Technical Report 2

Kyle Freeley

Structural Option

Advisor: Dr. Boothby

8 Cabot Road

Woburn, Massachusetts

PSUAE

Letter of Transmittal

September 26, 2014

Dr. Thomas Boothby

Thesis Advisor

The Pennsylvania State University

Enclosed: Structural Technical Report 2

Dear Dr. Boothby,

I am submitting the following technical report as part of AE 481W. The report includes calculations of gravity loads (both dead and live), wind loads, seismic loads, and snow loads for 8 Cabot Road. Hand calculations, excel spreadsheets, and loading diagrams were used in these calculations.

Thank you in advance for taking the time to review the following technical report, and I look forward to hearing your feedback.

Sincerely,

Kyle Freeley

Executive Summary

8 Cabot Road is owned and operated by Cummings Properties. It is a four story office and research building located in Woburn, Massachusetts. The building was constructed by Cummings Properties, who manage the property and lease portions of the building to companies looking for office space. The glass curtain walls and brick façade give the building a modern look, but it is mainly a functional structure, acting as offices and lab/research space.

The structural system of this building consists typically of 30’x30’ square bays and braced frames acting as the lateral force resisting system. Composite concrete and metal deck is supported by steel beams and girders, framing into steel columns.

The foundation was interesting, because the soil type made spread footings difficult. Instead, 100 foot piles with concrete caps connecting them to the columns were driven down into the bedrock beneath the loose organic soil.

Due to its location and zoning requirements, 780 CMR Massachusetts Building Code, 7th Edition and ASCE 7-02 were the codes referenced for 8 Cabot Road.

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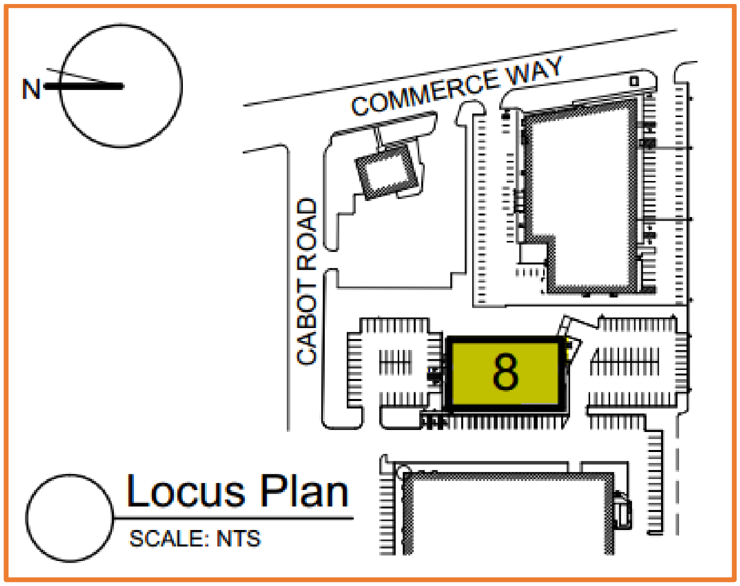
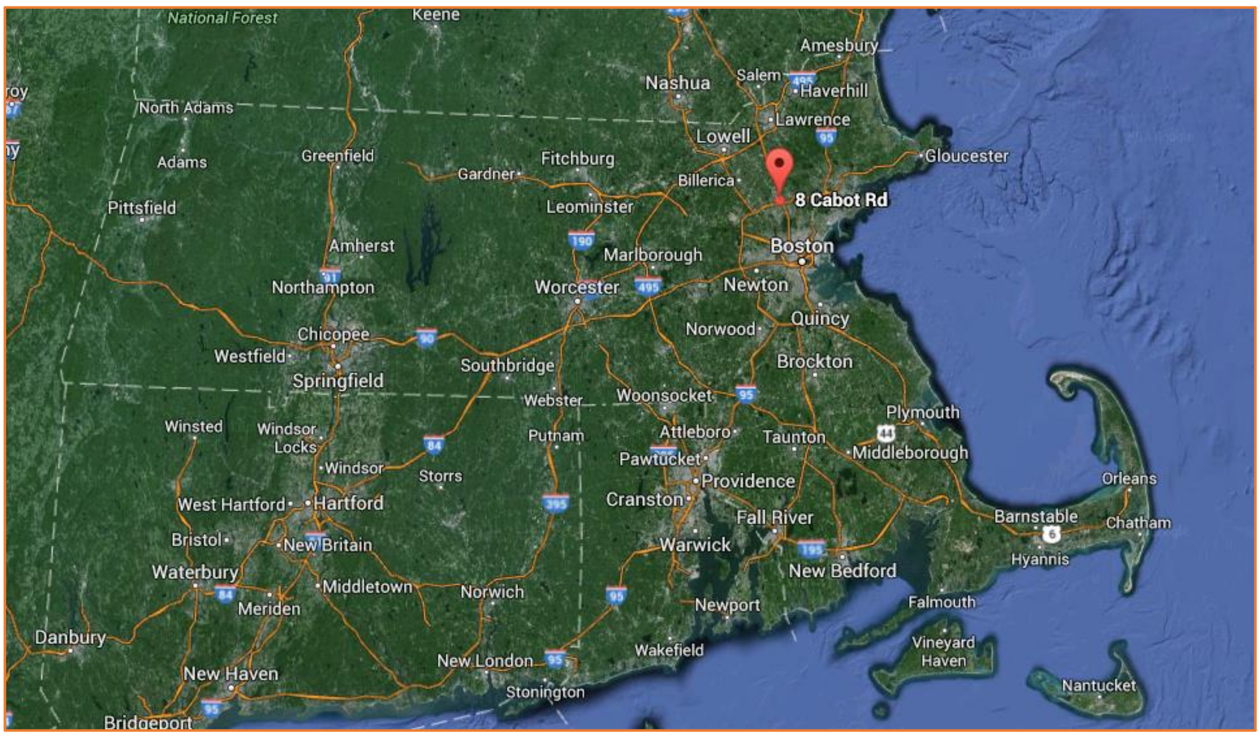
Site Plan and Location





8 Cabot Road is located in Woburn, Massachusetts, approximately 10 miles North of Boston, MA. The site was previously a parking lot and is in a flat, industrial area.

8 Cabot Road

Woburn, MA

General Information

Full Height:	90 feet
Number of Stories:	4
Total Size:	60,000 square feet
Cost:	Withheld by owner
Construction Dates:	May 2009 – January 2010
Delivery Method:	Design-build

Project Team

Cummings properties, as well as being the owner, also acted as the general contractor, CM, architect, and engineer for this project.

In Progress

Kyle Freeley – Structural Option

https://www.engr.psu.edu/ae/thesis/portfolios/2015/kpf5066/index.html

Purpose

This report is a detailed analysis of the loading conditions for 8 Cabot Road. The gravity, seismic, wind, and snow loads calculated in this document will be used in future reports for calculations in the design of gravity and lateral force resisting systems.

Reference Documents

International Building Code 2009

American Society of Civil Engineers

- ASCE 7-02
- ASCE 7-10

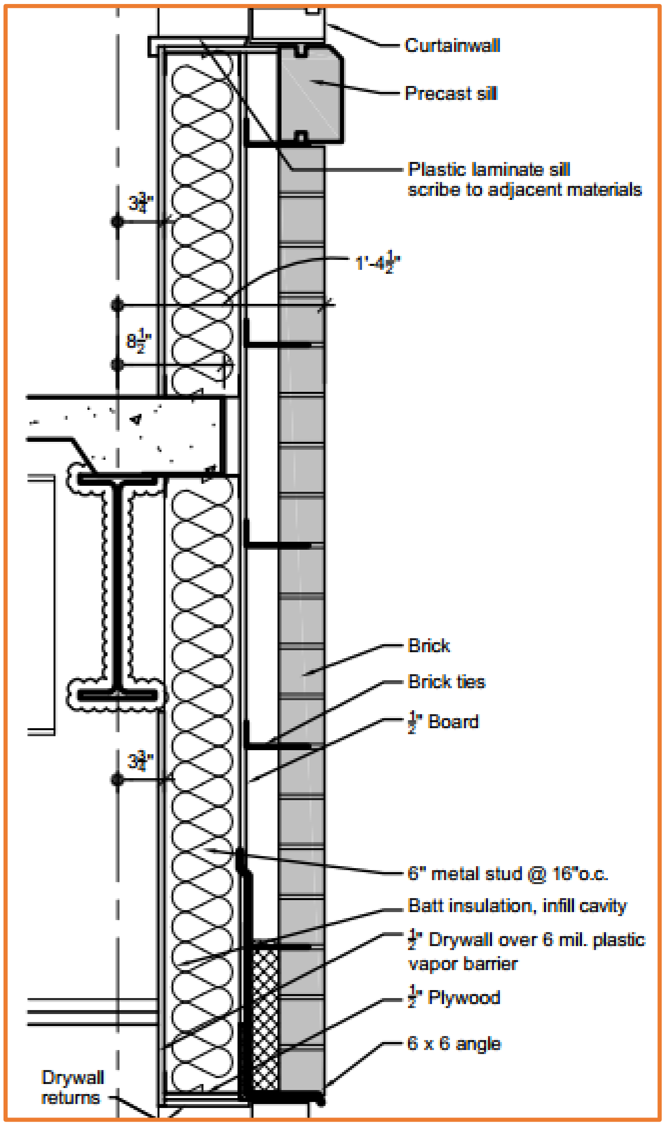
780 CMR 7th Edition

Vulcraft deck catalog

Previous course notes

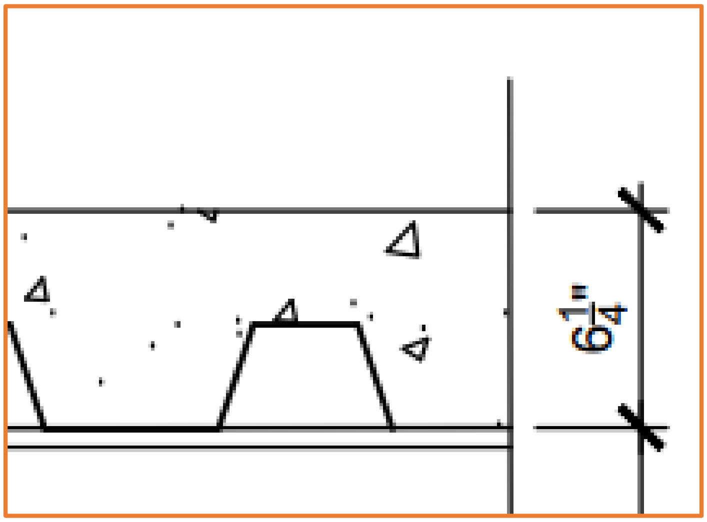
Gravity Loads

Exterior Enclosure



- Exterior stud walls with brick veneer – 48 psf

Dead Loads



Floor

- 6-1/4" lightweight concrete slab on 3" metal deck – 48psf
- Steel – 7psf
- HVAC/Misc. – 5psf

Roof

- Lightweight concrete with spray-on fireproofing – 40psf

Live Loads

Floor

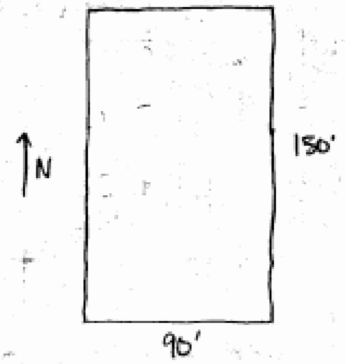
- Laboratory – 100psf
- Mechanical rooms – 125psf

Roof

- Snow – 40psf
- Min. per specifications – 20psf

Wind Loads

Wind Loads



4 story building
Woburn, MA
Max height → 70'

ASCE 7-02

1 - Basic wind speed = 105 mph

2 - Importance factor = 1.0

3 - Exposure category = B

∴ $K_z = 0.89$ (from table 6-3)

$$K_z = \begin{cases} 2.01\,(z/z_g)^{2/\alpha} & 15' < z < z_g \\ 2.01\,(15/z_g)^{2/\alpha} & z < 15' \end{cases}$$

4 - $K_{zt} = 1.0$ (flat surrounding area)

5 - Gust factor:

$z = 0.6(70) = 42 > 30$ ✓

$I_z = c(33/z)^{1/6} = 0.3\,(33/42)^{1/6} = 0.288$

$L_z = \ell(z/33)^{\epsilon} = 320\,(42/33)^{0.333} = 346.5$

*Note: c, z_{min}, ℓ, and ϵ values from table 6-2

$$Q_{NS} = \sqrt{\frac{1}{1+0.63\left(\frac{B+h}{L_z}\right)^{0.63}}} = \sqrt{\frac{1}{1+0.63\left(\frac{150}{346.5}\right)^{0.63}}} = 0.854$$

$$Q_{EW} = \sqrt{\frac{1}{1+0.63\left(\frac{210}{346.5}\right)^{0.63}}} = 0.828$$

Wind Loads cont. ASCE 7-02

$$G_{NS} = 0.925\left(\frac{1+1.7g_Q I_z Q}{1+1.7g_v I_z}\right) = 0.925\left[\frac{1+1.7(3.4)(0.288)(0.854)}{1+1.7(3.4)(0.288)}\right]$$

$$G_{NS} = 0.8406$$

$$G_{EW} = 0.925\left[\frac{1+1.7(3.4)(0.288)(0.828)}{1+1.7(3.4)(0.288)}\right] = 0.8256$$

6- Enclosed building

7- $GC_{pi} = \pm 0.18$

8- $C_p = \begin{cases} \text{Windward} = 0.8 \\ \text{Leeward} = -0.5 \\ \text{Side} = -0.7 \end{cases}$

9- $q_z = 0.00256 K_z K_{zt} V^2 I = 0.00256(0.89)(1)(0.85)(105)^2(1) = 21.35\text{psf}$

10- $p = qGC_p - q_i(GC_{pi})$

N-S

$P_{windward} = q(0.8406)(0.8) - q_i(-0.18)$

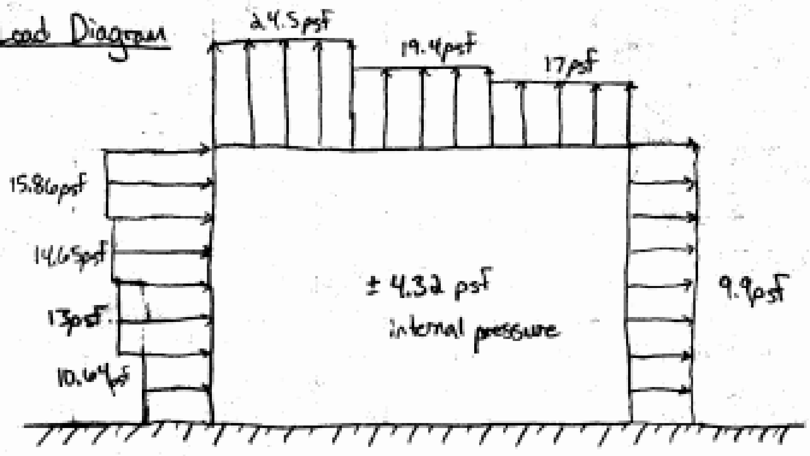
$P_{leeward} = q(0.8406)(-0.5) - q_i(0.18)$

E-W

$P_{ww} = q(0.8256)(0.8) - q_i(-0.18)$

$P_{lw} = q(0.8256)(-0.5) - q_i(0.18)$

Wind Load Diagram



$$\frac{150(15)(10.64) + 150(15)(13) + 150(15)(14.65) + 150(15)(15.86)}{1000} = 121.84 \text{ kips}$$

$$121.84 + \frac{9.9(150)(60)}{1000} = 210.94 \text{ kips}$$

Base shear = 210.94 kips

North-South

Location	z(ft)	q_z or q_h (psf)	C_p	q_zGC_p (psf)	GC_{pi}	q_hGC_{pi} (psf)	q_zGC_p-$q_h(+GC_{pi})$	q_zGC_p-$q_h(-GC_{pi})$
Windward	0	16.1	0.8	10.82	0.18	4.32	6.50	15.14
	15	16.1	0.8	10.82	0.18	4.32	6.50	15.14
	30	19.8	0.8	13.29	0.18	4.32	8.97	17.61
	45	22.2	0.8	14.90	0.18	4.32	10.58	19.22
	60	24.0	0.8	16.13	0.18	4.32	11.81	20.45
Leeward	All	24.0	-0.5	-10.08	0.18	4.32	-14.40	-5.76
Side	All	24.0	-0.7	-14.12	0.18	4.32	-18.44	-9.80
Roof (0-h/2)	60	24.0	-1.0	-20.17	0.18	4.32	-24.49	-15.85
Roof (h/2-h)	60	24.0	-0.76	-15.33	0.18	4.32	-19.65	-11.01
Roof (>h)	60	24.0	-0.64	-12.91	0.18	4.32	-17.23	-8.59

East-West

Location	z(ft)	q_z or q_h (psf)	C_p	q_zGC_p (psf)	GC_{pi}	q_hGC_{pi} (psf)	q_zGC_p-$q_h(+GC_{pi})$	q_zGC_p-$q_h(-GC_{pi})$
Windward	0	16.1	0.8	10.64	0.18	4.32	6.32	14.96
	15	16.1	0.8	10.64	0.18	4.32	6.32	14.96
	30	19.8	0.8	13.06	0.18	4.32	8.74	17.38
	45	22.2	0.8	14.65	0.18	4.32	10.33	18.97
	60	24.0	0.8	15.86	0.18	4.32	11.54	20.18
Leeward	All	24.0	-0.5	-9.91	0.18	4.32	-14.23	-5.59
Side	All	24.0	-0.7	-13.88	0.18	4.32	-18.20	-9.56
Roof (0-h/2)	60	24.0	-1.0	-19.83	0.18	4.32	-24.15	-15.51
Roof (h/2-h)	60	24.0	-0.76	-15.07	0.18	4.32	-19.39	-10.75
Roof (>h)	60	24.0	-0.64	-12.69	0.18	4.32	-17.01	-8.37

Snow Loads

Snow Loads

Flat roof snow loads

$p_f = 0.7 C_e C_t I p_g$

$p_g = 50$ psf (from map)

$I = 1.0$

Terrain category: B

Partially exposed

$C_e = 1.0$

$C_t = 1.0$

$p_f = 0.7(1)(1)(1)(50) = 35$ psf → compared to 40psf as stated in structural specifications

Seismic Loads

Seismic Loads

Site class: D

$S_s = 0.3$, $S_1 = 0.071$

$\frac{F_a - 1.6}{0.3 - 0.25} = \frac{1.4 - 1.6}{0.5 - 0.25} \rightarrow F_a = 1.56$, $F_v = 2.4$

$S_{MS} = 1.56(0.3) = 0.468$

$S_{M1} = 2.4(0.071) = 0.1704$

$S_{DS} = 2/3(0.468) = 0.312$

$S_{D1} = 2/3(0.1704) = 0.1136$

Seismic design category C

Lateral systems → eccentrically braced steel frames

$R = 8$, $\Omega_0 = 2$, $C_d = 4$

$I_e = 1.0$

$T_a = C_t h_n^x = 0.03(60)^{0.75} = 0.647 \text{ sec}$

$C_t = 0.03$, $x = 0.75$, $h = 60$ (mean roof height)

$T_L = 6 \text{ sec}$

$C_s = \frac{S_{DS}}{(R/I_e)} = \frac{0.313}{8} = 0.039$

check: $C_s \geq 0.044(S_{DS})I_e = 0.044(0.312)(1) = 0.014$

$S_1 < 0.6g$

Effective total seismic weight (W)

DL + 20% SL (on roof)

DL (on floor)

Seismic Loads cont.

$$W_{rF} = (150)(90)[45+0.2(40)] + 2(150+90)(\tfrac{15}{2})(40) = 859.5\text{kips}$$

$$W_{F1} = [(150)(90)(60) + 2(150+90)(\tfrac{15}{2}+\tfrac{15}{2})(48)]3 = 3{,}467\text{ kips}$$

Total load = 4,326.5 kips

Seismic base shear (V)

$$V = 0.02(4326.5) = 86.53 \text{ kips}$$

($S_{DS} = 0.46$ from structural plans)
($0.46 \cdot 0.044 = 0.02$)

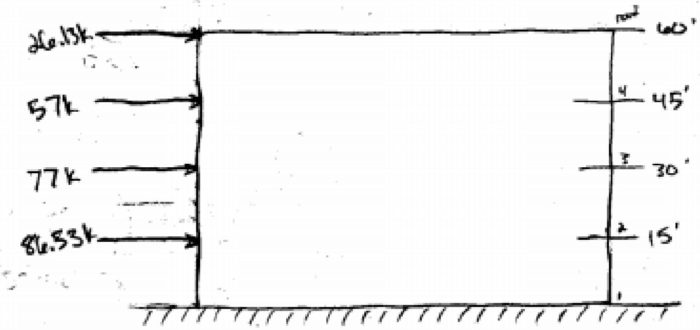
Vertical distribution of seismic forces (F_x)

$$F_x = VC_{vx} = V\left(\frac{W_x h_x^k}{\sum w_i h_i^k}\right)$$

$$\frac{2.5-0.5}{2-1} = \frac{2.5-0.647}{2-k} \rightarrow 2-k = 0.9265 \rightarrow k = 1.0735$$

Level	h(x)	W_x	$W_x h_x^k$	C_{vx}	$F_x = C_{vx}V$	V(x)
Roof	60	859.5	68,686	0.302	0.302(86.53) = 26.13	26.13
Floor 3	45	1155.7	81,326	0.357	30.89	57.02
Floor 2	30	1155.7	52,700	0.231	19.99	77.0
Floor 1	15	1155.7	25,102	0.110	9.52	86.53
		4326.5	227,815	1.0		

Seismic Load Diagram

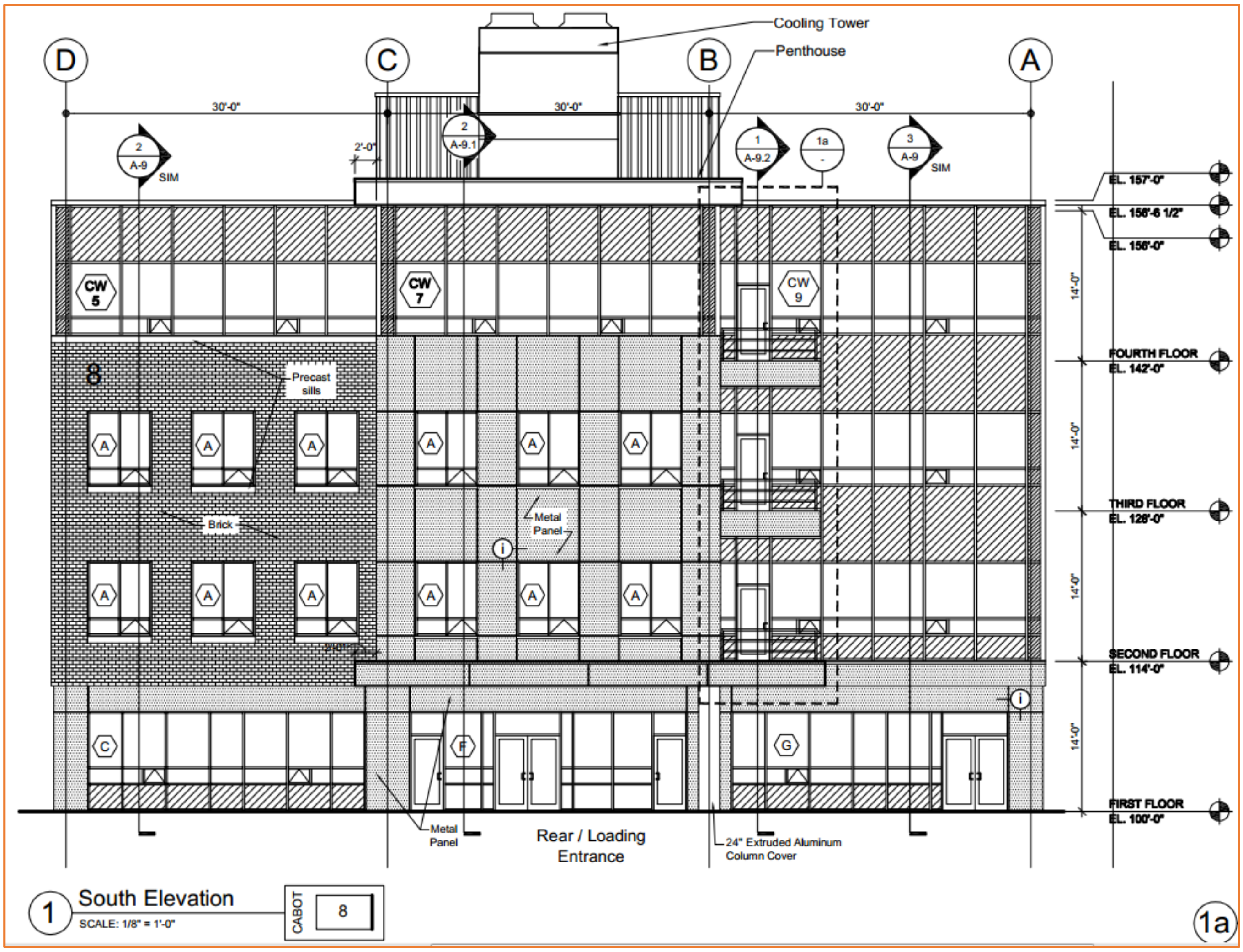


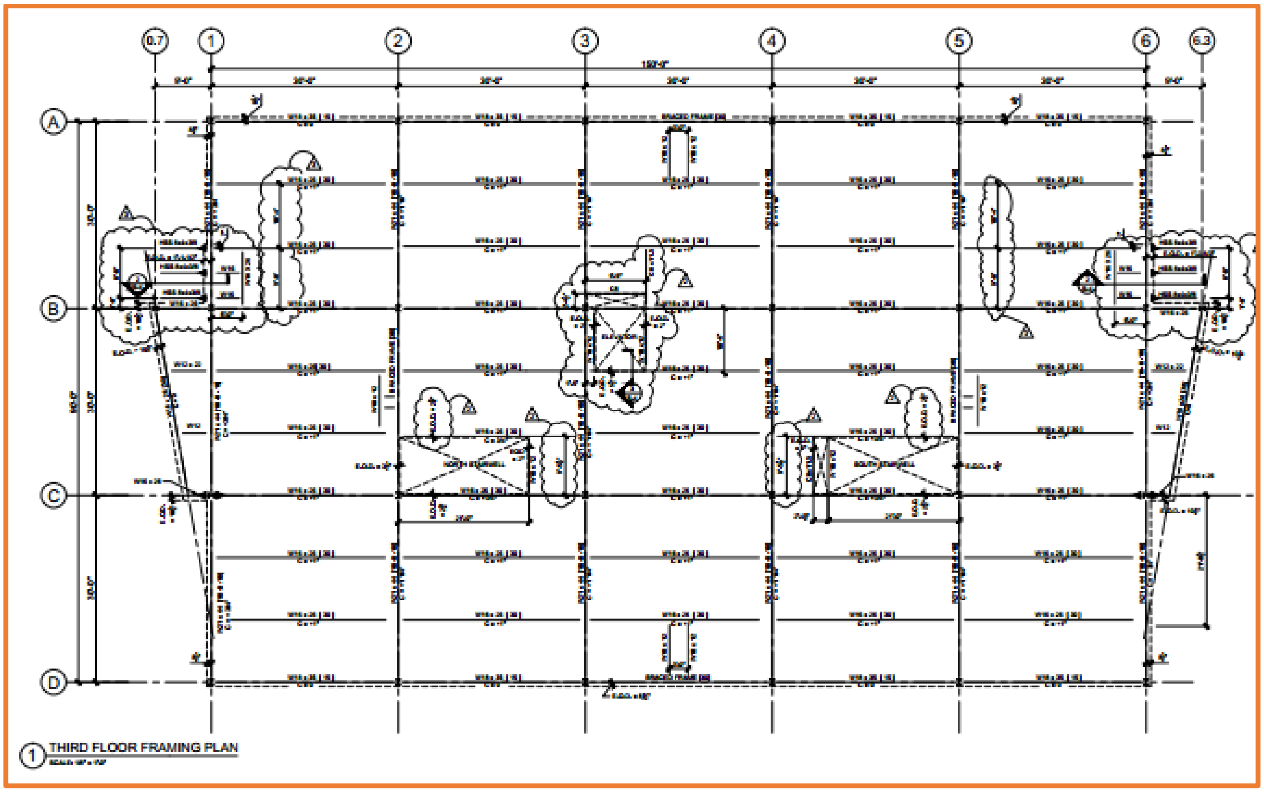
Seismic base shear = 246.7 kips

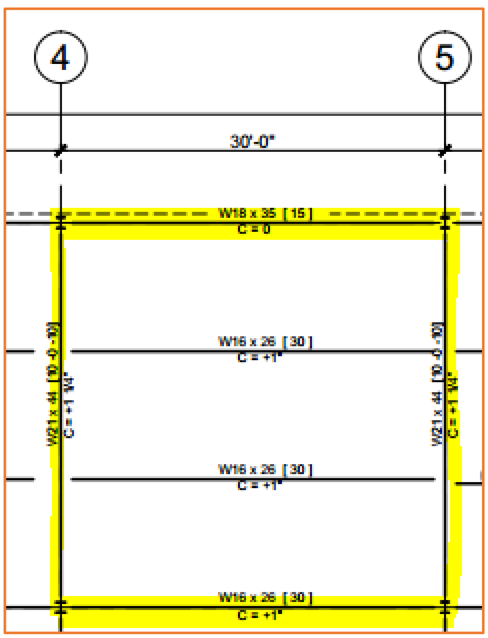
Conclusion

In this report, the loadings for 8 Cabot Road were examined, including gravity, wind, snow, and seismic. As was specified in the drawings, seismic loads controlled over wind loads for this project.

Appendix


Cooling Tower
Penthouse
D
C
B
A
30'-0"
30'-0"
30'-0"
2'-0"
SIM
SIM
EL. 157'-0"
EL. 156'-6 1/2"
EL. 156'-0"
FOURTH FLOOR
EL. 142'-0"
THIRD FLOOR
EL. 128'-0"
SECOND FLOOR
EL. 114'-0"
FIRST FLOOR
EL. 100'-0"
14'-0"
Precast sills
Brick
Metal Panel
Metal Panel
Rear / Loading Entrance
24" Extruded Aluminum Column Cover
South Elevation
SCALE: 1/8" = 1'-0"
CABOT
8
1a





Typical bay size: 30’x30’