I-2 MASONRY PARTITION BRACING

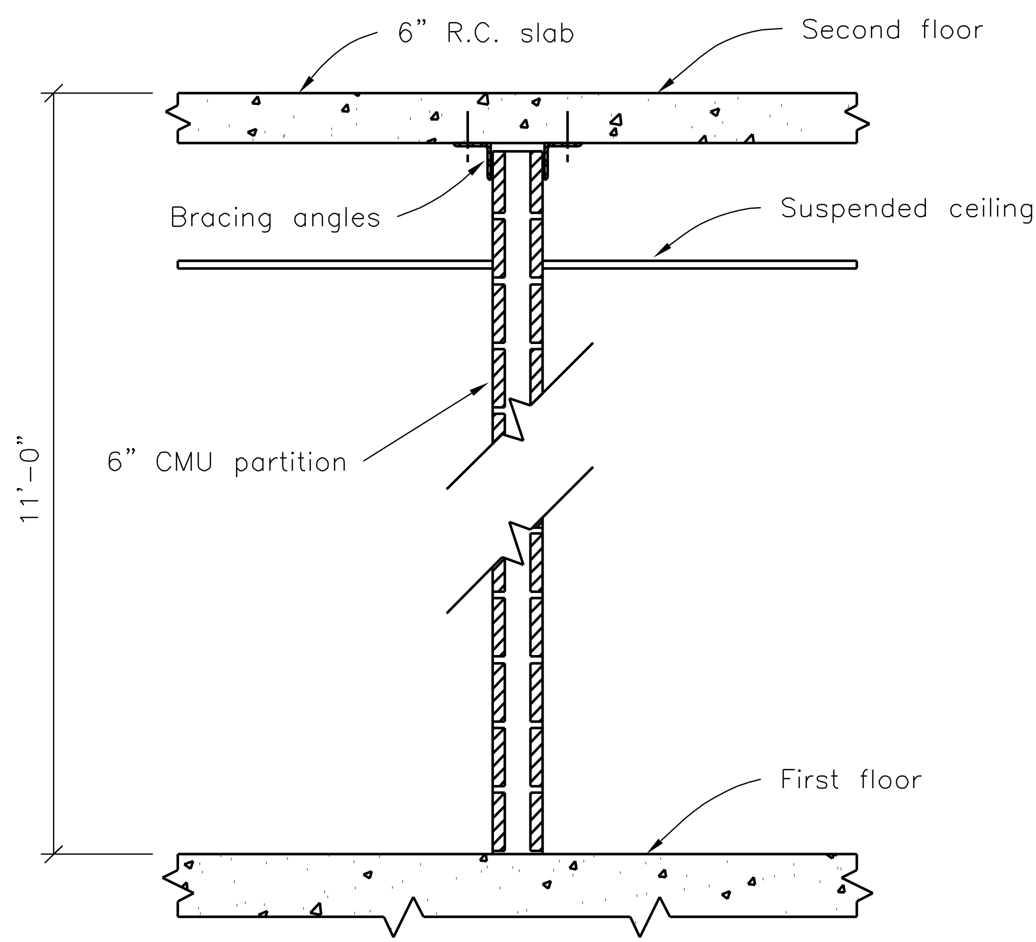
a. Introduction.

(1) Purpose. The purpose of this example problem is to illustrate the design of masonry partition bracing using Chapter 10 of TI 809-04, and Chapter 6 of FEMA 302 (Components). Unbraced masonry partitions are vulnerable to out-of-plane failure when subjected to lateral loads. Failure of these heavy partitions can cause injury to the occupants, preclude safe egress, and can obstruct essential functions in the building.

(2) Scope. The problem follows the steps in Table 4-6 to analyze the bracing and anchors. The solution is a modification of the bracing detail found in Figure 10-1. The building housing the partition is required to be functional after an earthquake.

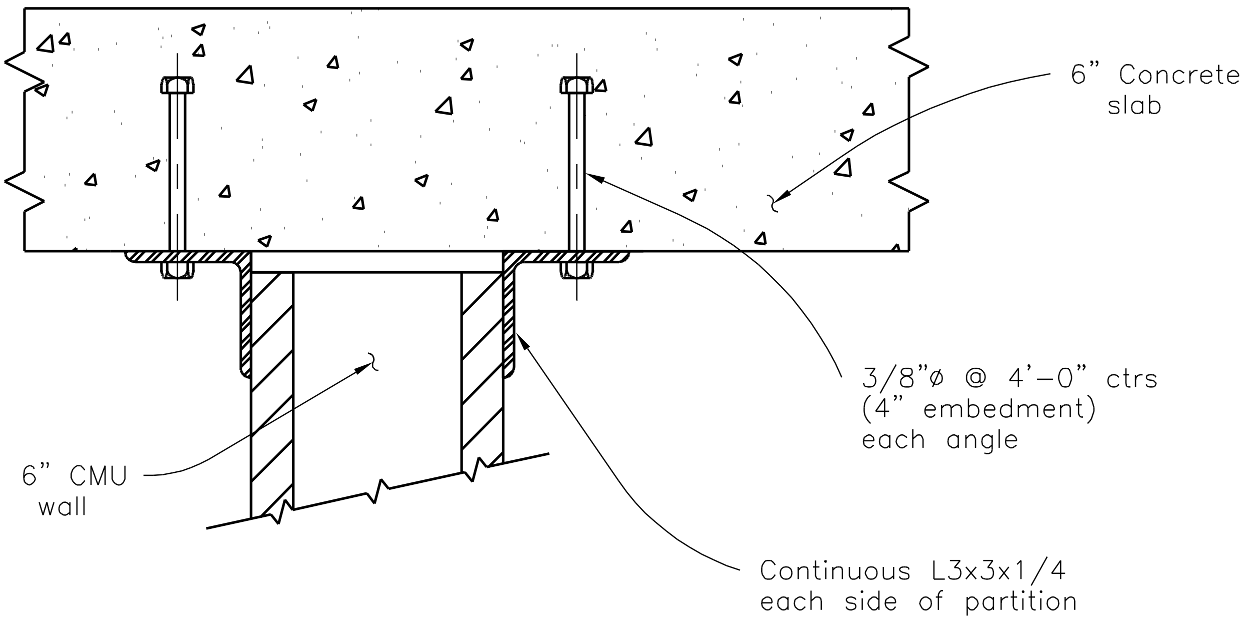
b. Component description.

The reinforced masonry partition used in this example problem forms part of an exit corridor below a concrete slab in a fire station. The partition is 10-1/2 (3.20m) feet high as shown in Figure I2-1. The bracing scheme is shown in Figure I2-2. The bracing is checked using a linear elastic analysis as described in paragraph 6-3a for force-controlled components.



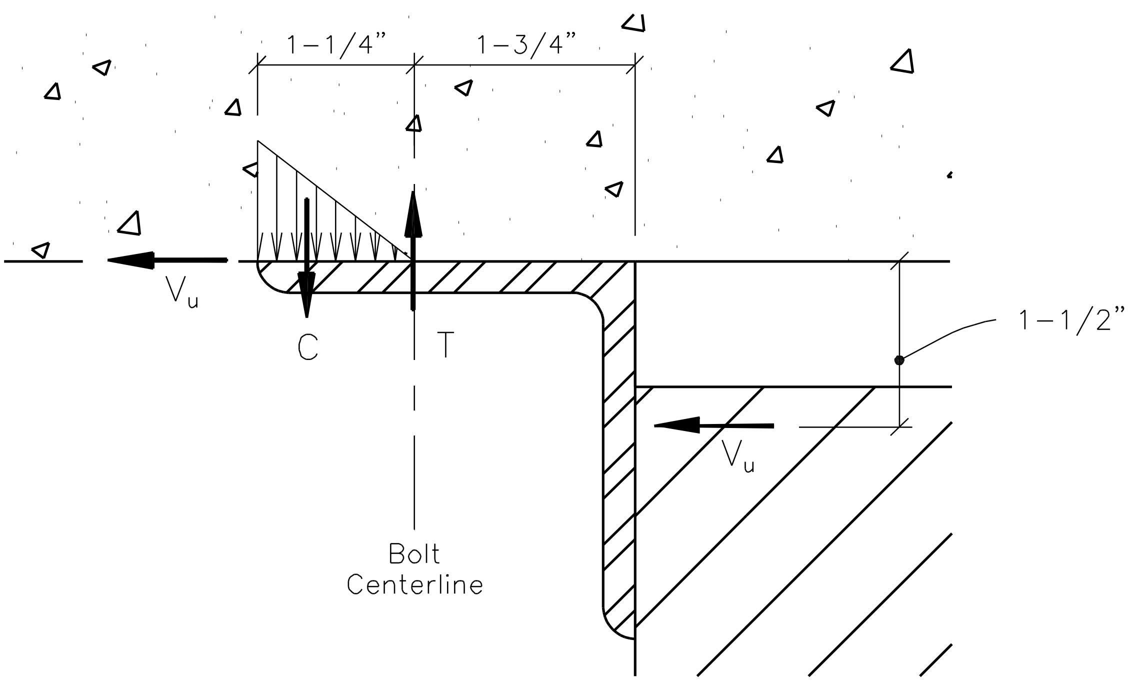
Note: For metric equivalents; 1-in = 25.4mm, 1-ft = 0.30m

Figure I2-1. Masonry partition in fire station



Note: For metric equivalents; 1-in = 25.4mm, 1-ft = 0.30m

Figure I2-2. Detail of lateral bracing for masonry partition



Note: For metric equivalents; 1-in = 25.4mm

Figure I2-3. Detail of forces in brace connection *c. Component design.*

A.1 *Determine appropriate Seismic Use Group*

Due to the requirement that the building be functional after and earthquake, the partition is given a performance level of immediate occupancy (IO). The Seismic Use Group and other performance parameters are determined from Table 4-4, as follows;

Performance Level:	IO	(per problem statement)
Seismic Use Group:	IIIE	(Table 4-4)
Ground Motion:	3/4 MCE (B)	(Table 4-4)
Performance Objective:	3B	(Table 4-4)

A.2 *Determine site seismicity.*

The following values are assumed for this example:

$S_S = 0.80g$ (MCE Maps)

A.3 *Determine site characteristics.*

Soil type C is assumed for this problem

Soil type: C (Table 3-1)

A.4 *Determine site coefficients.*

$F_a = 1.08$ (Table 3-2a)

A.5 *Determine adjusted MCE spectral response accelerations.*

$S_{MS} = F_a S_S = 1.08(0.80)g = 0.86g$ (EQ. 3-1)

A.6 *Determine design spectral response accelerations.*

$S_{DS} = 3/4\ S_{MS} = 3/4(0.86) = 0.65g$ (EQ. 3-3)

A.7 *Bracing system.*

Brace partitions with steel angles on each side. Angles to be bolted to 2nd floor concrete slab as indicated in Figure I2-2.

A.8 *Select R_p, a_p, and I_p factors.*

$a_p = 2.5$ (Table 10-1)

$R_p = 2.5$ (Table 10-1)

$I_p = 1.5$ (per Paragraph 10-1d)

A.10 *Determine member sizes for gravity load effects.*

No gravity load design is required.

Note: Table 4-6 was created as an aid for building design and is not entirely applicable in the design of nonstructural systems and components. The following steps are based on the intent of this document, and do not have a one to one correspondence to steps as listed in Table 4-6.

F.1 *Determine seismic force effects.*

Seismic forces (F_p) shall be determined in accordance with Chapter 10 as follows:

$$F_p = \frac{0.4a_p S_{DS} W_p}{R_p / I_p}\left(1+2\frac{z}{h}\right) \quad \text{(EQ. 10-1 TI 809-04)}$$

where; z/h = 1/2 (1st story of a 2-story building)

W_p;

Dead load = 40psf (1.92KN/m^2) (6-in. (152.4mm) CMU)

$$\therefore W_p = \frac{10.5'(40psf)4'}{2} = 840-lb \quad (3.74KN)$$

F_p is not required to be greater than:

$$F_p = 1.6S_{DS}I_pW_p \quad \text{(EQ. 10-2)}$$

nor less than:

$$F_p = 0.3S_{DS}I_pW_p \quad \text{(EQ. 10-3)}$$

$$F_p = \frac{0.4(2.5)0.65(840-lb)}{2.5/1.5}\left(1+2(\frac{1}{2})\right) = 0.78(840-lb) = 655-lb \quad (2.91KN)$$

$$(F_p)_{max} = 1.6(0.65)1.5(840-lb) = 1{,}310-lb > 655-lb = F_p \quad (5.83KN > 2.91KN)$$ **O.K.**

$$(F_p)_{max} = 0.3(0.65)1.5(840-lb) = 246-lb < 655-lb = F_p \quad (1.09KN < 2.91KN)$$ **O.K.**

F.2 *Design members.*

Design of angle brace;
Try L3x3x1/4 (L76.2mmX76.2MMX6.4mm) with 3/8-in. (9.53mm) ϕ bolt (A-307) @ 4'-0" (1.22m) on center with 4" (101.6mm) embedment (see Figure I2-2).

Check flexure in angle
Assume simple beam moment for angle spanning between bolts;

$$\phi M_n = \phi Z F_y > M_u$$

$w_p = F_p/4' = 655\text{-lb}/4' = 164plf$ (2.39KN/m)

$$M_u = \frac{w_pL^2}{8} = \frac{164plf(4')^2(12"/1')}{8} = 3{,}936^{in-lb} \text{ or } 3.94^{in-k} \quad (0.44kn\text{-}m)$$

For L3x3x1/4, Z = 1.04-in^3 (17.04X10^3 mm^3)

$$\therefore \phi M_n = 0.9ZF_y = 0.9(1.04-in^3)36ksi = 33.7^{in-k} > 3.94^{in-k} = M_u \quad (3.81KN\text{-}m > 0.44KN\text{-}m)$$ **O.K.**

Check bolt capacity
Determine loading;

$$V_u = 655-lb/bolt \quad (2.91KN)$$

The force in the bolt due to prying action is determined by summing moments about the bolt centerline (see Figure I2-3);

$665^{lb}(1.5") = C(1.25")2/3$

$P_u = T = C = 1{,}197$-lbs or 1.2^k (5.34KN)

Check capacity in shear;
Steel;

$$V_s = (0.75A_bF_u)n \quad \text{(EQ. 9.2.4.2-1 FEMA 302)}$$

For 3/8" (9.53mm) ϕ bolt (A 307)

where; $A_b = 0.11\text{-in}^2$ $(70.97mm^2)$
$F_u = 60ksi$ (413.7MPa)
n = 1-bolt

$$V_s = 0.75(0.11 - in^2)60ksi(1.0 - bolt) = 4.95^k > 0.665^k = V_u \quad (22.02KN > 2.96KN)$$ **O.K.**

Concrete;

$$\phi V_c = (\phi 800 A_b \lambda \sqrt{f_c^{'}})n$$ (EQ. 9.2.4.2-2 FEMA 302)

where; $\phi = 0.65$
$\lambda = 1.0$ (normal weight concrete)
$f_c' = 4{,}000psi$ (27.6MPa)
n = 1-bolt

$$\therefore \phi V_c = 0.65(800)0.11 - in^2(1.0)\sqrt{4{,}000psi} = 0.65(5.57^k) = 3.62^k \quad (16.1KN)$$

$$\phi V_c = 3.62^k > 0.665^k = V_u \quad (16.1KN > 2.96KN)$$ **O.K.**

Check capacity in tension;
Steel;

$$P_s = (0.9 A_b F_u)n$$ (EQ. 9.2.4.1-1 FEMA 302)

where; $A_b = 0.11\text{-in}^2$ $(70.97mm^2)$
$F_u = 60ksi$ (413.7MPa)
n = 1-bolt

$$\therefore P_s = 0.9(0.11 - in^2)60ksi(1 - bolt) = 5.94^k > 1.2^k = P_u \quad (26.4KN > 5.3KN)$$ **O.K.**

Concrete;

$$\phi P_c = \phi \lambda \sqrt{f_c^{'}}(2.8 A_s)n$$ (EQ. 9.2.4.1-2 FEMA 302)

where; $\phi = 0.65$
$\lambda = 1.0$ (normal weight concrete)
$f_c' = 4{,}000psi$ (27.6MPa)
$A_s = \pi(4")4" = 50.3\text{-in}^2$ $(32.45X10^3\ mm^2)$ (for a 4-in. (101.6mm) embedment)

$$\therefore \phi P_c = 0.65(1.0)\sqrt{4{,}000psi}(2.8(50.3 - in^2))(1 - bolt) = 0.65(8.91^k) = 5.79^k > 1.2^k = P_u$$ **O.K.**
(25.8KN > 5.3KN)

Check combined tension and shear;
Per section 9.2.4.3 of FEMA 302 , all of the following conditions shall be met;

condition (a) $$\frac{1}{\phi}\left(\frac{V_u}{V_c}\right) \le 1.0$$ (EQ. 9.2.4.3-1a FEMA 302)

$$\frac{1}{0.65}\left(\frac{0.665^k}{5.57^k}\right) = 0.18 \le 1.0$$ **O.K.**

condition (b) $$\frac{1}{\phi}\left(\frac{P_u}{P_c}\right) \le 1.0$$ (EQ. 9.2.4.3-1b FEMA 302)

$$\frac{1}{0.65}\left(\frac{1.2^k}{8.91^k}\right) = 0.21 \le 1.0$$ **O.K.**

condition (c) $$\frac{1}{\phi}\left[\left(\frac{P_u}{P_c}\right)^2 + \left(\frac{V_u}{V_c}\right)^2\right] \le 1.0$$ (EQ. 9.2.4.3-1c FEMA 302)

$$\frac{1}{0.65}\left[\left(\frac{1.2^k}{8.91^k}\right)^2 + \left(\frac{0.665^k}{5.57^k}\right)^2\right] = \frac{1}{0.65}(0.018 + 0.014) = 0.05 \le 1.0$$ **O.K.**

condition (d) $\left(\frac{P_u}{P_s}\right)^2 + \left(\frac{V_u}{V_s}\right)^2 \leq 1.0$ (EQ. 9.2.4.3-1d FEMA 302)

$$\left(\frac{1.2^k}{5.94^k}\right)^2 + \left(\frac{0.665^k}{4.95^k}\right)^2 = 0.041 + 0.018 = 0.06 \leq 1.0$$ **O.K.**

Check flexure in angle leg;

$\phi M_n = \phi Z F_y > M_u$

Moment @ bolt (assume 8" (203.2mm) length of angle is effective)

$M_u = 1.2^k(2/3)1.25" = 1.0^{in\text{-}k}$ (0.11KN-m)

Calculate Z;

For a rectangular section: $Z = \frac{bh^2}{4} = \frac{8"(0.25")^2}{4} = 0.125 - in^3$ ($2.05X10^3$ mm^3)

$\therefore \phi M_n = 0.9 Z F_y = 0.9(0.125 - in^3)36ksi = 4.05^{in-k} > 1.0^{in-k} = M_u$ **O.K.**

(0.46KN-m > 0.11KN-m)

Conclusion

In view of the stresses in the bolt and the angle, bolt spacing will be revised to 6'-0" (1.83m) on center. This should be confirmed by re-iteration of the shear calculations.