OFFICE BUILDING
Ontario, CA

Structural Technical Report 3
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Lateral System Analysis and Confirmation Design

Maggie Machinsky
Structural Option
Advisor: Andres Lepage

Executive Summary

The following report provides a thorough investigation and in-depth analysis of the lateral force resisting system that exists in Office Building B located in Ontario, California.

A RAM Steel computer model of the building was relied on heavily to aid in the comparison of calculations and designs, as well as forces and load combinations. RAM Frame was also used to analyze and isolate the frames for further analysis. The fact that I relied on ASCE 7-05 for the analysis of seismic and wind loads as opposed to the California Building Code, which was used by the design engineer, accounts for the differences in member sizes and forces.

This lateral force resisting system seems to be sufficiently designed to counteract the wind and seismic forces that Office Building B may undergo at any point in time.

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Introduction

This structure, Office Building B, is located in Ontario, California, and is part of a multi-facility complex which houses two additional buildings. All three buildings will primarily be used for office spaces. No specific construction dates have been established as of yet, however the owner would like to have the building constructed within the coming year.

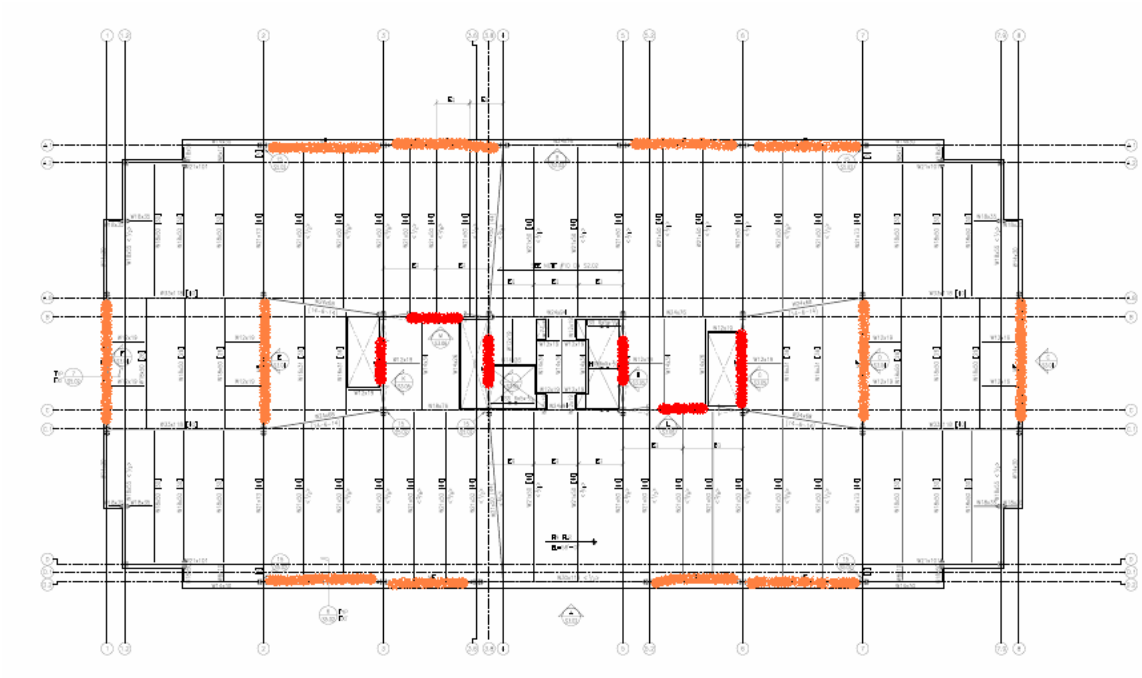
Building B which climbs six stories, is approximately 168,000 square feet of floor space and has a story height of 16 feet from the ground floor to the second floor, and 14 feet for all other floors. The exterior façade is comprised of an appealing combination of alternating ribbons of adobe colored brick and glass.

This steel superstructure is supported by a foundation consisting of a 5" thick slab on grade with #4 reinforcing bars spaced at 15" O.C. in both directions, which is supported by spread footings and grade beams. Floors two through six are comprised of a composite floor system with 3.25" of lightweight concrete fill supported by a 3" metal deck and composite beams.

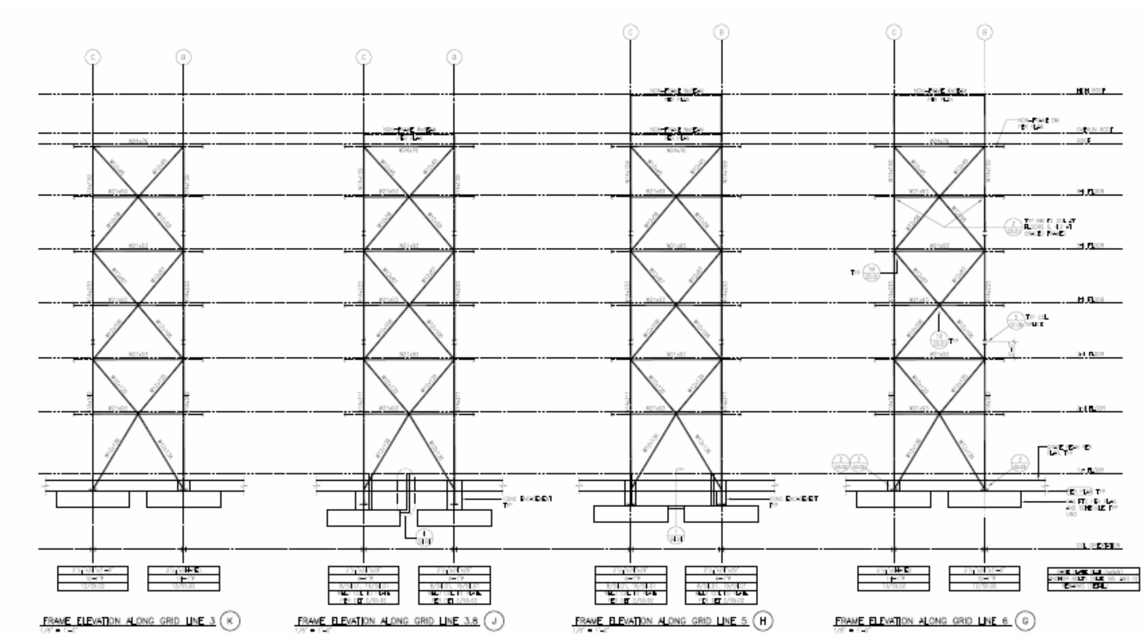
Lateral System Description

The lateral force resisting system in Office Building B consists of a network of specially braced frames and moment frames that combine to make up a dual system. This lateral System frames into the grade beams in order to counteract the large uplift force associated with this type of system. The moment frames are located mainly along the perimeter of the structural framing system with the exception of two on the interior, while the specially braced frames are placed solely on the interior near the center of the building in such places as elevator shafts.

The moment frames are made up of W shapes ranging in size from W36's on the second floor to W27's on the roof level. The braced frames were also constructed using W shapes. These braced frames were designed to distribute lateral forces through triangles formed by the members, much in the same fashion that a truss distributes forces, and range in size from W12x156 to W24x76.



Above is a floor plan with the braces framed highlighted in red and the moment frames highlighted in orange. Below is an elevation of the braced frames.



Lateral Loads

The following are calculations of wind and seismic loads that were computed with the reference of ASCE 7-05. It can be seen that the seismic forces are the forces that control the design of the lateral system.

Wind Pressures (psf)					
Period (T) = 0.6 kzt = 1.0 Ht. = 96 ft Exposure : C Wind Speed = 90 mph			Category II I = 1.0 kd = 0.85 kz = 0.85 Gcpi = +/- 0.18		
z (ft)	kz	qz	$P_{WINDWARD}$	$P_{LEEWARD}$	P_{TOTAL}
0-15	0.85	14.98	12.89	-13.44	26.33
20	0.9	15.86	13.63	-13.44	27.07
25	0.94	16.57	14.25	-13.44	27.69
30	0.98	17.27	14.85	-13.44	28.29
40	1.04	18.33	15.76	-13.44	29.2
50	1.09	19.21	16.52	-13.44	29.96
60	1.13	19.92	17.44	-13.44	30.88
70	1.17	20.62	17.73	-13.44	31.17
80	1.21	21.33	18.34	-13.44	31.78
90	1.24	21.86	18.79	-13.44	32.23
100	1.26	22.21	19.1	-13.44	32.54

Base Shear = 585 k
Overturning Moment = 30321.14 ft-k

Lateral Loads Continued

Seismic Loads

S_{D1} = 1.04	**R = 7.5**	**x = 0.75**
S_{DS} =2.64	**cd = 5**	**Cs = 0.375**
Fa = 1.6	**I = 1.0**	**Ta = 0.613**
Fv = 2.4	**ct = 0.02**	**k = 2**

Floor	Weight (k)	Wx*hx^k	Cvx	Fx
2	2371.5	607104	0.0123	29.47
3	2371.5	2134350	0.0432	103.51
4	2371.5	4591224	0.0929	222.61
5	2371.5	7977726	0.1614	386.74
6	2371.5	12293856	0.2488	596.17
Roof	2870.7	21231697.2	0.4296	1029.4
P.H.	63	580608	0.0117	28.04

Base Shear = 2396.17 k
Overturning Moment = 169947 ft-k

In order to get precise calculations and forces acting on the structure, RAM Structural System and RAM Frame were used to build a model of the framing system. The chart that follows is a comparison of the manually calculated story forces with that of the story forces obtained from the RAM model.

It should be noted that the forces obtained from the RAM model were calculated using a period (T) of 0.891 which is specific to a user – defined equation used by the design engineer, whereas the manual calculations were computed with a period of 0.8582. It is for this reason that differences in the story forces result..

Lateral Loads Continued

Ontario Office Building Story Forces (k)			
		Manual Calcs	RAM Output
Story	Height	Seismic (Y-Dir.)	Seismic (Y-Dir.)
Penthouse	96 ft	0	0
Roof	86ft	1029.4	647.06
6th	72ft	596.17	333.9
5th	58ft	386.74	269.28
4th	44ft	222.61	204.28
3rd	30ft	103.51	137.94
2nd	16ft	29.47	73.57
Base Shear		2396.17 k	
Overturning Moment		169947 ft-k	

Distribution of Lateral Loads

As the lateral loads act on the structure, they are then transformed into story forces which in turn get distributed to the fames. The percentage of these forces that get distributed to each frame is dependent upon the relative stiffness of the members making up the frame. These are the forces obtained from the RAM output, each with a different loading case.

Frame Story Shears							
Frame #	Load Case	Roof	6th	5th	4th	3rd	2nd
0	E4	42.86	40.76	38.41	28.93	33.14	22.36
1	E4	39.45	36.63	34.47	25.2	29.36	18.9
2	E4	148.24	257.05	359.22	448.55	490.21	515.42
3	E4	126.97	219.42	293.26	362.35	396.27	442.51
4	E4	130.55	210.87	272.48	322.72	343.34	365.62
5	E4	118.04	184.91	227.92	270.3	283.97	292.47
6	E4	26.4	20.8	19.36	10.93	14.89	5.62
7	E4	22.99	16.67	15.42	7.2	11.11	2.15

Frame Story Shears							
Frame #	Load Case	Roof	6th	5th	4th	3rd	2nd
0	E3	20.69	14.02	12.9	4.89	8.83	0.15
1	E3	24.94	19.12	17.77	9.47	13.45	4.35
2	E3	114.87	177.74	215.43	253.45	265.49	272.56
3	E3	132.4	211.07	271.74	318.62	337.09	353.69
4	E3	125.59	218.52	292.37	362.81	397.42	446.24
5	E3	150.42	262.24	372.74	468.53	513.29	542.92
6	E3	41.21	38.67	36.43	27	31.15	20.45
7	E3	45.46	43.78	41.3	31.57	35.77	24.65

Torsion

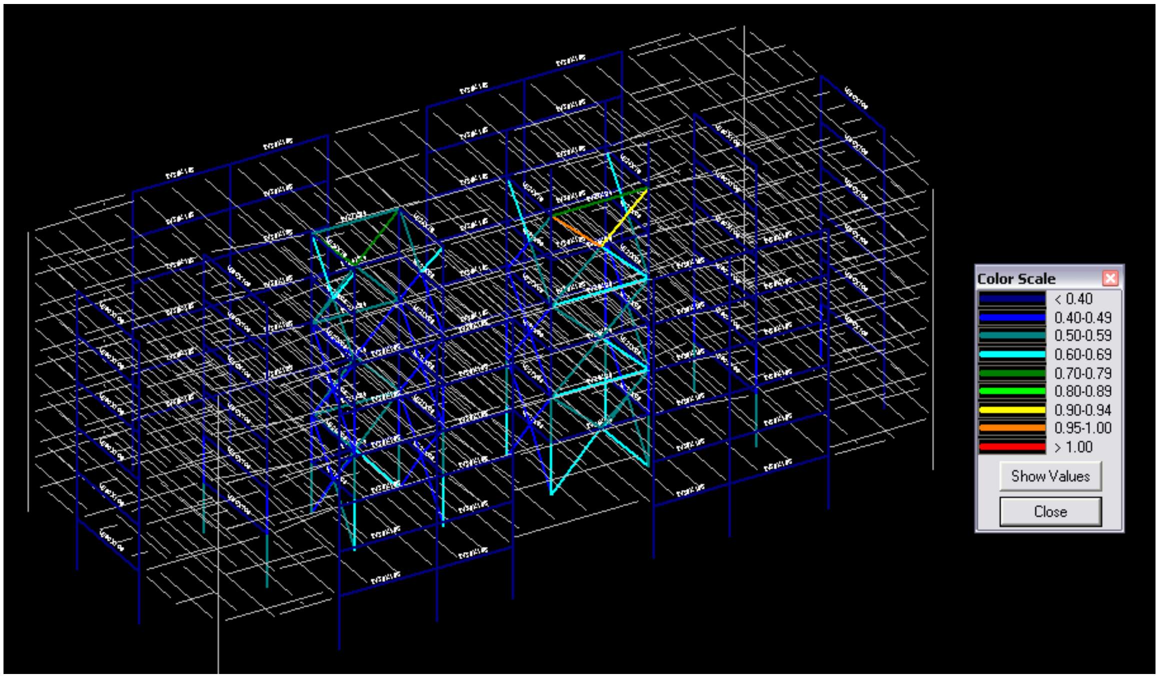
The center of mass as well as the center of rigidity must be calculated in order to calculate the torsion effects that the building experiences from lateral forces. The centers of mass, centers of rigidity and eccentricities are provided below. The overall center of mass of the building is (114.38', 54.84').

Centers of Rigidity						
	Centers of Rigidity		Centers of Mass		Eccentricity	
Level	Xr	Yr	Xm	Ym	Ex	Ey
PH	143.69	54.67	144.17	54.69	0.48	0.02
Roof	113.38	53.5	114.16	54.79	0.78	1.29
6	113.38	53.63	114.42	54.7	1.04	1.07
5	113.38	53.75	114.38	54.71	1	0.96
4	113.39	53.98	114.38	54.71	0.99	0.73
3	113.4	54.1	114.38	54.84	0.98	0.74
2	113.45	54.47	114.38	54.84	0.93	0.37

The eccentricities are extremely small and therefore cause no significant torsion on the building. For this reason in this particular case, torsion may be neglected, and no further analysis is required.

Member Checks

Using RAM Frame, a strength check was conducted on all members making up the lateral force resisting system. This was done using AISC's LRFD method. As pictured below, most members fall in the range of only being subjected to less than fifty percent of their design load.



A spot check on a member of frame #2 is shown on the following page. The applied story shear force was obtained from the RAM model output.

Drift Check

The following are calculations for building drift. Properly designed buildings move in a swaying motion (called drift) when lateral forces act upon them. It is an industry standard that buildings drift no more than H/400, where H is equal to the total building height.

Drift Calculations						
Level	**Height**	**Floor - Floor Ht.**	**H/400**	**Drift**	**Inner Story Displacement**	**H/400**
PH	96	14	2.88	1.9967	0.53289	0.42
Roof	86	14	2.58	1.46381	0.29835	0.42
6	72	14	2.16	1.16546	0.31425	0.42
5	58	14	1.74	0.85121	0.28605	0.42
4	44	14	1.32	0.56516	0.22873	0.42
3	30	14	0.9	0.33643	0.21061	0.42
2	16	16	0.48	0.12582	0.12582	0.48

It can be concluded that this building is far more than adequately designed to follow the code for building drift.

Lateral Frame Overturning Moment

The lateral frames resisting forces in the y – direction are analyzed for this part since they must counteract forces much larger than those resisting forces in the x – direction. Just like the entire building experiences an overturning moment, so does each individual frame. When loaded with lateral seismic forces, the frames undergo the forces calculated below.

Frame#	Overturning Moment
0	11,473.34
1	10,321.32
2	94,780.22
3	78,638.40
4	72,563.58
5	61,776.14
6	5,908.42
7	4,756.24