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West Chester, Pennsylvania
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Structural Technical Report 3

Executive Summary

Located in West Chester, Pennsylvania, Wellington at Hershey's Mill is a recently completed 370,000 square feet retirement community with 5 stories and 197 independent living units. Wellington's structure consists of a non-composite steel framing system on the lobby and first floors and a wood floor joist, wood framed system on the top three residential levels.

Technical Report 3 is an analysis and confirmation design study of the current lateral system for Wellington. Masonry towers located at the elevator shafts and stairwells combined with wood framed gypsum shear walls make up the lateral system. The shear walls are only located on the top three levels, therefore the first floor and lobby only use the masonry towers to resist shear.

The calculations for this report were performed by hand and using a spreadsheet.

The following is a summary of the results:

- The seismic forces will control the design of the lateral system
- Because the seismic forces are larger than the wind forces, 1.2D + 1.0E + 0.5L +0.2S is the controlling load combination
- The lateral distribution performed used two procedures:
    - Distribution by rigidity for the lobby and first floor because of the rigid diaphragm
    - Distribution by tributary area for the top floors because of the flexible diaphragm
- Spot checks of the masonry towers showed two towers were not adequate to resist the shear force on the first level. This may be due to incorrect assumptions or calculations. A spot check of a column proved it to be sufficient.
- The shear walls were not checked because the masonry towers sufficiently resisted the shear force on the top levels.
- Drift is not a problem for Wellington.
- Overturning moment was more than adequately resisted by the building weight.

Introduction

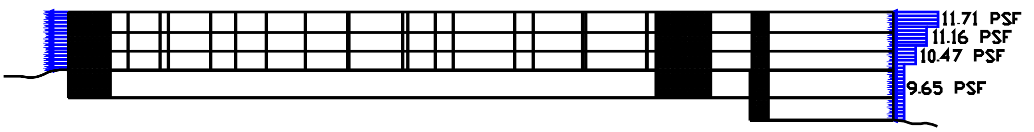
Wellington at Hershey's Mill is a 370,000 square feet, 5 story retirement community in West Chester, Pennsylvania. Wellington has an existing system that combines a non-composite steel beam and concrete slab system on the lobby and first levels with a wood joist floor system bearing on wood framed walls on the second and third levels. There is a garage under the residential levels.

The current lateral resisting system is composed of seven masonry towers at the elevator shafts and stairwells and wood framed gypsum shear walls on the top levels. The lobby and first floors have only the masonry towers as the lateral resisting system.

Lateral Loads & Load Combinations

Wind and seismic calculations are in accordance with ASCE 7-02. Because they are larger than the wind forces, the seismic forces will control for this report. The calculations can be found in Appendices 2 and 3. Gravity loads are in Appendix 1.

S-N Direction					
Level	**Floor Height**	**Building Width**	**Wind Pressure (psf)**	**Wind Force (Kips)**	**Floor Shear (Kips)**
5(Roof)	11'	483.17'	18.81	50	50
4	10'	483.17'	18.2	92.33	142.33
3	10'	483.17'	17.47	84.41	226.74
2	15'	483.17'	16.9	102.07	328.81
1	12'	483.17'	16.9	110.24	439.05
				Total Shear (Kips)	1186.93



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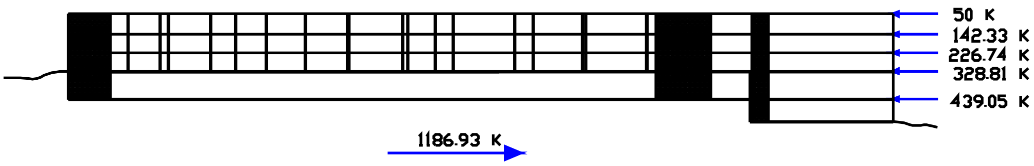
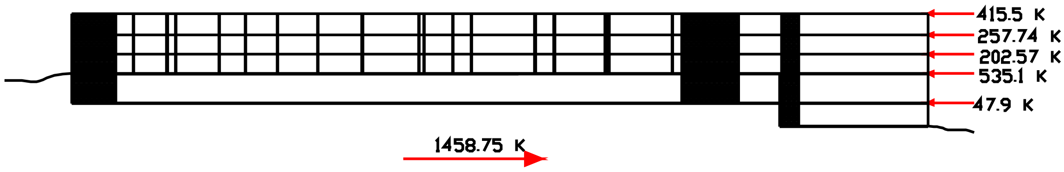


Floor Shears

S-N Direction

Level	wx (kips)	hx (ft)	wx*hx^1	Cvx	Fx
5 (Roof)	2396.5	58	138997	0.28483	415.502
4 (3rd fl)	1834.5	47	86221.5	0.17669	257.741
3 (2nd fl)	1831.5	37	67765.5	0.13887	202.571
2 (1st fl)	6629.43	27	178994.61	0.3668	535.066
1 (Lobby)	1334.5	12	16014	0.03282	47.8704
		Ó	487992.61	1	1458.75



The following load combinations are from ASCE 7-02:
1.4D
1.2D + 1.6L +0.5S
1.2D + 1.6S + (0.5L or 0.8W)
1.2D + 1.6W +0.5L + 0.5S
1.2D + 1.0E + 0.5L +0.2S
0.9D + (1.6W or 1.0E)

Because seismic is larger, the proven controlling load combination is **1.2D + 1.0E + 0.5L +0.2S.**

Lateral Load Distribution

The lateral loads were distributed to the masonry shear towers by two methods. The lobby and first floor have rigid diaphragms; therefore the lateral loads were distributed by rigidity. Since some of the towers are at an angle to the seismic force, the rigidity of a wall was found and then multiplied by the appropriate angle to find the desired component. Calculations are in Appendix 4.

The top three levels have a flexible diaphragm so tributary area was used to distribute the lateral loads. For the towers that are at an angle to the seismic force, an average tributary area was used for all of the walls of the tower.

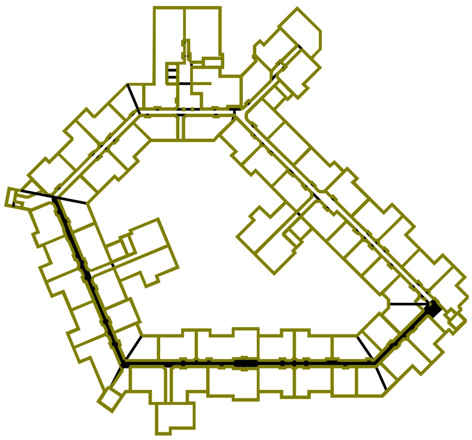
Strength Check

A strength check was performed on the masonry towers by taking the distributed shear and dividing by the area of the walls in shear. The values were then compared to the allowable shear stress of masonry, 35psi. Towers 3 and 7 on the first level failed to have the appropriate resistance with shear stress values of 71 psi. This could be due to incorrect assumptions or calculations. Towers 3, 4, and 5 were sufficient for the lobby level shear. The same check was carried out with the towers on the second and third levels and proved that they can resist the shear force as well.

A column on the first floor was checked and treated as a column beam. Because the shear force is divided among the elements on that level, the column was more than sufficient for resisting the force. Calculations are in Appendix 5.

Torsion

Torsion was checked on the masonry towers but was considered negligible. Even though direct shear was not checked on the shear walls, it is apparent from the geometry of the shear walls that torsion would be zero.



Drift

Story drift was conservatively calculated as 1% the story height. (ASCE 7-02, 9.5.4.4)

Total drift = 0.58” which was compared to an allowable drift of H/480 = 1.45”

Floors	story drift (in)	H/480
1	0.12	
2	0.15	
3	0.1	
4	0.1	
5	0.11	
Total Drift	0.58	1.45

Overturning Moment

Overturning moment was calculated using the seismic lateral loads. Even with a shallow foundation, overturning is not a problem for Wellington. The weight of the building provides a very large resisting moment that is more than enough. Calculations are available in Appendix 6.

Conclusion

This technical report was controlled by the seismic lateral forces and 1.2D + 1.0E + 0.5L +0.2S load combination. The lateral distribution consisted of an in depth method of distribution by rigidity for the lobby and first floors and a more brief method of distribution by tributary area for the top levels. All checks were found satisfactory for drift, torsion, and overturning. Most of the strength checks were successful, except for the two towers on the first level that were not adequate for resistance of the distributed shear force. This could be due to errors in assumptions or calculations.

APPENDIX 1 – Gravity Loads Calculations

Gravity Loads – ASCE 7-02

Live Loads (Table 4-1)

Private Rooms	40psf
Corridors	100psf
Stairs	100psf
Roof	20psf

Dead Loads

Woodframed roof:
- Ceiling } 1psf
- MEP } 10psf
- wood members 5psf
- Sheathing 3psf/in · 5/8" = 1.875psf = 2psf

Total: 18psf

Lobby-Steel framed roof:
- Ceiling } 1psf
- MEP } 10psf
- Steel members 10psf
- metal roof deck 2psf (Vulcraft website)

Total: 23psf

Wood Framed Floors (2 & 3):
- Carpet 1psf
- Ceiling } 1psf
- MEP } 10psf
- wood members 5psf
- sheathing 3psf/in · 3/4" = 2.25psf = 3psf

Total: 20psf

Steel framed floors (Lobby & 1):
- Carpet 1psf
- Ceiling } 1psf
- MEP } 10psf
- steel members 10psf
- metal floor deck 3psf (Vulcraft website)
- 4" conc. slab $4" \cdot \frac{1ft}{12"} \cdot 145pcf = 48.33psf = 49psf$

Total: 74psf

Snow Load Calculation - ASCE7-02

$$p_f = 0.7 C_e C_t I p_g$$

$C_e = 0.7$ (Table 7-2)
$C_t = 1.0$ (Table 7-3)
$I = 1.1$ (Table 7-4)
$p_g = 30psf$

$$p_f = 0.7(0.7)(1.0)(1.1)(30psf)$$
$$= 16.17psf < p_f = 20I = 22psf$$

$\therefore$ use $\boxed{p_f = 22psf}$

APPENDIX 2 - Wind Calculations

Wind Load Analysis – ASCE 7-02
Method 2 – Analytical Procedure

Building Information
N-S direction: gypsum shear walls + masonry towers
E-W direction: gypsum shear walls + masonry towers
Location: West Chester, PA
Exposure B

Assumption: S-N Wind pressure will control due to 5 stories of building above ground on windward side.

Velocity pressure (Case 1)

Z(ft)	K_z (Table 6-3)
0-15	0.70
20	0.70
25	0.70
30	0.70
40	0.76
50	0.81
60	0.85

Assume $K_{zT} = 1$
$K_d = 0.85$ (Table 6-4)
$V = 90$ mph (Figure 6-1)
Building Category III
$I = 1.15$ (Table 6-1)

$q_z = 0.00256 K_{zT} K_d V^2 I K_z = 0.00256(1.0)(0.85)(90)^2(1.15)K_z$

$= 20.27 K_z$

$q_h = \frac{58'-50}{60-50}(0.85-0.81)(20.27) + 20.27(0.81)$

$= 17.07$ psf

(1)

External Pressure Coefficients

Windward wall: $C_p = 0.8$

Leeward wall: (N-S) $L/B = 445.42'/483.17' = 0.92$

$\therefore C_p = -0.5$

Gust Factor Effect

N-S: $L = 445.42'$ $B = 483.17'$ $h = 58'$

Estimate Frequency

$$f = \frac{1}{C_t h^{0.75}} = \frac{1}{(0.02)(58')^{0.75}} = 2.38\ Hz > 1.0\ Hz$$

$\therefore$ RIGID STRUCTURE

$G = 0.85$

S-N Windward Pressure:

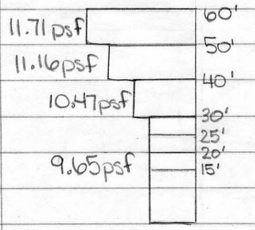
$$p_{wz} = q_z C_p G = q_z(0.8)(0.85) = 0.68 q_z = 13.78 K_z$$

S-N Leeward Pressure:

$$p_{lh} = q_h C_p G = (17.07\ psf)(-0.5)(0.85) = -7.25\ psf$$

z(ft)	pwz
0-15	9.65
20	9.65
25	9.65
30	9.65
40	10.47
50	11.16
60	11.71

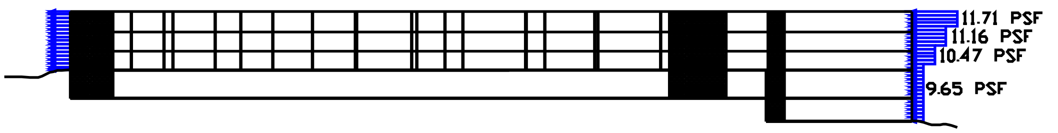
floor	H(ft)	pwz(psf)
1	12'	9.65
2	27'	9.65
3	37'	10.22
4	47'	10.95
5(ROOF)	58'	11.56



floor	$p = p_{wz} - p_{lh}$ (psf)
5(ROOF)	18.81
4	18.2
3	17.47
2	16.9
1	16.9

(2)

S-N Direction					
Level	**Floor Height**	**Building Width**	**Wind Pressure (psf)**	**Wind Force (Kips)**	**Floor Shear (Kips)**
5(Roof)	11'	483.17'	18.81	50	50
4	10'	483.17'	18.2	92.33	142.33
3	10'	483.17'	17.47	84.41	226.74
2	15'	483.17'	16.9	102.07	328.81
1	12'	483.17'	16.9	110.24	439.05
				Total Shear (Kips)	1186.93



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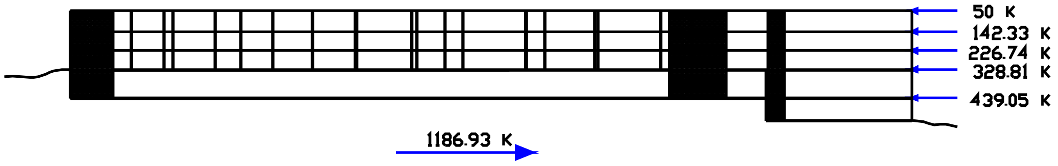


Floor Shears

APPENDIX 3 - Seismic Calculations

Seismic Analysis - ASCE 7-02

Building Information

N-S: Gypsum shear walls + Masonry shear towers

E-W: Gypsum shear walls + Masonry shear towers

Location: West Chester, PA

Seismic Design Category (SDC)

Seismic use group - II

$I = 1.25$

Site Classification - D

Accelerations from maps:

$S_S = 0.30$

$S_1 = 0.08$

Adjust for site class:

$F_a \cong 1.45$ (interpolation from table 9.4.1.2.4a)

$F_v = 2.4$ (Table 9.4.1.2.4b)

$S_{MS} = F_a S_S = (1.45)(0.30) = 0.435$

$S_{M1} = F_v S_1 = (2.4)(0.08) = 0.192$

Design Spectral Response Acceleration Parameters

$S_{DS} = 2/3\, S_{MS} = 0.29$

$S_{D1} = 2/3\, S_{M1} = 0.128$

SDC: Table 9.4.2.1a - C

Table 9.4.2.1b - B

Analytical Procedure: Equivalent Lateral Force Analysis permitted.

Assume S-N Direction controls

Check masonry shear towers:

$R = 3.5$ for Intermediate reinf. masonry shear walls

$W = w_{roof} + w_{3rdfl} + w_{2ndfl} + w_{1stfl} + w_{lobby}$

Roof DL: 18 psf

Wood floor DL: 20 psf

Steel floor DL: 74 psf

Snowload: 22 psf

Partition Load: 10 psf (9.5.3)

(1)

From drawings:

midline perimeter = 1066'-10 1/4"

avg. width = 65'

Approx. area = 1066.85' x 65' = 69345.52 ft^2

Add wings (areas from CAD drawing):

11,128.78 ft^2 + 3222.63 ft^2 + 3221.83 ft^2 + 1654.60 ft^2

Total area = 88573.42 ft^2 (For first - third floors)

Lobby (area from CAD) = 16,938.87 ft^2

L = 330' - 200' = 130' B = 460' - 290' = 170'

W_{roof} = [(88573.42 + 16,938.87)(18psf) + 10psf(5.5')(2)(130+170)
+ 0.2(88573.42 + 16,938.87)(22psf)] /1000
= 2396.48k

W_{LOBBY} = [16,938.87(74psf) + 10psf(13.5')(2)(130+170)] /1000
= 1334.5k

$W_{1st fl}$ = [88573.42(74) + 10(12.5)(2)(130+170)] /1000
= 6629.43k

$W_{2ND fl}$ = [88573.42(20psf) + 10psf(10')(2)(130+170)] /1000
= 1831.5k

$W_{3rd fl}$ = [88573.42(20psf) + 10psf(10.5')(2)(130+170)] /1000
= 1834.5k

W = 2396.5k + 1334.5k + 6629.43k + 1831.5k + 1834.5k
= 14026.43k

(2)

$I = 1.25$ (Table 9.1.4)

$T = C_t h_n^x = 0.02(58')^{0.75} = 0.42s$ for S-N direction

$$C_s = \frac{S_{DS}}{R/I} = \frac{0.29}{3.5/1.25} = 0.104 \Leftarrow \text{CONTROLS}$$

$$C_{s\,max} = \frac{S_{D1}}{T(R/I)} = \frac{0.128}{0.42(3.5/1.25)} = 0.106$$

$$C_{s\,min} = 0.044 I S_{DS} = 0.044(1.25)(0.29) = 0.016$$

$$V = C_s W = 0.104(14026.43) = 1458.75k$$

Vertical Distribution of Seismic Forces

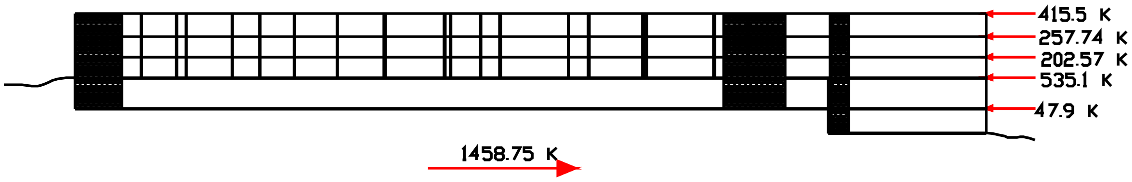
$$F_x = C_{vx} V; \quad C_{vx} = \frac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k}$$

$T = 0.42s < 0.5s \therefore k = 1$

(3)

S-N Direction

Level	wx (kips)	hx (ft)	wx*hx^1	Cvx	Fx
5 (Roof)	2396.5	58	138997	0.28483	415.502
4 (3rd fl)	1834.5	47	86221.5	0.17669	257.741
3 (2nd fl)	1831.5	37	67765.5	0.13887	202.571
2 (1st fl)	6629.43	27	178994.61	0.3668	535.066
1 (Lobby)	1334.5	12	16014	0.03282	47.8704
		Ó	487992.61	1	1458.75



APPENDIX 4: Lateral Load Distribution

Lobby Floor (Rigid Diaphragm)

- **Center of Mass:** X_{mass} = 153.43'
  Y_{mass} = 89.84'

Element		Area (sf)	Height (ft)	Unit Weight (k/cf)	Weight (kips)	Distance from Zero Reference X (ft)	Distance from Zero Reference Y(ft)	Wx (ft*k)	Wy (ft*k)
Tower 3									
	Wall 1	6	15	0.15	13.5	195.52	27	2639.52	364.5
	Wall 2	9	15	0.15	20.25	195.52	7.16	3959.28	144.99
Tower 4									
	Wall 1	9.12	15	0.15	20.52	156.57	98.69	3212.816	2025.119
	Wall 2	13.66	15	0.15	30.735	170.85	84.42	5251.075	2594.649
	Wall 3	12.89	15	0.15	29.0025	159.05	87.02	4612.848	2523.798
	Wall 4	12.89	15	0.15	29.0025	166.01	93.97	4814.705	2725.365
	Wall 5	12.89	15	0.15	29.0025	168.24	96.21	4879.381	2790.331
Tower 5									
	Wall 1	8	15	0.15	18	131.83	120.38	2372.94	2166.84
	Wall 2	8	15	0.15	18	116.03	104.58	2088.54	1882.44
	Wall 3	14.44	15	0.15	32.49	119.92	116.49	3896.201	3784.76
	Wall 4	14.44	15	0.15	32.49	127.94	108.47	4156.771	3524.19
				Ó	**272.9925**			**41884.08**	**24526.98**

Xm = ÓWx/ÓW	Ym = ÓWy/ÓW
153.4257	89.84489

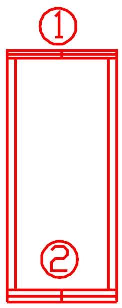
- **0.3 < H/L < 3.0** for all tower walls consider both flexural & shear
- $R/E = t(4(h/L)^3 + 3(h/L))^{-1}$

Element		Height (ft)	Length (ft)	H/L	Area (sf)	t (in)	R/E	Rx	Ry
Tower 3									
	Wall 1	15	9	1.66667	6	8	149.748	149.75	0
	Wall 2	15	9	1.66667	9	12	224.622	224.62	0
Tower 4									
	Wall 1	15	13.67	1.09729	9.12	8	44.7086	31.61	31.61
	Wall 2	15	13.67	1.09729	13.66	12	67.0629	47.42	47.42
	Wall 3	15	19.36	0.77479	12.89	8	18.3254	12.96	12.96
	Wall 4	15	19.36	0.77479	12.89	8	18.3254	12.96	12.96
	Wall 5	15	19.36	0.77479	12.89	8	18.3254	12.96	12.96

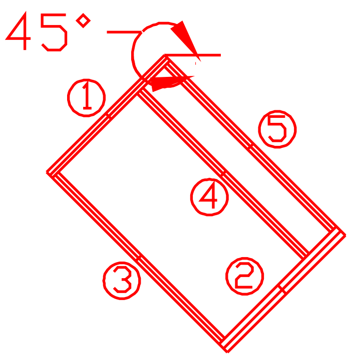
Tower 5

Wall 1	15	12	1.25	8	8	64.6333	45.7	45.7
Wall 2	15	12	1.25	8	8	64.6333	45.7	45.7
Wall 3	15	21.67	0.6922	14.44	8	14.4657	10.23	10.23
Wall 4	15	21.67	0.6922	14.44	8	14.4657	10.23	10.23
						Ó	**604.14**	**229.77**

Tower 3



Tower 4

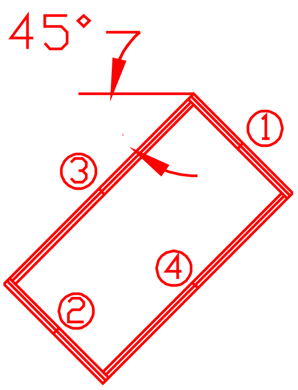


Wall 1: cos45° = Rx/R Rx = 31.61
sin45° = Ry/R Ry = 31.61

Wall 2: cos45° = Rx/R Rx = 47.42
sin45° = Ry/R Ry = 47.42

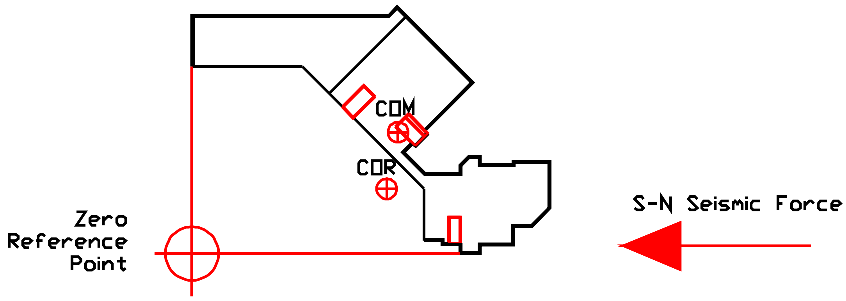
Walls 3, 4, & 5: cos45° = Rx/R Rx = 12.96
sin45° = Ry/R Ry = 12.96

Tower 5



Walls 1 & 2: cos45° = Rx/R Rx = 45.7
sin45° = Ry/R Rx = 45.7

Walls 3 & 4: cos45° = Rx/R Rx = 10.23
sin45° = Ry/R Rx = 10.23



Lobby Floor

Element		Proportion	Shear	Base Moment (ft*k)	Distance from Zero Reference X (ft)	Y(ft)	Rx	Ry
Tower 3								
	Wall 1	0.247873	132.6284	1989.426	195.52	27	149.75	0
	Wall 2	0.3718012	198.9382	2984.073	195.52	7.16	224.62	0
Tower 4								
	Wall 1	0.0523223	27.99589	419.9383	156.57	98.69	31.61	31.61
	Wall 2	0.0784917	41.99826	629.9739	170.85	84.42	47.42	47.42
	Wall 3	0.021452	11.47823	172.1734	159.05	87.02	12.96	12.96
	Wall 4	0.021452	11.47823	172.1734	166.01	93.97	12.96	12.96
	Wall 5	0.021452	11.47823	172.1734	168.24	96.21	12.96	12.96
Tower 5								
	Wall 1	0.0756447	40.47492	607.1238	131.83	120.38	45.7	45.7
	Wall 2	0.0756447	40.47492	607.1238	116.03	104.58	45.7	45.7
	Wall 3	0.0169332	9.060359	135.9054	119.92	116.49	10.23	10.23
	Wall 4	0.0169332	9.060359	135.9054	127.94	108.47	10.23	10.23
						Ó	**604.14**	**229.77**

$e_x = X_{mass} - X_{cr} = 153.43' - 144.96' = 8.47'$

$e_y = Y_{mass} - Y_{cr} = 89.84' - 47.92' = 41.93'$

Torsional Moment:

$M_t = P * e_y = 47.87k * 41.93' = 2007.19'k$

Element		Rx	Ry	X (ft)	Y(ft)	RxX^2	RyY^2	Rx/ÓRxX^2	Ry/ÓRyY^2	Torsional Shear (x)	Torsional Shear (y)
Tower 3											
	Wall 1	149.75	0	-	20.93	-	0	0.0014007	0	2.811455	0
	Wall 2	224.62	0	-	40.76	-	0	0.002101	0	4.217088	0
Tower 4											
	Wall 1	31.61	31.61	11.61	50.78	4260.778	81509.81	0.0002957	4.552E-05	0.593456	0.339293
	Wall 2	47.42	47.42	25.89	36.5	31785.25	63175.3	0.0004435	6.829E-05	0.890278	0.508994
	Wall 3	12.96	12.96	14.09	39.1	2572.924	19813.38	0.0001212	1.866E-05	0.243315	0.139109
	Wall 4	12.96	12.96	21.05	46.05	5742.608	27483.01	0.0001212	1.866E-05	0.243315	0.139109
	Wall 5	12.96	12.96	23.29	48.29	7029.816	30221.74	0.0001212	1.866E-05	0.243315	0.139109
Tower 5											
	Wall 1	45.7	45.7	13.14	72.45	7890.544	239879.4	0.0004275	6.581E-05	0.857987	0.490532
	Wall 2	45.7	45.7	28.93	56.66	38248.38	146713.3	0.0004275	6.581E-05	0.857987	0.490532
	Wall 3	10.23	10.23	25.04	68.57	6414.226	48099.87	9.569E-05	1.473E-05	0.192061	0.109806
	Wall 4	10.23	10.23	17.03	60.55	2966.914	37506.27	9.569E-05	1.473E-05	0.192061	0.109806
					Ó	106911.4	694402				

The torsional shears are so small, they will be assumed negligible.

Element		Rx	Ry	Direct Shear (x)	Direct Shear (y)	Area (sf)	Area (sq in)	Shear Stress (psi) (x)	Shear Stress (psi) (y)
Tower 3									
	Wall 1	149.75	0	11.86568	0	6	864	13.733427	0
	Wall 2	224.62	0	17.79813	0	9	1296	13.733121	0
Tower 4									
	Wall 1	31.61	31.61	2.504669	6.585589	9.12	1313.28	1.9071858	5.014611
	Wall 2	47.42	47.42	3.7574	9.879425	13.66	1967.04	1.9101796	5.022483
	Wall 3	12.96	12.96	1.026906	2.700071	12.89	1856.16	0.5532424	1.454654
	Wall 4	12.96	12.96	1.026906	2.700071	12.89	1856.16	0.5532424	1.454654
	Wall 5	12.96	12.96	1.026906	2.700071	12.89	1856.16	0.5532424	1.454654
Tower 5									
	Wall 1	45.7	45.7	3.621113	9.521082	8	1152	3.143327	8.264828
	Wall 2	45.7	45.7	3.621113	9.521082	8	1152	3.143327	8.264828
	Wall 3	10.23	10.23	0.81059	2.131306	14.44	2079.36	0.3898269	1.024982
	Wall 4	10.23	10.23	0.81059	2.131306	14.44	2079.36	0.3898269	1.024982
	Ó	**604.14**	**229.77**						

When the shear stress is compared with the allowable shear stress of masonry, all three towers are well below 35 psi.

First Floor (Rigid Diaphragm)

- **Center of Mass:** X_{mass} = 221.03’
  Y_{mass} = 274.98’

Element		Area (sf)	Height (ft)	Unit Weight (k/cf)	Weight (kips)	Distance from Zero Reference X (ft)	Y(ft)	Wx (ft*k)	Wy (ft*k)
Tower 1									
	Wall 1	18	15	0.15	40.5	9.91	223.46	401.355	9050.13
	Wall 2	18	15	0.15	40.5	20.78	216.62	841.59	8773.11
	Wall 3	18.64	15	0.15	41.94	2.31	212.95	96.8814	8931.123
	Wall 4	12.45	15	0.15	28.0125	13.35	206.14	373.9669	5774.497
Tower 2									
	Wall 1	8.22	15	0.15	18.495	328.76	27.01	6080.416	499.55
	Wall 2	15.33	15	0.15	34.4925	329.43	18.84	11362.86	649.8387
	Wall 3	20	15	0.15	45	327.09	7.17	14719.05	322.65
Tower 3									
	Wall 1	6	15	0.15	13.5	374.07	327	5049.945	4414.5
	Wall 2	9	15	0.15	20.25	374.07	307.17	7574.918	6220.193
Tower 4									
	Wall 1	9.12	15	0.15	20.52	335.13	398.7	6876.868	8181.324
	Wall 2	13.66	15	0.15	30.735	349.41	384.42	10739.12	11815.15
	Wall 3	12.89	15	0.15	29.0025	337.61	387.02	9791.534	11224.55
	Wall 4	12.89	15	0.15	29.0025	344.57	393.97	9993.391	11426.11
	Wall 5	12.89	15	0.15	29.0025	346.81	396.21	10058.36	11491.08
Tower 5									
	Wall 1	8	15	0.15	18	310.39	420.38	5587.02	7566.84
	Wall 2	8	15	0.15	18	294.59	404.58	5302.62	7282.44
	Wall 3	14.44	15	0.15	32.49	298.48	416.49	9697.615	13531.76
	Wall 4	14.44	15	0.15	32.49	306.49	408.47	9957.86	13271.19
Tower 6									
	Wall 1	13.67	15	0.15	30.7575	146.37	325.3	4501.975	10005.41
	Wall 2	9.11	15	0.15	20.4975	138.67	306.72	2842.388	6286.993
	Wall 3	12.86	15	0.15	28.935	136.48	318.42	3949.049	9213.483
	Wall 4	12.86	15	0.15	28.935	144.33	315.17	4176.189	9119.444
	Wall 5	12.86	15	0.15	28.935	148.49	313.45	4296.558	9069.676
Tower 7									
	Wall 1	6	15	0.15	13.5	268.59	208.37	3625.965	2812.995
	Wall 2	9	15	0.15	20.25	268.59	189.21	5438.948	3831.503
				Ó	**693.7425**			**153336.4**	**190765.5**

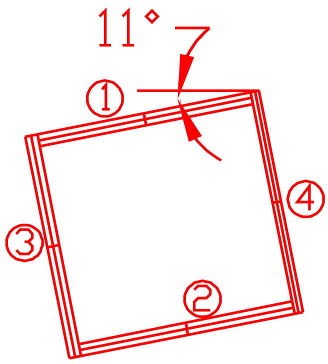
Xm = ÓWx/ÓW	Ym = ÓWy/ÓW
221.0279	274.9803

- **0.3 < H/L < 3.0** for all tower walls consider both flexural & shear
- $R/E = t(4(h/L)^3 + 3(h/L))^{-1}$

Element		Height (ft)	Length (ft)	H/L	Area (sf)	t (in)	R/E	Rx	Ry
Tower 1									
	Wall 1	15	18	0.83333	18	12	32.5778	31.98	6.22
	Wall 2	15	18	0.83333	18	12	32.5778	31.98	6.22
	Wall 3	15	18.67	0.80343	18.64	12	29.8719	5.7	29.32
	Wall 4	15	18.67	0.80343	12.45	8	19.9146	3.8	19.55
Tower 2									
	Wall 1	15	12.33	1.21655	8.22	8	59.8069	59.81	0
	Wall 2	15	15.33	0.97847	15.33	12	49.0544	49.05	0
	Wall 3	15	20	0.75	20	12	25.5833	25.58	0
Tower 3									
	Wall 1	15	9	1.66667	6	8	149.748	149.75	0
	Wall 2	15	9	1.66667	9	12	224.622	224.62	0
Tower 4									
	Wall 1	15	13.67	1.09729	9.12	8	44.7086	31.61	31.61
	Wall 2	15	13.67	1.09729	13.66	12	67.0629	47.42	47.42
	Wall 3	15	19.36	0.77479	12.89	8	18.3254	12.96	12.96
	Wall 4	15	19.36	0.77479	12.89	8	18.3254	12.96	12.96
	Wall 5	15	19.36	0.77479	12.89	8	18.3254	12.96	12.96
Tower 5									
	Wall 1	15	12	1.25	8	8	64.6333	45.7	45.7
	Wall 2	15	12	1.25	8	8	64.6333	45.7	45.7
	Wall 3	15	21.67	0.6922	14.44	8	14.4657	10.23	10.23
	Wall 4	15	21.67	0.6922	14.44	8	14.4657	10.23	10.23
Tower 6									
	Wall 1	15	13.67	1.09729	13.67	12	67.0629	62.18	25.12
	Wall 2	15	13.67	1.09729	9.11	8	44.7086	41.45	16.75
	Wall 3	15	19.28	0.77801	12.86	8	18.4972	6.93	17.15
	Wall 4	15	19.28	0.77801	12.86	8	18.4972	6.93	17.15
	Wall 5	15	19.28	0.77801	12.86	8	18.4972	6.93	17.15
Tower 7									
	Wall 1	15	9	1.66667	6	8	149.748	149.74	0
	Wall 2	15	9	1.66667	9	12	224.622	224.62	0
							Ó	1310.82	384.4

For the sum of the rigidities, the angle to the force direction will be used to calculate the components of the chosen wall rigidity.

Tower 1

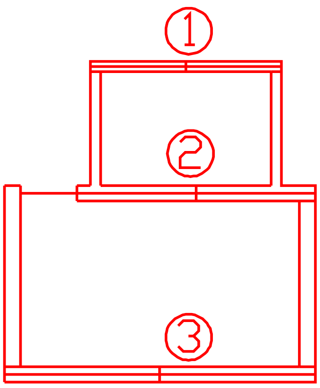


Walls 1&2: cos11° = Rx/R Rx = 31.98
sin11° = Ry/R Ry = 6.22

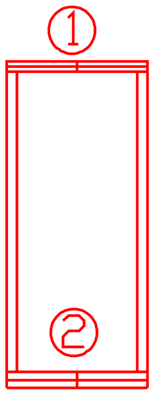
Wall 3: cos79° = Rx/R Rx = 5.7
sin79° = Ry/R Ry = 29.32

Wall 4: cos79° = Rx/R Rx = 3.8
sin79° = Ry/R Ry = 19.55

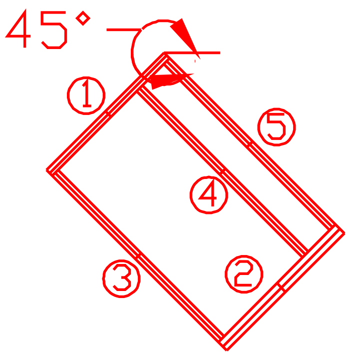
Tower 2



Tower 3



Tower 4

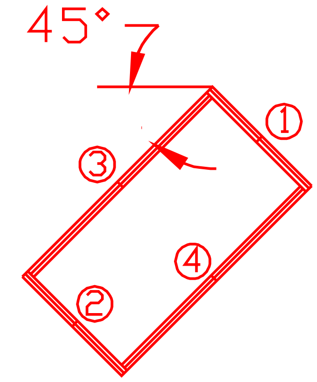


Wall 1: cos45° = Rx/R Rx = 31.61
sin45° = Ry/R Ry = 31.61

Wall 2: cos45° = Rx/R Rx = 47.42
sin45° = Ry/R Ry = 47.42

Walls 3, 4, & 5: cos45° = Rx/R Rx = 12.96
sin45° = Ry/R Ry = 12.96

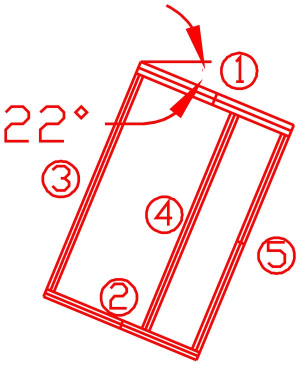
Tower 5



Walls 1 & 2: cos45° = Rx/R Rx = 45.7
sin45° = Ry/R Rx = 45.7

Walls 3 & 4: cos45° = Rx/R Rx = 10.23
sin45° = Ry/R Rx = 10.23

Tower 6

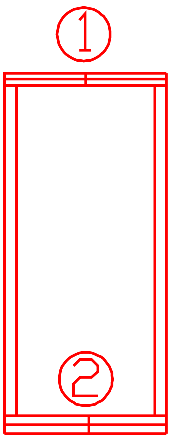


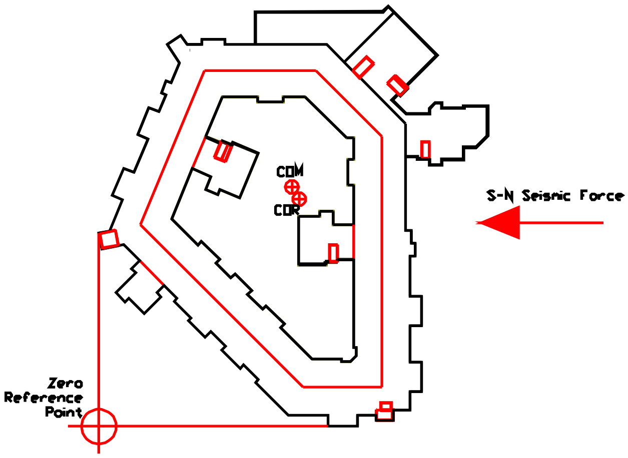
Wall 1: cos22° = Rx/R Rx = 62.18
sin22° = Ry/R Ry = 25.12

Wall 2: cos22° = Rx/R Rx = 41.45
sin22° = Ry/R Ry = 16.75

Walls 3, 4, & 5: cos68° = Rx/R Rx = 6.93
sin68° = Ry/R Ry = 17.15

Tower 7





First Floor

Element		Proportion	Shear	Base Moment (ft*k)	Distance from Zero Reference X (ft)	Y(ft)	Rx	Ry
Tower 1								
	Wall 1	0.0243969	13.053974	195.81	9.91	223.46	31.98	6.22
	Wall 2	0.0243969	13.053974	195.81	20.78	216.62	31.98	6.22
	Wall 3	0.0043484	2.3266934	34.9004	2.31	212.95	5.7	29.32
	Wall 4	0.0028989	1.5511289	23.2669	13.35	206.14	3.8	19.55
Tower 2								
	Wall 1	0.0456279	24.413953	366.209	328.76	27.01	59.81	0
	Wall 2	0.0374193	20.021809	300.327	329.43	18.84	49.05	0
	Wall 3	0.0195145	10.441547	156.623	327.09	7.17	25.58	0
Tower 3								
	Wall 1	0.1142415	61.126725	916.901	374.07	327	149.75	0
	Wall 2	0.1713584	91.688046	1375.32	374.07	307.17	224.62	0
Tower 4								
	Wall 1	0.0241147	12.902943	193.544	335.13	398.7	31.61	31.61
	Wall 2	0.0361758	19.356456	290.347	349.41	384.42	47.42	47.42
	Wall 3	0.0098869	5.290166	79.3525	337.61	387.02	12.96	12.96
	Wall 4	0.0098869	5.290166	79.3525	344.57	393.97	12.96	12.96
	Wall 5	0.0098869	5.290166	79.3525	346.81	396.21	12.96	12.96
Tower 5								
	Wall 1	0.0348637	18.654366	279.815	310.39	420.38	45.7	45.7
	Wall 2	0.0348637	18.654366	279.815	294.59	404.58	45.7	45.7
	Wall 3	0.0078043	4.1758023	62.637	298.48	416.49	10.23	10.23
	Wall 4	0.0078043	4.1758023	62.637	306.49	408.47	10.23	10.23
Tower 6								
	Wall 1	0.047436	25.381367	380.721	146.37	325.3	62.18	25.12

	Wall 2	0.0316214	16.919551	253.793	138.67	306.72	41.45	16.75
	Wall 3	0.0052868	2.8287693	42.4315	136.48	318.42	6.93	17.15
	Wall 4	0.0052868	2.8287693	42.4315	144.33	315.17	6.93	17.15
	Wall 5	0.0052868	2.8287693	42.4315	148.49	313.45	6.93	17.15
Tower 7								
	Wall 1	0.1142338	61.122643	916.84	268.59	208.37	149.74	0
	Wall 2	0.1713584	91.688046	1375.32	268.59	189.21	224.62	0
						Ó	**1310.82**	**384.4**

$e_x = X_{mass} - X_{cr}$ = 221.03' - 229.4908' = -8.46'

$e_y = Y_{mass} - Y_{cr}$ = 274.98' - 261.05' = 13.93'

Torsional Moment:

$M_t = P * e_y$ = 535.07k * 13.93'= 7453.53'k

Element		Rx	Ry	X (ft)	Y(ft)	RxX^2	RyY^2	Rx/ÓRxX^2	Ry/ÓRyY^2	Torsional Shear (x)	Torsional Shear (y)
Tower 1											
	Wall 1	31.98	6.22	219.59	37.59	1542068	8788.91	5.107E-06	1.624E-06	0.038064	0.012106
	Wall 2	31.98	6.22	216.15	54.91	1494132	18753.97	5.107E-06	1.624E-06	0.038064	0.012106
	Wall 3	5.7	29.32	227.19	48.1	294207	67835.05	9.102E-07	7.656E-06	0.006784	0.057067
	Wall 4	3.8	19.55	208.72	44.43	165543	38592.19	6.068E-07	5.105E-06	0.004523	0.038051
Tower 2											
	Wall 1	59.81	0	-	234.05	-	0	9.551E-06	0	0.071188	0
	Wall 2	49.05	0	-	242.21	-	0	7.833E-06	0	0.058381	0
	Wall 3	25.58	0	-	253.88	-	0	4.085E-06	0	0.030446	0
Tower 3											0
	Wall 1	149.75	0	-	65.94	-	0	2.391E-05	0	0.178238	0
	Wall 2	224.62	0	-	44.29	-	0	3.587E-05	0	0.267352	0
Tower 4											
	Wall 1	31.61	31.61	105.63	137.65	352695	598931.2	5.048E-06	8.254E-06	0.037623	0.061524
	Wall 2	47.42	47.42	119.91	123.37	681824	721739.8	7.572E-06	1.238E-05	0.056441	0.092295
	Wall 3	12.96	12.96	108.11	125.97	151474	205655	2.07E-06	3.384E-06	0.015426	0.025225
	Wall 4	12.96	12.96	115.07	132.92	171605	228973.7	2.07E-06	3.384E-06	0.015426	0.025225
	Wall 5	12.96	12.96	117.31	135.16	178351	236756.2	2.07E-06	3.384E-06	0.015426	0.025225
Tower 5											
	Wall 1	45.7	45.7	80.89	159.33	299024	1160142	7.298E-06	1.193E-05	0.054394	0.088948
	Wall 2	45.7	45.7	65.09	143.54	193618	941590.5	7.298E-06	1.193E-05	0.054394	0.088948

	Wall 3	10.23	10.23	68.98	155.44	48676.8	247173.1	1.634E-06	2.671E-06	0.012176	0.019911
	Wall 4	10.23	10.23	76.99	147.42	60637.9	222325.1	1.634E-06	2.671E-06	0.012176	0.019911
Tower 6											
	Wall 1	62.18	25.12	83.13	64.25	429701	103696.9	9.929E-06	6.56E-06	0.074009	0.048892
	Wall 2	41.45	16.75	90.83	45.67	341966	34936.29	6.619E-06	4.374E-06	0.049335	0.032601
	Wall 3	6.93	17.15	93.02	57.37	59963.4	56446.08	1.107E-06	4.478E-06	0.008248	0.03338
	Wall 4	6.93	17.15	85.17	54.12	50269.7	50231.91	1.107E-06	4.478E-06	0.008248	0.03338
	Wall 5	6.93	17.15	81.01	52.4	45479	47089.78	1.107E-06	4.478E-06	0.008248	0.03338
Tower 7											
	Wall 1	149.74	0	-	52.68	-	0	2.391E-05	0	0.178226	0
	Wall 2	224.62	0	-	71.84	-	0	3.587E-05	0	0.267352	0
					Ó	**6262210**	**3829516**				

The first floor torsional shears, like the lobby, are very small and will be considered negligible.

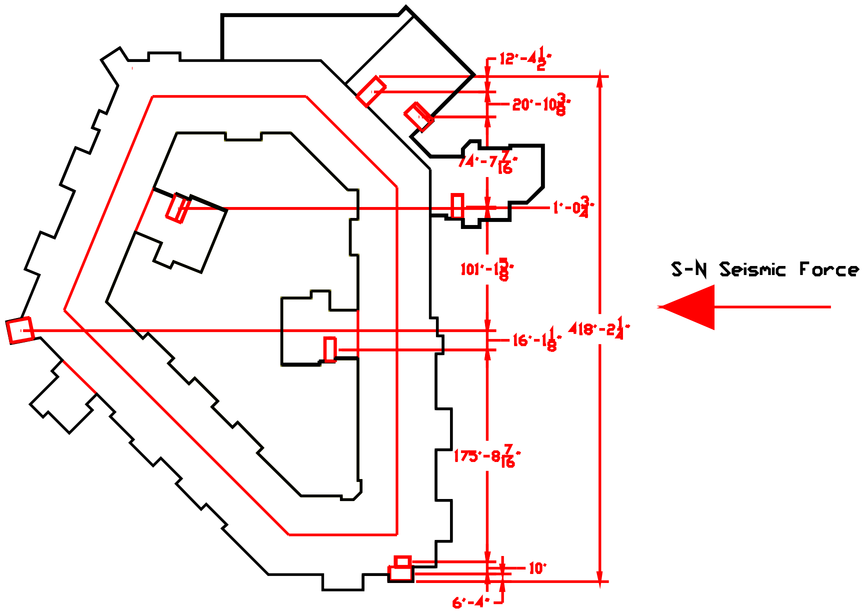
Element		**Rx**	**Ry**	**Direct Shear (x)**	**Direct Shear (y)**	**Area (sf)**	**Area (sq in)**	**Shear Stress (psi) (x)**	**Shear Stress (psi) (y)**
Tower 1									
	Wall 1	31.98	6.22	13.0541	8.658	18	2592	5.0362932	3.340278
	Wall 2	31.98	6.22	13.0541	8.658	18	2592	5.0362932	3.340278
	Wall 3	5.7	29.32	2.32671	40.8123	18.64	2684.16	0.8668301	15.204873
	Wall 4	3.8	19.55	1.55114	27.2128	12.45	1792.8	0.8652055	15.178964
Tower 2									
	Wall 1	59.81	0	24.4141	0	8.22	1183.68	20.625621	0
	Wall 2	49.05	0	20.022	0	15.33	2207.52	9.0698877	0
	Wall 3	25.58	0	10.4416	0	20	2880	3.6255642	0
Tower 3									
	Wall 1	149.75	0	61.1272	0	6	864	70.749053	0
	Wall 2	224.62	0	91.6887	0	9	1296	70.747478	0
Tower 4									
	Wall 1	31.61	31.61	12.903	43.9999	9.12	1313.28	9.8250486	33.503825
	Wall 2	47.42	47.42	19.3566	66.0068	13.66	1967.04	9.8404713	33.556417
	Wall 3	12.96	12.96	5.29021	18.0398	12.89	1856.16	2.8500806	9.7188933
	Wall 4	12.96	12.96	5.29021	18.0398	12.89	1856.16	2.8500806	9.7188933
	Wall 5	12.96	12.96	5.29021	18.0398	12.89	1856.16	2.8500806	9.7188933
Tower 5									
	Wall 1	45.7	45.7	18.6545	63.6126	8	1152	16.193147	55.219306
	Wall 2	45.7	45.7	18.6545	63.6126	8	1152	16.193147	55.219306
	Wall 3	10.23	10.23	4.17583	14.2398	14.44	2079.36	2.0082302	6.8481485
	Wall 4	10.23	10.23	4.17583	14.2398	14.44	2079.36	2.0082302	6.8481485
Tower 6									
	Wall 1	62.18	25.12	25.3816	34.9661	13.67	1968.48	12.893988	17.762981
	Wall 2	41.45	16.75	16.9197	23.3154	9.11	1311.84	12.897668	17.773017

	Wall 3	6.93	17.15	2.82879	23.8721	12.86	1851.84	1.5275566	12.891038
	Wall 4	6.93	17.15	2.82879	23.8721	12.86	1851.84	1.5275566	12.891038
	Wall 5	6.93	17.15	2.82879	23.8721	12.86	1851.84	1.5275566	12.891038
Tower 7									
	Wall 1	149.74	0	61.1231	0	6	864	70.744329	0
	Wall 2	224.62	0	91.6887	0	9	1296	70.747478	0
	Ó	**1310.82**	**384.4**						

When the shear stress is compared with the allowable shear stress of masonry, towers 3 and 7 both have shear stresses that surpass 35 psi. This can be due to a miscalculation or wrong assumption.

Second and Third Floors (Flexible Diaphragm)

Load Direction:	S-N
Seismic Load:	2nd Floor = 202.57k
	3rd Floor = 257.74k
Design Basis:	Capacity
Elements:	Masonry Towers
Height:	10 ft



Element		Area (sf)	Height (ft)	Length (ft)	Trib Width (ft)	Trib Area (sf)	Fraction of Trib Area	Shear Wall Load (2nd Fl)	Shear Wall Load (3rd Fl)	Area (sq in)	Shear Stress (psi) (2nd Fl)	Shear Stress (psi) (3rd Fl)
Tower 1												
	Wall 1	18	10	18	29.31	293.1	0.034287	6.9454196	8.8370067	2592	2.67956	3.409339
	Wall 2	18	10	18	29.31	293.1	0.034287	6.9454196	8.8370067	2592	2.67956	3.409339
	Wall 3	18.64	10	18.67	29.31	293.1	0.034287	6.9454196	8.8370067	2684.16	2.587558	3.29228
	Wall 4	12.45	10	18.67	29.31	293.1	0.034287	6.9454196	8.8370067	1792.8	3.874063	4.929165
Tower 2												
	Wall 1	8.22	10	12.33	87.85	878.5	0.102766	20.817302	26.4869	1183.68	17.58693	22.37674
	Wall 2	15.33	10	15.33	10	100	0.011698	2.3696416	3.0150142	2207.52	1.073441	1.365792
	Wall 3	20	10	20	6.33	63.3	0.007405	1.4999832	1.908504	2880	0.520827	0.662675
Tower 3												
	Wall 1	6	10	9	51.63	516.3	0.060396	12.23446	15.566519	864	14.16025	18.0168
	Wall 2	9	10	9	51.63	516.3	0.060396	12.23446	15.566519	1296	9.44017	12.0112
Tower 4												
	Wall 1	9.12	10	13.67	47.74	477.4	0.055846	11.312669	14.393678	1313.28	8.614057	10.9601
	Wall 2	13.66	10	13.67	47.74	477.4	0.055846	11.312669	14.393678	1967.04	5.751113	7.31743
	Wall 3	12.89	10	19.36	47.74	477.4	0.055846	11.312669	14.393678	1856.16	6.094663	7.754546
	Wall 4	12.89	10	19.36	47.74	477.4	0.055846	11.312669	14.393678	1856.16	6.094663	7.754546
	Wall 5	12.89	10	19.36	47.74	477.4	0.055846	11.312669	14.393678	1856.16	6.094663	7.754546
Tower 5												
	Wall 1	8	10	12	16.62	166.2	0.019442	3.9383444	5.0109537	1152	3.418702	4.349786
	Wall 2	8	10	12	16.62	166.2	0.019442	3.9383444	5.0109537	1152	3.418702	4.349786
	Wall 3	14.44	10	21.67	16.62	166.2	0.019442	3.9383444	5.0109537	2079.36	1.894018	2.409854
	Wall 4	14.44	10	21.67	16.62	166.2	0.019442	3.9383444	5.0109537	2079.36	1.894018	2.409854
Tower 6												
	Wall 1	13.67	10	13.67	25.82	258.2	0.030204	6.1184147	7.7847668	1968.48	3.108192	3.95471
	Wall 2	9.11	10	13.67	25.82	258.2	0.030204	6.1184147	7.7847668	1311.84	4.663995	5.934235
	Wall 3	12.86	10	19.28	25.82	258.2	0.030204	6.1184147	7.7847668	1851.84	3.303965	4.203801
	Wall 4	12.86	10	19.28	25.82	258.2	0.030204	6.1184147	7.7847668	1851.84	3.303965	4.203801
	Wall 5	12.86	10	19.28	25.82	258.2	0.030204	6.1184147	7.7847668	1851.84	3.303965	4.203801
Tower 7												
	Wall 1	6	10	9	8.045	80.45	0.009411	1.9063767	2.425579	864	2.206455	2.807383
	Wall 2	9	10	9	87.85	878.5	0.102766	20.817302	26.4869	1296	16.06273	20.43742
					Ó	8548.55						

APPENDIX 5: Strength Check

- ***Masonry towers checked in Appendix 4***
- ***Column – First floor W10x49***

Analysis of columns as beam columns $P_u/b + M_u/m < 1$

Trib Area = 463.1662 sq ft

Dead Load = 74 psf * 463.1662 sq ft = 34274.3 lbs = 34.3k
Live Load = 40 psf * 463.1662 sq ft = 18526.65 lbs = 18.5k

Seismic Load = 535.066k/100 columns = 5.35k
Wind Load = 328.81k/100 = 3.3k

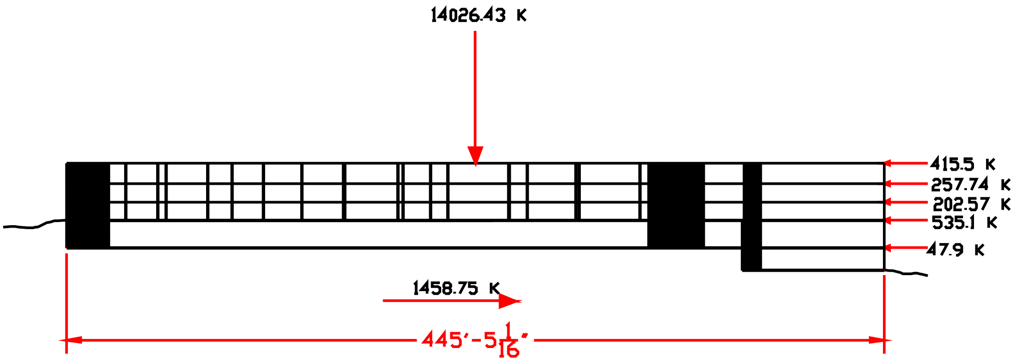
P_u = 1.2D + 1.0E + 0.5L +0.2S = 1.2(34.3) + 1.0(5.35k) + 0.5(18.5) = 55.76k

Mu = 129.75’k

b = 2.36 x 10^3 & m = 4.30 x 10^3 (Table 6-2, AISC)

$P_u/b + M_u/m$ = 55.76/2.36 x 10^3 + 129.75’k/4.3 x 10^3 = 0.0538 < 1 **O.K.**

APPENDIX 6: Overturning Moment



CCW+: ΣM = 47.9k(12') + 535.1k(27') + 202.57k(37') + 257.74k(47') + 415.5k(58')
= 58730.37'k

Resisting Moment

CW+: ΣM = 14026.43k(222.71') = 3,123,839.375'k

The weight of the structure is more than adequate for resistance of the overturning moment.