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November 21, 2008

1100 Broadway
Oakland, CA

Technical Report 3: Lateral System Analysis and Confirmation Design

http://www.engr.psu.edu/ae/thesis/portfolios/2009/sgh132/

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Executive Summary

1100 Broadway is a 20-story office building located in the Bay Area of Oakland, California. It contains 310,000 square feet of office space and 10,000 square feet of retail space at the ground level. The project is currently in the design development phase and construction is scheduled to begin in June of 2010. The gravity system is composite metal deck supported by composite steel beams and the lateral system is composed of eleven total steel moment and concentric braced frames.

The purpose of this technical report is to analyze the building's lateral system and determine the load path and distribution of wind and seismic forces through the structure. To confirm the current design is adequate, spot checks will be performed on a critical frame.

Calculations for this assignment were performed by hand using Microsoft Excel. A 3D ETABS model was also created for reference but the only values taken from the model were displacements to determine the initial stiffness of each frame and drift values.

It was determined that the current lateral system is sufficient to carry wind and seismic loads. Members were significantly over designed according to member checks but this is likely due to a different design controlling parameter such as drift because calculated drift values exceeded those allowed by ASCE 7-05 for seismic.

Introduction

Architectural Overview

1100 Broadway is a 20-story tower primarily used for offices but also provides shopping and entertainment at the ground level. Its architecture combines a new high-rise tower with the adaptive re-use of the Key System Building facade which houses a smaller portion of the building. The Key System Building is a 37,000 square foot historic office building which was damaged in the 1989 Loma Prieta earthquake and has remained vacant ever since. It is now a National Historic Landmark and its facade is incorporated into the design of the first eight floors of 1100 Broadway. Sustainability was a primary concern in the design of 1100 Broadway. It aims to achieve a LEED Gold rating by incorporating many green features into its design. It takes advantage of the opportunity to utilize Transit Oriented Development (TOD) due to its location directly above the 12th Street/City Center BART public transportation station. It features photovoltaic solar panels on the tower roof, a green roof on the Key System Building portion, and a rainwater collection, filtration and reuse system. The building envelope is comprised of high performance glass from floor to roof with large curtain walls on two of the four elevations. The high performance glass is "tuned" depending on which side of the building it's on: At the south and west facades, which receive more direct sun, the glass is slightly darker, at the north and east facades the glass is slightly clearer.

Structural System

Typical office floors are 3¼″ light weight concrete fill on a 3″ 18 gage Verco W3 Formlock composite steel deck for a total thickness of 6¼″. Composite steel beams support the deck. Columns supporting the composite deck are standard structural steel wide flange sections. Mechanical areas are similar to the typical office floors with the exception of normal weight concrete fill in place of the lightweight fill on composite metal deck. The roof system on the tower portion of the structure consists of the same composite steel deck system as the typical office floors.

Wind and earthquake forces are resisted by a dual system composed of Steel Special Concentric Braced Frames located around and across the building core and Special Moment Resisting Frames (SMRF) at the building perimeter. Braces are wide flange members with welded connections. Diagonal bracing member sizes range from W12x96 to W14x132. Member sizes of the moment resisting frames range from W24x94 to W24x207. Lateral forces are distributed to the SMRF at the perimeter of the building and the loads are distributed to surrounding members based on their relative stiffnesses with a higher percentage of the load being distributed to the stiffer members.

The main tower of the building is supported by 110 ton, 14″-square, driven prestressed precast concrete piles beneath a reinforced concrete mat foundation. The structure utilizes 117 existing 14″ square piles and requires 334 new 70′-0″ long prestressed concrete piles. The concrete mat slab is 5′-9″ thick with #11 bars spaced at 12″ O.C. each way on both faces. The remaining portion of the foundation is a 9″ thick reinforced concrete slab with #5 bars spaced at 12″ O.C. Framing within Key System portion of the structure is supported by 6′-0″ square spread footings.

Report Overview

This report provides an analysis of 1100 Broadway's lateral force resisting system. It begins with a determination of the critical wind and seismic loads and load combinations for the structure. The relative stiffness of each frame will be determined and the load distribution path through the structure can then be traced. An analysis of the current lateral system and strength checks will be performed on critical members to confirm that the current system is adequate to carry the lateral loads.

Loads and Load Combinations

Basic load combinations for strength design from ASCE 7-05 were considered and the two critical cases relevant to this analysis are highlighted below.

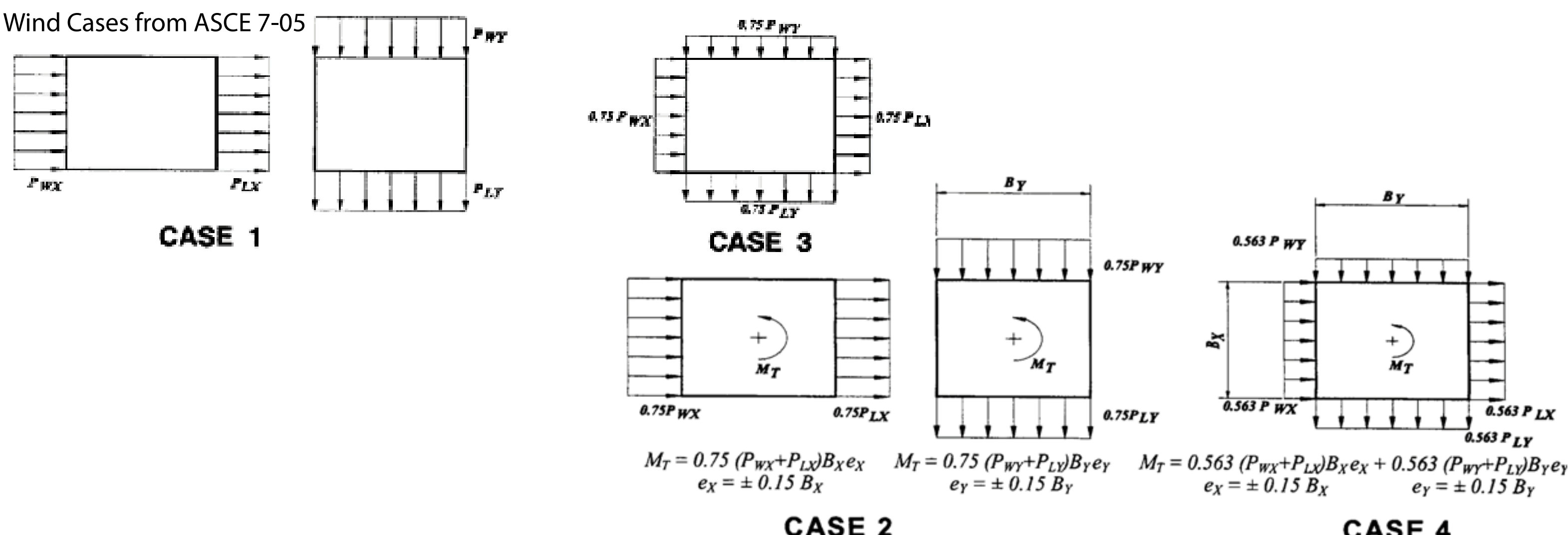
1. 1.4(D + F)
2. 1.2(D + F + T) + 1.6(L + H) + 0.5(Lr or S or R)
3. 1.2D + 1.6(Lr or S or R) + (L or 0.8W)
4. 1.2D + 1.6W + L + 0.5(Lr or S or R)
5. 1.2D + 1.0E + L + 0.2S
6. 0.9D + 1.6W + 1.6H
7. 0.9D + 1.0E + 1.6H

Wind Loads for the Main Wind-Force Resisting System (MWFRS) were determined in accordance with ASCE 7-05, Chapter 6. Flowcharts from "Structural Load Determination Under 2006 IBC and ASCE/SEI 7-05," by David A. Fanella, were used for reference. Method 2, Analytical Procedure, was used to determine the minimum design loads for 1100 Broadway. Seismic Loads were determined in accordance with ASCE 7-05, Chapters 11 and 12. Flowchart 6.8 from "Structural Load Determination Under 2006 IBC and ASCE/SEI 7-05," by David A. Fanella, is used for reference. The Equivalent Lateral Force Procedure was used to determine the minimum seismic design loads for 1100 Broadway.

For wind loads, Case 1,2, and 3 from ASCE 7-05 were considered. See Figure 1. Case 1 is the full design wind pressure acting perpendicular to the principal axis of the structure. Case 2 considers 75% of the wind load acting on the structure with an additional torsional moment. Case 3 is similar to Case 1 except 75% of the wind loads act simultaneously on the structure in each direction. Case 4 was not likely to control due to the regularity of the structure and was not considered. After looking at the three cases there was not much of a difference in the loads computed. This is likely due to the structure's rectangular shape and that its center of rigidity in the East/West direction coincides with the center of pressure of the structure and only differs by several feet in the North/South direction. This prevents the contribution of large torsional forces from moments caused by eccentricity.

Figure 1:

Wind Cases from ASCE 7-05



Loads and Load Combinations

Gravity Loads used in spot checks and seismic load calculations for for the structure are summarized below in Table 1. For live loads see Table 2.

Table 1:
Gravity Loads

	Load Type (psf)								
Level	Beams	Columns	Braces	green roof	Comp. Deck	Misc.	total psf/floor	Floor Area (sf)	**Wx (k)**
Roof	8.8	0.0	0		46.0	25.0	**80**	15613	1245.9
20	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
19	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
18	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
17	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
16	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
15	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
14	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
13	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
12	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
11	8.8	5.9	1.7		46.0	25.0	**87**	15613	1364.6
10	8.8	5.9	1.7		46.0	25.0	**87**	15613	1364.6
9	8.6	5.9	1.7	100	46.0	25.0	**187**	20579	3852.4
8	8.6	8.0	1.7		46.0	25.0	**89**	20579	1837.7
7	8.6	8.0	1.7		46.0	25.0	**89**	20579	1837.7
6	8.6	8.0	1.7		46.0	25.0	**89**	20579	1837.7
5	8.6	9.5	1.7		46.0	25.0	**91**	20579	1868.6
4	8.6	9.5	2.6		46.0	25.0	**92**	20579	1887.1
3	8.6	9.5	2.6		46.0	25.0	**92**	20579	1887.1
2	4.3	9.5	2.6		46.0	25.0	**87**	20579	1798.6
								W=	32950.7

Table 2:
Live Loads

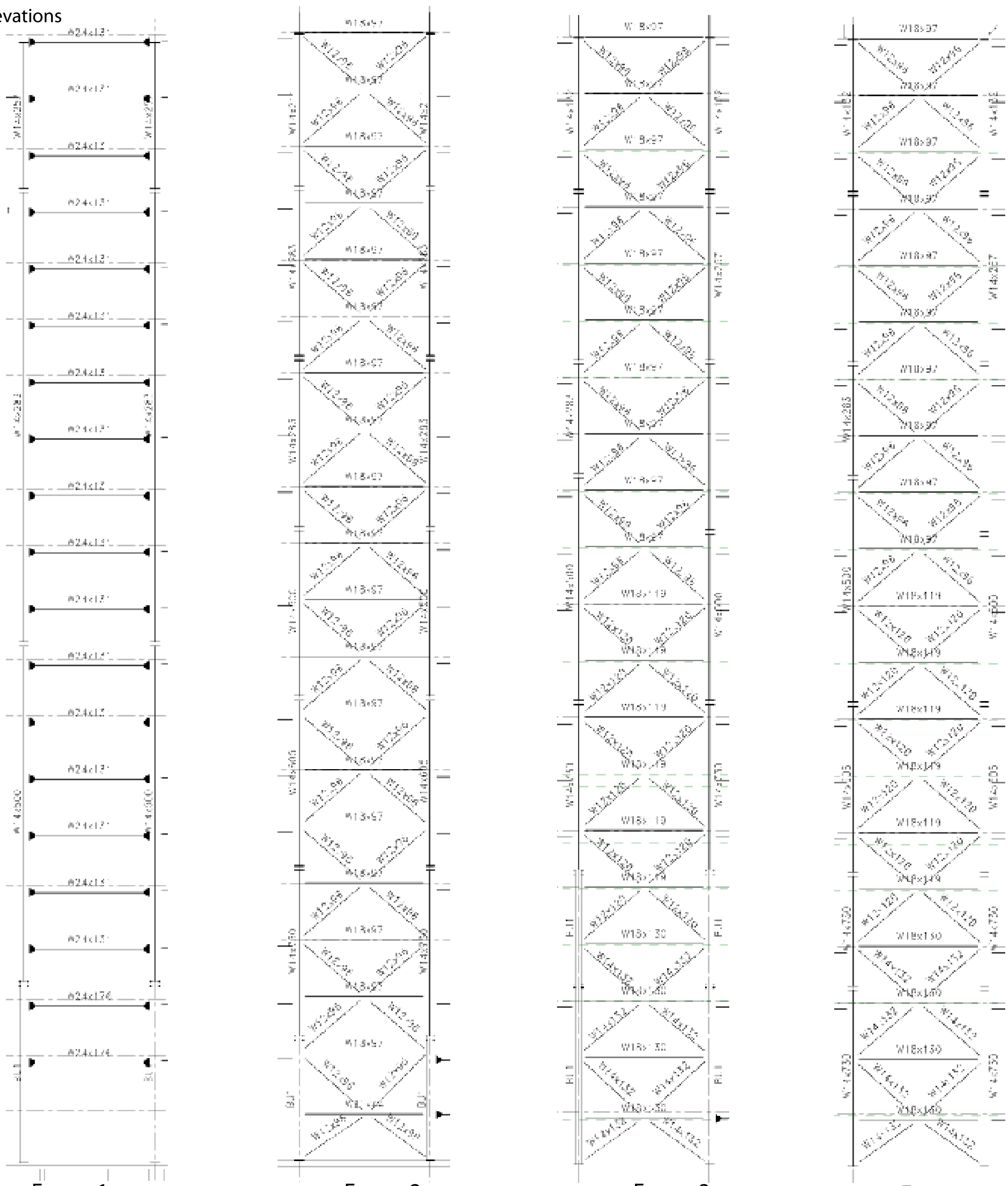
Live Load (psf)	
Corridors	80*
Roof	20

* ASCE 7-05 requires a minimum live load of 100 psf for lobbies and first floor corridors and a live load of 80 psf for corridors above the first floor. Typical floors are open office plans with no designated corridors and therefore a live load of 80 psf was used in spot check calculations in lieu of the 50 psf office load to be conservative since partition layout in the offices are subject to change.

Distribution of Lateral Loads

Lateral forces are resisted by a combination of steel moment and concentric braced frames. In the East/West direction lateral forces are resisted by a total of 7 frames, Frames 1 through 7, see Figures 2 and 3. In the North/South direction lateral forces are resisted by 4 frames, Frames A through D, see Figure 4. A typical plan indicating the frame layout can be seen in Figure 5.

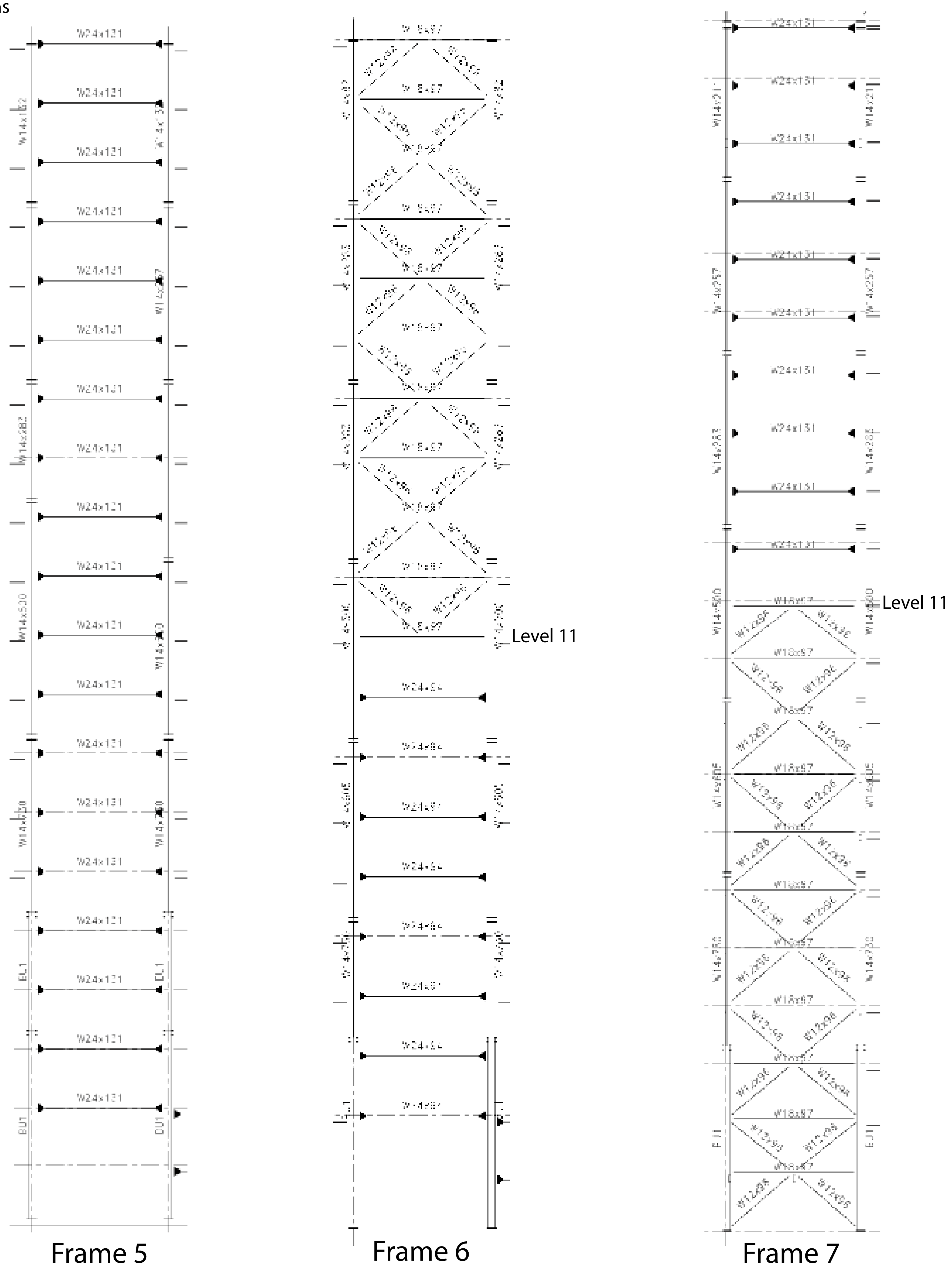
Figure 2:
Frame 1-4 Elevations



Frame 1 Frame 2 Frame 3 Frame 4

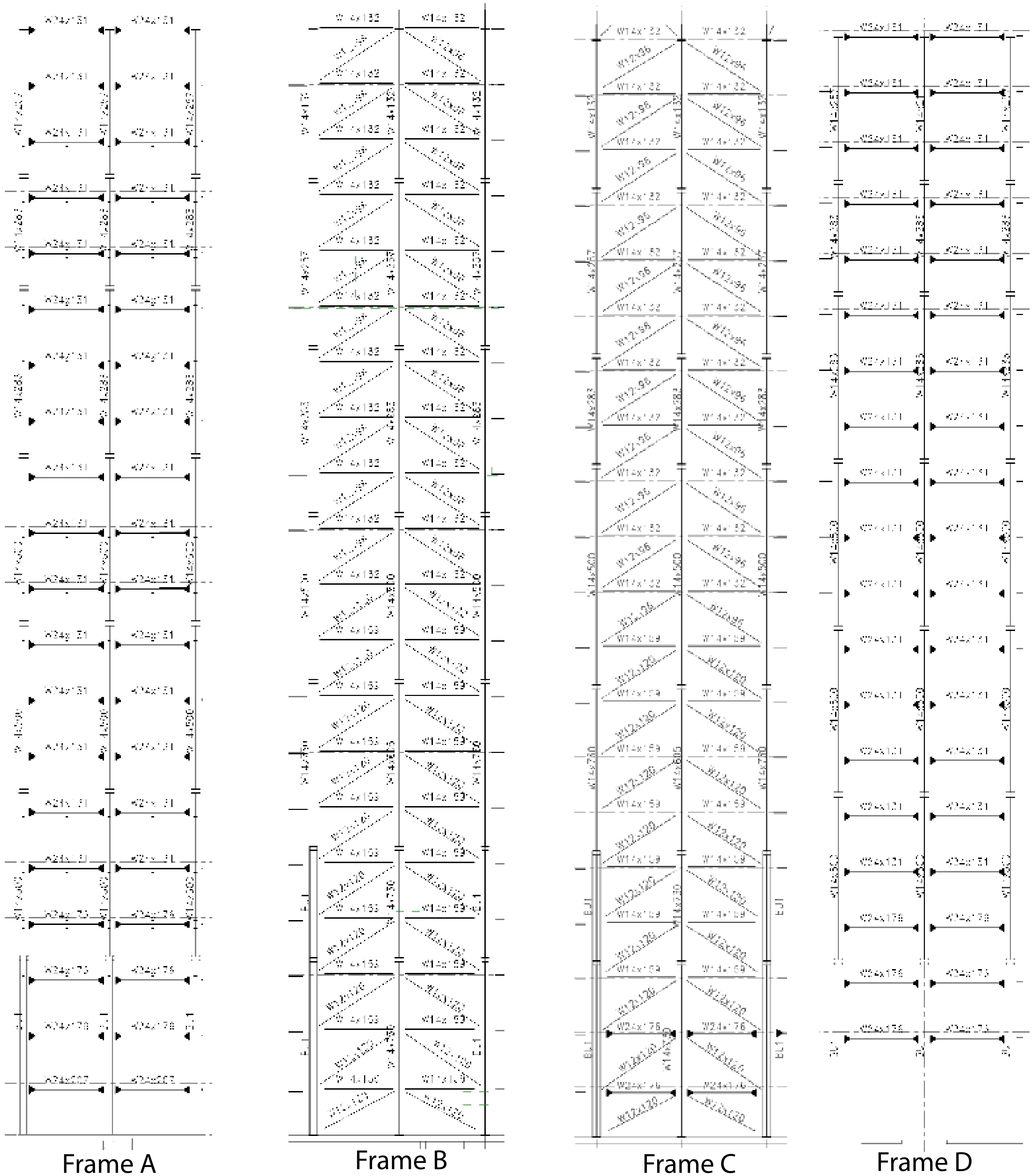
Distribution of Lateral Loads

Figure 3:
Frame 5-7 Elevations



Distribution of Lateral Loads

Figure 4:
Frame A-D Elevations



Distribution of Lateral Loads

Figure 5:
Lateral Load Resisting Frame Layout

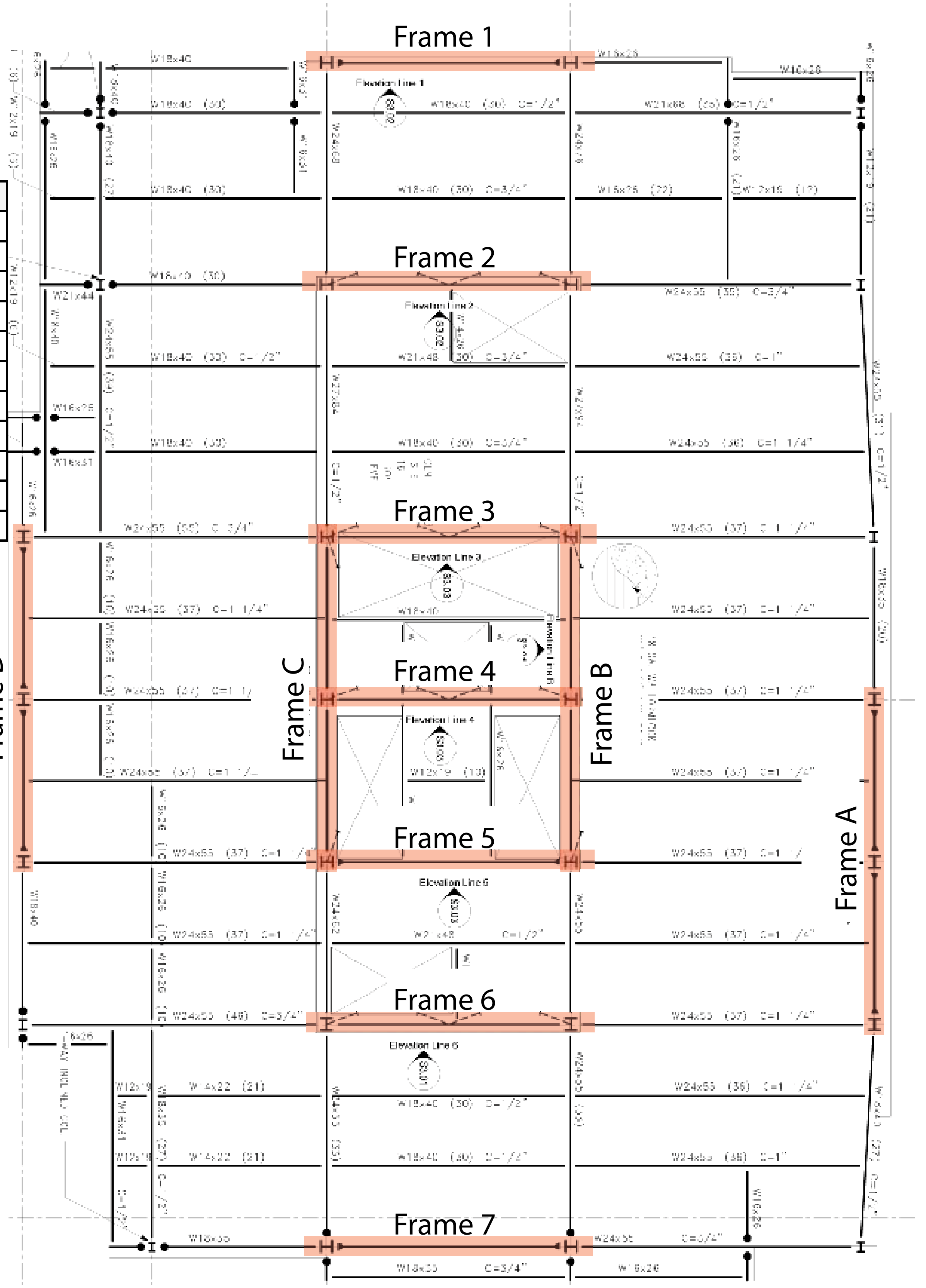


Table 3:
Frame designation and type

Frame	Type
1	Moment
2	Braced
3	Braced
4	Braced
5	Moment
6	Moment/Braced
7	Braced/Moment
A	Moment
B	Braced
C	Braced
D	Moment

Distribution of Lateral Loads

The entire lateral system was modeled in 3-D using ETABS software. To determine the stiffness of each frame I looked at each one separately and locked the rotation, providing a 2-D analysis. I applied a 1 kip unit load at the Roof level and recorded the displacement. This was done for each frame and stiffness was determined by dividing the unit load by the displacement. The relative stiffness of each frame was determined and can be seen below in Table 4. Nine of the eleven frames maintain a similar relative stiffness throughout their height but Frame 6 changes from a moment frame to braced frame at Level 11 and Frame 7 changes from a braced frame to a moment frame at Level 11. This change affects the relative stiffness of all the frames at the corresponding level and it is inaccurate to assume the relative stiffness found at the Roof level is valid throughout the entire height of the frame. Therefore a 1 kip unit load was applied at Level 11 and the same type of analysis was run. Displacements at Level 11 were recorded for each frame and the relative stiffness of each frame at Level 11 was determined. This can also be seen in Table 4.

Table 4:
Determination of Frame Relative Stiffness

	Displacement (inches)		Stiffness K (k/in)		Relative Stiffness Ki/∑kx	
N/S direction	**Roof**	**Level 11**	**Roof**	**Level 11**	**Roof**	**Level 11**
Frame A	0.078192	0.024955	12.8	40.1	10.89%	7.25%
Frame B	0.021717	0.004225	46.0	236.7	39.20%	42.82%
Frame C	0.021693	0.004195	46.1	238.4	39.25%	43.13%
Frame D	0.079863	0.026626	12.5	37.6	10.66%	6.80%
		∑kx=	117.5	552.7		

	Displacement (inches)		Stiffness K (k/in)		Relative Stiffness Ki/∑ky	
E/W direction	**Roof**	**Level 11**	**Roof**	**Level 11**	**Roof**	**Level 11**
Frame 1	0.182731	0.064684	5.5	15.5	4.79%	1.90%
Frame 2	0.035647	0.005462	28.1	183.1	24.56%	22.45%
Frame 3	0.034356	0.004835	29.1	206.8	25.48%	25.36%
Frame 4	0.035469	0.00493	28.2	202.8	24.68%	24.87%
Frame 5	0.180082	0.060477	5.6	16.5	4.86%	2.03%
Frame 6	0.110563	0.079125	9.0	12.6	7.92%	1.55%
Frame 7	0.113649	0.005609	8.8	178.3	7.70%	21.86%
		∑ky=	114.2	815.7		

Distribution of Lateral Loads

Knowing the relative stiffness of each frame allows for the determination of the lateral load distribution to each frame in a particular direction. Since load follows stiffness the frames with higher relative stiffness will resist a larger portion of the total load. In the East/West direction approximately 75% of the total lateral load is distributed evenly between Frames 2, 3, and 4. This is not surprising because the frames are all double-story X-braced with similar member sizes and the other frames in the East/West direction are moment frames or a combination of the two types which makes them less stiff. The largest change in the distribution of loads occurs at Level 11 in Frames 6 and 7. Frame 6 changes from a moment frame at the first eleven levels to a braced frame at all levels above the 11th. Its relative stiffness increases from 1.6% to 7.9%. Making it take a significantly larger portion of the lateral load. Frame 7 sees a reduced portion of the lateral load for levels above the 11th due to its change from a braced frame to a moment frame. Its relative stiffness decreases significantly from 21.9% to 7.7%.

In the North/South direction Frames A through D are nearly symmetric about the center of mass making the center of rigidity coordinate coincide with the center of mass coordinate in that direction. Frames A and D are both moment frames and Frames B and C are chevron-braced frames. Due to relative symmetry and similar relative stiffness Frames A and D see the same amount of load and as do Frames B and C. Approximately 40% of the total load in the North/South direction is distributed to each Frame A and D and approximately 10% to each Frame B and C.

The majority of the lateral system is composed in the center core of the building. Four of the five frames located at the core of the building are braced frames, making that portion of the building very stiff. The frames at the core are connected and interact to provide even more rigidity than they would on their own. This was not accounted for since each frame was isolated and analyzed separately which could account for some difference in the computer model and hand calculations.

Lateral Analysis: Wind

Story forces determined in Technical Report One were applied to the structure and their distribution throughout the frame was analyzed. After showing the direct forces for the entire frame, to keep the report clear, only two levels will be compared instead of all twenty levels. See Table 5 for story forces and direct forces for all levels for each frame. Documentation of the entire frame can be found in Appendix if desired. I chose Level 19 and Level 8 which should be representative of the upper frame and lower frame respectively.

Table 5:
Story and direct forces for all levels of each frame

	y-direction	Fi Direct - Direct Forces in Frames (k)						
Level	Story Force E/W	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7
PR	32.49	1.56	7.98	8.28	8.02	1.58	2.57	2.50
P20	64.54	3.09	15.85	16.45	15.93	3.14	5.11	4.97
P19	64.52	3.09	15.85	16.44	15.93	3.14	5.11	4.97
P18	64.52	3.09	15.85	16.44	15.93	3.14	5.11	4.97
P17	64.27	3.08	15.78	16.38	15.86	3.12	5.09	4.95
P16	62.05	2.97	15.24	15.81	15.32	3.02	4.91	4.78
P15	61.53	2.95	15.11	15.68	15.19	2.99	4.87	4.74
P14	61.10	2.93	15.01	15.57	15.08	2.97	4.84	4.71
P13	59.89	2.87	14.71	15.26	14.78	2.91	4.74	4.61
P12	59.29	2.84	14.56	15.11	14.63	2.88	4.69	4.57
P11	58.65	-16.09	0.60	14.12	15.68	-15.65	-36.94	96.92
P10	57.18	1.08	12.83	14.50	14.22	1.16	0.89	12.50
P9	56.46	1.07	12.67	14.32	14.04	1.14	0.87	12.34
P8	54.96	1.04	12.34	13.93	13.67	1.11	0.85	12.01
P7	53.70	1.02	12.05	13.62	13.35	1.09	0.83	11.74
P6	52.05	0.99	11.68	13.20	12.94	1.06	0.81	11.38
P5	50.53	0.96	11.34	12.81	12.57	1.02	0.78	11.04
P4	48.73	0.92	10.94	12.36	12.12	0.99	0.76	10.65
P3	45.07	0.85	10.12	11.43	11.21	0.91	0.70	9.85
P2	38.14	0.72	8.56	9.67	9.49	0.77	0.59	8.34

Ptotal= PR+P20+P19+...+P11
Ptotal= 652.84
F11=(K11/∑ky)*Ptotal-(Kroof/∑ky)*PR-(Kroof/∑ky)*P20-...-(Kroof/∑ky
F11=(K11/∑ky)*Ptotal-FR-F20-...-F12

	x-direction	Fi Direct - Direct Forces in Frames			
Level	Story Force N/S	Frame A	Frame B	Frame C	Frame D
PR	15.17	1.65	5.95	5.95	1.62
P20	30.10	3.28	11.80	11.82	3.21
P19	30.09	3.28	11.80	11.81	3.21
P18	30.09	3.28	11.80	11.81	3.21
P17	29.96	3.26	11.74	11.76	3.19
P16	28.76	3.13	11.28	11.29	3.07
P15	28.48	3.10	11.16	11.18	3.04
P14	28.24	3.08	11.07	11.08	3.01
P13	27.59	3.00	10.82	10.83	2.94
P12	27.27	2.97	10.69	10.70	2.91
P11	26.93	-8.08	21.52	22.32	-8.83
P10	26.13	2.85	10.24	11.27	1.78
P9	25.74	2.80	10.09	11.10	1.75
P8	24.94	2.72	9.78	10.75	1.69
P7	24.25	2.64	9.51	10.46	1.65
P6	23.36	2.54	9.16	10.08	1.59
P5	22.55	2.46	8.84	9.72	1.53
P4	21.56	2.35	8.45	9.30	1.47
P3	19.64	2.14	7.70	8.47	1.33
P2	16.37	1.78	6.42	7.06	1.11

Ptotal=PR+P20+P19+...+P11
Ptotal= 302.68

Notice the forces are redistributed at Level 11 due to the changing relative stiffness at that level.

Lateral Analysis: Wind

As mentioned previously the three Cases described in ASCE 7-05 were analyzed to determine which is the critical case. Torsion has the potential to have a large amplification on the lateral forces a given frame sees. Values used in the calculation of torsional forces can be seen below in Table 6. Torsion is produced when there is an eccentricity between the center of pressure where the wind load is applied to the structure and the center of rigidity of the lateral elements which the building rotates about. Values for Case 1 can be seen below in Tables 7 and 8.

Table 6:
Values for the determination of forces caused by torsional moments

		Roof			Level 11		
Frame	**dx (in)**	**Ki**	**ki*di^2**	**Ki*di/∑ki*di^2**	**Ki**	**ki*di^2**	**Ki*di/∑ki*di^2**
Frame 1	795.7	5.5	3464866	0.000122	15.5	9788178	0.000045
Frame 2	467.7	28.1	6136373	0.000367	183.1	40048204	0.000316
Frame 3	95.7	29.1	266576	0.000078	206.8	1894207	0.000073
Frame 4	-144.3	28.2	587062	-0.000114	202.8	4223629	-0.000108
Frame 5	-384.3	5.6	820107	-0.000060	16.5	2442027	-0.000023
Frame 6	-624.3	9.0	3525144	-0.000158	12.6	4925757	-0.000029
Frame 7	-952.3	8.8	7979615	-0.000234	178.3	161682170	-0.000626
Frame	**dy (in)**	**Ki**	**ki*di^2**	**Ki*di/∑ki*di^2=**	**Ki**	**ki*di^2**	**Ki*di/∑ki*di^2**
Frame A	-630.0	12.8	5075805.7	-0.000225	40.1	15904123.43	-0.000093
Frame B	-182.0	46.0	1525089.1	-0.000234	236.7	7839138.485	-0.000159
Frame C	178.0	46.1	1460727.4	0.000230	238.4	7553649.607	0.000157
Frame D	626.0	12.5	4907009.8	0.000219	37.6	14718264.86	0.000087

Coordinates (in)	
CR - x	795.7
CR - y	626.01
CP - x level 10-roof	895
CP - y level 10-roof	628
CP - x base-Level 9	1179.75
CP - y base-Level 9	628

Table 7:
Case 1: Forces caused by torsional moments

			Forces caused by torsional moment (k)										
	x-direction story force N/S	**Moment caused by eccentricity y-dir. (k-in)**	**Frame 1**	**Frame 2**	**Frame 3**	**Frame 4**	**Frame 5**	**Frame 6**	**Frame 7**	**Frame A**	**Frame B**	**Frame C**	**Frame D**
P19	30.09	-60	-0.007	-0.022	-0.005	0.007	0.004	0.009	0.014	0.013	0.014	-0.014	-0.013
P8	24.94	-50	-0.002	-0.016	-0.004	0.005	0.001	0.001	0.031	0.005	0.008	-0.008	-0.004

			Forces caused by torsional moment (k)										
	y-direction story force E/W	**Moment caused by eccentricity x-dir. (k-in)**	**Frame 1**	**Frame 2**	**Frame 3**	**Frame 4**	**Frame 5**	**Frame 6**	**Frame 7**	**Frame A**	**Frame B**	**Frame C**	**Frame D**
P19	64.52	-6407	-0.780	-2.352	-0.499	0.729	0.382	1.012	1.502	1.444	1.502	-1.471	-1.405
P8	54.96	-21106	-0.958	-6.668	-1.541	2.279	0.495	0.614	13.222	1.966	3.354	-3.305	-1.831

Table 8:
Case 1: Net Forces

	Net Force (k)										
Level	**Frame 1**	**Frame 2**	**Frame 3**	**Frame 4**	**Frame 5**	**Frame 6**	**Frame 7**	**Frame A**	**Frame B**	**Frame C**	**Frame D**
19	2.311	13.495	15.943	16.655	3.519	6.121	6.472	3.290	11.812	11.797	3.195
8	0.084	5.667	12.393	15.946	1.609	1.466	25.233	2.720	9.784	10.747	1.690

Lateral Analysis: Wind

Values for Case 2 where 75% of the wind load acting on the structure with an additional torsional moment can be seen below in Tables 9 and 10.

Table 9:
Case 2: Forces caused by torsional moments

			Forces caused by torsional moment (k)										
	x-direction story force N/S (.75P)	Moment caused by eccentricity y-dir. (k-in) M=.75P(.15x+d)	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
P19	22.57	4207	0.512	1.544	0.328	-0.479	-0.251	-0.665	-0.986	-0.948	-0.986	0.966	0.923
P8	18.70	3486	0.158	1.280	0.255	-0.377	-0.082	-0.101	-2.184	-0.325	-0.554	0.546	0.302

			FT = Forces caused by torsional moment (k)										
	(.75P) y-direction story force E/W	Moment caused by eccentricity x-dir. (k-in) M=.75P(.15x+d)	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
P19	48.39	12322	1.501	4.522	0.960	-1.402	-0.736	-1.946	-2.888	-2.777	-2.888	2.828	2.702
P8	41.22	-1242	-0.056	-0.456	-0.091	0.134	0.029	0.036	0.778	0.116	0.197	-0.194	-0.108

Table 10:
Case 2: Net Forces

	Net Force (k)										
Level	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
19	4.592	20.369	17.402	14.524	2.401	3.163	2.082	2.328	10.811	12.776	4.131
8	0.985	11.879	13.844	13.800	1.143	0.888	12.790	2.390	9.222	11.301	1.997

Values for Case 3 where 75% of the wind loads act simultaneously on the structure in each direction can be seen in Tables 11 and 12.

Table 11:
Case 3: Forces caused by torsional moments

		Forces caused by torsional moment (k)												
	Moment caused by eccentricity y-dir. (k-in) M=.75Pd	Moment caused by eccentricity x-dir. (k-in) M=.75Pd	Sum Moments (k-in)	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
P19	-44.914	-4805	-4850	-0.591	-1.780	-0.378	0.552	0.290	0.766	1.137	1.093	1.137	-1.113	-1.064
P8	-37.217	-15829	-15866	-0.720	-5.823	-1.159	1.714	0.372	0.462	9.940	1.478	2.522	-2.484	-1.376

Table 12:
Case 3: Net Forces

	Net Forces (k)										
	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
P19	1.728	10.105	11.954	12.497	2.642	4.598	4.865	3.551	9.985	7.745	1.343
P8	0.061	3.428	9.292	11.963	1.208	1.101	18.948	2.834	10.531	5.582	-0.106

Lateral Analysis: Seismic

Seismic story force loads were computed in Technical Report 1 and were distributed to each frame in a similar manner as the wind loads. For seismic the force is applied at the center of mass and rotates about the center of rigidity versus the center of pressure that was used for the wind analysis. See Table 13 below for the direct forces for all levels of each frame due to seismic loads.

Table 13:
Direct forces in each frame due to seismic loads

	y-direction	Fi Direct - Direct Forces in Frames (k)						
	Story Force E/W	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7
PR	194.43	9.32	47.75	49.55	47.99	9.45	15.40	14.98
P20	175.85	8.43	43.19	44.81	43.40	8.55	13.92	13.55
P19	158.17	7.58	38.85	40.31	39.04	7.69	12.52	12.18
P18	141.40	6.77	34.73	36.03	34.90	6.87	11.20	10.89
P17	125.54	6.01	30.83	31.99	30.99	6.10	9.94	9.67
P16	110.59	5.30	27.16	28.18	27.30	5.38	8.76	8.52
P15	96.56	4.63	23.72	24.61	23.84	4.69	7.65	7.44
P14	83.46	4.00	20.50	21.27	20.60	4.06	6.61	6.43
P13	71.28	3.41	17.51	18.16	17.59	3.47	5.64	5.49
P12	60.03	2.88	14.74	15.30	14.82	2.92	4.75	4.62
P11	50.18	-34.30	-14.47	11.19	14.73	-33.49	-76.75	183.27
P10	40.72	0.77	9.14	10.33	10.13	0.83	0.63	8.90
P9	90.97	1.72	20.42	23.07	22.62	1.84	1.41	19.88
P8	33.25	0.63	7.46	8.43	8.27	0.67	0.52	7.27
P7	24.41	0.46	5.48	6.19	6.07	0.49	0.38	5.34
P6	16.90	0.32	3.79	4.29	4.20	0.34	0.26	3.69
P5	10.91	0.21	2.45	2.77	2.71	0.22	0.17	2.38
P4	6.08	0.12	1.36	1.54	1.51	0.12	0.09	1.33
P3	2.57	0.05	0.58	0.65	0.64	0.05	0.04	0.56
P2	0.52	0.01	0.12	0.13	0.13	0.01	0.01	0.11

	x-direction	Fi Direct - Direct Forces in Frames (k)			
	Story Force N/S	Frame A	Frame B	Frame C	Frame D
PR	194.43	21.17	76.22	76.31	20.73
P20	175.85	19.15	68.94	69.02	18.75
P19	158.17	17.22	62.01	62.08	16.86
P18	141.40	15.40	55.43	55.50	15.07
P17	125.54	13.67	49.22	49.27	13.38
P16	110.59	12.04	43.36	43.40	11.79
P15	96.56	10.51	37.86	37.90	10.29
P14	83.46	9.09	32.72	32.75	8.90
P13	71.28	7.76	27.94	27.97	7.60
P12	60.03	6.54	23.53	23.56	6.40
P11	50.18	-40.65	65.56	68.91	-43.64
P10	40.72	4.43	15.96	17.56	2.77
P9	90.97	9.90	35.66	39.23	6.18
P8	33.25	3.62	13.03	14.34	2.26
P7	24.41	2.66	9.57	10.53	1.66
P6	16.90	1.84	6.63	7.29	1.15
P5	10.91	1.19	4.28	4.71	0.74
P4	6.08	0.66	2.38	2.62	0.41
P3	2.57	0.28	1.01	1.11	0.17
P2	0.52	0.06	0.20	0.22	0.04

Lateral Analysis: Seismic

The forces caused by torsional moments were computed and can be seen below in Table 14. Net seismic forces are located in Table 15.

Table 14:
Torsional forces in each frame due to seismic loads

			Forces caused by torsional moment (k)										
Level	x-direction story force N/S	Moment caused by eccentricity y-dir. (k-in)	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
P19	158.17	-315	-0.038	-0.116	-0.025	0.036	0.019	0.050	0.074	0.071	0.074	-0.072	-0.069
P8	33.25	-66	-0.003	-0.021	-0.005	0.007	0.002	0.002	0.041	0.006	0.011	-0.010	-0.006

			Forces caused by torsional moment (k)										
Level	y-direction story force E/W (k)	Moment caused by eccentricity x-dir. (k-in)	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
P19	158.17	-15706	-1.913	-5.765	-1.224	1.787	0.938	2.481	3.682	3.540	3.682	-3.605	-3.444
P8	33.25	-12768	-0.580	-4.034	-0.933	1.379	0.299	0.372	7.999	1.189	2.029	-1.999	-1.108

Table 15:
Net forces in each frame due to seismic loads

	Net Force (k)										
Level	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
P19	6.790	36.47	39.80	39.78	8.08	13.55	13.70	18.68	63.52	60.59	15.44
P8	-0.330	0.78	6.89	10.55	1.17	1.13	20.52	5.59	16.40	11.03	0.42

Lateral Analysis: Summary

After performing the lateral analysis the wind and seismic loads can be compared by looking at the critical load cases:

1.2D + 1.6W + L + 0.5(Lr or S or R)
1.2D + 1.0E + L + 0.2

When factored, earthquake is multiplied by 1.0 and wind by 1.6. It's typical throughout the frames that earthquake forces are larger than wind for the upper half of the frame and wind forces are larger than earthquake forces for the lower portion of the frame. The controlling load combination may be dependent on the particular floor under consideration. See Table 16 below.

Table 16:
1.0Earthquake vs. 1.6Wind Comparison

1.0 Earthquake (k)										
Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
9.3	47.8	49.5	48.0	9.5	15.4	15.0	21.2	76.2	76.3	20.7
8.4	43.2	44.8	43.4	8.5	13.9	13.5	19.1	68.9	69.0	18.7
7.6	38.8	40.3	39.0	7.7	12.5	12.2	17.2	62.0	62.1	16.9
6.8	34.7	36.0	34.9	6.9	11.2	10.9	15.4	55.4	55.5	15.1
6.0	30.8	32.0	31.0	6.1	9.9	9.7	13.7	49.2	49.3	13.4
5.3	27.2	28.2	27.3	5.4	8.8	8.5	12.0	43.4	43.4	11.8
4.6	23.7	24.6	23.8	4.7	7.6	7.4	10.5	37.9	37.9	10.3
4.0	20.5	21.3	20.6	4.1	6.6	6.4	9.1	32.7	32.8	8.9
3.4	17.5	18.2	17.6	3.5	5.6	5.5	7.8	27.9	28.0	7.6
2.9	14.7	15.3	14.8	2.9	4.8	4.6	6.5	23.5	23.6	6.4
-34.3	-14.5	11.2	14.7	-33.5	-76.8	183.3	-40.6	65.6	68.9	-43.6
0.8	9.1	10.3	10.1	0.8	0.6	8.9	4.4	16.0	17.6	2.8
1.7	20.4	23.1	22.6	1.8	1.4	19.9	9.9	35.7	39.2	6.2
0.6	7.5	8.4	8.3	0.7	0.5	7.3	3.6	13.0	14.3	2.3
0.5	5.5	6.2	6.1	0.5	0.4	5.3	2.7	9.6	10.5	1.7
0.3	3.8	4.3	4.2	0.3	0.3	3.7	1.8	6.6	7.3	1.1
0.2	2.4	2.8	2.7	0.2	0.2	2.4	1.2	4.3	4.7	0.7
0.1	1.4	1.5	1.5	0.1	0.1	1.3	0.7	2.4	2.6	0.4
0.0	0.6	0.7	0.6	0.1	0.0	0.6	0.3	1.0	1.1	0.2
0.0	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.2	0.2	0.0

1.6 Wind (k)										
Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
2.5	12.8	13.2	12.8	2.5	4.1	4.0	2.6	9.5	9.5	2.6
4.9	25.4	26.3	25.5	5.0	8.2	8.0	5.2	18.9	18.9	5.1
4.9	25.4	26.3	25.5	5.0	8.2	8.0	5.2	18.9	18.9	5.1
4.9	25.4	26.3	25.5	5.0	8.2	8.0	5.2	18.9	18.9	5.1
4.9	25.3	26.2	25.4	5.0	8.1	7.9	5.2	18.8	18.8	5.1
4.8	24.4	25.3	24.5	4.8	7.9	7.6	5.0	18.0	18.1	4.9
4.7	24.2	25.1	24.3	4.8	7.8	7.6	5.0	17.9	17.9	4.9
4.7	24.0	24.9	24.1	4.8	7.7	7.5	4.9	17.7	17.7	4.8
4.6	23.5	24.4	23.7	4.7	7.6	7.4	4.8	17.3	17.3	4.7
4.5	23.3	24.2	23.4	4.6	7.5	7.3	4.8	17.1	17.1	4.7
-25.8	1.0	22.6	25.1	-25.0	-59.1	155.1	-12.9	34.4	35.7	-14.1
1.7	20.5	23.2	22.8	1.9	1.4	20.0	4.6	16.4	18.0	2.8
1.7	20.3	22.9	22.5	1.8	1.4	19.7	4.5	16.1	17.8	2.8
1.7	19.7	22.3	21.9	1.8	1.4	19.2	4.3	15.6	17.2	2.7
1.6	19.3	21.8	21.4	1.7	1.3	18.8	4.2	15.2	16.7	2.6
1.6	18.7	21.1	20.7	1.7	1.3	18.2	4.1	14.7	16.1	2.5
1.5	18.1	20.5	20.1	1.6	1.3	17.7	3.9	14.1	15.6	2.5
1.5	17.5	19.8	19.4	1.6	1.2	17.0	3.8	13.5	14.9	2.3
1.4	16.2	18.3	17.9	1.5	1.1	15.8	3.4	12.3	13.6	2.1
1.2	13.7	15.5	15.2	1.2	0.9	13.3	2.9	10.3	11.3	1.8

Drift

Service loads were applied to the structure and displacements were tabulated using the ETABS model. The corresponding story drifts were then calculated. Seismic loads produced the greatest drift in each direction. The wind loads were well within the industry standard servicibility criterion of h/400. Seismic loads were compared with the ASCE 7-05 limit of 0.02hsx and were all higher than the limit. See Tables 17 and 18 respectively below.

Table 17:
Allowable story drift from ASCE 7-05

TABLE 12.12-1 ALLOWABLE STORY DRIFT, $\Delta_a^{a,b}$

Structure	Occupancy Category		
	I or II	III	IV
Structures, other than masonry shear wall structures, 4 stories or less with interior walls, partitions, ceilings and exterior wall systems that have been designed to accommodate the story drifts.	$0.025h_{sx}^{c}$	$0.020h_{sx}$	$0.015h_{sx}$
Masonry cantilever shear wall structures [d]	$0.010h_{sx}$	$0.010h_{sx}$	$0.010h_{sx}$
Other masonry shear wall structures	$0.007h_{sx}$	$0.007h_{sx}$	$0.007h_{sx}$
All other structures	$0.020h_{sx}$	$0.015h_{sx}$	$0.010h_{sx}$

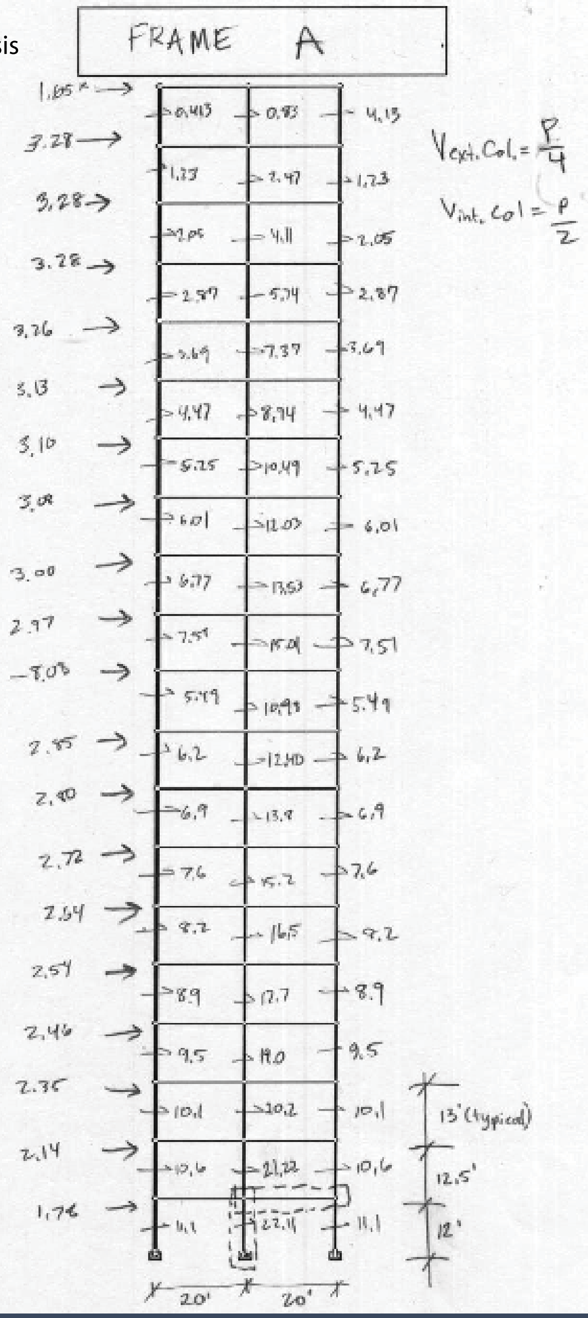
Table 18:
Maximum drift for earthquake and wind loads in each direction

	Drift (in.)				Allowable story drift	Story Drift
Level	Earthquake X	Wind X	Earthquake Y	Wind Y	=0.02hsx Earthquake (in)	=h/400 Wind (in)
ROOF	7.310	1.634	5.971	2.855	5.17	7.76
20	6.889	1.552	5.590	2.695	4.91	7.37
19	6.447	1.467	5.199	2.531	4.65	6.98
18	5.989	1.378	4.800	2.363	4.39	6.59
17	5.520	1.286	4.400	2.193	4.13	6.20
16	5.044	1.192	3.998	2.020	3.87	5.81
15	4.567	1.095	3.602	1.847	3.61	5.42
14	4.094	0.998	3.210	1.674	3.35	5.03
13	3.630	0.900	2.838	1.504	3.09	4.64
12	3.191	0.804	2.477	1.338	2.83	4.25
11	2.764	0.709	2.143	1.178	2.57	3.86
10	2.364	0.618	1.826	1.021	2.31	3.47
9	1.995	0.531	1.536	0.873	2.05	3.08
8	1.641	0.446	1.253	0.727	1.79	2.69
7	1.306	0.364	0.994	0.589	1.53	2.30
6	0.995	0.285	0.749	0.456	1.27	1.91
5	0.715	0.211	0.537	0.335	1.01	1.52
4	0.468	0.143	0.344	0.222	0.75	1.13
3	0.261	0.083	0.191	0.128	0.49	0.74
2	0.096	0.032	0.064	0.046	0.24	0.36

Member Checks

Spot checks were performed on critical members to check the adequacy of the current design. A W14x730 interior column at the base of Frame A and a W14x207 Level 2 beam were considered. Portal analysis was used to determine the moments in the column and beam. See Figure 6. It was determined that the beam will only carry approximately 22% of its capacity and the column will only carry about 10% of its capacity. The over design of the lateral system could be a result of drift controlling rather than what was considered in the spot check. The drift analysis showed that drift due to seismic forces was significantly higher than what was prescribed by ASCE 7-05 and this will have large repercussions on member design. A building overturning check was also performed and calculations show the weight of the building is more than sufficient to keep it from overturning.

Figure 6:
Portal Analysis



Conclusion

1100 Broadway's current lateral system is sufficient to resist wind and seismic loads. A drift analysis was performed and it was found that drift due to wind was within industry accepted values but the seismic drift was approximately two inches greater than that allowed by ASCE 7-05. Member checks revealed the current lateral system is significantly over designed but after performing the drift analysis this could be an indication that large drifts controlled the design of members of the lateral system.

The effects of overturning were taken into account in both the wind and seismic analyses. Forces with torsional effects were not significantly higher to those without which could be a result of the regular geometry of the building and its rather symmetrical lateral framing system.

Appendix A: Wind

Table A.1
Determination of Frame Relative Stiffness

	Displacement (inches)		Stiffness K (k/in)		Relative Stiffness Ki/∑kx	
N/S direction	**Roof**	**Level 11**	**Roof**	**Level 11**	**Roof**	**Level 11**
Frame A	0.078192	0.024955	12.8	40.1	10.89%	7.25%
Frame B	0.021717	0.004225	46.0	236.7	39.20%	42.82%
Frame C	0.021693	0.004195	46.1	238.4	39.25%	43.13%
Frame D	0.079863	0.026626	12.5	37.6	10.66%	6.80%
		∑kx=	117.5	552.7		

	Displacement (inches)		Stiffness K (k/in)		Relative Stiffness Ki/∑ky	
E/W direction	**Roof**	**Level 11**	**Roof**	**Level 11**	**Roof**	**Level 11**
Frame 1	0.182731	0.064684	5.5	15.5	4.79%	1.90%
Frame 2	0.035647	0.005462	28.1	183.1	24.56%	22.45%
Frame 3	0.034356	0.004835	29.1	206.8	25.48%	25.36%
Frame 4	0.035469	0.00493	28.2	202.8	24.68%	24.87%
Frame 5	0.180082	0.060477	5.6	16.5	4.86%	2.03%
Frame 6	0.110563	0.079125	9.0	12.6	7.92%	1.55%
Frame 7	0.113649	0.005609	8.8	178.3	7.70%	21.86%
		∑ky=	114.2	815.7		

Table A.2
Direct Forces in Frames

	x-direction	Fi Direct - Direct Forces in Frames			
Level	Story Force N/S	Frame A	Frame B	Frame C	Frame D
PR	15.17	1.65	5.95	5.95	1.62
P20	30.10	3.28	11.80	11.82	3.21
P19	30.09	3.28	11.80	11.81	3.21
P18	30.09	3.28	11.80	11.81	3.21
P17	29.96	3.26	11.74	11.76	3.19
P16	28.76	3.13	11.28	11.29	3.07
P15	28.48	3.10	11.16	11.18	3.04
P14	28.24	3.08	11.07	11.08	3.01
P13	27.59	3.00	10.82	10.83	2.94
P12	27.27	2.97	10.69	10.70	2.91
P11	26.93	-8.08	21.52	22.32	-8.83
P10	26.13	2.85	10.24	11.27	1.78
P9	25.74	2.80	10.09	11.10	1.75
P8	24.94	2.72	9.78	10.75	1.69
P7	24.25	2.64	9.51	10.46	1.65
P6	23.36	2.54	9.16	10.08	1.59
P5	22.55	2.46	8.84	9.72	1.53
P4	21.56	2.35	8.45	9.30	1.47
P3	19.64	2.14	7.70	8.47	1.33
P2	16.37	1.78	6.42	7.06	1.11

Ptotal=PR+P20+P19+...+P11
Ptotal= 302.68

	y-direction	Fi Direct - Direct Forces in Frames (k)						
Level	Story Force E/W	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7
PR	32.49	1.56	7.98	8.28	8.02	1.58	2.57	2.50
P20	64.54	3.09	15.85	16.45	15.93	3.14	5.11	4.97
P19	64.52	3.09	15.85	16.44	15.93	3.14	5.11	4.97
P18	64.52	3.09	15.85	16.44	15.93	3.14	5.11	4.97
P17	64.27	3.08	15.78	16.38	15.86	3.12	5.09	4.95
P16	62.05	2.97	15.24	15.81	15.32	3.02	4.91	4.78
P15	61.53	2.95	15.11	15.68	15.19	2.99	4.87	4.74
P14	61.10	2.93	15.01	15.57	15.08	2.97	4.84	4.71
P13	59.89	2.87	14.71	15.26	14.78	2.91	4.74	4.61
P12	59.29	2.84	14.56	15.11	14.63	2.88	4.69	4.57
P11	58.65	-16.09	0.60	14.12	15.68	-15.65	-36.94	96.92
P10	57.18	1.08	12.83	14.50	14.22	1.16	0.89	12.50
P9	56.46	1.07	12.67	14.32	14.04	1.14	0.87	12.34
P8	54.96	1.04	12.34	13.93	13.67	1.11	0.85	12.01
P7	53.70	1.02	12.05	13.62	13.35	1.09	0.83	11.74
P6	52.05	0.99	11.68	13.20	12.94	1.06	0.81	11.38
P5	50.53	0.96	11.34	12.81	12.57	1.02	0.78	11.04
P4	48.73	0.92	10.94	12.36	12.12	0.99	0.76	10.65
P3	45.07	0.85	10.12	11.43	11.21	0.91	0.70	9.85
P2	38.14	0.72	8.56	9.67	9.49	0.77	0.59	8.34

Ptotal= PR+P20+P19+...+P11
Ptotal= 652.84
F11=(K11/∑ky)*Ptotal-(Kroof/∑ky)*PR-(Kroof/∑ky)*P20-...-(Kroof/∑ky)P12
F11=(K11/∑ky)*Ptotal-FR-F20-...-F12

Appendix A: Wind

Table A.3
Determination of forces caused by torsional moments

		Roof			Level 11		
Frame	**dx (in)**	**Ki**	**ki*di^2**	**Ki*di/∑ki*di^2**	**Ki**	**ki*di^2**	**Ki*di/∑ki*di^2**
Frame 1	795.7	5.5	3464866	0.000122	15.5	9788178	0.000045
Frame 2	467.7	28.1	6136373	0.000367	183.1	40048204	0.000316
Frame 3	95.7	29.1	266576	0.000078	206.8	1894207	0.000073
Frame 4	-144.3	28.2	587062	-0.000114	202.8	4223629	-0.000108
Frame 5	-384.3	5.6	820107	-0.000060	16.5	2442027	-0.000023
Frame 6	-624.3	9.0	3525144	-0.000158	12.6	4925757	-0.000029
Frame 7	-952.3	8.8	7979615	-0.000234	178.3	161682170	-0.000626
Frame	**dy (in)**	**Ki**	**ki*di^2**	**Ki*di/∑ki*di^2=**	**Ki**	**ki*di^2**	**Ki*di/∑ki*di^2**
Frame A	-630.0	12.8	5075805.7	-0.000225	40.1	15904123.43	-0.000093
Frame B	-182.0	46.0	1525089.1	-0.000234	236.7	7839138.485	-0.000159
Frame C	178.0	46.1	1460727.4	0.000230	238.4	7553649.607	0.000157
Frame D	626.0	12.5	4907009.8	0.000219	37.6	14718264.86	0.000087

Coordinates (in)	
CR - x	795.7
CR - y	626.01
CP - x level 10-roof	895
CP - y level 10-roof	628
CP - x base-Level 9	1179.75
CP - y base-Level 9	628

Table A.4
Case 1: Forces caused by torsional moments (North/South Wind)

			Forces caused by torsional moment (k)										
	x-direction story force N/S	**Moment caused by eccentricity y-dir. (k-in)**	**Frame 1**	**Frame 2**	**Frame 3**	**Frame 4**	**Frame 5**	**Frame 6**	**Frame 7**	**Frame A**	**Frame B**	**Frame C**	**Frame D**
PR	15.17	-30	-0.004	-0.011	-0.002	0.003	0.002	0.005	0.007	0.007	0.007	-0.007	-0.007
P20	30.10	-60	-0.007	-0.022	-0.005	0.007	0.004	0.009	0.014	0.014	0.014	-0.014	-0.013
P19	30.09	-60	-0.007	-0.022	-0.005	0.007	0.004	0.009	0.014	0.013	0.014	-0.014	-0.013
P18	30.09	-60	-0.007	-0.022	-0.005	0.007	0.004	0.009	0.014	0.013	0.014	-0.014	-0.013
P17	29.96	-60	-0.007	-0.022	-0.005	0.007	0.004	0.009	0.014	0.013	0.014	-0.014	-0.013
P16	28.76	-57	-0.007	-0.021	-0.004	0.007	0.003	0.009	0.013	0.013	0.013	-0.013	-0.013
P15	28.48	-57	-0.007	-0.021	-0.004	0.006	0.003	0.009	0.013	0.013	0.013	-0.013	-0.012
P14	28.24	-56	-0.007	-0.021	-0.004	0.006	0.003	0.009	0.013	0.013	0.013	-0.013	-0.012
P13	27.59	-55	-0.007	-0.020	-0.004	0.006	0.003	0.009	0.013	0.012	0.013	-0.013	-0.012
P12	27.27	-54	-0.007	-0.020	-0.004	0.006	0.003	0.009	0.013	0.012	0.013	-0.012	-0.012
P11	26.93	-54	-0.007	-0.020	-0.004	0.006	0.003	0.008	0.013	0.012	0.013	-0.012	-0.012
P10	26.13	-52	-0.002	-0.016	-0.004	0.006	0.001	0.002	0.033	0.005	0.008	-0.008	-0.005
P9	25.74	-51	-0.002	-0.016	-0.004	0.006	0.001	0.001	0.032	0.005	0.008	-0.008	-0.004
P8	24.94	-50	-0.002	-0.016	-0.004	0.005	0.001	0.001	0.031	0.005	0.008	-0.008	-0.004
P7	24.25	-48	-0.002	-0.015	-0.004	0.005	0.001	0.001	0.030	0.004	0.008	-0.008	-0.004
P6	23.36	-46	-0.002	-0.015	-0.003	0.005	0.001	0.001	0.029	0.004	0.007	-0.007	-0.004
P5	22.55	-45	-0.002	-0.014	-0.003	0.005	0.001	0.001	0.028	0.004	0.007	-0.007	-0.004
P4	21.56	-43	-0.002	-0.014	-0.003	0.005	0.001	0.001	0.027	0.004	0.007	-0.007	-0.004
P3	19.64	-39	-0.002	-0.012	-0.003	0.004	0.001	0.001	0.024	0.004	0.006	-0.006	-0.003
P2	16.37	-33	-0.001	-0.010	-0.002	0.004	0.001	0.001	0.020	0.003	0.005	-0.005	-0.003

Appendix A: Wind

Table A.5
Case 1: Forces caused by torsional moments (East/West Wind)

	y-direction story force E/W	Moment caused by eccentricity x-dir. (k-in)	Forces caused by torsional moment (k)										
			Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
PR	32.49	-3226	-0.393	-1.184	-0.251	0.367	0.193	0.510	0.756	0.727	0.756	-0.740	-0.707
P20	64.54	-6409	-0.781	-2.352	-0.499	0.729	0.383	1.012	1.502	1.445	1.502	-1.471	-1.405
P19	64.52	-6407	-0.780	-2.352	-0.499	0.729	0.382	1.012	1.502	1.444	1.502	-1.471	-1.405
P18	64.52	-6407	-0.780	-2.352	-0.499	0.729	0.382	1.012	1.502	1.444	1.502	-1.471	-1.405
P17	64.27	-6382	-0.777	-2.342	-0.497	0.726	0.381	1.008	1.496	1.438	1.496	-1.465	-1.399
P16	62.05	-6161	-0.751	-2.261	-0.480	0.701	0.368	0.973	1.444	1.389	1.444	-1.414	-1.351
P15	61.53	-6110	-0.744	-2.242	-0.476	0.695	0.365	0.965	1.432	1.377	1.432	-1.402	-1.340
P14	61.10	-6067	-0.739	-2.227	-0.473	0.690	0.362	0.958	1.422	1.367	1.422	-1.393	-1.330
P13	59.89	-5947	-0.724	-2.183	-0.463	0.677	0.355	0.939	1.394	1.340	1.394	-1.365	-1.304
P12	59.29	-5887	-0.717	-2.161	-0.459	0.670	0.351	0.930	1.380	1.327	1.380	-1.351	-1.291
P11	58.65	-5824	-0.709	-2.138	-0.454	0.663	0.348	0.920	1.365	1.313	1.365	-1.337	-1.277
P10	57.18	-5678	-0.692	-2.084	-0.442	0.646	0.339	0.897	1.331	1.280	1.331	-1.303	-1.245
P9	56.46	-21684	-0.984	-6.851	-1.584	2.342	0.508	0.631	13.584	2.020	3.446	-3.395	-1.881
P8	54.96	-21106	-0.958	-6.668	-1.541	2.279	0.495	0.614	13.222	1.966	3.354	-3.305	-1.831
P7	53.70	-20622	-0.936	-6.515	-1.506	2.227	0.484	0.600	12.919	1.921	3.278	-3.229	-1.789
P6	52.05	-19991	-0.907	-6.316	-1.460	2.159	0.469	0.582	12.523	1.862	3.177	-3.130	-1.734
P5	50.53	-19406	-0.881	-6.131	-1.417	2.096	0.455	0.565	12.157	1.808	3.084	-3.038	-1.684
P4	48.73	-18715	-0.849	-5.913	-1.367	2.021	0.439	0.545	11.724	1.743	2.974	-2.930	-1.624
P3	45.07	-17310	-0.786	-5.469	-1.264	1.869	0.406	0.504	10.844	1.612	2.751	-2.710	-1.502
P2	38.14	-14650	-0.665	-4.629	-1.070	1.582	0.343	0.426	9.177	1.365	2.328	-2.294	-1.271

Table A.6
Case 1: Net Force in each frame

	Net Force (k)										
Level	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
ROOF	1.163	6.794	8.027	8.385	1.772	3.082	3.259	1.658	5.952	5.945	1.610
20	2.312	13.500	15.948	16.661	3.520	6.123	6.474	3.291	11.816	11.801	3.196
19	2.311	13.495	15.943	16.655	3.519	6.121	6.472	3.290	11.812	11.797	3.195
18	2.311	13.495	15.943	16.655	3.519	6.121	6.472	3.290	11.812	11.797	3.195
17	2.302	13.442	15.880	16.590	3.506	6.097	6.447	3.275	11.758	11.744	3.181
16	2.222	12.978	15.331	16.017	3.384	5.886	6.224	3.145	11.290	11.276	3.054
15	2.204	12.869	15.203	15.882	3.356	5.837	6.172	3.114	11.178	11.164	3.024
14	2.188	12.778	15.096	15.771	3.332	5.796	6.129	3.088	11.085	11.072	2.999
13	2.145	12.526	14.798	15.459	3.267	5.682	6.007	3.016	10.828	10.815	2.929
12	2.123	12.400	14.649	15.304	3.234	5.624	5.947	2.981	10.702	10.689	2.895
11	-16.804	-1.534	13.669	16.347	-15.305	-36.015	98.288	-8.068	21.528	22.310	-8.840
10	0.392	10.750	14.056	14.865	1.498	1.783	13.828	2.850	10.253	11.263	1.771
9	0.086	5.822	12.733	16.382	1.653	1.506	25.925	2.808	10.101	11.096	1.745
8	0.084	5.667	12.393	15.946	1.609	1.466	25.233	2.720	9.784	10.747	1.690
7	0.082	5.537	12.109	15.580	1.572	1.432	24.655	2.645	9.516	10.453	1.644
6	0.079	5.368	11.739	15.103	1.524	1.388	23.901	2.548	9.167	10.070	1.584
5	0.077	5.211	11.396	14.662	1.479	1.348	23.202	2.459	8.847	9.718	1.528
4	0.074	5.025	10.990	14.140	1.427	1.300	22.376	2.352	8.460	9.293	1.461
3	0.069	4.648	10.164	13.078	1.320	1.202	20.695	2.142	7.707	8.466	1.331
2	0.058	3.933	8.602	11.068	1.117	1.018	17.515	1.786	6.423	7.056	1.110

Appendix A: Wind

Table A.7
Case 2: Forces caused by torsional moments (North/South Wind)

			Forces caused by torsional moment (k)										
	x-direction story force N/S (.75P)	Moment caused by eccentricity y-dir. (k-in) M=.75P(.15x+d)	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
PR	11.37	2120	0.258	0.778	0.165	-0.241	-0.127	-0.335	-0.497	-0.478	-0.497	0.487	0.465
P20	22.58	4209	0.513	1.545	0.328	-0.479	-0.251	-0.665	-0.987	-0.949	-0.987	0.966	0.923
P19	22.57	4207	0.512	1.544	0.328	-0.479	-0.251	-0.665	-0.986	-0.948	-0.986	0.966	0.923
P18	22.57	4207	0.512	1.544	0.328	-0.479	-0.251	-0.665	-0.986	-0.948	-0.986	0.966	0.923
P17	22.47	4188	0.510	1.537	0.326	-0.477	-0.250	-0.662	-0.982	-0.944	-0.982	0.961	0.918
P16	21.57	4021	0.490	1.476	0.313	-0.458	-0.240	-0.635	-0.943	-0.906	-0.943	0.923	0.882
P15	21.36	3981	0.485	1.461	0.310	-0.453	-0.238	-0.629	-0.933	-0.897	-0.933	0.914	0.873
P14	21.18	3949	0.481	1.449	0.308	-0.449	-0.236	-0.624	-0.926	-0.890	-0.926	0.906	0.866
P13	20.69	3857	0.470	1.416	0.301	-0.439	-0.230	-0.609	-0.904	-0.869	-0.904	0.885	0.846
P12	20.45	3812	0.464	1.399	0.297	-0.434	-0.228	-0.602	-0.894	-0.859	-0.894	0.875	0.836
P11	20.20	3765	0.459	1.382	0.293	-0.428	-0.225	-0.595	-0.882	-0.849	-0.883	0.864	0.826
P10	19.60	3653	0.166	1.341	0.267	-0.395	-0.086	-0.106	-2.289	-0.340	-0.581	0.572	0.317
P9	19.31	3599	0.163	1.321	0.263	-0.389	-0.084	-0.105	-2.255	-0.335	-0.572	0.564	0.312
P8	18.70	3486	0.158	1.280	0.255	-0.377	-0.082	-0.101	-2.184	-0.325	-0.554	0.546	0.302
P7	18.19	3391	0.154	1.244	0.248	-0.366	-0.079	-0.099	-2.124	-0.316	-0.539	0.531	0.294
P6	17.52	3267	0.148	1.199	0.239	-0.353	-0.077	-0.095	-2.046	-0.304	-0.519	0.511	0.283
P5	16.91	3152	0.143	1.157	0.230	-0.340	-0.074	-0.092	-1.975	-0.294	-0.501	0.494	0.273
P4	16.17	3015	0.137	1.106	0.220	-0.326	-0.071	-0.088	-1.888	-0.281	-0.479	0.472	0.262
P3	14.73	2746	0.125	1.008	0.201	-0.297	-0.064	-0.080	-1.720	-0.256	-0.436	0.430	0.238
P2	12.28	2289	0.104	0.840	0.167	-0.247	-0.054	-0.067	-1.434	-0.213	-0.364	0.358	0.199

x=dimension of building perpendicular to direction of wind= 1256"

Table A.8
Case 2: Forces caused by torsional moments (East/West Wind)

			FT = Forces caused by torsional moment (k)										
	(.75P) y-direction story force E/W	Moment caused by eccentricity x-dir. (k-in) M=.75P(.15x+d)	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
PR	24.36	6204	0.756	2.277	0.483	-0.706	-0.370	-0.980	-1.454	-1.398	-1.454	1.424	1.360
P20	48.41	12326	1.501	4.524	0.960	-1.403	-0.736	-1.947	-2.889	-2.778	-2.889	2.829	2.703
P19	48.39	12322	1.501	4.522	0.960	-1.402	-0.736	-1.946	-2.888	-2.777	-2.888	2.828	2.702
P18	48.39	12322	1.501	4.522	0.960	-1.402	-0.736	-1.946	-2.888	-2.777	-2.888	2.828	2.702
P17	48.20	12274	1.495	4.505	0.956	-1.397	-0.733	-1.939	-2.877	-2.766	-2.877	2.817	2.691
P16	46.54	11849	1.443	4.349	0.923	-1.349	-0.707	-1.872	-2.777	-2.671	-2.778	2.720	2.598
P15	46.15	11750	1.431	4.312	0.916	-1.337	-0.701	-1.856	-2.754	-2.648	-2.754	2.697	2.576
P14	45.82	11667	1.421	4.282	0.909	-1.328	-0.697	-1.843	-2.735	-2.630	-2.735	2.678	2.558
P13	44.92	11437	1.393	4.198	0.891	-1.302	-0.683	-1.807	-2.681	-2.578	-2.681	2.625	2.508
P12	44.47	11322	1.379	4.155	0.882	-1.288	-0.676	-1.788	-2.654	-2.552	-2.654	2.599	2.483
P11	43.99	11201	1.364	4.111	0.873	-1.275	-0.669	-1.769	-2.625	-2.524	-2.626	2.571	2.456
P10	42.88	10919	0.496	4.007	0.797	-1.179	-0.256	-0.318	-6.840	-1.017	-1.735	1.710	0.947
P9	42.35	-1276	-0.058	-0.468	-0.093	0.138	0.030	0.037	0.799	0.119	0.203	-0.200	-0.111
P8	41.22	-1242	-0.056	-0.456	-0.091	0.134	0.029	0.036	0.778	0.116	0.197	-0.194	-0.108
P7	40.27	-1213	-0.055	-0.445	-0.089	0.131	0.028	0.035	0.760	0.113	0.193	-0.190	-0.105
P6	39.04	-1176	-0.053	-0.432	-0.086	0.127	0.028	0.034	0.737	0.110	0.187	-0.184	-0.102
P5	37.90	-1142	-0.052	-0.419	-0.083	0.123	0.027	0.033	0.715	0.106	0.181	-0.179	-0.099
P4	36.55	-1101	-0.050	-0.404	-0.080	0.119	0.026	0.032	0.690	0.103	0.175	-0.172	-0.096
P3	33.80	-1018	-0.046	-0.374	-0.074	0.110	0.024	0.030	0.638	0.095	0.162	-0.159	-0.088
P2	28.61	-862	-0.039	-0.316	-0.063	0.093	0.020	0.025	0.540	0.080	0.137	-0.135	-0.075

x=dimension of building perpendicular to direction of wind=2359.5"

Appendix A: Wind

Table A.9
Case 2: Net Forces

	Net Force (k)										
Level	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
ROOF	2.312	10.255	8.761	7.312	1.209	1.592	1.048	1.173	5.448	6.439	2.082
20	4.594	20.376	17.408	14.529	2.402	3.164	2.083	2.329	10.815	12.781	4.132
19	4.592	20.369	17.402	14.524	2.401	3.163	2.082	2.328	10.811	12.776	4.131
18	4.592	20.369	17.402	14.524	2.401	3.163	2.082	2.328	10.811	12.776	4.131
17	4.574	20.289	17.334	14.467	2.392	3.151	2.074	2.318	10.763	12.719	4.112
16	4.416	19.588	16.735	13.967	2.309	3.042	2.002	2.226	10.334	12.212	3.948
15	4.379	19.423	16.594	13.850	2.290	3.016	1.986	2.203	10.231	12.091	3.909
14	4.348	19.287	16.478	13.753	2.274	2.995	1.972	2.185	10.147	11.991	3.877
13	4.262	18.906	16.153	13.481	2.229	2.936	1.933	2.135	9.911	11.713	3.787
12	4.220	18.716	15.990	13.345	2.206	2.906	1.913	2.110	9.796	11.577	3.743
11	-14.730	4.715	14.996	14.410	-16.321	-38.704	94.298	-8.928	20.633	23.187	-8.003
10	1.579	16.841	15.296	13.040	0.903	0.568	5.657	2.505	9.664	11.843	2.093
9	1.012	12.205	14.223	14.178	1.174	0.912	13.140	2.468	9.521	11.667	2.062
8	0.985	11.879	13.844	13.800	1.143	0.888	12.790	2.390	9.222	11.301	1.997
7	0.963	11.607	13.527	13.484	1.117	0.867	12.497	2.325	8.969	10.991	1.942
6	0.933	11.252	13.113	13.071	1.083	0.841	12.114	2.240	8.641	10.589	1.871
5	0.906	10.923	12.729	12.689	1.051	0.816	11.760	2.161	8.338	10.218	1.806
4	0.874	10.534	12.276	12.237	1.014	0.787	11.341	2.067	7.974	9.772	1.727
3	0.808	9.743	11.354	11.318	0.938	0.728	10.489	1.883	7.264	8.902	1.573
2	0.684	8.246	9.609	9.579	0.793	0.616	8.877	1.569	6.054	7.419	1.311

Appendix A: Wind

Table A.10
Case 3: Forces caused by torsional moments

		Forces caused by torsional moment (k)													
	Moment caused by eccentricity y-dir. (k-in) M=.75Pd	Moment caused by eccentricity x-dir. (k-in) M=.75Pd	Sum Moments (k-in)	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
PR	-23	-2419	-2442	-0.297	-0.896	-0.190	0.278	0.146	0.386	0.572	0.550	0.572	-0.561	-0.535
P20	-45	-4807	-4852	-0.591	-1.781	-0.378	0.552	0.290	0.766	1.137	1.094	1.137	-1.114	-1.064
P19	-45	-4805	-4850	-0.591	-1.780	-0.378	0.552	0.290	0.766	1.137	1.093	1.137	-1.113	-1.064
P18	-45	-4805	-4850	-0.591	-1.780	-0.378	0.552	0.290	0.766	1.137	1.093	1.137	-1.113	-1.064
P17	-45	-4787	-4831	-0.588	-1.773	-0.376	0.550	0.288	0.763	1.132	1.089	1.133	-1.109	-1.059
P16	-43	-4621	-4664	-0.568	-1.712	-0.363	0.531	0.278	0.737	1.093	1.051	1.093	-1.071	-1.023
P15	-43	-4582	-4625	-0.563	-1.697	-0.360	0.526	0.276	0.730	1.084	1.042	1.084	-1.062	-1.014
P14	-42	-4550	-4592	-0.559	-1.685	-0.358	0.523	0.274	0.725	1.076	1.035	1.077	-1.054	-1.007
P13	-41	-4460	-4501	-0.548	-1.652	-0.351	0.512	0.269	0.711	1.055	1.015	1.055	-1.033	-0.987
P12	-41	-4415	-4456	-0.543	-1.635	-0.347	0.507	0.266	0.704	1.044	1.004	1.045	-1.023	-0.977
P11	-40	-4368	-4408	-0.537	-1.618	-0.343	0.502	0.263	0.696	1.033	0.994	1.033	-1.012	-0.967
P10	-39	-4258	-4297	-0.195	-1.577	-0.314	0.464	0.101	0.125	2.692	0.400	0.683	-0.673	-0.373
P9	-38	-16263	-16301	-0.740	-5.983	-1.191	1.761	0.382	0.475	10.212	1.518	2.591	-2.552	-1.414
P8	-37	-15829	-15866	-0.720	-5.823	-1.159	1.714	0.372	0.462	9.940	1.478	2.522	-2.484	-1.376
P7	-36	-15466	-15503	-0.704	-5.690	-1.132	1.674	0.363	0.451	9.712	1.444	2.464	-2.427	-1.345
P6	-35	-14993	-15028	-0.682	-5.515	-1.098	1.623	0.352	0.437	9.414	1.400	2.388	-2.353	-1.304
P5	-34	-14555	-14588	-0.662	-5.354	-1.065	1.576	0.342	0.425	9.139	1.359	2.319	-2.284	-1.266
P4	-32	-14036	-14069	-0.639	-5.163	-1.027	1.519	0.330	0.410	8.813	1.310	2.236	-2.203	-1.220
P3	-29	-12982	-13012	-0.591	-4.775	-0.950	1.405	0.305	0.379	8.151	1.212	2.068	-2.037	-1.129
P2	-24	-10987	-11012	-0.500	-4.041	-0.804	1.189	0.258	0.321	6.898	1.026	1.750	-1.724	-0.955

Table A.11
Case 3: Net Forces

	Net Forces (k)										
	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
PR	0.870	5.087	6.018	6.292	1.330	2.315	2.449	1.789	5.031	3.903	0.677
P20	1.728	10.108	11.958	12.501	2.643	4.599	4.866	3.552	9.989	7.748	1.343
P19	1.728	10.105	11.954	12.497	2.642	4.598	4.865	3.551	9.985	7.745	1.343
P18	1.728	10.105	11.954	12.497	2.642	4.598	4.865	3.551	9.985	7.745	1.343
P17	1.721	10.065	11.907	12.448	2.632	4.580	4.846	3.535	9.941	7.709	1.336
P16	1.661	9.717	11.495	12.017	2.541	4.422	4.678	3.400	9.550	7.396	1.277
P15	1.648	9.636	11.399	11.916	2.519	4.384	4.639	3.368	9.458	7.321	1.263
P14	1.636	9.568	11.319	11.833	2.502	4.354	4.606	3.341	9.381	7.259	1.251
P13	1.604	9.379	11.095	11.599	2.452	4.268	4.515	3.267	9.167	7.087	1.219
P12	1.588	9.285	10.984	11.482	2.428	4.225	4.470	3.231	9.062	7.003	1.203
P11	-12.608	-1.165	10.249	12.265	-11.476	-27.005	73.725	-5.066	17.170	15.730	-7.588
P10	0.618	8.048	10.560	11.128	0.970	0.790	12.065	1.821	9.076	7.780	0.959
P9	0.063	3.522	9.547	12.291	1.241	1.131	19.468	2.918	10.860	5.776	-0.102
P8	0.061	3.428	9.292	11.963	1.208	1.101	18.948	2.834	10.531	5.582	-0.106
P7	0.060	3.350	9.079	11.689	1.180	1.075	18.514	2.763	10.253	5.418	-0.109
P6	0.058	3.247	8.801	11.331	1.144	1.042	17.947	2.670	9.893	5.205	-0.113
P5	0.056	3.152	8.544	11.000	1.110	1.012	17.422	2.585	9.560	5.010	-0.116
P4	0.054	3.040	8.240	10.608	1.071	0.976	16.802	2.483	9.161	4.772	-0.122
P3	0.050	2.812	7.621	9.812	0.990	0.903	15.540	2.280	8.377	4.317	-0.128
P2	0.042	2.380	6.450	8.304	0.838	0.764	13.151	1.916	7.008	3.571	-0.121

Appendix B: Seismic

Table B.1
Determination of building loads

	Load Type (psf)								
Level	Beams	Columns	Braces	green roof	Comp. Deck	Misc.	total psf/floor	Floor Area (sf)	**Wx (k)**
Roof	8.8	0.0	0		46.0	25.0	**80**	15613	1245.9
20	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
19	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
18	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
17	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
16	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
15	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
14	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
13	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
12	8.8	5.9	0.9		46.0	25.0	**87**	15613	1352.1
11	8.8	5.9	1.7		46.0	25.0	**87**	15613	1364.6
10	8.8	5.9	1.7		46.0	25.0	**87**	15613	1364.6
9	8.6	5.9	1.7	100	46.0	25.0	**187**	20579	3852.4
8	8.6	8.0	1.7		46.0	25.0	**89**	20579	1837.7
7	8.6	8.0	1.7		46.0	25.0	**89**	20579	1837.7
6	8.6	8.0	1.7		46.0	25.0	**89**	20579	1837.7
5	8.6	9.5	1.7		46.0	25.0	**91**	20579	1868.6
4	8.6	9.5	2.6		46.0	25.0	**92**	20579	1887.1
3	8.6	9.5	2.6		46.0	25.0	**92**	20579	1887.1
2	4.3	9.5	2.6		46.0	25.0	**87**	20579	1798.6
								W=	32950.7

Table B.2
Determination of Seismic Loads

Seismic Design Category: D Site Class: D		
I=	1.00	
Ss=	1.50	(g)
S1=	0.60	(g)
SDs=	1.00	(g)
SD1=	0.60	(g)
Cs=	0.0475	(g)
R=	7	
Fa=	1.0	
Fv=	1.5	
Ta≈T	2.373	(s)
TL	8	(s)
Cs	0.0429	
W	32951	(k)
V	1412	(k)
k	1.9365	

Level	Height (ft)	Wx (k)	wihi^k	Fx - Lateral seismic force (k)	Vx - seismic design story shear (k)	Moments (ft-k)
Roof	257.17	1352	62860639	184	184	47269
20	244.17	1352	56852915	166	350	40590
19	231.17	1352	51137470	150	500	34566
18	218.17	1352	45715324	134	633	29163
17	205.17	1352	40587555	119	752	24349
16	192.17	1352	35755317	105	856	20091
15	179.17	1352	31219839	91	948	16356
14	166.17	1352	26982448	79	1027	13110
13	153.17	1352	23044573	67	1094	10321
12	140.17	1352	19407769	57	1151	7954
11	127.17	1365	16222227	47	1198	6032
10	114.17	1365	13164868	38	1237	4395
9	101.17	3852	29409631	86	1323	8700
8	88.17	1838	10748855	31	1354	2771
7	75.17	1838	7892292	23	1377	1735
6	62.17	1838	5463921	16	1393	993
5	49.17	1869	3527240	10	1404	507
4	36.17	1887	1965452	6	1409	208
3	23.17	1887	829576	2	1412	56
2	10.42	1799	168179	0	1412	5
Ground	0.00	1799	0	0	1412	0
		Sum wihi^k=	482956090			

Overturning Moment (ft-k)= 269169

Base Shear (k)= 1412

Appendix B: Seismic

Table B.3
Direct seismic force in Frames 1 through 7

	y-direction	Fi Direct - Direct Forces in Frames (k)						
	Story Force E/W	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7
PR	194.43	9.32	47.75	49.55	47.99	9.45	15.40	14.98
P20	175.85	8.43	43.19	44.81	43.40	8.55	13.92	13.55
P19	158.17	7.58	38.85	40.31	39.04	7.69	12.52	12.18
P18	141.40	6.77	34.73	36.03	34.90	6.87	11.20	10.89
P17	125.54	6.01	30.83	31.99	30.99	6.10	9.94	9.67
P16	110.59	5.30	27.16	28.18	27.30	5.38	8.76	8.52
P15	96.56	4.63	23.72	24.61	23.84	4.69	7.65	7.44
P14	83.46	4.00	20.50	21.27	20.60	4.06	6.61	6.43
P13	71.28	3.41	17.51	18.16	17.59	3.47	5.64	5.49
P12	60.03	2.88	14.74	15.30	14.82	2.92	4.75	4.62
P11	50.18	-34.30	-14.47	11.19	14.73	-33.49	-76.75	183.27
P10	40.72	0.77	9.14	10.33	10.13	0.83	0.63	8.90
P9	90.97	1.72	20.42	23.07	22.62	1.84	1.41	19.88
P8	33.25	0.63	7.46	8.43	8.27	0.67	0.52	7.27
P7	24.41	0.46	5.48	6.19	6.07	0.49	0.38	5.34
P6	16.90	0.32	3.79	4.29	4.20	0.34	0.26	3.69
P5	10.91	0.21	2.45	2.77	2.71	0.22	0.17	2.38
P4	6.08	0.12	1.36	1.54	1.51	0.12	0.09	1.33
P3	2.57	0.05	0.58	0.65	0.64	0.05	0.04	0.56
P2	0.52	0.01	0.12	0.13	0.13	0.01	0.01	0.11

Table B.4
Direct seismic force in Frames A through D

	x-direction	Fi Direct - Direct Forces in Frames (k)			
	Story Force N/S	Frame A	Frame B	Frame C	Frame D
PR	194.43	21.17	76.22	76.31	20.73
P20	175.85	19.15	68.94	69.02	18.75
P19	158.17	17.22	62.01	62.08	16.86
P18	141.40	15.40	55.43	55.50	15.07
P17	125.54	13.67	49.22	49.27	13.38
P16	110.59	12.04	43.36	43.40	11.79
P15	96.56	10.51	37.86	37.90	10.29
P14	83.46	9.09	32.72	32.75	8.90
P13	71.28	7.76	27.94	27.97	7.60
P12	60.03	6.54	23.53	23.56	6.40
P11	50.18	-40.65	65.56	68.91	-43.64
P10	40.72	4.43	15.96	17.56	2.77
P9	90.97	9.90	35.66	39.23	6.18
P8	33.25	3.62	13.03	14.34	2.26
P7	24.41	2.66	9.57	10.53	1.66
P6	16.90	1.84	6.63	7.29	1.15
P5	10.91	1.19	4.28	4.71	0.74
P4	6.08	0.66	2.38	2.62	0.41
P3	2.57	0.28	1.01	1.11	0.17
P2	0.52	0.06	0.20	0.22	0.04

Appendix B: Seismic

Table B.5
Seismic forces caused by torsional moments (North South direction)

			Forces caused by torsional moment (k)										
Level	x-direction story force N/S	Moment caused by eccentricity y-dir. (k-in)	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
PR	194.43	-387	-0.047	-0.142	-0.030	0.044	0.023	0.061	0.091	0.087	0.091	-0.089	-0.085
P20	175.85	-350	-0.043	-0.128	-0.027	0.040	0.021	0.055	0.082	0.079	0.082	-0.080	-0.077
P19	158.17	-315	-0.038	-0.116	-0.025	0.036	0.019	0.050	0.074	0.071	0.074	-0.072	-0.069
P18	141.40	-281	-0.034	-0.103	-0.022	0.032	0.017	0.044	0.066	0.063	0.066	-0.065	-0.062
P17	125.54	-250	-0.030	-0.092	-0.019	0.028	0.015	0.039	0.059	0.056	0.059	-0.057	-0.055
P16	110.59	-220	-0.027	-0.081	-0.017	0.025	0.013	0.035	0.052	0.050	0.052	-0.051	-0.048
P15	96.56	-192	-0.023	-0.071	-0.015	0.022	0.011	0.030	0.045	0.043	0.045	-0.044	-0.042
P14	83.46	-166	-0.020	-0.061	-0.013	0.019	0.010	0.026	0.039	0.037	0.039	-0.038	-0.036
P13	71.28	-142	-0.017	-0.052	-0.011	0.016	0.008	0.022	0.033	0.032	0.033	-0.033	-0.031
P12	60.03	-119	-0.015	-0.044	-0.009	0.014	0.007	0.019	0.028	0.027	0.028	-0.027	-0.026
P11	50.18	-100	-0.012	-0.037	-0.008	0.011	0.006	0.016	0.023	0.023	0.023	-0.023	-0.022
P10	40.72	-81	-0.004	-0.026	-0.006	0.009	0.002	0.002	0.051	0.008	0.013	-0.013	-0.007
P9	90.97	-181	-0.008	-0.057	-0.013	0.020	0.004	0.005	0.113	0.017	0.029	-0.028	-0.016
P8	33.25	-66	-0.003	-0.021	-0.005	0.007	0.002	0.002	0.041	0.006	0.011	-0.010	-0.006
P7	24.41	-49	-0.002	-0.015	-0.004	0.005	0.001	0.001	0.030	0.005	0.008	-0.008	-0.004
P6	16.90	-34	-0.002	-0.011	-0.002	0.004	0.001	0.001	0.021	0.003	0.005	-0.005	-0.003
P5	10.91	-22	-0.001	-0.007	-0.002	0.002	0.001	0.001	0.014	0.002	0.003	-0.003	-0.002
P4	6.08	-12	-0.001	-0.004	-0.001	0.001	0.000	0.000	0.008	0.001	0.002	-0.002	-0.001
P3	2.57	-5	0.000	-0.002	0.000	0.001	0.000	0.000	0.003	0.000	0.001	-0.001	0.000
P2	0.52	-1	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000

Table B.6
Seismic forces caused by torsional moments (East/West direction)

			Forces caused by torsional moment (k)										
Level	y-direction story force E/W (k)	Moment caused by eccentricity x-dir. (k-in)	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
PR	194.43	-19307	-2.352	-7.086	-1.504	2.197	1.153	3.050	4.525	4.351	4.526	-4.432	-4.233
P20	175.85	-17462	-2.127	-6.409	-1.361	1.987	1.042	2.758	4.093	3.936	4.093	-4.008	-3.829
P19	158.17	-15706	-1.913	-5.765	-1.224	1.787	0.938	2.481	3.682	3.540	3.682	-3.605	-3.444
P18	141.40	-14041	-1.710	-5.153	-1.094	1.598	0.838	2.218	3.291	3.165	3.291	-3.223	-3.079
P17	125.54	-12466	-1.518	-4.575	-0.971	1.419	0.744	1.969	2.922	2.810	2.922	-2.862	-2.733
P16	110.59	-10982	-1.338	-4.031	-0.856	1.250	0.656	1.735	2.574	2.475	2.574	-2.521	-2.408
P15	96.56	-9589	-1.168	-3.519	-0.747	1.091	0.572	1.515	2.248	2.161	2.248	-2.201	-2.103
P14	83.46	-8287	-1.009	-3.042	-0.646	0.943	0.495	1.309	1.943	1.868	1.943	-1.902	-1.817
P13	71.28	-7078	-0.862	-2.598	-0.552	0.805	0.423	1.118	1.659	1.595	1.659	-1.625	-1.552
P12	60.03	-5961	-0.726	-2.188	-0.464	0.678	0.356	0.942	1.397	1.343	1.397	-1.368	-1.307
P11	50.18	-4982	-0.607	-1.829	-0.388	0.567	0.297	0.787	1.168	1.123	1.168	-1.144	-1.093
P10	40.72	-4043	-0.493	-1.484	-0.315	0.460	0.241	0.639	0.948	0.911	0.948	-0.928	-0.887
P9	90.97	-34935	-1.586	-11.038	-2.551	3.773	0.819	1.017	21.885	3.254	5.552	-5.470	-3.031
P8	33.25	-12768	-0.580	-4.034	-0.933	1.379	0.299	0.372	7.999	1.189	2.029	-1.999	-1.108
P7	24.41	-9375	-0.426	-2.962	-0.685	1.013	0.220	0.273	5.873	0.873	1.490	-1.468	-0.813
P6	16.90	-6491	-0.295	-2.051	-0.474	0.701	0.152	0.189	4.066	0.605	1.032	-1.016	-0.563
P5	10.91	-4190	-0.190	-1.324	-0.306	0.453	0.098	0.122	2.625	0.390	0.666	-0.656	-0.363
P4	6.08	-2335	-0.106	-0.738	-0.171	0.252	0.055	0.068	1.463	0.217	0.371	-0.366	-0.203
P3	2.57	-985	-0.045	-0.311	-0.072	0.106	0.023	0.029	0.617	0.092	0.157	-0.154	-0.085
P2	0.52	-200	-0.009	-0.063	-0.015	0.022	0.005	0.006	0.125	0.019	0.032	-0.031	-0.017

Appendix B: Seismic

Table B.7
Net seismic forces in each frame

	Net Force (k)										
Level	**Frame 1**	**Frame 2**	**Frame 3**	**Frame 4**	**Frame 5**	**Frame 6**	**Frame 7**	**Frame A**	**Frame B**	**Frame C**	**Frame D**
PR	8.919	46.56	49.29	48.36	9.65	15.91	15.74	21.90	76.99	75.56	20.01
P20	7.637	40.81	44.31	44.14	8.94	14.95	15.06	20.61	70.46	67.53	17.33
P19	6.790	36.47	39.80	39.78	8.08	13.55	13.70	18.68	63.52	60.59	15.44
P18	5.987	32.35	35.53	35.64	7.26	12.22	12.41	16.85	56.95	54.01	13.66
P17	5.230	28.47	31.49	31.72	6.49	10.96	11.18	15.12	50.73	47.79	11.97
P16	4.541	24.88	27.70	28.01	5.75	9.74	9.98	13.44	44.81	41.98	10.43
P15	3.875	21.45	24.13	24.54	5.06	8.62	8.88	11.90	39.30	36.48	8.94
P14	3.253	18.25	20.79	21.30	4.42	7.58	7.86	10.47	34.15	31.35	7.55
P13	2.684	15.30	17.70	18.28	3.82	6.59	6.90	9.11	29.35	26.60	6.28
P12	2.152	12.56	14.83	15.49	3.27	5.69	6.02	7.88	24.93	22.20	5.10
P11	-35.015	-16.63	10.73	15.40	-33.14	-75.82	184.65	-39.32	66.94	67.56	-44.93
P10	0.078	7.04	9.88	10.78	1.17	1.53	10.26	5.72	17.30	16.25	1.52
P9	0.738	13.55	21.48	24.97	2.35	2.04	33.50	11.93	39.12	35.83	4.30
P8	-0.330	0.78	6.89	10.55	1.17	1.13	20.52	5.59	16.40	11.03	0.42
P7	-0.476	-1.05	4.68	8.30	0.98	0.98	18.28	4.58	12.86	7.29	-0.13
P6	-0.589	-2.54	2.82	6.37	0.81	0.85	16.25	3.71	9.81	4.15	-0.59
P5	-0.676	-3.70	1.35	4.81	0.68	0.74	14.57	3.00	7.37	1.66	-0.95
P4	-0.736	-4.56	0.17	3.54	0.56	0.64	13.08	2.41	5.36	-0.31	-1.21
P3	-0.739	-4.91	-0.62	2.51	0.46	0.54	11.43	1.90	3.76	-1.61	-1.33
P2	-0.657	-4.52	-0.94	1.72	0.35	0.44	9.31	1.42	2.54	-2.07	-1.24

Appendix B: Seismic

Table B.8
Load combination comparison - 1.0 Earthquake vs. 1.6 Wind

1.0 Earthquake										
Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
9.3	47.8	49.5	48.0	9.5	15.4	15.0	21.2	76.2	76.3	20.7
8.4	43.2	44.8	43.4	8.5	13.9	13.5	19.1	68.9	69.0	18.7
7.6	38.8	40.3	39.0	7.7	12.5	12.2	17.2	62.0	62.1	16.9
6.8	34.7	36.0	34.9	6.9	11.2	10.9	15.4	55.4	55.5	15.1
6.0	30.8	32.0	31.0	6.1	9.9	9.7	13.7	49.2	49.3	13.4
5.3	27.2	28.2	27.3	5.4	8.8	8.5	12.0	43.4	43.4	11.8
4.6	23.7	24.6	23.8	4.7	7.6	7.4	10.5	37.9	37.9	10.3
4.0	20.5	21.3	20.6	4.1	6.6	6.4	9.1	32.7	32.8	8.9
3.4	17.5	18.2	17.6	3.5	5.6	5.5	7.8	27.9	28.0	7.6
2.9	14.7	15.3	14.8	2.9	4.8	4.6	6.5	23.5	23.6	6.4
-34.3	-14.5	11.2	14.7	-33.5	-76.8	183.3	-40.6	65.6	68.9	-43.6
0.8	9.1	10.3	10.1	0.8	0.6	8.9	4.4	16.0	17.6	2.8
1.7	20.4	23.1	22.6	1.8	1.4	19.9	9.9	35.7	39.2	6.2
0.6	7.5	8.4	8.3	0.7	0.5	7.3	3.6	13.0	14.3	2.3
0.5	5.5	6.2	6.1	0.5	0.4	5.3	2.7	9.6	10.5	1.7
0.3	3.8	4.3	4.2	0.3	0.3	3.7	1.8	6.6	7.3	1.1
0.2	2.4	2.8	2.7	0.2	0.2	2.4	1.2	4.3	4.7	0.7
0.1	1.4	1.5	1.5	0.1	0.1	1.3	0.7	2.4	2.6	0.4
0.0	0.6	0.7	0.6	0.1	0.0	0.6	0.3	1.0	1.1	0.2
0.0	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.2	0.2	0.0

1.6 Wind										
Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 7	Frame A	Frame B	Frame C	Frame D
2.5	12.8	13.2	12.8	2.5	4.1	4.0	2.6	9.5	9.5	2.6
4.9	25.4	26.3	25.5	5.0	8.2	8.0	5.2	18.9	18.9	5.1
4.9	25.4	26.3	25.5	5.0	8.2	8.0	5.2	18.9	18.9	5.1
4.9	25.4	26.3	25.5	5.0	8.2	8.0	5.2	18.9	18.9	5.1
4.9	25.3	26.2	25.4	5.0	8.1	7.9	5.2	18.8	18.8	5.1
4.8	24.4	25.3	24.5	4.8	7.9	7.6	5.0	18.0	18.1	4.9
4.7	24.2	25.1	24.3	4.8	7.8	7.6	5.0	17.9	17.9	4.9
4.7	24.0	24.9	24.1	4.8	7.7	7.5	4.9	17.7	17.7	4.8
4.6	23.5	24.4	23.7	4.7	7.6	7.4	4.8	17.3	17.3	4.7
4.5	23.3	24.2	23.4	4.6	7.5	7.3	4.8	17.1	17.1	4.7
-25.8	1.0	22.6	25.1	-25.0	-59.1	155.1	-12.9	34.4	35.7	-14.1
1.7	20.5	23.2	22.8	1.9	1.4	20.0	4.6	16.4	18.0	2.8
1.7	20.3	22.9	22.5	1.8	1.4	19.7	4.5	16.1	17.8	2.8
1.7	19.7	22.3	21.9	1.8	1.4	19.2	4.3	15.6	17.2	2.7
1.6	19.3	21.8	21.4	1.7	1.3	18.8	4.2	15.2	16.7	2.6
1.6	18.7	21.1	20.7	1.7	1.3	18.2	4.1	14.7	16.1	2.5
1.5	18.1	20.5	20.1	1.6	1.3	17.7	3.9	14.1	15.6	2.5
1.5	17.5	19.8	19.4	1.6	1.2	17.0	3.8	13.5	14.9	2.3
1.4	16.2	18.3	17.9	1.5	1.1	15.8	3.4	12.3	13.6	2.1
1.2	13.7	15.5	15.2	1.2	0.9	13.3	2.9	10.3	11.3	1.8

Appendix C: Drift

Table C.1
Story Displacements tabulated in ETABS

	Story Displacement (in)			
Level	Earthquake X	Wind X	Earthquake Y	Wind Y
ROOF	0.4207	0.0814	0.3805	0.1596
20	0.4424	0.0853	0.3917	0.1643
19	0.4580	0.0889	0.3986	0.1677
18	0.4686	0.0919	0.3997	0.1702
17	0.4760	0.0945	0.4028	0.1728
16	0.4770	0.0964	0.3958	0.1730
15	0.4731	0.0975	0.3917	0.1733
14	0.4639	0.0980	0.3727	0.1694
13	0.4387	0.0953	0.3600	0.1665
12	0.4276	0.0953	0.3346	0.1599
11	0.3998	0.0914	0.3168	0.1565
10	0.3689	0.0867	0.2897	0.1480
9	0.3544	0.0847	0.2836	0.1465
8	0.3348	0.0822	0.2585	0.1376
7	0.3104	0.0788	0.2451	0.1337
6	0.2802	0.0738	0.2126	0.1206
5	0.2473	0.0682	0.1927	0.1126
4	0.2065	0.0601	0.1527	0.0944
3	0.1655	0.0513	0.1269	0.0824
2	0.0959	0.0318	0.0642	0.0456

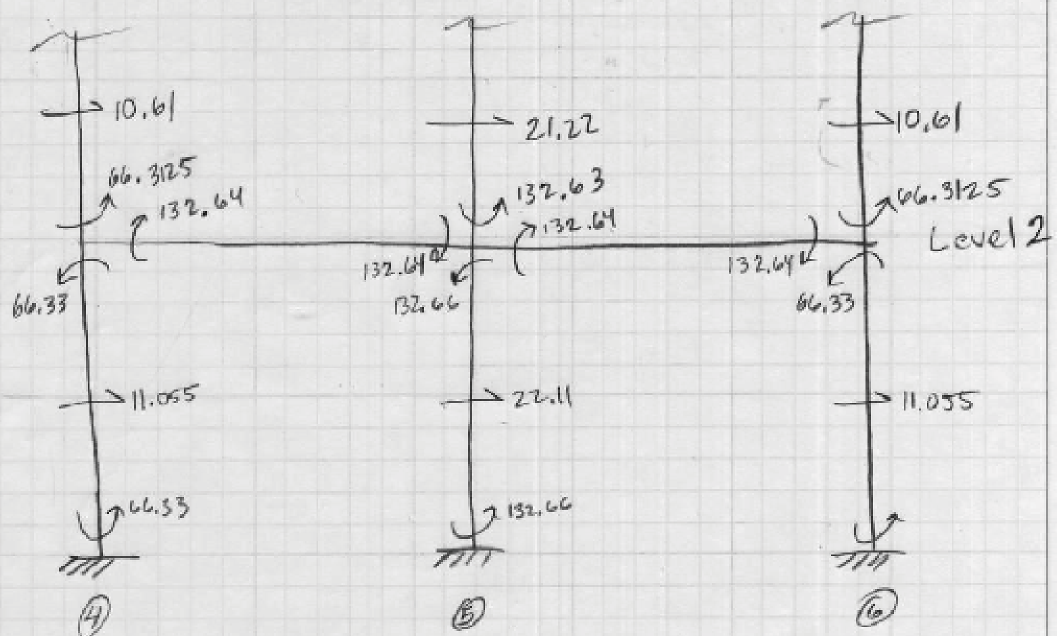
Table C.2
Maximum drift for earthquake and wind loads in each direction

	Drift (in.)				Allowable story drift =0.02hsx Earthquake (in)	Story Drift =h/400 Wind (in)
Level	Earthquake X	Wind X	Earthquake Y	Wind Y		
ROOF	7.310	1.634	5.971	2.855	5.17	7.76
20	6.889	1.552	5.590	2.695	4.91	7.37
19	6.447	1.467	5.199	2.531	4.65	6.98
18	5.989	1.378	4.800	2.363	4.39	6.59
17	5.520	1.286	4.400	2.193	4.13	6.20
16	5.044	1.192	3.998	2.020	3.87	5.81
15	4.567	1.095	3.602	1.847	3.61	5.42
14	4.094	0.998	3.210	1.674	3.35	5.03
13	3.630	0.900	2.838	1.504	3.09	4.64
12	3.191	0.804	2.477	1.338	2.83	4.25
11	2.764	0.709	2.143	1.178	2.57	3.86
10	2.364	0.618	1.826	1.021	2.31	3.47
9	1.995	0.531	1.536	0.873	2.05	3.08
8	1.641	0.446	1.253	0.727	1.79	2.69
7	1.306	0.364	0.994	0.589	1.53	2.30
6	0.995	0.285	0.749	0.456	1.27	1.91
5	0.715	0.211	0.537	0.335	1.01	1.52
4	0.468	0.143	0.344	0.222	0.75	1.13
3	0.261	0.083	0.191	0.128	0.49	0.74
2	0.096	0.032	0.064	0.046	0.24	0.36

Appendix D: Member Check Hand Calculation

Portal Frame Analysis: Column Check

Values in (K) + (feet)



Looking @ Interior Column (5): W14x730

Tributary Area to Column: $\frac{37.33'}{2} + 20' = 373.3'$

– Supports 19 floors and roof

Roof: 80 psf (DL) LL = 20 (Reducible)

$L_r = L_o R_1 R_2$

$L_r = 20(0.8267)(1.0)$

$L_r = 16.534$ psf

$R_1 \Rightarrow$ for $200 ft^2 < A_t < 600 ft^2$

$R_1 = 1.2 - 0.001 A_t$

$= 1.2 - 0.001 (373.3')$

$= 0.8267$

$R_2 = 1.0$

Factored: $1.2D + 1.0L + 1.6W$

$[1.2(80 psf) + 1.0(16.5 psf)] * \frac{373.3 ft}{1000} = 41.97 K$

Appendix D: Member Check Hand Calculation

Portal Frame Analysis: Column Check

DL of other typ. floors avg = 90 psf. L = 80 psf (Reduc)

$L_L = L_o\left(0.25 + \frac{15}{\sqrt{19 \cdot K_{LL} A_T}}\right) = L_o\left(0.25 + \frac{15}{\sqrt{19 \times 373.3}}\right)$

$L_L = 0.43 L_o \geq 0.4 L_o$ ∴ ok

∴ $L_L = 0.43(80 psf) = 34.4 psf$

Factored. $[1.2(90 psf) + 1.0(34.4 psf)] \times 373.3 ft^2 / 1000$

$= 53.16 k \times 19$ floors

$= 1010^k$

$P_u = 1010^k$ (19 typ. floors) $+ 41.97^k$ (roof) $= 1052 K$

$\phi M_y = 3060$ ft-k
$\phi M_x = 6230$ ft-k

M_u from Portal Method: $KL = 12'$ → $\phi P_n = 9030$ K

$M_u = 132.66$ → Factored $= 1.6 N = 1.6(132.66) = 212.3$ ft-k

$\frac{P_u}{\phi P_n} \geq 0.2$ $\frac{1052k}{9030k} = 0.117 \ngeq$ (H1-1a)

∴ use $\frac{P_u}{\phi P_n} < 0.2$ (H1-1b)

$$\frac{P_u}{2\phi P_n} + \left(\frac{M_{ux}}{\phi M_x} + \frac{M_{uy}}{\phi M_y}\right) \leq 1.0$$

$$\frac{1052}{2(9030)} + \left(\frac{212.3}{6230} + \frac{0}{3060}\right) \leq 1.0$$

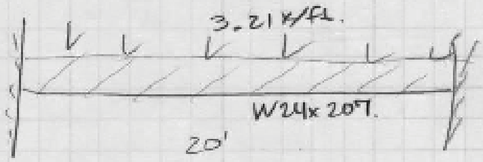
$0.092 \leq 1.0$ ✓

→ only 9.2% of capacity.

Appendix D: Member Check Hand Calculation

Portal Analysis: Beam Check

Check beam in Moment Frame.



$T_w = \frac{37.33}{2} = 18.7$ ft

Check $K_{LL} A_T > 400$

$2(\frac{37.33}{2} * 20 \text{ ft.})$

$746.6 \text{ ft}^2 > 400$

∴ L_o reducible.

$1.2d + 1.0L + 1.6W$

$w_u = [1.2(90 \text{ psf}) + 1.0(63.92 \text{ psf})] * 18.7\text{ft} / 1000.$

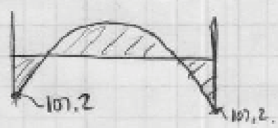
$w_u = 3.21$ k/ft.

$L_L = L_o(0.25 + \frac{15}{\sqrt{K_{LL} A_T}})$

$M_u = \frac{wl^2}{12} = \frac{(3.21 \text{k/ft})(20\text{ft})^2}{12}$

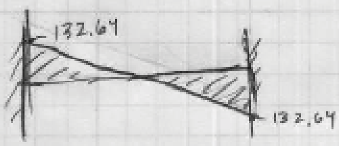
$L_L = 80(0.25 + \frac{15}{\sqrt{2(373.3)}})$

$M_u = 107.2$ k-ft. (D+L).



$L_L = 63.92$ psf

+



W24x207

$\phi M_n = 1510$ ft-k.

M_u from Portal Analysis = 132.64.

→ factored.

$M_u = 1.6(132.64)$
$= 212.2$ ft-k.

(=) 319.5 ft-k = M_u beam.

$\phi M_n > M_u$.

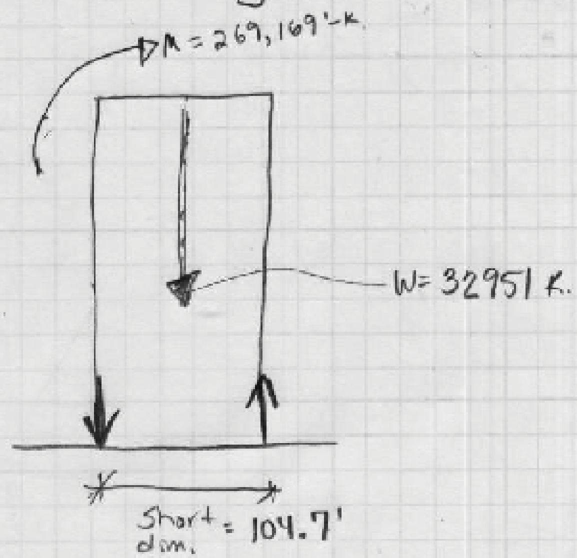
$1510^{'k} > 319.5^{'k}$ ∴ o.k.

The W24x207 is sized to ≈22% of its capacity.

Appendix D: Member Check Hand Calculation

Building Overturning Check

Check Overturning: Seismic Controls ⇒ Overturning Moment = 269,169'-k.



In order to resist overturning $\frac{W}{2} > \frac{M}{d}$

$$\frac{32{,}951\ k}{2} > \frac{269{,}169\ ft\text{-}k}{104.7\ ft.}$$

$$16{,}475.5\ k \gg 2570.9\ K.$$

∴ No overturning will occur.