Best Buy Corporate Building D (4)
Richfield, MN

Technical Assignment III

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Structural Option
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Executive Summary:

Building D of the Best Buy Corporate Complex consists of a composite floor design on each floor of the building. The main lateral system for this building is a braced frame system. The braced frames extend through all six floors of the building and brace the building in both the N-S and the E-W conditions. Wind and seismic values were transferred from Technical Report 1 and obtained from ASCE 7-05.

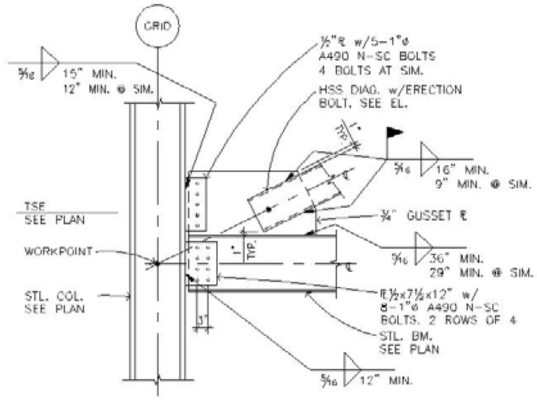
This technical report contains a complete lateral analysis of Best Buy Corporate Building D. Lateral forces were distributed by finding the individual stiffness of each moment frame in the building. This stiffness was then used to distribute direct and torsional shear forces throughout the building. To find the deflection and story drift, a model of each moment frame was created in SAP2000 and the portal method was used to check the computer deflection values. These drift values were checked against the criteria of H/400 and passed for both the individual members and the structure as a whole. The building was also checked for overturning and strength, both of which passed analysis. Lastly, three members were spot checked to see if the proposed design matched up with the loads calculated.

General Information:

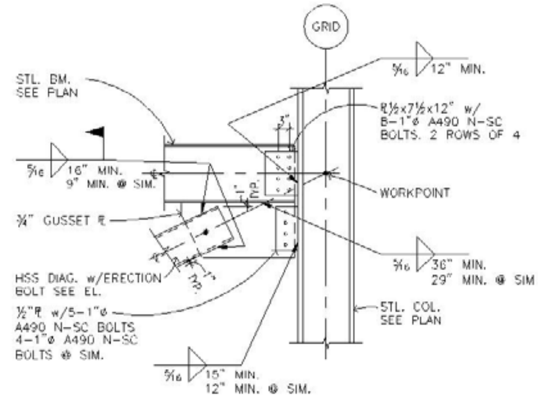
The Best Buy corporate campus consists of four buildings connected by a central hub. This report focuses on building number four, which is a six story composite steel system with architectural precast panels surrounding it. The 304,610 square foot building consists of slab on grade construction with wide flange steel columns supported on concrete piers. Lateral loads are supported by a braced frame system. The exterior of the building consists of an architectural precast curtain wall with integrated ribbon windows. The occupancy of the building, as expected, is primarily for office use.

Lateral Systems:

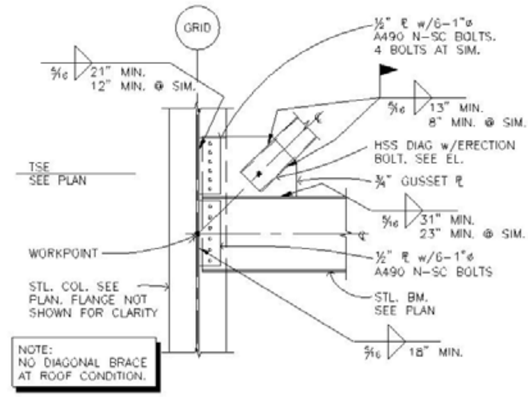
For the lateral system, this building utilizes a composite floor system and braced framing. The vertical members of the braced frame consist of 3 W14 columns spliced together at the 3rd and 5th floors. The beams between these columns are heavier, W16x57 as compared to W16x26 elsewhere in the building. As shown below, there are 2 diagonal HSS members to provide further support. The following page shows the various connection details used on the braced frame.



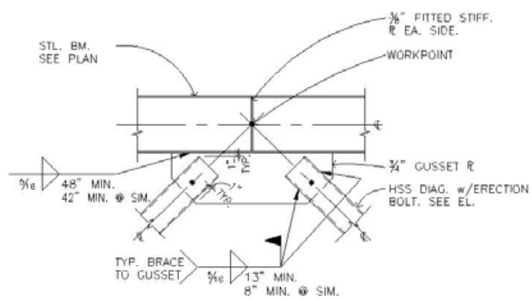
DETAIL
BRACE CONNECTION AT FLOOR



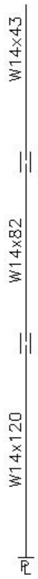
DETAIL
BRACE CONNECTION AT ROOF

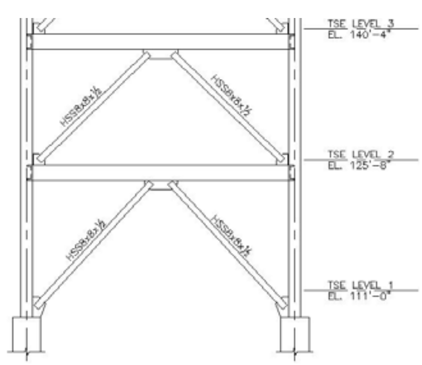


DETAIL
BRACE CONNECTION AT FLOOR



DETAIL
BRACE CONNECTION AT FLOOR





BRACE FRAME ELEVATION

Load Cases:

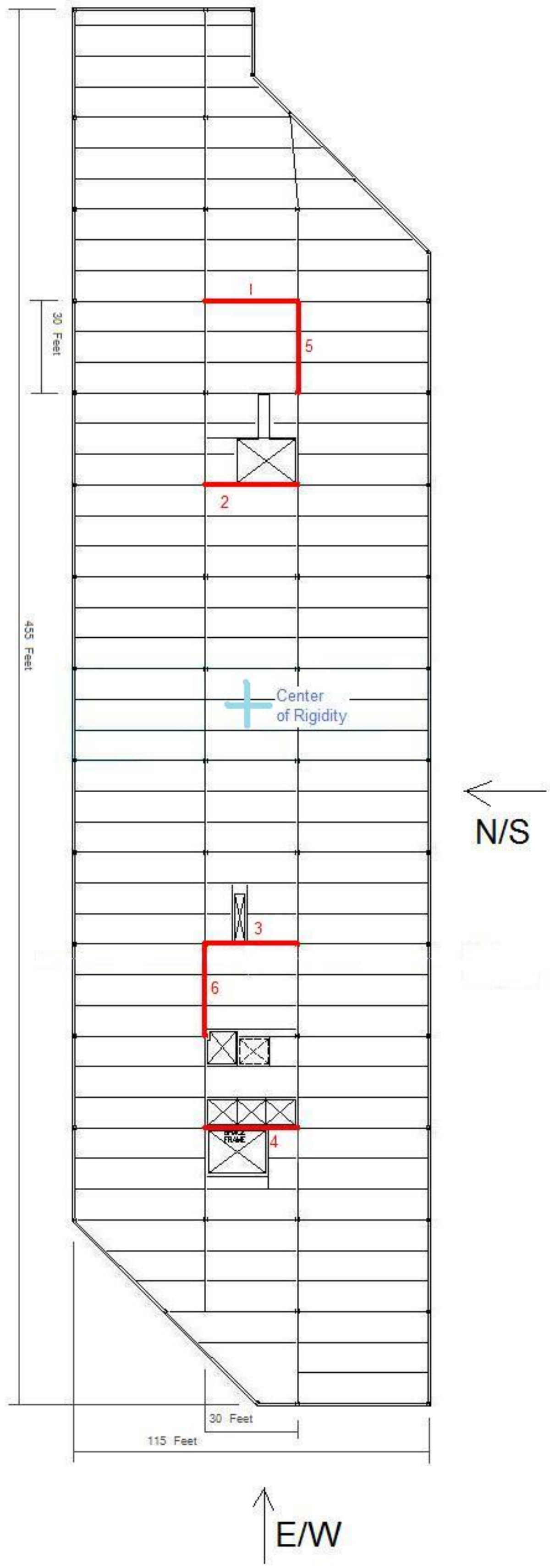
Building 4 was designed using UBC 1997, however, as with the previous reports, ASCE 7-05 will be used to analyze the structure. From ASCE 7-05 there are 7 controlling load cases:

- Case #1: 1.4D
- Case #2: 1.2D + 1.6L + 0.5S
- Case #3: 1.2D + 1.6S + 0.8W
- Case #4: 1.2D + 1.6W + 1.0L + 0.5S
- Case #5: 1.2D + 1.0E + 1.0L + 0.2S
- Case #6: 0.9D +1.6W + 1.6H
- Case #7: 0.9D + 1.0E + 1.6H

For this assignment, the braced frames were checked for lateral forces by using case #4 where wind loading controls, and case #5 where seismic loading controls. From the comparison, it was found that the wind loading force controlled the design in both the North-South and East-West directions. This means that load case #4 should be used to check the foundations, uplift, and overturning.

Lateral Design:

For the lateral design, full wind and seismic loads calculations were completed and compiled in the first technical report as seen in the Appendix. SAP2000 was used to analyze each moment frame individually in the building. Using a 1k force at the top of the each frame structure, story deflections were found and then converted into stiffness values by the equation Stiffness (K) = 1/deflection (Δ). When combined, this stiffness gives the load distribution for the moment frame, the floor, and the total section. The center of rigidity and wind direction are shown below.


455 Feet
30 Feet
1
5
2
Center
of Rigidity
N/S
3
6
4
30 Feet
115 Feet
E/W

Loads:

All gravity load calculations found in the existing building used Uniform Building Code 1997 as their design standard. For simplicity and current accurate standards, I will use ASCE 7-05 to find, factor, and calculate all gravity loads in the building. If uniform differences in sizes occur, it may be a result of this change.

Live Loads:

Roof:		40 psf
Floor:	Level 1:	100 psf
	Levels 2-6:	80 psf
Stairs, Corridors and Lobbies:		100 psf
Mechanical Rooms:		125 psf

Dead Loads:

Roof:	(Design)	25 psf
Floor:	(Superimposed)	5 psf
	(Finishes @ Level 1)	25 psf
	(Partitions @ Levels 2-6)	20 psf

Snow Loads:

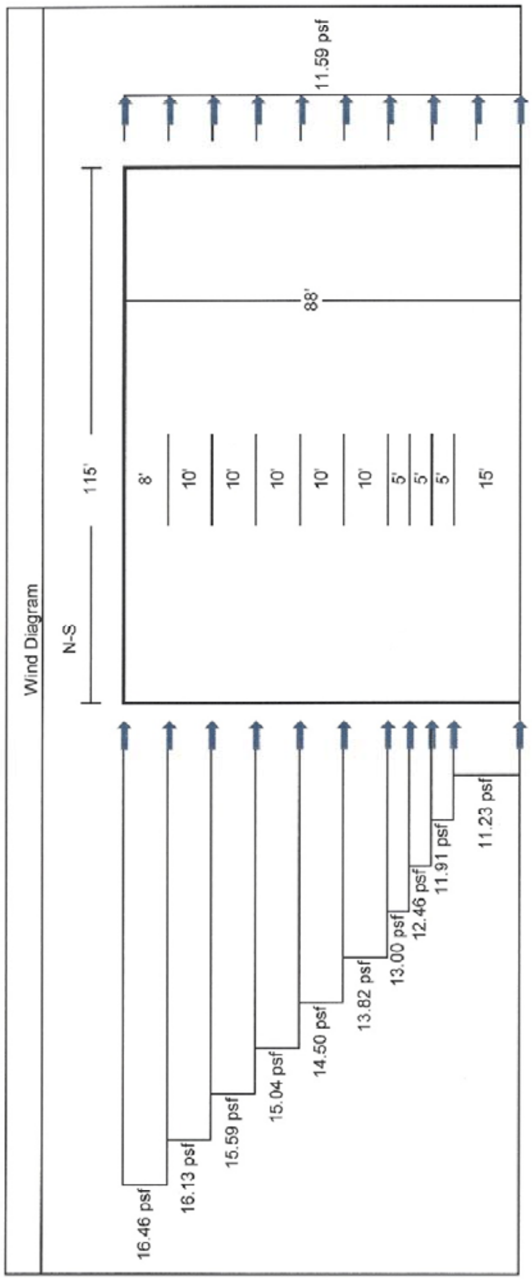
Use the equation	$p_f=0.7*C_e*C_t*I*p_g$
From Table 7-2, Exposure Factor, C_e =	0.9
From Table 7-3, Thermal Factor, C_t =	1.0
From Table 7-4, Importance Factor, I =	1.1
From Figure 7-1, Ground Snow Load, p_g =	50 psf
Total Snow Load =	34.65 psf

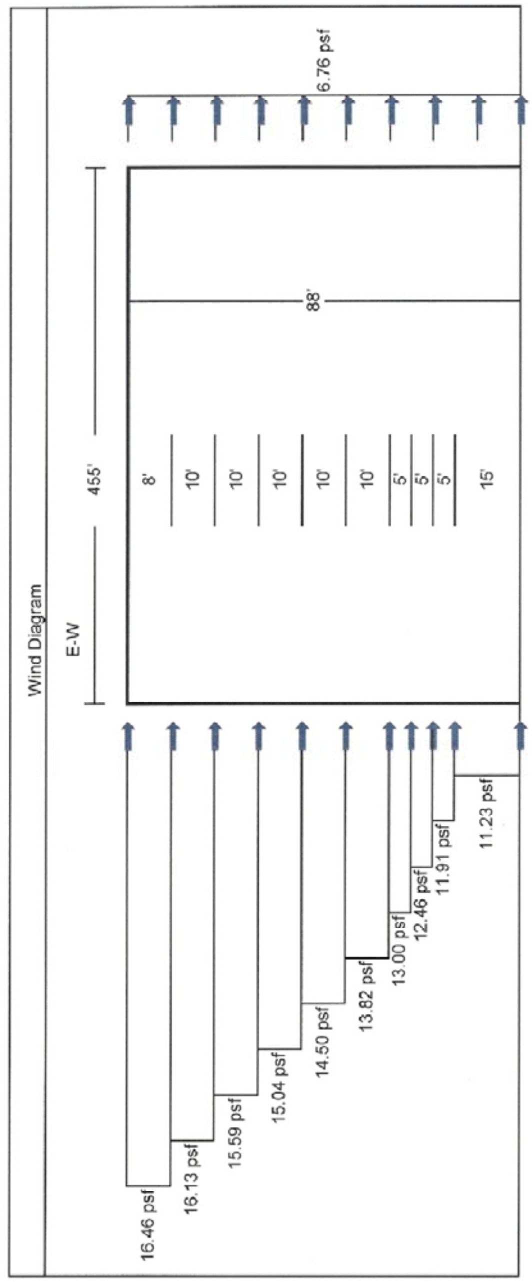
Wind Loads:

The charts below summarize the results found from my wind calculation analysis. Specific calculations of wind forces are located in the Appendix in Excel form. Wind loading diagrams also follow.

	Windward		Leeward		Max (psf) N-S	Max (psf) E-W
Z(ft)	N-S	E-W	N-S	E-W		
0-15	11.23	11.23	-11.59	-6.76	22.82	17.99
20	11.91	11.91	-11.59	-6.76	23.50	18.67
25	12.46	12.46	-11.59	-6.76	24.05	19.22
30	13.00	13.00	-11.59	-6.76	24.59	19.76
40	13.82	13.82	-11.59	-6.76	25.41	20.58
50	14.50	14.50	-11.59	-6.76	26.09	21.26
60	15.04	15.04	-11.59	-6.76	26.63	21.80
70	15.59	15.59	-11.59	-6.76	27.18	22.35
80	16.13	16.13	-11.59	-6.76	27.72	22.89
90	16.54	16.54	-11.59	-6.76	28.13	23.30
88	16.46	16.46	-11.59	-6.76	28.05	23.22

	N-S	E-W
Shear @ 6	185.97	38.87
Shear @ 5	181.91	37.83
Shear @ 4	176.29	36.41
Shear @ 3	170.60	34.97
Shear @ 2	156.75	31.65
Shear @ 1	3.43	0.68
Shear @ Ground	152.35	30.36
Base Shear	1,027.29	210.76
Overturning Moment	52,210.43	10,808.69


Wind Diagram
N-S
115'
88'
8'
10'
10'
10'
10'
10'
5'
5'
5'
15'
11.59 psf
16.46 psf
16.13 psf
15.59 psf
15.04 psf
14.50 psf
13.82 psf
13.00 psf
12.46 psf
11.91 psf
11.23 psf


Wind Diagram
E-W
455'
88'
8'
10'
10'
10'
10'
10'
5'
5'
5'
15'
6.76 psf
16.46 psf
16.13 psf
15.59 psf
15.04 psf
14.50 psf
13.82 psf
13.00 psf
12.46 psf
11.91 psf
11.23 psf

Seismic Loads:

The charts below summarize the results found from my seismic calculation analysis. Specific calculations of seismic forces are located in the Appendix in Excel form.

Summary N-S						
Level	w_x	h_x	$w_x h_x^k$	C_{vx}	F_x (kips)	M_x (ft-kips)
6	1,796.14	88.00	2,376,777.04	0.25556	82.45	7,255.79
5	2,867.05	73.35	2,832,213.68	0.30454	98.25	7,206.76
4	2,867.05	58.68	1,979,465.13	0.21284	68.67	4,029.51
3	2,867.05	44.01	1,247,305.17	0.13412	43.27	1,904.31
2	2,867.05	29.34	650,545.91	0.06995	22.57	662.14
1	2,867.05	14.67	213,800.17	0.02299	7.42	108.81
Σ	16,131.39		9,300,107.09	1.00	322.63	21,167.32

Summary E-W						
Level	w_x	h_x	$w_x h_x^k$	C_{vx}	F_x (kips)	M_x (ft-kips)
6	1,796.14	88.00	2,376,777.04	0.25556	82.45	7,255.79
5	2,867.05	73.35	2,832,213.68	0.30454	98.25	7,206.76
4	2,867.05	58.68	1,979,465.13	0.21284	68.67	4,029.51
3	2,867.05	44.01	1,247,305.17	0.13412	43.27	1,904.31
2	2,867.05	29.34	650,545.91	0.06995	22.57	662.14
1	2,867.05	14.67	213,800.17	0.02299	7.42	108.81
Σ	16,131.39		9,300,107.09	1.00	322.63	21,167.32

Load Distribution:

For each moment frame, load is distributed from both shear and torsional components. The direct shear on each moment frame is calculated by relative stiffness of the frame. This stiffness is determined by the equation: relative stiffness (q) = stiffness (k)/ sum of stiffnesses (Σk). This stiffness was then multiplied by the highest story shear in order to confirm that every floor was designed to capacity. The center of rigidity was found using the moment frame system and AutoCAD as seen in the drawing on page 6. Next, an eccentricity for the moment frame relative to the entire building was found and this was applied with the maximum shear force to create a torsional moment. This torsional moment was distributed over the frame per foot of area and a torsional shear was found. As shown below, the torsional shear was negligible to the direct shear so issues caused by torsion do not need to be heavily considered.

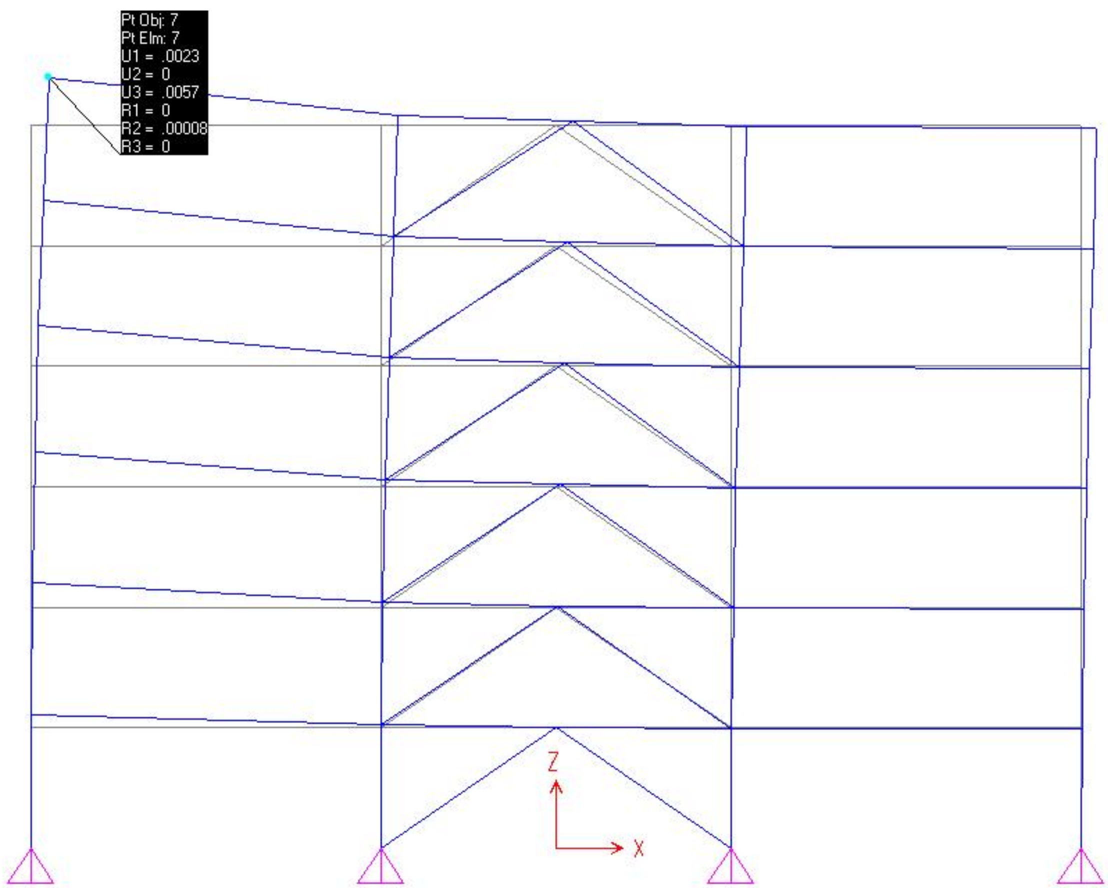
Direct Shear & Torsion:

The values for torsion are near negligible due to the fact that the center of rigidity is very close to the center of mass. The following chart shows the direct shear and torsion that each frame would expect to see.

	Direct Shear	Torsion
Frame 1	33.17	0.002742626
Frame 2	33.17	0.001500682
Frame 3	33.17	0.001604178
Frame 4	33.17	0.002846122
Frame 5	51.75	0.000434881
Frame 6	37.49	0.000374259

Deflection & Drift:

To calculate the story drift and total drift of the building, a SAP2000 model was used. First, a force of 100k was placed at the top of every moment frame to determine which one would have the highest deflection. One moment frame was also hand checked to verify that the computer results were accurate. The value obtained was almost exactly the same as the computer deflection, so this method of analysis can be assumed to be accurate. After this was determined, the appropriate direct shear and torsional force was applied to the frame with the largest deflection and compared to the allowable H/400 drift criteria. The results are below:



Deflection Calculation H/400: ((88')*(12in/ft))/400 = 2.64"
N-S Section Frame: Story Drift = 2.60" < 2.64" Allowable
E-W Section Frame: Story Drift = .87" < 2.64" Allowable

As you can see above, each frame section passed the drift comparison and is adequately designed for drift. Since the worse case in all three sections passed the H/400 drift requirement, it is safe to say that the overall section would also pass this requirement. The building is therefore acceptable in both total drift and story drift values.

Overturning & Uplift:

To calculate the overturning moment, wind forces were considered because they control the design. Each floor was analyzed by the appropriate wind force multiplied by the distance of the base. The total moment resulting from this calculation is considered to be the overturning moment of the structure. This moment is then compared to the weight of the structure (found in the Seismic Calculations, W = 16131k). The calculation produced this table and result:

Overturning (Wind N-S)			
Story #	Story Shear	Height	Story Moment
1st Floor	874.94	14.67	12,835.41
2nd Floor	871.52	29.33	25,561.55
3rd Floor	714.77	44.00	31,449.76
4th Floor	544.17	58.67	31,926.43
5th Floor	367.88	73.33	26,976.61
6th Floor	185.97	88.00	16,365.56
Overturning Moment			145,115.32
Overturning Force			1,451.15

N-S Controlling Section: 1451k < 16131k Allowable

Clearly, the weight of the structure is more than enough to hold down the structure from uplift.

Strength Check:

To check the strength requirement in the lateral systems, two columns in critical sections were chosen to represent the structure. The first column is used in the braced frame connection on the west end of the building. The second column is used in the braced frame connection on the east end of the building. To compare the values, the equation $P_u/b + M_u/m < 1$ was used. Both columns are located on the first floor and stiffness values were used to obtain the specific axial and moment force exerted on the column.

Section 1:
W14x120, $P_u/b + M_u/m = 166.37/0.47 + 387.34/0.668 = 0.934 < 1$ Allowable

Section 2:
W14x90, $P_u/b + M_u/m = 173.08/0.516 + 403.23/0.741 = 0.880 < 1$ Allowable

Both columns have enough strength to overcome the forces that are placed on them.

Member Spot Check:

Member spot checks were performed to ensure that the lateral system was designed to hold the controlling lateral force. All the checks were done for the 2nd story of the building, and the lateral force was distributed appropriately by stiffness and tributary area. Three checks in all were performed to represent the building.

Check #1

The first member chosen to spot check, is a typical bay in the east moment frame to verify wind loading controlled

Wind Force on one member: M_u = 331.06'k
Projected Member Design: W16x50 where $øM_n$ = 345'k
Seismic Force on one member: M_u = 277.56'k
Projected Member Design: W16x45 where $øM_n$ = 309'k
Actual Member Design: W16x57

This member comparison shows that the controlling wind load case was correct.

Check #2

For the second spot check, I chose the moment frame on the west end to represent an E-W member in design. All appropriate tributary areas were applied, giving the results:

Wind Force on one member: M_u = 350.30'k
Projected Member Design: W21x44 where $øM_n$ = 358'k
Seismic Force on one member: M_u = 280.22'k
Projected Member Design: W18x40 where $øM_n$ = 294'k
Actual Member Design: W21x50

Again, the controlling case produced the correct member design with the seismic slightly lower.

Conclusion:

The design of the lateral system has met all checks and passed all requirements. Calculations for torsion, drift, overturning, and strength all produced acceptable values. The design was ultimately controlled by wind forces using Case #4: 1.2D + 1.6W + 1.0L + 0.5S. Based on the location of the building, Richfield, MN, the fact that wind forces control is expected.

Appendix

Load (psf)	
D = dead load	50
D_i = weight of ice	
E = earthquake load	322.6
F = load due to fluids with well-defined pressures and maximum hieghts	
F_a = flood load	
H = load due to lateral earth pressure, ground water pressure, or pressure of bulk materials	
L = live load	100
L_r = roof live load	
R = rain load	
S = snow load	34.65
T = self-straining force	
W = wind load	256.1
W_i = wind-on-ice determined in accordance with Chapter 10	

Loading Case		
Case #1	70.00	1.4(D + F)
Case #2	237.33	1.2(D + F + T) + 1.6(L + H) + 0.5(L_r or S or R)
Case #3	320.28	1.2D + 1.6(L_r or S or R) + (L or 0.8W)
Case #4	587.01	1.2D + 1.6W +1.0 L + 0.5(L_r or S or R)
Case #5	489.56	1.2D + 1.0E + L + 0.2S
Case #6	454.68	0.9D + 1.6W + 1.6H
Case #7	367.63	0.9D + 1.0E + 1.6H

EXCEPTIONS:

1. The load factor on *L* in combinations (3), (4), and (5) is permitted to equal 0.5 for all occupancies in which L_o in Table 4-1 is less than or equal to 100 psf, with the exception of garages or areas occupied as places of public assembly.

2. The load factor on *H* shall be set equal to zero in combinations (6) and (7) if the structural action due to *H* counteracts that due to *W* or *E*. Where lateral earth pressure provides resistance to structural actions from other forces, it shall not be included in *H* but shall be included in the design resistance.

3. In combinations (2), (4), and (5), the companion load *S* shall be taken as either the flat roof snow load (p_f) or the sloped roof snow load (p_s).

*Note: All Calculations done without live load reduction of 0.5

Wind Loading Calculations:

Wind Load Analysis

Building Properties	
B (ft)	115
L (ft)	455
h (ft)	88.00
K_{zt}	1
K_d	0.85
V (mph)	90
Importance	III
I_w	1.15
Exposure	B
α	7
z_g	1200
z_{min}	30
c	0.3
$\in$	0.333333
l	320
$\bar{\alpha}$	0.250
$\bar{b}$	0.45
$\underline{\underline{a}}$	0.143
$\underline{\underline{b}}$	0.84

Period Parameters	
Struct. Type	Steel
C_t	0.02
x	0.75
(check eq) T	0.5746
Natural f	1.7402
Rigidity	Rigid

Rigid	
$g_Q=g_v$	3.4
$\check{z}$	52.8
$I_{\check{z}}$	0.277397
$L_{\check{z}}$	374.2743
Q	0.83668
G	0.85

Flexible	
g_R	4.32
R_n	0.024
N_1	15.97
η_h	17.28
η_B	0.196
η_L	299.07
R_h	0.056
R_B	0.881
R_L	0.003
$V_{\check{z}}$	40.77
β	0.05
R	0.11
G_f	0.8388

Windward	
Cp	0.8

	Leeward	
	Ratio	C_p
N-S	0.253	-0.50
E-W	3.957	-0.20

Pressure Coefficients		
Internal Enc. Type	Enclosed	
Internal (GC_{pi})	0.18	+/-

Pressures			
Windward	N-S	P_z	0.851
	E-W	P_z	0.851
Leeward	N-S	P_h	-0.599
	E-W	P_h	-0.350

Flexiblity	
g_R	4.32
R_n	0.024
N_1	15.97
η_h	17.28
η_B	0.196
η_L	299.07
R_h	0.056
R_B	0.881
R_L	0.003
$V_{\check{z}}$	40.77
β	0.05
R	0.11
G_f	0.8388

K_z and q_z		
Z(ft)	K_z	q_z
0-15	0.57	11.55
20	0.62	12.57
25	0.66	13.38
30	0.70	14.19
40	0.76	15.40
50	0.81	16.42
60	0.85	17.23
70	0.89	18.04
80	0.93	18.85
90	0.96	19.46
88.00	0.95	19.34

	Leeward	
	Ratio	C_p
N-S	0.253	-0.50
E-W	3.957	-0.20

Wind Distribution N-S									
Min	Max	pressure (psf)	Level	h/floor	Z-real	Area	Force	V (k)	M(ft-k)
0	14.67	22.82	Ground	0	0	6674.85	152.35	152.35	0.00
14.67	15	22.82	1	14.67	14.67	150.15	3.43	3.43	50.28
15	20	23.50	2			2275.00	53.47		
20	25	24.05	2	14.67	29.34	2275.00	54.71	156.75	4599.00
25	29.34	24.59	2			1974.70	48.56		
29.34	30	24.59	3			300.30	7.39		
30	40	25.41	3	14.67	44.01	4550.00	115.61	170.60	7508.00
40	44.01	26.09	3			1824.55	47.60		
44.01	50	26.09	4	14.67	58.68	2725.45	71.10	176.29	10344.71
50	58.68	26.63	4			3949.40	105.19		
58.68	60	26.63	5			600.60	16.00		
60	70	27.18	5	14.67	73.35	4550.00	123.66	181.91	13342.89
70	73.35	27.72	5			1524.25	42.25		
73.35	80	27.72	6	14.65	88.00	3025.75	83.88	185.97	16365.56
80	88	28.05	6			3640.00	102.09		
							Sum	1027.29	52210.43

Wind Distribution E-W									
Min	Max	pressure (psf)	Level	h/floor	Z-real	Area	Force	V (k)	M(ft-k)
0	14.67	17.99	Ground	0	0	1687.05	30.36	30.36	0.00
14.67	15	17.99	1	14.67	14.67	37.95	0.68	0.68	10.02
15	20	18.67	2	14.67	29.34	575.00	10.74	31.65	928.64
20	25	19.22	2			575.00	11.05		
25	29.34	19.76	2			499.10	9.86		
29.34	30	19.76	3	14.67	44.01	75.90	1.50	34.97	1538.95
30	40	20.58	3			1150.00	23.66		
40	44.01	21.26	3			461.15	9.80		
44.01	50	21.26	4	14.67	58.68	688.85	14.64	36.41	2136.36
50	58.68	21.80	4			998.20	21.76		
58.68	60	21.80	5	14.67	73.35	151.80	3.31	37.83	2774.58
60	70	22.35	5			1150.00	25.70		
70	73.35	22.89	5			385.25	8.82		
73.35	80	22.89	6	14.65	88.00	764.75	17.51	38.87	3420.14
80	88	23.22	6			920.00	21.36		
							Sum	210.76	10808.69

Pressure Distribution						
			N-S		E-W	
Level	h/floor (ft)	Z (ft)	V (k)	M (ft-k)	V (k)	M (ft-k)
6	14.65	88.00	185.97	16,365.56	38.87	3,420.14
5	14.67	73.35	181.91	13,342.89	37.83	2,774.58
4	14.67	58.68	176.29	10,344.71	36.41	2,136.36
3	14.67	44	170.60	7,508.00	34.97	1,538.95
2	14.67	29.34	156.75	4,599.00	31.65	928.64
1	14.67	14.67	3.43	50.28	0.68	10.02
0	0	0	152.35		30.36	
Σ			1,027.29	52,210.43	210.76	10,808.69

Seismic Loading Calculations:

Building Properties	
B (ft)	115
L (ft)	455
h (ft)	88.00
# of Stories	6.00
ave. h/floor (ft)	14.67
Seismic Use group	III
Imp. (e)	1.5
Site Classification	B
S_s (%g)	0.06
S_1 (%g)	0.027
R	3
C_t	0.028
x	0.8
T_L	12
C_u	1.7
F_a	1
F_v	1
S_{MS}	0.06
S_{M1}	0.027
S_{DS}	0.04
S_{D1}	0.018

Response	
T_a	1.01
C_s	0.02

Load Summary (psf)	
Roof Dead	25
Snow	34.65
Floor Dead	50
Ex. Wall Dead	15
avg. wroof (lbs)	1,796.14
avg. wfloors (lbs)	2,867.05
Wtotal (lbs)	16,131.39
V (lbs)	322.63

Distribution	
k	1.60539

Summary N-S						
Level	w_x	h_x	$w_x h_x^k$	C_{vx}	F_x (kips)	M_x (ft-kips)
6	1,796.14	88.00	2,376,777.04	0.25556	82.45	7,255.79
5	2,867.05	73.35	2,832,213.68	0.30454	98.25	7,206.76
4	2,867.05	58.68	1,979,465.13	0.21284	68.67	4,029.51
3	2,867.05	44.01	1,247,305.17	0.13412	43.27	1,904.31
2	2,867.05	29.34	650,545.91	0.06995	22.57	662.14
1	2,867.05	14.67	213,800.17	0.02299	7.42	108.81
Σ	16,131.39		9,300,107.09	1.00	322.63	21,167.32

Summary E-W						
Level	w_x	h_x	$w_x h_x^k$	C_{vx}	F_x (kips)	M_x (ft-kips)
6	1,796.14	88.00	2,376,777.04	0.25556	82.45	7,255.79
5	2,867.05	73.35	2,832,213.68	0.30454	98.25	7,206.76
4	2,867.05	58.68	1,979,465.13	0.21284	68.67	4,029.51
3	2,867.05	44.01	1,247,305.17	0.13412	43.27	1,904.31
2	2,867.05	29.34	650,545.91	0.06995	22.57	662.14
1	2,867.05	14.67	213,800.17	0.02299	7.42	108.81
Σ	16,131.39		9,300,107.09	1.00	322.63	21,167.32

Stiffness Calculations:

Frames 1-4		
Floor #	Displacement	Stiffness
6	0.1106	9.0416
5	0.1031	9.6993
4	0.0920	10.8696
3	0.0773	12.9366
2	0.0588	17.0068
1	0.0349	28.6533
Total Stiffness		88.2072

Frame 5		
Floor #	Displacement	Stiffness
6	0.0709	14.1044
5	0.0675	14.8148
4	0.0620	16.1290
3	0.0542	18.4502
2	0.0432	23.1481
1	0.0271	36.9004
Total Stiffness		123.5469

Frame 6		
Floor #	Displacement	Stiffness
6	0.0812	12.3153
5	0.0777	12.8700
4	0.0719	13.9082
3	0.0632	15.8228
2	0.0506	19.7628
1	0.0316	31.6456
Total Stiffness		106.3247

Direct Shear:

Direct Shear	Stiffness	Relative Stiffness	Max Story Shear	Direct Shear
Frames 1-4	88.20719	0.10250402	323.63	33.17
Frame 5	123.5469	0.15990049	323.63	51.75
Frame 6	106.3247	0.11582701	323.63	37.49

Torsional Shear:

Torsion	K	x (ft)	Kx^2	Torsion
Frame 1	88.2072	132.5	1548587	0.002743
Frame 2	88.2072	72.5	463639	0.001501
Frame 3	88.2072	77.5	529794	0.001604
Frame 4	88.2072	137.5	1667667	0.002846
Frame 5	123.5469	15	27798	0.000435
Frame 6	106.3247	15	23923	0.000374