Drexel University Race Street Dormitory

Technical Report I

Douglas Tower

Structural

10/4/06

Advisor: Parfitt

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I. Executive Summary

The Race Street Dormitory has a foundation of concrete drilled piers at two very distinct and different grade levels. The flooring is a lighter, prefabricated hollow core concrete plank system. It is a rigid steel structure with six diagonally braced frames that carry lateral loads while not invading important interior open space. The brace frames are also designed in a way to alter the rigidity of parts of the building in the case of an earthquake. Further analysis of lateral stiffness of shear wall replacement of brace frames could be revealing. Also, results of code analysis show that all codes are met within a necessarily flexible range of uncertainty. This includes how independent calculations of seismic base shear show it to be accurately calculated, as well as controlling over wind shear, which is thereby adequately resisted. Two size checked members are roughly acceptable.

II. General Structural System

Foundation:

The dormitory is built on two grade levels. The lower grade level is the level of the ground floor and is only found running east-west about the size of a third of the roof and upper floor plans. The steel columns over this section begin at this level. The higher grade level is the first floor level, ten feet higher than the ground floor. At this level the other columns supporting the rest of the building begin, but are exposed at this level, simply holding the building on stilts (the first floor above the ground floor area is enclosed). The foundation consists of drilled concrete piers of 28 day 3000 psi compressive strength and a minimum 1-1/2" aggregate placed deep into the higher grade area and under the lower ground floor of the building. Steel columns rest either directly on the piers (as is the case of the higher grade area) or above the piers on grade beams which span piers and often serve as footings for non-load bearing concrete walls on the exterior, and even the interior, of the ground level. The footing concrete requirements are the same as that of the piers. The ground floor consists of a 4" slab on grade in its interior and a 5" slab on its south east corner for the dumpster and generator, each with a minimum 28 day 4000 psi compressive strength and 1-1/2" aggregate.

Framing:

The dormitory is predominantly framed with steel W shaped columns and beams. Beam sizes range from W12 to W18, but are predominately W18. The 3rd through 11th floors have identical beam systems, while the beams at the first and second floors are unique and generally larger. The column layout is generally uniform for each floor except for those that begin on piers at the building corner and North-South section because of the grade difference under the building, as well as the diagonal columns on either end of the southern face which carry load from grade level to the second floor over the course of one bay. Diagonal members brace the columns and beams along various, but not all, vertical grid-planes. When used at the ground and first floors, diagonal braces are generally W shapes sized W10 to W12 and on floors 2 though 11 Angles L6 to L8. All braces are connected using 3/4” A325-SC grade bolts to A36 grade gusset plates. Bolts are typically A325 grade, but occasionally A490 grade. All plates, channels, angles, and bars are A36 grade, and all W shapes are A992 grade.

Flooring:

Each floor consists of Prefabricated Hollow Core Concrete Planks 8” deep, typically 8’ wide by 22’8” or 28’2” long. Some are shaped to fit building irregularities, and most run perpendicular to the long sides of the building. The hollow core planks tend to be lighter and quicker to erect than slabs with similar strength. On the roof at the bend in the building plan there is a 30’x50’ penthouse area with partial concrete decking for the elevator machine room and partial hollow core plank flooring for the mechanical room.

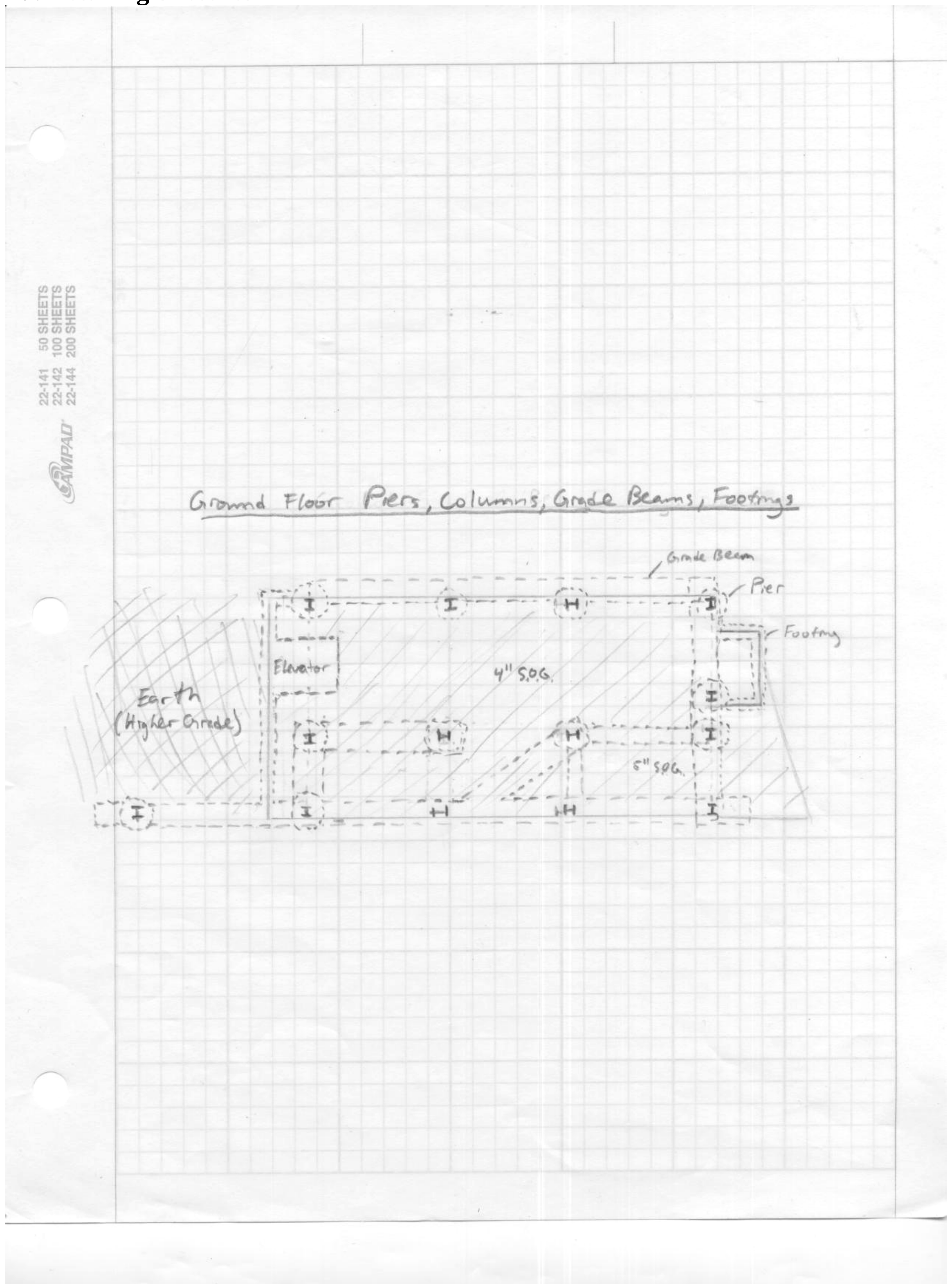
Roofing:

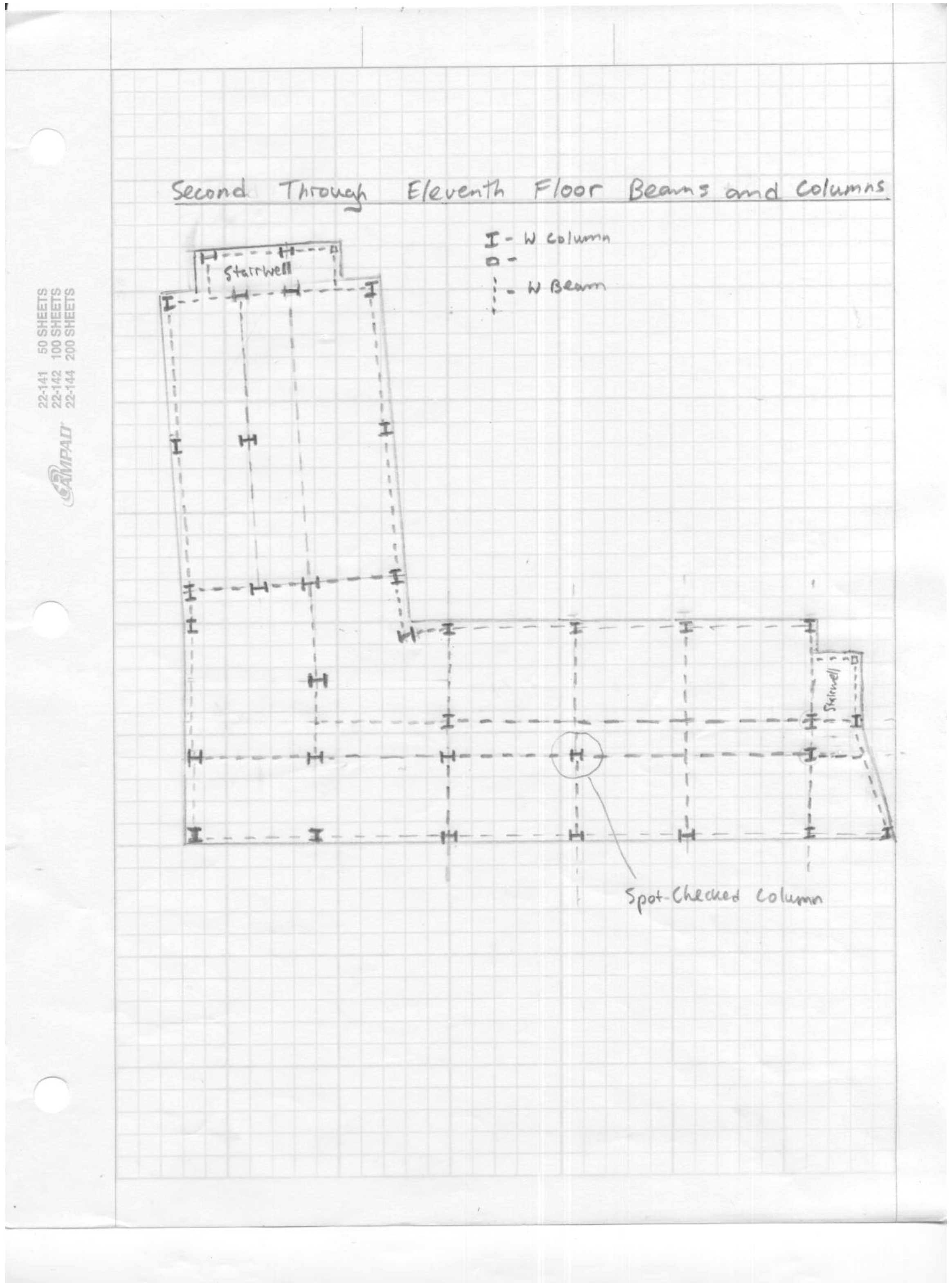
The roof is flat and consists of mainly W12 beams spaced 6’ on center and steel decking supporting EPDM single-ply membrane roofing over rigid insulation.

III. Codes

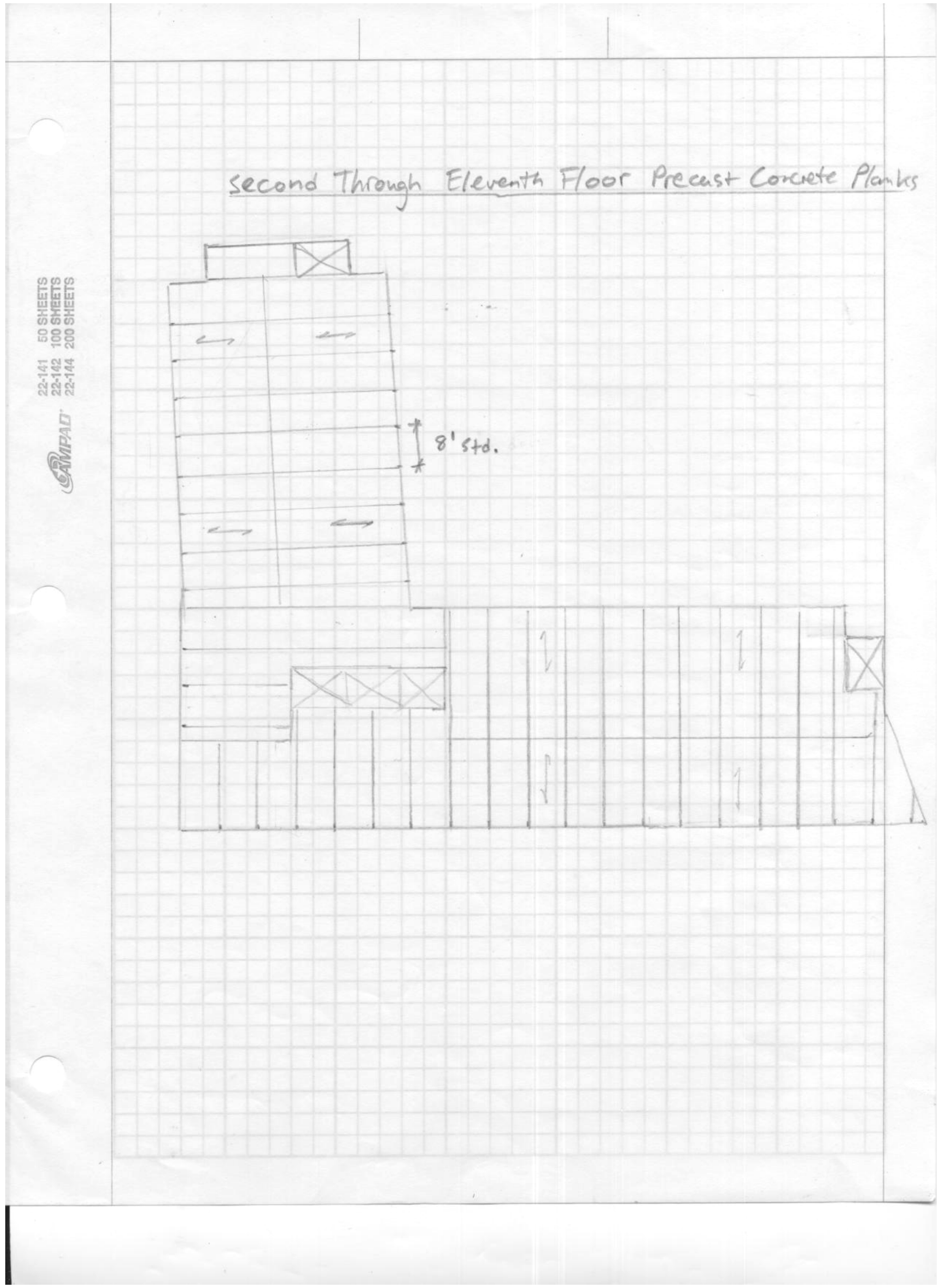
- 2004 Philadelphia Building Construction and Occupancy Code
  (Building Subcode: IBC 2003).
- *“Minimum design loads for buildings and other structures”*
  ASCE 7-02
- *“Building code requirements for reinforced concrete.”*
  ACI 318-02
- *“ACI Manual of Concrete Practice.”*
  Parts 1-5, 2001
- *“Manual 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

IV. Detailing Sketches





Second Through Eleventh Floor Beams and Columns
W Column
W Beam
Stairwell
Stairwell
Spot-Checked Column


Second Through Eleventh Floor Precast Concrete Planks
8' std.

V. Detailed Description of Structure

The dormitory is a basic steel bay system with hollow core plank flooring designed with load factor and resistance design (see calculations for loading), but the bracing system warrants further discussion.

Diagonal Bracing and Theories concerning Design:

The structure is predominantly two bays in the direction transverse to the building's length along each leg of the "L" shape. At diagonally braced frames (which also run perpendicular the building's length in most cases) there is another column running the height of the building and creating three bays. This allows the middle bay to stay un-braced (relatively narrow) for an unobstructed hallway along the center of the building.

The brace frames are also designed in other cases to provide lateral support without sacrificing open space needs in the interior. Brace frame three (BF3) provides west-east support at the bend of the building (over the lobby). In order to create an open lobby at level 1, the diagonal members begin at floor level 2. To allow for this, the lateral force on the braced frame is distributed from level 2 to the foundation by the continuation of the braced frame two bays to the east, along the same layout line, connected by a beam in the intermediate bay at floor level 2 (see sketch).

The design of BF3 also 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.

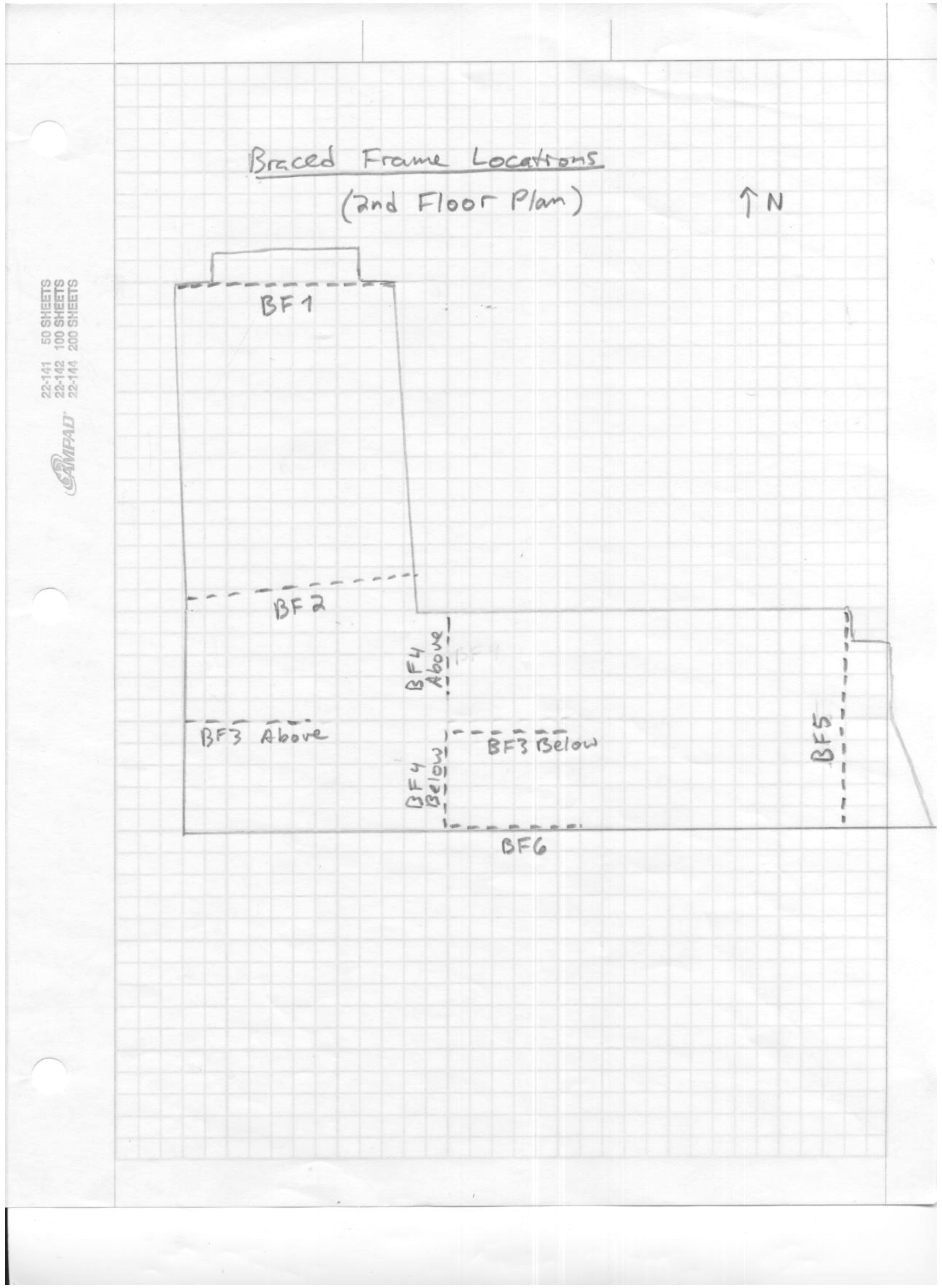
This offset brace frame design is also used in BF4 creating open bays at levels 1 and 2 for open elevator lobbies at ground and first floor levels. Here, the southern bay of this north-south brace frame, which does begin at ground level, only continues through the first floor, probably for plumbing space, uniformity of partitions within a floor plan (the north bay of the brace frame runs along the elevators, so for the exception of the ground and first floor, wall thickness is not critical), or to lessen the rigidity of the frame for seismic reasons already mentioned.

The other full building height brace frames (BF1, BF2, BF5) run across all three bays perpendicular the building's length. 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 complex diagonals to carry the lateral load from the second floor to the ground level (see sketch). BF6 is on the southern edge of the building at the ground and first floors and seems to support the lateral loads of angled columns at the end of this wing of the building.

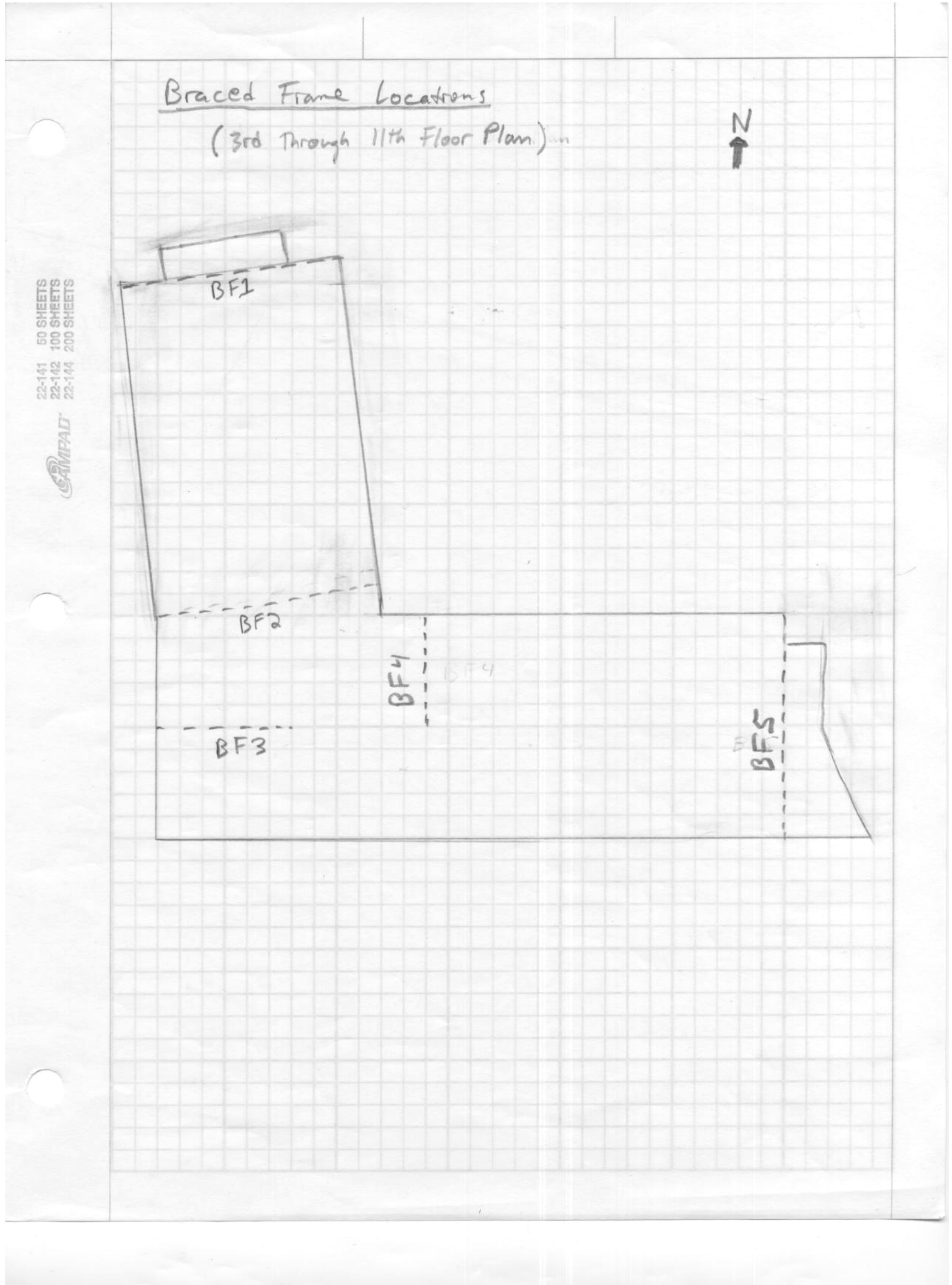
Overall, there is strong seismic factor that played into the design of the structure. The highly rigid BF1 and BF2 at one end of the building and the highly rigid BF5 at the other reduce torsion, while BF3 strengthens the connection between the wings and BF4 carries lateral loads while leaving the structure more flexible along the wing to balance with the naturally flexible "soft" columns on the other. The blending of this with the need for open spaces through brace frame planes is well done.

Shear Wall Concept:

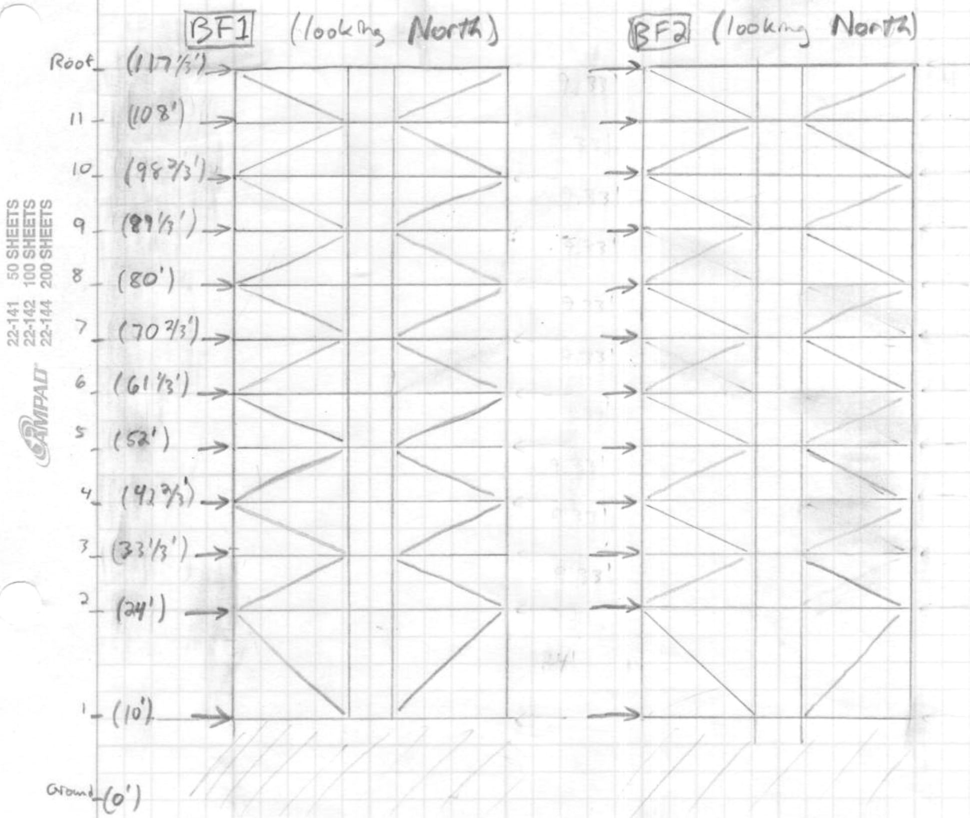
Shear walls are a possibility to replace some diagonal bracing, especially at ground level. The exterior concrete walls at ground level might work as shear walls (replacing BF6) if the piers continue up through the wall so that the columns start at the first floor level. At the ends of the building the diagonal braces (BF1 and BF5) could be replaced with shear walls (with cutouts to enter the stairwells). Moreover, the stairwells could be an easy way to support lateral loading and seismic torsion (high rigidity at long moment arm from center of rigidity) if constructed of CMU with brick instead of steel studs with brick.



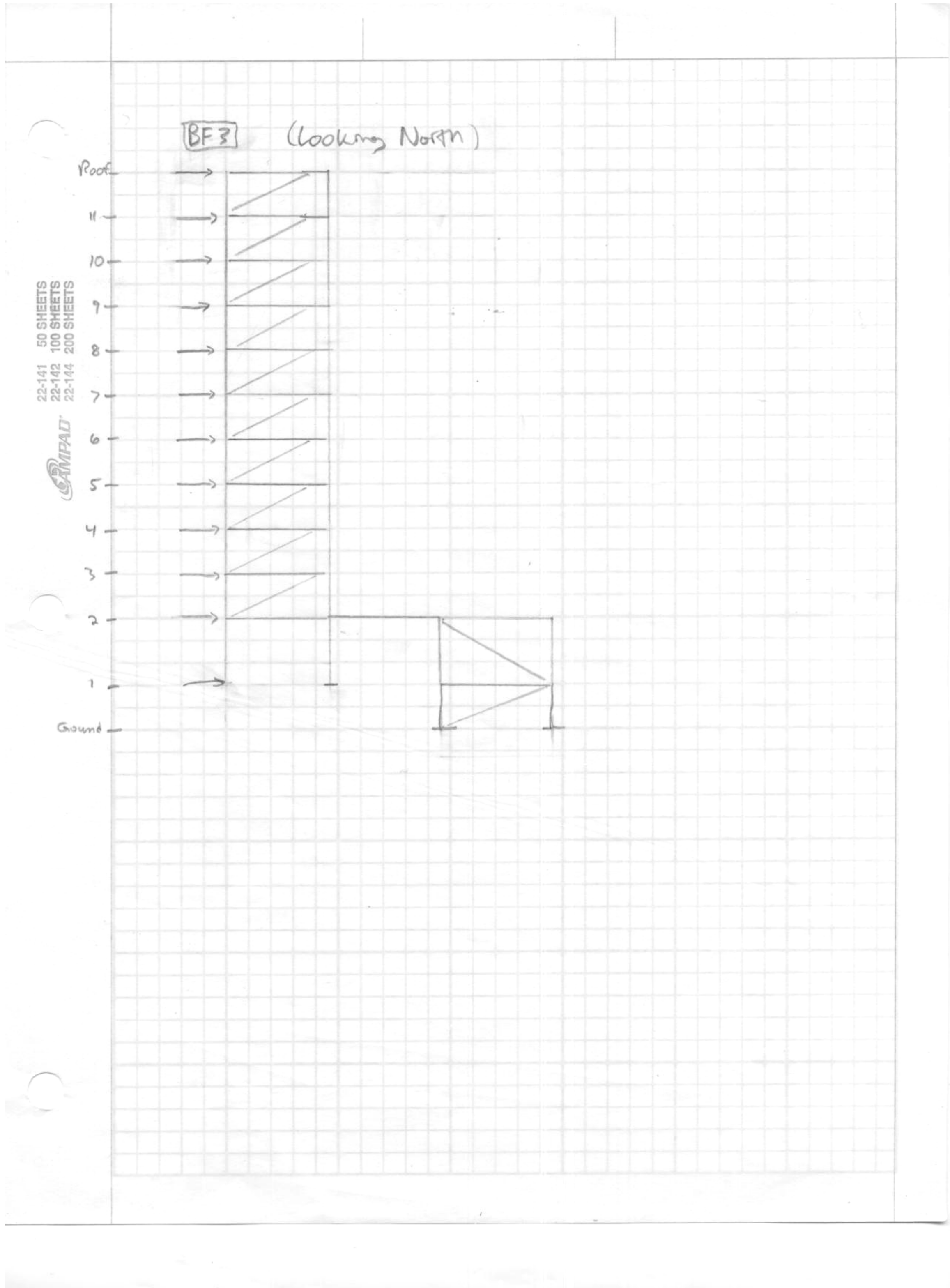
Braced Frame Locations
(2nd Floor Plan)
↑N
BF1
BF2
BF4 Above
BF3 Above
BF3 Below
BF4 Below
BF5
BF6



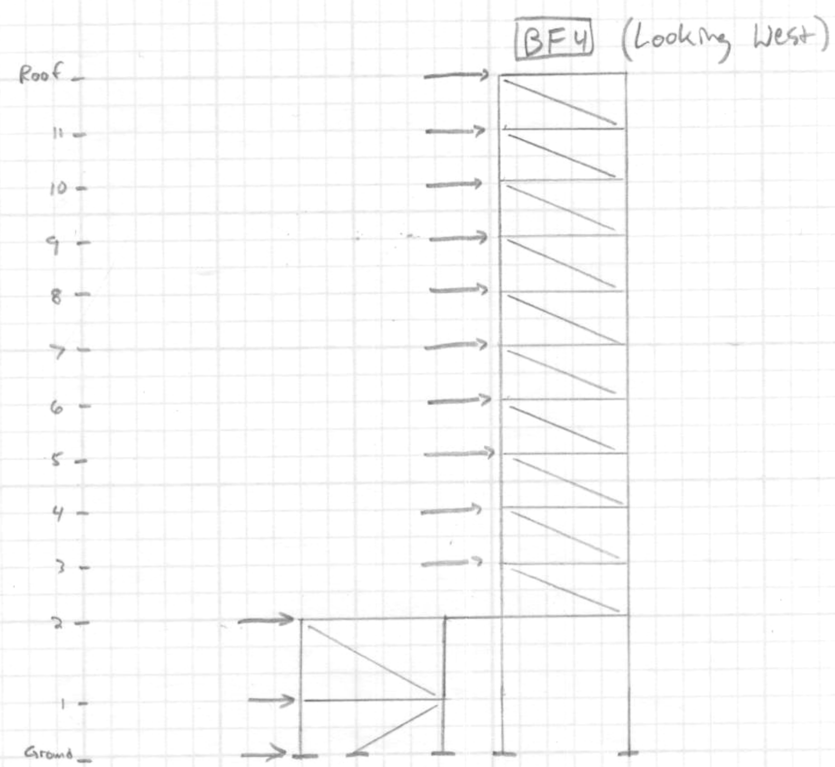
Braced Frame Locations
(3rd Through 11th Floor Plan)
N
BF1
BF2
BF3
BF4
BF5



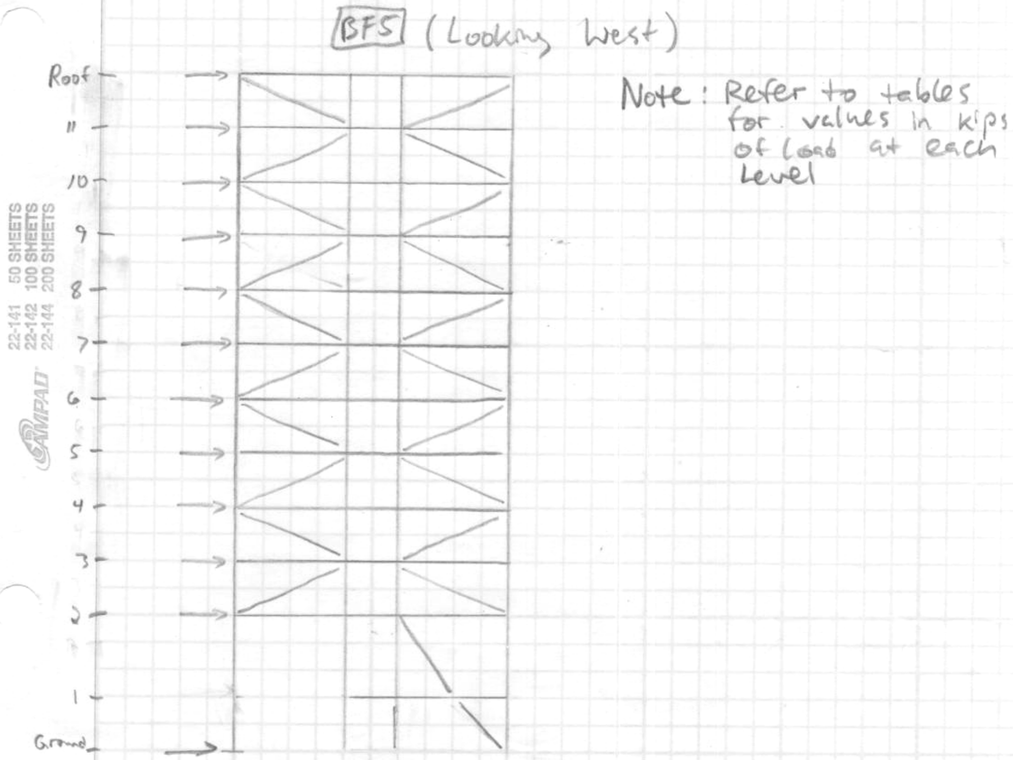
Note: see Tables for Load values at each level



BF3
(Looking North)
Roof
11
10
9
8
7
6
5
4
3
2
1
Ground



BF4 (Looking West)
Roof
11
10
9
8
7
6
5
4
3
2
1
Ground


BF5 (Looking West)
Note: Refer to tables for values in kips of Load at each Level
Roof
11
10
9
8
7
6
5
4
3
2
1
Ground

VI. General Loading

LOADING	Design	Estimate/Code (IBC 2003)
Gravity Loads		
Service Level Live Loads (psf)		
All floors, u.n.o.	40	40
Lobbies	100	100
Kitchens	150	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		5
Mechanical		5
Concrete Plank Weight		30
Steel Member Weight		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

Notes: It is unclear how the designers incorporated these loadings in their design with such ambiguities as the line between kitchen and living or general space in the suites, and the lack of consideration for corridor live load. For the purposes of this study, a later gravity load spot check uses a floor live load of 100 psf to accommodate the varying floor live loads. Dead loads for other elements not shown in design are for seismic loading purposes. The ground snow load looks to be off, but is probably just more accurate due to familiarity with the area.

VII. Wind Loading

Refer to tables and sketches for wind load on brace frames at floor levels.

Wind Load Variables	Design	Code
Basic Wind Speed (3s Gust)	90 mph	90 mph
Building Category	II	II
Wind Importance Factor, Iw	1	1
Wind Exposure	B	B
Internal Pressure Coefficient	0.18	0.18

Roof Wind Load
-25.8 psf

Wall Wind Loading					
			Uniform Wind Load p (psf) (see diagram)		
Height above Ground, z (ft)	Velocity Pressure Exposure Coefficient, K_z	q_z	Section1	Section 2	Section 3
0-15	0.57	10.05	9.76	8.71	9.76
20	0.62	10.93	10.91	10.12	10.91
25	0.66	11.63	11.82	11.24	11.82
30	0.7	12.34	12.74	12.37	12.74
40	0.76	13.40	14.11	14.06	14.11
50	0.81	14.28	15.26	15.47	15.26
60	0.85	14.98	16.18	16.60	16.18
70	0.89	15.69	17.09	17.73	17.09
80	0.93	16.39	18.01	18.85	18.01
90	0.96	16.92	18.70	19.70	18.70
100	0.99	17.45	19.38	20.54	19.38
120	1.04	18.33	20.53	21.95	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	30.67	0				
1	30.67	9.76	5	10.91	2	2.17
2	30.67	10.91	8	11.82	3.67	4.01
3	30.67	11.82	1.33	12.74	8	3.61
4	30.67	12.74	2	14.11	7.33	3.95
5	30.67	14.11	2.67	15.26	6.66	4.27
6	30.67	15.26	3.34	16.18	6	4.54
7	30.67	16.18	4	17.09	5.33	4.78
8	30.67	17.09	4.67	18.01	4.66	5.02
9	30.67	18.01	5.34	18.70	4	5.24
10	30.67	18.70	6	19.38	3.33	5.42
11	30.67	19.38	9.33			5.55
R	30.67	20.53	4.67			2.94

BF2 (Different Wind Loading on either Side)						
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 (lb), Side A
G	35.67	0				
1	35.67	9.76	5	10.91	2	2519.00
2	35.67	10.91	8	11.82	3.67	4660.16
3	35.67	11.82	1.33	12.74	8	4196.37
4	35.67	12.74	2	14.11	7.33	4599.31
5	35.67	14.11	2.67	15.26	6.66	4969.55
6	35.67	15.26	3.34	16.18	6	5280.26
7	35.67	16.18	4	17.09	5.33	5557.94
8	35.67	17.09	4.67	18.01	4.66	5841.06
9	35.67	18.01	5.34	18.70	4	6098.23
10	35.67	18.70	6	19.38	3.33	6304.15
11	35.67	19.38	9.33			6451.27
R	35.67	20.53	4.67			3419.93

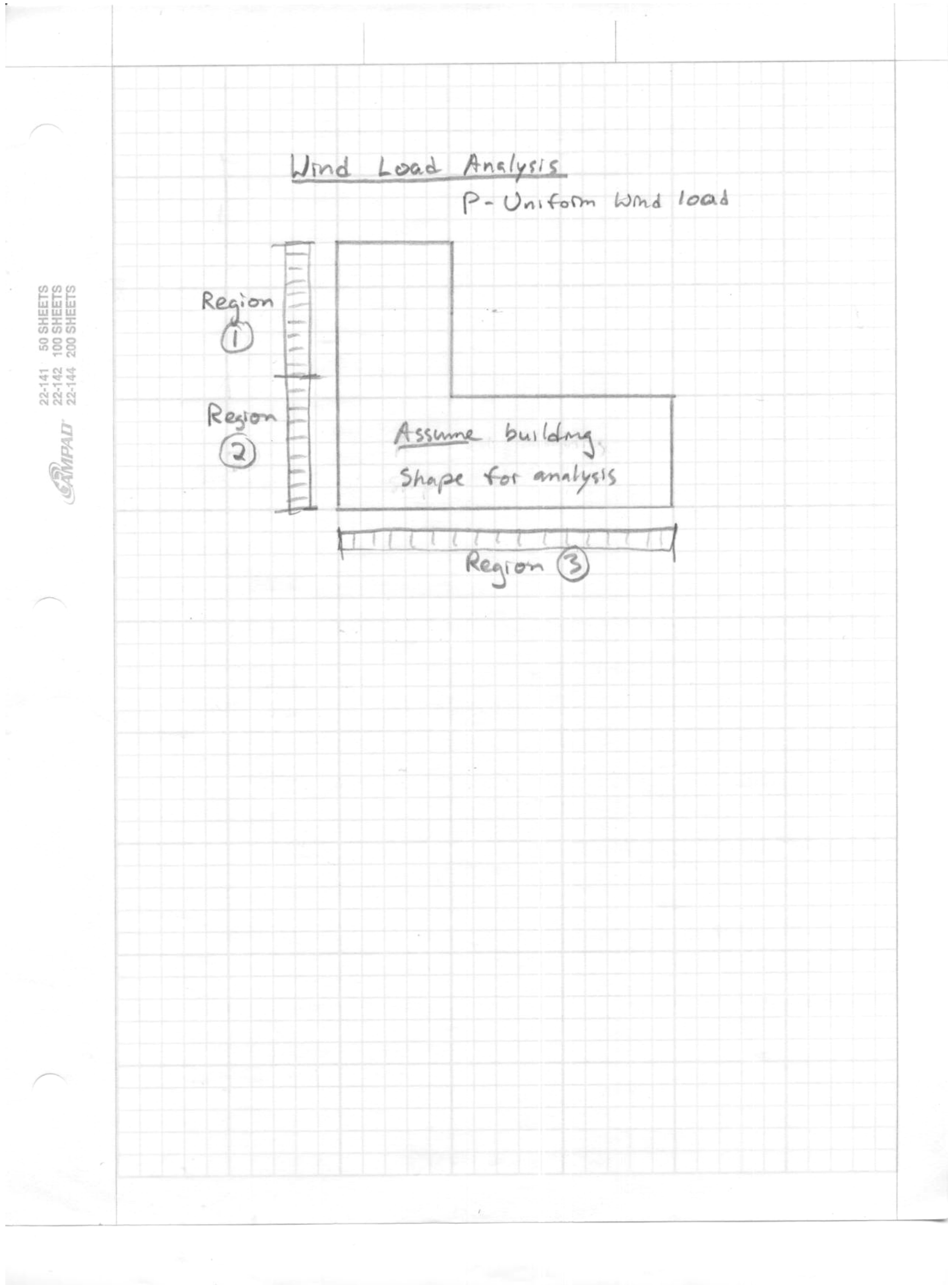
Horizontal Tributary Area (ft)	Distributed Wind Load (psf)	Vertical Tributary Area in previous distributed load region (ft)	Distributed wind load (psf)	Vertical Tributary Area in previous distributed load region (ft)	Load at Floor Level (lb), Side B	Total Load at Floor Level (kips)
13.75	0					
13.75	8.71	5	10.12	2	876.79	3.40
13.75	10.12	8	11.24	3.67	1680.13	6.34
13.75	11.24	1.33	12.37	8	1566.39	5.76
13.75	12.37	2	14.06	7.33	1757.43	6.36
13.75	14.06	2.67	15.47	6.66	1932.98	6.90
13.75	15.47	3.34	16.60	6	2079.85	7.36
13.75	16.60	4	17.73	5.33	2211.96	7.77
13.75	17.73	4.67	18.85	4.66	2346.19	8.19
13.75	18.85	5.34	19.70	4	2467.68	8.57
13.75	19.70	6	20.54	3.33	2565.76	8.87
13.75	20.54	9.33			2635.52	9.09
13.75	21.95	4.67			1409.66	4.83

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	35.75	8.71	5			1.56
1	35.75	8.71	10	10.12	2	3.84
2	35.75	10.12	8	11.24	3.67	4.37
3	35.75	11.24	1.33	12.37	8	4.07
4	35.75	12.37	2	14.06	7.33	4.57
5	35.75	14.06	2.67	15.47	6.66	5.03
6	35.75	15.47	3.34	16.60	6	5.41
7	35.75	16.60	4	17.73	5.33	5.75
8	35.75	17.73	4.67	18.85	4.66	6.10
9	35.75	18.85	5.34	19.70	4	6.42
10	35.75	19.70	6	20.54	3.33	6.67
11	35.75	20.54	9.33			6.85
R	35.75	21.95	4.67			3.67

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	101.23	9.76	5			4.94
1	101.23	9.76	10	10.91	2	12.09
2	101.23	10.91	8	11.82	3.67	13.23
3	101.23	11.82	1.33	12.74	8	11.91
4	101.23	12.74	2	14.11	7.33	13.05
5	101.23	14.11	2.67	15.26	6.66	14.10
6	101.23	15.26	3.34	16.18	6	14.99
7	101.23	16.18	4	17.09	5.33	15.77
8	101.23	17.09	4.67	18.01	4.66	16.58
9	101.23	18.01	5.34	18.70	4	17.31
10	101.23	18.70	6	19.38	3.33	17.89
11	101.23	19.38	9.33			18.31
R	101.23	20.53	4.67			9.71

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	76.5	9.76	12							8.96
1										
2	76.5	9.76	3	10.91	5	11.82	5	12.74	3.67	6.41
3	76.5	11.82	1.33	12.74	8					9.00
4	76.5	12.74	2	14.11	7.33					9.86
5	76.5	14.11	2.67	15.26	6.66					10.66
6	76.5	15.26	3.34	16.18	6					11.32
7	76.5	16.18	4	17.09	5.33					11.92
8	76.5	17.09	4.67	18.01	4.66					12.53
9	76.5	18.01	5.34	18.70	4					13.08
10	76.5	18.70	6	19.38	3.33					13.52
11	76.5	19.38	9.33							13.84
R	76.5	20.53	4.67							7.33

Total Wind Base Shear West/East Direction (kips)	Total Wind Shear South/North Direction (kips)
199.22	308.30


Wind Load Analysis
P - Uniform Wind load
Region ①
Region ②
Assume building
Shape for analysis
Region ③

VIII. Seismic Loading

Refer to tables and sketches for seismic load on brace frames at floor levels.

Seismic Dead Loads (psf)	Floors 2 to 11	Roof	
Steel Members	10		
Mechanical	4	5	
Finish	5		
Partitions	15		
Concrete Planks	30		
Roof Deck+Insulation+EDPM		5	
Total	64	10	
Total Shear, V (kips)			319.65

Equations

Fx=CvxV

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

BF1 Seismic Loading					
Floor	Horizontal Tributary Area (ft)	hx	wh^k	Cvx	Floor Shear, Fx (kips)
G	30.67	0	N/A	N/A	N/A
1	30.67	10	N/A	N/A	N/A
2	30.67	24	436838400	0.01	0.86
3	30.67	33.33	842498142	0.02	1.66
4	30.67	41.67	1.317E+09	0.03	2.60
5	30.67	52	2.051E+09	0.05	4.05
6	30.67	61.33	2.853E+09	0.07	5.63
7	30.67	70.67	3.788E+09	0.09	7.48
8	30.67	80	4.854E+09	0.12	9.58
9	30.67	89.33	6.052E+09	0.15	11.95
10	30.67	98.67	7.384E+09	0.18	14.57
11	30.67	108	8.846E+09	0.22	17.46
R	30.67	117.33	1.631E+09	0.04	3.22

BF2 Seismic Loading					
Floor	Horizontal Tributary Area (ft)	hx	wh^k	Cvx	Floor Shear, Fx (kips)
G	35.67	0	N/A	N/A	N/A
1	35.67	10	N/A	N/A	N/A
2	35.67	24	436838400	0.01	1.00
3	35.67	33.33	842498142	0.02	1.93
4	35.67	41.67	1.317E+09	0.03	3.02
5	35.67	52	2.051E+09	0.05	4.71
6	35.67	61.33	2.853E+09	0.07	6.55
7	35.67	70.67	3.788E+09	0.09	8.70
8	35.67	80	4.854E+09	0.12	11.14
9	35.67	89.33	6.052E+09	0.15	13.89
10	35.67	98.67	7.384E+09	0.18	16.95
11	35.67	108	8.846E+09	0.22	20.31
R	35.67	117.33	1.631E+09	0.04	3.75

BF3 Seismic Loading					
Floor	Horizontal Tributary Area (ft)	hx	wh^k	Cvx	Floor Shear, Fx (kips)
G	35.75	0	N/A	N/A	N/A
1	35.75	10	N/A	N/A	N/A
2	35.75	24	436838400	0.01	1.01
3	35.75	33.33	842498142	0.02	1.94
4	35.75	41.67	1.317E+09	0.03	3.03
5	35.75	52	2.051E+09	0.05	4.72
6	35.75	61.33	2.853E+09	0.07	6.56
7	35.75	70.67	3.788E+09	0.09	8.71
8	35.75	80	4.854E+09	0.12	11.17
9	35.75	89.33	6.052E+09	0.15	13.92
10	35.75	98.67	7.384E+09	0.18	16.99
11	35.75	108	8.846E+09	0.22	20.35
R	35.75	117.33	1.631E+09	0.04	3.75

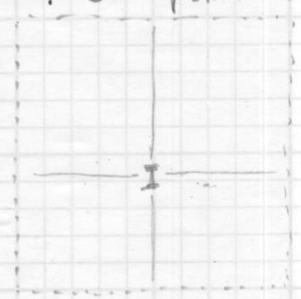
BF4 Seismic Loading					
Floor	Horizontal Tributary Area (ft)	hx	wh^k	Cvx	Floor Shear, Fx (kips)
G	101.229	0	N/A	N/A	N/A
1	101.229	10	N/A	N/A	N/A
2	101.229	24	436838400	0.01	2.17
3	101.229	33.33	842498142	0.02	4.18
4	101.229	41.67	1.317E+09	0.03	6.53
5	101.229	52	2.051E+09	0.05	10.16
6	101.229	61.33	2.853E+09	0.07	14.14
7	101.229	70.67	3.788E+09	0.09	18.77
8	101.229	80	4.854E+09	0.12	24.06
9	101.229	89.33	6.052E+09	0.15	29.99
10	101.229	98.67	7.384E+09	0.18	36.60
11	101.229	108	8.846E+09	0.22	43.84
R	101.229	117.33	1.631E+09	0.04	8.09

BF5 Seismic Loading					
Floor	Horizontal Tributary Area (ft)	hx	wh^k	Cvx	Floor Shear, Fx (kips)
G	76.5	0	N/A	N/A	N/A
1		10	N/A	N/A	N/A
2	76.5	24	436838400	0.01	1.64
3	76.5	33.33	842498142	0.02	3.16
4	76.5	41.67	1.317E+09	0.03	4.93
5	76.5	52	2.051E+09	0.05	7.68
6	76.5	61.33	2.853E+09	0.07	10.68
7	76.5	70.67	3.788E+09	0.09	14.19
8	76.5	80	4.854E+09	0.12	18.18
9	76.5	89.33	6.052E+09	0.15	22.67
10	76.5	98.67	7.384E+09	0.18	27.66
11	76.5	108	8.846E+09	0.22	33.13
R	76.5	117.33	1.631E+09	0.04	6.11

IX. Gravity Loading Member Check

Interior Column Ground Level Spot-Check

Grid point B-4 (see sketch)



$A_T = \left(\frac{27.5}{2} + \frac{22}{2}\right)(30) = 742.5\ ft^2$

$A_I = (27.5 + 22)(30) = 1485\ ft^2$

Roof — $1.2D + 1.6(L + S\ or\ L_r)$

DL = 10 psf (see seismic) — $1.2(10) + 1.6(27) = 55.2\ psf$

LL = 20 psf (service)

SL = 27 psf (see loading)

Floor

DL = 64 psf (see seismic) — $1.2(64) + 1.6(64) = 179.2\ psf$

LL = 100 psf (account for variation from 40 psf → 150 psf, see Gravity Loads) — $(179.2\ psf)(11) = 1971.2\ psf$

$L = 100\left(0.25 + \frac{15}{\sqrt{1485}}\right) = 64$

Total Design Load — $742.5(55.2 + 1971.2) = 1504.6^k$

Length = 26 ft

Unbraced Length = 14 ft

W14 x 145

$\phi P_n = 1590^k$

Designed With – W12 x 170 → Works

$\phi P_n = 1740$

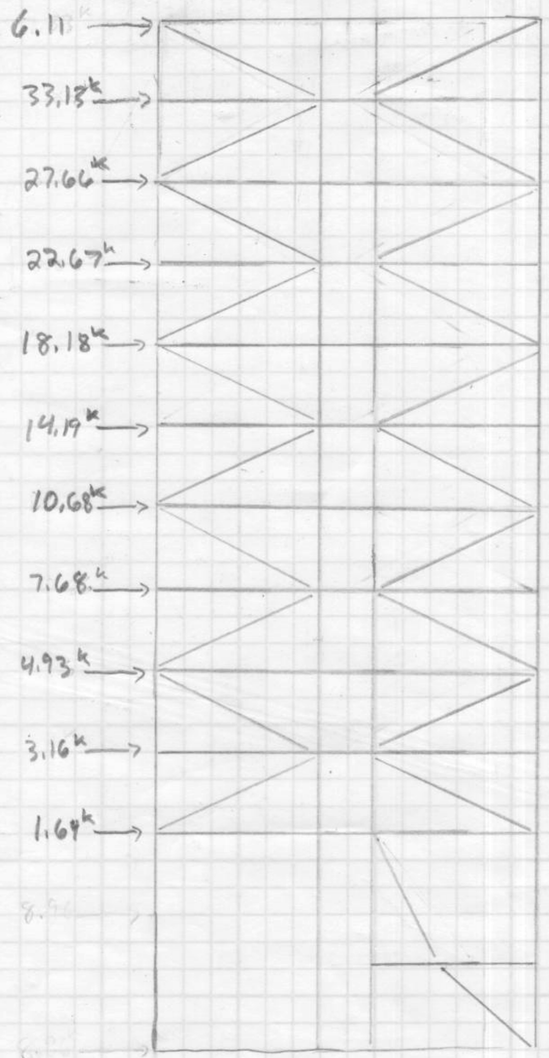
X. Lateral Loading Brace Member Check

Lateral Load Spot-Check

Seismic Loads (controls over wind)

BF5 - Floor Level 2

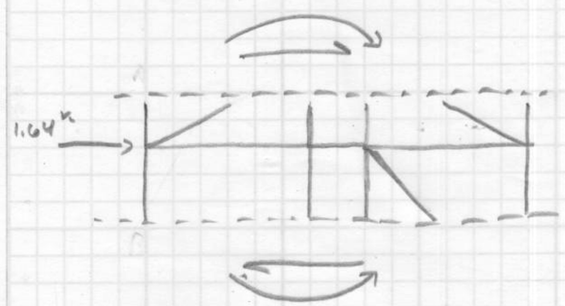
Load at Floor Level = 1.64 k



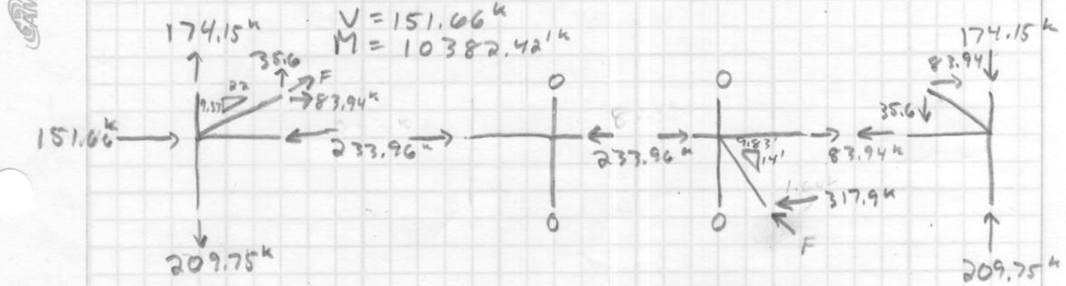
Lateral Spot Check- Diagonal Below Floor Two of BF5 (Seismic Controls)			
Floor	Floor Shear, Fx (kips)	Moment Arm (ft)	Moment (ft-k)
2	1.64		
3	3.16	4.67	14.74
4	4.93	14	69.05
5	7.68	23.33	179.20
6	10.68	32.66	348.96
7	14.19	42	595.84
8	18.18	51.32	932.99
9	22.67	60.65	1374.78
10	27.66	69.98	1935.32
11	33.13	79.31	2627.75
R	6.11	88.64	541.60
Shear Top	150.02	Moment Top	8620.22
Shear Bottom	151.66	Moment Bottom	10382.42
Axial Top	174.15		
Axial Bottom	209.75		

- See seismic Lateral spot Check Table for calculations

M = 8620.22'k
V = 150.02k



V = 151.66k
M = 10382.42'k



$\sqrt{9.33^2+22^2} = 23.9$

$35.6 = \frac{9.33}{23.9} F$

F = 91.2k (T)

$\frac{22}{23.9}(91.2^k) = 83.94^k$

$\sqrt{9.83^2+14^2} = 17.1$

$317.9^k = \frac{9.83}{17.1} F$

F = 553k (C)

HSS 10x10x1/2

$\phi P_n = 557$ in compression

Designed with

HSS 10x8x1/2

$\phi P_n = 450$

→ Close

XI. Calculations

Dead Loads

- See seismic Loading

Roof Snow Load

Ground Snow Load

Philadelphia – 30 psf

Terrain Category

Urban – B

Thermal Factor

Full Heating – 1.0

Exposure of Roof

Fully Exposed

Snow Exposure Factor

Fully Exposed/Type B Terrain – 0.9

Importance Factor

II or III?

III – "Buildings and other Structures with occupant load greater than 500 for colleges and adult education facilities"

– Estimates more than 500 occupancy (houses 490 Students)

→ use type II because dormitory, not academic building

Snow Importance Factor

II → 1.0

$P = C_e C_t I p_g = (.9)(1)(1)(30) = \underline{27\text{ psf}}$

CALCULATIONS

Live Loads

Uniform Floor Load
27. Residential
Hotels and Multifamily Dwellings
Private rooms and corridors serving them
→ 40 psf

Lobbies
4. Assembly areas and theaters
Lobbies
→ 100 psf

Kitchens
27. consider part of Private rooms and coridors serving them?
→ 40 psf
or
public rooms and corridors serving them
→ 100 psf ? use

Mechanical Rooms / Mechanical Penthouse Floor / Storage Room / Elevator Machine Room
23. Storage Warehouses
Heavy
→ 250 psf

Corridors
9. Corridors
→ 100 psf

Roof

$L_r = 20 R_1 R_2 \qquad 12 \leq L_r \leq 20$

$A_{t\,max} : 6' \times 27.5' = 165\ ft^2 \leq 200\ ft^2$

$\rightarrow R_1 = 1 \qquad R_2 = 1$ (flat)

→ 20 psf

CALCULATIONS

Wind Loading

Category II (from snow calc)

Importance Factor → 1.0

Exposure = Terrain ⇒ B

Wind Speed – V = 90 mph, assume no unusually high wind due to terrain

Directionality factor – k_d

Buildings

Components + Cladding → 0.85

Importance Factor

Cat II → I = 1.0

Exposure B

Velocity Pressure Exposure Coefficients, K_h and K_z

Case 2 - a) all main wind force resisting systems in buildings except those in low-rise buildings

b) All main wind force resisting systems in other structures

200 ft, both cases are same → 1.20

Assume Rigid

Assume Topographic Factor = 1.0

Assume Gust Effect Factor = 1.0

Velocity Pressure at height h – Case 2, Exp. B

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

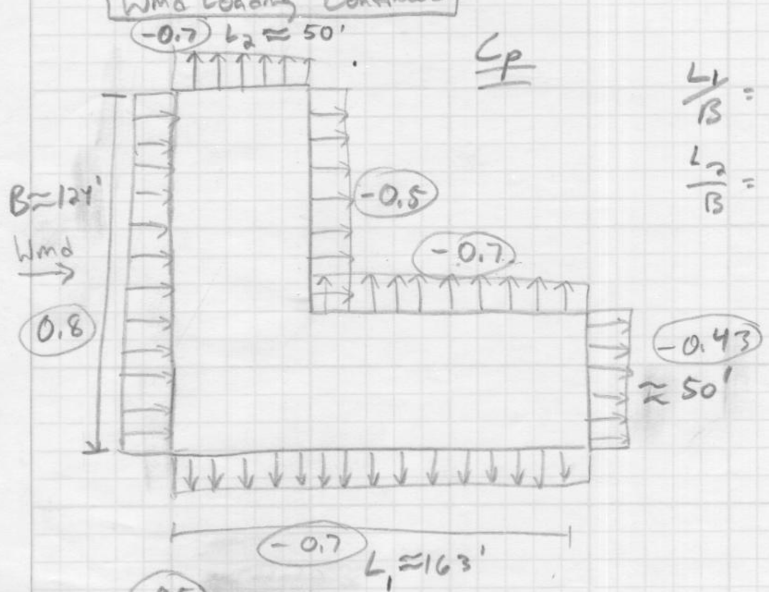
$q_h = 0.00256(1.2)(1.0)(0.85)(90)^2(1.0) = 21.15 \frac{lb}{ft^2}$

Internal Pressure Coefficients – GC_{pi}

Enclosed Buildings – ±0.18

CALCULATIONS

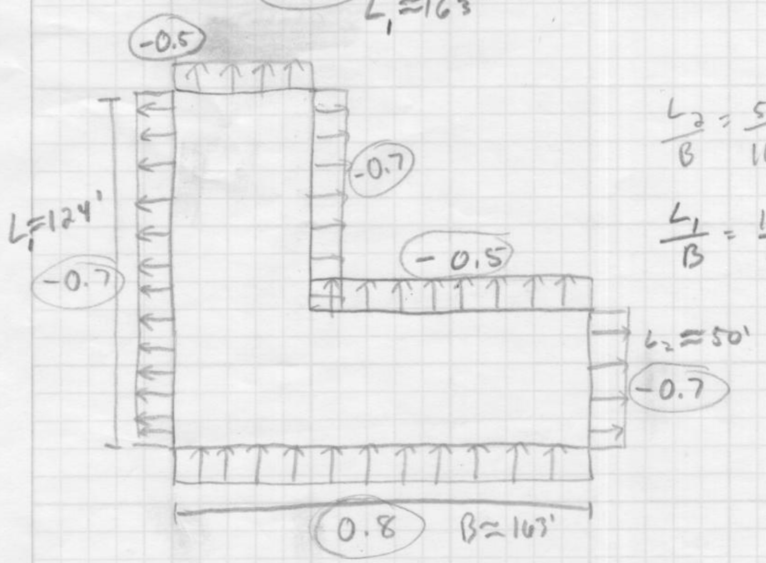
Wind Loading Continued



C_p

$\frac{L_1}{B} = 1.31 \rightarrow -0.43$

$\frac{L_2}{B} = \frac{50}{124} = 0.4 \rightarrow -0.5$



$\frac{L_2}{B} = \frac{50}{163'} < 1 \rightarrow -0.5$

$\frac{L_1}{B} = \frac{124}{163} < 1 \rightarrow -0.5$

Note: See Next page for net Cp coefficients for wind blowing in these major cases

CALCULATIONS

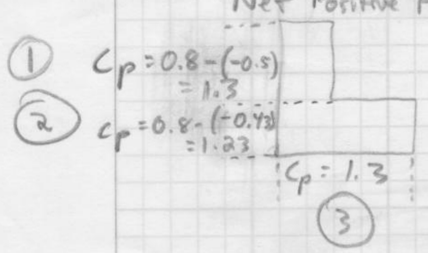
Wall Wind Loading Cont.

Velocity Pressure Exposure Coefficients, K_z

Height above ground, z	K_z	q_z (lb/ft²)	p (lb/ft²) 1	2	3
0-15	0.57	10.05	SEE EXCEL Spreadsheet - ①		Same as ①
20	0.62	10.93			
25	0.66	11.63			
30	0.70	12.34			
40	0.76	13.40			
50	0.81	14.28			
60	0.85	14.98			
70	0.89	15.69			
80	0.93	16.39			
90	0.96	16.92			
100	0.99	17.45			
q_h → 120	1.04	18.33			

$$p = q_z G C_p - q_h (G C_{pi})$$ (with $G = 1$, $GC_{pi} = 0.18$)

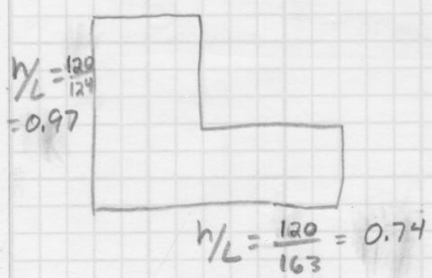
Net Positive Pressure Coefficient on Resisting Systems (C_p)

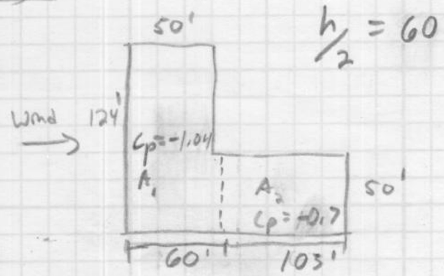


$$p = q_z(1)C_p - (18.33)(0.18)$$

CALCULATIONS

Roof Wind Loading

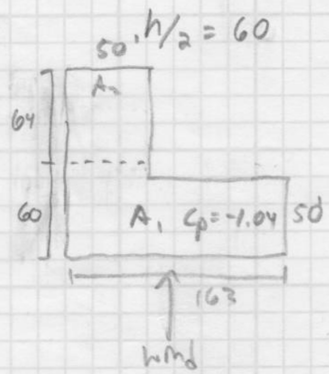




$A_1 = (60 \times 50) + (124 - 50)(50)$
$= 6700 \text{ ft}^2$

Reduction factor = 0.8

$C_p = -1.3(0.8) = -1.04$



$A_1 = 60(50) + (163 - 50)(50)$
$= 8650 \text{ ft}^2$

Reduction factor = 0.8

$C_p = -1.04$

<u>Note</u>: Design roof for $C_p = -1.04$

$p = \overset{q_h}{18.33}(-1.04 - 0.18) = -25.8 \text{ psf}$

CALCULATIONS

Seismic Loading

Assume site Classification (Soil) is correct — Class C

F_A - Accelleration related site coefficient
Table 9.4.1.2.4a
C, btw 0.25 and 0.50
both same values → 1.2

F_V - Velocity related site coefficient
Table 9.4.1.2.4b
→ 1.7

$S_{MS} = F_a S_s = 1.2(0.3) = 0.36$

$S_{M1} = F_V S_1 = 1.7(0.08) = 0.136$

$S_{DS} = \frac{2}{3} S_{MS} = \frac{2}{3}(0.36) = 0.24$

$S_{D1} = \frac{2}{3} S_{M1} = 2/3(0.136) = 0.091$

Seismic Design Category
Table 9.4.2.1a
→ B

— Structural Steel Systems Not Specifically Detailed for Seismic Resistance

$R^a = 3$
$W_o^g = 3$
$C_d^b = 3$

Equivalent Lateral Force Procedure

CALCULATIONS

Equivalent Lateral Force Procedure

Seismic Continued

Seismic Responce Coefficient

$$C_s = \frac{S_{DS}}{R/I} = \frac{0.24}{3/1} = 0.08$$

must be less than:

$$C_s = \frac{S_{D1}}{T_a(R/I)} = \frac{0.091}{3T_a} = \frac{0.091}{3(0.73)} = 0.0415$$

↓ from below ↓

T_a - Approximate Fundamental Period

$T_a = C_t h_n^x$

$C_u = 1.7$

$h_n = 121$

Table 9.5.5.3.2

Does not fit structure types

Use "All other structural systems"

$C_t = 0.02$

$x = 0.75$

$$T_a = 0.02(121)^{0.75} = 0.73\ s$$

$$Freq = \frac{1}{T_a} = 1.37$$ → Rigid Structure Assumption Correct

$$V = C_s W$$

$$F_x = \frac{1.2\ S_{DS}}{R} w_x$$

W:
1. 25% storage Live load
2. 10 psf assumed for ponding of concrete
3. 10 psf assumed for member weight
4. 100% weight of equipment
5. Floor weight
6. Partition Dead load

CALCULATIONS

Floor Area $\simeq$ (50)(124) + (50)(113) = 11850 sf

$F_2 \rightarrow F_{11}$ (each floor) –

10 psf steel member weight

Assume – 4 psf mechanical/plumbing

Assume – 5 psf finish

15 psf partitions

Assume – 30 psf concrete planks
($\frac{1}{3}$ weight of solid Concrete)

64 psf × 10 floors = 640 psf

Roof –

4 psf mechanical

7,840 lb Unit

5 psf built up roof

9 psf + 7,840

$V = C_p W$

$V = 0.0415((649)(11850) + 7,840))$

$= 319.5$ kips

Lateral Load at Each Floor

$F_x = 0.01 w_x$