Partition Wall Design Program Background Information

This program is intended as a preliminary design tool for design professionals who are experienced and competent in masonry design. This program is not intended to replace sound engineering knowledge, experience, and judgment. Users of this program must determine the validity of the results. The International Masonry Institute assumes no responsibility for the use or application of this program.

This document provides the background to the Partition Wall Design Program.

Automatic Parameters:

Automatic parameters are provided for the wall properties. By unchecking the automatic box, users are able to override these values should the design situation warrant.

Cross-sectional properties are determined based on face shell bedding for hollow masonry, and full bedding for solid masonry. Grout cells are included in determining the cross-sectional properties. The values for CMU masonry are as follows, which are determined from NCMA TEK 14-1B, or calculated based on the cross-section dimensions if not given in NCMA TEK 14-1B.

Grout Spacing	Nominal Wythe Thickness (in.), with actual wall thickness below (in.)				
	4 3.625	6 5.625	8 7.625	10 9.625	12 11.625
Net Area (in^2/ft)					
No grout	18	24.0	30.0	30.0	30.0
120 in o.c.		27.0	34.3	36.0	37.6
112 in o.c.		27.2	34.6	36.3	38.1
104 in o.c.		27.5	34.9	36.8	38.8
96 in o.c.		27.8	35.3	37.5	39.6
88 in o.c.		28.1	35.8	38.1	40.3
80 in o.c.		28.5	36.4	38.9	41.4
72 in o.c.		29.0	37.1	39.9	42.7
64 in o.c.		29.6	38.0	41.1	44.2
56 in o.c.		30.4	39.1	42.7	46.3
48 in o.c.		31.5	40.7	44.9	49.1
40 in o.c.		33.0	42.8	47.9	52.9
32 in o.c.		35.3	46.0	52.4	58.7
24 in o.c.		39.1	51.3	59.8	68.2
16 in o.c.		46.6	62.0	74.8	87.3
Full Grout	43.5	67.5	91.5	115.5	139.5
Solid Units	43.5	67.5	91.5	115.5	139.5
Section Modulus (in^3/ft)					
No grout	21.0	46.3	81.0	110.1	139.6
120 in o.c.		47.5	83.4	115.4	148.7
112 in o.c.		47.6	83.6	115.7	149.3
104 in o.c.		47.7	83.8	116.1	150.0
96 in o.c.		47.8	84.0	116.7	151.0
88 in o.c.		47.9	84.3	117.2	151.9
80 in o.c.		48.1	84.6	117.9	153.1
72 in o.c.		48.3	85.0	118.9	154.8
64 in o.c.		48.5	85.5	119.9	156.5
56 in o.c.		48.9	86.2	121.3	159.0
48 in o.c.		49.3	87.1	123.2	162.4

40 in o.c.		49.9	88.3	125.9	166.9
32 in o.c.		50.7	90.1	129.8	173.8
24 in o.c.		52.2	93.2	136.3	185.2
16 in o.c.		55.1	99.3	149.5	208.0
Full Grout	26.3	63.3	116.3	185.3	270.3
Solid Units	26.3	63.3	116.3	185.3	270.3

Cross-sectional properties for clay masonry are as follows, with the assumption being that solid clay masonry units will be used. As there are not standard hollow clay masonry unit sizes, cross-sectional properties would need to be input for the specific hollow brick that is being used.

Nominal Thickness (in)	Actual wall thickness (in)	Net area (in^2)	Section modulus (in^3)
4	3.5	42	24.5
6	5.5	66	60.5
8	7.5	90	112.5

The definitions for units are given in ASTM C90 as:

- Light weight: density less than 105 pcf
- Medium weight: density greater than or equal to 105 pcf but less than 125 pcf
- Normal weight: density of 125 pcf or more

The upper limits of the C90 designations, with a value of 135 pcf for normal weight units, are used. This will be conservative for seismic loads, as increased wall weights results in increased loads. As the wall weight is beneficial in resisting flexural tension in unreinforced masonry, using the upper limit of the wall weight will be slightly unconservative for unreinforced masonry designed for other than seismic loads. The degree of unconservatism is less than 10%. The designer should consider choosing a lighter unit designation in this case, or entering the actual wall weight for units with a density less than 105 pcf. The wall weights from NCMA TEK-14-13B are used in the program.

Grout Spacing	Nominal Thickness (in.)				
	4	6	8	10	12
Density of Unit: **105** pcf (Light weight units)					
No grout	16	24	31	36	39
120 in o.c.		26	34	40	44
112 in o.c.		26	34	40	45
104 in o.c.		27	34	40	45
96 in o.c.		27	35	41	46
88 in o.c.		27	35	41	46
80 in o.c.		27	35	42	47
72 in o.c.		28	36	42	48
64 in o.c.		28	37	43	49
56 in o.c.		29	38	44	51
48 in o.c.		30	39	46	53
40 in o.c.		31	40	48	55
32 in o.c.		32	43	51	59
24 in o.c.		35	47	57	66
16 in o.c.		41	55	68	80
Full Grout		58	78	100	121
Solid Units	33	50	68	86	104
Density of Unit: **125** pcf (Medium weight units)					
No grout	19	28	36	41	46
120 in o.c.		30	39	46	51
112 in o.c.		30	39	46	52
104 in o.c.		31	40	46	52
96 in o.c.		31	40	47	53
88 in o.c.		31	40	47	53
80 in o.c.		31	41	48	54
72 in o.c.		32	41	49	55
64 in o.c.		32	42	50	56
56 in o.c.		33	43	51	57
48 in o.c.		34	44	52	59
40 in o.c.		35	46	54	62
32 in o.c.		37	48	58	66
24 in o.c.		39	52	63	73
16 in o.c.		45	60	74	87
Full Grout		62	84	106	128
Solid Units	39	5	80	101	122
Density of Unit: 135 pcf (Normal weight units)					

No grout	20	30	39	45	49
120 in o.c.		32	42	49	55
112 in o.c.		33	42	49	55
104 in o.c.		33	42	50	55
96 in o.c.		33	43	50	56
88 in o.c.		33	43	50	57
80 in o.c.		34	44	51	57
72 in o.c.		34	44	52	58
64 in o.c.		34	45	53	59
56 in o.c.		35	46	54	61
48 in o.c.		36	47	55	63
40 in o.c.		37	48	58	66
32 in o.c.		39	51	61	70
24 in o.c.		41	55	66	77
16 in o.c.		47	63	77	90
Full Grout		64	86	109	132
Solid Units	41	63	86	108	131

Wall weights for clay masonry are determined from ASCE 7-10 and are as follows.

Nominal Thickness (in.)	Wall Weight (psf)
4	39
6	59
8	79

The specified masonry compressive strength, f'_m, is automatically determined, with the option to override the default should the design conditions warrant. For the 2009 and 2012 IBC, the default values are based on an 1900 psi CMU unit strength and an 8000 psi clay unit strength. For the 2015 IBC, the default values are based on a 2000 psi CMU unit strength due to the change in ASTM C90. The values of f'_m used by the program are:

Mortar	f'_m (psi)		
	CMU		Clay
	2009, 2012 IBC	2015 IBC	All codes
Type N Mortar	1350	1750	2440
Type S Mortar	1500	2000	2930

Bond Pattern:

The program is applicable to both running bond and masonry not laid in running bond for vertical spanning walls, both simple support and cantilever. The program is limited to masonry laid in running bond for horizontal spanning walls. For masonry not laid in running bond, the effective compression width is limited to 16 inches for reinforced walls.

Seismic Loads:

The seismic load is set to 0 for the following conditions:

- Seismic Design Category A (ASCE 7 Section 11.7)
- Seismic Design Category B and component importance factor, I_P, is 1.0 (ASCE 7 Section 13.1.4).

For other cases, the out-of-plane seismic design force is obtained as:

$$F_p = \frac{0.4 a_p S_{DS} W_p}{\left(\frac{R_p}{I_p}\right)}\left(1 + 2\frac{z}{h}\right)$$

where F_p is the out-of-plane seismic design force in psf, a_p =1.0 (Table 13.5-1), W_p is the weight of the wall in psf, z is the height above ground, h is the height of the building, R_p = 1.5 for unreinforced partition walls and R_p = 2.5 for reinforced partition walls, and I_p is the component importance factor. The program is based on z = h, which results in the out-of-plane seismic design force becoming:

$$F_p = \frac{1.2 S_{DS} W_p}{\left(\frac{R_p}{I_p}\right)}$$

When W_p is expressed in terms of wall weight, w_{wall}, then F_p becomes the out-of-plane seismic load, w_E.

Several other parameters affect the seismic

- Risk Category IV structure. ASCE 7 defines as a Risk Category IV structure, which is as follows.
  - Buildings and other structures designated as essential facilities.
  - Buildings and other structures, the failure of which could pose a substantial hazard to the community.
  - Buildings and other structures (including, but not limited to, facilities that manufacture, process, handle, store, use, or dispose of such substances as hazardous fuels, hazardous chemicals, or hazardous waste) containing sufficient quantities of highly toxic substances where the quantity exceeds a threshold quantity established by the

authority having jurisdiction to be dangerous to the public if released and is sufficient to pose a threat to the public if released.
    - Buildings and other structures required to maintain the functionality of other Risk Category IV structures.
- Egress stairway. If partition is part of an egress stairway, the component importance factor, I_P, is 1.5. Otherwise, I_P=1.0. (ASCE 7 Section 13.1.3)
- Seismic Design Category: The Seismic Design Category is determined from (ASCE 7 Table 11.6-1 and Table 11.6-2):

Value of S_{DS}	Risk Category	
	I or II or III	IV
$S_{DS} < 0.167$	A	A
$0.167 \le S_{DS} < 0.33$	B	C
$0.33 \le S_{DS} < 0.50$	C	D
$0.50 \le S_{DS}$	D	D

Value of S_{D1}	Risk Category	
	I or II or III	IV
$S_{D1} < 0.067$	A	A
$0.067 \le S_{D1} < 0.133$	B	C
$0.133 \le S_{D1} < 0.20$	C	D
$0.20 \le S_{D1}$	D	D

Vertical seismic loads are included in the analysis through the $0.7*0.2*S_{DS}$ term in computing the axial load. The program automatically checks for both the seismic load acting upward (uplift) and downward.

The software automatically calculates the seismic load; it should not have to be entered as a horizontal uniform load.

Load Combinations:

The program is based on allowable stress design and uses the following load combinations for vertical spanning walls (both simple supports and cantilever):

A. $0.6D + w_L$
B. $0.6D + w_L + P_L$
C. $D + w_L + P_L$
D. $0.6D + H_L$
E. $0.6D + H_L + P_L$
F. $D + H_L + P_L$
G. $0.6D + 0.7E$
H. $0.6D + 0.75w_L + 0.75*0.7E$
I. $0.6D + 0.75w_L + 0.75P_L + 0.75*0.7E$
J. $D + 0.75w_L + 0.75P_L + 0.75*0.7E$
K. $0.6D + 0.75H_L + 0.75*0.7E$
L. $0.6D + 0.75H_L + 0.75P_L + 0.75*0.7E$
M. $D + 0.75H_L + 0.75P_L + 0.75*0.7E$

where:

D = dead load (wall weight)
w_L = horizontal uniform load (default value is 5 psf)
P_L = vertical load
H_L = horizontal concentrated load
E = seismic load

The seismic load consists of a horizontal uniform seismic load, w_E, and a vertical load, $0.2S_{DS}D$.

The program does not account for a combination of a uniform horizontal load and a concentrated load in combination. The IBC and ASCE 7 are unclear as to whether these should be combined. Our interpretation is that these load do not need to be combined.

For horizontally spanning walls, the program uses the following load:

A. w_L
B. $0.7w_E$
C. $0.75w_L + 0.75*0.7w_E$

Structural Analysis:

An axial force and moment is determined for each load combination. These are given in the following table. The notation is w_{wall} is the weight of the wall, h is the height of the wall, e is the eccentricity, h_L is the height of the horizontal load from the bottom, and x is the distance from the top of the wall to the location of maximum moment, R_b is the reaction at the bottom of the wall, and R_t is the reaction at the top of the wall. The eccentric vertical load is assumed to act at the top of the partition wall.

Simply supported wall

Load Combination	Location of Max Moment (x) Axial Force (P) Top Reaction (R_t)	Moment
A	x = h/2 P = 0.6*w_{wall}*(h/2) R_{t-} = w_Lh/2	$w_L h^2/8$
B	$x = \max\left(\frac{h}{2} - \frac{P_L e}{w_L h}, 0\right)$ P = 0.6*w_{wall}*x + P_L R_{t-} = w_Lh/2 – P_Le/h	$\begin{cases} \frac{P_L e}{2} + \frac{w_L h^2}{8} + \frac{(P_L e)^2}{2 w_L h^2} & \text{if } x > 0 \\ P_L e & \text{if } x \le 0 \end{cases}$
C	$x = \max\left(\frac{h}{2} - \frac{P_L e}{w_L h}, 0\right)$ P = w_{wall}*x + P_L R_{t-} = w_Lh/2 – P_Le/h	$\begin{cases} \frac{P_L e}{2} + \frac{w_L h^2}{8} + \frac{(P_L e)^2}{2 w_L h^2} & \text{if } x > 0 \\ P_L e & \text{if } x \le 0 \end{cases}$
D	x = h/2 Axial force = 0.6*w_{wall}*(h-h_L) R_t = $H_L h_L$/h	H_L*(h_L/h)*(h-h_L)
E	If $P_L e \geq H_L h_L$ then x =0 If $P_L e < H_L h_L$ then x = h-h_L P = 0.6*w_{wall}*x + P_L R_t = $H_L h_L$/h - P_Le/h	If x=0 then M = P_Le If x ≠ 0 then $M = \left(\frac{H_L(h - h_L) + P_L e}{h}\right) h_L$
F	If $P_L e \geq H_L h_L$ then x =0 If $P_L e < H_L h_L$ then x = h-h_L P = w_{wall}*x + P_L R_t = $H_L h_L$/h - P_Le/h	If x=0 then M = P_Le If x ≠ 0 then $M = \left(\frac{H_L(h - h_L) + P_L e}{h}\right) h_L$
G	x = h/2 P =(0.6-0.7*0.2*S_{DS}) w_{wall}*(h/2) R_{t-} = 0.7w_Eh/2	0.7*$w_E h^2$/8
H	x = h/2 P = (0.6-0.75*0.7*0.2*S_{DS}) *w_{wall}*(h/2) R_{t-} = 0.75(0.7w_E+w_L)h/2	0.75*0.7*$w_E h^2$/8 + 0.75*$w_L h^2$/8

I	$x = \max\left(\frac{h}{2} - \frac{P_L e}{(0.7w_E + w_L)h}, 0\right)$ P = (0.6-0.75*0.7*0.2*S_{DS}) w_{wall}*x R_t = 0.75[(0.7w_E+w_L)h/2 – P_Le/h]	if x > 0 $0.75\left(\frac{P_L e}{2} + \frac{(w_L + 0.7w_E)h^2}{8} + \frac{(P_L e)^2}{2(w_L + 0.7w_E)h^2}\right)$ if x ≤ 0 $0.75P_L e$
J	Everything is the same as Load Combination I, except axial load. P = (1+0.75*0.7*0.2*S_{DS}) w_{wall}*x	Moments are the same as for Load Combination I
K	Calculate reaction at bottom, R_b $R_b = 0.75\left(\frac{0.7w_E h}{2} + \frac{H_L(h-h_L)}{h}\right)$ Three possible cases: A. If R_b < 0.75*0.7$w_E h_L$ maximum moment occurs below H_L. x = h – R_b/(0.75*0.7w_E) B. If 0.75*0.7$w_E h_L$ ≤ R_b ≤ 0.75(0.7$w_E h_L$+H_L) maximum moment occurs at H_L. x = h-h_L C. If R_b > 0.75(0.7$w_E h_L$+H_L) maximum moment occurs above H_L. x = h - (R_b-0.75H_L)/(0.75*0.7w_E) P = (0.6-0.75*0.7*0.2*S_{DS}) w_{wall}*x R_{t-} = 0.75[0.7w_Eh/2+$H_L h_L$/h]	Determine the maximum moment depending on the case. A. $R_b(h-x) - 0.75\frac{0.7w_E(h-x)^2}{2}$ B. $R_b h_L - 0.75\frac{0.7w_E h_L^2}{2}$ C. $R_b(h-x) - 0.75\left(\frac{0.7w_E(h-x)^2}{2} + H_L(h-x-h_L)\right)$
L	Calculate reaction at bottom, R_b $R_b =$ $0.75\left(\frac{0.7w_E h}{2} + \frac{H_L(h-h_L)}{h} + \frac{P_L e}{h}\right)$ Four possible cases. First three are the same as above, Load Combination K. Three possible cases: A. max moment occurs below H_L. B. max moment occurs at H_L. C. If 0.75(0.7$w_E h_L$+H_L) <R_b ≤ 0.75(0.7w_Eh+H_L) maximum moment occurs above H_L, but below top. D. If R_b > 0.75(0.7w_Eh+H_L) maximum moment occurs at top. x = 0	=Determine the maximum moment depending on the case. A. $R_b(h-x) - 0.75\frac{0.7w_E(h-x)^2}{2}$ B. $R_b h_L - 0.75\frac{0.7w_E h_L^2}{2}$ C. $R_b(h-x) - 0.75\left(\frac{0.7w_E(h-x)^2}{2} + H_L(h-x-h_L)\right)$ D. $M = 0.75P_L e$

	P = $(0.6-0.75*0.7*0.2*S_{DS})\ w_{wall}*x +$ $0.75P_L$ $R_t = 0.75[0.7w_E h/2 + H_L h_L/h - P_L e/h]$	
M	Everything is the same as Load Combination L, except axial load is: $P = (1+0.75*0.7*0.2*S_{DS})\ w_{wall}*x +$ $0.75P_L$	Moments are the same as for Load Combination L

Cantilever Wall

Load Combination	Axial	Moment
A	$0.6*w_{wall}*h$	$w_L h^2/2$
B	$0.6*w_{wall}*h + P_L$	$w_L h^2/2 + P_L*e$
C	$w_{wall}*h + P_L$	$w_L h^2/2 + P_L*e$
D	$0.6*w_{wall}*h$	H_L*h_L
E	$0.6*w_{wall}*h + P_L$	$H_L*h_L + P_L*e$
F	$w_{wall}*h + P_L$	$H_L*h_L + P_L*e$
G	$(0.6-0.7*0.2*S_{DS})\ *w_{wall}*h$	$0.7*w_E h^2/2$
H	$(0.6-0.75*0.7*0.2*S_{DS})\ *w_{wall}*h$	$0.75*0.7*w_E h^2/2 + 0.75*w_L h^2/2$
I	$(0.6-0.75*0.7*0.2*S_{DS})\ *w_{wall}*h + 0.75*P_L$	$0.75*0.7*w_E h^2/2 + 0.75(w_L h^2/2 + P_L*e)$
J	$(1+0.75*0.7*0.2*S_{DS})\ *w_{wall}*h + 0.75*P_L$	$0.75*0.7*w_E h^2/2 + 0.75(w_L h^2/2 + P_L*e)$
K	$(0.6-0.75*0.7*0.2*S_{DS})\ *w_{wall}*h$	$0.75*0.7*w_E h^2/2 + 0.75*H_L*h_L$
L	$(0.6-0.75*0.7*0.2*S_{DS})\ *w_{wall}*h + 0.75*P_L$	$0.75*0.7*w_E h^2/2 + 0.75(H_L*h_L + P_L*e)$
M	$(1+0.75*0.7*0.2*S_{DS})\ *w_{wall}*h + 0.75*P_L$	$0.75*0.7*w_E h^2/2 + 0.75(H_L*h_L + P_L*e)$

Horizontal Span (h is being used for the length of the wall). With horizontal span, there is no axial force.

Load Combination	Maximum moment
A	$w_L h^2/8$
B	$0.7*w_E h^2/8$
C	$0.75*0.7*w_E h^2/8 + 0.75*w_L h^2/8$

Unreinforced Design:

Flexural Tension Stress

The maximum flexural tension stress is calculated as $-\frac{P}{A_n}+\frac{12M}{S_n}$, where P is axial load, A_n is the net area, M is the moment, and S_n is the section modulus, and the 12 is to convert feet to inches.

For the 2015 IBC (2013 TMS 402/602), the allowable flexural tensile stresses are as follows (units of psi):

	Type S Portland cement lime	Type N Portland cement lime	Type S Masonry cement	Type N Masonry cement
Vertical Span:				
No grout	33	25	20	12
Full grout	65	63	61	58
Solid units	53	40	32	20
Horizontal Span:				
No grout	66	50	40	25
Full grout	106	80	64	40
Solid units	106	80	64	40

For the 2012 IBC (2011 TMS 402/602), the allowable flexural tensile stresses are as follows (units of psi):

	Type S Portland cement lime	Type N Portland cement lime	Type S Masonry cement	Type N Masonry cement
Vertical Span:				
No grout	33	25	20	12
Full grout	86	84	81	77
Solid units	53	40	32	20
Horizontal Span:				
No grout	66	50	40	25
Full grout	106	80	64	40
Solid units	106	80	64	40

For the 2009 IBC (2008 TMS 402/602), any load combination involving seismic loads (Load combinations G through M for vertical span and Load combinations B and C for horizontal span), the allowable flexural tension stresses are the same as for the 2012 IBC. For the other load combinations which do not include seismic, the allowable flexural tension stresses are as follows.

	Type S Portland cement lime	Type N Portland cement lime	Type S Masonry cement	Type N Masonry cement
Vertical Span:				
No grout	25	19	15	9
Full grout	65	63	61	58

Solid units	40	30	24	15
Horizontal Span:				
No grout	50	38	30	19
Full grout	80	60	48	30
Solid units	80	60	48	30

Flexural Compression Stress

Use the "unity" equation. Steps for both CMU and clay masonry would be (and for both IBC 2009 and IBC 2012):

1. Determine the axial stress as $f_a = P/A_n$ and the bending stress as $f_b = 12M/S_n$.
2. Determine the allowable flexural compressive stress as $F_b = (1/3)f'_m$.
3. For horizontal spanning walls, compare the bending stress, f_b, to the allowable flexural compressive stress. Chances of it controlling are none, but we should probably check anyway.
4. For vertically spanning walls, determine the radius of gyration as r = sqrt(S_n*t/2A_n), where S_n is the section modulus, t is the actual thickness, and A_n is the area. For example, for 8 inch block with no grout, r = sqrt(81*7.625/(2*30)) = 3.21 inches.
5. Determine h/r, where h is the height of the wall (will need to convert height to inches).
6. If h/r is ≤ 99, then $F_a = \frac{1}{4}f'_m\left(1-\left(\frac{h}{140r}\right)^2\right)$. If h/r >99, then $F_a = \frac{1}{4}f'_m\left(\frac{70}{(h/r)^2}\right)$.
7. Calculate the quantity of $\frac{f_a}{F_a}+\frac{f_b}{F_b}$. If this quantity is ≤ 1, then OK. If it is greater than 1, then NO GOOD.

The TMS 402 Code also requires that when using allowable stress design the following equations be checked:

$$P \le (1/4)P_e$$

$$P_e = \frac{\pi^2 E_m I}{h^2}\left(1-0.577\frac{e}{r}\right)^3$$

This equation limits the eccentricity of an applied axial load 1.733r, where r is the radius of gyration. This equation will result in a negative number if the load is applied at an eccentricity greater than 1.733r, not matter how small the load (e.g. a picture). The program prints a warning if the applied axial load is greater the P_e, but also prints the results for flexural tension and flexural compression. The designer will need to judge whether, under a small axial load, if the wall is adequate even if P_e is exceeded.

Reinforced Design:

For reinforced design, an area of steel is determined based on the grout spacing selected. There are several limitations to reinforced design.

- Reinforced only applies to CMU. There are no standard unit sizes for clay masonry.
- If the user selects no grout or solid units, we cannot have a reinforced wall.
- The reinforcement is assumed to be in the center of the wall.

The design procedure for reinforced walls is as follows:

1. Determine the allowable stresses. For the 2012 IBC, allowable steel stress, F_s, is 32,000 psi and the allowable masonry compressive stress, F_b, is 0.45f'_m. For the 2009 IBC, the allowable stresses are the same for load combinations that include seismic. For load combinations that do not include seismic, then the allowable steel stress, F_s, is 24,000 psi and the allowable masonry compressive stress, F_b, is f'_m/3.
2. Determine k for balanced condition, k_b. n is the modular ratio which is determined as 29,000,000/(900*f'_m). $k_b = \dfrac{F_b}{F_b + \dfrac{F_s}{n}}$
3. Determine k for the applied loading conditions as follows. This assumes that compression controls.
   $k = \dfrac{3}{d}\left[\dfrac{d}{2} - \sqrt{\left(\dfrac{d}{2}\right)^2 - \dfrac{2(12M)}{3F_b b}}\right]$ where b is the width, or 12 inches/foot to get in proper units, and d, the depth to the reinforcement is t/2 (bars are centered in the wall).
4. If $k \geq k_b$ compression controls. Determine the area of steel as follows.
   $A_s = \dfrac{\dfrac{3F_b(kd)b}{6} - P}{nF_b\left(\dfrac{1}{k} - 1\right)}$ It is possible with this equation to get a negative area of steel, which means that there is sufficient capacity with just the masonry.
5. If $k < k_b$ tension controls. The area of steel is determined through an iterative process.
   a. Start with k from above (step 3)
   b. Calculate $M' = P\left(\dfrac{t}{2} - \dfrac{kd}{3}\right)\dfrac{1}{12}$
   c. Calculate $A_s = \dfrac{12(M - M')}{F_s d\left(1 - \dfrac{k}{3}\right)}$
   d. Calculate $\zeta = \dfrac{(P + A_s F_s)n}{F_s b}$

e. Calculate a new k. $(k)_2 = \frac{\sqrt{\zeta^2 + 2\zeta d} - \zeta}{d}$

f. If k_2 is sufficiently close to the value of value of k used in step b, then convergence has been achieved. Convergence is based on being within 1%:

$$\frac{|k_2 - k|}{k} \le 0.01$$

6. The value of A_s is area of steel per foot of wall. This is converted to required bar area by multiplying by grout spacing. For example, if $A_s = 0.06in^2/ft$, and the grout spacing is 32 inches, then $(0.06in^2/ft)(32in)(1ft/12in) = 0.16in^2$ of steel is required in every grouted cell.
7. Finally determine bar size. This is done by the following table.

A_s (in^2/cell)	Bar size	Bar diameter (inch)
$A_s \le 0.11$	#3	0.375
$0.11 < A_s \le 0.20$	#4	0.5
$0.20 < A_s \le 0.31$	#5	0.625
$0.31 < A_s \le 0.44$	#6	0.75
$0.44 < A_s \le 0.60$	#7	0.875
$0.60 < A_s$	Redesign	

8. For the chosen bar size, the development/lap length is calculated as (using TMS 402/602):

$$l_{de} = \frac{0.13 d_b^2 f_y \gamma}{K\sqrt{f'_m}} \ge 12in.$$

where d_b is the bar diameter, f_y is the yield strength (60,000 psi), f'_m is the specified compressive strength, $\gamma = 1.0$ for #3, #4, and #5 bars, and $\gamma = 1.3$ for #6 and #7 bars, and K is determined as the minimum of {masonry cover, $9d_b$}. The masonry cover is the $(t-d_b)/2$.

The TMS 402/602 Code allows a smaller lap length to be used if transverse steel is used. This option is not included in this design program as typically there is not transverse steel in partition walls, and the effect of transverse steel on the lap length is minor for the smaller bar sizes typically used in partition walls.

The IBC allows the lap length to also be calculated as $0.002d_bf_s$, where f_s is the computed stress in the reinforcement due to design loads. In regions where the design tensile stress is the reinforcement is greater than 80% of the allowable steel tension stress, the lap length is required to be increased not less than 50% of the minimum required length. The lap length must be at least 12 inches, and not less than $40d_b$.

Using an allowable stress of 32000 psi, the lap length would be $0.002d_b(32000psi)(1.5) = 96d_b$.

For small bars, the TMS 402/602 Code equations typically result in smaller required lap lengths than using the IBC alternative procedure. The smaller of the two lap lengths is output in the program.