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Structural Option
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Wellington at Hershey's Mill
West Chester, Pennsylvania
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Structural Technical Report 1

Executive Summary

Wellington at Hershey's Mill is a retirement community consisting of 197 residential units on the top three floors and a garage level below them. Wellington is five stories with the number of stories above grade alternating around the perimeter of the building. The lower and lobby levels are separate from the residential section and contain the businesses in connection with Wellington. Wellington is 370,000 square feet and located off a prominent road in West Chester, Pennsylvania.

This report consists of an assessment of the structural system and explores the structural design concepts that may have been used in the design of Wellington. The 2000 International Building Code is the basis of the building design but I will be using ASCE 7-02 for my calculations. The design codes are as follows:

Structural Steel	AISC- "Specifications for Structural Steel Buildings"
Reinforced Concrete	ACI 318- "Building Code Requirements For Reinforced Concrete"
	ACI 301– "Specifications For Structural Concrete"
Masonry	ACI 530- "Building Code Requirements For Masonry Structures"
	ACI 530.1- "Specifications For Masonry Structures"
Lumber	1996 BOCA National Building Code
Foundations	In accordance with a geotechnical report prepared by Earth Engineering, Inc. dated January 29, 2003

The structural system is a combination of many structural materials. The foundation is slab on grade with strip footings in the exterior, spread footings in the interior, and a cmu foundation wall. The lobby floor and roof and first floor framing is steel joists bearing on girders on steel columns. The second and third floors are 2x6 wood framing with open web wood trusses bearing on the walls. The roof framing is similar to the second and third floor except for slightly sloped wood roof trusses. Wood framed gypsum shear walls and masonry towers located at the elevator shafts and stairwells make up the lateral load resisting system.

The exterior walls of the lower and lobby levels as well as the garage level are cmu block with a conventional red stucco finish for the parts of the wall above grade. The first through third floors' exterior walls are 2x6 wood studs framing with two layers of white stucco finish over wood sheathing.

A spot check was performed on the first floor steel framing and the third floor wood framing. The spot check of a steel girder and steel column resulted in different sizes than the actual design. This could be due to incorrect loading assumptions and calculations. The spot check on the steel joist, wood truss, and wood stud bearing wall all resulted in the same sizes as designed. After a lateral load distribution was performed, the masonry towers were determined to be sufficient for the top levels and the shear walls were not checked. Two towers on the lower levels were found to be inadequate for the lateral loading. This could be due to incorrect calculations or assumptions.

Summary of Overall Structural System

Load Path

For the steel framing, the floor slab is supported by the steel joists, the steel joists bear on steel girders and exterior cmu walls, and the girders sit on the steel columns. In the wood framing, the joists support the wood sheathing and bear on the wood framed walls.

Building Geometry

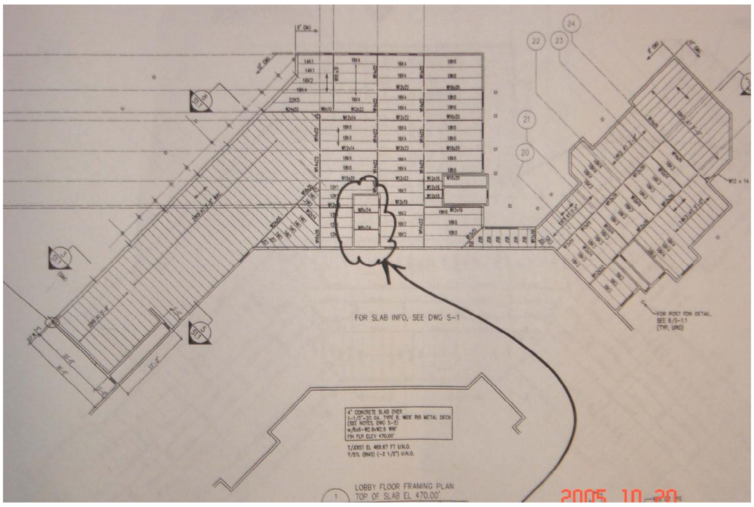
The lobby and lower level are almost a separate section from the residential. The lobby is located directly over the lower level and is close to the elevation of the garage level which is the level beneath the three residential floors. A branch of the first through third floors is above the lobby, but the rest of the lobby ends at the first floor level.

Foundation (Lower Level & Garage Level)

Wellington's foundation consists of a 12" CMU foundation wall with 2' wide strip footings and 4" slab on grade with 6x6-W2.0xW2.0 WWF over 2-4" porous fill. The interior steel columns sit on concrete spread footings ranging in size from 3'x3' to 4'-6"x4'-6". There are two pier sizes in the foundation; 18"x18" and 20"x20".

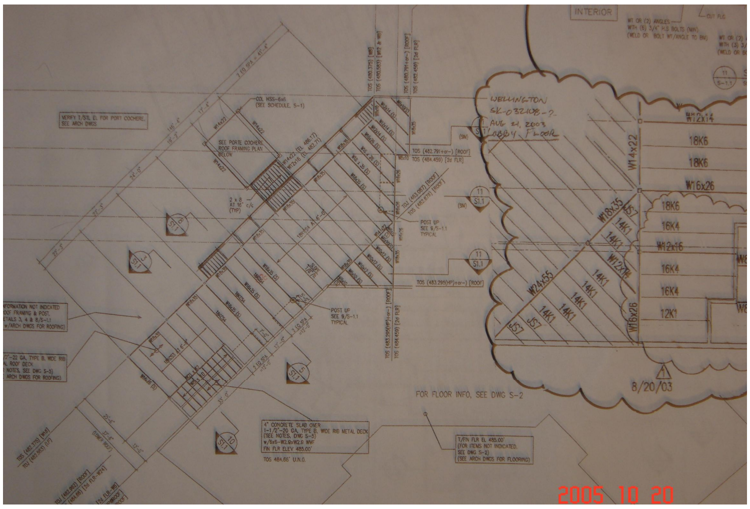
Lobby Floor & Roof Framing

A 4" concrete slab is over a 1-1/2" 20 GA. Type B, wide rib metal deck, manufactured by Vulcraft, with 6x6-W2.9xW2.9 WWF. The beams range in size from W8's to W16's and the joists from 12K to 24K and a section with JS8's. There are no typical bays in the building due to the irregular shape.



Lobby Floor Framing

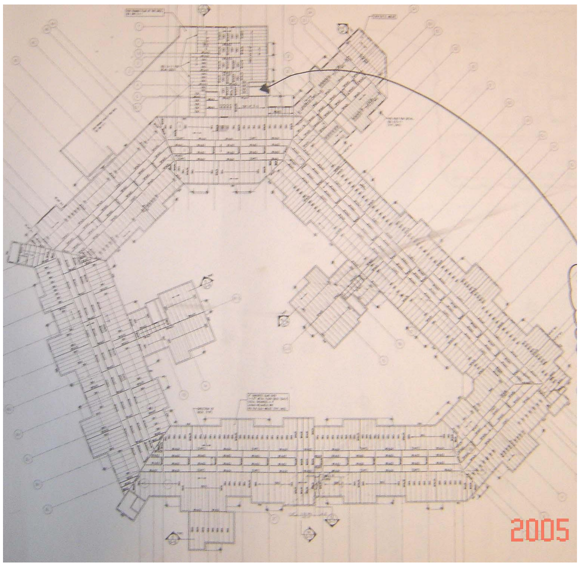
The lobby roof framing has the same concrete slab system as the floor framing but some different steel sizes and the framing is slightly sloped. The beams range in size from W8's to W21's and the joists are all 18KCS. Metal roof deck is installed over the beams.



Lobby Roof Framing

First Floor Framing

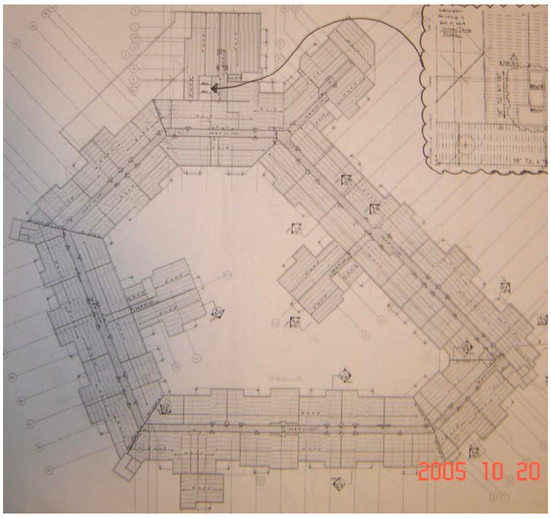
The first floor framing consists of a 4" concrete slab over 1-1/2" metal floor deck (galvanized) with 6x6-W2.9xW2.9 WWF. The steel beams range in size from W8's to W18's; they span over the corridor. The joists range from 10K's to 18K's and is the framing system for the rest of the areas on the first floor. Metal studs are used to frame the walls.



First Floor Framing

Second & Third Floor Framing

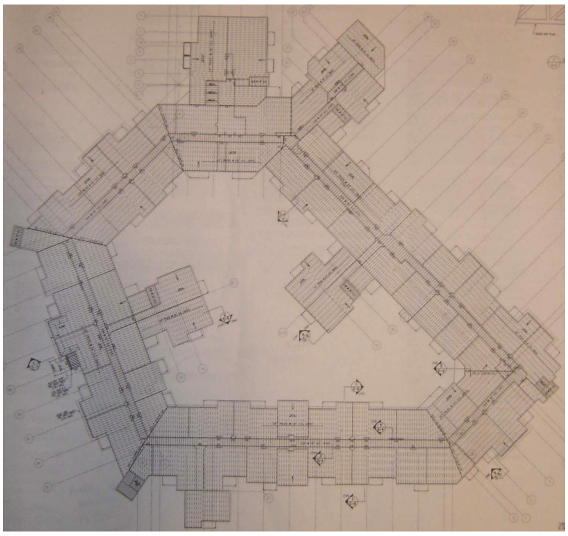
The framing for these two floors consist of wood framing made up of 2x8s at 16" in the corridor and TJLs, open web wood trusses, at 16" everywhere else. The floor is made up of plywood floor sheathing. There are W8x24s at the elevator shafts and stairwells. The interior bearing walls are 2x6 at 16" o.c. on either side of the corridors.



Second & Third Floor Framing

Roof Framing

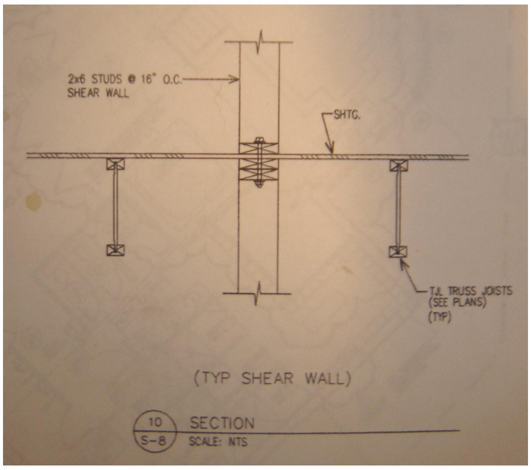
The roof framing also has 2x8’s at 16” o.c. in the corridors but the trusses are sloped 24” at 24” o.c. maximum. The five 1-3/4”x18” LVL’s are in the same location as the second and third floors. The same size steel is present in the same locations as the second and third floors as well.



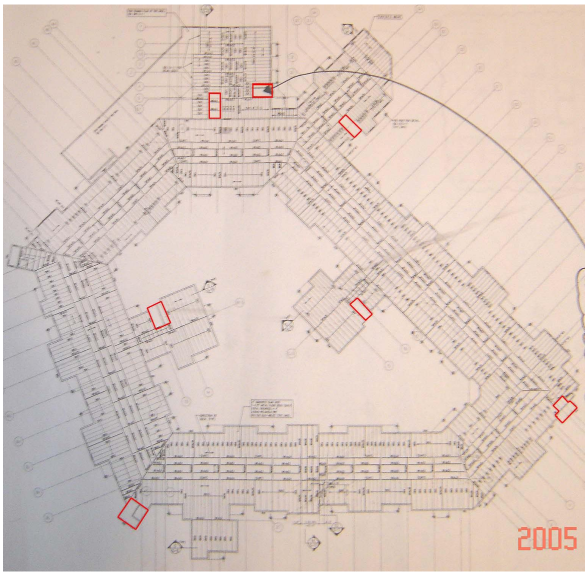
Roof Framing

Lateral Load Resisting System

Wood framed gypsum shear walls and masonry towers located at the elevator shafts and stairwells (see plan below) make up the lateral load resisting system.



Typical Shear Wall



Masonry Tower locations

Codes and Code Requirements for Gravity and Lateral load conditions

The design of the structural system of Wellington at Hershey's Mill is based on the 2000 International Building Code. For my purposes, I will be using the ASCE7-02 in my wind and seismic analysis.

The design codes are as follows:

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Load Calculations and Spot Checks

The gravity loads were determined from ASCE 7-02. The live load used in the spot checks will be the 40 psf for private rooms and the corridors that serve them. The dead loads were split by floor because of the difference in materials. Appendix 1 contains the calculations.

The calculations of the wind and seismic loads were performed also in accordance with ASCE 7-02. The South-North direction was determined to be the critical direction because all five levels were exposed to the loads. The seismic loads are much larger than the wind loads and will be the controlling lateral load for the lateral resisting system check.

The lateral load distribution to the masonry towers consisted of two methods; distribution by rigidity for the rigid diaphragm of the lobby and first floor and distribution by tributary area for the flexible diaphragm of the remaining floors. For the walls that are at an angle to the shear force, the individual wall rigidities were calculated and then multiplied by the appropriate angle to find the component needed. Appendix 4 includes all of the calculations.

The wood framed gypsum shear walls were not checked because the masonry towers were found to sufficiently resist the shear force. Two towers on the first floor, though, did not have the adequate capacity for the shear stress. The towers are the only lateral resisting system on the first level, so this may be due to incorrect assumptions or calculations.

Spot checks were performed on the first floor steel framing and third floor wood framing. Calculations can be found in Appendix 5. The steel joists were checked using The New Columbia Joist Company Steel Joists and Joists Girders catalogue. An 18k9 was chosen using the calculated live and dead loads and given joist spacing. The designed steel joist was an 18k9.

A steel girder was checked using the joist weights and resultant forces on the steel girder. The chosen girder has a column at its mid-span acting as a support. The support was assumed to act as a pinned connection for the analysis. Because of this arrangement, a moment distribution was performed and resulted in a W14x61. The designed girder is a W14x34 and the difference could be due to incorrect assumptions in loading or calculations.

A steel column was checked using the calculated live and dead loads, the weights from the girder and joist, and a moment resulting from the moment distribution on the girder. A W10x33 was chosen while the designed column was a W10x45. This difference could again be due to incorrect assumption in loading and calculations.

The spot checks for the wood framing resulted in the same sizes as designed. The wood trusses were checked using the Open Web Truss manual from Trus Joist. The resulting truss is an 18" TJL truss. The NDS was used for the check of a wood stud bearing wall. Assumptions included 16" stud spacing, the studs lined up with the joists therefore each stud supports each joist. The studs were Southern Pine No. 1 non-dense. The analysis resulted in a 2x6 stud.

Conclusion

Wellington is a building made up of many structural materials and a unique shape which make it an interesting building to study. All the analyses were performed by hand and with a spread sheet instead of structural software. The main method of analysis was LRFD, but ASD was used for the wood member checks. The discrepancy from some of the spot checks shows the difference in assumptions and loads from what was actually designed. I look forward to further investigation of Wellington and its design.

APPENDIX 1: GRAVITY LOADS

Gravity Loads - ASCE 7-02

Live Loads (Table 4-1)

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

Dead Loads

Wood framed 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 – ASCE 7-02

$$p_f = 0.7\, C_e C_t I\, p_g$$

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

$$p_f = 0.7(0.7)(1.0)(1.1)(30\text{psf})$$
$$= 16.17\text{psf} < p_f = 20I = 22\text{psf}$$

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

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)

$q_z = 0.00256 K_{zT} K_d V^2 I K_z = 0.00256(1.0)(0.85)(90)^2(1.15)K$
$= 20.27 K_z$

$q_h = \frac{58'-50}{60-50}(0.85-0.81)(20.27) + 20.27(0.81)$
$= 17.07$ 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:

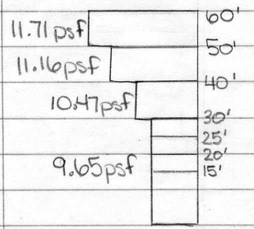
$$p_{wz} = q_z C_p G = q_z(0.8)(0.85) = 0.68\, q_z = 13.78 K_z$$

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

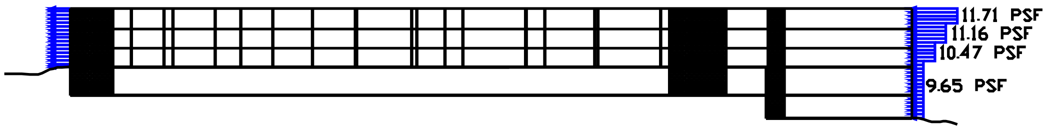
floor	H(ft)	pwz(psf)
1	12'	9.65
2	27'	9.65
3	37'	10.22
4	47'	10.95
5(ROOF)	58'	11.56



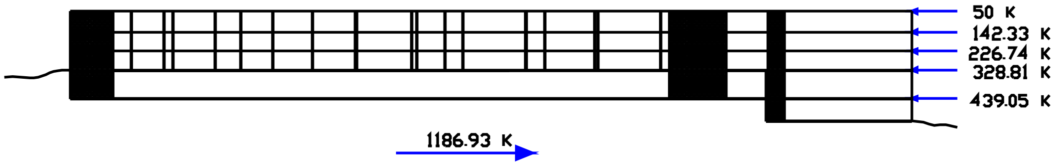
floor	p=pwz-plh (psf)
5(ROOF)	18.81
4	18.2
3	17.47
2	16.9
1	16.9

(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



EAST ELEVATION



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

$W = \omega_{roof} + \omega_{3rd fl} + \omega_{2nd fl} + \omega_{1st fl} + \omega_{lobby}$

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 + 1654.66 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

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

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

$$C_{smin} = 0.044 I S_{DS} = 0.044(1.25)(0.29) = 0.016$$

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

Vertical Distribution of Seismic Forces

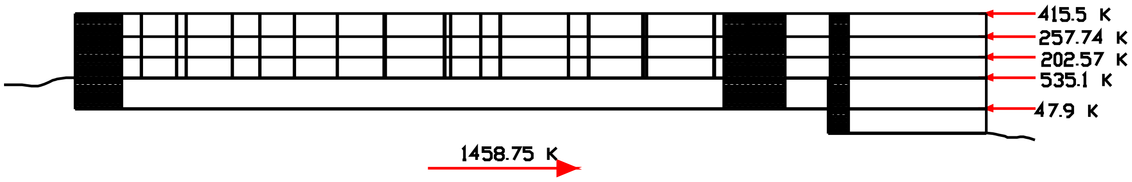
$$F_x = C_{vx} V; \quad C_{vx} = \frac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k}$$

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

(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

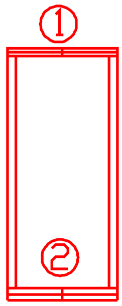
- **0.3 < H/L < 3.0** for all tower walls consider both flexural & shear
- $R/E = t(4(h/L)^3 + 3(h/L))^{-1}$

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

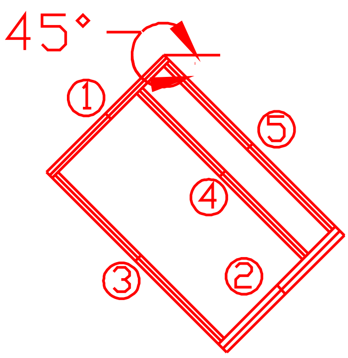
Tower 5

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

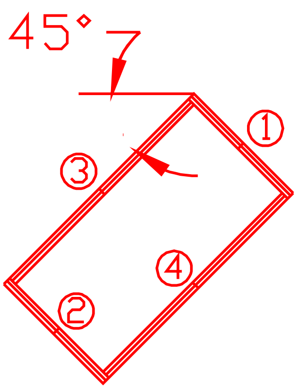


Wall 1: cos45° = Rx/R   Rx = 31.61
sin45° = Ry/R   Ry = 31.61

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

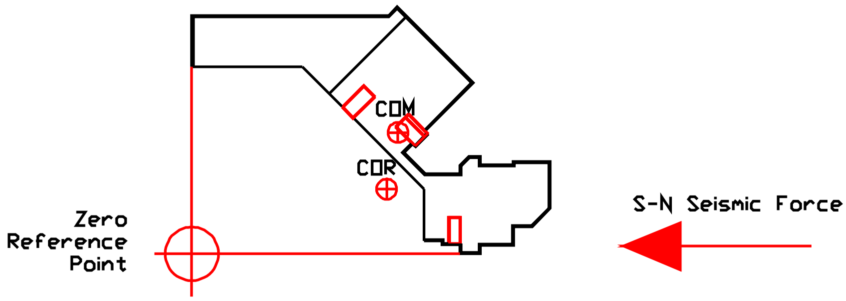
Walls 3, 4, & 5: cos45° = Rx/R   Rx = 12.96
sin45° = Ry/R   Ry = 12.96

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		Wx (ft*k)	Wy (ft*k)
						X (ft)	Y(ft)		
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**

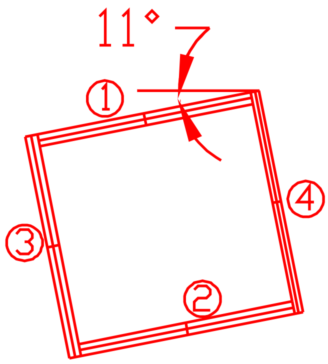
Xm = ÓWx/ÓW	Ym = ÓWy/ÓW
221.0279	274.9803

- **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

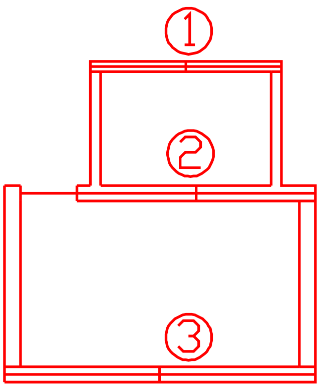


Walls 1&2: $\cos 11^\circ = Rx/R$ Rx = 31.98
$\sin 11^\circ = Ry/R$ Ry = 6.22

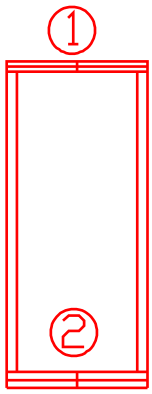
Wall 3: $\cos 79^\circ = Rx/R$ Rx = 5.7
$\sin 79^\circ = Ry/R$ Ry = 29.32

Wall 4: $\cos 79^\circ = Rx/R$ Rx = 3.8
$\sin 79^\circ = Ry/R$ Ry = 19.55

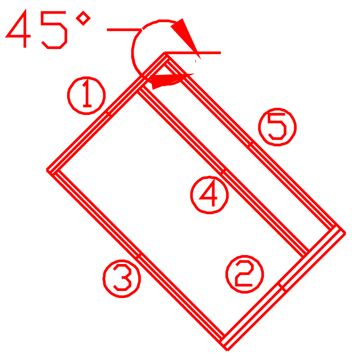
Tower 2



Tower 3



Tower 4

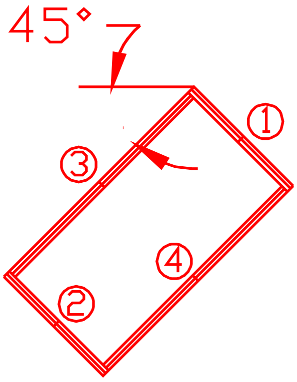


Wall 1: $\cos 45^\circ = Rx/R$ Rx = 31.61
$\sin 45^\circ = Ry/R$ Ry = 31.61

Wall 2: $\cos 45^\circ = Rx/R$ Rx = 47.42
$\sin 45^\circ = Ry/R$ Ry = 47.42

Walls 3, 4, & 5: $\cos 45^\circ = Rx/R$ Rx = 12.96
$\sin 45^\circ = Ry/R$ Ry = 12.96

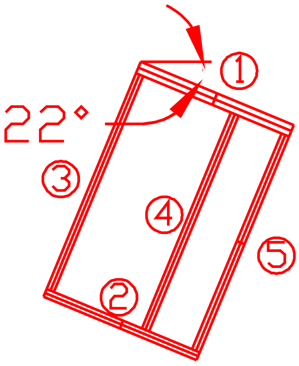
Tower 5



Walls 1 & 2: cos45º = Rx/R Rx = 45.7
sin45º = Ry/R Rx = 45.7

Walls 3 & 4: cos45º = Rx/R Rx = 10.23
sin45º = Ry/R Rx = 10.23

Tower 6

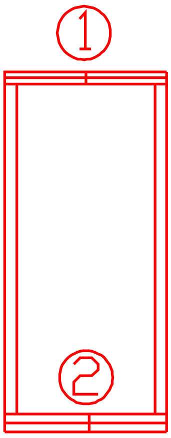


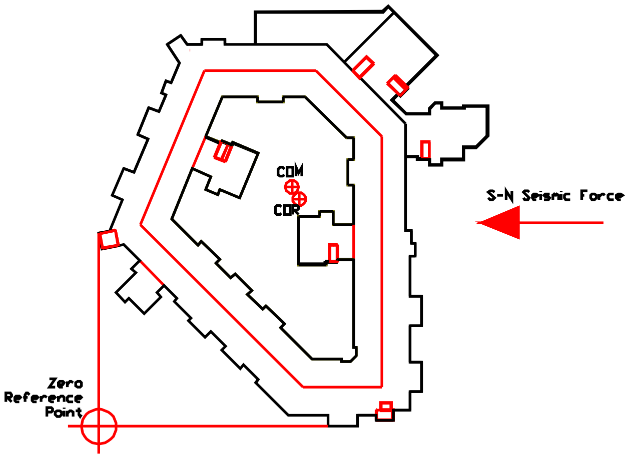
Wall 1: cos22º = Rx/R Rx = 62.18
sin22º = Ry/R Ry = 25.12

Wall 2: cos22º = Rx/R Rx = 41.45
sin22º = Ry/R Ry = 16.75

Walls 3, 4, & 5: cos68º = Rx/R Rx = 6.93
sin68º = 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.

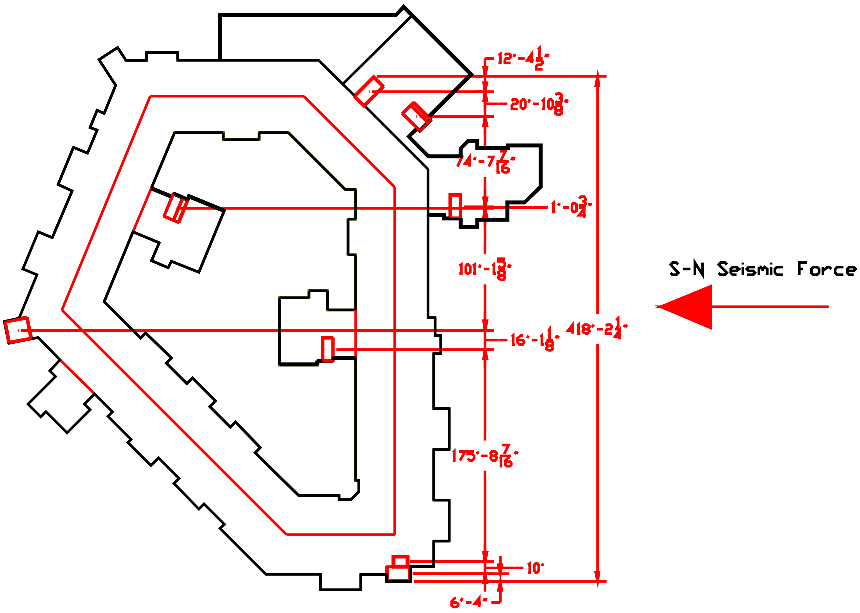
Element		**Rx**	**Ry**	**Direct Shear (x)**	**Direct Shear (y)**	**Area (sf)**	**Area (sq in)**	**Shear Stress (psi) (x)**	**Shear Stress (psi) (y)**
Tower 1									
	Wall 1	31.98	6.22	13.0541	8.658	18	2592	5.0362932	3.340278
	Wall 2	31.98	6.22	13.0541	8.658	18	2592	5.0362932	3.340278
	Wall 3	5.7	29.32	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)

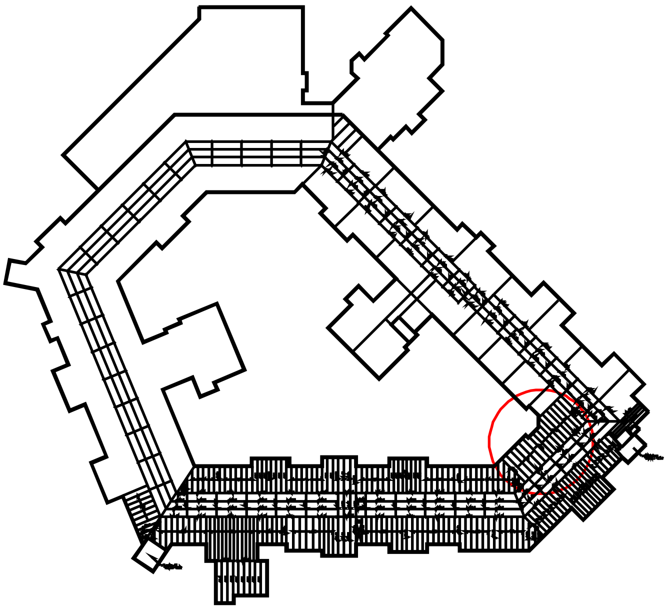
Load Direction: S-N
Seismic Load: 2nd Floor = 202.57k
3rd Floor = 257.74k
Design Basis: Capacity
Elements: Masonry Towers
Height: 10 ft

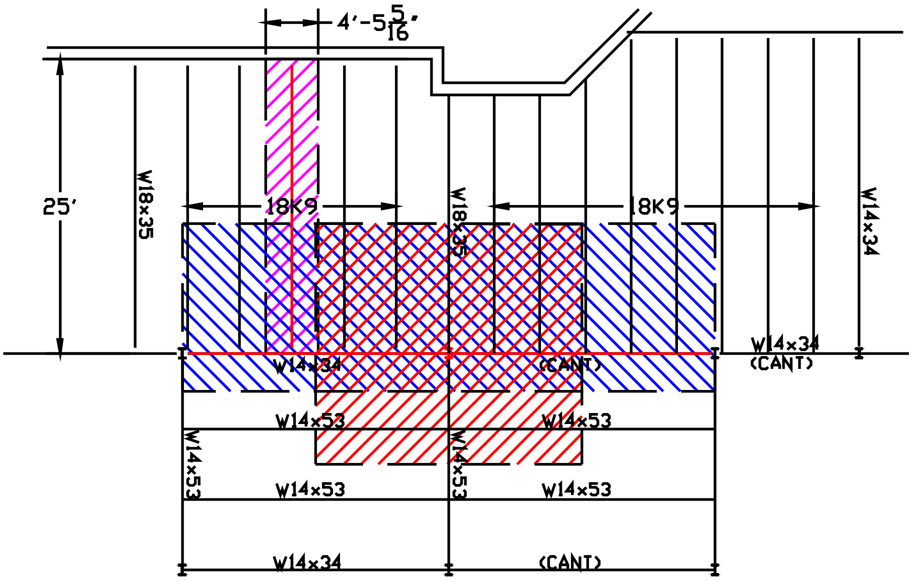


Element		Area (sf)	Height (ft)	Length (ft)	Trib Width (ft)	Trib Area (sf)	Fraction of Trib Area	Shear Wall Load (2nd Fl)	Shear Wall Load (3rd Fl)	Area (sq in)	Shear Stress (psi) (2nd Fl)	Shear Stress (psi) (3rd Fl)
Tower 1												
	Wall 1	18	10	18	29.31	293.1	0.034287	6.9454196	8.8370067	2592	2.67956	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: MEMBER SPOT CHECKS

First Floor Steel

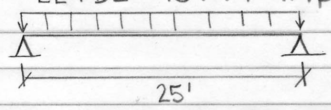




STEEL FRAMING – spot checks

Joist

LL + DL = 40 + 74 = 114 psf



Joist spacing = 6 eq. spaces = 4'-5 5/16" = 4.44'

114 psf (4.44') = 506.16 plf

40 psf (4.44') = 177.6 plf

From joist table (NCJ catalogue)

Try 18k9

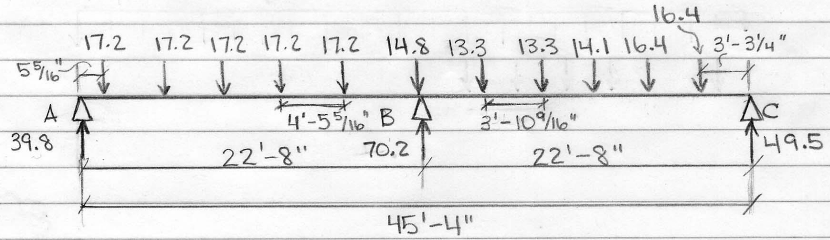
TL = 550 plf > 506.16 plf

LL = 377 plf > 177.6 plf

∴ **Use 18k9**

Girder $1.2D + 1.6L = 152.8$ psf

Assumption: treat midspan support as pinned connection



Joist wts + factored loads 18k9 = 10.2 plf

10.2 plf (25') + 152.8 psf (4.44')(25') = 17.2k

10.2 plf (22') + 152.8 psf (3.88')(22') = 13.3k

10.2 plf (23.35') + 152.8 psf (3.88')(23.35') = 14.1k

10.2 plf (27.23') + 152.8 psf (3.88')(27.23') = 16.4k

Beam wt + factored loads W18x35 = 35 plf

35 plf (22') + 152.8 psf (4.16')(22') = 14.8k

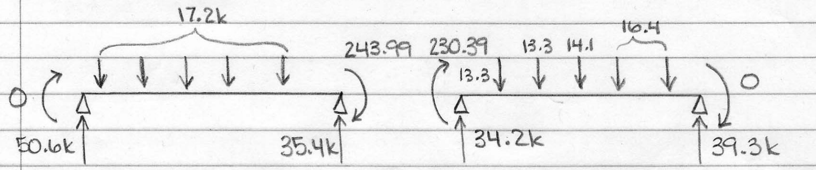
Moment Distribution EI = constant

$k_{AB} = k_{BC} = \frac{EI}{22.67'} = k$ $\quad k_{BC}^{M} = 3/4\,k = 0.75k = k_{BA}^{M}$

$FEM_{AB} = \frac{-Pab^2}{l^2} = -162.98'k$ $\quad FEM_{BA} = \frac{Pa^2b}{l^2} = 159.1'k$

$FEM_{BC} = -150.89'k$ $\quad FEM_{CB} = 165.79'k$ (see table for calcs)

Joints	A	B		C
Members	AB	BA	BC	CB
k	k	k	k	k
k^M		0.75k	0.75k	
DF	1.0	0.5	0.5	1.0
FEMs	-162.98	159.1	-150.89	165.79
	+162.98 →	+81.49	-82.9 ←	-165.79
		+3.4	+3.4	
	0	+243.99	-230.39	0

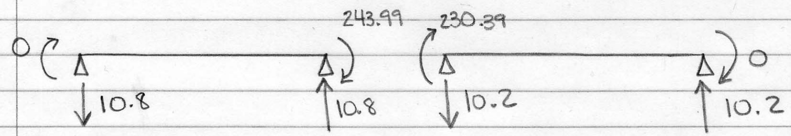


SBR

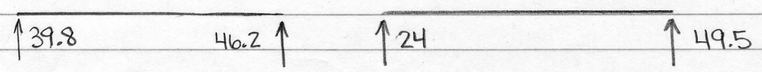
$\Sigma M_B = 0$: 1147.12'k $- R_A(22.67') = 0$ ∴ $R_A = 50.6k$

$\Sigma M_C = 0$: 774.621'k $- R_B(22.67') = 0$ ∴ $R_B = 34.2k$

See table for calcs.

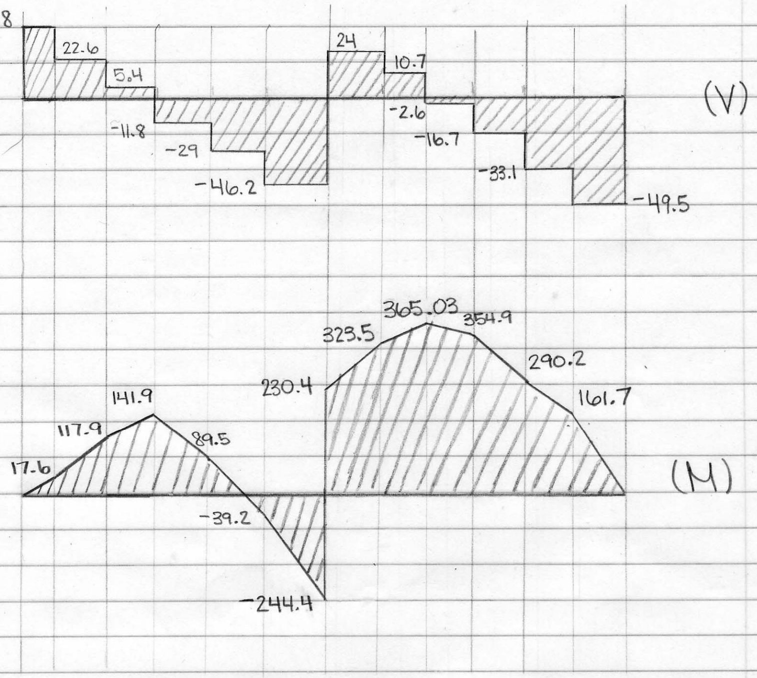


243.99 / 22.67 = 10.8k   230.39 / 22.67 = 10.2



	P (kips)	a (ft)	b (ft)	L (ft)	FEM (ft*k)
AB	17.2	0.433	22.227	22.67	-7.15937321
	17.2	4.886	17.784	22.67	-51.7175292
	17.2	9.329	13.341	22.67	-55.5695997
	17.2	13.772	8.898	22.67	-36.4928031
	17.2	18.227	4.443	22.67	-12.0418504
				FEM AB	**-162.981156**
BA	17.2	0.433	22.227	22.67	0.139470401
	17.2	4.886	17.784	22.67	14.20894331
	17.2	9.329	13.341	22.67	38.85831612
	17.2	13.772	8.898	22.67	56.48223015
	17.2	18.227	4.443	22.67	49.40058673
				FEM BA	**159.0895467**
BC	13.3	3.88	18.79	22.67	-35.4514405
	13.3	7.76	14.91	22.67	-44.644258
	14.1	11.64	11.03	22.67	-38.8525992
	16.4	15.52	7.15	22.67	-25.3188869
	16.4	19.4	3.27	22.67	-6.61969596
				FEM BC	**-150.88688**
CB	13.3	3.88	18.79	22.67	7.320467755
	13.3	7.76	14.91	22.67	23.23537503
	14.1	11.64	11.03	22.67	41.00129232
	16.4	15.52	7.15	22.67	54.95791948
	16.4	19.4	3.27	22.67	39.27281396
				FEM CB	**165.7878686**

	P (kips)	Moment Arm (ft)	Moment (ft*k)
ÓM @ B	17.2	22.227	382.3044
	17.2	17.784	305.8848
	17.2	13.341	229.4652
	17.2	8.898	153.0456
	17.2	4.443	76.4196
		Ó	**1147.12**
ÓM @ C	13.3	18.79	249.907
	13.3	14.91	198.303
	14.1	11.03	155.523
	16.4	7.15	117.26
	16.4	3.27	53.628
		Ó	**774.621**



$V_u = 49.5k$
$M_u = 365.03'k$

Table 5-3(LRFD) Try W14x61

$\phi V_n = 141k > 49.5k$
$\phi M_p = 383'k > 365.03'k$

Use W14x61

Column # floors above 1st floor = 2

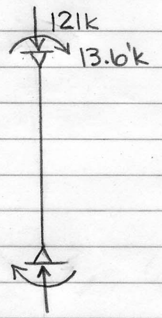
DL = 74 psf
LL = 40 psf

Girder wt = 40 plf · 45'-4" = 1.8k
Beam wt = 35 plf · 22' = 0.8k

Trib area = 463.2 ft^2 (from CAD dwg.)
$A_T = 2(463.2) = 926.4 ft^2$
$A_I = 4(926.4) = 3705.6 ft^2$

$L = L_o(0.25 + \frac{15}{\sqrt{A_I}}) \geq 0.4L_o = 0.496L_o > 0.4L_o$

Use $L = 0.496L_o = 19.84 psf \cdot (926.4 ft^2)/1000 = 18.4k$
Roof LL = $20 psf (926.4 ft^2)/1000 = 18.5k$
DL = $74 psf (926.4 ft^2)/1000 = 68.6k$
$P_u = 1.2D + 1.6L + 0.5L_R = 121k$



Moment from girder = 13.6'k

$\alpha = \frac{24}{d} = \frac{24}{15} = 1.6$

$P_{eff} = P_u + \alpha M$
$= 121k + 1.6(13.6'k)$
$= 142.8k$

K = 1.0 for both X-X & Y-Y axis

$Kl_x = Kl_y = 15'$

Table 4-2 (LRFD) Try W10x33

$\phi P_n = 220k > 142.8k$ OK

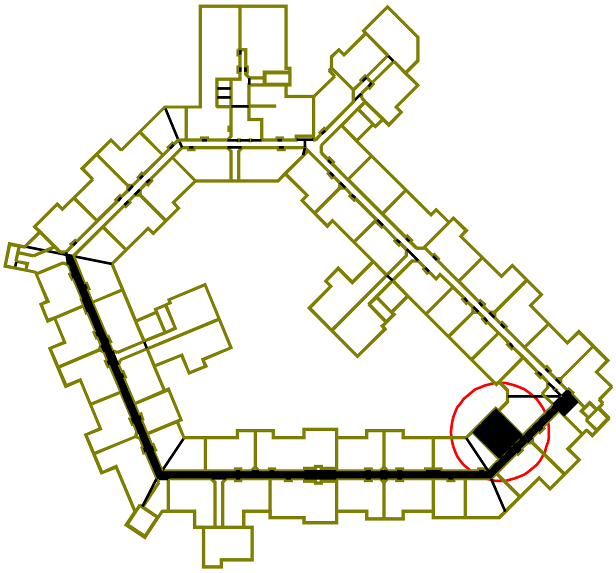
Use W10x33

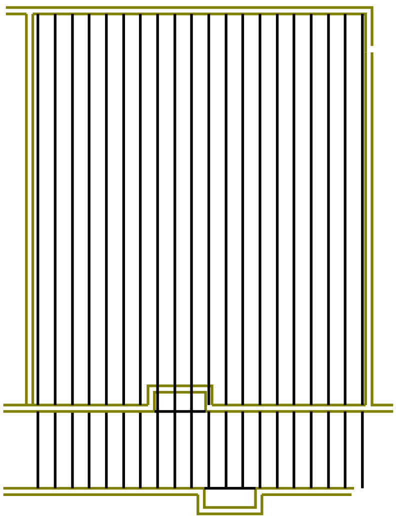
STANDARD LOAD TABLE/OPEN WEB STEEL JOISTS, K-SERIES
Based on a Maximum Allowable Tensile Stress of 30 ksi

Joist Designation	18K3	18K4	18K5	18K6	18K7	18K9	18K10	20K3	20K4	20K5	20K6	20K7	20K9	20K10	22K4	22K5	22K6	22K7	22K9	22K10	22K11
Depth (In.)	18	18	18	18	18	18	18	20	20	20	20	20	20	20	22	22	22	22	22	22	22
Approx. Wt. (lbs./ft.)	6.6	7.2	7.7	8.5	9	10.2	11.7	6.7	7.6	8.2	8.9	9.3	10.8	12.2	8	8.8	9.2	9.7	11.3	12.6	13.8
Span (ft.) ↓																					
18	550 550	550 550	550 550	550 550	550 550	550 550	550 550														
19	514 494	550 523	550 523	550 523	550 523	550 523	550 523														
20	463 423	550 490	550 490	550 490	550 490	550 490	550 490	517 517	550 550	550 550	550 550	550 550	550 550	550 550							
21	420 364	506 426	550 460	550 460	550 460	550 460	550 460	468 453	550 520	550 520	550 520	550 520	550 520	550 520							
22	382 316	460 370	518 414	550 438	550 438	550 438	550 438	426 393	514 461	550 490	550 490	550 490	550 490	550 490	550 548	550 548	550 548	550 548	550 548	550 548	550 548
23	349 276	420 323	473 362	516 393	550 418	550 418	550 418	389 344	469 402	529 451	550 468	550 468	550 468	550 468	518 491	550 518	550 518	550 518	550 518	550 518	550 518
24	320 242	385 284	434 318	473 345	526 382	550 396	550 396	357 302	430 353	485 396	528 430	550 448	550 448	550 448	475 431	536 483	550 495	550 495	550 495	550 495	550 495
25	294 214	355 250	400 281	435 305	485 337	550 377	550 377	329 266	396 312	446 350	486 380	541 421	550 426	550 426	438 381	493 427	537 464	550 474	550 474	550 474	550 474
26	272 190	328 222	369 249	402 271	448 299	538 354	550 361	304 236	366 277	412 310	449 337	500 373	550 405	550 405	404 338	455 379	496 411	550 454	550 454	550 454	550 454
27	252 169	303 198	342 222	372 241	415 267	498 315	550 347	281 211	339 247	382 277	416 301	463 333	550 389	550 389	374 301	422 337	459 367	512 406	550 432	550 432	550 432
28	234 151	282 177	318 199	346 216	385 239	463 282	548 331	261 189	315 221	355 248	386 269	430 298	517 353	550 375	348 270	392 302	427 328	475 364	550 413	550 413	550 413
29	218 136	263 159	296 179	322 194	359 215	431 254	511 298	243 170	293 199	330 223	360 242	401 268	482 317	550 359	324 242	365 272	398 295	443 327	532 387	550 399	550 399
30	203 123	245 144	276 161	301 175	335 194	402 229	477 269	227 153	274 179	308 201	336 218	374 242	450 286	533 336	302 219	341 245	371 266	413 295	497 349	550 385	550 385
31	190 111	229 130	258 146	281 158	313 175	376 207	446 243	212 138	256 162	289 182	314 198	350 219	421 259	499 304	283 198	319 222	347 241	387 267	465 316	550 369	550 369
32	178 101	215 118	242 132	264 144	294 159	353 188	418 221	199 126	240 147	271 165	295 179	328 199	395 235	468 276	265 180	299 201	326 219	363 242	436 287	517 337	549 355
33	168 92	202 108	228 121	248 131	276 145	332 171	393 201	187 114	226 134	254 150	277 163	309 181	371 214	440 251	249 164	281 183	306 199	341 221	410 261	486 307	532 334
34	158 84	190 98	214 110	233 120	260 132	312 156	370 184	176 105	212 122	239 137	261 149	290 165	349 195	414 229	235 149	265 167	288 182	321 202	386 239	458 280	516 314
35	149 77	179 90	202 101	220 110	245 121	294 143	349 168	166 96	200 112	226 126	246 137	274 151	329 179	390 210	221 137	249 153	272 167	303 185	364 219	432 257	494 292
36	141 70	169 82	191 92	208 101	232 111	278 132	330 154	157 88	189 103	213 115	232 125	259 139	311 164	369 193	209 126	236 141	257 153	286 169	344 201	408 236	467 269
37								148 81	179 95	202 106	220 115	245 128	294 151	349 178	198 116	223 130	243 141	271 156	325 185	386 217	442 247
38								141 74	170 87	191 98	208 106	232 118	279 139	331 164	187 107	211 119	230 130	256 144	308 170	366 200	419 228
39								133 69	161 81	181 90	198 98	220 109	265 129	314 151	178 98	200 110	218 120	243 133	292 157	347 185	397 211
40								127 64	153 75	172 84	188 91	209 101	251 119	298 140	169 91	190 102	207 111	231 123	278 146	330 171	377 195
41															161 85	181 95	197 103	220 114	264 135	314 159	359 181
42															153 79	173 88	188 96	209 106	252 126	299 148	342 168
43															146 73	165 82	179 89	200 99	240 117	285 138	326 157
44															139 68	157 76	171 83	191 92	229 109	272 128	311 146

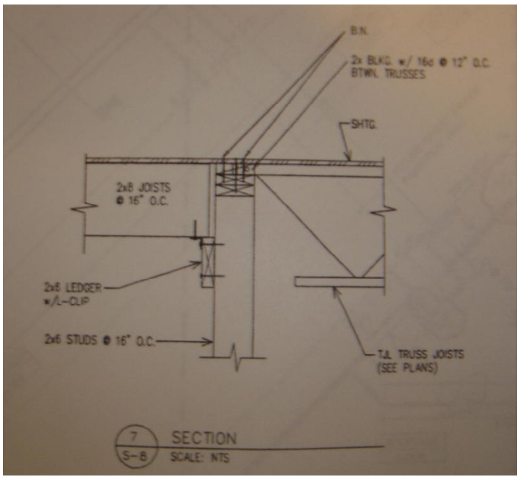
STEEL JOIST INSTITUTE STANDARD

Third Floor Wood





Section of Wood Framing

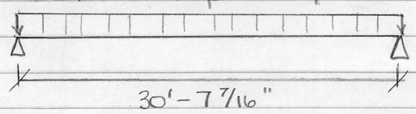


Wood Stud Bearing Wall

WOOD FRAMING - Spot checks

Joist

LL+DL = 40psf + 20psf



Joist spacing = 16" = 1.33'
Span in table = 30'-7 7/16" + 3"
= 30'-10 7/16"
Use 32' span

TL = 60psf (1.33') = 80 plf
LL = 20psf (1.33') = 26.6 plf

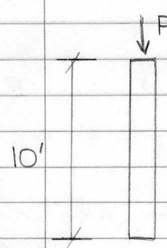
115% TL = 92 plf
125% TL = 100 plf

From TJL allowable PLF table
try 18" TJL
115% TL = 95 plf > 92 plf
125% TL = 103 plf > 100 plf OK

Use 18" TJL truss

Bearing stud wall

Assumption: stud spacing @ 16" o.c. and joists lined up w/studs
Southern Pine No.1 non-dense (given in dwgs.)



Joist weight + loading
4.25 lbs/ft + 80 plf = 84.25 plf
P = 84.25 plf (30'-7 7/16") = 2579.72 lbs = 2.6k

Try 2x4 SP $A = 5.25 in^2$

all. $P = F'_c A \Rightarrow F'_c = \frac{2579.72 lbs}{5.25 in^2} = 491.4 psi$

From NDS Table 4B: C_F included in table values for SP.

$F_c = 1700 psi$

Column Capacity of 2x4 stud

$$\left(\frac{l_e}{d}\right)_x = \frac{10'(12in/ft)}{3.5''} = 34.3$$

$C_M = 0.9$ $C_t = 1.0$ $C_T = 1.0$ $C_i = 1.0$ $C_D = 1.0$

$E = 1.6E6psi$

$E' = 1.6E6psi\,(0.9)(1.0)(1.0)(1.0) = 1.44E6psi$

$K_{cE} = 0.3$ $c = 0.8$ for visually graded sawn lumber

$$F_{cE} = \frac{K_{cE}(E')}{(l_e/d)_x^2} = \frac{0.3(1.44E6psi)}{34.3^2} = 367.2\,psi$$

$F_c^* = F_c C_D C_M C_t C_i = 1700psi\,(1.0)(0.8)(1.0)(1.0)$
(C_M = 0.8 for Fc)

$= 1360psi$

$F_{cE}/F_c^* = 367.2psi/1360psi = 0.27$

$[1 + F_{cE}/F_c^*]/2c = [1+0.27]/2(0.8) = 0.794$

$$C_P = \frac{1 + F_{cE}/F_c^*}{2c} - \sqrt{\left(\frac{1+F_{cE}/F_c^*}{2c}\right)^2 - \frac{F_{cE}/F_c^*}{c}}$$

$$= 0.794 - \sqrt{(0.794)^2 - 0.27/0.8} = 0.253$$

$F'_c = F_c C_D C_M C_t C_P C_i = 1700psi(1.0)(0.8)(1.0)(0.253)(1.0)$
$= 344.08\,psi < 491.4\,psi$ ∴ NG

Try 2x6 SP $A = 8.25in^2$

$$\text{all.}P = F'_c A \Rightarrow F'_c = \frac{2579.72lbs}{8.25in^2} = 312.7\,psi$$

From NDS Table 4B:

$F_c = 1600psi$

Column Capacity of 2x6 Stud

$$\left(\frac{l_e}{d}\right)_x = \frac{10'(12in/ft)}{5.5''} = 21.8$$

$E' = 1.44E6psi$ (same as 2x4 calculation)

$K_{cE} = 0.3$ $c = 0.8$

$$F_{cE} = \frac{K_{cE}(E')}{(l_e/d)_x^2} = \frac{0.3(1.44E6psi)}{21.8^2} = 909 psi$$

$F_c^* = 1600psi(1.0)(0.8)(1.0)(1.0) = 1280psi$

$F_{cE}/F_c^* = 0.71$

$[1+F_{cE}/F_c^*]/2c = [1+0.71]/2(0.8) = 1.07$

$$C_p = 1.07 - \sqrt{(1.07)^2 - (0.71/0.8)} = 0.563$$

$F'_c = 1600psi(1.0)(0.8)(1.0)(0.563)(1.0)$

$= 720.64psi > 312.7psi$ OK

Use 2x6 SP studs @ 16" o.c.

TJL™ Allowable Uniform Load Table (PLF) ■ Parallel Chord

For economical truss design, see page 5.

Span	Depth 14"		16"		18"		20"		22"		24"		26"		28"		30"		32"		34"		36"		38"		40"	
	100% TL	115% TL	100% TL	115% TL	100% TL	115% TL	100% TL	115% TL	100% TL	115% TL	100% TL	115% TL	100% TL	115% TL	100% TL	115% TL	100% TL	115% TL	100% TL	115% TL	100% TL	115% TL	100% TL	115% TL	100% TL	115% TL	100% TL	115% TL
	100% LL	125% TL	100% LL	125% TL	100% LL	125% TL	100% LL	125% TL	100% LL	125% TL	100% LL	125% TL	100% LL	125% TL	100% LL	125% TL	100% LL	125% TL	100% LL	125% TL	100% LL	125% TL	100% LL	125% TL	100% LL	125% TL	100% LL	125% TL
14'	288	330	322	370	332	382	334	393	347	377	313	360	308	354	***314***	357	301	327	289	325	279	321	264	306	262	302	***230***	283
	261	359		402		416		426		410		391		385		394		376		361		341		309		328		308
16'	224	259	254	297	281	340	***299***	355	315	365	307	362	307	361	296	340	291	342	280	325	270	291	261	283	257	296	244	273
	174	281	230	323		355		385		397		387		384		370		363		353		337		305		305		276
18'	188	218	220	253	249	286	278	313	296	333	295	339	309	338	283	325	282	334	272	313	256	300	250	294	245	282	***234***	263
	124	235	164	279	208	310	255	340		357		366		360		352		352		343		325		319		306		282
20'	***126***	182	182	208	204	232	226	261	246	281	268	307	284	317	274	307	273	314	260	307	248	289	235	280	***220***	262	***233***	261
	90	198	122	227	154	256	190	281	227	306		324		330		325		316		305		314		305		285		283
22'	***70***	155	***142***	177	173	199	192	220	210	240	228	251	235	269	251	292	266	290	258	289	245	278	246	278	***203***	264	***209***	259
	66	168	90	192	117	216	144	240	174	263	205	273		299		295		299		301		276		280		282		282
24'		127	***90***	148	145	169	***161***	184	180	206	195	218	210	238	224	255	233	267	236	270	241	260	240	263	227	258	***183***	242
		138	69	162	90	181	112	203	136	220	159	237	186	259	214	273		274		277		269		267		270		252
26'		107		123	***104***	143	138	160	153	175	***163***	186	175	207	187	223	205	232	210	244	***207***	237	***225***	231	***207***	240	***171***	235
		118		137	70	156	88	175	108	193	128	210	150	225	172	240	194	254		254		241		247		249		247
28'		93		109	***68***	124	***112***	138	132	151	144	164	***155***	181	170	191	***177***	205	***186***	214	190	221	200	219	***188***	222	200	214
		101		119	55	136	70	152	86	165	103	181	120	195	139	212	158	220	179	227		240		235		230		227
30'		82		96		108	***78***	120	115	132	127	145	137	158	147	166	158	179	***163***	189	***167***	195	***176***	199	***173***	199	***171***	201
		84		105		118	57	132	70	145	84	156	98	170	114	183	129	196	147	206	165	211		217		211		204
32'		70		82		95		105	***86***	116	111	126	121	140	130	148	138	155	148	167	151	176	161	180	***162***	183	***150***	186
		70		88		103		115	57	127	69	139	81	151	94	158	107	170	121	183	137	191	151	196		199		198
34'		58		72		83		93	***62***	103	***90***	112	106	123	116	133	124	143	130	149	135	156	141	164	148	169	***141***	173
		58		78		91		101	47	112	57	123	68	135	79	146	90	153	102	163	115	170	128	178	141	183		187
36'		49		65		73		83		92		100	***86***	109	102	118	110	127	116	135	123	142	***126***	148	132	151	***136***	160
		49		66		80		91		100		110	57	119	66	129	76	139	87	148	97	154	109	160	120	167	132	171
38'		42		56		66		74		82		90	***65***	98	***86***	105	98	112	105	120	111	127	***115***	135	***112***	138	***115***	142
		42		56		72		81		89		98	48	106	56	115	65	124	74	133	83	140	93	147	102	150	113	154
40'				48		59		68		75		82		89	***69***	96	***88***	103	***95***	110	***99***	117	***101***	121	***101***	127	***100***	131
				48		62		74		81		89		97	48	105	56	113	63	120	71	127	80	133	88	139	97	144
42'				42		54		62		68		75		81		88	***62***	93	***77***	99	***82***	106	***84***	112	***85***	116	***82***	121
				42		54		67		74		82		89		95	48	102	55	109	62	116	69	122	76	127		132
44'						47		56		62		68		73		80		86	***60***	90	***66***	96	***69***	102	***69***	107	***63***	111
						47		59		67		74		80		87		92	48	98	54	105	60	111	67	117		121
46'						41		51		56		62		67		72		78		83		88		93		97		100
						41		51		61		67		73		79		85		90		95		101		107		112
48'								45		52		57		61		66		71		76		81		86		90		94
								45		55		61		72		72		77		83		88		93		99		102
50'								40		48		52		57		61		66		70		75		79		84		88
								40		49		57		61		72		72		76		81		86		91		94
52'										44		48		52		57		61		65		69		73		77		81
										44		53		57		61		66		71		75		79		84		88
54'												45		49		53		57		60		64		68		72		76
										39		47		53		57		62		66		70		74		78		82
56'												42		45		49		53		56		60		63		67		70
												42		49		53		57		61		65		69		73		76
58'														42		46		49		52		56		59		62		66
												38		45		50		53		57		61		64		68		71
60'														40		43		46		49		52		55		58		62
														40		47		49		53		61		60		63		67

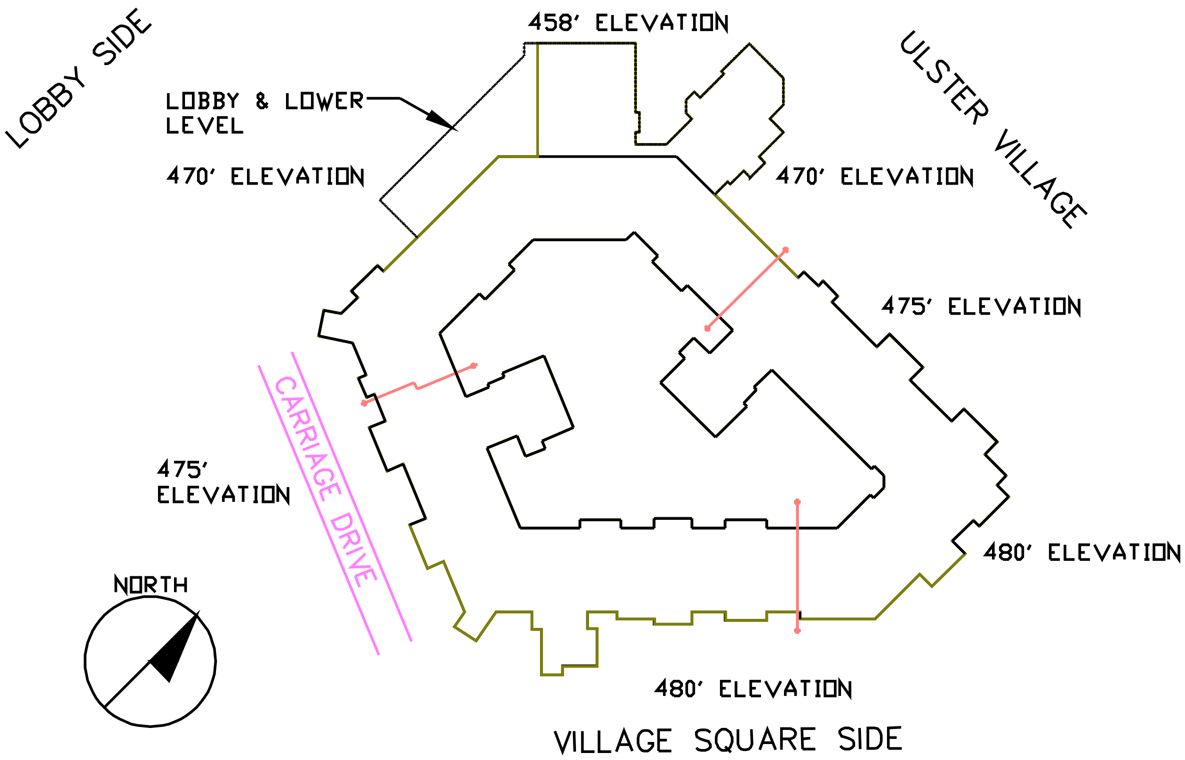
See page 4 for available depths and profiles. For depths and profiles not shown, use TJ-Beam® software or contact your Trus Joist representative for assistance.

General Notes

- **Open-web trusses will be custom designed to the specified loads. Values shown are maximum allowable load capacities based on the following assumptions:**
  - Simple span, uniformly loaded conditions, with provisions for positive drainage (1/4" per foot slope minimum) in roof applications.
  - "Span" indicates distance from inside face to inside face of bearing plus 3".
  - Top chord no-notch bearing clips with 1¾" bearing. Higher values may be possible with other types of bearing clips.
- Straight line interpolations may be made between depths and spans.
- These tables may also be used for bottom chord bearing trusses with or without cantilevers — at one or both ends. Cantilevers are limited to 1/3 of the main span provided that the inboard shear for cantilevered conditions is limited to 2,500 lbs for the TJL™ and TJLX™ series.
- Values in shaded areas may be increased 7% for repetitive-member use.

General Notes continued on page 7

APPENDIX 6: ELEVATION PLAN



APPENDIX 7: GENERAL BUILDING SECTION