Major Structural Changes in TMS 402/602-22

TMS20221026

October 26, 2022

Richard M. Bennett, Ph.D., P.E., FTMS
Professor
University of Tennessee

THE MASONRY SOCIETY

The Masonry Society

AIA Provider: 50119857

Course Description

This webinar will provide an overview of the major structural changes in TMS 402-22. One of the biggest changes was the introduction of compression-controlled sections in strength design. As a result of this the maximum reinforcement provisions were deleted except for beams and intermediate and special shear walls under in-plane loads. The basis for the provisions, the impact on design, and some design aids will be presented.

Other structural changes that will be covered include: definition of net shear area particularly for beams, anchor bolt steel strength changing from being based on yield strength to ultimate strength, an increase of the allowable compressive force for masonry in allowable stress design, a change in the partially grouted shear wall factor, and an increase in the allowable shear friction strength as well as a change in the nominal shear friction strength for shear span ratios greater than 1.

Learning Objectives

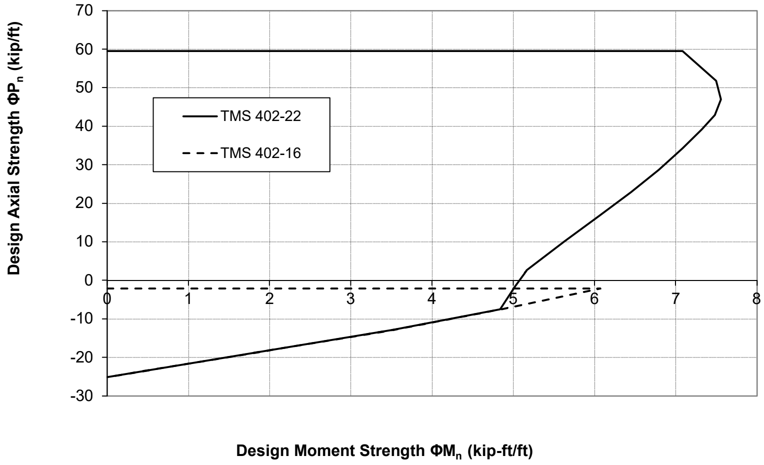
- Understand the compression-controlled strength design provisions in TMS 402-22 and the effect on design
- Understand anchor bolt steel strength in TMS 402-22 and the effect on design
- Understand changes to shear friction strength for shear span ratios greater than 1 in TMS 402-22
- Understand other structural changes in TMS 402-22 and how they affect design

Tension and Compression Controlled Sections

- Motivation
- Provisions
- Design Aids

Motivation

8 in. CMU wall, f'_m = 2 ksi, Grade 60 No. 5 at 8 in., out-of-plane loading



Requirements

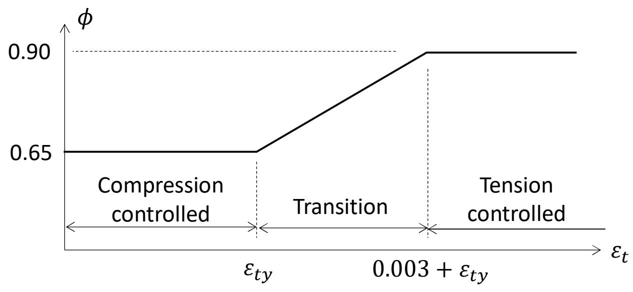
9.1.4.4 *Combinations of flexure and axial load in reinforced masonry* — The value of ϕ for reinforced masonry subjected to flexure, axial load, or combinations thereof shall be in accordance with Table 9.1.4.

9.1.4.4.1 The value of ε_{ty} shall be f_y / E_s. For Grade 60 reinforcement it shall be permitted to take ε_{ty} equal to 0.002.

9.1.4.4.2 In the tension-controlled and transition regions, the value of ϕ for axial load shall be limited so that $\phi P_n \leq 0.65 P_{bal}$, where P_{bal} is determined using a strain gradient corresponding to a strain in the extreme tensile reinforcement equal to ε_{ty} and a maximum strain in the masonry as given by Section 9.3.2(c). {0.0025 for concrete masonry and 0.0035 for clay masonry}

TMS 402 Table 9.1.4

Net Tensile Strain	Classification	Strength-reduction factor, ϕ
$\varepsilon_t \leq \varepsilon_{ty}$	Compression controlled	0.65
$\varepsilon_{ty} < \varepsilon_t < 0.003 + \varepsilon_{ty}$	Transition	$0.65 + 0.25\dfrac{\varepsilon_t - \varepsilon_{ty}}{0.003}$
$\varepsilon_t \geq 0.003 + \varepsilon_{ty}$	Tension controlled	0.90



ε_t = net tensile strain in extreme longitudinal reinforcement

ε_{ty} = ~~value of net tensile strain in extreme layer of longitudinal tension reinforcement used to define a compression-controlled section~~; yield strain

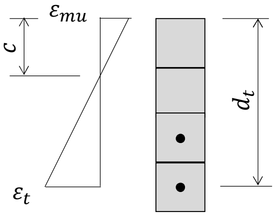
c/d_t Ratio

Useful for drawing interaction diagram

c/d_t ratio		Strength-reduction factor, ϕ
CMU	Clay	
$c/d_t \geq 0.556$	$c/d_t \geq 0.636$	0.65
$0.333 < c/d_t < 0.556$	$0.412 < c/d_t < 0.636$	$0.65 + \frac{0.25}{0.003}\left(\left(\frac{1}{c/d_t} - 1\right)\varepsilon_{mu} - \varepsilon_{ty}\right)$
$c/d_t \leq 0.333$	$c/d_t \leq 0.412$	0.90

c = depth to neutral axis

d_t = distance from compression surface to furthest longitudinal tension reinforcement



Maximum Reinforcement

- Deleted for out-of-plane, ordinary reinforced shear walls, columns, and pilasters
- Same maximum reinforcement (ductility) requirements for intermediate and special reinforced shear walls
- Beams have to be tension controlled

Beams: Tension Controlled

2016: Strain limit of $1.5\varepsilon_y$

2022: Strain limit of $\varepsilon_{ty} + 0.003 = 2.5\varepsilon_y$ for Grade 60 steel

$$\rho_t = \frac{0.8(0.8)f'_m}{f_y}\left(\frac{\varepsilon_{mu}}{\varepsilon_{mu} + \varepsilon_{ty} + 0.003}\right)$$

Grade 60 steel, f'_m in ksi

CMU	$\rho_t = 0.00356 f'_m$	$\rho_t = 0.00711$ for $f'_m = 2$ ksi	$\rho_t = 0.60\rho_{bal}$
Clay	$\rho_t = 0.00439 f'_m$	$\rho_t = 0.0132$ for $f'_m = 3$ ksi	$\rho_t = 0.65\rho_{bal}$

Beams: Example

Design a 4 ft deep 8 in. CMU lintel with a clear span of 16 ft, a superimposed uniformly distributed load of 2000 lb/ft dead load and 700 lb/ft roof live load.

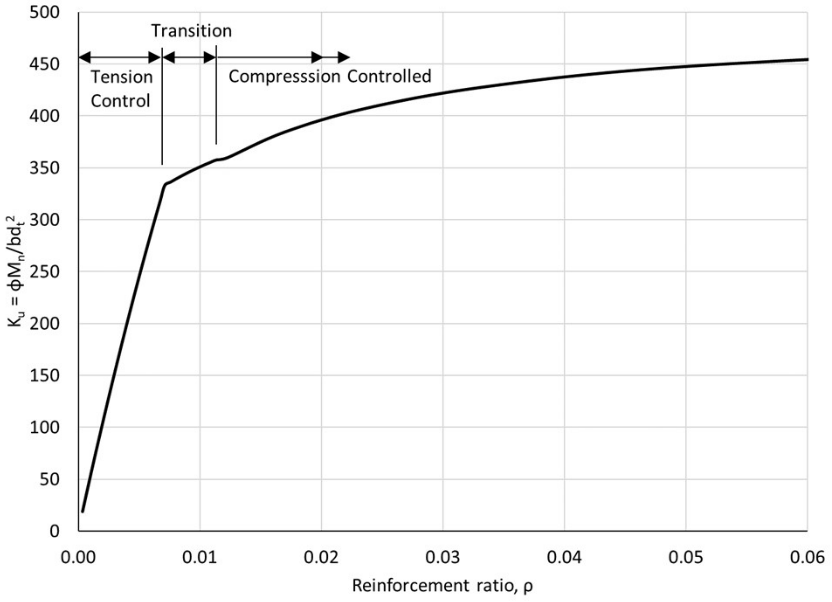
Final Design: 4 – No. 4 bars, 2 each in bottom two courses

$\rho = 0.80\text{in.}^2/((7.63\text{in.})(40\text{in.})) = \boxed{0.00262}$

CMU	$\boxed{\rho_t = 0.00711}$ for $f'_m = 2$ ksi
Clay	$\rho_t = 0.0132$ for $f'_m = 3$ ksi

Non-Bearing Walls: Tension Controlled

Masonry	Concrete	Clay
f'_m	2,000 psi	3,000 psi
ρ_t	0.00711	0.01318
Nominal Wall Thickness	Max. reinforcement to be tension controlled (in.^{2}/ft)	
6 in.	0.24	0.44
8 in.	0.32	0.60
10 in.	0.41	0.76
12 in.	0.50	0.92



Non-Bearing Walls: Example

Design a 20 ft high non-loadbearing partially grouted wall constructed of 8 in. CMU, Type N masonry cement mortar, face shell bedding, and Grade 60 reinforcement. The wind load is 28 psf.

Final Design: No. 5 @ 40 in. (0.31 in^2 / 40 in.×12 in./ft = **0.093 in.^{2}/ft**)

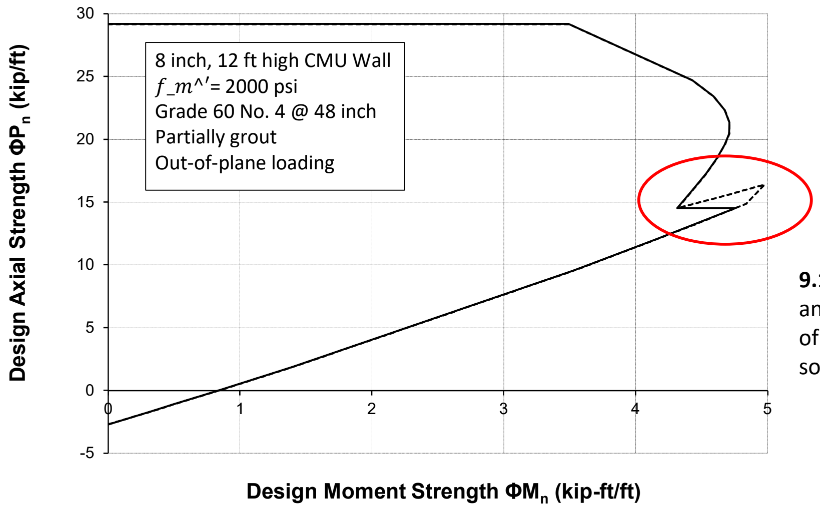
Masonry	Concrete	Clay
f'_m	2,000 psi	3,000 psi
ρ_t	0.00711	0.01318
Nominal Wall Thickness	Max. reinforcement to be tension controlled (in.^{2}/ft)	
6 in.	0.24	0.44
8 in.	**0.32**	0.60
10 in.	0.41	0.76
12 in.	0.50	0.92

Maximum Axial Load: Tension Controlled

TMS 402-22 Table CC-9.1-1

Masonry Element	Concrete Masonry	Clay Masonry
Fully grouted section with single layer of tension reinforcement	$P_u \le 0.19 f'_m bd - 0.9 A_s f_y$	$P_u \le 0.24 f'_m bd - 0.9 A_s f_y$
Fully grouted shear wall subjected to in-plane loads with uniformly distributed reinforcement	$P_u \le 0.19 f'_m bd_v - 0.48 A_s f_y$	$P_u \le 0.24 f'_m bd_v - 0.42 A_s f_y$

Partially Grouted Walls: Out-of-Plane



9.1.4.4.2 In the tension-controlled and transition regions, the value of ϕ for axial load shall be limited so that $\phi P_n \le 0.65 P_{bal}$

Maximum Axial Load: Tension Controlled

TMS 402-22 Table CC-9.1-1
Partially grouted wall with a single layer of tension reinforcement
subjected to out-of-plane loads

Concrete Masonry	Clay Masonry
$P_u \le 0.19 f'_m bd - 0.9A_s f_y$ for $t_{fs} \ge 0.27d$	$P_u \le 0.24 f'_m bd - 0.9A_s f_y$ for $t_{fs} \ge 0.33d$
$P_u \le 0.72 f'_m (bt_{fs} + (0.27d - t_{fs})b_w - 0.9A_s f_y$ for $t_{fs} < 0.27d$	$P_u \le 0.72 f'_m (bt_{fs} + (0.33d - t_{fs})b_w - 0.9A_s f_y$ for $t_{fs} < 0.33d$
but not greater than $P_u \le 0.52 f'_m (bt_{fs} + (0.44d - t_{fs})b_w) - 0.65A_s f_y$	but not greater than $P_u \le 0.52 f'_m (bt_{fs} + (0.50d - t_{fs})b_w) - 0.65A_s f_y$

Bearing Walls:

Maximum Axial Load, P_u, for Section to be Tension Controlled Out-of-Plane Loads
Concrete Masonry, f'_m = 2 ksi , Grade 60 Reinforcement,

Bar Size	Bar Spacing					
	8 in.	16 in.	24 in.	32 in.	40 in.	48 in.
	8 in. unit, centered reinforcement					
No. 4	1.2 kip/ft	9.3 kip/ft	12.0 kip/ft	13.3 kip/ft	14.1 kip/ft	14.5 kip/ft
No. 5	-7.7 kip/ft	4.8 kip/ft	9.0 kip/ft	11.1 kip/ft	12.4 kip/ft	13.2 kip/ft
No. 6	-18.2 kip/ft	-0.4 kip/ft	5.5 kip/ft	8.5 kip/ft	10.3 kip/ft	11.4 kip/ft
	12 in. unit, centered reinforcement					
No. 4	10.3 kip/ft	16.2 kip/ft	17.1 kip/ft	16.8 kip/ft	16.5 kip/ft	16.4 kip/ft
No. 5	1.4 kip/ft	11.8 kip/ft	15.0 kip/ft	15.1 kip/ft	15.2 kip/ft	15.3 kip/ft
No. 6	-9.1 kip/ft	6.5 kip/ft	11.6 kip/ft	13.2 kip/ft	13.7 kip/ft	14.0 kip/ft
	12 in. unit, offset reinforcement, d = 11.625 in. – 2.5 in. = 9.125 in.					
No. 4	25.4 kip/ft	24.0 kip/ft	23.2 kip/ft	21.3 kip/ft	20.2 kip/ft	19.4 kip/ft
No. 5	16.5 kip/ft	19.5 kip/ft	20.2 kip/ft	19.7 kip/ft	18.9 kip/ft	18.3 kip/ft
No. 6	6.0 kip/ft	14.3 kip/ft	16.7 kip/ft	17.8 kip/ft	17.4 kip/ft	17.1 kip/ft

Bearing Walls:

Maximum Axial Load, P_u, for Section to be Tension Controlled Out-of-Plane Loads

Clay Masonry, f'_m = 3 ksi , Grade 60 reinforcement,

Bar Size	Bar Spacing					
	6 in.	12 in.	18 in.	24 in.	30 in.	36 in.
	6 in. unit, centered reinforcement, t_{sp} = 5.5 in., t_{fs} = 1.0 in.					
No. 4	2.2 kip/ft	13.0 kip/ft	16.0 kip/ft	16.7 kip/ft	17.1 kip/ft	17.4 kip/ft
No. 5	-9.7 kip/ft	7.0 kip/ft	12.6 kip/ft	14.6 kip/ft	15.4 kip/ft	15.9 kip/ft
No. 6	-23.8 kip/ft	0.0 kip/ft	7.9 kip/ft	11.9 kip/ft	13.4 kip/ft	14.2 kip/ft
	8 in. unit, centered reinforcement, t_{sp} = 7.5 in., t_{fs} = 1.25 in					
No. 4	10.8 kip/ft	21.6 kip/ft	22.3 kip/ft	22.6 kip/ft	22.8 kip/ft	22.9 kip/ft
No. 5	-1.1 kip/ft	15.7 kip/ft	19.5 kip/ft	20.4 kip/ft	21.0 kip/ft	21.4 kip/ft
No. 6	-15.1 kip/ft	8.6 kip/ft	16.1 kip/ft	17.9 kip/ft	19.0 kip/ft	19.7 kip/ft

Bearing Walls: Example

Design a 16 ft – 8 in. high 8 in. CMU bearing wall with an eccentric axial dead load of 700 lb/ft, an eccentric axial roof live load of 300 lb/ft, and an out-of-plane wind load of 30 lb/ft^2. The eccentricity is 2.48 in. There is a 3 ft – 4 in. parapet (total height = 20 ft).

Final Design: No. 4 @ 48 in.
By inspection, maximum axial load is less than 14.5 kip/ft

Bar Size	Bar Spacing					
	8 in.	16 in.	24 in.	32 in.	40 in.	48 in.
	8 in. unit, centered reinforcement					
No. 4	1.2 kip/ft	9.3 kip/ft	12.0 kip/ft	13.3 kip/ft	14.1 kip/ft	14.5 kip/ft
No. 5	-7.7 kip/ft	4.8 kip/ft	9.0 kip/ft	11.1 kip/ft	12.4 kip/ft	13.2 kip/ft
No. 6	-18.2 kip/ft	-0.4 kip/ft	5.5 kip/ft	8.5 kip/ft	10.3 kip/ft	11.4 kip/ft

Other Changes

- ASD Modifications
- Net Shear Area
- Anchor Bolt Strength
- Shear Friction …..

ASD Modifications

Allowable Compressive Force of Reinforced Masonry Increased

Harmonize with compression-controlled sections

0.25 factor on $f'_m A_n$ increased to 0.30

$$h/r \leq 99 \qquad P_a = (\mathbf{0.30} f'_m A_n + 0.65 A_{st} F_s)\left[1 - \left(\frac{h}{140r}\right)^2\right]$$

Equation 8-16

$$h/r > 99 \qquad P_a = (\mathbf{0.30} f'_m A_n + 0.65 A_{st} F_s)\left(\frac{70r}{h}\right)^2$$

Equation 8-17

ASD Shear Strength: Reinforced Masonry

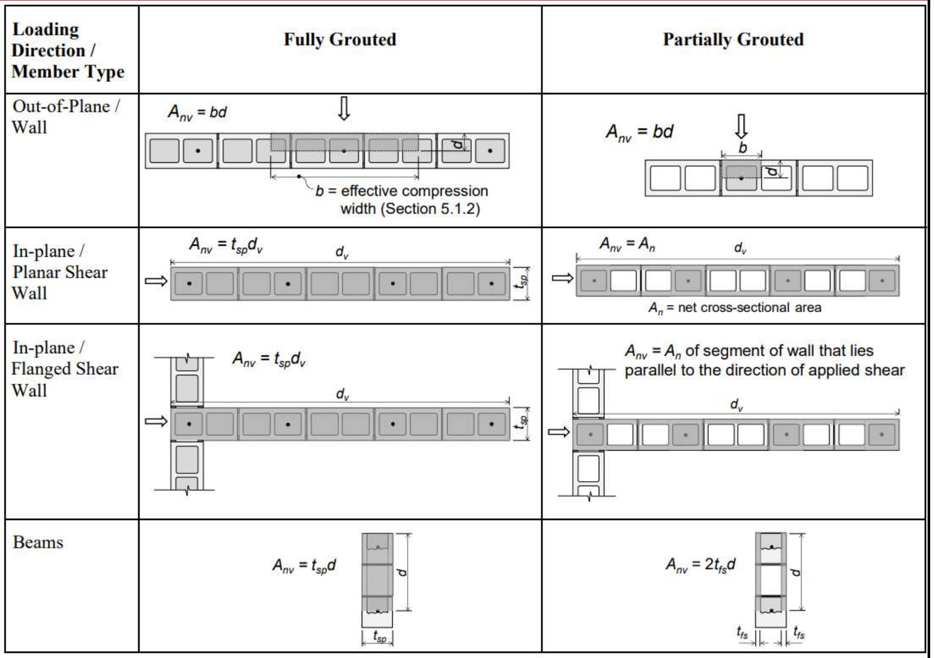
- Separate allowable shear stress equation for special reinforced masonry shear walls deleted.
- Shear capacity for ASD changed so shear is doubled instead of increased by 1.5.
- Factor on axial load changed from 0.25 to 0.20 (load combination issue)

$$F_{vm} = \frac{1}{2}\left[\left(4.0 - 1.75\left(\frac{M}{V d_v}\right)\right)\sqrt{f'_m}\right] + \mathbf{0.20}\frac{P}{A_n}$$

Equation 8-23

Net Shear Area

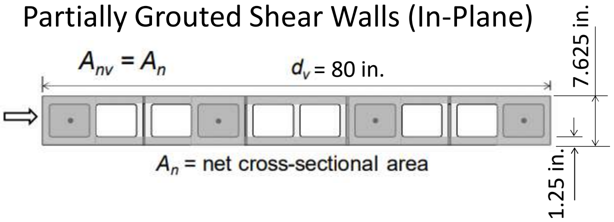
TMS 402 Table 4.4.5



Loading Direction / Member Type	Fully Grouted	Partially Grouted
Out-of-Plane / Wall	$A_{nv} = bd$ b = effective compression width (Section 5.1.2)	$A_{nv} = bd$
In-plane / Planar Shear Wall	$A_{nv} = t_{sp}d_v$	$A_{nv} = A_n$ A_n = net cross-sectional area
In-plane / Flanged Shear Wall	$A_{nv} = t_{sp}d_v$	$A_{nv} = A_n$ of segment of wall that lies parallel to the direction of applied shear
Beams	$A_{nv} = t_{sp}d$	$A_{nv} = 2t_{fs}d$

Net Shear Area

Partially Grouted Shear Walls (In-Plane)



$$A_{nv} = 2t_{fs}d_v + n_{cell}(8\text{ in.})(t_{sp} - 2t_{fs})$$

$$= 2(1.25\ in.)(80 in.) + 4(8\ in.)(7.625\ in. - 2\ (1.25\ in.))$$
$$= 364\ in.^2$$

t_{fs} = face shell thickness
t_{sp} = specified wall thickness

$$A_{nv} = t_{eq}d_v$$

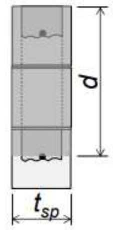
Grout Spacing (in.)	Equivalent Thickness, t_{eq} (in.)	
	8 in.	12 in.
16	5.17	7.28
24	4.28	5.69
32	3.83	4.89
40	3.57	4.41
48	3.39	4.09
72	3.09	3.56

$$A_{nv} = 4.28\ in.(80\ in.) = 342\ in.^2$$

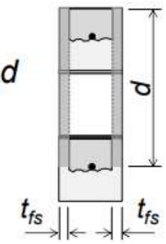
Net Shear Area

- Clarified A_{nv} for beams is calculated using d, not d_v
- Partially grouted beams are allowed
- Beams need to be fully grouted if shear reinforcement is required

$A_{nv} = t_{sp}d$



$A_{nv} = 2t_{fs}d$



Shear Force

Provisions for using shear at d/2 from face of support in beam design moved from Chapter 8 to Chapter 5 so it applies to SD as well as ASD.

~~8.3.5.4~~ 5.3.1.5 *Shear* — In cantilever beams, the maximum shear shall be used. In noncantilever beams, the maximum shear shall be used except that sections located within a distance $d/2$ from the face of support shall be permitted to be designed for the same shear as that calculated at a distance $d/2$ from the face of support when the following conditions are met:

(a) support reaction, in direction of applied shear force, introduces compression into the end regions of the beam, and

(b) no concentrated load occurs between face of support and a distance $d/2$ from face.

Anchor Bolt Strength

2 Truths and a Lie

TMS 402-16 Commentary:

9.1.6.3 Anchors conforming to A307, Grade A specifications are allowed by the Code, but the ASTM A307, Grade A specification does not specify a yield strength. Use of a yield strength of 37 ksi in the Code design equations for A307 anchors will result in anchor capacities similar to those obtained using the American Institute of Steel Construction provisions.

9.1.6.3.1.1 Steel strength is calculated using the effective tensile stress area of the anchor (that is, including the reduction in area of the anchor shank due to threads).

Anchor Bolt Strength

	Strength Design	Allowable Stress Design
Tensile Strength	$B_{ans} = A_b f_u$ Equation 9-2	$B_{as} = 0.5 A_b f_u$ Equation 8-2
Shear Strength	$B_{vns} = 0.6 A_b f_u$ Equation 9-7	$B_{vs} = 0.25 A_b f_u$ Equation 8-7

The value of f_u shall not be taken greater than the smaller of $1.9 f_y$ and 125,000 psi (862 MPa).

Anchor Bolt Strength

TMS 402 **6.3.8** Effective Cross-Sectional Area

$$A_b = \frac{\pi}{4}\left(d_o - \frac{0.9743}{n_t}\right)^2$$

d_o = nominal anchor diameter
n_t = number of threads per inch

Bolt size – threads per inch	A_b (in.^{2})
1/2 – 13	0.142
5/8 – 11	0.226
3/4 – 10	0.334
7/8 – 9	0.462
1 – 8	0.606

Partially Grouted Shear Wall Factor

$F_v = (F_{vm} + F_{vs})\gamma_g$ Equation 8-20

$V_n = (V_{nm} + V_{ns})\gamma_g$ Equation 9-15

γ_g changed from **0.75** to **0.70**

Shear Friction Strength: ASD

Shear Span Ratio	Allowable Shear Friction	
	2016	2022
$\frac{M}{Vd_v} \leq 0.5$	$F_f = \frac{\mu(A_{sp}F_s + P)}{A_{nv}}$	
$\frac{M}{Vd_v} \geq 1.0$	$F_f = \frac{0.65(0.6A_{sp}F_s + P)}{A_{nv}}$	$F_f = \frac{0.65(0.75A_{sp}F_s + P)}{A_{nv}}$

For $0.5 < \frac{M}{Vd_v} < 1.0$

- $\mu = 1.0 \quad F_f = \frac{\left(0.488+1.024\left(1-\frac{M}{Vd_v}\right)\right)A_{sp}F_s+\left(0.65+0.70\left(1-\frac{M}{Vd_v}\right)\right)P}{A_{nv}}$
- $\mu = 0.7 \quad F_f = \frac{\left(0488+ \ .424\left(1-\frac{M}{Vd_v}\right)\right)A_{sp}F_s+\left(0.65+0.10\left(1-\frac{M}{Vd_v}\right)\right)P}{A_{nv}}$

Shear Friction Strength: SD

Shear Span Ratio	Nominal Shear Friction Strength	
	2016	2022
$\frac{M_u}{V_u d_v} \leq 0.5$	$V_{nf} = \mu(A_{sp}f_y + P_u)$	
$\frac{M_u}{V_u d_v} \geq 1.0$	$V_{nf} = 0.42f'_m A_{nc}$	$V_{nf} = 0.65(0.75A_{sp}f_y + P_u)$

$0.5 < \frac{M_u}{V_u d_v} < 1.0$

- $\mu = 1.0 \quad V_{nf} = \left(0.488 + 1.024\left(1 - \frac{M_u}{V_u d_v}\right)\right)A_{sp}f_y + \left(0.65 + 0.70\left(1 - \frac{M_u}{V_u d_v}\right)\right)P_u$
- $\mu = 0.7 \quad V_{nf} = \left(0488 + 0.424\left(1 - \frac{M_u}{V_u d_v}\right)\right)A_{sp}f_y + \left(0.65 + 0.10\left(1 - \frac{M_u}{V_u d_v}\right)\right)P_u$

Cracked Moment of Inertia: OOP Loading

2016 Equation 9-30

$$I_{cr} = n\left(A_s + \frac{P_u}{f_y}\frac{t_{sp}}{2d}\right)(d-c)^2 + \frac{bc^3}{3}$$

Centered Reinforcement:

$$\boxed{I_{cr} = n\left(A_s + \frac{P_u}{f_y}\right)(d-c)^2 + \frac{bc^3}{3}}$$

2022 Equation 9-28

$$I_{cr} = nA_s(d-c)^2 + \frac{nP_u}{f_y}\left(\frac{t_{sp}}{2} - c\right)^2 + \frac{bc^3}{3}$$

Centered Reinforcement:

$$I_{cr} = nA_s\left(\frac{t_{sp}}{2} - c\right)^2 + \frac{nP_u}{f_y}\left(\frac{t_{sp}}{2} - c\right)^2 + \frac{bc^3}{3}$$

$$\boxed{I_{cr} = n\left(A_s + \frac{P_u}{f_y}\right)(d-c)^2 + \frac{bc^3}{3}}$$

Size of Reinforcement in Grout

2016: Differing requirements in ASD and Strength Design

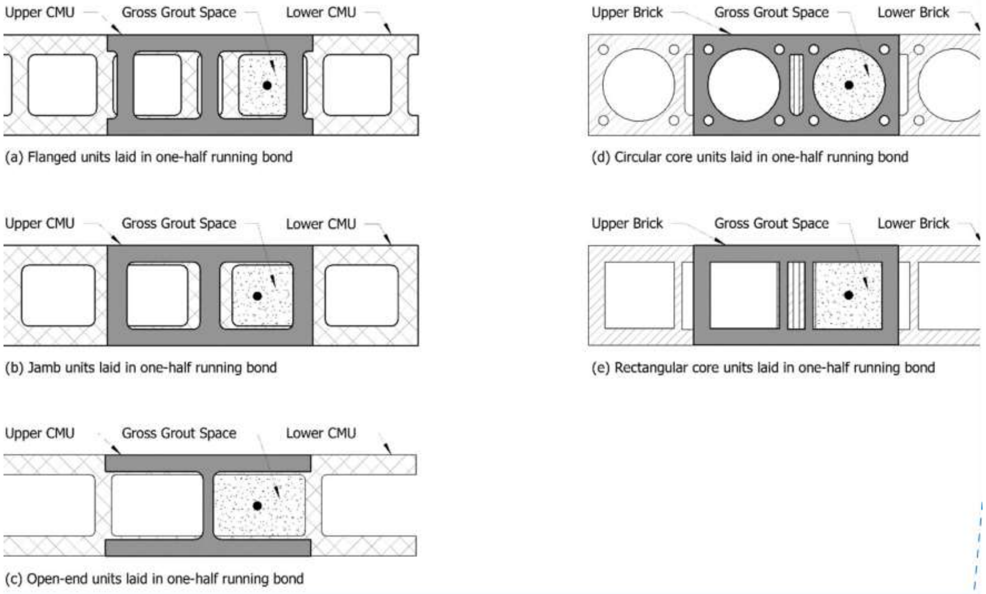
2022: Harmonized to three requirements (Chapter 6).

Reinforcement size limited to:

- one-eighth the least nominal member dimension.
- one-third the least dimension of the gross grout space.
- 4% of the gross grout space for clay and concrete masonry except 8% at laps.

Gross grout space: area within the continuous grouted cell, core, bond beam course, or collar joint, considering the effect of unit offset in adjacent courses but neglecting possible mortar protrusions and the presence of perpendicular reinforcement, if any.

Gross Grout Space



(a) Flanged units laid in one-half running bond

(d) Circular core units laid in one-half running bond

(b) Jamb units laid in one-half running bond

(e) Rectangular core units laid in one-half running bond

(c) Open-end units laid in one-half running bond

Maximum Vertical Reinforcement: One-Half Running Bond Two-Celled Hollow Concrete of Clay Masonry

Nominal Unit Thickness	Maximum Vertical Reinforcement per Cell		
	Flanged Units	Jamb Units	Open-End Units
6 in.	1 - #6 or 2 - #4	1 - #6 or 2 - #5	1 - #6 or 2 - #5
8 in.	1 - #7 or 2 - #5	1 - #8 or 2 - #6	1 - #8 or 2 - #6
10 in.	1 - #8 or 2 - #6	1 - #9 or 2 - #6	1 - #10 or 2 - #7
12 in.	1 - #9 or 2 - #6	1 - #10 or 2 - #7	1 - #11 or 2 - #8

Maximum Vertical Reinforcement: Stack Bond Two-Celled Hollow Concrete of Clay Masonry

Nominal Unit Thickness	Maximum Vertical Reinforcement per Cell		
	Flanged Units	Jamb Units	Open-End Units
6 in.	1 - #6 or 2 - #5	1 - #6 or 2 - #5	1 - #6 or 2 - #6
8 in.	1 - #8 or 2 - #6	1 - #8 or 2 - #6	1 - #8 or 2 - #7
10 in.	1 - #9 or 2 - #6	1 - #9 or 2 - #6	1 - #10 or 2 - #8
12 in.	1 - #10 or 2 - #7	1 - #11 or 2 - #8	1 - #11 or 2 - #8

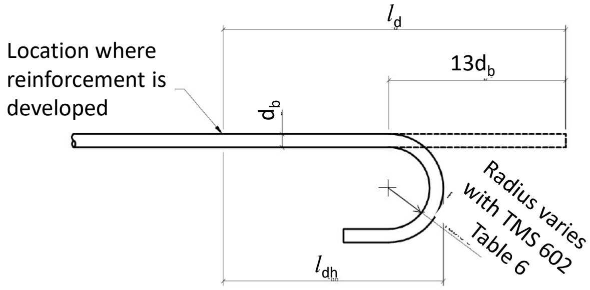
Contribution of Hooks to Development Length

2016: Equivalent embedment length of $13d_b$.

2022: Required development length: $l_{dh} = l_d - \gamma_h d_b$

$\gamma_h = 9.0$ for No. 3 through No. 8 bars

$\gamma_h = 8.0$ for No. 9 through No. 11 bars



Hooks for Shear Reinforcement

TMS 402-16

6.1.7.1 *Horizontal shear reinforcement*

6.1.7.1.1 Except at wall intersections, the end of a horizontal reinforcing bar needed to satisfy shear strength requirements of Section 9.3.4.1.2 or Section 11.3.4.1.2 shall be bent around the edge vertical reinforcing bar with a 180-degree standard hook.

6.1.7.1.2 At wall intersections, horizontal reinforcing bars needed to satisfy shear strength requirements of Section 9.3.4.1.2 or 11.3.4.1.2 shall be bent around the edge vertical reinforcing bar with a 90- degree standard hook and shall extend horizontally into the intersecting wall a minimum distance at least equal to the development length.

TMS 402-16

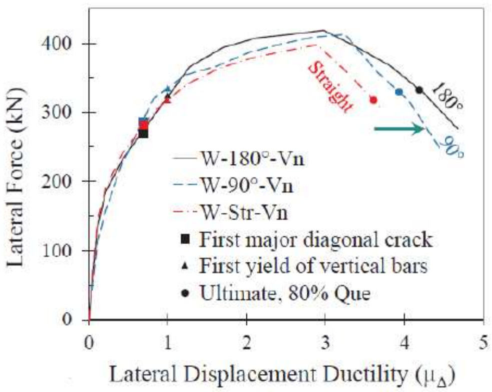
- Requirement deleted except for certain cases of special reinforced shear walls
- Research has shown that hooks provide little to no benefit.

Hooks for Shear Reinf.: The Research

Hoque (2013): The tests showed no significant difference in strength due to changes in the bond beam anchorage type from straight to 180° hooks.

Rizaee (2015): The results of this research and comparisons to past studies showed no beneficial effect of having 180° hooks at the ends of horizontal rebar over having it straight, having 90° hooks, or having studded ends.

Seif ElDin, H.M., and Galal, K. (2017):



This concludes The American Institute of Architects Continuing Education Systems Course

The Masonry Society

Dr. Richard Bennett
rmbennett@utk.edu