-4”</td>
<td>29’-0”</td>
<td>25’ max</td>
</tr>
</tbody>
</table>

![Diagram showing Masonry Wall with Expansion Joints and no openings.](image)
Suggested Guidelines

Multi-Wythe

- Exterior Clay Masonry Wythe (EJs)

  - **Corners**
    1. 4” min preferred
    2. $L_1 + L_2 < S$ (wrap)
    3. Either $L_1$ or $L_2 < 10$ ft (one side)
Suggested Guidelines

Multi-Wythe

- Exterior Clay Masonry Wythe (EJs)
  - **Support of masonry above opening**
    - Arch (jamb support)
    - Reinforced brick beam (jamb support)
    - Loose steel lintel (jamb support)
    - Shelf angle (backup support)
Suggested Guidelines

Multi-Wythe

■ Exterior Clay Masonry Wythe (EJs)
  ■ Support of masonry above opening
    ■ True arch (jamb support)

Diagram:
- 2’ EJ
- S = 25’
- 4” EJ
Suggested Guidelines

Multi-Wythe

- **Exterior Clay Masonry Wythe (EJs)**
  - Support of masonry above opening
  - Reinforced brick beam (jamb support)
Suggested Guidelines

Multi-Wythe

- Exterior Clay Masonry Wythe (EJ's)
  - Support of masonry above opening
  - Loose steel lintel (jamb support, 8’ max)

BIA 18A (2006)
Suggested Guidelines

Multi-Wythe

- Exterior Clay Masonry Wythe (EJs)
  - Support of masonry above opening
  - Shelf angle or plate (one-piece lintel)

One-piece lintel

![Diagram of EJ EJ EJ EJ with dimensions 2', 12', S = 25', 4']
Suggested Guidelines

Multi-Wythe

■ Exterior Clay Masonry Wythe (EJs)

■ Single panel with openings

■ Symmetrical sections

<table>
<thead>
<tr>
<th>Jt size</th>
<th>Openings</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/8”</td>
<td>15’ max</td>
</tr>
<tr>
<td>1/2”</td>
<td>20’ max</td>
</tr>
</tbody>
</table>

2’ 12’ S = 25’

4” EJ
Suggested Guidelines

Multi-Wythe

- Exterior Clay Masonry Wythe (EJs)
Suggested Guidelines

Multi-Wythe

- Interior Concrete Masonry Wythe (CJs)
  - Straight run walls with no openings

<table>
<thead>
<tr>
<th>Lesser of:</th>
<th>Length Height</th>
<th>CJ spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empirical Method</td>
<td>1 1/2</td>
<td>25’ max</td>
</tr>
<tr>
<td>Engineered Method</td>
<td>2</td>
<td>20’ max</td>
</tr>
<tr>
<td></td>
<td>2 1/2</td>
<td>25’ max</td>
</tr>
</tbody>
</table>

$S_c = 20'$

CJ

CJ
Suggested Guidelines

Multi-Wythe

- **Interior Concrete Masonry Wythe (CJs)**
  - **Corners**
    - \( L_1 \) and \( L_2 \leq \frac{1}{2} S_c \) (both sides)

1'-4'' < 10'

\[ S = 20' \]

4' < 10'

\( CJ \)

\( CJ \)

\( CJ \)
Suggested Guidelines

Multi-Wythe

- **Interior Concrete Masonry Wythe (CJs)**
  - **Unreinforced openings**
    - Joints placed at ends of lintels w/slip plane
    - ≤ 6’ one side above & below

![Diagram of Multi-Wythe structure](image)
Suggested Guidelines

Multi-Wythe

- Interior Concrete Masonry Wythe (CJs)
  - Unreinforced openings
    - Joints placed at ends of lintels w/slip plane
    - > 6’ both sides above & below

One piece steel lintel

1’-4” 13’-4”

S = 20’
Suggested Guidelines

Multi-Wythe

■ Interior Concrete Masonry Wythe (CJs)
  ■ Reinforced openings
  ■ Masonry lintels
Suggested Guidelines

Multi-Wythe

- Interior Concrete Masonry Wythe (CJs)

**ONE PIECE STEEL LINTEL (UNREINFORCED OPENING)**

**CMU LINTEL (REINFORCED OPENING)**

1’-4” 13’-4” 17’-4” 17’-4” 20’-0” 4’-0”
Suggested Guidelines

MSJC 2011

- Provisions for dimension changes resulting from the following are required to be included on the project drawings:
  - Show EJs on Architectural Elevations
  - Show CJs on Structural Plans (discuss with SER) and/or on Steel Reinforcement Shop Drawings (openings)