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MOVEMENT CONTROL CONCRETE MASONRY

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CONCRETE MASONRY

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SHRINKAGE PATTERN

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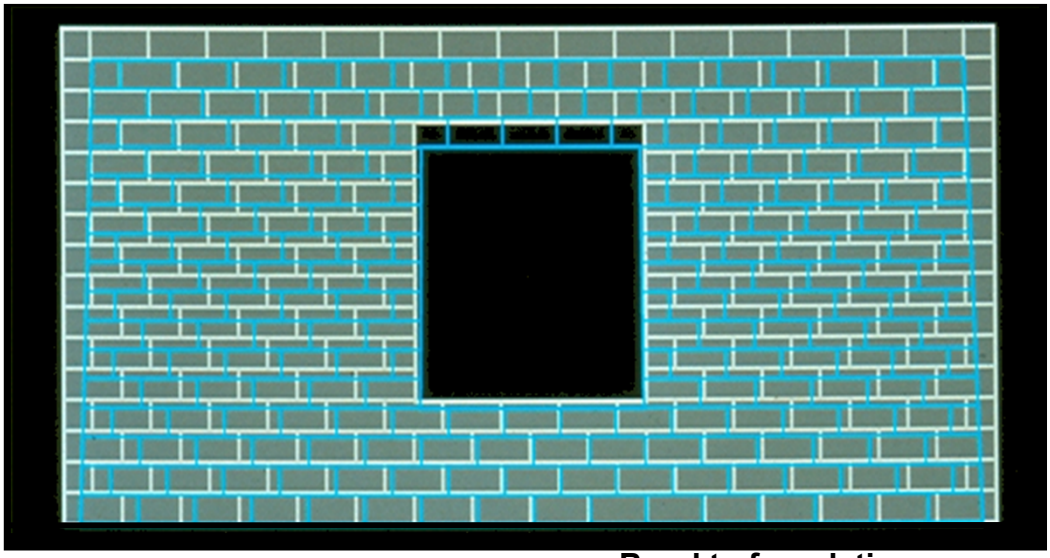

Bond to foundation

3

CONCRETE VOLUME CHANGES

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Concrete masonry units are largest at time of manufacturing.

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ANTICIPATED MOVEMENT

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NCMA TEK 10-1A

- Crack Control Coefficient (CCC) – Typical range 0.00063 – 0.00108 in/in

TMS 402/602-16

- Coefficient of Creep = 2.5 x 10^{-7}, per psi
- Coefficient of Thermal Expansion = 4.5 x 10^{-6} in/in/°F
- Coefficient of Shrinkage = $0.5s_l$

Thermal Expansion (70°) temperature change = 0.00028 in/in = 0.34" in 100'-0" wall

Coefficient of thermal expansion of steel:

7.2 x 10^{-6} in/in/°F

Table 4.2.6 Coefficients of Creep

Material	Coefficient (k_c)
Clay Masonry	0.7 x 10^{-7}, per psi (0.1 x 10^{-4}, per MPa)
Concrete Masonry	2.5 x 10^{-7}, per psi (0.36 x 10^{-4}, per MPa)
AAC Masonry	5.0 x 10^{-7}, per psi (0.72 x 10^{-4}, per MPa)

4.2.7 *Prestressing steel*
For prestressing steels not specifically listed in ASTM A416/A416M, A421/A421M, or A722/A722M, tensile strength and relaxation losses shall be determined by tests.

Table 4.2.3 Coefficients of Thermal Expansion

Material	Coefficient (k_t)
Clay Masonry	4 x 10^{-6} in./in./°F (7.2 x 10^{-6} mm/mm/°C)
Concrete Masonry	4.5 x 10^{-6} in./ in./°F (8.1 x 10^{-6} mm/mm/°C)
AAC Masonry	4.5 x 10^{-6} in./ in./°F (8.1 x 10^{-6} mm/mm/°C)

4.2.5 *Coefficients of shrinkage*
4.2.5.1 *Concrete masonry*
$k_m = 0.5\ s_l$

Aggregate	s_l
Sand and gravel	2.3x10^{-4}
Cinders	4.2x10^{-4}
Expanded Slag	3.4x10^{-4}
Expanded Shale	3.1x10^{-4}
Mean value	3.3x10^{-4}
Maximum (C 90)	6.5x10^{-4}

Based on saturated condition

In the field, units will be <70% saturated. So, highest drying shrinkage is 0.00045 in/in or 0.54" in 100'-0" wall

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CONCRETE WALL SHRINKAGE

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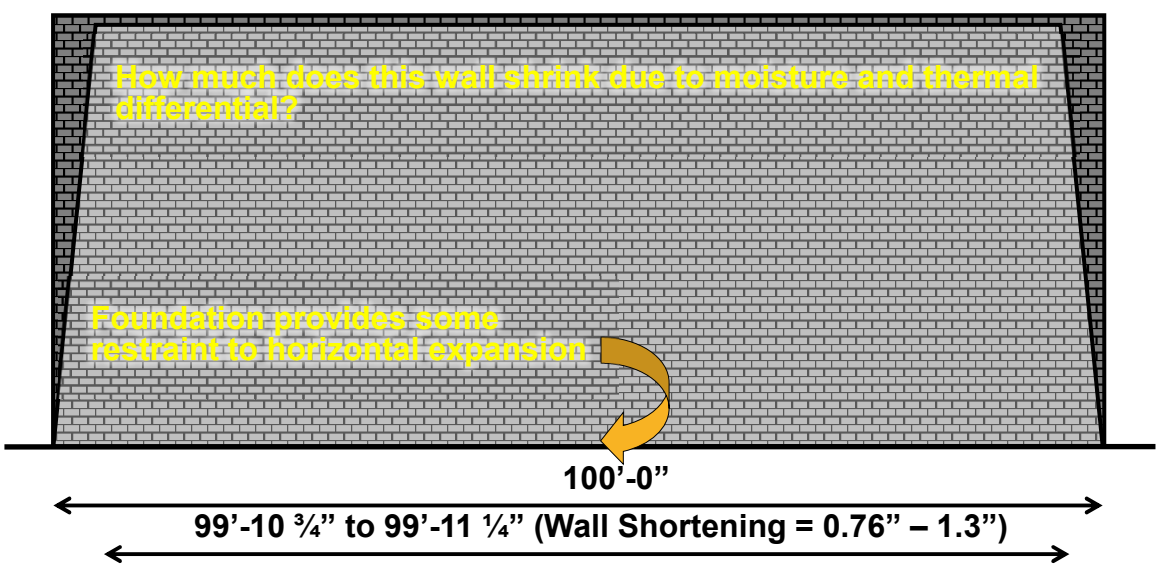

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CONCRETE WALL SHRINKAGE

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CONTROL JOINT (CJ)

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Evidence of movement

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HORIZONTAL JOINT REINFORCEMENT

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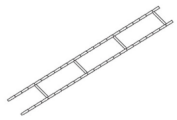
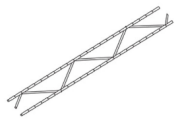
- There are two types of joint reinforcement:
  - Ladder-Type (Reinforced)
  - Truss-Type (Unreinforced)



(a) Ladder-Type Joint Reinforcing



(b) Truss-Type Joint Reinforcing

FIGURE 1.4.4 Joint Reinforcement

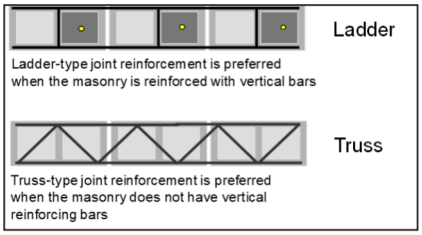


Figure 3 - Recommended use of horizontal joint reinforcement

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HORIZONTAL JOINT REINFORCEMENT

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- Different bar diameters (gages) are available
  - 9 gage (W1.7) is the most common and is <u>recommended</u>
  - Section 6.2.3 states "Longitudinal and cross wires of joint reinforcement shall have a minimum wire size of W1.1 and a maximum wire size of one-half the joint thickness"
    - 3/16" is *possible*
    - What about tolerances?

Table CC-6.1.2 — Physical properties of steel reinforcing wire and bars

Designation	Diameter, in. (mm)	Area, in.^{2} (mm^2)	Perimeter, in. (mm)
Wire			
W1.1 (11 gage) (MW7)	0.121 (3.1)	0.011 (7.1)	0.380 (9.7)
W1.7 (9 gage) (MW11)	0.148 (3.8)	0.017 (11.0)	0.465 (11.8)
W2.1 (8 gage) (MW13)	0.162 (4.1)	0.020 (12.9)	0.509 (12.9)
W2.8 (3/16 in. wire) (MW18)	0.187 (4.8)	0.027 (17.4)	0.587 (14.9)
W4.9 (1/4 in. wire) (MW32)	0.250 (6.4)	0.049 (31.6)	0.785 (19.9)
Bars			
No. 3 (M#10)	0.375 (9.5)	0.11 (71.0)	1.178 (29.9)
No. 4 (M#13)	0.500 (12.7)	0.20 (129)	1.571 (39.9)
No. 5 (M#16)	0.625 (15.9)	0.31 (200)	1.963 (49.9)
No. 6 (M#19)	0.750 (19.1)	0.44 (284)	2.356 (59.8)
No. 7 (M#22)	0.875 (22.2)	0.60 (387)	2.749 (69.8)
No. 8 (M#25)	1.000 (25.4)	0.79 (510)	3.142 (79.8)
No. 9 (M#29)	1.128 (28.7)	1.00 (645)	3.544 (90.0)
No. 10 (M#32)	1.270 (32.3)	1.27 (819)	3.990 (101)
No. 11 (M#36)	1.410 (35.8)	1.56 (1006)	4.430 (113)

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HORIZONTAL JOINT REINFORCEMENT

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Although 3/16" joint reinforcement could still require a 3/8" bed joint, it is not advisable because:

- The height of a masonry unit is permitted to vary from the specified height and the height difference is accommodated by varying the bed joint thickness.
- Joint reinforcement is not manufactured to be perfectly flat along its length.
- Mortar joint thickness may be one-quarter inch and still meet the TMS 602 tolerances.

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HORIZONTAL JOINT REINFORCEMENT

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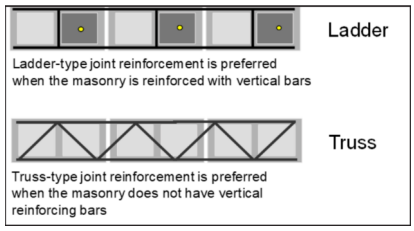
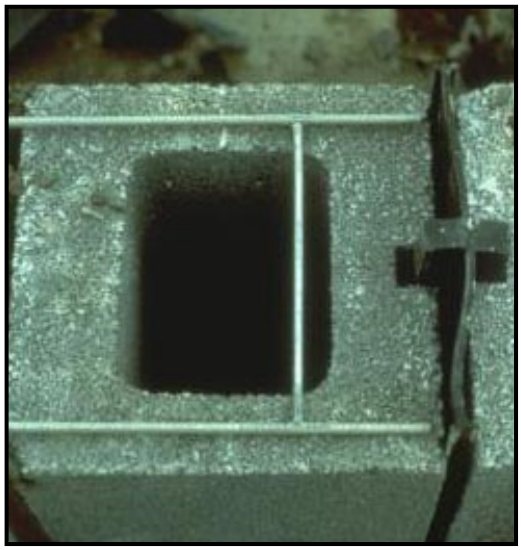
Exactly 16" – there are some manufacturers with cross wires at 15" o.c.

- **2.7 Reinforcement**

C. Masonry-Joint Reinforcement, General: Ladder type complying with ASTM A951

5. Spacing of Cross Rods: Not more than 16 inches o.c.





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HORIZONTAL JOINT REINFORCEMENT

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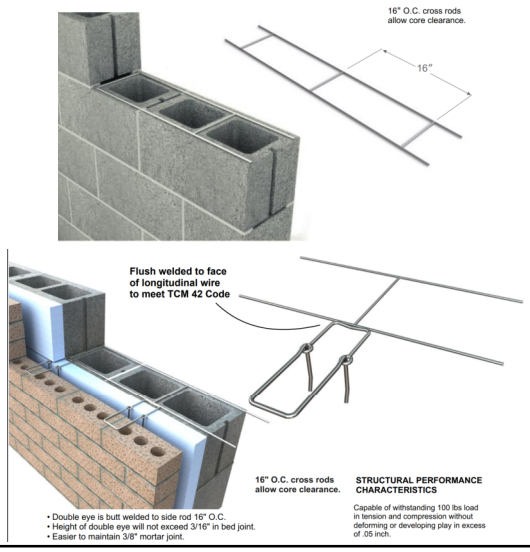

MIM's reference specification includes the following joint reinforcement:

1. Type for Single-Wythe Masonry: Ladder type with a single pair of longitudinal wires spaced for placement over each face shell.
2. Type for Multi-Wythe Masonry: Ladder type with single pair of longitudinal wires spaced for placement over each face shell, with "eyes" to receive pintle anchors butt welded next to one of the longitudinal wires. Engage double pintle anchors in "eyes" of joint reinforcement with sufficient length to extend minimum 1-1/2 inches into veneer with minimum 5/8-inch cover to exterior face.

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ACCESSORIES

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Uncoated includes epoxy coated and galvanization.

The lock down type is recommended and will not move during construction.

Wire-Bond Core Lock Double Rebar Positioner

- **2.7 Reinforcement**

A. Uncoated Steel Reinforcing Bars: ASTM A615 or ASTM A996, Grade 60.

B. Reinforcing Bar Positioners: Wire units designed to fit into mortar bed joints spanning masonry unit cells to hold reinforcing bars in the center of cells. Units are formed from 0.148-inch steel wire, hot-dip galvanized after fabrication. Provide units designed for number of bars indicated.

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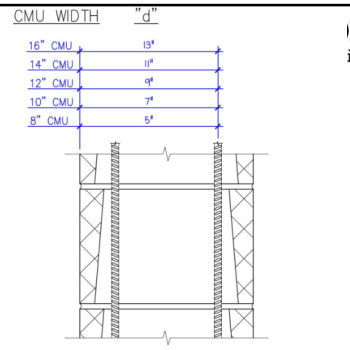
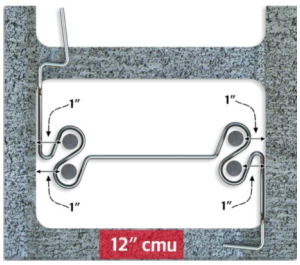
ACCESSORIES

- Rebar positioners are <u>not</u> required by the TMS 402/602.
- If you choose to specify rebar positioners, be mindful that in doing so it will dictate your *effective depth* (*d*) used in structural analysis.
  - TMS 402 equations are a function of *d* and changing it will affect your analysis!
  - In most cases, rebar positioners will place the center of the bar 2-5/8" from the outside face of the wall if doubly reinforced.





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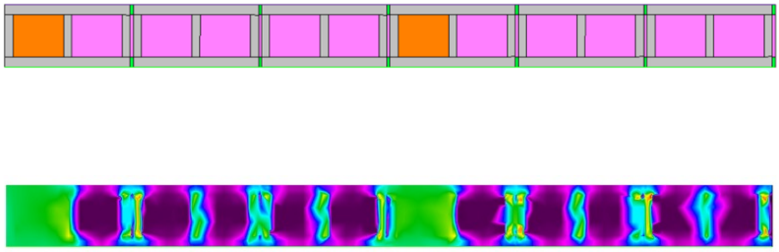
VERTICAL REINFORCEMENT



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VERTICAL REINFORCEMENT – POLL 1

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- 'Stronger' masonry:

  18 ft wall, 8 in. CMU
  40 psf wind pressure
  3,000 lb/ft axial

Table 2 – Design Impact of TMS 402/602 Revisions		
Code Edition[1]	Reinforcement Size	Reinforcement Spacing
2009 IBC[2]	No. 5	40 inches
2012 IBC[2]	No. 5	48 inches
2015 IBC[3]	No. 5	96 inches[4]

[1]The 2009, 2012, and 2015 editions of the IBC adopt the 2008, 2011, and 2013 editions of TMS 402/602, respectively.
[2]f'_m = 1,500 psi
[3]f'_m = 2,000 psi
[4]Incorporating 9 gage bed joint reinforcement at 16 inches.

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CONTROL JOINT (CJ)

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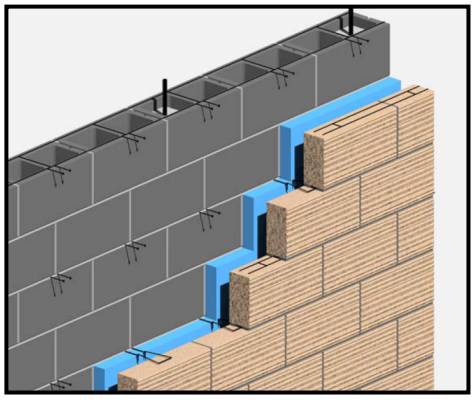
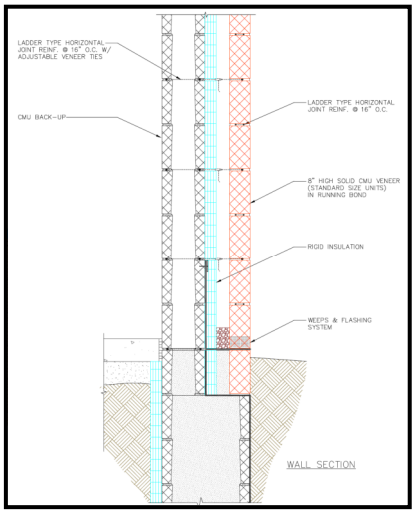
Horizontal Joint Reinforcement





MIM Generic Wall Design Details

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CONTROL JOINT (CJ)

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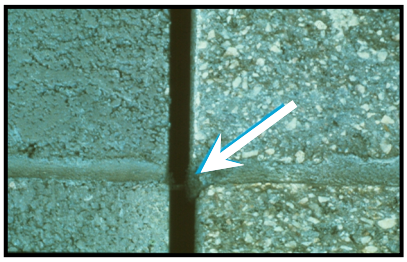
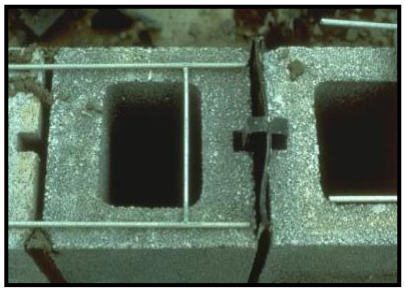
No material should be continuous through a control joint unless for structural reasons





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BOND BEAMS

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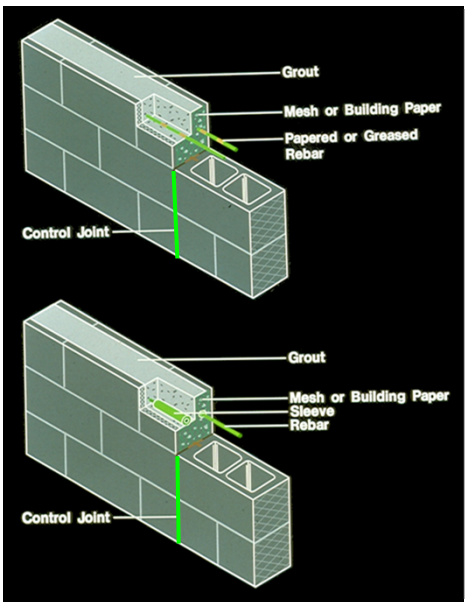
Non-continuous (discuss with SER)



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BOND BEAMS

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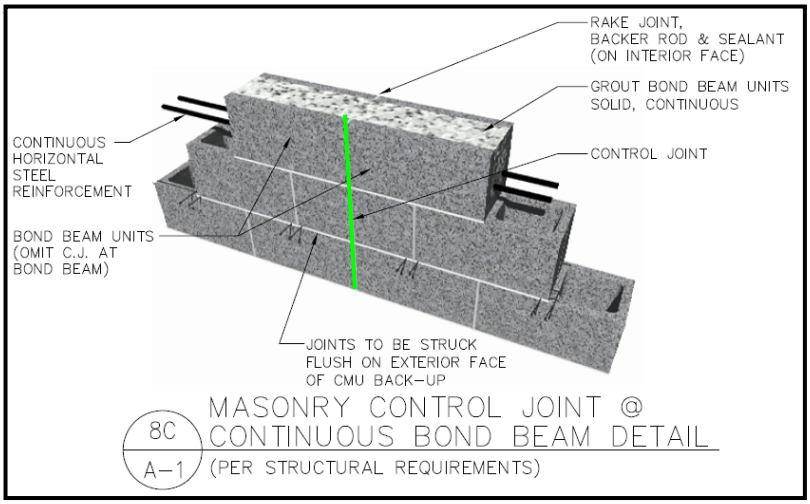
Continuous (discuss with SER)



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BOND BEAMS

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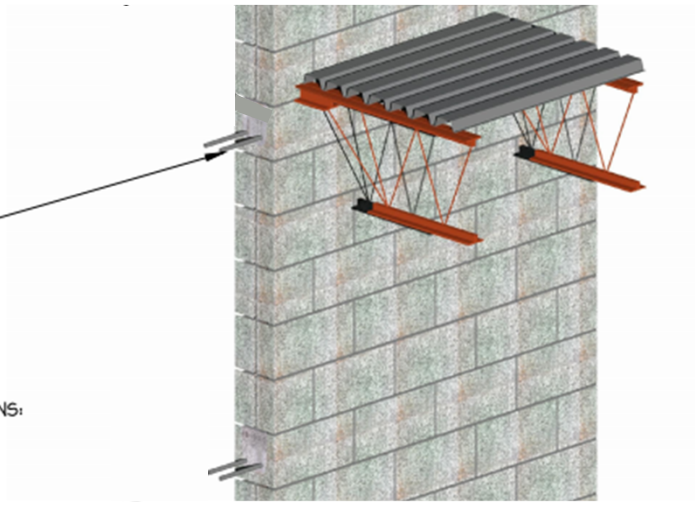
Continuous (discuss with SER)



BOND BEAM AT JOIST BEARING:
-USUALLY PART OF A ROOF DIAPHRAGM CHORD DESIGN
-REQUIRES HORIZONTAL REINFORCEMENT TO BE CONTINUOUS, INCLUDING THROUGH CONTROL JOINTS WHEN FUNCTIONING AS A DIAPHRAGM CHORD

ADDITIONAL BOND BEAM STRUCTURAL FUNCTIONS:
1) A BEARING SURFACE FOR GRAVITY LOADS
2) A TIE DOWN ANCHORAGE FOR ROOF UPLIFT
3) LATERALLY BRACE TOP OF WALL

MIM GWDC Structural Masonry Details

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TYPES OF CONTROL JOINTS

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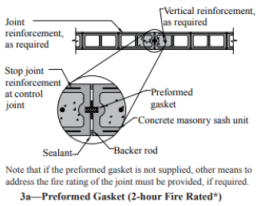
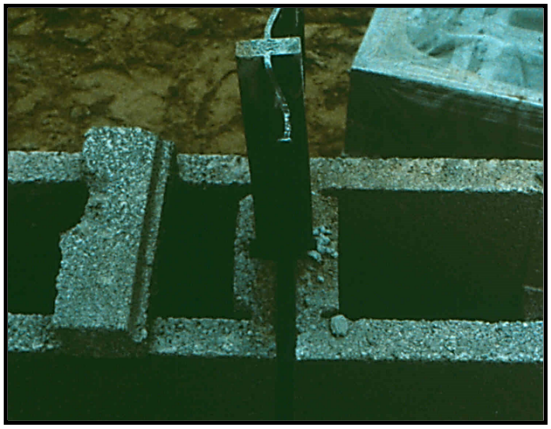
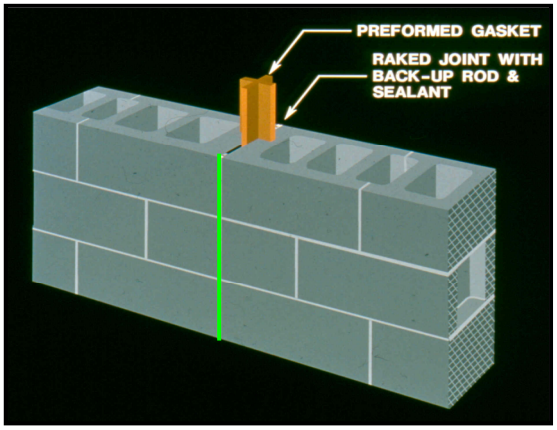
Pre-formed gasket







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TYPES OF CONTROL JOINTS

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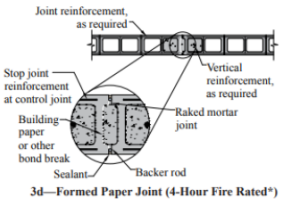
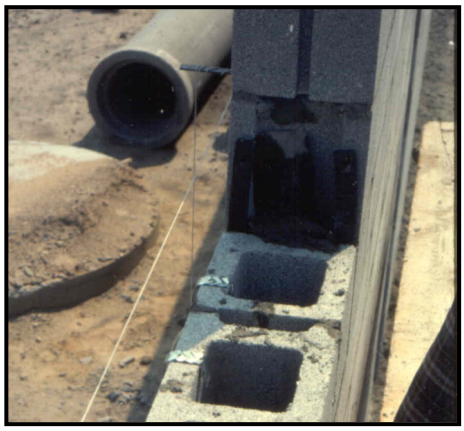
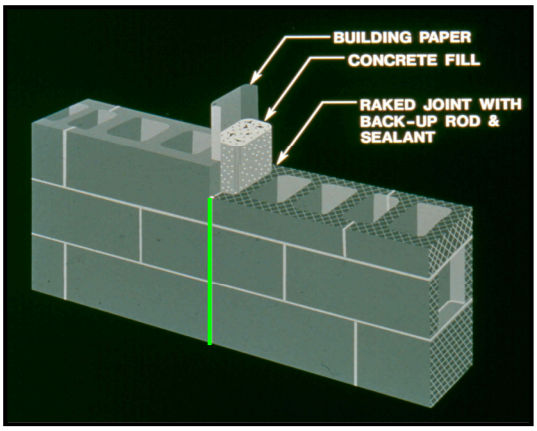
Michigan control joint







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FIRE-RESISTANCE RATINGS

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Most CMU producers do not have Underwriters Laboratory (UL) ratings and have not undergone UL testing and so the *Calculations Procedure* from IBC Section 703.3 is typically used for masonry.

703.3 Methods for determining fire resistance.

The application of any of the methods listed in this section shall be based on the fire exposure and acceptance criteria specified in ASTM E119 or UL 263. The required *fire resistance* of a building element, component or assembly shall be permitted to be established by any of the following methods or procedures:

1. *Fire-resistance* designs documented in approved sources.
2. Prescriptive designs of fire-resistance-rated building elements, components or assemblies as prescribed in Section 721.
3. Calculations in accordance with Section 722.
4. Engineering analysis based on a comparison of building element, component or assemblies designs having *fire-resistance ratings* as determined by the test procedures set forth in ASTM E119 or UL 263.
5. Alternative protection methods as allowed by Section 104.11.
6. *Fire-resistance* designs certified by an approved agency.

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FIRE-RESISTANCE RATINGS

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Most commonly, the *equivalent thickness method* is used for masonry discussion as presented in IBC Section 722.3.2.

- Note: Fully grouted masonry (or masonry filled with an approved material) will have an *equivalent thickness* equal to the specified thickness. Partially grouted masonry will have an *equivalent thickness* equal to that of a hollow unit.

722.3.2 Concrete masonry walls.

The *fire-resistance rating* of walls and partitions constructed of concrete masonry units shall be determined from Table 722.3.2. The rating shall be based on the equivalent thickness of the masonry and type of aggregate used.

TABLE 722.3.2 MINIMUM EQUIVALENT THICKNESS (inches) OF BEARING OR NONBEARING CONCRETE MASONRY WALLS[a, b, c, d]

TYPE OF AGGREGATE	FIRE-RESISTANCE RATING (hours)															
	1/2	3/4	1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4
Pumice or expanded slag	1.5	1.9	2.1	2.5	2.7	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.5	4.7
Expanded shale, clay or slate	1.8	2.2	2.6	2.9	3.3	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	4.9	5.1
Limestone, cinders or unexpanded slag	1.9	2.3	2.7	3.1	3.4	3.7	4.0	4.3	4.5	4.8	5.0	5.2	5.5	5.7	5.9
Calcareous or siliceous gravel	2.0	2.4	2.8	3.2	3.6	3.9	4.2	4.5	4.8	5.0	5.3	5.5	5.8	6.0	6.2

For SI: 1 inch = 25.4 mm.

a. Values between those shown in the table can be determined by direct interpolation.
b. Where combustible members are framed into the wall, the thickness of solid material between the end of each member and the opposite face of the wall, or between members set in from opposite sides, shall be not less than 93 percent of the thickness shown in the table.
c. Requirements of ASTM C55, ASTM C73, ASTM C90 or ASTM C744 shall apply.
d. Minimum required equivalent thickness corresponding to the hourly fire-resistance rating for units with a combination of aggregate shall be determined by linear interpolation based on the percent by volume of each aggregate used in manufacture.

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FIRE-RESISTANCE RATINGS

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Fire resistance ratings of conventional CMU are disc
07-01D, *Fire R*
Masonry Asser

- Note: The fire r
is typically gove
and not structu
- *Equivalent thickn*
that would be c
contained in a l

	FIRE RESISTANCE RATING WALL GUIDE			
units	1-hour	2-hour	3-hour	4-hour
8" CMU	1. NW/MW 2. LW	1. NW/MW 2. LW	1. NW/MW with cell fill 2. LW with cell fill	1. NW/MW with cell fill 2. LW with cell fill
10" CMU	1. MW/LW 2. NW	1. MW/LW 2. NW	1. MW/LW 2. NW	1. LW 2. MW 3. NW with cell fill
12" CMU	1. MW/LW 2. NW	1. MW/LW 2. NW	1. MW/LW 2. NW	1. LW 2. MW 3. NW with cell fill

Notes:
1. Units meet ASTM C90 (8" and 12" units more widely used)
2. NW - normal weight (125 pcf or more)
3. MW - medium weight (105 pcf to less than 125 pcf)
4. LW - lightweight (less than 105 pcf)
5. cell fill - solid grouted, sand, pea gravel, crushed stone, slag, pumice, scoria, expanded shale, expanded clay, expanded slate, expanded slag, expanded fly ash, cinders perlite, and
6. The numbering order (1, 2, or 3) is by preference

lent Thicknesses of
nry Units, in. (mm)

ow	Based on percent solid (75%)	(100%)
3.8]	2.7 (69)	3.6 (91)
5.0]	4.2 (107)	5.6 (142)
3.0]	5.7 (145)	7.6 (193)
6.3]	7.2 (183)	9.6 (244)
4.0]	8.7 (221)	11.6 (295)
0.2]	10.2 (259)	13.6 (345)
8.4]	11.7 (297)	15.6 (396)

rcent solid values based on typical
y units.

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INTERSECTING WALLS

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5.1.1 Intersections walls

5.1.1.1 Wall intersections shall meet one of the following requirements:

(a) Design shall conform to the provisions of Section 5.1.1.2

(b) Transfer of shear between the walls shall be prevented

5.1.1.2 Design of wall intersection

5.1.1.2.1 Masonry shall be in running bond

5.1.1.2.2 Flanges shall be considered effective in resisting applied loads.

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INTERSECTING WALLS

MASONRY Institute of Michigan

5.1.1.2.3 The width of the flange considered effective on each side of the web shall be the smaller of the of the actual flange on either side of the web wall and the value shown in Table 5.1.1.2.3 based on the state of stress in the flange and whether or not the masonry is reinforced. The effective flange width shall not extend past a movement joint.

Stress State in Flange	Unreinforced (U) or Reinforced(R) Masonry	Effective Flange Width
Compression	U, R	6 x nominal flange thickness
Tension	U	6 x nominal flange thickness
	R	0.75 x floor-to-floor wall height

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INTERSECTING WALLS

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5.1.1.2.5 The connection of intersecting walls shall conform to one of the following requirements:

(a) At least fifty percent of the masonry units at the interface shall interlock

(b) Walls shall be anchored by steel connectors grouted into the wall and meeting the following requirements…

(c) Intersecting reinforced bond beams shall be provided at a maximum spacing of 48 in…

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INTERSECTING WALLS

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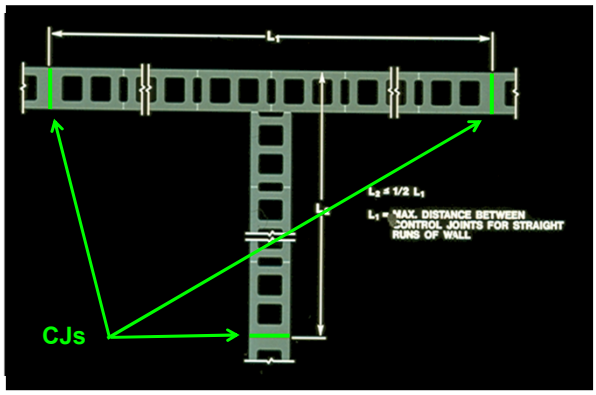
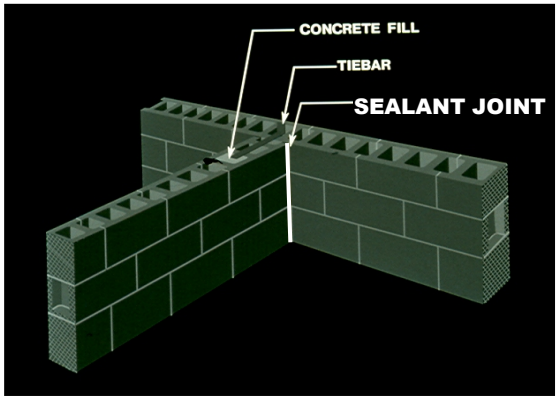
Shear Wall Locations (discuss with SER)





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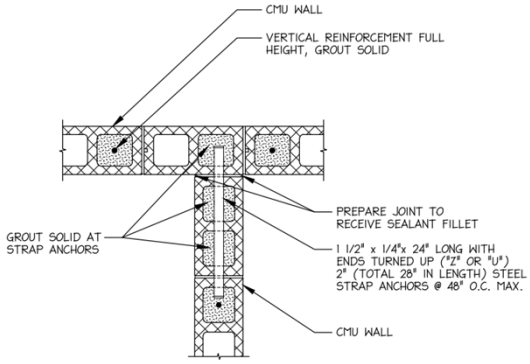
INTERSECTING WALLS

MASONRY Institute of Michigan

Shear Wall Locations



2 / S-2 FLANGED SHEAR WALL CONNECTION DETAIL

(APPLIES ONLY WHERE SPECIFICALLY CALLED FOR ON THE PLANS)

NOTE TO DESIGN PROFESSIONAL:
THIS DETAIL DEVELOPS FLANGE ACTION (SHEAR TRANSFER). FOR ECONOMY, DETAIL 1 IS RECOMMENDED WHEN FLANGE ACTION HAS NOT BEEN USED IN THE WALL DESIGN.

MIM GWDC Structural Masonry Details

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INTERSECTING WALLS

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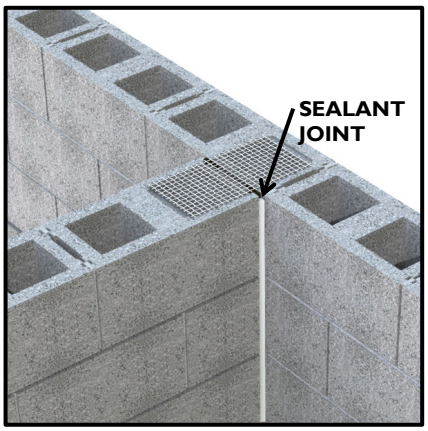
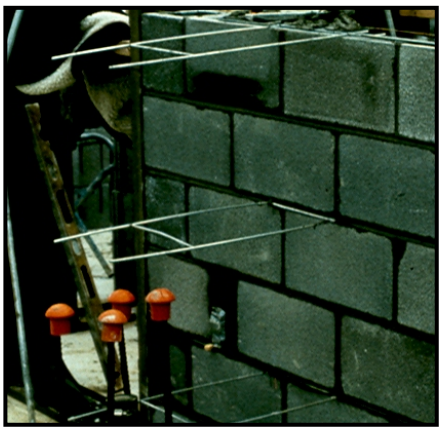
Hinged Joint





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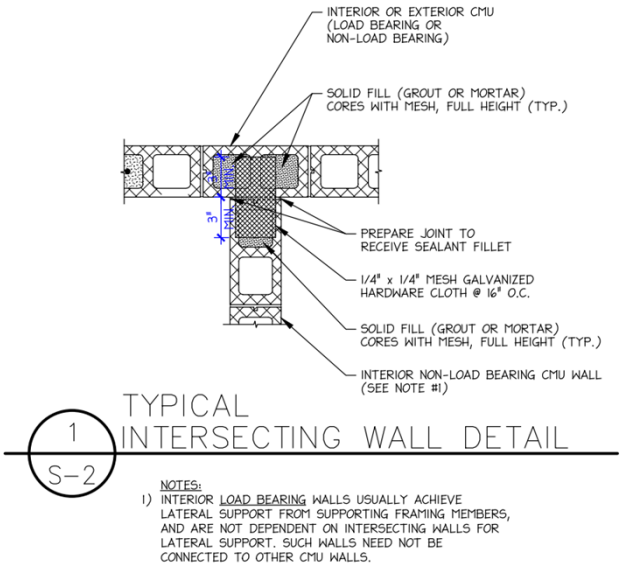
INTERSECTING WALLS

MASONRY Institute of Michigan

Hinged Joint



NOTES:
1) INTERIOR LOAD BEARING WALLS USUALLY ACHIEVE LATERAL SUPPORT FROM SUPPORTING FRAMING MEMBERS, AND ARE NOT DEPENDENT ON INTERSECTING WALLS FOR LATERAL SUPPORT. SUCH WALLS NEED NOT BE CONNECTED TO OTHER CMU WALLS.

MIM GWDC Structural Masonry Details

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POLL QUESTION #2

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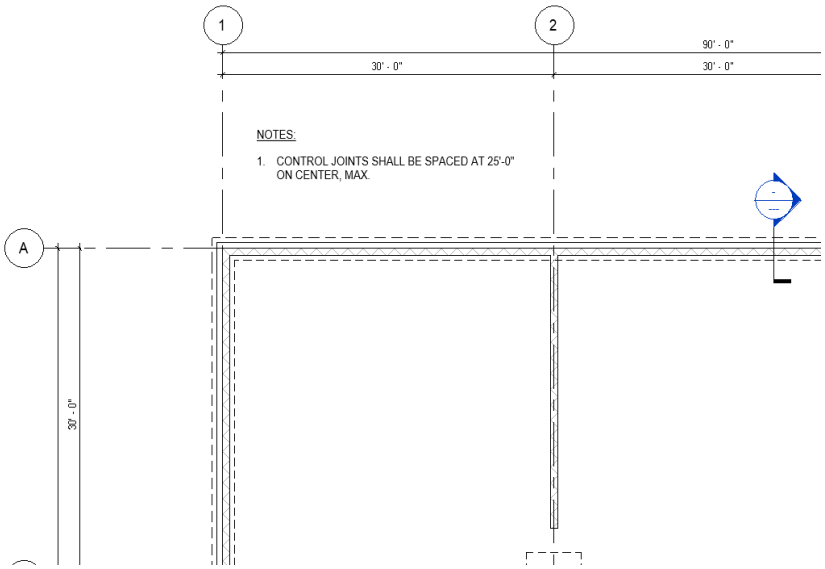

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JOINT SPACING – EMPIRICAL METHOD

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Table 1—Recommended Control Joint Spacing for Above Grade Exposed Concrete Masonry Walls[a]

Distance between joints should not exceed the lesser of:

Length to height ratio	or ft
1½	25

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 mm^2/m) of height to keep unplanned cracks closed (see Table 2).

NCMA TEK 10-2C (2010)

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JOINT SPACING – ENGINEERED METHOD

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Table 1—Criteria for Controlling Cracking in Reinforced Concrete Masonry Walls[a]

		Crack Control Coefficient in./in. (mm/mm)	
		0.0010	0.0015
Maximum wall panel dimensions[2]	length, ft (m)	25 (7.62)	20 (6.10)
	length/height ratio	2 ½	2
Minimum horizontal reinforcement ratio A_s/A_n		0.0007	0.0007

NCMA TEK 10-3 (2003)

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ENGINEERED METHOD

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Table 2—Maximum Spacing of Horizontal Reinforcement to Meet the Criteria As > 0.0007An[1]

Typ.

Wall thickness, in. (mm)	Maximum spacing of horizontal reinforcement, in. (mm) Reinforcement size								
	No. 5 (M 16)	No. 4 (M 13)	No. 3 (M 10)	4 x3/16 in. (MW 18)	4 x 8 gage (MW 13)	4 x 9 gage (MW 11)	2 x3/16 in. (MW 18)	2 x 8 gage (MW 13)	2 x 9 gage (MW 11)
Ungrouted or partially grouted walls									
6 (152)	144 (3658)	128 (3251)	64 (1626)	72 (1829)	56 (1422)	48 (1219)	40 (1016)	24 (610)	24 (610)
8 (203)	144 (3658)	96 (2438)	40 (1016)	64 (1626)	48 (1219)	40 (1016)	32 (813)	24 (610)	16 (406)
10 (254)	136 (3458)	80 (2032)	32 (1219)	56 (1422)	40 (1016)	32 (813)	16 (406)	16 (406)	16 (406)
12 (305)	120 (3048)	72 (1829)	24 (610)	48 (1219)	40 (1016)	32 (813)	16 (406)	16 (406)	16 (406)
Fully grouted walls									
6 (152)	72 (1829)	48 (1219)	24 (610)	24 (610)	16 (406)	16 (406)	8 (203)	8 (203)	8 (203)
8 (203)	56 (1422)	32 (813)	16 (406)	16 (406)	8 (203)	8 (203)	8 (203)	8 (203)	—
10 (254)	40 (1016)	24 (610)	16 (406)	16 (406)	8 (203)	8 (203)	8 (203)	—	—
12 (305)	32 (813)	24 (610)	8 (203)	8 (203)	8 (203)	8 (203)	—	—	—

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

NCMA TEK 10-3 (2003)

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ENGINEERED METHOD

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Table 3—Maximum Spacing of Horizontal Reinforcement to Meet the Criteria As > 0.002An[1]

(Control joints may be eliminated)

Wall thickness, in. (mm)	Maximum spacing of horizontal reinforcement, in. (mm) Reinforcement size		
	No. 6 (M19)	No. 5 (M16)	No.4 (M13)
Ungrouted or partially grouted walls			
6 (152)	48 (1219)	48 (1219)	32 (813)
8 (203)	48 (1219)	40 (1016)	24 (610)
10 (254)	48 (1219)	32 (813)	16 (406)
12 (305)	48 (1219)	24 (610)	8 (203)
Fully grouted walls			
6 (152)	32 (813)	24 (610)	16 (406)
8 (203)	24 (610)	16 (406)	8 (203)
10 (254)	16 (406)	16 (406)	8 (203)
12 (305)	16 (406)	8 (203)	8 (203)

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

NCMA TEK 10-3 (2003)

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CJ PLACEMENT – EMPIRICAL METHOD

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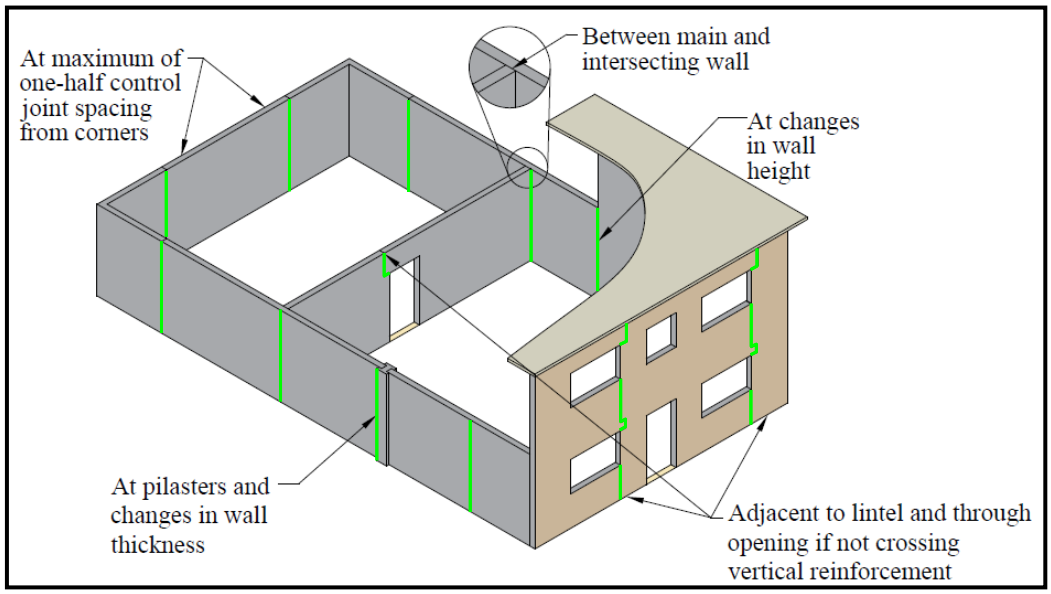

NCMA TEK 10-2C (2010)

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REINFORCED WALL – POLL QUESTION 3

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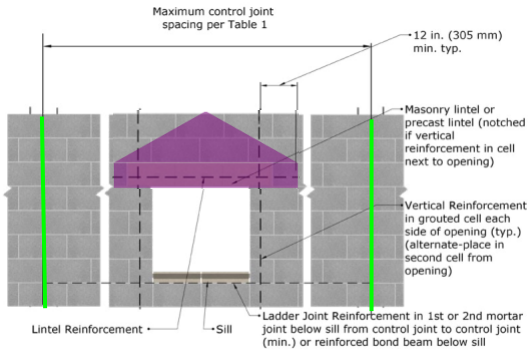

3c—Preferred strengthening of opening with reinforcement—extending lintel reinforcement and joint reinforcement under sill

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

NCMA TEK 10-3 (2003)

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UNREINFORCED OPENING

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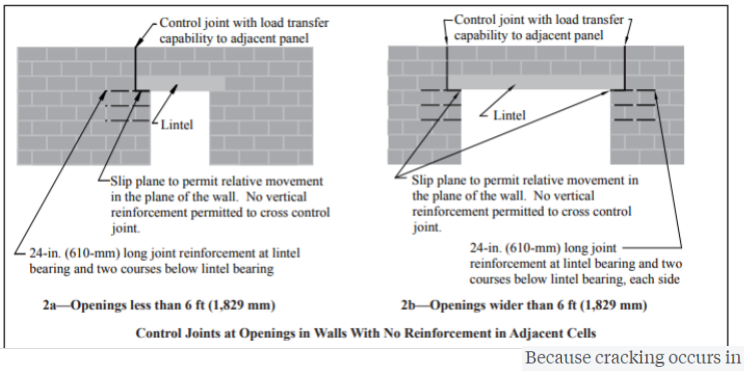

2a—Openings less than 6 ft (1,829 mm) **2b—Openings wider than 6 ft (1,829 mm)**

Control Joints at Openings in Walls With No Reinforcement in Adjacent Cells

Because cracking occurs in the planes of greatest weakness, openings are particularly vulnerable. For an opening of up to 6 ft (1.83 m) in width that are not wrapped with reinforcement, a control joint should be placed at one side of the opening as shown in Figure 2a. Notice that the joint goes around the lintel and allowance for movement (a slip plane in the form of flashing or other bond breaker) between the lintel and the masonry must be provided. Because the lintel is not laterally supported at the bottom due to the slip plane, control joints capable of providing load transfer between panels are required, such as the joints shown in Figures 3a, 3d, 3e, 3f, 3h and 3i.

NCMA TEK 10-2C (2010)

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UNREINFORCED OPENING

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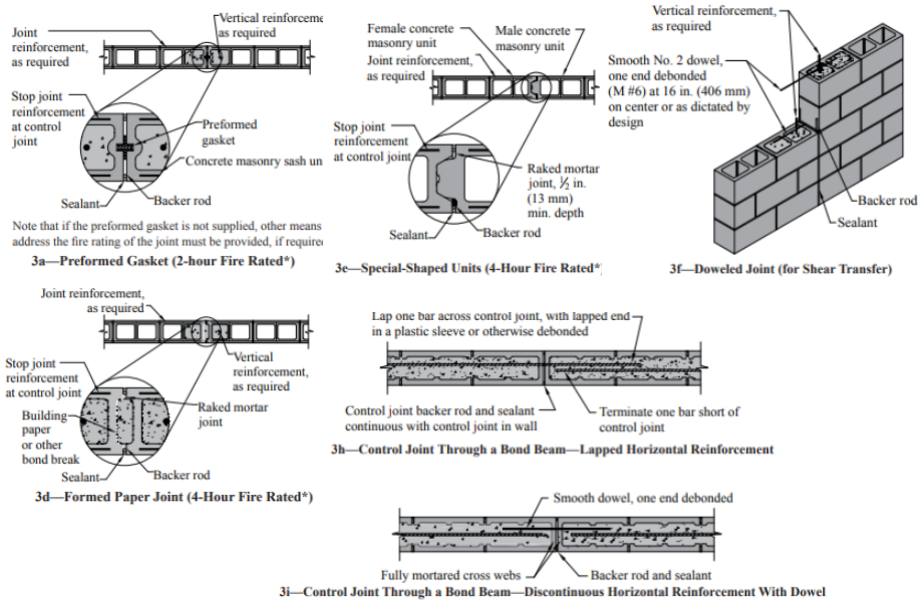

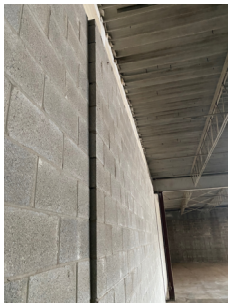

NCMA TEK 10-2C (2010)

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POLL QUESTION #4

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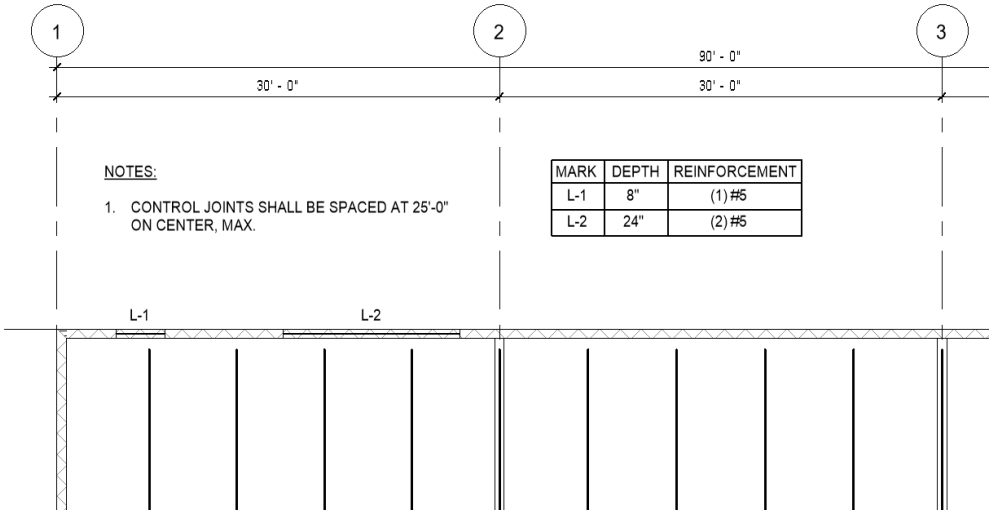

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A GUIDE FOR PLACING CONTROL JOINTS IN CMU

May 2020

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- Control Joint Location Guide
- Control Joint Calculator
- Control Joint Elevations
- Appendix

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FAQS

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1. **What are masonry control joints?**

   Answer: Control joints (CJs) are used to accommodate volume shrinkage of concrete masonry, including cast stone. According to the National Concrete Masonry Association (NCMA), concrete masonry undergoes irreversible volume shrinkage over time. Most of the size change occurs during the first year after manufacture.

2. **Will a concrete masonry veneer require horizontal joint reinforcement?**

   Answer: Yes, because the net effect is shrinkage, a combination of horizontal joint reinforcement and proper placement of control joints should be employed to reduce the potential for shrinkage cracking.

3. **Who is responsible in locating masonry movement joints on the drawings?**

   Answer: According to TMS 602-16 Specification for Masonry Structures, in the Mandatory Requirements Checklist, Part 3 – Execution, Article 3.3 D.6 Movement joints, Notes to the Architects/Engineers, states; "Indicate type and location of movement joints on the project drawings".

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CONTROL JOINT LOCATION GUIDE

Straight Wall Length	Corner Offset	Unreinforced Openings	Reinforced Openings	Tools
OPTION #1: Concrete Masonry Veneer (wire 16 in. o.c.)				
CJ Spacing (L/H=1 1/2, max 20 ft) Location[1,2,3,4]	4 in.	End of lintel (one or both sides of larger openings)		NCMA TEK 10-04
OPTION #2: Empirical Method, Concrete Masonry (8" high units, wire 16 in. o.c.)				
CJ Spacing (L/H=1 1/2, max 25 ft) Location[1,3,4,5]	Half of the CJ spacing, max	One side of lintel (above and below openings $\leq$ 6 ft)[6] Both sides of lintel (above and below openings > 6ft)[6]	Away from openings	NCMA TEK 10-02D
OPTION #3: Empirical Method, Concrete Masonry (4" high units, wire 12 in. o.c.)				
CJ Spacing (L/H=1 1/2, max 20 ft) Location[1,3,4,5]	Half of the CJ spacing, max	One side of lintel (above and below openings $\leq$ 6 ft)[6] Both sides of lintel (above and below openings > 6ft)[6]	Away from openings	NCMA TEK 10-02D
OPTION #4: Engineered Method, Concrete Masonry (wire 16 in. o.c.[8])				
Crack Control Coefficient = 0.0010[7] CJ Spacing (L/H=2 1/2, max 25 ft)[1,3,4,5]	Half of the CJ spacing, max	One side of lintel (above and below openings $\leq$ 6 ft)[6] Both sides of lintel (above and below openings > 6ft)[6]	Away from openings	NCMA TEK 10-03
Crack Control Coefficient = 0.0015[7] CJ Spacing (L/H=2, max 20 ft)[1,3,4,5]	Half of the CJ spacing, max	One side of lintel (above and below openings $\leq$ 6 ft)[6] Both sides of lintel (above and below openings > 6ft)[6]	Away from openings	NCMA TEK 10-03

[1] where stress concentrations occur
[2] reduce veneer movement by incorporating integral water repellents
[3] discontinue joint reinforcement at control joints
[4] at changes in wall height or thickness
[5] at movement joints in foundations and floors, and at movement joints in roofs and floors that bear on a wall
[6] provide slip planes
[7] requires more detailed knowledge of the masonry characteristics than the empirical approach
[8] ungrouted or partially grouted walls

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CONTROL JOINT CALCULATOR

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8" High CMU Control Joint Spacing					
Wall Height:	12	ft	8	in	
Method:	Empirical				
Crack Control Coefficient:	0.0015	(Engineered Method Only)			
Maximum Length-to-Height Ratio:	1.5				
Maximum Control Joint Spacing:	25				
Straight Wall Length (ft):	18.667	ft			
Corner Length (ft):	9.333	ft			

Empirical Method TEK 10-2D (2010)

	Maximum Length-to-Height Ratio of Concrete Masonry Panel	Maximum spacing, in. (mm)
Above Grade Concrete Masonry Walls		
Nominal Unit Height: 8 in. (203 mm)[2]	1.5 to 1	25 ft. (7.62 m)
Nominal Unit Height: 4 in. (102 mm)[3]	1.5 to 1	20 ft. (6.10 m)

[1]Adjust spacing as needed where local experience or project conditions warrant.
[2]Include horizontal reinforcement having an equilavent area of not less than 0.025 in.^{2}/ft. (52.9 mm^2/m) of height. See Table 2A.
[3]Include horizontal reinforcement having an equivalent area of not less than 0.034 in. ^{2}/ft. (72.0 mm^2/m) of height. See Table 2B.

Reinforcement size	Maximum spacing, in. (mm)
W1.7 (9 gage) (MW11)[1]	16 (406)
W2.1 (8 gage) (MW13)[1]	16 (406)
W2.8 (3/16 in.) (MW18)[1]	24 (610)
No. 3 (M#10)	48 (129)
No. 4 (M#13)	96 (2,348)
No. 5 (M#16) or larger	144 (3,658)

[1] Minimum two wires per course.

Table 2A-Maximum Spacing of Horizontal Reinforcement to Provide 0.025 Square Inches per Foot of Masonry Height (52.9 Square Millimeters per Meter)

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CONCRETE MASONRY VENEER

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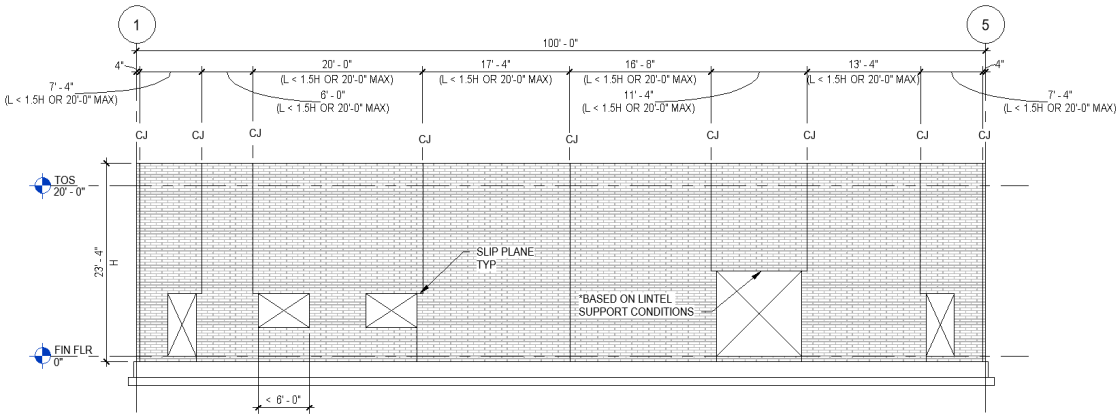
OPTION 1



W1.7 (9 gage) at 16" on center (0.025in^2/ft)

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EMPIRICAL METHOD, CONCRETE MASONRY

(8-INCH HIGH UNITS)

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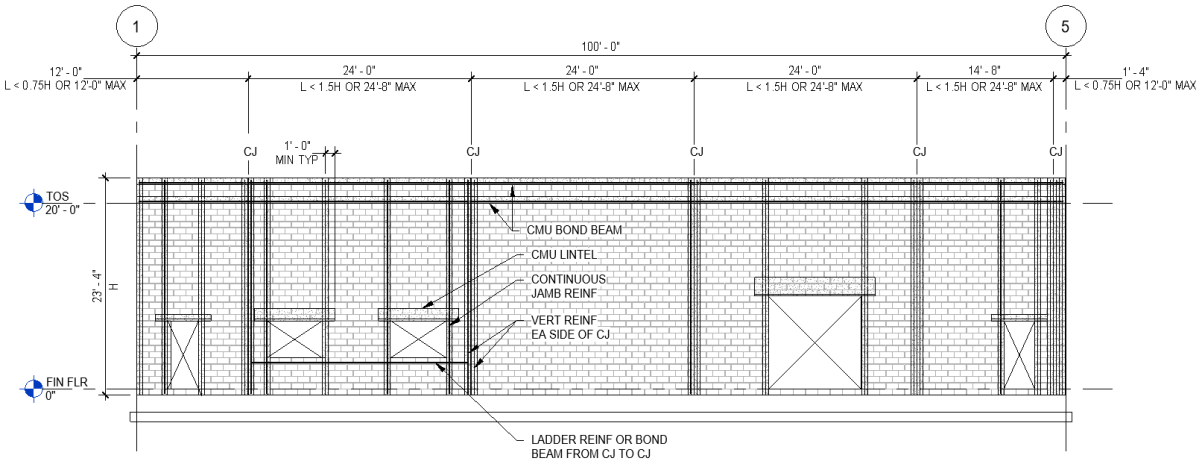
OPTION 2

Reinforced Opening



W1.7 (9 gage) at 16" on center (0.025in^2/ft)

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EMPIRICAL METHOD, CONCRETE MASONRY

(8-INCH HIGH UNITS)

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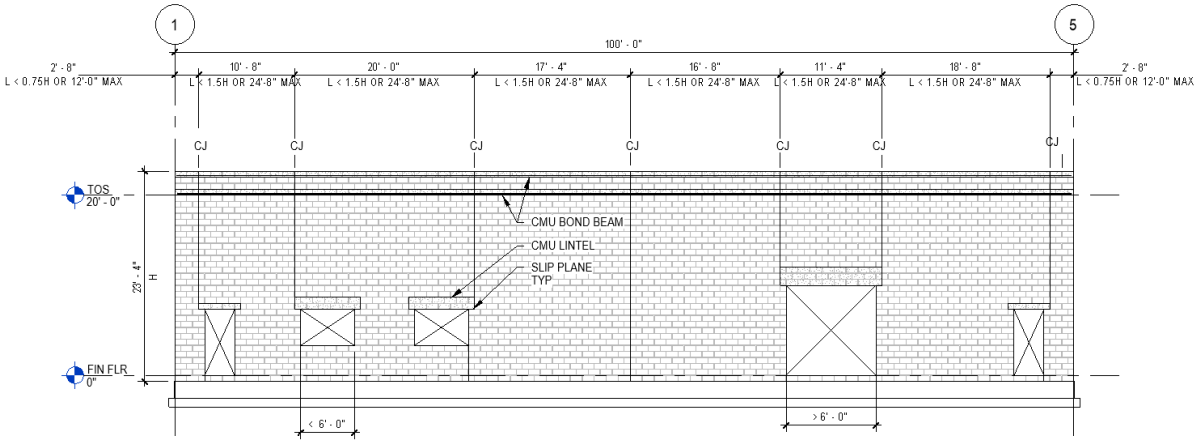
OPTION 2

Unreinforced Opening



W1.7 (9 gage) at 16" on center (0.025in^2/ft)

T = Table

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EMPIRICAL METHOD, CONCRETE MASONRY

(4-INCH HIGH UNITS)

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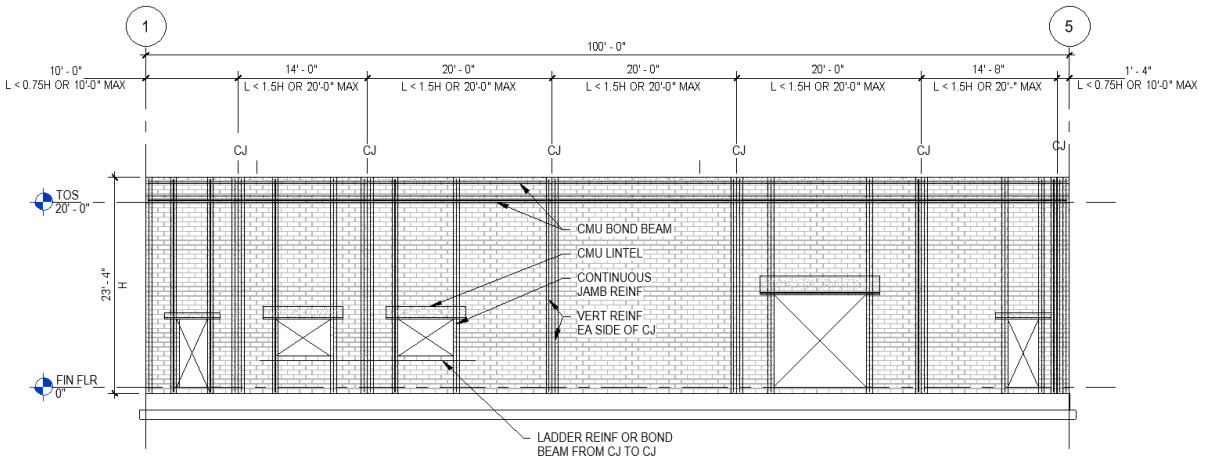
OPTION 3



W1.7 (9 gage) at 12" on center (0.034in^2/ft)

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EMPIRICAL METHOD, CONCRETE MASONRY

(4-INCH HIGH UNITS)

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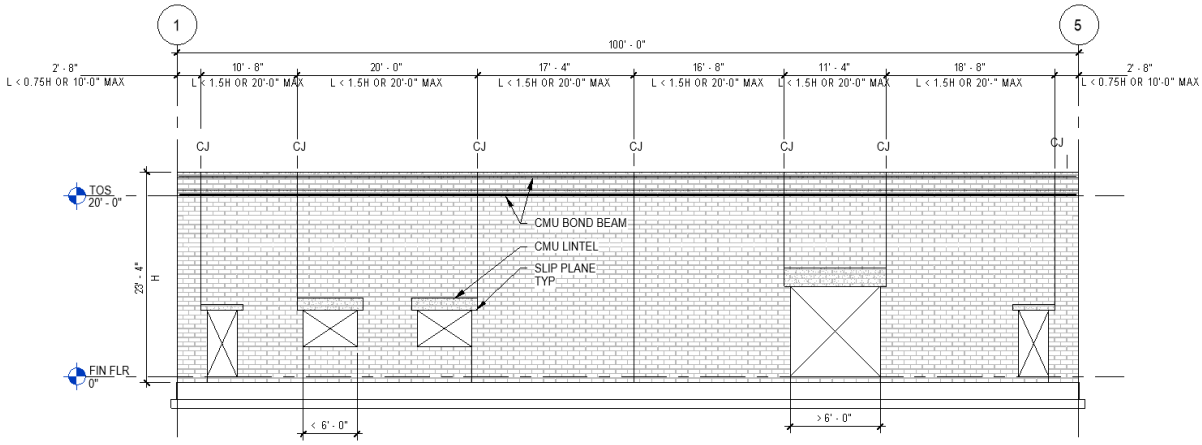
OPTION 3

Unreinforced Opening



W1.7 (9 gage) at 12" on center (0.034in^2/ft)

T = Table

54

ENGINEERED METHOD, CONCRETE MASONRY

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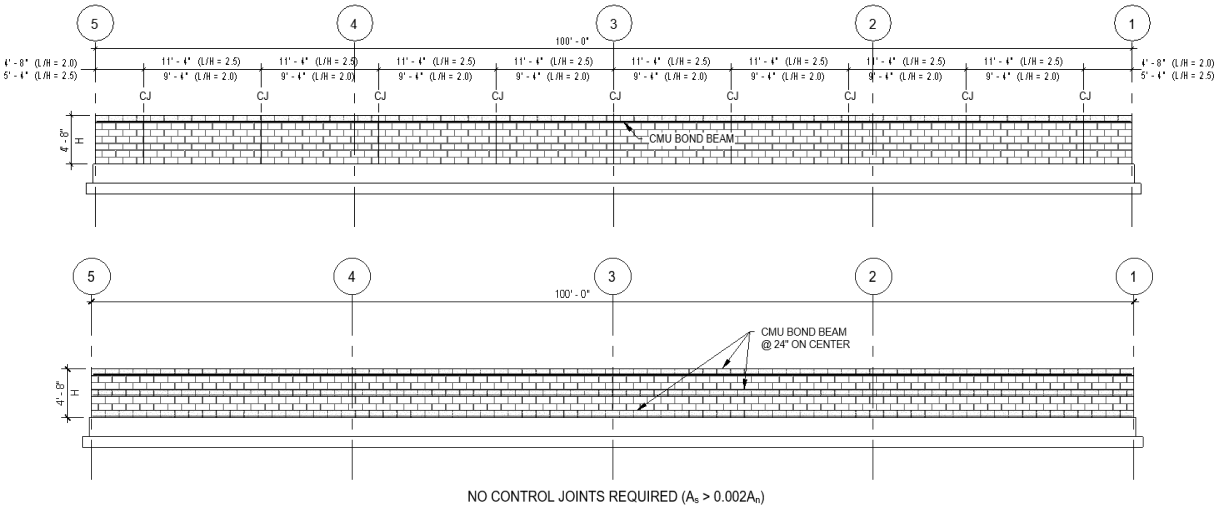
OPTION 4



NO CONTROL JOINTS REQUIRED ($A_s > 0.002A_n$)

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APPENDIX

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CONTROL JOINT SPACING

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CONTROL JOINT LOCATION GUIDE			CONCRETE MASONRY[1,3,4,5]								
			Veneer[2]	EMPIRICAL METHOD				ENGINEERED METHOD			
				8" high units		4" high units					
			wire 16" o.c.	wire 16" o.c.		wire 12" o.c.		wire 16" o.c.			
Height, H (ft-in)			Straight walls, L (ft-in) max. 20'-0"	Straight walls, L (ft-in) max. 24'-8"	Corners L (ft-in) max. 12'-0"	Straight walls, L (ft-in) max. 20'-0"	Corners L (ft-in) max. 10'-0"	Straight walls, L (ft-in) max. 20'-0"	CCC = 0.0015[6] corners max. L (ft-in)	Straight walls, L (ft-in) max. 24'-8"	CCC = 0.0010[6] corners max. L (ft-in)
inches	feet	ft-in	L/H = 1.5	L/H = 1.5	L/H = 1.5	L/H = 1.5	L/H = 1.5	L/H = 2.0	L/H = 2.0	L/H = 2.5	L/H = 2.5
56	4.67	4 - 8	-	-	-	-	-	-	-	-	-
60	5.00	5 - 0	-	-	-	-	-	-	-	12'-0"	6'-0"
64	5.33	5 - 4	-	-	-	-	-	-	-	13'-4"	6'-8"
68	5.67	5 - 8	-	-	-	-	-	-	-	14'-0"	6'-8"
72	6.00	6 - 0	-	-	-	-	-	12'-0"	6'-0"	14'-8"	7'-4"
76	6.33	6 - 4	-	-	-	-	-	12'-8"	6'-0"	15'-4"	7'-4"
80	6.67	6 - 8	-	-	-	-	-	13'-4"	6'-8"	16'-8"	8'-0"
84	7.00	7 - 0	-	-	-	-	-	14'-0"	6'-8"	17'-4"	8'-8"
88	7.33	7 - 4	-	-	-	-	-	14'-8"	7'-4"	18'-0"	8'-8"
92	7.67	7 - 8	-	-	-	-	-	15'-4"	7'-4"	18'-8"	9'-4"
96	8.00	8 - 0	12'-0"	12'-0"	6'-0"	12'-0"	6'-0"	16'-0"	8'-0"	20'-0"	10'-0"
100	8.33	8 - 4	12'-0"	12'-0"	6'-0"	12'-0"	6'-0"	16'-8"	8'-0"	20'-8"	10'-0"
104	8.67	8 - 8	12'-8"	12'-8"	6'-0"	12'-8"	6'-0"	17'-4"	8'-8"	21'-4"	10'-8"
108	9.00	9 - 0	13'-4"	13'-4"	6'-8"	13'-4"	6'-8"	18'-0"	8'-8"	22'-0"	10'-8"
112	9.33	9 - 4	14'-0"	14'-0"	6'-8"	14'-0"	6'-8"	18'-8"	9'-4"	23'-4"	11'-4"
116	9.67	9 - 8	14'-0"	14'-0"	6'-8"	14'-0"	6'-8"	19'-4"	9'-4"	24'-0"	12'-0"
120	10.00	10 - 0	14'-8"	14'-8"	7'-4"	14'-8"	7'-4"	20'-0"	10'-0"	24'-8"	12'-0"
124	10.33	10 - 4	15'-4"	15'-4"	7'-4"	15'-4"	7'-4"	20'-0"	10'-0"	24'-8"	12'-0"
128	10.67	10 - 8	16'-0"	16'-0"	8'-0"	16'-0"	8'-0"	20'-0"	10'-0"	24'-8"	12'-0"
132	11.00	11 - 0	16'-0"	16'-0"	8'-0"	16'-0"	8'-0"	20'-0"	10'-0"	24'-8"	12'-0"
136	11.33	11 - 4	16'-8"	16'-8"	8'-0"	16'-8"	8'-0"	20'-0"	10'-0"	24'-8"	12'-0"
140	11.67	11 - 8	17'-4"	17'-4"	8'-8"	17'-4"	8'-8"	20'-0"	10'-0"	24'-8"	12'-0"
144	12.00	12 - 0	18'-0"	18'-0"	8'-8"	18'-0"	8'-8"	20'-0"	10'-0"	24'-8"	12'-0"
148	12.33	12 - 4	18'-0"	18'-0"	8'-8"	18'-0"	8'-8"	20'-0"	10'-0"	24'-8"	12'-0"
152	12.67	12 - 8	18'-8"	18'-8"	9'-4"	18'-8"	9'-4"	20'-0"	10'-0"	24'-8"	12'-0"
156	13.00	13 - 0	19'-4"	19'-4"	9'-4"	19'-4"	9'-4"	20'-0"	10'-0"	24'-8"	12'-0"
160	13.33	13 - 4	20'-0"	20'-0"	10'-0"	20'-0"	10'-0"	20'-0"	10'-0"	24'-8"	12'-0"
164	13.67	13 - 8	20'-0"	20'-0"	10'-0"	20'-0"	10'-0"	20'-0"	10'-0"	24'-8"	12'-0"
168	14.00	14 - 0	20'-0"	20'-8"	10'-0"	20'-0"	10'-0"	20'-0"	10'-0"	24'-8"	12'-0"
172	14.33	14 - 4	20'-0"	21'-4"	10'-8"	20'-0"	10'-0"	20'-0"	10'-0"	24'-8"	12'-0"
176	14.67	14 - 8	20'-0"	22'-0"	10'-8"	20'-0"	10'-0"	20'-0"	10'-0"	24'-8"	12'-0"
180	15.00	15 - 0	20'-0"	22'-0"	10'-8"	20'-0"	10'-0"	20'-0"	10'-0"	24'-8"	12'-0"
184	15.33	15 - 4	20'-0"	22'-8"	11'-4"	20'-0"	10'-0"	20'-0"	10'-0"	24'-8"	12'-0"
188	15.67	15 - 8	20'-0"	23'-4"	11'-4"	20'-0"	10'-0"	20'-0"	10'-0"	24'-8"	12'-0"
192	16.00	16 - 0	20'-0"	24'-0"	12'-0"	20'-0"	10'-0"	20'-0"	10'-0"	24'-8"	12'-0"
196	16.33	16 - 4	20'-0"	24'-0"	12'-0"	20'-0"	10'-0"	20'-0"	10'-0"	24'-8"	12'-0"
200	16.67	16 - 8	20'-0"	24'-8"	12'-0"	20'-0"	10'-0"	20'-0"	10'-0"	24'-8"	12'-0"
204	17.00	17 - 0	20'-0"	24'-8"	12'-0"	20'-0"	10'-0"	20'-0"	10'-0"	24'-8"	12'-0"
208	17.33	17 - 4	20'-0"	24'-8"	12'-0"	20'-0"	10'-0"	20'-0"	10'-0"	24'-8"	12'-0"
212	17.67	17 - 8	20'-0"	24'-8"	12'-0"	20'-0"	10'-0"	20'-0"	10'-0"	24'-8"	12'-0"
216	18.00	18 - 0	20'-0"	24'-8"	12'-0"	20'-0"	10'-0"	20'-0"	10'-0"	24'-8"	12'-0"

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CLAY MASONRY

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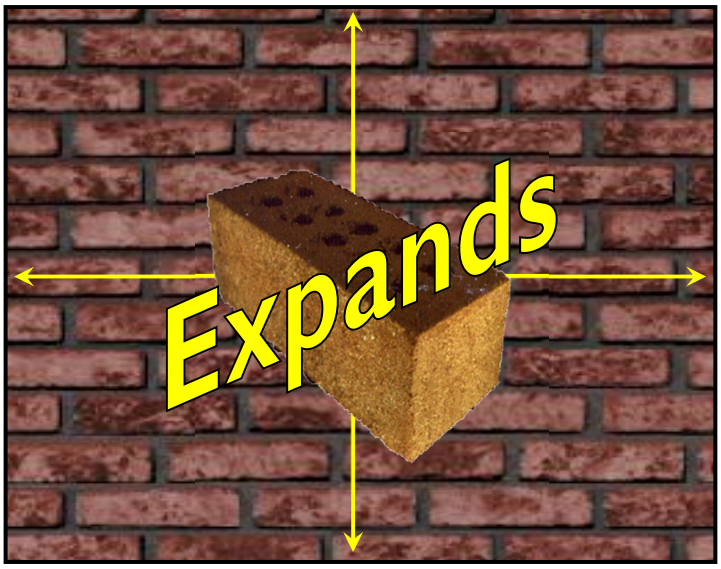

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CLAY MASONRY

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TABLE 1
Types of Movement of Building Materials

Building Material	Thermal	Reversible Moisture	Irreversible Moisture	Elastic Deformation	Creep
Brick Masonry	✓	—	✓	✓	✓
Concrete Masonry	✓	✓	—	✓	✓
Concrete	✓	✓	—	✓	✓
Steel	✓	—	—	✓	—
Wood	✓	✓	—	✓	✓

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CLAY VOLUME CHANGES

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

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SHRINKAGE PATTERN

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BIA Technical Note 18 (Volume Changes) shows the direction of brick expansion and the projected expansion over time

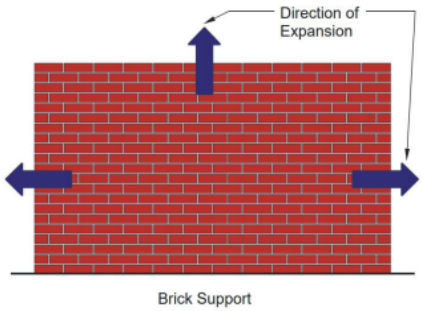

Figure 1
Direction of Brick Expansion

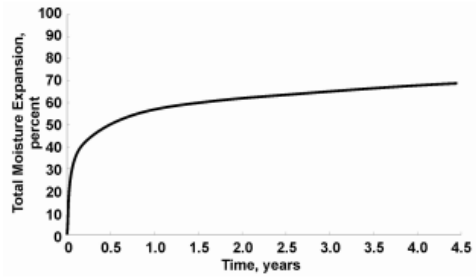

Figure 2
Projected Moisture Expansion of Fired Brick vs. Time

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ANTICIPATED MOVEMENT

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Based on Wall Elevation

South/West Elevations have higher temperature change potential

BIA Technical Note 18

- Thermal Expansion: 4×10^{-6} in/in/°F
- Moisture Expansion: 3×10^{-4} in/in (brick), 5×10^{-4} in/in (veneer)
- Creep: 0.7×10^{-7} in/in

TMS 402/602-16

- Coefficient of Creep = 0.7×10^{-7}, per psi
- Coefficient of Thermal Expansion = 4×10^{-6} in/in/°F

Table 4.2.6 Coefficients of Creep

Material	Coefficient (k_c)
Clay Masonry	0.7×10^{-7}, per psi (0.1×10^{-4}, per MPa)
Concrete Masonry	2.5×10^{-7}, per psi (0.36×10^{-4}, per MPa)
AAC Masonry	5.0×10^{-7}, per psi (0.72×10^{-4}, per MPa)

4.2.7 *Prestressing steel*
For prestressing steels not specifically listed in ASTM A416/A416M, A421/A421M, or A722/A722M, tensile strength and relaxation losses shall be determined by tests.

Table 4.2.3 Coefficients of Thermal Expansion

Material	Coefficient (k_t)
Clay Masonry	4×10^{-6} in./in./°F (7.2×10^{-6} mm/mm/°C)
Concrete Masonry	4.5×10^{-6} in./ in./°F (8.1×10^{-6} mm/mm/°C)
AAC Masonry	4.5×10^{-6} in./ in./°F (8.1×10^{-6} mm/mm/°C)

TABLE 2
Types of Movement of Building Materials

Material	Design Coefficients of Linear Thermal Expansion	
	$\times 10^{-6}$ in./in. per °F	$\times 10^{-6}$ in./in. per °C
Brickwork	4.0	7.2
Concrete Masonry	4.5	8.1
Stone		
Granite	4.4	7.9
Limestone	4.4	7.9
Marble	7.3	13.1
Concrete	5.5	9.9
Metal		
Aluminum	12.8	23.1
Bronze	10.1	18.1
Stainless Steel	9.9	17.8
Structural Steel	6.5	11.7
Wood, Parallel to Fiber		
Fir	2.1	3.7
Oak	2.7	4.9
Pine	3.0	5.4
Wood, Perpendicular to Fiber		
Fir	32	58
Oak	30	54
Pine	19	34
Autoclaved Aerated Concrete	4.5	8.1

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ANTICIPATED MOVEMENT

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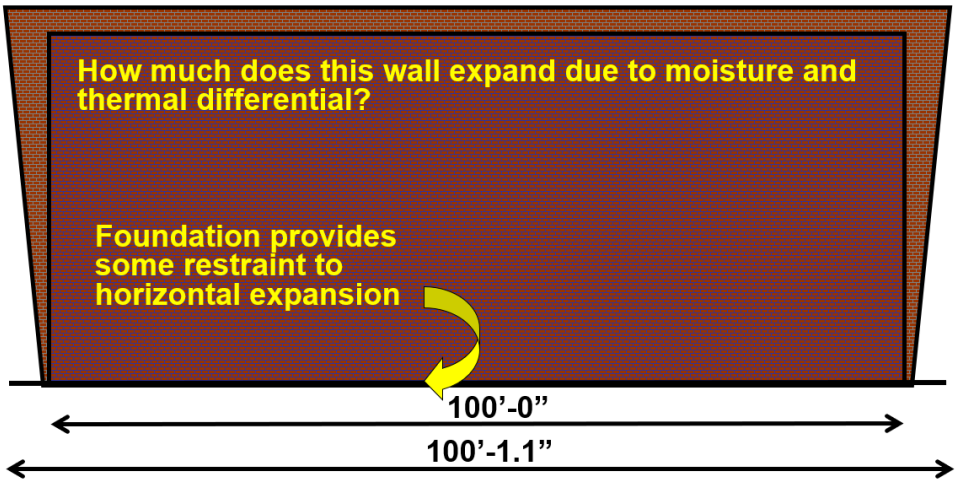
$m_u = (k_e + k_f + k_t \Delta T)L$

For 100'-0" long veneer with 100°F ΔT:

$m_u = (0.0005 + 0.000004(100))(100')(12) = 1.08"$



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CLAY MASONRY EXPANSION

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Evidence of movement

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TYPICAL LOCATION OF EJS

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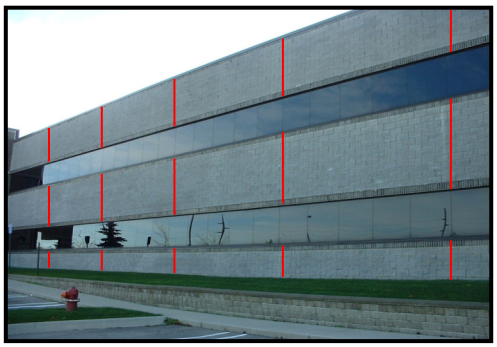
- Long Walls
- Corners
- Setbacks & Offsets
- Differences in height
- Different support conditions
- Beneath shelf angles
- Inside corners
- Openings



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TYPICAL LOCATION OF EJS

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

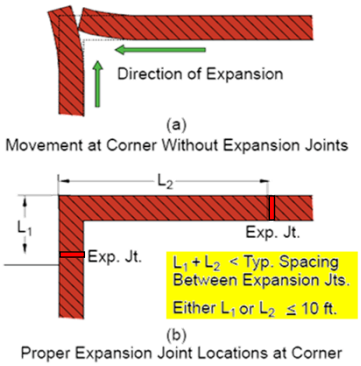

Figure 3
Vertical Expansion Joints at Corners

BIA 18A (2006)

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TYPICAL LOCATION OF EJS

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

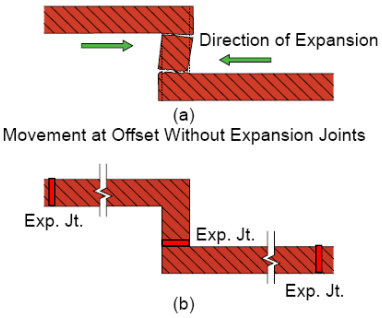

Figure 4
Vertical Expansion Joints at Offsets

BIA 18A (2006)

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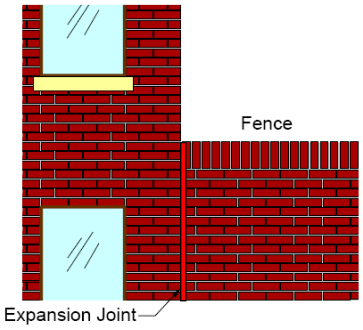
TYPICAL LOCATION OF EJS

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



Different Environmental Exposure
(a)

BIA 18A (2006)

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TYPICAL LOCATION OF EJS

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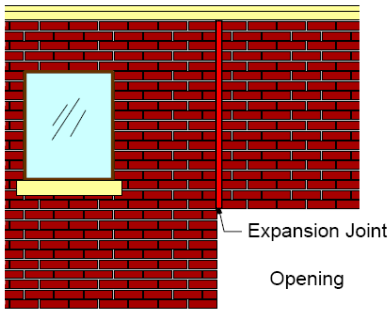
- Long Walls
- Corners
- Setbacks & Offsets
- Differences in height
- Different support conditions
- Beneath shelf angles
- Inside corners
- Openings



Different Support Conditions
(b)

BIA 18A (2006)

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TYPICAL LOCATION OF EJS

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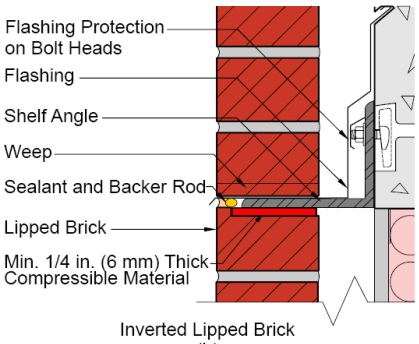
- Long Walls
- Corners
- Setbacks & Offsets
- Differences in height
- Different support conditions
- Beneath shelf angles
- Inside corners
- Openings



Inverted Lipped Brick
(b)

BIA 18A (2006)

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POLL QUESTION #5

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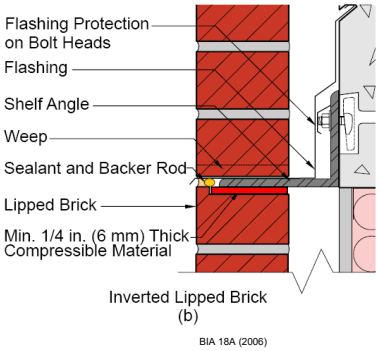
- Under the prescriptive method of Chapter 12 of the TMS 402/602, it states the following:
  - For CFMF Backup (12.2.2.7) – If anchored veneer exceeds 30'-0" (or 38'-0") at the gable, the weight shall be supported by noncombustible construction at each story above 30'-0" in height
  - For wood backup (12.2.2.6.4) – Anchored veneer shall not exceed 30'-0" (or 38'-0") at the gable above the point of support.
  - For CMU backup there are no limitations on height!



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A GUIDE FOR PLACING EXPANSION JOINTS IN CLAY MASONRY VENEER

June 2020

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- FAQs
- Expansion Joint Location Guide Instructions
- Expansion Joint Location Guide
- Options 1 - 3

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FAQS

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1. **What are masonry expansion joints?**

   Answer: Expansion joints (EJs) are used to accommodate volume expansion of clay masonry. According to the Brick Industry Association (BIA), clay masonry undergoes irreversible moisture volume expansion over time, with the majority of the size change occurring during the first year after manufacture. As the clay masonry increases in size, or volume, the movement (expansion) joint decreases in width. The sealant in the movement (expansion) joint needs to be capable of continuing to function as intended, by remaining intact and adhered to the joint sides, while being squeezed.

2. **Who is responsible in locating masonry movement joints on the drawings?**

   Answer: According to TMS 602-16 Specification for Masonry Structures, in the Mandatory Requirements Checklist, Part 3 – Execution, Article 3.3 D.6 Movement joints, Notes to the Architects/Engineers, states; "Indicate type and location of movement joints on the project drawings".

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EXPANSION JOINT LOCATION GUIDE INSTRUCTIONS

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- **Step 1**: Select applicable Option from Guide to determine EJ spacing:
  - Option #1: Symmetrically placed around openings (preferred)
  - Option #2: End of lintel (one slip plane)
  - Option #3: Aligned with opening (two slip planes)
- **Step 2**: Determine corner spacing
- **Step 3**: Make adjustments, as needed, to remaining dimensions (minus the opening and corner expansion joint spacings)

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EXPANSION JOINT LOCATION GUIDE FOR CLAY MASONRY VENEER

	OPENINGS		NO OPENINGS		CORNERS
	3/8 inch Joints (max. 14 ft.- 4 in.)	1/2 inch Joints (max. 20 ft.- 0 in.)	3/8 inch Joints (max. 19 ft.- 4in.)	1/2 inch Joints (max. 25 ft.- 0 in.)	
OPTION #1 Symmetrically placed around openings (preferred)	No slip plane	No slip plane	EJ Calculator or Table 1	EJ Calculator or Table 2	1) within 2 ft preferred 2) L1 + L2 < L 3) L1 or L2 <10 ft
OPTION #2 End of lintel	1 slip plane	1 slip plane			
OPTION #3 Aligned with opening	2 slip planes	2 slip planes			

Sources: BIA Technical Notes 18, May 2019, and BIA Technical Notes 18A, May 2019

Location: Consider placing EJs at areas of natural stress concentrations, such as corners, offsets, openings, wall intersections, changes in wall heights, junctions, parapets, material transitions, deflection of supports, and deflection of wood.

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EXPANSION JOINT CALCULATOR

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Volume Changes - Analysis and Effects of Movement (BIA Technical Note 18, May 2019)							
Known Values:							
Coefficient of Linear Moisture Expansion (k_e):	0.0005	in/in	(BIA Technical Note 18, 2019)				
Coefficient of Thermal Expansion (k_t):	0.000004	in/in	(BIA Technical Note 18, 2019)				
Input Values:							
Expansion Joint Width:	3/8"	in	=	0.375	in		
Expansion Joint Compressibility:	50%						
Construction Temperature:	60	°F					
Building Elevation:	South/West						
Brick Color:	Medium						
Maximum Brick Temperature:	140	°F					
Results:							
Maximum Joint Spacing (Technical Note 18):	19.000	ft	=	19	ft	0	in
Maximum Joint Spacing (Technical Note 18A):	17.333	ft	=	17	ft	4	in
Maximum Corner Offset (Technical Note 18A):	a. Within 2'-0" of corner						
	b. L1 + L2 shall be less than joint spacing (see wall elevations)						
	c. L1 or L2 < 10'-0"						
Maximum Joint Spacing at Openings (Tehnical Note 18A):	a. Maximum spacing shall be reduced from 25'-0" to 20'-0" for 1/2" EJ or from 20'-0" to 15'-0" for 3/8" EJ for joints symmetrically placed						
Maximum Joint Spacing at Parapets (Tehnical Note 18A):	a. When joint spacing is greater than 15'-0", design EJs through parapet for additional movement, or						
	b. add EJs placed halfway between those running full height that continue down to a horizontal expansion joint, or						
	c. install joint reinforcement at 8 in. on center vertically in the parapet						

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CLAY BRICK VENEER

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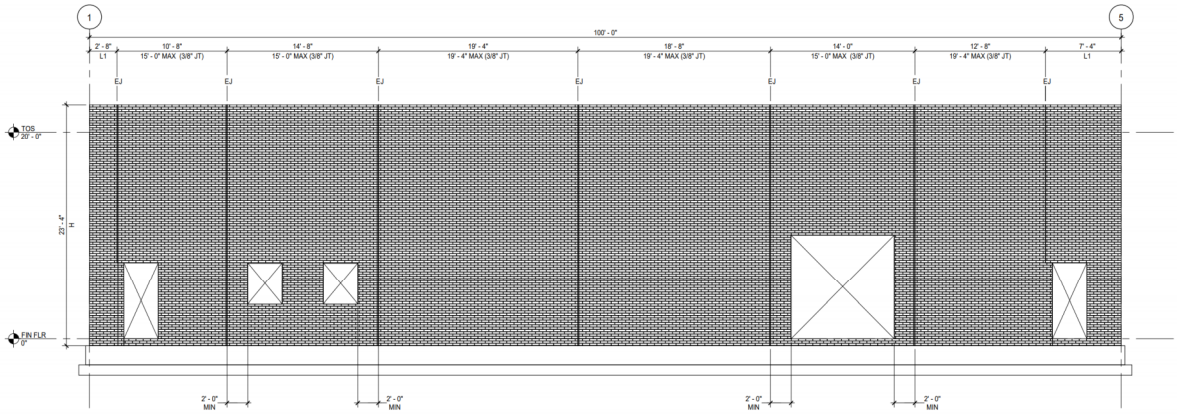
OPTION 1



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CLAY BRICK VENEER

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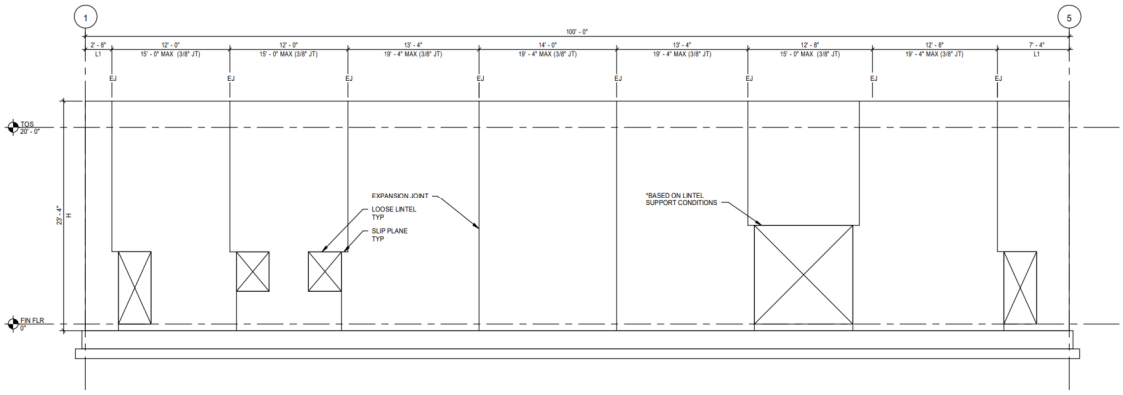
OPTION 2



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CLAY BRICK VENEER

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OPTION 3

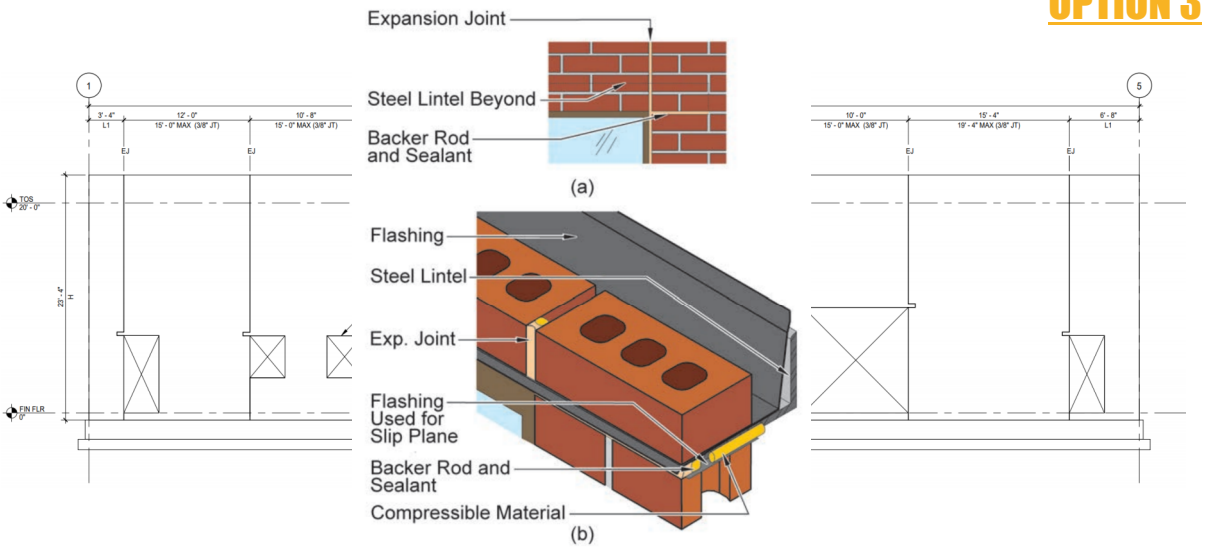

Figure 5

Expansion Joint at a Loose Lintel

BIA 18A (2006)

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CLAY BRICK VENEER

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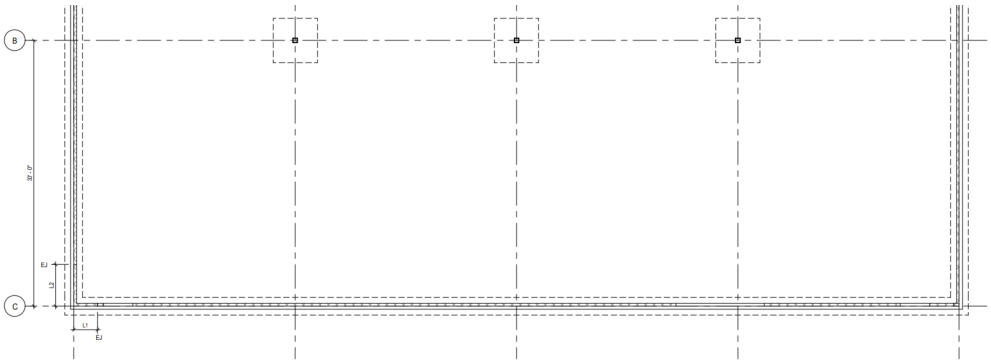

2 3/8" EJ PLACED AT END OF LOOSE LINTEL
SCALE : 3/16" = 1'-0"

NOTES:

1. L1 SHALL BE LOCATED AS FOLLOWS:
   A. WITHIN 2' - 0" OF CORNER (PREFERED)
   B. L1 + L2 < L_{MAX}
   C. L1 OR L2 < 10' - 0"
2. JOINT LOCATIONS SHOWN ARE FOR SOUTH OR WEST FACING ELEVATIONS WITH DARK COLOR BRICK
3. TEMPERATURE VARIATION IS ASSUMED TO BE 100 DEGREES FAHRENHEIT
4. SEE MASONRY INSTITUTE OF MICHIGAN EXPANSION JOINT CALCULATOR FOR ADDITIONAL INFORMATION

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APPENDIX

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3/8 INCH EXPANSION JOINT LOCATION GUIDE[1,2,3,4]

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TABLE 1

	Construction Temperature, °F	Maximum Temperature, °F	Straight Walls Long Equation EJ Spacing, (max. 19 ft.-4in.) [5]	Straight Walls Short Equation EJ Spacing, ft-in [6]
SOUTH AND WEST ELEVATIONS				
DARK COLOR	30	160	15'-0"	17'-4"
	40	160	15'-8"	17'-4"
	50	160	16'-4"	17'-4"
	60	160	17'-4"	17'-4"
	70	160	18'-0"	17'-4"
	80	160	19'-0"	17'-4"
	90	160	19'-4"	17'-4"
	100	160	19'-4"	17'-4"
	110	160	19'-4"	17'-4"
	120	160	19'-4"	17'-4"
MEDIUM COLOR	30	140	16'-4"	17'-4"
	40	140	17'-4"	17'-4"
	50	140	18'-0"	17'-4"
	60	140	19'-0"	17'-4"
	70	140	19'-4"	17'-4"
	80	140	19'-4"	17'-4"
	90	140	19'-4"	17'-4"
	100	140	19'-4"	17'-4"
	110	140	19'-4"	17'-4"
	120	140	19'-4"	17'-4"
LIGHT COLOR	30	120	18'-0"	17'-4"
	40	120	19'-0"	17'-4"
	50	120	19'-4"	17'-4"
	60	120	19'-4"	17'-4"
	70	120	19'-4"	17'-4"
	80	120	19'-4"	17'-4"
	90	120	19'-4"	17'-4"
	100	120	19'-4"	17'-4"
	110	120	19'-4"	17'-4"
	120	120	19'-4"	17'-4"

	Construction Temperature, °F	Maximum Temperature, °F	Straight Walls Long Equation EJ Spacing, (max. 19 ft.-4in.) [5]	Straight Walls Short Equation EJ Spacing, ft-in [6]
NORTH AND EAST ELEVATIONS				
ALL COLOR	30	100	19'-4"	17'-4"
	40	100	19'-4"	17'-4"
	50	100	19'-4"	17'-4"
	60	100	19'-4"	17'-4"
	70	100	19'-4"	17'-4"
	80	100	19'-4"	17'-4"
	90	100	19'-4"	17'-4"
	100	100	19'-4"	17'-4"
	110	100	19'-4"	17'-4"
	120	100	19'-4"	17'-4"

NOTES:

[1] BIA Technical Notes 18, May 2019 and BIA Technical Notes 18A, May 2019

[2] EJ compressibility 50%

[3] Moisture coefficient 0.0005 (clay masonry veneer)

[4] Thermal coefficient 0.000004

[5] Long equation: max. temperature (brick color): dark 160, medium 140, light 120

[6] Short equation: $T_{max.} - T_{construction} = 100$ degree F

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1/2 INCH EXPANSION JOINT LOCATION GUIDE[1,2,3,4]

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TABLE 2

	Construction Temperature, °F	Maximum Temperature, °F	Straight Walls Long Equation EJ Spacing, (max. 25 ft.-0in.) [5]	Straight Walls Short Equation EJ Spacing, ft-in [6]
SOUTH AND WEST ELEVATIONS				
DARK COLOR	30	160	20'-4"	23'-0"
	40	160	21'-0"	23'-0"
	50	160	22'-0"	23'-0"
	60	160	23'-0"	23'-0"
	70	160	24'-0"	23'-0"
	80	160	25'-0"	23'-0"
	90	160	25'-0"	23'-0"
	100	160	25'-0"	23'-0"
	110	160	25'-0"	23'-0"
	120	160	25'-0"	23'-0"
MEDIUM COLOR	30	140	22'-0"	23'-0"
	40	140	23'-0"	23'-0"
	50	140	24'-0"	23'-0"
	60	140	25'-0"	23'-0"
	70	140	25'-0"	23'-0"
	80	140	25'-0"	23'-0"
	90	140	25'-0"	23'-0"
	100	140	25'-0"	23'-0"
	110	140	25'-0"	23'-0"
	120	140	25'-0"	23'-0"
LIGHT COLOR	30	120	24'-0"	23'-0"
	40	120	25'-0"	23'-0"
	50	120	25'-0"	23'-0"
	60	120	25'-0"	23'-0"
	70	120	25'-0"	23'-0"
	80	120	25'-0"	23'-0"
	90	120	25'-0"	23'-0"
	100	120	25'-0"	23'-0"
	110	120	25'-0"	23'-0"
	120	120	25'-0"	23'-0"

	Construction Temperature, °F	Maximum Temperature, °F	Straight Walls Long Equation EJ Spacing, (max. 25 ft.-0in.) [5]	Straight Walls Short Equation EJ Spacing, ft-in [6]
NORTH AND EAST ELEVATIONS				
ALL COLOR	30	100	25'-0"	23'-0"
	40	100	25'-0"	23'-0"
	50	100	25'-0"	23'-0"
	60	100	25'-0"	23'-0"
	70	100	25'-0"	23'-0"
	80	100	25'-0"	23'-0"
	90	100	25'-0"	23'-0"
	100	100	25'-0"	23'-0"
	110	100	25'-0"	23'-0"
	120	100	25'-0"	23'-0"

NOTES:

[1] BIA Technical Notes 18, May 2019 and BIA Technical Notes 18A, May 2019

[2] EJ compressibility 50%

[3] Moisture coefficient 0.0005 (clay masonry veneer)

[4] Thermal coefficient 0.000004

[5] Long equation: max. temperature (brick color): dark 160, medium 140, light 120

[6] Short equation: $T_{max.} - T_{construction} = 100$ degree F

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HORIZONTAL BONDING

MASONRY Institute of Michigan

units	inches	feet	ft	in
1/2	4	0.33	0	4
1	8	0.67	0	8
1-1/2	12	1.00	1	0
2	16	1.33	1	4
2-1/2	20	1.67	1	8
3	24	2.00	2	0
3-1/2	28	2.33	2	4
4	32	2.67	2	8
4-1/2	36	3.00	3	0
5	40	3.33	3	4
5-1/2	44	3.67	3	8
6	48	4.00	4	0
6-1/2	52	4.33	4	4
7	56	4.67	4	8
7-1/2	60	5.00	5	0
8	64	5.33	5	4
8-1/2	68	5.67	5	8
9	72	6.00	6	0
9-1/2	76	6.33	6	4
10	80	6.67	6	8
10-1/2	84	7.00	7	0
11	88	7.33	7	4
11-1/2	92	7.67	7	8
12	96	8.00	8	0
12-1/2	100	8.33	8	4

units	inches	feet	ft	in
13	104	8.67	8	8
13-1/2	108	9.00	9	0
14	112	9.33	9	4
14-1/2	116	9.67	9	8
15	120	10.00	10	0
15-1/2	124	10.33	10	4
16	128	10.67	10	8
16-1/2	132	11.00	11	0
17	136	11.33	11	4
17-1/2	140	11.67	11	8
18	144	12.00	12	0
18-1/2	148	12.33	12	4
19	152	12.67	12	8
19-1/2	156	13.00	13	0
20	160	13.33	13	4
20-1/2	164	13.67	13	8
21	168	14.00	14	0
21-1/2	172	14.33	14	4
22	176	14.67	14	8
22-1/2	180	15.00	15	0
23	184	15.33	15	4
23-1/2	188	15.67	15	8
24	192	16.00	16	0
24-1/2	196	16.33	16	4
25	200	16.67	16	8

units	inches	feet	ft	in
25-1/2	204	17.00	17	0
26	208	17.33	17	4
26-1/2	212	17.67	17	8
27	216	18.00	18	0
27-1/2	220	18.33	18	4
28	224	18.67	18	8
28-1/2	228	19.00	19	0
29	232	19.33	19	4
29-1/2	236	19.67	19	8
30	240	20.00	20	0
30-1/2	244	20.33	20	4
31	248	20.67	20	8
31-1/2	252	21.00	21	0
32	256	21.33	21	4
32-1/2	260	21.67	21	8
33	264	22.00	22	0
33-1/2	268	22.33	22	4
34	272	22.67	22	8
34-1/2	276	23.00	23	0
35	280	23.33	23	4
35-1/2	284	23.67	23	8
36	288	24.00	24	0
36-1/2	292	24.33	24	4
37	296	24.67	24	8
37-1/2	300	25.00	25	0

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