Drexel University Race Street Dormitory

Douglas Tower - Technical Report III - Structural

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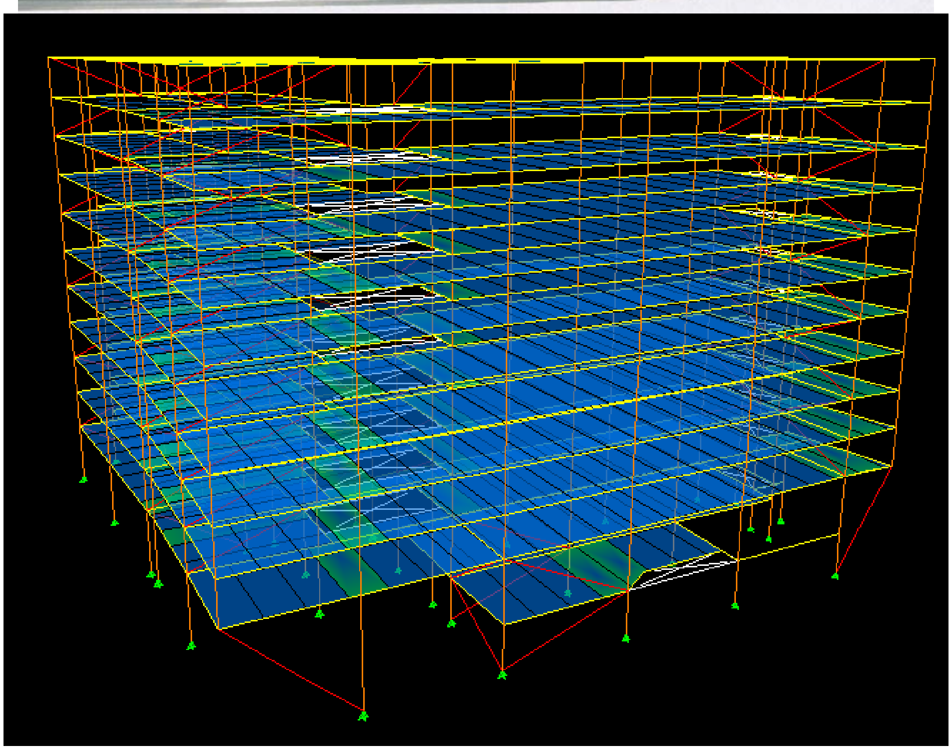
12/2/06



ETABS Model

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*Changes have been made from previous technical reports:
-First floor live load will be considered unfactored 40 psf like the rest of the floors
-Hollow core plank system was found to be 82.5 psf, not 30 psf as used in technical report 1
-Hand calculated North-South and East-West wind has been simplified to the same loading for all of the wind loaded sides of the building.
-The horizontal tributary area method has been changed to frame relative rigidity percentage load pickup

I. Executive Summary

This report focuses on the lateral load resistance of the Drexel University Race Street Dormitory in Philadelphia, PA. The dormitory is a 12 story 117’ high steel framed ‘L’ shaped building with pre-cast pre-stressed hollow core plank flooring. The focus of this report is how the building resists lateral wind and seismic loads through five major braced framed and two moment frames.

ETABS, SAP2000 v9, and hand calculations were used to evaluate lateral resisting frame rigidity, building drift, base shear, floor shear, torsion, and overturning under different loading conditions. Lateral resisting frame relative rigidity was used to distribute lateral loading to each frame. Seismic loading showed to be controlling over wind loading. ETABS and hand calculations were reasonably close, supporting seismic and wind base shear results (although seismic base shear was close to twice that noted in the original structural drawings). ETABS analysis resulted in some confusing results for drift, none of which exceeded code requirements. The torsional effects due to wind on the building are small due to the location of lateral load resisting frames.

Overall, the building resists lateral loading effectively. No critical members fail under loading, overturning does not occur, and drift, although questionable, is well below code requirements.

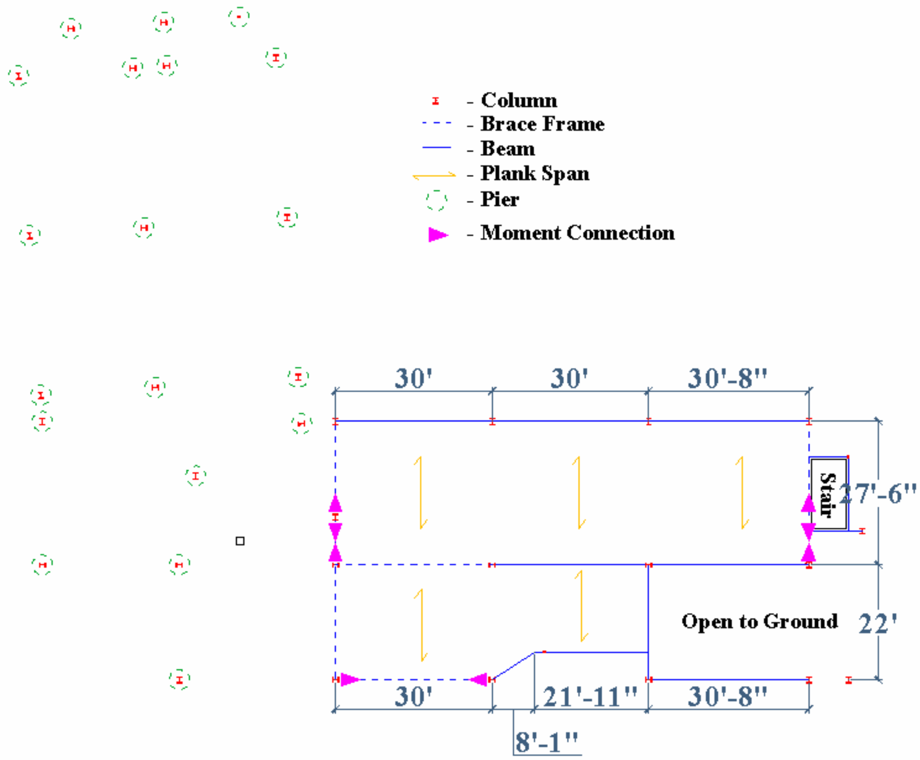
II. Introduction

This report is a lateral analysis of the Drexel University Race Street Dormitory. It includes a discussion of the building, its structural system and lateral load resisting system, and calculations and discussion of wind loading, seismic loading, drift, overturning moment, and member checks. ETABS, SAP2000 version 9, as well as hand calculations were used to compare wind and seismic loading. ETABS was used to calculate the building drift. Hand calculations were used for overturning moment and member checks.

i. Existing Building

The Race Street Dormitory is a twelve story, 120 ft high steel framed Drexel University Building with wind and seismic loading corresponding to Philadelphia, PA. The dormitory is an ‘L’ shaped building with legs roughly 116 ft and 165 ft long that veer 4 degrees off a right angle at one point. (See figure 2) At its lowest level above grade, the building consists of only part of one leg of the ‘L’ shape- a roughly rectangular length running east-west. Figure 1 shows the flooring above this ground floor. This ground level consists of mechanical rooms, an electrical room, and maintenance rooms as well as a shop and bicycle room. This floor is abutted against a higher grade (one story higher) on which sits the shorter wing of the building on free standing columns. Figure 1 shows some of the flooring at this level and the piers for the free standing columns. An enclosed first floor lies on the footprint of the ground floor and contains the main entrance lobby, a security entrance, a mailroom, a Resident Assistant suite, and a large common room. The second floor and consecutive floors sit form the main “L” shape of the building. (See figure 2) These floors have a central hallway with rows of suites on either side. Suites have two bedrooms, common room, bathroom, and kitchen. There are three elevators at the south-east corner (bend) in the building, two of which begin at the ground story level. There are two stairways at the far north and east ends of the building. (See figures 1-3)

Figure 1 - First Floor Framing Plan



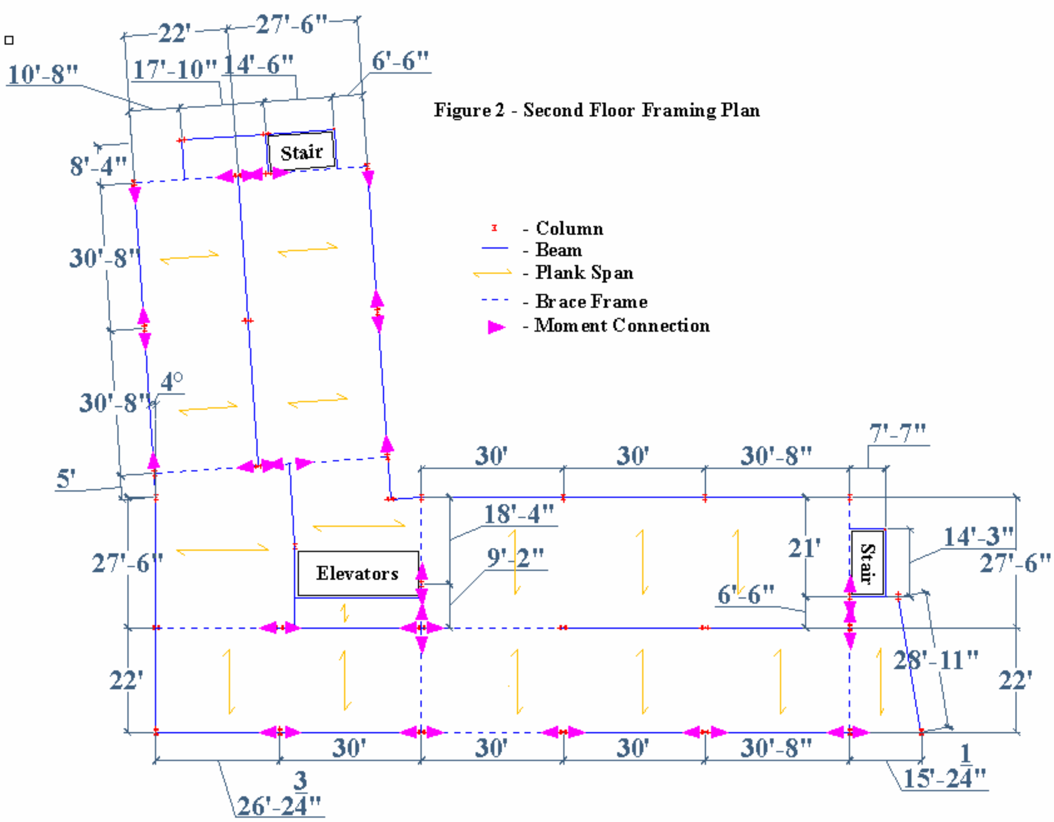


Figure 2 - Second Floor Framing Plan

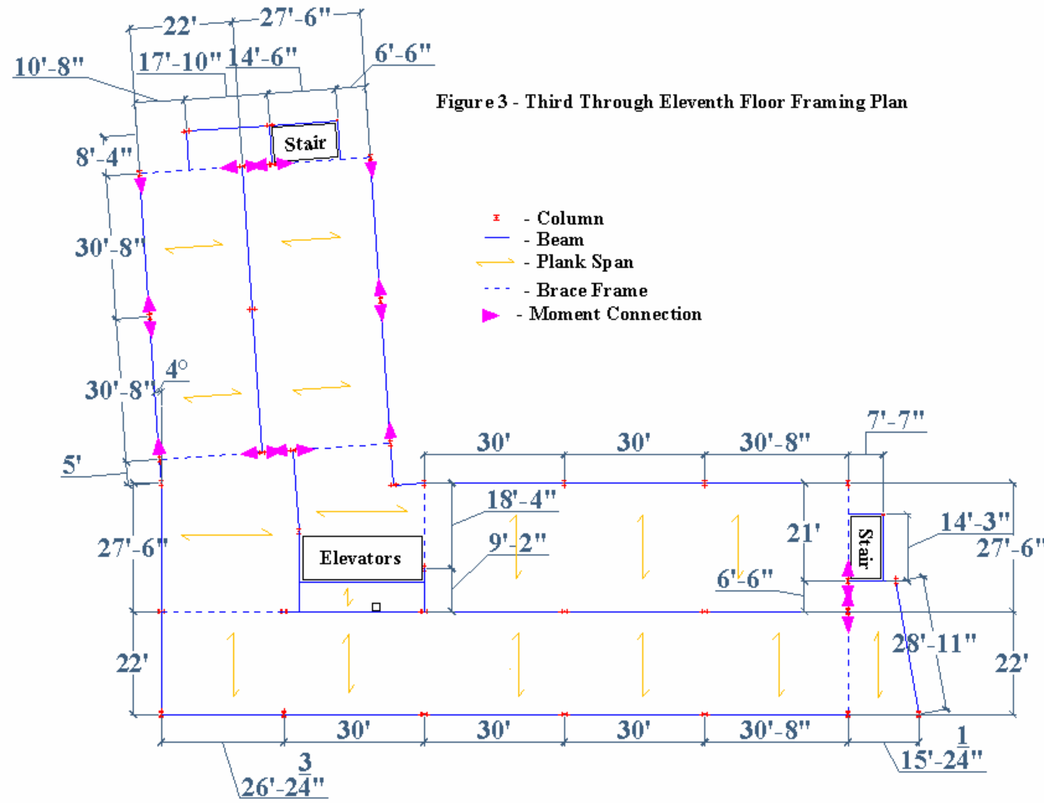


Figure 3 - Third Through Eleventh Floor Framing Plan

ii. Existing Structural System

The residence hall is a steel W-shaped column and beam frame with moment connections, moment frames, braced frames. The floor heights are 9'4" for floors two through eleven, 14' for level one, and 10' for ground level. (See figure 5 for height layout) Beams run predominately longitudinally along the building, as floor planks span two horizontal bays. (See figures 1-3) Beam sizes are mainly W12 or W18, and span up to 30'8". The third through eleventh floors have identical beam systems, while the beams at the first and second floors are unique and generally larger.

The roof is flat and consists of mainly W12 purlins spaced 6' on center and Grade 33 structural galvanized steel decking supporting EPDM single-ply membrane roofing over rigid insulation.

Each floor consists of pre-stressed pre-cast hollow core concrete planks 8" deep, typically 8' wide with 2" cast-in-place concrete topping. (See figures 1-3) The planks are typically 22'8 or 28'2" long (8" overhang typical). The maximum depth of the floors is about 28" (roughly 18" beams, 8" decking, and 2" leveling slab), but, as noted before, beams do not frame each bay of the system, and are not intermediately placed within bays. This allows for up to 90' expanses of 10" deep flooring uninterrupted by beams (see fig. 3).

iii. Lateral Load Resisting System

The lateral load resisting system is a series of diagonally braced frames with moment connections and moment frames that I have modeled in SAP2000 version 9 for the purpose of finding their rigidity relative to each other in both the North-South (vertical in plans) and East-West (horizontal in plans) directions. (See table 30 in the Distribution section) I have also drawn elevation views and shown wind load distribution in AutoCAD 2007. (See figures 4-7) Some of the brace frames accommodate a hallway through the center of the building with another column and moment connections. (See figures 1-7)

Figure 9 - Third Through Eleventh Floor Braced Frames

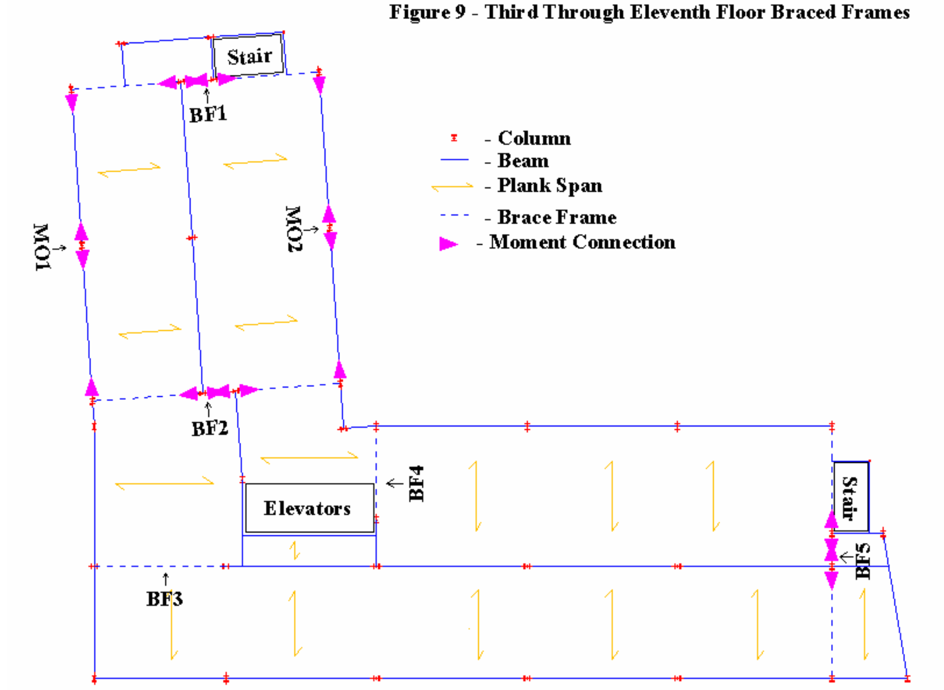
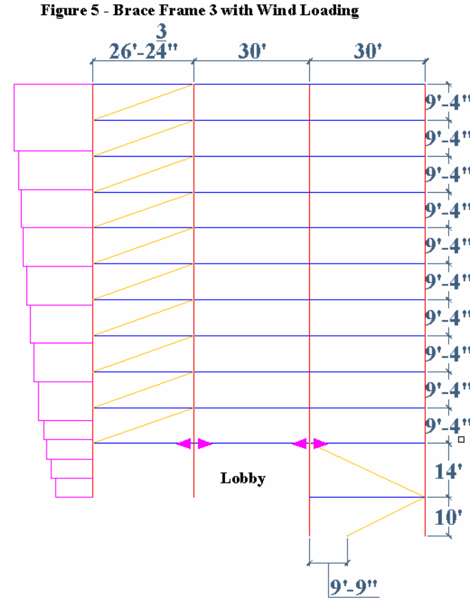


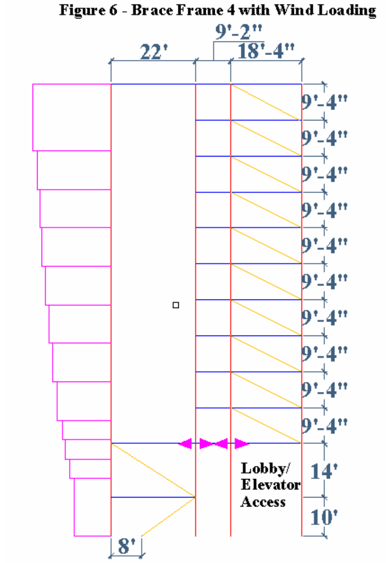
Figure 5 - Brace Frame 3 with Wind Loading



Brace frame three (BF3) provides west-east support at the bend of the building (over the lobby). (Figure 5) The design of BF3 ties the wing resting on higher grade to the wing on lower grade. The wing on higher grade is so-called “soft” structure, or resting on an open level of free standing columns, creating a more flexible structure. The lower grade wing has a lower base and concrete cladding, making it a more rigid structure. In an earthquake, the two wings move at different frequencies and directions. This more rigid connection between the two wings in the ‘L’ shape helps prevent structural failure due to torsion under such seismic loadings. BF3, however, is assumed to resist just 12% of the lateral loads in the East-West Direction based on its rigidity.

The design of BF3 also does not restrict the lobby at level 1, with its continuation of diagonal members three bays left

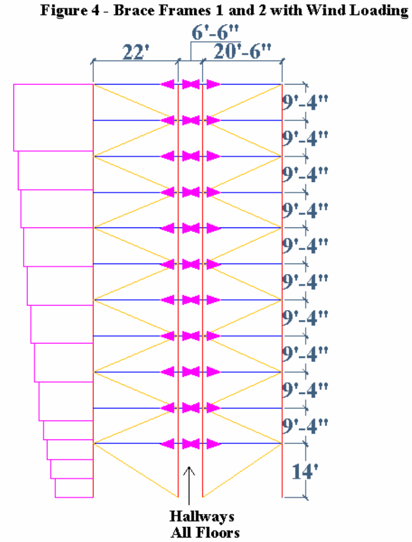
Figure 6 - Brace Frame 4 with Wind Loading



below floor level 2. The moment is carried across using moment connections at level 2. (See figure 5)

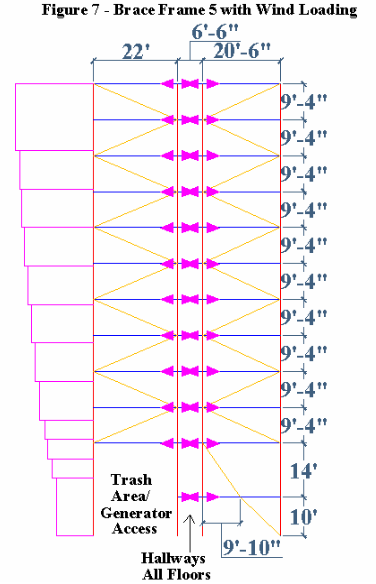
This offset brace frame design is also used in BF4 creating open bays at levels 1 and 2 for open elevator lobbies at ground and first floor levels. (Figure 6) I assumed the plank flooring is a diaphragm carrying the loading from the left to right across the brace frame at floor levels (not shown). BF4 is assumed to carry 27% of the lateral loading in the North-South direction based on its rigidity.

Figure 4 - Brace Frames 1 and 2 with Wind Loading



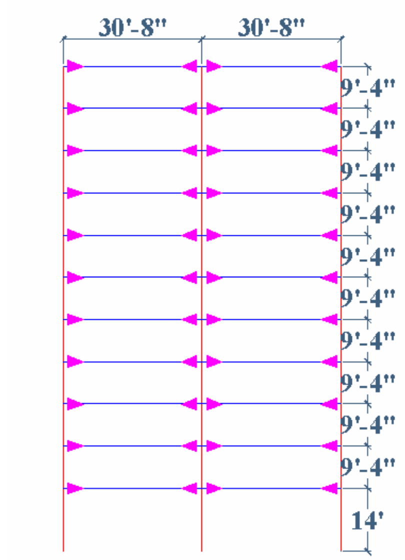
The other full building height brace frames - BF1 (fig. 4), BF2 (fig. 4), BF5 (fig. 7) - run across all three bays perpendicular the building's length and are the most rigid. BF1 is assumed to carry 34% of the East-West lateral load, and BF2 53%. BF5 is assumed to carry 50% of the lateral load in the North-South direction. The north bay of BF5 is open at the ground and first floors for open air generator and dumpster area under the building. BF5 also uses oddly angled braces to carry the lateral load from the second floor to the ground level, but details behind this are unclear. (Figure 7) BF6 (not shown) is on the southern edge of the building at only the ground and first floors and seems to support the lateral loads of angled columns at the end of this wing of the building. BF6 was not considered in lateral load resistance due to its free standing diagonal end members and low profile.

Figure 7 - Brace Frame 5 with Wind Loading



Moment Frames 1 and 2 (I have noted them MO1 and MO2, see figure 9) also resist some North-South lateral loading, which I have assumed as 12% each based on much less rigidity than the brace frames.

Figure 9 - Moment Frames 1 and 2



Overall, there is strong seismic factor that played into the design of the structure. The highly rigid BF1 and BF2 at one end of the building and the highly rigid BF5 at the other reduce torsion, while BF3 strengthens the connection between the wings. (See figure 3) The frames are also devised to accommodate architectural needs.

III. Loads and Load Cases

The Race Street Dormitory is a twelve story dormitory in Philadelphia, PA that resists gravity loads, wind loads, seismic loads, snow loads. Gravity Loads include the weight of steel members, hollow-core concrete planks, mechanical systems, finish conditions, and steel stud partitions and facade, live loads, and snow loads. Table 1 compares design values of live loads, dead loads, and snow loads with those used in this report. Floors two through eleven are typical student residence floors with a uniform live loading of 40 psf, or factored load of 64 psf. For this analysis, floor one will use similar loading (this is a change from previous technical reports because the drawings do not note a higher live loading.) For roof loads, roof snow load will be considered a uniform 27 psf (this will control over roof live load of 20 psf), which is a factored 43.2 psf (See table 1).

The existing design used the following codes and design standards:

- 2004 Philadelphia Building Construction and Occupancy Code
  (Building Subcode: IBC 2003).
- *"Minimum design loads for buildings and other structures"*
  ASCE 7-02
- *"Building code requirements for reinforced concrete."*
  ACI 318-02
- *"ACI Manual of Concrete Practice."*
  Parts 1-5, 2001
- *"Manual of Standard Practice."*
  CRSI, March 2001
- *"Manual of Steel Construction: Load and Resistance Factor Design."*
  "Detailing for Steel Construction."
  AISC 2001
- *"Structural Welding Code"-Steel, Reinforcing Steel, Stainless Steel.*
  AWS/ASCE
- *"Manual for Floor Decks and Roof Decks."*
  Steel Deck Institute
- *"Manual for the design of hollow core slabs."*
  Pre-cast/Pre-stressed Concrete Institute, 2nd Edition, 1998

This analysis will use:

- IBC 2003 for hand calculations
- ASCE 7-05 for hand calculations
- IBC 2000 for ETABS seismic loading
- ASCE 7-98 for ETABS wind loading

The following Load Cases will be used for lateral load analysis according to ASCE 7:

1) 1.2D + 1.6S + (0.5L or 0.8W)
2) 1.2D + 1.6W + 0.5L + 0.5S
3) 1.2D +/- 1.0E + 0.5L + 0.2S
4) 0.9D +/- (1.6W or 1.0E)

Default ETABS combinations:

5) 1.4D+1.5E+0.5L
6) 1.2D+1.3W+0.5L

Combinations 2 and 5 showed the highest lateral drift in the ETABS analysis discussed later.

IV. Distribution

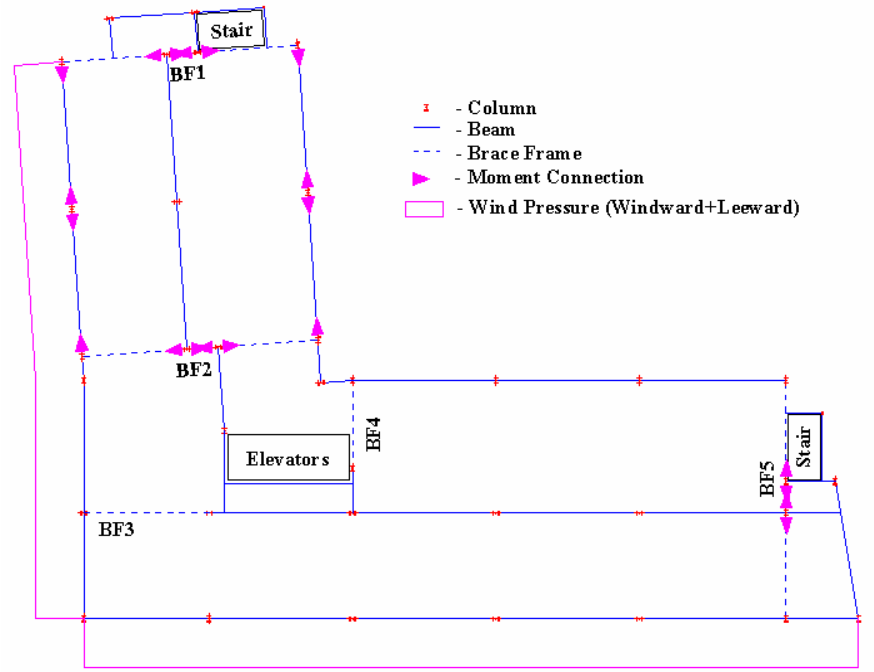
For the purpose of brace and moment frame analysis, lateral loads have been horizontally distributed to the frames based on their relative rigidity, determined with SAP2000 version 9. I attributed the percentage of load carried to a percentage of wall area in order to accommodate tables designed to calculated floor loads in technical report 1.
(See table 30)

Table 30 - Brace Frame Relative Rigidity				
East-West	Drift under 1 kip load	1/Drift	Percent of Wall Load Resisted	Horizontal Area (ft)
BF1	0.00513	194.93	34.30%	39.84
BF2	0.0033	303.03	53.31%	61.93
BF3	0.0142	70.42	12.39%	14.39
North-South				
BF4	0.0152	65.79	26.55%	43.02
BF5	0.008	125.00	50.45%	81.73
MO1	0.0351	28.49	11.50%	18.63
MO2	0.0351	28.49	11.50%	18.63

i. Wind Loads

For the hand analysis of wind loading, the long sides of the building will receive a combination of wind pressure and leeward suction coefficients that create the worst case scenario for the loading. The added coefficients result in positive loading shown in figure 8. Vertically, the uniform wind loading changes based on the heights outlined in ASCE 7 (see figures 4-7). The load at floor level has been found using the vertical tributary area of each floor level, which was very complicated due to the varying uniform loads and tributary areas. I have solved this problem using Microsoft Excel and have created tables that set up a method to find the point load at each floor level (see tables 3-14). Base shear shows that seismic loading controls over wind loading.

Figure 8 - Wind Loading (Shown on plan for floors 3-11)



ii. Seismic Loads

The seismic calculations give a shear at each floor level which is distributed to brace frames using the same horizontal area as with wind loading. For ease of analysis, this loading assumes the building begins at the first floor level. (See tables 16-20)

V. Results

Analysis has been carried out using Microsoft Excel for so called "hand calculations" and using the ETABS Nonlinear v8.2.6 computer program. Errors occurred in analyzing the structure in ETABS, including warnings that the building is unstable. After thorough study of the errors with the aid of more proficient ETABS designers, I have found no conclusions as to the cause of the errors. Luckily, most results are not far off from the hand calculations, but results for drift- calculations I did not perform by hand - are questionable.

i. Wind Loading

Hand calculations of wind calculations, brace frame loading, and overturning moments on brace frames are shown in tables 3-14. Refer to table 2, shown below, for base shear hand and ETABS calculation comparison, from results in tables 26 and 27. In table 2 the 'ground level' column refers to how the grade level changes under the dormitory. This distinction is necessary for proper comparison to hand calculations which only evaluate wind loading base shear at the higher ground level. This table also shows shearing perpendicular to loading due to torsional effects (calculated by ETABS). I did not do hand calculations for a 45 deg wind loading into the concave side of the building corner which seems to control in the x-direction. The hand calculations and computer calculations are not far off, but not precise, probably due to ETABS model error.

Table - 2		East-West Wind Direction (x)		North-South Wind Direction (y)		Southwest-Northeast Wind Direction (45 deg from northeast)	
	Ground Level (ft)	Base Shear along wind direction (kips)	Base shear perpendicular to wind direction due to torsion (kips)	Base Shear along wind direction (kips)	Base shear perpendicular to wind direction due to torsion (kips)	Base Shear in X direction (kips)	Base shear in Y direction (kips)
Hand Calculations	10	199.22		308.30			
ETABS Analysis	10	269	0	355.67	0	301.24	301.24
ETABS Analysis	0	108.62	9.55	316.71	63.43	187.22	257.23

ii. Seismic Loading

Table 15 combines dead loads at each floor for an overall total seismic shear on the building. Based on hand calculations, the total seismic base shear is 577.84 kips, which compares to 658.28 kips in the ETABS calculations, but is far from the 327 kips reported in the original design drawings. I cannot account for this discrepancy as ETABS has supported my hand calculations. Tables 16-20 show the floor load due to seismic loads at each brace frame using hand calculations.

iii. Drift

According to ASCE 7-05, the maximum allowable seismic story drift for this structure is 0.02*hx, where hx is the height of each story. Based on the roof level at 1408" high, the maximum building drift is 28.16". According to ETABS analysis of building diaphragm displacement, the maximum seismic (controls over wind) building drift is 2" in the East-West Direction (x). This occurred with a 1.4D+1.5E+0.5L load combination (See table 24). The maximum allowable wind drift for this structure is h/400, or 3.52". The 0.9D+1.6W load combination gave a pure wind deflection of 1.1" which is reasonable, but still small. It is odd that ETABS warned of structure instability, and then calculated a very small story drifts. These results are questionable, but do fail the code requirements.

iv. Frame Rigidity and Torsion

According to ETABS analysis of diaphragm displacement under wind load, there are small torsional effects due to wind loading in the East-West and North-South directions. Under pure East-West (x) wind loading, floor diaphragms have a side drift in the North-South direction a maximum of 27% of their drift in the wind direction. Under pure North-South (y) wind loading, floor diaphragms have a side drift in the East-West direction a maximum of 3% of their drift in the wind direction. Although oddly different, these are relatively small torsional effects, especially from a wind load in the North-South direction, which shows a greater surface area for wind to hit. (See tables 21-22) Torsional effects under load combinations are much higher.

v. Overturning

The overturning moments by wind on each brace frame are shown in tables 6, 10, 12, and 14. According to an ETABS analysis of each column in the brace frames, no column is in tension under the 0.9D+1.6W loading case, thereby ruling out overturning. The bottom stories on this table vary due to different grade levels. (See table 29 below)

Table 29 - Column Axial Force under 0.9D+1.6W load combination (negative being compression)		
Story	Column	P (kips)
STORY2	C1	-338.32
STORY2	C3	-249.86
STORY2	C4	-588.95
STORY2	C5	-545.88
STORY2	C6	-606.79
STORY2	C7	-690.36
STORY2	C8	-65.07
STORY2	C9	-115.01
STORY2	C10	-97.89
STORY2	C11	-962.35
STORY2	C12	-291.59
STORY2	C13	-199.06
STORY2	C14	-240.27
STORY2	C15	-90.98
STORY1	C16	-607.11
STORY2	C17	-746.19
STORY1	C23	-252.76
STORY2	C24	-365.76
STORY1	C27	-231.72
STORY1	C35	-258.98
STORY1	C36	-452.06
STORY1	C37	-185.03
STORY1	C39	-331.67

VI. Member Checks

I hand checked both the diagonal members between the 9th and 10th floors of brace frame 5 under the controlling seismic loading, as well as the bottom column on the windward side (west) of brace frame 1 for uplift. For the diagonal members I designed with 2L6x4x5/16 members and the design engineer used 2L6x4x1/2 members, probably sized up with load safety factors. Based on full dead loading and actual wind load (not 0.9D+1.6W as checked with ETABS discussed earlier), the windward bottom column in brace frame 1 is in compression, thereby creating no foundational concern. (See Calculations)

VII. Conclusion

Calculations confirm that the structure conforms to code and does not fail under seismic and wind lateral loading, despite some questionable ETABS analysis results and other ETABS results that match my hand calculations. Under lateral loading, overturning is not a factor, and torsional effects are small, probably due to brace frame location in plan. Member checks confirm members show likelihood of proper member sizing. Overall, the Race Street Dormitory's brace frames, moment frames, and floor diaphragms effectively resist the required lateral loads.

VIII. Tables

Table 1 - LOADING	Existing Design	This Design (IBC 2003)
Service Level Live Loads (psf)		
All floors, u.n.o.	40	40
Lobbies	100	100
Mechanical Rooms	250	250
Mechanical Penthouse Floor	250	250
Storage Rooms	200	250
Roof	20	20
Corridors	None	100
Elevator Machine Room Floor	125 + Machine Reactions	250
Dead Loads (psf)		
Partitions	15	15
Finish	Not noted	4
Mechanical	Not noted	5
Concrete Plank Weight	Not noted	82.5
Steel Member Weight	Not noted	10
Roof Snow Load		
Ground Snow Load, Pg	20 psf	30 psf
Terrain Category	B	B
Exposure of Roof	Fully Exposed	Fully Exposed
Snow Exposure Factor, Ce	1	0.9
Thermal Factor, Ct	1	1
Snow Importance Factor, I	1	1
Flat Roof Snow Load, P	20 psf	27 psf

Table 3 - Wind Load Variables	Existing Design	This Design
Basic Wind Speed (3s Gust)	90 mph	90 mph
Building Category	II	II
Wind Exposure	B	B
Internal Pressure Coefficient	0.18	0.18

Wall Wind Loading			
Height above Ground, z (ft)	Velocity Pressure Exposure Coefficient, Kz	qz	Uniform Wind Load p (psf)
0-15	0.57	10.05	9.76
20	0.62	10.93	10.91
25	0.66	11.63	11.82
30	0.7	12.34	12.74
40	0.76	13.40	14.11
50	0.81	14.28	15.26
60	0.85	14.98	16.18
70	0.89	15.69	17.09
80	0.93	16.39	18.01
90	0.96	16.92	18.70
100	0.99	17.45	19.38
120	1.04	18.33	20.53

BF1 Wind Loading						
Floor	Horizontal Tributary Area (ft)	Distributed Wind Load (psf)	Vertical Tributary Area in previous distributed load region (ft)	Distributed wind load (psf)	Vertical Tributary Area in previous distributed load region (ft)	Total Load at Floor Level (kips)
G	39.84	0				
1	39.84	9.76	5	10.91	2	2.81
2	39.84	10.91	8	11.82	3.67	5.20
3	39.84	11.82	1.33	12.74	8	4.69
4	39.84	12.74	2	14.11	7.33	5.14
5	39.84	14.11	2.67	15.26	6.66	5.55
6	39.84	15.26	3.34	16.18	6	5.90
7	39.84	16.18	4	17.09	5.33	6.21
8	39.84	17.09	4.67	18.01	4.66	6.52
9	39.84	18.01	5.34	18.70	4	6.81
10	39.84	18.70	6	19.38	3.33	7.04
11	39.84	19.38	9.33			7.21
R	39.84	20.53	4.67			3.82

BF2 Wind Loading						
Floor	Horizontal Tributary Area (ft)	Distributed Wind Load (psf)	Vertical Tributary Area in previous distributed load region (ft)	Distributed wind load (psf)	Vertical Tributary Area in previous distributed load region (ft)	Load at Floor Level (kips)
G	61.93	0				
1	61.93	9.76	5	10.91	2	4.37
2	61.93	10.91	8	11.82	3.67	8.09
3	61.93	11.82	1.33	12.74	8	7.29
4	61.93	12.74	2	14.11	7.33	7.99
5	61.93	14.11	2.67	15.26	6.66	8.63
6	61.93	15.26	3.34	16.18	6	9.17
7	61.93	16.18	4	17.09	5.33	9.65
8	61.93	17.09	4.67	18.01	4.66	10.14
9	61.93	18.01	5.34	18.70	4	10.59
10	61.93	18.70	6	19.38	3.33	10.95
11	61.93	19.38	9.33			11.20
R	61.93	20.53	4.67			5.94

BF3 Wind Loading						
Floor	Horizontal Tributary Area (ft)	Distributed Wind Load (psf)	Vertical Tributary Area in previous distributed load region (ft)	Distributed wind load (psf)	Vertical Tributary Area in previous distributed load region (ft)	Total Load at Floor Level (kips)
G	14.39	9.76	5			0.70
1	14.39	9.76	10	10.91	2	1.72
2	14.39	10.91	8	11.82	3.67	1.88
3	14.39	11.82	1.33	12.74	8	1.69
4	14.39	12.74	2	14.11	7.33	1.86
5	14.39	14.11	2.67	15.26	6.66	2.01
6	14.39	15.26	3.34	16.18	6	2.13
7	14.39	16.18	4	17.09	5.33	2.24
8	14.39	17.09	4.67	18.01	4.66	2.36
9	14.39	18.01	5.34	18.70	4	2.46
10	14.39	18.70	6	19.38	3.33	2.54
11	14.39	19.38	9.33			2.60
R	14.39	20.53	4.67			1.38

BF4 Wind Loading						
Floor	Horizontal Tributary Area (ft)	Distributed Wind Load (psf)	Vertical Tributary Area in previous distributed load region (ft)	Distributed wind load (psf)	Vertical Tributary Area in previous distributed load region (ft)	Total Load at Floor Level (kips)
G	43.02	9.76	5			2.10
1	43.02	9.76	10	10.91	2	5.14
2	43.02	10.91	8	11.82	3.67	5.62
3	43.02	11.82	1.33	12.74	8	5.06
4	43.02	12.74	2	14.11	7.33	5.55
5	43.02	14.11	2.67	15.26	6.66	5.99
6	43.02	15.26	3.34	16.18	6	6.37
7	43.02	16.18	4	17.09	5.33	6.70
8	43.02	17.09	4.67	18.01	4.66	7.04
9	43.02	18.01	5.34	18.70	4	7.35
10	43.02	18.70	6	19.38	3.33	7.60
11	43.02	19.38	9.33			7.78
R	43.02	20.53	4.67			4.12

BF5 Wind Loading										
Floor	Horizontal Tributary Area (ft)	Distributed Wind Load (psf)	Vertical Tributary Area in previous distributed load region (ft)	Distributed wind load (psf)	Vertical Tributary Area in previous distributed load region (ft)	Distributed wind load (psf)	Vertical Tributary Area in previous distributed load region (ft)	Distributed wind load (psf)	Vertical Tributary Area in previous distributed load region (ft)	Total Load at Floor Level (kips)
G	81.73	9.76	12							9.57
1										
2	81.73	9.76	3	10.91	5	11.82	5	12.74	3.67	6.85
3	81.73	11.82	1.33	12.74	8					9.61
4	81.73	12.74	2	14.11	7.33					10.54
5	81.73	14.11	2.67	15.26	6.66					11.39
6	81.73	15.26	3.34	16.18	6					12.10
7	81.73	16.18	4	17.09	5.33					12.73
8	81.73	17.09	4.67	18.01	4.66					13.38
9	81.73	18.01	5.34	18.70	4					13.97
10	81.73	18.70	6	19.38	3.33					14.44
11	81.73	19.38	9.33							14.78
R	81.73	20.53	4.67							7.84

MO1 and 2 Wind Loading						
Floor	Horizontal Tributary Area (ft)	Distributed Wind Load (psf)	Vertical Tributary Area in previous distributed load region (ft)	Distributed wind load (psf)	Vertical Tributary Area in previous distributed load region (ft)	Total Load at Floor Level (kips)
G	18.63	9.76				
1	18.63	9.76	5	10.91	2	1.32
2	18.63	10.91	8	11.82	3.67	2.43
3	18.63	11.82	1.33	12.74	8	2.19
4	18.63	12.74	2	14.11	7.33	2.40
5	18.63	14.11	2.67	15.26	6.66	2.60
6	18.63	15.26	3.34	16.18	6	2.76
7	18.63	16.18	4	17.09	5.33	2.90
8	18.63	17.09	4.67	18.01	4.66	3.05
9	18.63	18.01	5.34	18.70	4	3.19
10	18.63	18.70	6	19.38	3.33	3.29
11	18.63	19.38	9.33			3.37
R	18.63	20.53	4.67			1.79

BF1 Overturning Moment x		
Height- hx (ft)	Floor Shear- Fx (kips)	Overturning Moment x (kip-ft)
0	0.00	0.00
10	2.81	28.14
24	5.20	124.92
33.33	4.69	156.22
41.67	5.14	214.06
52	5.55	288.63
61.33	5.90	361.70
70.67	6.21	438.70
80	6.52	521.92
89.33	6.81	608.45
98.67	7.04	694.75
108	7.21	778.20
117.33	3.82	448.17
	Total	4635.71

BF2 Overturning Moment x		
Height- hx (ft)	Floor Shear- Fx (kips)	Overturning Moment x (kip-ft)
0	0.00	0.00
10	4.37	43.74
24	8.09	194.19
33.33	7.29	242.85
41.67	7.99	332.77
52	8.63	448.69
61.33	9.17	562.28
70.67	9.65	681.98
80	10.14	811.34
89.33	10.59	945.86
98.67	10.95	1080.03
108	11.20	1209.74
117.33	5.94	696.71
	Total	7206.43

BF3 Overturning Moment x		
Height- hx (ft)	Floor Shear- Fx (kips)	Overturning Moment x (kip-ft)
0	0.00	0.00
10	1.02	10.16
24	1.88	45.13
33.33	1.69	56.44
41.67	1.86	77.33
52	2.01	104.27
61.33	2.13	130.67
70.67	2.24	158.49
80	2.36	188.55
89.33	2.46	219.81
98.67	2.54	250.99
108	2.60	281.14
117.33	1.38	161.91
	Total	1674.73

BF4 Overturning Moment y		
Height- hx (ft)	Floor Shear- Fx (kips)	Overturning Moment x (kip-ft)
0	2.10	0.00
10	5.14	51.37
24	5.62	134.88
33.33	5.06	168.67
41.67	5.55	231.12
52	5.99	311.63
61.33	6.37	390.53
70.67	6.70	473.66
80	7.04	563.51
89.33	7.35	656.93
98.67	7.60	750.12
108	7.78	840.21
117.33	4.12	483.89
	Total	5005.15

BF5 Overturning Moment y		
Height- hx (ft)	Floor Shear- Fx (kips)	Overturning Moment x (kip-ft)
0	9.57	0.00
10	0.00	0.00
24	6.85	164.41
33.33	9.61	320.47
41.67	10.54	439.13
52	11.39	592.10
61.33	12.10	742.00
70.67	12.73	899.96
80	13.38	1070.67
89.33	13.97	1248.17
98.67	14.44	1425.23
108	14.78	1596.40
117.33	7.84	919.39
	Total	9417.93

MO1 and 2 Overturning Moment y		
Height- hx (ft)	Floor Shear- Fx (kips)	Overturning Moment x (kip-ft)
0	0.00	0.00
10	1.32	13.16
24	2.43	58.41
33.33	2.19	73.05
41.67	2.40	100.10
52	2.60	134.97
61.33	2.76	169.14
70.67	2.90	205.14
80	3.05	244.06
89.33	3.19	284.52
98.67	3.29	324.88
108	3.37	363.90
117.33	1.79	209.57
	Total	2167.74

Table 15 - Seismic Dead Loads (psf)	Floors 2 to 11	Roof	
Steel Members	10		
Mechanical	5	5	
Finish	4		
Partitions	15		
Concrete Planks	82.5		
Roof Deck+Insulation+EDPM		5	
Total	116.5	10	
Total Shear, V (kips)			577.84

Equations

Fx=CvxV

Cvx=wh^k/Sum wh^k up to floor

BF1 Seismic Loading					
Floor	Horizontal Area (ft)	hx	wh^k	Cvx	Floor Shear, Fx (kips)
G	39.84	0	N/A	N/A	N/A
1	39.84	10	N/A	N/A	N/A
2	39.84	24	795182400	0.01	2.06
3	39.84	33.33	1.534E+09	0.02	3.98
4	39.84	41.67	2.397E+09	0.03	6.22
5	39.84	52	3.733E+09	0.05	9.68
6	39.84	61.33	5.193E+09	0.07	13.47
7	39.84	70.67	6.895E+09	0.10	17.88
8	39.84	80	8.835E+09	0.12	22.92
9	39.84	89.33	1.102E+10	0.15	28.58
10	39.84	98.67	1.344E+10	0.19	34.86
11	39.84	108	1.61E+10	0.22	41.77
R	39.84	117.33	1.631E+09	0.02	4.23

BF2 Seismic Loading					
Floor	Horizontal Area (ft)	hx (ft)	wh^k	Cvx	Floor Shear, Fx (kips)
G	61.93	0	N/A	N/A	N/A
1	61.93	10	N/A	N/A	N/A
2	61.93	24	795182400	0.01	3.21
3	61.93	33.33	1.534E+09	0.02	6.18
4	61.93	41.67	2.397E+09	0.03	9.67
5	61.93	52	3.733E+09	0.05	15.05
6	61.93	61.33	5.193E+09	0.07	20.94
7	61.93	70.67	6.895E+09	0.10	27.80
8	61.93	80	8.835E+09	0.12	35.63
9	61.93	89.33	1.102E+10	0.15	44.42
10	61.93	98.67	1.344E+10	0.19	54.19
11	61.93	108	1.61E+10	0.22	64.93
R	61.93	117.33	1.631E+09	0.02	6.58

BF3 Seismic Loading					
Floor	Horizontal Area (ft)	hx (ft)	wh^k	Cvx	Floor Shear, Fx (kips)
G	14.39	0	N/A	N/A	N/A
1	14.39	10	N/A	N/A	N/A
2	14.39	24	795182400	0.01	0.75
3	14.39	33.33	1.534E+09	0.02	1.44
4	14.39	41.67	2.397E+09	0.03	2.25
5	14.39	52	3.733E+09	0.05	3.50
6	14.39	61.33	5.193E+09	0.07	4.87
7	14.39	70.67	6.895E+09	0.10	6.46
8	14.39	80	8.835E+09	0.12	8.28
9	14.39	89.33	1.102E+10	0.15	10.32
10	14.39	98.67	1.344E+10	0.19	12.59
11	14.39	108	1.61E+10	0.22	15.09
R	14.39	117.33	1.631E+09	0.02	1.53

BF4 Seismic Loading					
Floor	Horizontal Area (ft)	hx (ft)	wh^k	Cvx	Floor Shear, Fy (kips)
G	43.02	0	N/A	N/A	N/A
1	43.02	10	N/A	N/A	N/A
2	43.02	24	795182400	0.01	1.69
3	43.02	33.33	1.534E+09	0.02	3.27
4	43.02	41.67	2.397E+09	0.03	5.11
5	43.02	52	3.733E+09	0.05	7.95
6	43.02	61.33	5.193E+09	0.07	11.06
7	43.02	70.67	6.895E+09	0.10	14.69
8	43.02	80	8.835E+09	0.12	18.83
9	43.02	89.33	1.102E+10	0.15	23.47
10	43.02	98.67	1.344E+10	0.19	28.64
11	43.02	108	1.61E+10	0.22	34.31
R	43.02	117.33	1.631E+09	0.02	3.48

BF5 Seismic Loading					
Floor	Horizontal Area (ft)	hx (ft)	wh^k	Cvx	Floor Shear, Fy (kips)
G	81.73	0	N/A	N/A	N/A
1	81.73	10	N/A	N/A	N/A
2	81.73	24	795182400	0.01	3.22
3	81.73	33.33	1.534E+09	0.02	6.21
4	81.73	41.67	2.397E+09	0.03	9.70
5	81.73	52	3.733E+09	0.05	15.11
6	81.73	61.33	5.193E+09	0.07	21.02
7	81.73	70.67	6.895E+09	0.10	27.91
8	81.73	80	8.835E+09	0.12	35.77
9	81.73	89.33	1.102E+10	0.15	44.60
10	81.73	98.67	1.344E+10	0.19	54.41
11	81.73	108	1.61E+10	0.22	65.18
R	81.73	117.33	1.631E+09	0.02	6.60

MO1 and MO2 Seismic Loading					
Floor	Horizontal Area (ft)	hx (ft)	wh^k	Cvx	Floor Shear, Fy (kips)
G	18.63	0	N/A	N/A	N/A
1	18.63	10	N/A	N/A	N/A
2	18.63	24	68256000	0.00	0.05
3	18.63	33.33	131640335	0.01	0.10
4	18.63	41.67	205762085	0.01	0.16
5	18.63	52	320424000	0.02	0.25
6	18.63	61.33	445722215	0.03	0.34
7	18.63	70.67	591818495	0.04	0.45
8	18.63	80	758400000	0.05	0.58
9	18.63	89.33	945612095	0.06	0.72
10	18.63	98.67	1.154E+09	0.07	0.88
11	18.63	108	1.382E+09	0.09	1.06
R	18.63	117.33	1.01E+10	0.63	7.74

Table 21 - 1.0Wx (X direction)				
Story	Diaphragm	Displacement X	Displacement Y	Percentage of X drift
ROOF	ROOF	0.3612	-0.0433	11.99%
STORY11	STORY11	0.3401	-0.0382	11.23%
STORY10	STORY10	0.3195	-0.0368	11.52%
STORY9	STORY9	0.2943	-0.0349	11.86%
STORY8	STORY8	0.2663	-0.0321	12.05%
STORY7	STORY7	0.2342	-0.029	12.38%
STORY6	STORY6	0.2004	-0.0254	12.67%
STORY5	STORY5	0.1644	-0.0223	13.56%
STORY4	STORY4	0.1275	-0.0188	14.75%
STORY3	STORY3	0.0903	-0.0156	17.28%
STORY2	STORY2	0.0539	-0.0125	23.19%
STORY1	STORY1	0.0278	-0.0075	26.98%

Table 22 - 1.0Wy (y direction)				
Story	Diaphragm	Displacement X	Displacement Y	Percentage of Y drift
ROOF	ROOF	-0.023	1.1643	1.98%
STORY11	STORY11	-0.0284	1.1245	2.53%
STORY10	STORY10	-0.0293	1.0722	2.73%
STORY9	STORY9	-0.0289	1.0083	2.87%
STORY8	STORY8	-0.0268	0.9332	2.87%
STORY7	STORY7	-0.024	0.8498	2.82%
STORY6	STORY6	-0.019	0.7621	2.49%
STORY5	STORY5	-0.0147	0.6748	2.18%
STORY4	STORY4	-0.0085	0.5873	1.45%
STORY3	STORY3	-0.0031	0.5025	0.62%
STORY2	STORY2	0.0043	0.4136	1.04%
STORY1	STORY1	0.0008	0.2229	0.36%

Table 23 - 1.0W45 (45 degrees off X direction)			
Story	Diaphragm	Displacement X	Displacement Y
ROOF	ROOF	0.4037	0.9226
STORY11	STORY11	0.3709	0.8993
STORY10	STORY10	0.3462	0.8569
STORY9	STORY9	0.3173	0.8055
STORY8	STORY8	0.2865	0.746
STORY7	STORY7	0.2514	0.68
STORY6	STORY6	0.2164	0.6112
STORY5	STORY5	0.1782	0.5421
STORY4	STORY4	0.1406	0.4737
STORY3	STORY3	0.1021	0.4069
STORY2	STORY2	0.0663	0.3367
STORY1	STORY1	0.0349	0.1798

Table 24 - Maximum Story Drift - 1.4D+1.5E+0.5L				
Story	Diaphragm	Displacement X	Displacement Y	Percentage of X drift
ROOF	ROOF	2.0161	-0.774	38.39%
STORY11	STORY11	1.8094	-0.6405	35.40%
STORY10	STORY10	1.6693	-0.5924	35.49%
STORY9	STORY9	1.5024	-0.5344	35.57%
STORY8	STORY8	1.3194	-0.4692	35.56%
STORY7	STORY7	1.1172	-0.4015	35.94%
STORY6	STORY6	0.9109	-0.3285	36.06%
STORY5	STORY5	0.7022	-0.2635	37.52%
STORY4	STORY4	0.4967	-0.1948	39.22%
STORY3	STORY3	0.3024	-0.134	44.31%
STORY2	STORY2	0.128	-0.0802	62.66%
STORY1	STORY1	0.1091	-0.0034	3.12%

Table 25 - 1.2D + 1.6Wx + 0.5L + 0.5S				
Story	Diaphragm	Displacement X	Displacement Y	Percentage of X drift
ROOF	ROOF	0.7259	-0.4456	61.39%
STORY11	STORY11	0.6497	-0.3976	61.20%
STORY10	STORY10	0.5891	-0.3626	61.55%
STORY9	STORY9	0.5225	-0.3241	62.03%
STORY8	STORY8	0.4518	-0.2849	63.06%
STORY7	STORY7	0.3762	-0.2465	65.52%
STORY6	STORY6	0.2988	-0.2085	69.78%
STORY5	STORY5	0.2207	-0.1747	79.16%
STORY4	STORY4	0.1427	-0.1411	98.88%
STORY3	STORY3	0.0683	-0.1107	162.08%
STORY2	STORY2	0.0002	-0.0843	42150.00%
STORY1	STORY1	0.0393	-0.0378	96.18%

Table 26 - STORY SHEAR WIND LOADING IN X DIRECTION								
Story	Load	Loc	P	VX	VY	T	MX	MY
ROOF	WINDX	Top	0.17	-13.58	0.03	13132.79	148.508	-135.443
ROOF	WINDX	Bottom	0	-13.98	0	13462.86	0.001	-1565.65
STORY11	WINDX	Top	0	-41.55	0	39853.78	0.001	-1565.65
STORY11	WINDX	Bottom	0	-41.55	0	39853.78	0.001	-6219.73
STORY10	WINDX	Top	0	-68.59	0	65730.34	0.001	-6219.73
STORY10	WINDX	Bottom	0	-68.59	0	65730.34	0.002	-13902
STORY9	WINDX	Top	0	-95.17	0	91169.2	0.002	-13902
STORY9	WINDX	Bottom	0	-95.17	0	91169.2	0.003	-24561.4
STORY8	WINDX	Top	0	-121.26	0	116136.2	0.003	-24561.4
STORY8	WINDX	Bottom	0	-121.26	0	116136.2	0.003	-38142.5
STORY7	WINDX	Top	0	-146.81	0	140590.1	0.003	-38142.5
STORY7	WINDX	Bottom	0	-146.81	0	140590.1	0.004	-54585.4
STORY6	WINDX	Top	0	-171.77	0	164479.7	0.004	-54585.4
STORY6	WINDX	Bottom	0	-171.77	0	164479.7	0.005	-73824
STORY5	WINDX	Top	0	-196.08	0	187739.2	0.005	-73824
STORY5	WINDX	Bottom	0	-196.08	0	187739.2	0.006	-95784.6
STORY4	WINDX	Top	0	-219.63	0	210280.9	0.006	-95784.6
STORY4	WINDX	Bottom	0	-219.63	0	210280.9	0.006	-120383
STORY3	WINDX	Top	0	-242.3	0	231980	0.006	-120383
STORY3	WINDX	Bottom	0	-242.3	0	231980	0.007	-147521
STORY2	WINDX	Top	0	-269	0	257536.7	0.007	-147521
STORY2	WINDX	Bottom	0	**-269**	**0**	257536.7	-0.343	-192713
STORY1	WINDX	Top	28.47	-108.62	9.55	50628.21	13694.27	-55819.1
STORY1	WINDX	Bottom	28.47	**-108.62**	**9.55**	50628.21	12548.26	-68853.2

Table 27 - STORY SHEAR WIND LOADING IN Y DIRECTION									
Story	Load	Loc	P	VX	VY	T	MX	MY	
ROOF	WINDY	Top	0.16	0.7	-18.29	-22432.5	139.976	-129.823	
ROOF	WINDY	Bottom	0	0	-18.35	-21848.5	2055.182	-0.001	
STORY11	WINDY	Top	0	0	-54.69	-65117.8	2055.182	-0.001	
STORY11	WINDY	Bottom	0	0	-54.69	-65117.8	8180.509	-0.002	
STORY10	WINDY	Top	0	0	-90.47	-107714	8180.509	-0.002	
STORY10	WINDY	Bottom	0	0	-90.47	-107714	18312.65	-0.003	
STORY9	WINDY	Top	0	0	-125.64	-149589	18312.65	-0.003	
STORY9	WINDY	Bottom	0	0	-125.64	-149589	32383.84	-0.004	
STORY8	WINDY	Top	0	0	-160.15	-190688	32383.84	-0.004	
STORY8	WINDY	Bottom	0	0	-160.15	-190688	50321.01	-0.006	
STORY7	WINDY	Top	0	0	-193.96	-230943	50321.01	-0.006	
STORY7	WINDY	Bottom	0	0	-193.96	-230943	72044.7	-0.007	
STORY6	WINDY	Top	0	0	-226.99	-270268	72044.7	-0.007	
STORY6	WINDY	Bottom	0	0	-226.99	-270268	97467.53	-0.008	
STORY5	WINDY	Top	0	0	-259.15	-308556	97467.53	-0.008	
STORY5	WINDY	Bottom	0	0	-259.15	-308556	126491.9	-0.009	
STORY4	WINDY	Top	0	0	-290.31	-345662	126491.9	-0.009	
STORY4	WINDY	Bottom	0	0	-290.31	-345662	159006.8	-0.01	
STORY3	WINDY	Top	0	0	-320.31	-381382	159006.8	-0.01	
STORY3	WINDY	Bottom	0	0	-320.31	-381382	194881.6	-0.011	
STORY2	WINDY	Top	0	0	-355.67	-423487	194881.6	-0.011	
STORY2	WINDY	Bottom	0	**0**	**-355.67**	-423487	254634.9	-0.013	
STORY1	WINDY	Top	-44.14	-63.43	-316.71	-302407	150296.4	31264	
STORY1	WINDY	Bottom	-44.14	**-63.43**	**-316.71**	-302407	188301	23652.96	

Table 28 - STORY SHEAR WIND LOADING AT 45 DEGREES FROM X DIRECTION								
Story	Load	Loc	P	VX	VY	T	MX	MY
ROOF	WIND45	Top	0.33	-14.46	-15.46	-5492.39	294.36	-270.429
ROOF	WIND45	Bottom	0	-15.54	-15.54	-4591.88	1740.673	-1740.68
STORY11	WIND45	Top	0	-46.32	-46.32	-13685.8	1740.673	-1740.68
STORY11	WIND45	Bottom	0	-46.32	-46.32	-13685.8	6928.626	-6928.64
STORY10	WIND45	Top	0	-76.62	-76.62	-22638.3	6928.626	-6928.64
STORY10	WIND45	Bottom	0	-76.62	-76.62	-22638.3	15510.22	-15510.2
STORY9	WIND45	Top	0	-106.41	-106.41	-31439.4	15510.22	-15510.2
STORY9	WIND45	Bottom	0	-106.41	-106.41	-31439.4	27428.06	-27428.1
STORY8	WIND45	Top	0	-135.64	-135.64	-40077.2	27428.06	-27428.1
STORY8	WIND45	Bottom	0	-135.64	-135.64	-40077.2	42620.25	-42620.3
STORY7	WIND45	Top	0	-164.28	-164.28	-48537.5	42620.25	-42620.3
STORY7	WIND45	Bottom	0	-164.28	-164.28	-48537.5	61019.51	-61019.6
STORY6	WIND45	Top	0	-192.25	-192.25	-56802.5	61019.51	-61019.6
STORY6	WIND45	Bottom	0	-192.25	-192.25	-56802.5	82551.82	-82551.9
STORY5	WIND45	Top	0	-219.49	-219.49	-64849.5	82551.82	-82551.9
STORY5	WIND45	Bottom	0	-219.49	-219.49	-64849.5	107134.6	-107135
STORY4	WIND45	Top	0	-245.88	-245.88	-72648.3	107134.6	-107135
STORY4	WIND45	Bottom	0	-245.88	-245.88	-72648.3	134673.6	-134674
STORY3	WIND45	Top	0	-271.29	-271.29	-80155.5	134673.6	-134674
STORY3	WIND45	Bottom	0	-271.29	-271.29	-80155.5	165058.4	-165058
STORY2	WIND45	Top	0	-301.24	-301.24	-89004.9	165058.4	-165058
STORY2	WIND45	Bottom	0	**-301.24**	**-301.24**	-89004.9	215667.4	-215668
STORY1	WIND45	Top	-2.7	-187.22	-257.23	-193868	147113.1	-41121.8
STORY1	WIND45	Bottom	-2.7	**-187.22**	**-257.23**	-193868	177981	-63588.8

IX. References

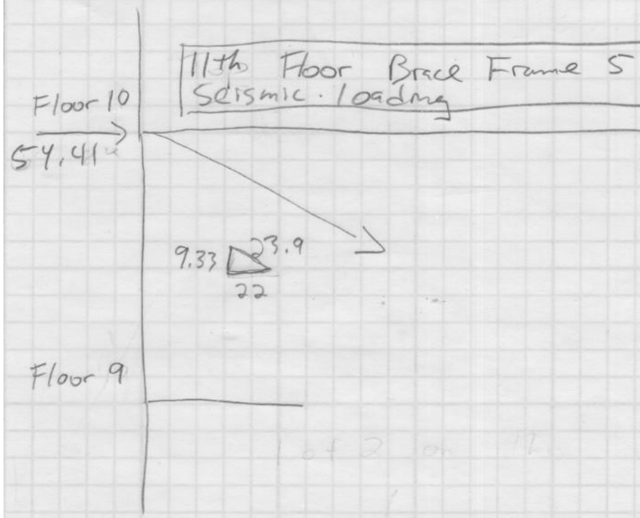
1) AISC Manual of Steel Construction, Load and Resistance Factor Design, 3rd Edition

2) IBC 2003

3) ASCE 7-2005

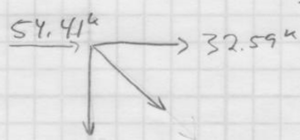
X. Calculations

11th Floor Brace Frame 5 under Seismic loading



1 of 2 braces between Floor 11 and Floor 10.

$$\frac{54.41}{2} = 27.2^k$$



$$27.2 = F\frac{22}{23.9}$$

$F = 29.55^k$ (C) or (T) on other side.

Compression - 2L6x4x5/16 → use

Tension - Much smaller

Design engineer used 2L6x4x1/2

Brace Frame 1 Uplift Check

Column Tributary Area

Windward - $\frac{30'8''}{2} \times \frac{22'}{2} = 168.67\ ft^2$

$168.67\ ft^2 \times 10$ floors $= 1686.67\ ft$

$1686.67\ ft^2 \times 116.5$ psf $(D) = 196.5^k$

$168.67\ ft^2 \times 10$ psf $(D_R) = \underline{1.7^k}$

198.2^k (C

+ Weight of colu

Overturning Moment $= 4635.71^{'k}$

$/2 = 2317.86'$

$22' + 27.5' = 49.5'$

$/2 = 24.75'$

Tensile Force

$$\frac{2317.86^{'k}}{24.75'} = 93.65^k\ (T)$$

Net Force in Column

$198.2 - 93.65 = 104.5^k\ (C)$

+ Weight of Columns above

No uplift