Fraser Centre

State College, Pennsylvania

Technical Report III

Tyler Strange

Structural Option

AE Consultant: Dr. Thomas Boothby

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Executive Summary

This report is an analysis and study of Fraser Centre's lateral force resisting system. Lateral loads are resisted by only two shear walls. The wind and seismic calculations from Technical Report 1 have been corrected and included in this report.

The distribution of the lateral forces was determined by hand calculations and the use of excel spreadsheets. A computer model of the ## shear walls was used to determine the relative stiffness. The shear walls are 14 inch and 16 inch concrete.

All of the concrete walls throughout Fraser Centre will distribute the lateral loads in reality. The two shear walls are the only ones that have any continuity from base to roof. This provides a continuous path through the wall to the foundations.

In this analysis it was determined that the building stays within the allowable drift and deflection criteria of L/400 for unfactored wind and 0.02H for factored seismic. Seismic proved to be the biggest factor in drift considerations with a deflection of 0.4282 inches, which is well below the maximum allowed drift of 3.16 inches. Unfactored wind had a deflection of 0.3448 inches with a maximum allowable drift of 4.74 inches. Despite the discontinuous nature of the shear walls, they are more than adequate to the lateral loads that might be applied to it.

Introduction

Figure 1: Site view of Fraser Centre (blue) bounded by Fraser St., Calder Way, Miller Alley, and Beaver Ave. Photo courtesy of Bing Maps.

The Fraser Centre is a mixed-use, high-rise development located in downtown State College, Pennsylvania (See Fig. 1). The site will encompass an entire block on the corner of Beaver Avenue and Fraser Street, at an approximate elevation of 1100 feet above sea level. The development was designed by Wallace, Roberts, and Todd LLC, to be the only building in State College to have an all glass and aluminum façade. The structure was engineered by David Chou and Associates, Inc.; the MEP was engineered by AKF Engineers; and the theater was engineered by JKR Partners, LLC.

Fraser Centre is an eleven story multi-use building. The first floor is exclusively parking; with 94 parking spaces. Residential parking takes up the majority of the second floor along with the theater lobby and 3 retail spaces. The entire third floor is occupied by the ten-auditorium movie theatre. The mechanical equipment is located on the fourth floor, or mechanical floor. At the fourth floor the building foot print reduces from roughly 270ft x 165ft to 190ft x 76ft. Floors five through eleven are all residential levels; floor five consists of nine units, levels six through ten all have eight units, and three penthouse suites makes up the penthouse or eleventh floor.

The structural system of Fraser Centre is reinforced concrete. The gravity load resisting system consists of concrete columns, shear walls, and two-way slabs. The lateral system is composed of reinforced concrete shear walls located throughout the entire building.

Structural Systems

Gravity System

Columns are designed with 5000 psi concrete for the columns below the sixth level and 4000 psi concrete will be used for columns above the sixth level. Figure 2 in the Appendix shows the column locations and the column size and reinforcement can be found in Figure 3a through 3g. Column sizes vary from 18"x24" and 16"x32" to 24"x72" and 36"x60" and there are also 24" diameter columns.

Beams on level 2 garage vary in width from 10" to 36" with 18" being the most common and a depth between 24" and 111", 30" is the most common depth. The theater level beams vary from 12" to 72" and 20" to 48" in width and depth respectively. Beams vary in depth from 24" to 40" and 16" to 48" on the mechanical floor. 12"x 78" and 48"x30" is the range of beams on the roof. All beams are made with 4000 psi concrete.

The parking garage has 9" slabs on grade reinforced with 13#5 bars on top and a bottom grid of #4 bars at 12" each way. 4000psi concrete will be used for the slab on grade. 18#5 top bars and a grid of #5 bottom bars at 12" reinforce the 14" concrete slab of the theatre level. In addition to #7 bottom bars at 9" East-West and #5 bottom bars North-South in the 16" slab, the mechanical floor also has a 12'-6"x7' transfer girder with 40 #11 bottom bars and 20 #11 top bars. The residential levels and penthouse (5 through 11) as well as the roof have 12" slabs reinforced with a grid of #5 bars at 14" east-west and 12" north-south. All of the structural slabs will have 5000 psi concrete and a typical span of 40 feet. Steel beams are used for the projection of the mezzanine floor, and they vary from W8x10 to W12x22.

Lateral System

Concrete shear walls will be used in Fraser Centre to resist lateral loads. Shear walls are composed of 5000 psi concrete and reinforced with #5 horizontal bars and #6 vertical bars. Shear walls are located along column lines 3, 4, 5, 6, and 7 as shown in Figures 2 and 3. The theatre level has 14" shear walls and 16" walls are typical of the parking levels and the residential levels.

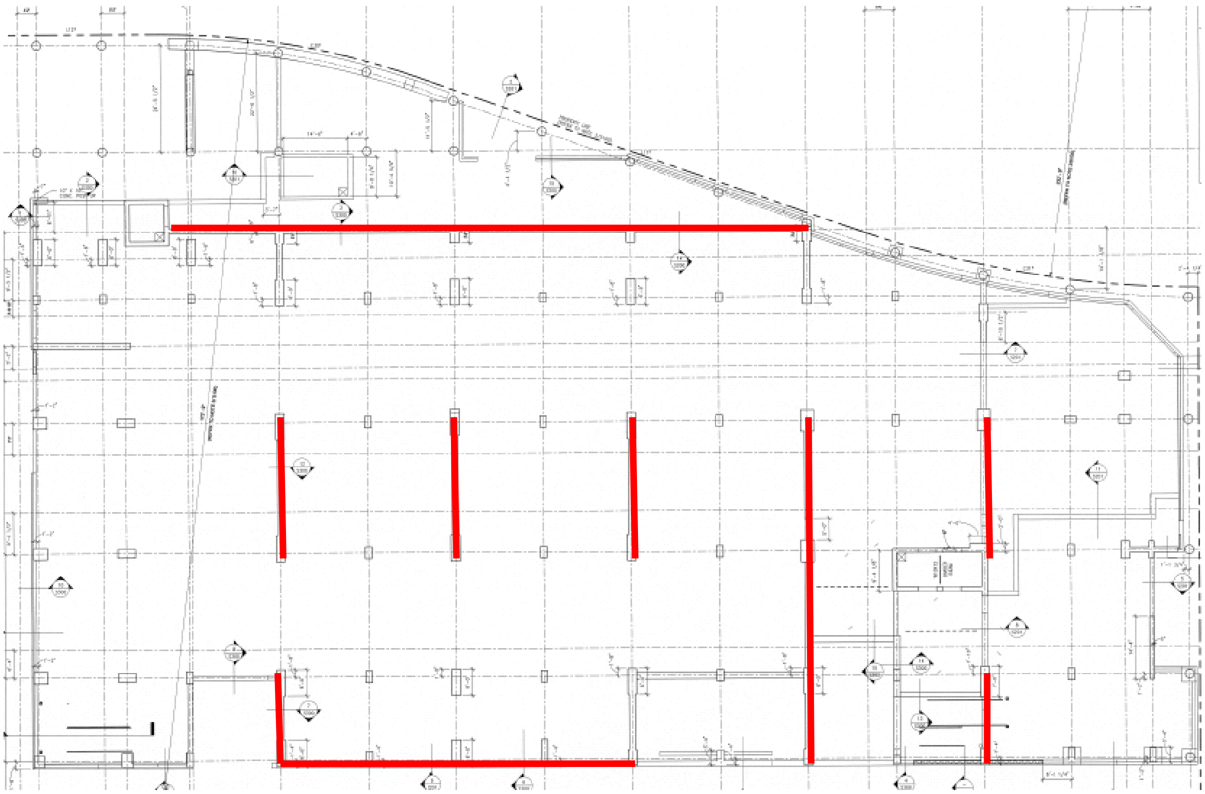

Figure 2: First Floor Shear Wall Plan

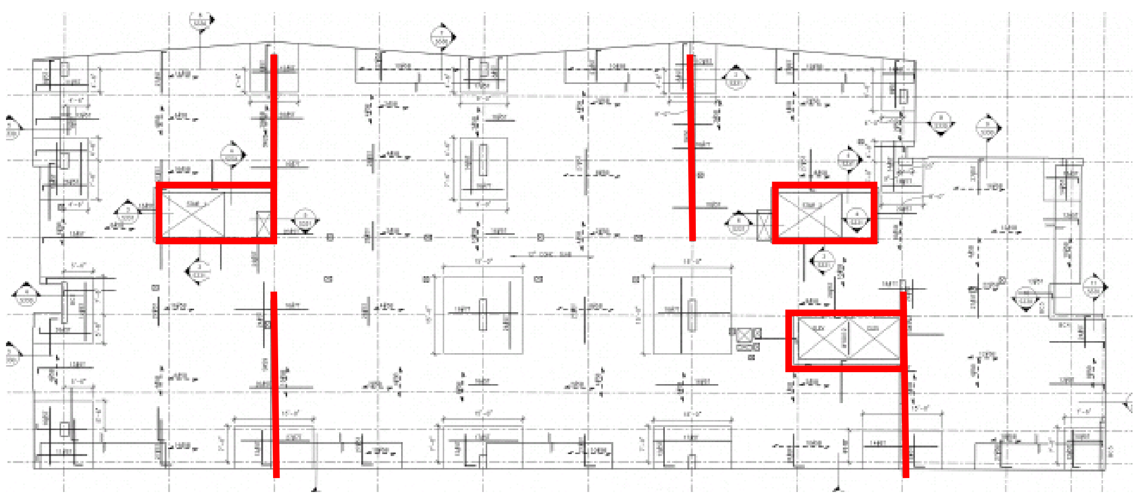

Figure 3: Typical Residential Floor Shear Wall Plan

Design Criteria

The following data is provided to illustrate the general design criteria for Fraser Centre.

Codes & Design Standards

Applied to Original Design
International Building Code **IBC 2006**
American Concrete Institute Building Code **ACI 318-05**
American Institute of Steel Connection **AISC, 9th Edition**
Steel Deck Institute **SDI Specification**
Building Code Requirements for Masonry Structures **ACI 530-05**
American Society for Civil Engineers **ASCE 7-05**

Substituted for Analysis
International Building Code **IBC 2006**
American Concrete Institute Building Code **ACI 318-08**
American Institute of Steel Connection **AISC, 13th Edition**
American Society for Civil Engineers **ASCE 7-10**

Table 1: Codes and Standards used for Original Design and Analysis.

Material Strength Requirements

Material	Strength Requirement
Cast –In-Place Concrete:	
Footings	4 ksi NWC
Basement and Bearing Walls	4 ksi NWC
Shear Walls and Columns	5 ksi NWC
Grade Beams and Slab on Grade	4 ksi NWC
Structural Slab	5 ksi NWC
Reinforcement	ASTM A615, Grade 60
Structural Steel:	
Steel Shapes	ASTM A992
Structural Tubes	ASTM A500
Plates	ASTM A36

Table 2: Material Strength Requirements per drawing S001

Dead and Live Loads

Area	Design Live Load (psf)
Roof/Ground Snow (from drawing S001)	Min 40
Mechanical	125
Rooms	40
Stairs/Public Rooms/Corridors/ Balconies	100
Theater	60
Retail Sales	100
Light Storage	125

	Design Super-Imposed Dead Load (psf)
Roofing	10
Partitions	20
4” Hollow Non-Bearing Block	30 (/sf of wall)
8” Hollow Non-Bearing Block	55 (/sf of wall)
Brick Veneer	40 (/sf of wall)

Table 3: Design Live and Super-Imposed Dead Loads per drawing S001

Lateral Design Loads

Wind Loads

Wind loads were calculated referencing ASCE7-10 and Method 2 for the Main Wind-Force Resisting System (MWFRS). The structure was determined to be rigid according to ASCE 7-10. Fraser Centre was simplified into rectangular shapes for this preliminary analysis. Refer to tables 4 and 5, and figure 4 for a detailed breakdown of the worst case scenario wind loads. For the lateral analysis only the North-South wind forces are used since they resulted in larger forces. Refer to Appendix A for all wind calculations.

North/South Wind Pressure (psf)			
Level	**Height Above Ground (ft)**	**Windward Pressure**	**Leeward Pressure**
Roof	158	10.09	-12.11
	150.25	9.90	-12.11
11	142.5	9.71	-12.11
	136.75	9.55	-12.11
10	131	9.38	-12.11
	125.5	9.21	-12.11
9	120	9.04	-12.11
	114.5	8.88	-12.11
8	109	8.71	-12.11
	103.5	8.54	-12.11
7	98	8.37	-12.11
	92.5	8.17	-12.11
6	87	7.97	-12.11
	81.5	7.77	-12.11
5	76	7.52	-12.11
	70.5	7.25	-12.11
4	65	6.98	-12.11
	48.5	6.16	-12.11
3	32	5.07	-12.11
	21.5	4.10	-12.11
2	11	3.34	-12.11
	5.5	3.34	-12.11
1	0	3.34	-12.11

Table 4: Wind Pressures Acting in the North/South Direction

North/South Wind Forces (kips)			
Level	Height Above Ground (ft)	Story Force	Story Shear
Roof	158	69.6	69.6
11	142.5	50.8	120.3
10	131	47.8	168.1
9	120	47.1	215.2
8	109	46.3	261.5
7	98	45.5	307.0
6	87	44.6	351.6
5	76	43.5	395.1
4	65	161.5	556.6
3	32	91.8	648.5
2	11	44.5	693.0
1	0	0	693.0

Table 5: Wind Forces Acting in the North/South Direction

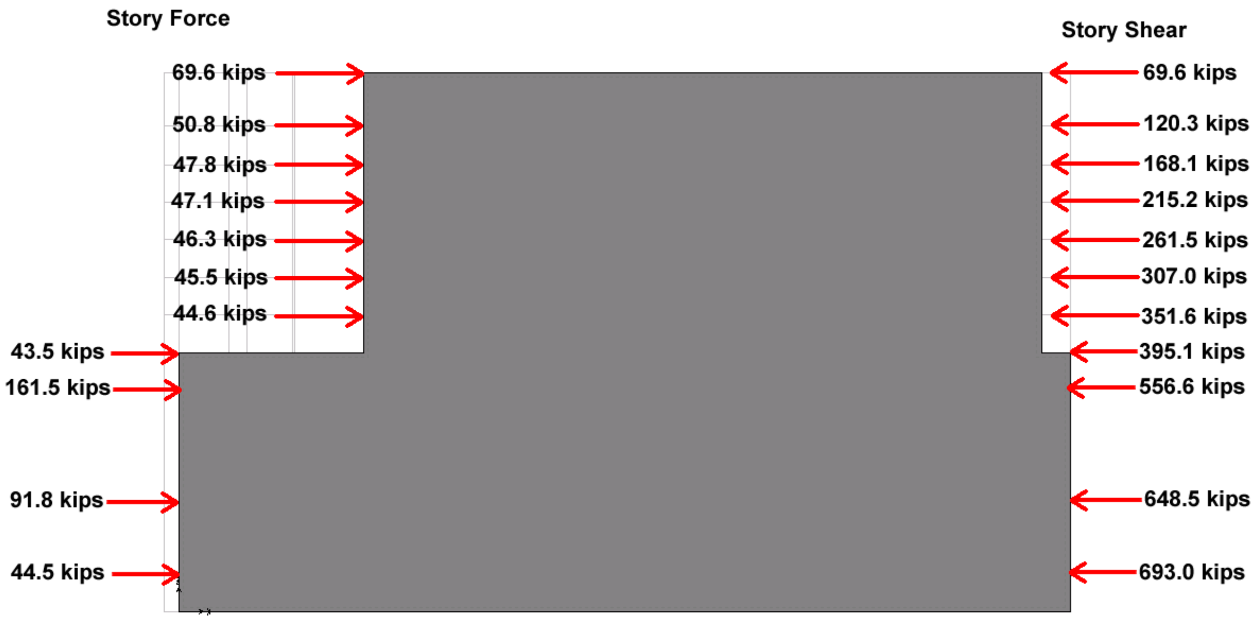

Figure 4: Diagram of Wind Forces Acting in the North/South Direction

Seismic Loads

Seismic loads were calculated referencing ASCE 7-10. These values are detailed in Table 6 and diagramed in Figure 5. The structure was determined to be flexible. Table 7in Appendix B details the building weights of Fraser Centre used to calculate seismic loads. Refer to Appendix B for spreadsheets and calculations.

Seismic Story Shear (kips)			
Level	**Height (ft)**	**Story Force**	**Story Shear**
Roof	158	59.33	0
11	142.5	87.51	59.33
10	131	72.20	146.84
9	120	63.33	219.04
8	109	55.46	282.37
7	98	47.89	337.83
6	87	40.63	385.71
5	76	34.72	426.34
4	65	54.42	461.06
3	32	65.28	515.48
2	11	3.74	580.76
1	0	0	584.50

Table 6: Seismic Story Forces and Shears

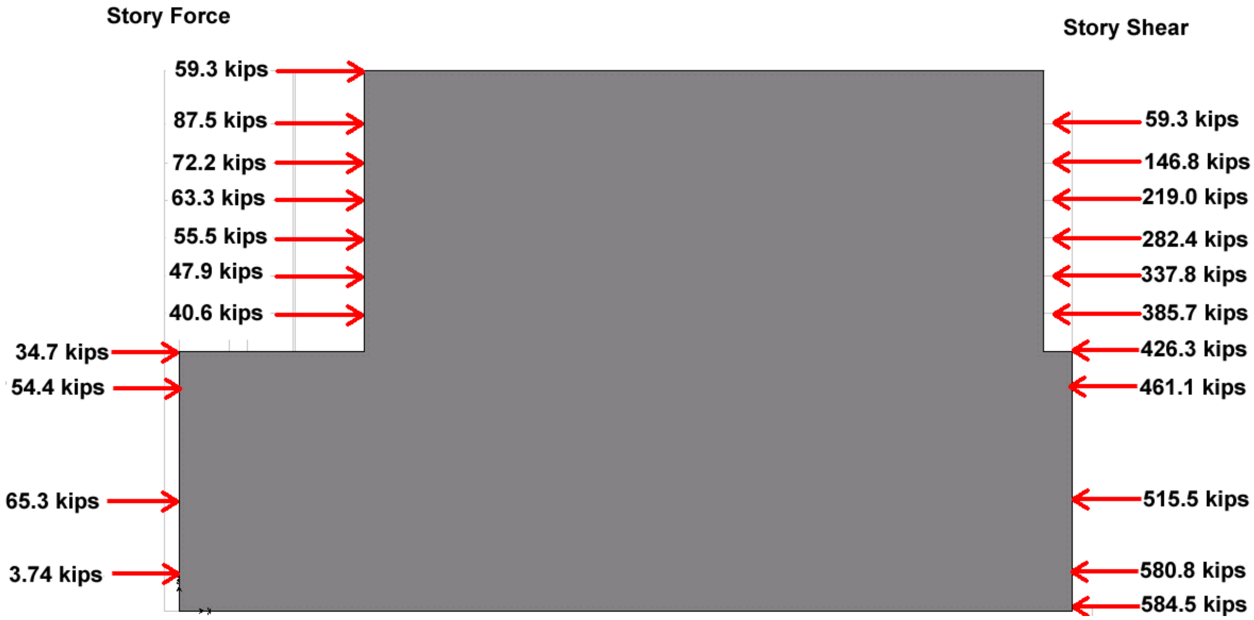

Figure 5: Diagram of Seismic Story Forces and Shears

Lateral Load Distribution

The worst case factored lateral loads are shown in Table 8. Due to the discontinuity of the shear walls through the floors there are only three walls that can reasonably resist the lateral load. SAP was used to model the two walls to determine their relative stiffness to be used in the distribution of the lateral loads. Lateral deflections obtained from the computer models are shown in Table 9 as well as their relative stiffness.

Factored Lateral Story Forces						
Level	1.0 Earthquake		1.6 Wind EW		1.6 Wind NS	
	Story Shear	Story Force	Story Shear	Story Force	Story Shear	Story Force
Roof	0	59.33	91.2	91.2	111.4	111.4
11	59.3	87.51	157.6	66.4	192.5	81.3
10	146.8	72.20	219.8	62.2	269.0	76.5
9	219.0	63.33	281.0	61.1	344.3	75.4
8	282.4	55.46	340.8	59.8	418.4	74.1
7	337.8	47.89	399.4	58.6	491.2	72.8
6	385.7	40.63	456.5	57.1	562.6	71.4
5	426.1	34.72	512.0	55.4	632.2	69.6
4	461.1	54.42	742.6	230.6	890.6	258.4
3	515.5	65.28	871.8	129.1	1037.6	146.9
2	580.8	3.74	933.8	61.9	1108.8	71.2
Base	584.5	0	933.8	0	1108.8	0

Table 8: Worst Case Story Forces and Shears

The largest factored lateral loads come from the 1.6*Wind component with a base shear of 1108.8 kips in the North South direction. Since wind drift is a serviceability requirement the unfactored loads were used and resulted in smaller deflections than the loads due to seismic. The maximum allowable story drifts can be found in table 10.

Story Drift and Building Deflection								
	Story Drift				Total Drift			
Relative Stiffness	0.5894		0.4106					
Level	CL 6 Shear Wall		CL 7 Shear Wall		CL 6 Shear Wall		CL 7 Shear Wall	
Load	E	W_{NS}	E	W_{NS}	E	W_{NS}	E	W_{NS}
Roof	-	-	0.0716	0.0601	-	-	0.4059	0.3448
11	0.0625	0.0451	0.0532	0.0443	0.4282	0.3231	0.3343	0.2847
10	0.0597	0.0431	0.0502	0.0417	0.3657	0.2780	0.2811	0.2404
9	0.0590	0.0429	0.0485	0.0400	0.3060	0.2349	0.2309	0.1987
8	0.0573	0.0419	0.0453	0.0376	0.2470	0.1920	0.1824	0.1587
7	0.0542	0.0400	0.0404	0.0336	0.1897	0.1501	0.1371	0.1211
6	0.0495	0.0368	0.0337	0.0282	0.1355	0.1101	0.0967	0.0875
5	0.0467	0.0352	0.0252	0.0215	0.0860	0.0733	0.0630	0.0593
4	0.0293	0.0259	0.0287	0.0272	0.0393	0.0381	0.0378	0.0378
3	0.0056	0.0068	0.0078	0.0091	0.0100	0.0122	0.0091	0.0106
2	0.0044	0.0054	0.0013	0.0015	0.0044	0.0054	0.0013	0.0015

Table 9: Building and Story Drift

Maximum Allowable Story Drift		
Level	**Seismic Drift (inches)**	**Wind Drift (inches)**
Building	3.16	4.74
11	0.31	0.465
10	0.23	0.345
4-9	0.22	0.33
3	0.66	0.99
2	0.42	0.63

Table 10: Maximum Allowable Story Drifts

Conclusion

This study provided a better understanding of the design Fraser Centre's lateral system. Though this analysis wasn't entirely realistic, with respect to the load distribution, it confirms that assuming only the two continuous shear walls resist the lateral load the structure is properly designed.

In the analysis Fraser Centre stayed well within the allowable story drift and building deflection criteria of L/400 and 0.02H for wind and seismic, respectively. Seismic proved to be the biggest factor in drift considerations with its largest story drift being 0.0716 inches and a building drift of 0.4282 inches. These deflections are drastically smaller than the allowable drifts shown in Table 10.

The comparison between the total forces of the wind load combination and the seismic load combination were relatively similar. The forces from the wind-controlling load seem to stay fairly consistent from the top of the building to the bottom. However, the seismic changes noticeably from floor to floor.

Appendix A: Wind Calculations

Wind calcs

$V = 90$ mph
$K_d = 0.85$

Exposure Category: B

$K_{zt} = 1.0$

$K_z = 1.13$

$q_z = 0.00256\, K_z K_{zt} K_d V^2$
$q_h = 0.00256\, k_h K_{zt} K_d V^2$

$p = q\,GC_p - q_i\,(GC_{pi})$

$q = q_z$ for windward walls
$= q_h$ for leeward, side, and roof

$q_i = q_h$

Gust effect

$L_{eff} = \frac{\Sigma h_i L_i}{\Sigma h_i} \Rightarrow h_z \le 300$
$h_z \le 4 L_{eff}$

$n_a = 75/h \Rightarrow$ flexible building

$$G_f = 0.925\left(\frac{1 + 1.71 I_{\bar{z}} \sqrt{g_Q^2 Q^2 + g_R^2 R^2}}{1 + 1.7\, g_v I_{\bar{z}}}\right)$$

$g_Q = 3.4$
$g_v = 3.4$
$g_R = \sqrt{2\ln(3600 n_a)} + \frac{0.577}{\sqrt{2\ln(3600 n_a)}}$

$R = \sqrt{\frac{1}{\beta} R_n R_h R_B (0.53 + 0.47 R_L)}$
$\beta = 0.02$
$R_n = \frac{7.47 N_1}{(1 + 10.3 N_1)^{5/3}}$
$N_1 = \frac{n_a L_{\bar{z}}}{\bar{V}_{\bar{z}}}$
$\bar{V}_z = \bar{b}\left(\frac{\bar{z}}{33}\right)^{\bar{\alpha}} \cdot \left(\frac{88}{60}\right) V$ T26.9-1

$R_\ell = \frac{1}{\eta} - \frac{1}{2\eta^2}(1 - e^{-2\eta})$

$R_\ell = R_h$: $\eta = 4.6 n_a h / \bar{V}_{\bar{z}}$
$R_\ell = R_B$: $\eta = 4.6 n_a B / \bar{V}_{\bar{z}}$
$R_\ell = R_L$: $\eta = 15.4 n_a L / \bar{V}_{\bar{z}}$

$I_{\bar{z}} = c\left(\frac{33}{\bar{z}}\right)^{1/6}$
$L_{\bar{z}} = \ell\left(\frac{\bar{z}}{33}\right)^{\bar{\epsilon}}$
$\bar{z} = 0.6h$
$Q = \sqrt{\frac{1}{1 + 0.63\left(\frac{B+h}{L_{\bar{z}}}\right)^{0.63}}}$

C_p from Fig 27.4-1, 27.4-2, 27.4-3

GC_{pi} from Table 26.11-1

East/West Pressure		
L/B (1-4)		1.588
L/B (5-R)		2.671
V		90
K_d		0.85
Exposure Category B		
K_{zt}		1
GC_{pi}	+/-	0.18
α		7.0
n_s		0.475
G		0.8926

Level	Z(ft)	K_z	q_z (psf)	q_h (psf)	C_p WW	C_p LW	C_p Side	P_{ww}	P_{LW}	P_{side}	B (width)	Story Height	Area	Force (kips	Story Force	Story Shear	Overturning Moment
Roof	158	1.126	19.846	19.846	0.8	-0.267	-0.7	10.09	-8.13	-15.53	203	7.75	1573.25	28.7	57.0	57.0	9011.2
	150.25	1.111	19.573	19.846	0.8	-0.267	-0.7	9.90	-8.13	-15.53	203	7.75	1573.25	28.4			
11	142.5	1.095	19.300	19.846	0.8	-0.267	-0.7	9.71	-8.13	-15.53	203	5.75	1167.25	20.8	41.5	98.5	23048.0
	136.75	1.082	19.069	19.846	0.8	-0.267	-0.7	9.55	-8.13	-15.53	203	5.75	1167.25	20.6			
10	131	1.068	18.815	19.846	0.8	-0.267	-0.7	9.38	-8.13	-15.53	203	5.5	1116.5	19.6	38.9	137.4	41049.8
	125.5	1.054	18.573	19.846	0.8	-0.267	-0.7	9.21	-8.13	-15.53	203	5.5	1116.5	19.4			
9	120	1.040	18.331	19.846	0.8	-0.267	-0.7	9.04	-8.13	-15.53	203	5.5	1116.5	19.2	38.2	175.6	62120.2
	114.5	1.026	18.088	19.846	0.8	-0.267	-0.7	8.88	-8.13	-15.53	203	5.5	1116.5	19.0			
8	109	1.013	17.846	19.846	0.8	-0.267	-0.7	8.71	-8.13	-15.53	203	5.5	1116.5	18.8	37.4	213.0	85338.4
	103.5	0.999	17.604	19.846	0.8	-0.267	-0.7	8.54	-8.13	-15.53	203	5.5	1116.5	18.6			
7	98	0.984	17.344	19.846	0.8	-0.267	-0.7	8.37	-8.13	-15.53	203	5.5	1116.5	18.4	36.6	249.6	109801.8
	92.5	0.968	17.053	19.846	0.8	-0.267	-0.7	8.17	-8.13	-15.53	203	5.5	1116.5	18.2			
6	87	0.951	16.762	19.846	0.8	-0.267	-0.7	7.97	-8.13	-15.53	203	5.5	1116.5	18.0	35.7	285.3	134626.9
	81.5	0.935	16.471	19.846	0.8	-0.267	-0.7	7.77	-8.13	-15.53	203	5.5	1116.5	17.7			
5	76	0.914	16.110	19.846	0.8	-0.267	-0.7	7.52	-8.13	-15.53	203	5.5	1116.5	17.5	34.6	320.0	158946.2
	70.5	0.892	15.722	19.846	0.8	-0.267	-0.7	7.25	-8.13	-15.53	203	5.5	1116.5	17.2			
4	65	0.870	15.334	19.846	0.8	-0.382	-0.7	6.98	-10.10	-15.53	262	16.5	4323	73.8	144.1	464.1	189113.0
	48.5	0.803	14.145	19.846	0.8	-0.382	-0.7	6.16	-10.10	-15.53	262	16.5	4323	70.3			
3	32	0.712	12.549	19.846	0.8	-0.382	-0.7	5.07	-10.10	-15.53	262	10.5	2751	41.7	80.7	544.9	206548.3
	21.5	0.632	11.139	19.846	0.8	-0.382	-0.7	4.10	-10.10	-15.53	262	10.5	2751	39.0			
2	11	0.570	10.047	19.846	0.8	-0.382	-0.7	3.34	-10.10	-15.53	262	5.5	1441	19.4	38.7	583.6	212967.7
	5.5	0.570	10.047	19.846	0.8	-0.382	-0.7	3.34	-10.10	-15.53	262	5.5	1441	19.4			
1	0	0.570	10.047	19.846	0.8	-0.382	-0.7	3.34	-10.10	-15.53	262	0	0	0.0			
															Total=	583.58	212967.7

North/South Pressure		
L/B (1-4)		0.630
L/B (5-R)		0.374
V		90
K_d		0.85
Exposure Category B		
K_{zt}		1
GC_{pi}	+/-	0.18
α		7.0
n_1		0.475
G		0.8604

Level	Z(ft)	K_z	q_z (psf)	q_h (psf)	C_p WW	C_p LW	C_p Side	P_{ww}	P_{LW}	P_{side}	B (width)	Story Height	Area	Force (kips	Story Force	Story Shear	Overturning Moment
Roof	158	1.126	19.846	19.846	0.8	-0.500	-0.7	10.09	-12.11	-15.53	203	7.75	1573.25	34.9	69.6	69.6	10989.2
	150.25	1.111	19.573	19.846	0.8	-0.500	-0.7	9.90	-12.11	-15.53	203	7.75	1573.25	34.6			
11	142.5	1.095	19.300	19.846	0.8	-0.500	-0.7	9.71	-12.11	-15.53	203	5.75	1167.25	25.5	50.8	120.3	28133.5
	136.75	1.082	19.069	19.846	0.8	-0.500	-0.7	9.55	-12.11	-15.53	203	5.75	1167.25	25.3			
10	131	1.068	18.815	19.846	0.8	-0.500	-0.7	9.38	-12.11	-15.53	203	5.5	1116.5	24.0	47.8	168.1	50155.9
	125.5	1.054	18.573	19.846	0.8	-0.500	-0.7	9.21	-12.11	-15.53	203	5.5	1116.5	23.8			
9	120	1.040	18.331	19.846	0.8	-0.500	-0.7	9.04	-12.11	-15.53	203	5.5	1116.5	23.6	47.1	215.2	75975.4
	114.5	1.026	18.088	19.846	0.8	-0.500	-0.7	8.88	-12.11	-15.53	203	5.5	1116.5	23.4			
8	109	1.013	17.846	19.846	0.8	-0.500	-0.7	8.71	-12.11	-15.53	203	5.5	1116.5	23.2	46.3	261.5	104475.8
	103.5	0.999	17.604	19.846	0.8	-0.500	-0.7	8.54	-12.11	-15.53	203	5.5	1116.5	23.1			
7	98	0.984	17.344	19.846	0.8	-0.500	-0.7	8.37	-12.11	-15.53	203	5.5	1116.5	22.9	45.5	307.0	134558.9
	92.5	0.968	17.053	19.846	0.8	-0.500	-0.7	8.17	-12.11	-15.53	203	5.5	1116.5	22.6			
6	87	0.951	16.762	19.846	0.8	-0.500	-0.7	7.97	-12.11	-15.53	203	5.5	1116.5	22.4	44.6	351.6	165146.0
	81.5	0.935	16.471	19.846	0.8	-0.500	-0.7	7.77	-12.11	-15.53	203	5.5	1116.5	22.2			
5	76	0.914	16.110	19.846	0.8	-0.500	-0.7	7.52	-12.11	-15.53	203	5.5	1116.5	21.9	43.5	395.1	195173.9
	70.5	0.892	15.722	19.846	0.8	-0.500	-0.7	7.25	-12.11	-15.53	203	5.5	1116.5	21.6			
4	65	0.870	15.334	19.846	0.8	-0.500	-0.7	6.98	-12.11	-15.53	262	16.5	4323	82.5	161.5	556.6	231355.5
	48.5	0.803	14.145	19.846	0.8	-0.500	-0.7	6.16	-12.11	-15.53	262	16.5	4323	79.0			
3	32	0.712	12.549	19.846	0.8	-0.500	-0.7	5.07	-12.11	-15.53	262	10.5	2751	47.3	91.8	648.5	252106.6
	21.5	0.632	11.139	19.846	0.8	-0.500	-0.7	4.10	-12.11	-15.53	262	10.5	2751	44.6			
2	11	0.570	10.047	19.846	0.8	-0.500	-0.7	3.34	-12.11	-15.53	262	5.5	1441	22.3	44.5	693.0	259729.7
	5.5	0.570	10.047	19.846	0.8	-0.500	-0.7	3.34	-12.11	-15.53	262	5.5	1441	22.3			
1	0	0.570	10.047	19.846	0.8	-0.500	-0.7	3.34	-12.11	-15.53	262	0	0	0.0			
															Total=	693.01	259729.7

Appendix B: Seismic Calculations

Seismic Calcs

Seismic Importance factor: I=1.25

latitude: 40.793°

Risk Category: III

longitude: -77.862°

Seismic Design Category A

Site Class B

$S_s = 0.147g$
$S_1 = 0.049g$

S_s & S_1 obtained from USGS Ground motion Parameter calculator

$S_{ms} = F_a S_s$

$S_{m1} = F_v S_1$

$S_{DS} = \frac{2}{3} S_{ms}$

$S_{D1} = \frac{2}{3} S_{m1}$

$T_a = C_t h_n^x$

$T = C_u T_a$

$$C_s = \min \begin{cases} \frac{S_{DS}}{R/I} \\ \frac{S_{D1}}{T(R/I)} \\ \frac{S_{D1} T_L}{T^2(R/I)} \end{cases}$$

$V_b = C_s W$

distribution of story shears

$F_x = C_{vx} V_b$

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

$$V_x = \sum_{i=1}^{n} F_i$$

			k=1.38			Story Shear
Level	h_x (ft)	W_x (kips)	$W_x h_x^k$	$C_{v,x}$	F_x	V_x
Roof	158	2533	2740198	0.1015	59.33	0.00
11	142.5	4308	4041478	0.1497	87.51	59.33
10	131	3992	3334455	0.1235	72.20	146.84
9	120	3952	2924739	0.1083	63.33	219.04
8	109	3952	2561330	0.0949	55.46	282.37
7	98	3952	2211612	0.0819	47.89	337.83
6	87	3952	1876521	0.0695	40.63	385.71
5	76	4069	1603284	0.0594	34.72	426.34
4	65	7915	2513456	0.0931	54.42	461.06
3	32	25244	3014846	0.1117	65.28	515.48
2	11	6316	172808	0.0064	3.74	580.76
1	0	1942	0	0	0	584.50

Level	Story Weight (kips)
Roof	2533.1
11	4307.7
10	3991.5
9	3951.9
8	3951.9
7	3951.9
6	3951.9
5	4068.5
4	7915.1
3	25243.7
2	6315.5
1	1941.6
Total Building Weight	72124.4

Table 7: Building Weight by Story