James W. & Frances G. McGlothlin Medical Education Center
Virginia Commonwealth University
Richmond, VA

September 27, 2013

Professor Linda Hanagan
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University Park, PA 16802
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Dear Professor Hanagan,

I am formally submitting Structural Technical Report #2 – Building Codes, Specifications, and Loads. This report is a compilation of previous findings, contract drawings/specifications and codes used for reference, and the calculations to find gravity, wind, and seismic loadings on the building. A table of contents and numbering of pages has been provided for ease of navigating this report. All calculations of loadings have been done by hand, and therefore have been scanned to be inserted in to this report. I look forward to discussing this report and my findings with you in the near future.

Sincerely,

Marissa Delozier

Enclosure: Report of Findings Related to Gravity, Wind, and Seismic Loadings on the James W. & Frances G. McGlothlin Medical Education Center

General Information

The James W. & Frances G. McGlothlin Medical Education Center is a 13-story building that has both a basement and small sub-basement located below ground level, which is at an elevation of 153 feet. Since the building was constructed following the demolition of the A.D. Williams Building, the foundation system is designed to accommodate existing conditions. The superstructure of the building is composed of a braced moment frame system with concrete slabs on metal decking. Both the 13^{th} Floor and the rooftop are homes to mechanical equipment, requiring added strength. A bridge traveling over E. Marshall Street connects the new building on the 2^{nd} Floor with the existing Main Hospital 1^{st} Floor. Further information about the building and its location in downtown Richmond, Virginia can be found on the following pages.

NOTE: To decrease confusion and provide easier reading, from this point in the report and forward the James W. & Frances G. McGlothlin Medical Education Center will be referred to as VCU SOM project, short for Virginia Commonwealth University School of Medicine project.

Building Abstract

James W. & Frances G. McGlothlin Medical Education Center

Virginia Commonwealth University – Richmond, VA

Project Information

Type of Building :	Multipurpose Education Facility
Functions :	Administrative/Classrooms/Research
Size :	220,000 GSF
Height :	13 stories
Time Frame :	Oct. 2009 – March 2013
Cost :	$159 million
Delivery :	Design–Assist–Build

Project Team

Owner :	Virginia Commonwealth University
CM :	Gilbane Building Company
Architect :	Ballinger
Structural + MEP :	Ballinger
Exterior Façade :	Pei Cobb Freed & Partners
Civil :	Draper Aden Associates
Geotechnical :	Geotech, Inc.

Architectural

– Erected following demolition of 8-story A.D. Williams Building, which previously housed VCU School of Medicine

– Exterior façade was designed by internationally acclaimed design firm Pei Cobb Freed & Partners

Sustainability

– Climate Wall System: double-layered glass walls on South & West facades trap & exhaust heated air

– Recovery Wheels: recover exhausted air & use contained energy to heat & cool building

– Storm Water Retention: collect water from roof to be used in toilets/urinals

Structural

– Drilled pier/slab-on-grade system works in conjunction with pre-existing caissons

– Structural steel braced moment frame system

– Bridge connects 2nd Floor of building to adjacent Main Hospital 1st Floor across E. Marshall Street

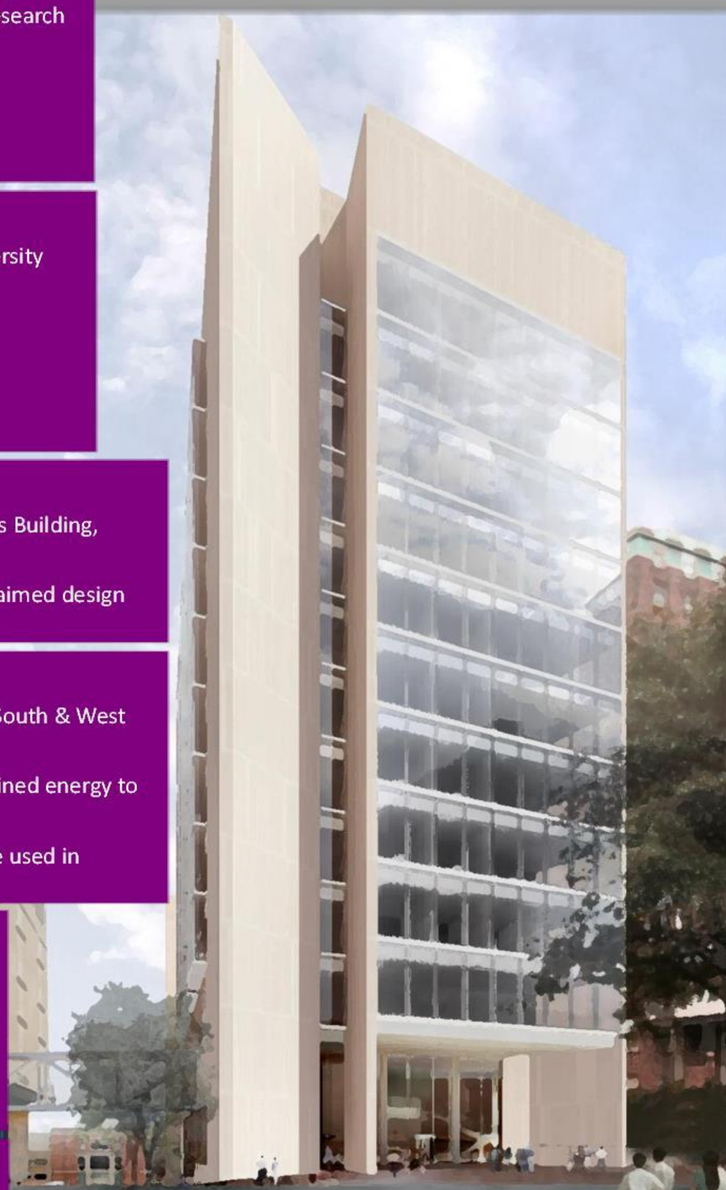
MEP

– 6 Air Handling Units serve the Lobby, Student Forum, Auditorium, and Chilled Beam system

– Cooling Tower on roof removes heat from 3 Chillers

– Use of Recovery Wheels saves 450 tons of cooling

– Daylighting sensors throughout building ensure energy is conserved



Marissa Delozier

Structural Option

http://www.engr.psu.edu/ae/thesis/portfolios/2013/mnd5036/

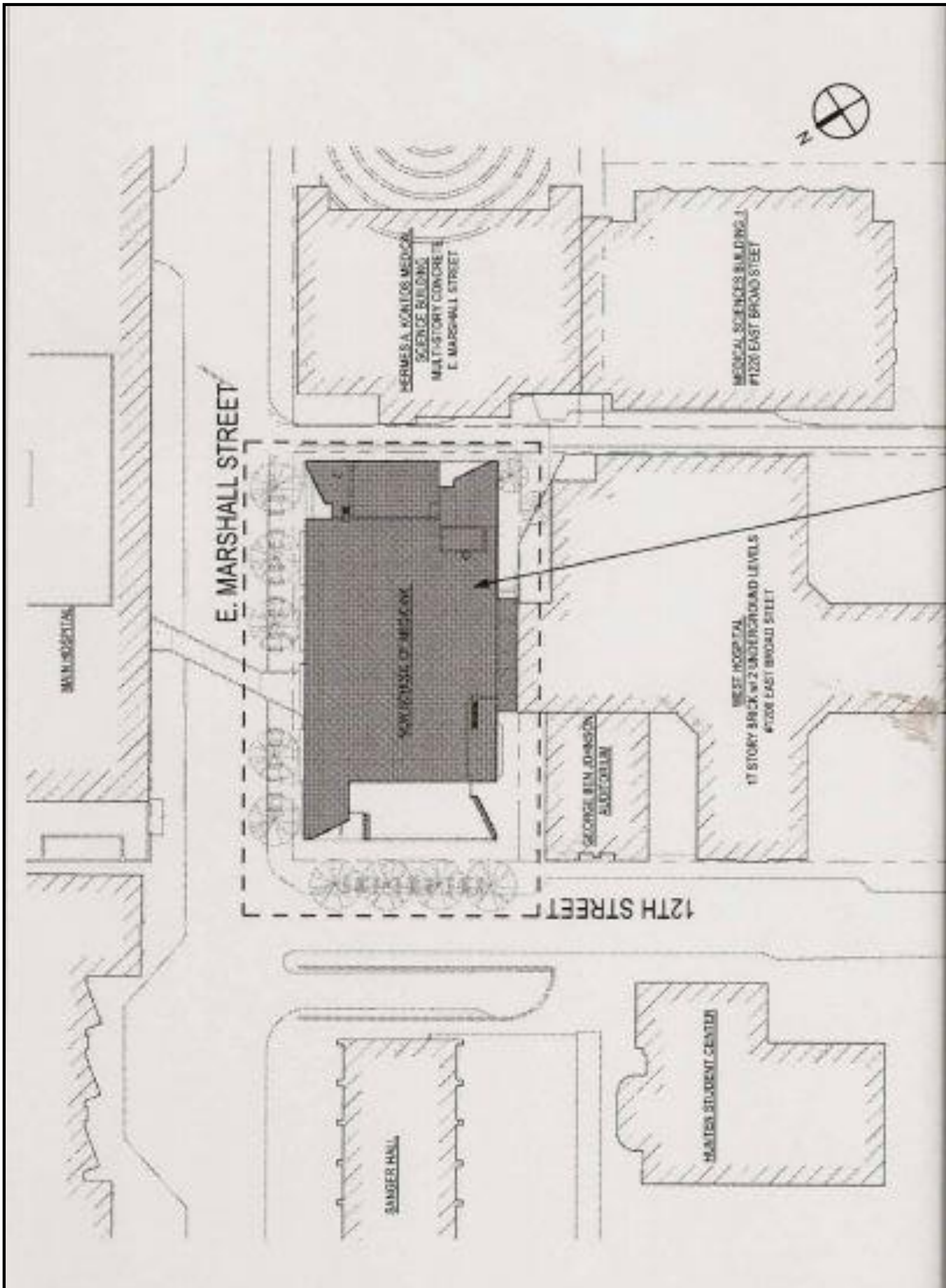
Executive Summary from Technical Report 1

The following technical report is a thorough overview of the existing conditions of the structural system found in the newly constructed James W. & Frances G. McGlothlin Medical Education Center. This report is composed of detailed descriptions of the drilled pier/slab-on-grade system, floor framing, braced moment frame system, roof scheme, bridge connecting to an adjacent structure, and all other components that contribute to the strength of the structure.

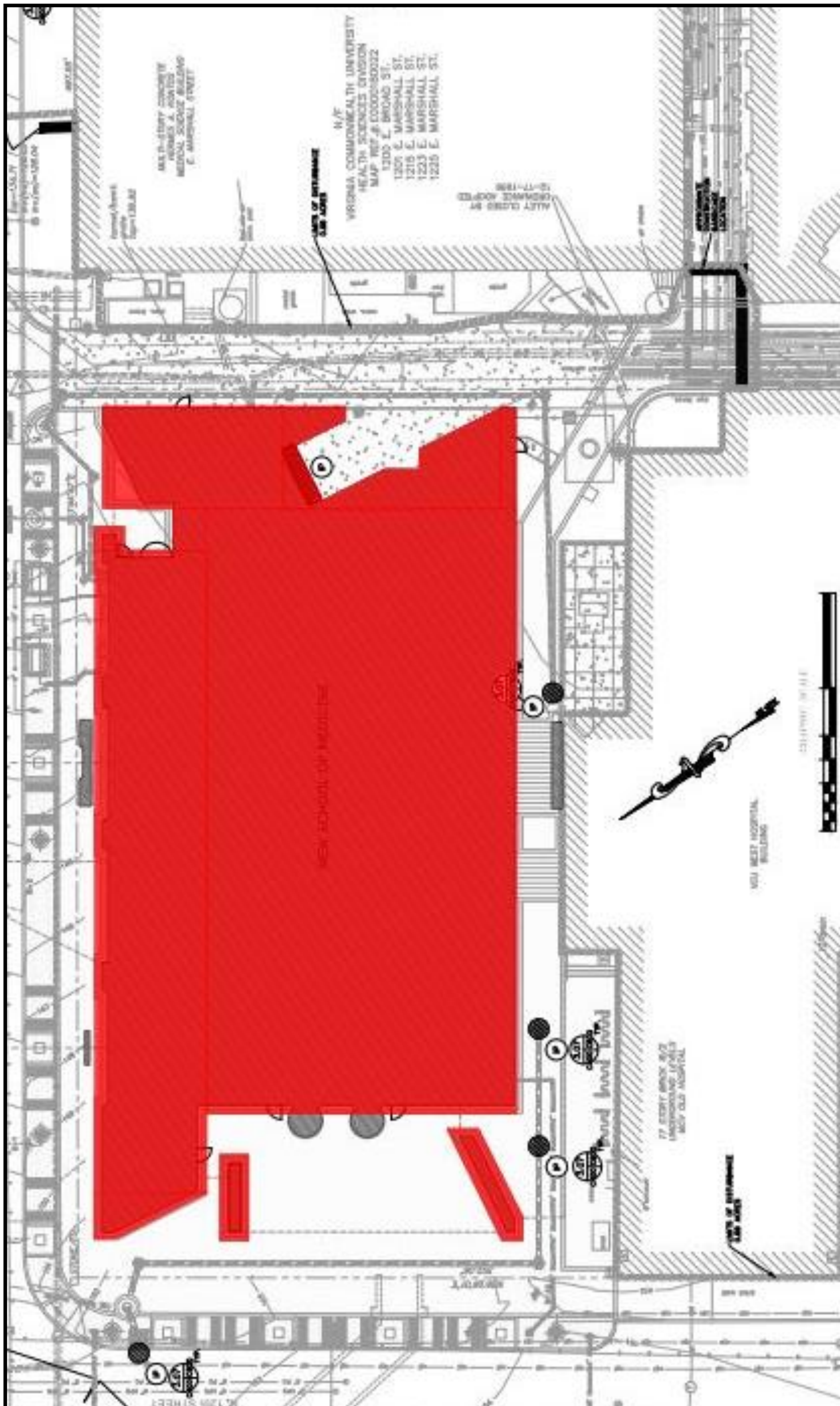
Though it is said that the sum is greater than its parts, the structural apparatuses that compose this project are diverse, complicated systems that must be thoroughly examined to fully appreciate the building. Many challenges exist surrounding the project: the site location, building size, intended function, connection to existing structures, and many more. This report is only the first investigation in to the structure of the James W. & Frances C. McGlothlin Medical Education Center – further analysis and study will be necessary to fully comprehend the magnitude of these systems.

In order to provide background information, floor plans, bays, columns, and other elements from the structure are referenced throughout the report and can be found in the appendices for further examination. State and national codes used in the design of the structure are also cited in the following report; these codes, more specifically loading values, will be utilized in further research and subsequent technical reports.

Location Plan



Site Plan



Reference Documents

In the preparation of the calculations found on the following pages, several documents outside the construction drawings and specifications were referenced. The main source of information was the American Society of Civil Engineers (ASCE) 7-05 code, specifically for both wind and seismic loads. All of the necessary variables, equations, and values needed to calculate the loadings and base shears were found from this document. A document utilized in the calculation of both roof and floor loadings was the Vulcraft Steel Roof and Floor Deck catalog. The American Institute of Steel Construction (AISC) 2005 code was also used for gravity loadings, to estimate size and weight.

Gravity Loads

Live Loads			
Floor/Area	Design (psf)	ASCE 7-05 (psf)	Typical Use
Sub-Basement	250	150	Mechanical†
Loading Dock	350	—	—
Basement	100	100	Offices + Storage
1st	↑	100	Lobby
2nd		60	Assembly (fixed seat)
3rd		60	Assembly (fixed seat)
4th		80	Offices + Corridors
5th		80	Classrooms + Corridors
6th		↑	↑
7th			
8th			
9th		↓	↓
10th		80	Classrooms + Corridors
11th	↓	80	Offices + Corridors
12th	100	80	Offices + Corridors
13th	150	150	Mechanical†
Roof	45	20	Flat Roof

† This value was assumed.

Dead Loads°	
System	Assumed Loads (psf)
Decking	2
Insulation	2
Roofing	20
Misc. DL	10

°No known dead loads were referenced in the contract documents, so values were assumed based on common practice.

Snow Loads		
Area	Design (psf)	ASCE 7-05 (psf)
Ground	20	20
Roof	30 + drift	22*

* Value found with $P_f = 0.7 C_e C_t I P_g$

P_g = ground snow load

C_t = thermal factor

C_e = snow exposure factor

I = snow load importance factor

$P_f = 0.7(0.9)(1.0)(1.1)(20) = 14$ psf

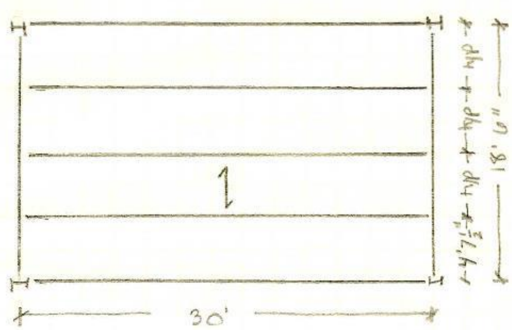
$14 \text{ psf} < 20 \text{ psf}$ ∴ NOT OK

$P_f = I P_g = 1.1(20) = 22$ psf

Gravity Loads (cont.)

• Roof Construction

- Typical Roof Bay



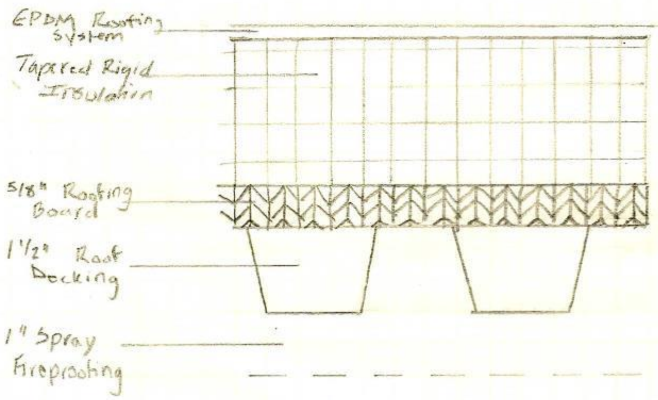
Design: 1 1/2" wide rib galvanized steel deck

LL = 45 psf
DL = 20 (roofing) + 10 (misc. DL) + 2 (insulation) + 2 (decking) = 34 psf
SL = 30 + drift

$1.2DL + 1.6LL + 0.5SL = 1.2(34) + 1.6(45) + 0.5(30) = 128$ psf

clear span ~ 5'0" → using max const. span of 5'10" (> 5' ∴ ok ✓)
assume wide rib — allowable total load = 154 psf > 128 psf ∴ ok ✓
(excellent load carrying capacity)

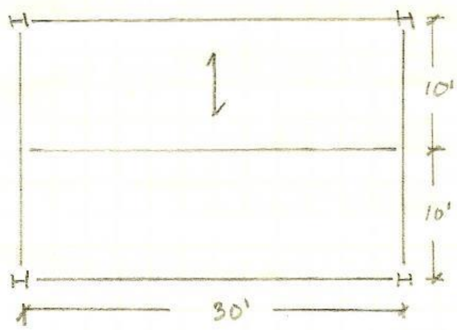
Design: 1 1/2" wide rib ∴ ok ✓
1.46 psf < 2 psf assumed ∴ ok ✓



Gravity Loads (cont.)

• Floor Construction

- Typical Floor Bay → assume 4th Floor



Design: 3", 20 gage decking

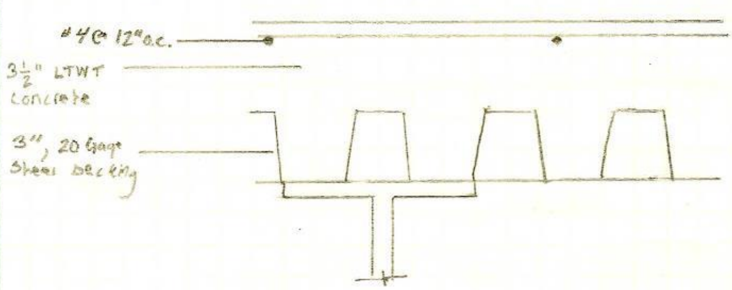
LL = 80 psf
DL = 5 (self wt) + 10 (misc. DL)

1.2 DL + 1.6 LL = 1.2(5 + 10) + 1.6 (80)
= 146 psf

Assume: 2 hr spray fireproofing → ≥ 3 1/4" LTWT conc. topping

t = 3.25 → total slab depth = 6.25
clr span = 10', 2 spans
max span = 12' 10"
3VLI20 decking → 149 psf > 146 psf ∴ ok ✓

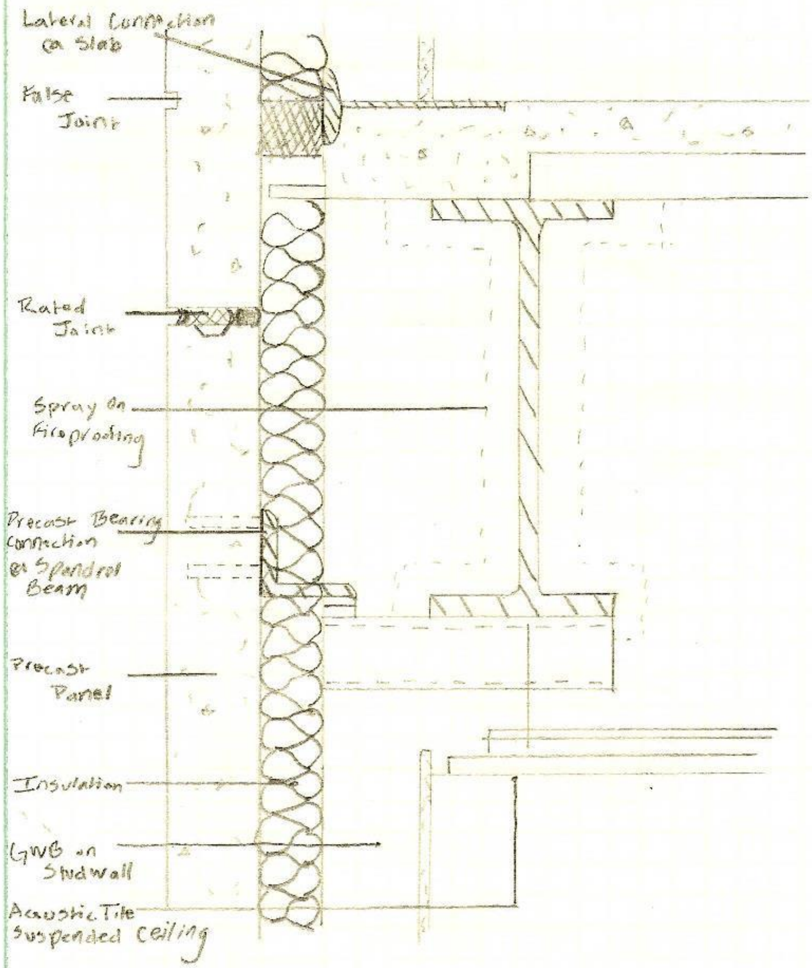
Design: 3", 20 gage + 3 1/4" LTWT conc ∴ ok ✓



Floor Construction Typical to Floors 5-12

Gravity Loads (cont.)

· Exterior Wall Construction



As seen above and noted in the contract drawings, the exterior walls of the building are not load supporting. The curtainwall is composed of concrete precast panels and glass. A typical detail of a precast panel is shown above. The precast panel is connected at the floor slab and base of beam for support.

Gravity Loads (cont.)

· Non-Typical Loads

Floor/Area	Design/Assumption	Justification
Sub-basement	250/150 psf	- 150 psf was assumed based on the following: maintenance, vibration, movement, etc.
Loading Dock	350 psf	- This value was used for design. Due to the high delivery traffic and possibility of heavy point loads, it is better to be conservative.
13th Floor	150 psf	- Once again, 150 psf was assumed, but was also the design value.
Elevators @ Roof	75 psf	- Additional equipment and concrete on metal decking is required in this roughly 15' x 30' area. The value of 75 psf is an estimate based on live loads only, caused by some equipment and light maintenance.

AMPAD

Wind Loads

Variables	Value
Wind Speed (V)	90 mph
Wind Importance Factor (I)	1.15
Wind Exposure	B
Wind Directionality Factor (K_d)	0.85
Topographic Factor (K_{zt})	1.0
Velocity Pressue Exposure Coefficient (K_z)	varies w/ height
Building Category	III
Gust - Effect Factor (G)	0.85
Enclosure Factor	±0.18

$q_s = 0.00256(V)^2 = 0.00256(90)^2 = 20.7$ psf

$q_z = q_s I K_z K_{zt} K_d = (20.7)(1.15)K_{zt}(1.0)(0.85) = (20.23)K_{zt}$

Height Above Ground Level (ft)	K_{zt}	q_z (psf)
0 - 15	0.57	11.5
20	0.62	12.5
25	0.66	13.4
30	0.70	14.2
40	0.76	15.4
50	0.81	16.4
60	0.85	17.2
70	0.89	18.0
80	0.93	18.8
90	0.96	19.4
100	0.99	20.0
120	1.04	21.0
140	1.09	22.1
160	1.13	22.9
180	1.17	23.7
200	1.21*	24.5

Assume: rigid structure, ∴ G = 0.85
ground level is at 154'6" (street level)

Internal Pressures

$p = q_z G C_p = 24.5(0.85)(\pm 0.18) = \pm 4$ psf

Wind Loads (cont.)

Windward Wind Pressures

Level	Height Above Ground Level (ft)	q_z (psf)	p (psf)
Ground	0	11.5	7.82
2nd	14' 8"	11.5	7.82
3rd	29' 4"	14.2	9.66
4th	44' 0"	15.8	10.7
5th	58' 8"	17.1	11.6
6th	73' 4"	18.3	12.4
7th	88' 0"	19.3	13.1
8th	102' 8"	20.1	13.7
9th	117' 4"	20.9	14.2
10th	132' 0"	21.7	14.8
11th	146' 8"	22.4	15.2
12th	161' 4"	22.9	15.5
13th	176' 0"	23.5	16.0
Roof	196' 0"	24.3	16.5
Parapet	200' 8"	24.5	16.7

$G = 0.85$
$C_p = 0.8$
$p = q_z G C_p = 0.68 q_z$

For wind NW-SE
(building sits at an angle to N-S direction)

Side Wall Wind Pressures

$C_p = -0.7$ $\quad q_z = 24.5$ (at parapet)
$G = 0.85$

$p = q_z G C_p = 24.5(0.85)(-0.7) = \boxed{-14.6 \text{ psf}}$

Leeward Wind Pressure

L/B = dimension of building parallel to wind / dimension of building normal to wind
$= 177'/86' \sim 2$

$\therefore C_p = -0.3$
$G = 0.85$
$q_z = 24.5$ (at parapet)

$p = q_z G C_p = 24.5(0.85)(-0.3) = \boxed{-6.25 \text{ psf}}$

Roof Wind Pressure

$h/L = 200'8"/177' \sim 1.13$ and $\theta < 10°$ $\rightarrow h/L = 1.13 > 1.0$

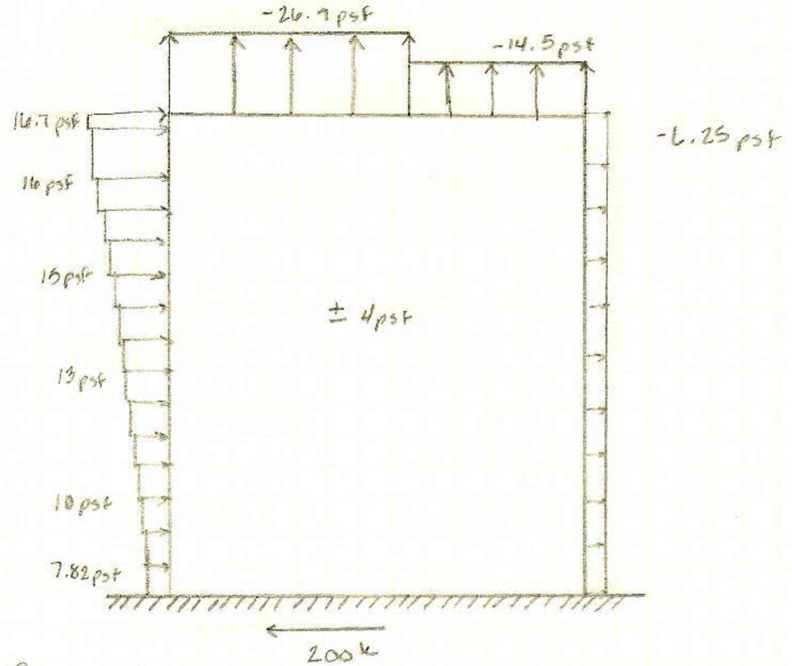
0 to $h/2 \rightarrow C_p = -1.3$
$> h/2 \rightarrow C_p = -0.7$

for 0 to $h/2 = 100'$:
$p = q_{roof} G C_p = 24.3(0.85)(-1.3) = \boxed{-26.9 \text{ psf}}$

for $> 100'$:
$p = 24.3(0.85)(-0.7) = \boxed{-14.5 \text{ psf}}$

Wind Loads (cont.)

For Wind NW-SE (cont.)



Base shear

Floor	Contributing Height (ft)	Length (ft)	Resultant Wind force (kip/ft)	Resultants (k)
2	14' 8"	86'	0.11	9.87
3	↕	↕	0.13	11.03
4			0.15	12.84
5			0.16	14.07
6			0.18	15.14
7			0.19	16.09
8			0.20	16.91
9			0.20	17.60
10			0.21	18.29
11			0.22	18.92
12	14' 8"		0.23	19.37
13	(14'8" + 20')/2		0.27	23.54
Roof	20'/2	86'	0.08	6.88
			Total =	**200k**

Resultant wind force = [(Floor below's force)(Floor below Ht)/2 + (Floor above's force)(Floor above Ht)/2] / 1000

Wind Loads (cont.)

For wind NE-SW

Windward Wind Pressures

- will remain the same values as those found in other direction

Side Wall Wind Pressures

- will remain the same values as those found in other direction

Leeward Wind Pressures

$L/B \approx 86'/177' = 0.5$

$\therefore C_p = -0.5$

$G = 0.85$

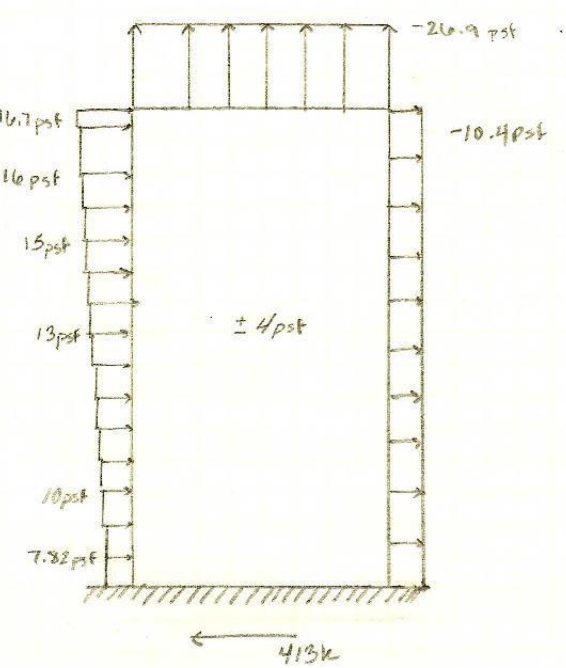
$q_z = 24.5$ (at parapet)

$p = q_z G C_p = 24.5(0.85)(-0.5) = \boxed{-10.4 \text{ psf}}$

Roof Wind Pressure

$h/L = 200'8''/86' \approx 2.33 > 1.0$

- will remain the same values as those found in other direction



Base Shear

- only length changes

L = 177'

using same chart and equations,

total force = $\boxed{413k}$

Seismic Loads

Variable	Value
Occupancy Category	III
Seismic Importance Factor (I)	1.25
Spectral Response Coefficients	
(S_s)	0.215
(S_1)	0.059
Site Class	D
Response Modification Factor	3
Seismic Design Category	B
Resisting System	Braced Frames
Site Coefficients	
(F_a)	1.6
(F_v)	2.4

$S_{MS} = F_a S_s = 1.6(0.215) = 0.344 \longrightarrow S_{DS} = 2/3\ S_{MS} = 2/3\,(0.344) = 0.23$

$S_{M1} = F_v S_1 = 2.4(0.059) = 0.142 \longrightarrow S_{D1} = 2/3\ S_{M1} = 2/3\,(0.142) = 0.095$

$T = C_t h_n^x = (0.028)(196)^{0.8} = 1.9s$

- C_t & x are values based on resisting system

$k = 1 + \frac{T - 0.5}{2} = 1 + \frac{1.9 - 0.5}{2} = 1.7$

$V = \frac{S_{D1}}{T(R/I)} W = \frac{0.095}{1.9(3/1.25)} 28157 = \boxed{587 \text{ kips}}$

Floor	DL (psf)	Weight (kips)	Height (ft)	wh^k	Force (kips)
2nd	150	2283	14' 8"	219,500	1.6
3rd	↑	↑	29' 4"	712,750	5.2
4th			44' 0"	1,420,090	10.4
5th			58' 8"	2,316,400	16.9
6th			73' 4"	3,384,421	24.7
7th			88' 0"	4,614,520	33.7
8th			102' 8"	5,991,360	43.8
9th			117' 4"	7,524,910	55.0
10th			132' 0"	9,193,520	67.2
11th			146' 8"	10,997,300	80.4
12th	↓	↓	161' 4"	12,930,700	94.5
13th	150	2283	176' 0"	14,992,600	110
Roof	50	761	196' 0"	6,000,950	43.9

$W = 28{,}157$ kips

$\Sigma wh^k = 80{,}305{,}200$

$F = \frac{w_i h_i^k}{\Sigma wh^k} V$

Seismic Loads (cont.)