Letter of Transmittal

September 26, 2016

Dr. Aly Said

The Pennsylvania State University

209 Engineering Unit A

University Park, PA 16802

aly.said@engr.psu.edu

Dear Dr. Said,

The attached document contains a detailed analysis of the structural loading conditions for the Brendan Iribe Center for Computer Science and Innovation in College Park, MD.

This report includes a list of references that were used to determine gravity, wind, and seismic loads for the building. A combination of hand calculations and excel spreadsheets were used to perform these calculations.

Thank you for taking time to review this technical report. I look forward to your feedback and discussing where to go from here.

Best Regards,

Brendan Barrett

NOTEBOOK SUBMISSION A

THE BRENDAN IRIBE CENTER FOR COMPUTER SCIENCE AND INNOVATION

COLLEGE PARK, MD

Brendan Barrett

Structural Option

Advisor: Dr. Said

Executive Summary

As one of the world's top computer science institutions, the University of Maryland continues to grow. There is no longer enough room in the existing facilities to keep up with the latest advancements in virtual reality. The Brendan Iribe Center for Computer Science and Innovation will help separate the University of Maryland from its competitors.

Six stories of collaborative classrooms, research labs, seminar rooms, offices, and many common areas will welcome students and faculty alike. A 300-seat auditorium will provide the University of Maryland an opportunity to showcase its latest research such as cybersecurity, computational biology, and quantum computing. The open floor plans will help promote collaborating amongst peers, and ultimately set these students up for successful careers.

Structurally, the Brendan Iribe Center for Computer Science and Innovation utilizes steel wide flange girders and columns to support gravity loads. The curvilinear shape of the building results in unequal bays as infill beams change as the shape of the building changes. Due to the irregular shape, there are several unique components of this system such as curved HSS beams along the southern wall. The 300- seat Antonov Auditorium utilizes wide flange girders and columns, as well as a 90' truss to support the different levels and roof.

From a lateral standpoint, the Brendan Iribe Center for Computer Science and Innovation uses ordinary moment frames and vertical trusses throughout each wing of the building and the auditorium. All loads are in accordance with the 2015 International Building Code and ASCE 7-10.

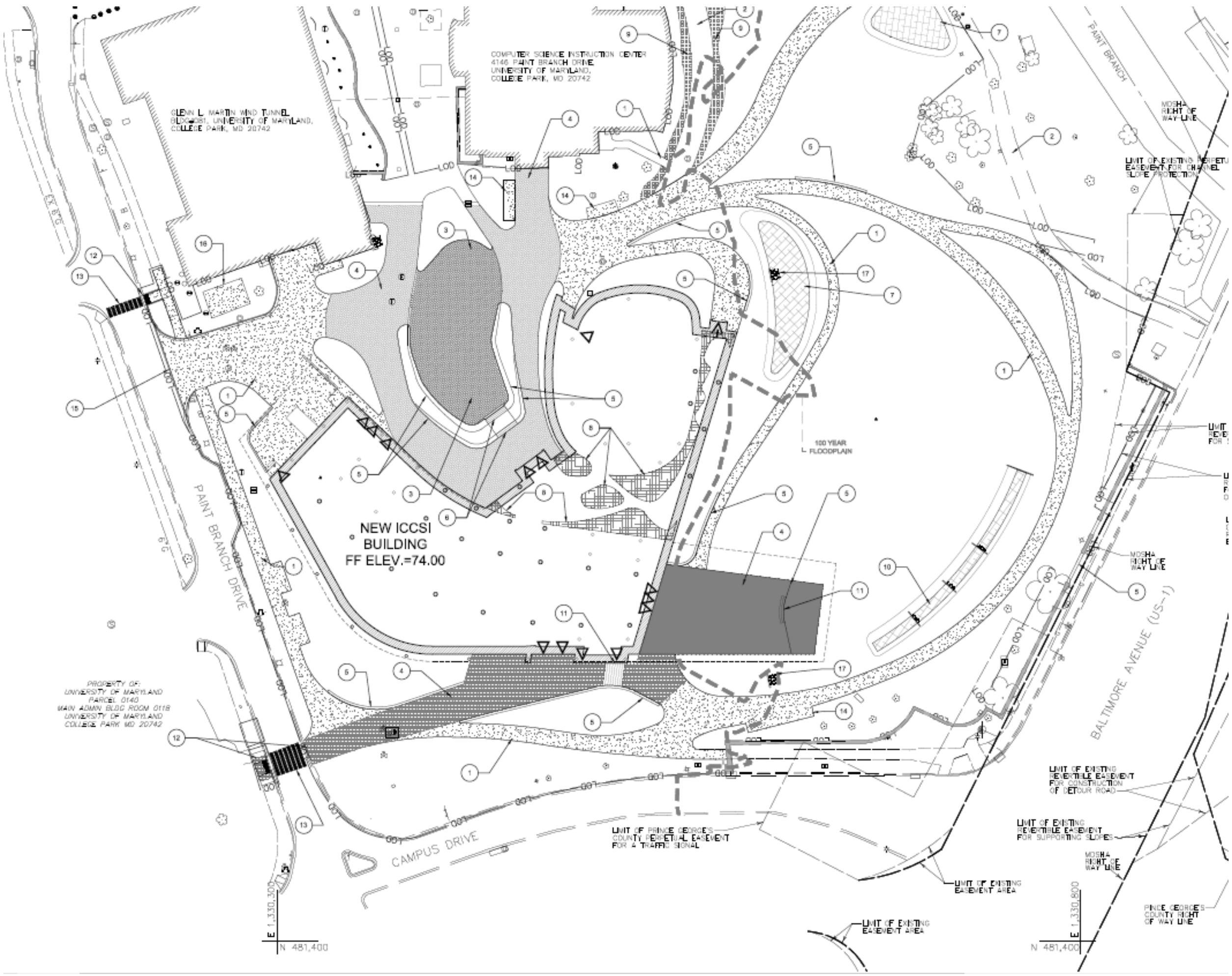
This report will provide gravity and lateral calculations which will be used for further analysis of the building.

Table of Contents

1. General Information

1.1 Site Plan

The Brendan Iribe Center for Computer Science and Innovation is located at the eastern part of campus at the intersection of Baltimore Pike and Campus Drive.



1.2 Documents used in Preparation of Report

The following is a list of codes, standards, and other references that were used for calculations throughout this report.

- Brendan Iribe Center for Computer Science and Innovation
    - Structural Drawings
- International Code Council
    - 2015 International Building Code
- American Society of Civil Engineers
    - ASCE 7-10: Minimum Design Loads for Buildings and Other Structures

2. Gravity Loads

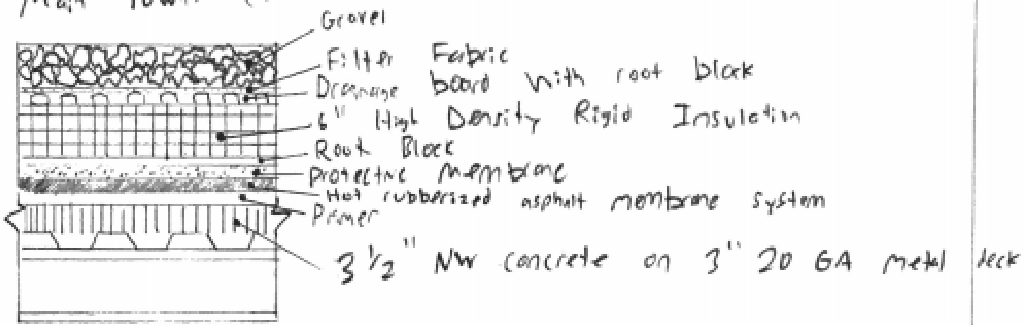
2.1 Roof Loads

See Appendix A to view bay used in determination of gravity loads

Brendan Barrett | Gravity Loads

Roof Loads

Main Tower (Area A + B) Ground Floor to 6th Floor



Dead Loads

Gravel = 6 PSF

Filter Fabric = Negligible

Drainage Board with root block = 3 PSF

6" High Density Rigid Insulation = 0.75 per 1/2" = 9 PSF

Root Block = 2 PSF

Protective Membrane = 1 PSF

Hot rubberized asphalt Membrane system = 1 PSF

Primer = 1 PSF

Roof Deck = 65 PSF

M/E/C/L = 10 PSF

Soil (Green roof) = 40 PSF

Framing = 84 PLF(40.67') + 33 PLF(40') + 68 PLF(39.75') + 76 PLF(39.5') + 84 PLF(39.75') + 90 PLF(39.75') + 99 PLF(38') = 21120 lb/1386 SF = 16 PSF

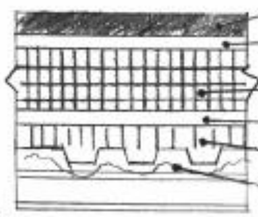
Total Dead = 154 PSF

Live Load

L_R = 30 PSF * Minimum L_R is 20 PSF

Brendan Barrett | Gravity Loads

Auditorium (Area C)



Dead Loads

Metal Panel over ice and water shield = 1 PSF

Overlayment board = 0.75 PSF

High Density Rigid Insulation: 9 PSF

Underlayment board: 0.75 PSF

Roof Deck = 2 PSF

Spray Foam Insulation = 1 PSF

M/E/C/L = 10 PSF

Framing: 22 PLF (32')(3) + 30 PLF (32') + 26 PLF (32')
+ 19 PLF (16.5') + 120 PLF (16.5')
= 6200 lb / 530 SF = 12 PSF

Total Dead = 36.5 PSF

Live Load

L_R = 30 PSF   * Minimum L_R is 20 PSF

2.2 Snow Loads

Brendan Barrett	Gravity Loads

Snow Loads

Ground Snow load $p_g = 35$ PSF (Figure 7-1)

$p_f = 0.7 C_e C_t I_s p_g$

$C_e = 0.9$ (Terrain Cat B, Fully exposed)

$C_t = 1.0$ (All Structures)

$I_s = 1.1$ (Risk Category III)

$p_f = 0.7(0.9)(1.0)(1.1)(35)$

$= 24.26$ PSF + Unbalanced, drifting, and sliding

Drift at rooftop garden:

- Leeward drift → $\ell_u = 265'$

$h_d = 0.43 \sqrt[3]{\ell_u} \sqrt[4]{p_g + 10} - 1.5$

$= 0.43 \sqrt[3]{265} \sqrt[4]{35 + 10} - 1.5$

$= 5.66$ ft

$\gamma = 0.13 p_g + 14$

$= 0.13(35) + 14$

$= 18.6$ pcf

$h_b = 24.26 \text{ psf} / 18.6 \text{ pcf} = 1.3'$ ⇒ flat roof height

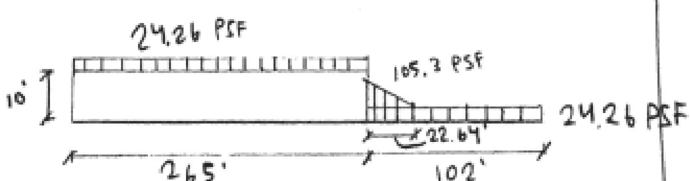
$h_c = 10' - 1.3' = 8.7'$ $\frac{h_c}{h_b} = \frac{8.7}{1.3} = 6.7 > 0.2$ ∴ drift

$h_d < h_c$ → $w = 4 h_d = 4(5.66) = 22.64'$

$p_d = h_d \gamma$

$= 5.66(18.6)$

$= 105.3$ PSF



Brendan Barrett	Gravity Loads

Drift from Tower onto auditorium:

Leeward drift -> $\ell_u = 58'$

$h_d = 0.43\sqrt[3]{58}\sqrt[4]{35+10} - 1.5$

$= 2.81$ ft.

$\gamma = 18.6$ pcf

$h_b = 1.3'$

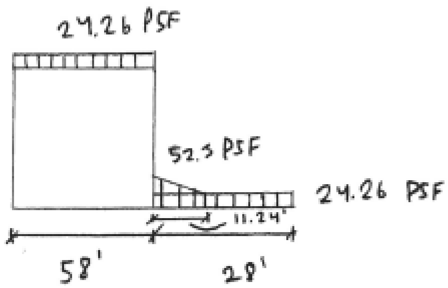
$h_c = 68' - 1.3' = 66.7'$

$h_d < h_c$ -> $w = 4h_d = 4(2.81) = 11.24'$

$p_d = h_d \gamma$

$= (2.81)(18.6)$

$= 52.3$ PSF

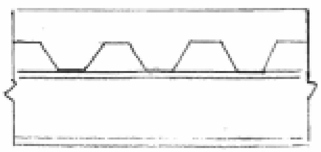


2.3 Floor Loads

Brendan Barrett | Gravity Loads

Floor Loads

Typical Floor (Ground Floor to 6th Floor)



3 1/4" LW Concrete
3" 20 GA Galvanized deck

Dead Load:

Beams = 84 PLF (43.167') + 76 PLF (42.75') + 68 PLF (42.67') + 76 PLF (42.58')
+ 76 PLF (42.67) = 16256

Girders = 116 PLF (38.33') + 84 PLF (31.58')
= 7100 lbs

Framing = (16256 + 7100) lbs / 1600 SF = 14.6 PSF ≈ 15 PSF

Slab = 46 PSF

Metal Deck = 2 PSF

M/E/C/L = 10 PSF

Total Dead = 73 PSF

Live Load: (Table 4-1)

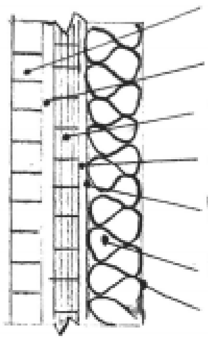
L_o = 100 PSF (Corridors)

* Minimum L_R is 100 PSF

2.4 Perimeter Loads

Brendan Barrett	Gravity Loads

Exterior Wall at Auditorium



Dead Load:

Steel Manual — 4" Brick = 40 PSF

ASCE 7-10 — 3" Polystyrene Insulation = 0.2 PSF/1" = 0.6 PSF

ASCE 7-10 — 5/8" Glass Fiber Gypsum Board = 0.55 PSF/1/8" = 0.55(5) = 2.75 PSF

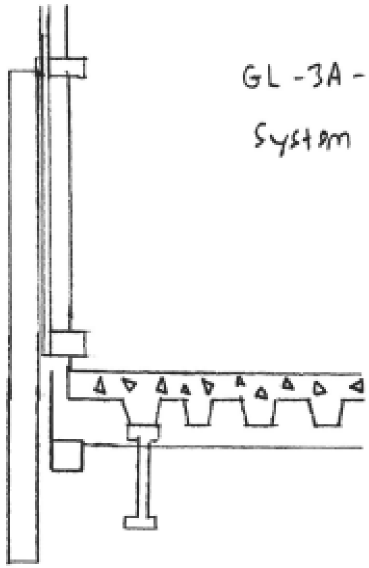
R-25 Batt Insulation = 0.04 PSF/1" = 0.04(8) = 0.32 PSF

Steel Manual — 8" CFMF = 1 PSF

Total = 45 PSF × 29'-10 3/4" = 1345 PLF

Brendan Barrett | Gravity Loads

Exterior Wall at North Facade



GL-3A - Monolithic Glass Fins in Curtain Wall System w/ Frit Pattern

Dead Load = 15 PSF × 98' = 1470 PLF

2.5 Non-Typical Loads

Brendan Barrett | Gravity Loads

Non-Typical Loads

Penthouse (Area A and B)

- Dead Load = 103 PSF
  - -> larger than typical floor due to additional 3/4" of concrete (4 1/2" NW concrete on 3" metal deck)
- Live Load = 150 PSF
  - -> larger than typical floor due to mechanical equipment

Terrace (Area C)

- Dead Load = 288 PSF
  - -> increase due to green roof
- Live Load = 100 PSF
  - -> Corridors

3. Wind Loads

See Appendix B for determination of wind load direction

Brendan Barrett | Wind Loads

Wind Loads

Step 1: Risk Category III (Table 1.5-1)

Step 2: V = 120 mph (Figure 26.5-1B)

Step 3: $K_d = 0.85$ (Table 26.6-1)

Exposure Category B (Section 26.7)

$K_{zt} = 1.0$ -> no escarpment (Section 26.8)

Gust Effect Factor Calculation:

Natural Frequency: $n_a = \frac{22.2}{h^{0.8}} = \frac{22.2}{118.67^{0.8}} = 0.49 < 1.0$ ∴ G needs to be calculated

Iz calculation

c	0.3
z bar	71.202
Iz	0.2639

g_r calculation

g_r	4.013938

Q calculation

l	245
z bar	71.202
ε	0.333333
L_z bar	316.5863
B	380
h	118.67
Q	0.737452

R calculation

α bar	0.25
b bar	0.45
V_z	95.98862
β	0.015
B	380
L	245
h	118.67
N_1	1.604
R_n	0.101
η_h	2.765
R_h	0.296
η_B	8.855
R_B	0.107
η_L	19.114
R_L	0.051
R	0.344

$$G_f = 0.925\left(\frac{1 + 1.7 I_{\bar{z}} \sqrt{g_Q^2 + Q^2 + g_R^2 R^2}}{1 + 1.7 g_v I_{\bar{z}}}\right)$$

$= 0.837$

Enclosure Classification: Enclosed Building (Section 26.10)

Internal Pressure Coefficient: +/- 0.18

Brendan Barrett | Wind Loads

Step 4: Velocity Pressure Exposure Coefficient (Table 27.3-1)

K_z at h: 118.67'

Height	Exposure B K_z
100	0.99
118.67	**1.037**
120	1.04

Step 5: Velocity Pressure (Eqn 27.3-1)

Story	Height z (ft)	Story Height (ft)	Kz	Kd	Kzt	qz (psf)
Ground	0	25.5	0.57	0.85	1	**17.9**
1	25.5	14.67	0.664	0.85	1	**20.8**
2	40.17	14.67	0.76085	0.85	1	**23.8**
3	54.84	14.67	0.82936	0.85	1	**26.0**
4	69.51	14.67	0.88804	0.85	1	**27.8**
5	84.18	14.67	0.94254	0.85	1	**29.5**
Penthouse	98.85	19.83	0.98655	0.85	1	**30.9**
Roof	118.67		1.036675	0.85	1	**32.5**

Step 6: External Pressure Coefficient

Wall Pressure Coefficients:

$C_{p\,winward} = 0.8$

$L/B = 245/380 = 0.65 \; {>0 \atop <1} \rightarrow C_{p\,leeward} = -0.5$

$C_{p\,sidewall} = -0.7$

Brendan Barrett | Wind Loads

Roof Pressure Coefficients

$h/L = 0.48$

0 to h/2 -> 0 - 59.3' -> $C_p = -0.9$

h/2 to h -> 59.3' - 118.67' -> $C_p = -0.9$

h to 2h -> 118.67' - 237.34' -> $C_p = -0.5$

> 2h -> >237.34' -> $C_p = -0.3$

Step 7: Wind Pressure

North-South Direction L = 245' B = 380'

$p = q_z G_f C_p$

	z (ft)	q_z (psf)	$P_{windward}$	$P_{leeward}$	P_{roof}	Trib Height	Trib Weight	Story Force
Ground	0	17.86	11.95	-13.59		12.75	245	79.79
1	25.5	20.81	13.93	-13.59		20.085	245	135.39
2	40.17	23.84	15.96	-13.59		14.67	245	106.19
3	54.84	25.99	17.39	-13.59		14.67	245	111.35
4	69.51	27.83	18.62	-13.59		14.67	245	115.78
5	84.18	29.53	19.77	-13.59		14.67	245	119.88
Penthouse	98.85	30.91	20.69	-13.59		17.25	245	144.87
Roof (0'-59.3')	118.67	32.48	21.75	↓	-24.459	9.915	245	
Roof (59.3-118.67')	118.67	32.48	↓	↓	-24.459	9.915	245	
Roof (118.67-237.34')	118.67	32.48	↓	↓	-13.588	9.915	245	
Roof (> 237.34')	118.67	32.48	↓	↓	-8.153	9.915	245	
							Base Shear	813.25

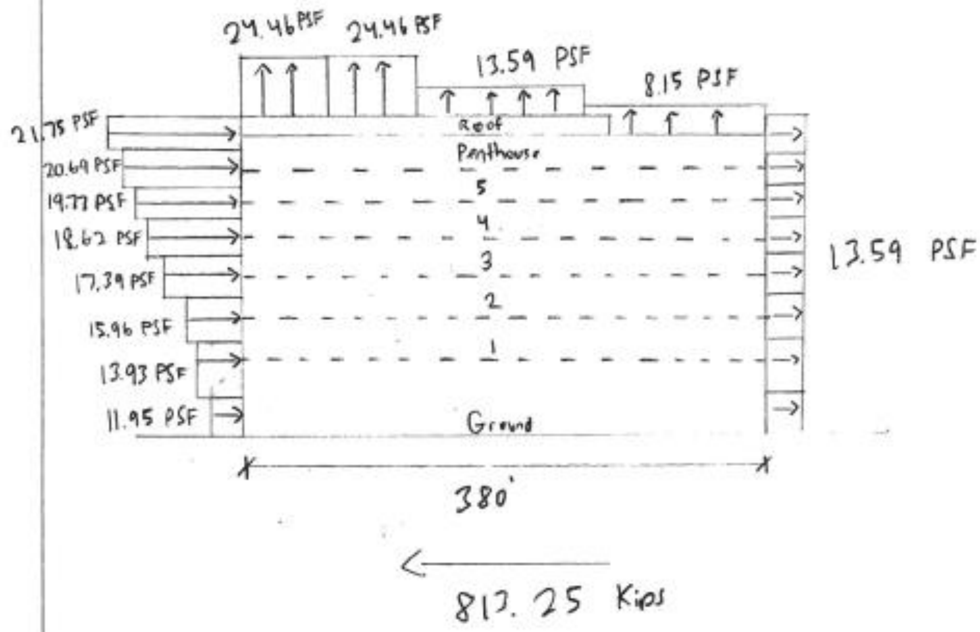
East-West Direction L = 380' B = 245'

* same calculations as N-S direction except $G_f = 0.88$

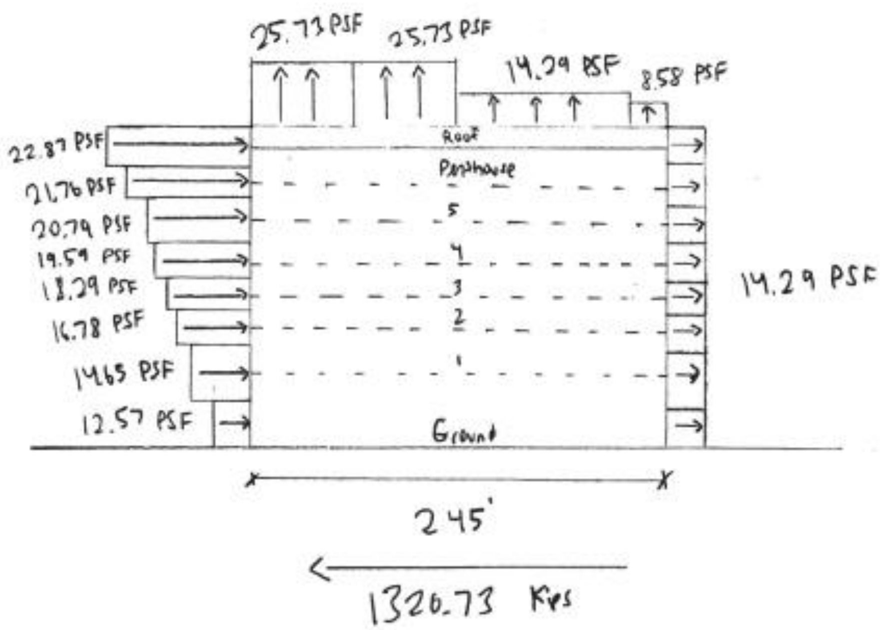
	z (ft)	q_z (psf)	$P_{windward}$	$P_{leeward}$	P_{roof}	Trib Height	Trib Weight	Story Force
Ground	0	17.86	12.57	-14.29		12.75	380	130.17
1	25.5	20.81	14.65	-14.29		20.085	380	220.87
2	40.17	23.84	16.78	-14.29		14.67	380	173.24
3	54.84	25.99	18.29	-14.29		14.67	380	181.66
4	69.51	27.83	19.59	-14.29		14.67	380	188.88
5	84.18	29.53	20.79	-14.29		14.67	380	195.58
Penthouse	98.85	30.91	21.76	-14.29		17.25	380	236.34
Roof (0'-59.3')	118.67	32.48	22.87	↓	-25.726	9.915	380	
Roof (59.3-118.67')	118.67	32.48	↓	↓	-25.726	9.915	380	
Roof (118.67-237.34')	118.67	32.48	↓	↓	-14.292	9.915	380	
Roof (> 237.34')	118.67	32.48	↓	↓	-8.575	9.915	380	
							Base Shear	1326.73

Brendan Barrett | Wind Loads

North-South Direction



East - West Direction



4. Seismic Loads

Brendan Barrett | Seismic Loads

Seismic Loads

Structure Non-exempt (Section 11.1.2)

Site Class D (Sheet S-001)

$S_s = 0.119\,g$ $S_{MS} = 0.190\,g$ $S_{DS} = 0.127g$ } USGS
$S_1 = 0.051\,g$ $S_{M1} = 0.122\,g$ $S_{D1} = 0.081\,g$

Seismic Design Category B (Section 11.6)
Risk Category III

Equivalent Lateral Force Analysis Permitted (Section 12.6)

Ordinary Braced Frame -> $R = 3$ (B-12) } Table 12.2-1
Ordinary Moment Frame -> $R = 3\frac{1}{2}$ (C-4)

∴ use smaller R value -> $R = 3$
$\Omega_0 = 2$
$C_d = 3$

Seismic Importance Factor = 1.25 (Table 1.5-2)
Risk Category III

Fundamental Period

$T_a = C_t h_n^x$

where $C_t = 0.02$
$x = 0.75$
$h_n = 139'$

$T_a = 0.02(139)^{0.75} = 0.815$

$T_L = 8$ sec (Figure 22-12)

Brendan Barrett | Seismic Loads

$$C_s = \frac{S_{DS}}{R/I_e} = \frac{0.127}{3/1.25} = 0.53 \geq \frac{S_{D1}}{T\left(\frac{R}{I_e}\right)} = \frac{0.081}{0.81\left(\frac{3}{1.25}\right)} = 0.04$$

$$C_s = 0.044\, S_{DS} I_e = 0.044(0.127)(1.25) = 0.007 \leq C_s = 0.053$$

..OK

Total Seismic Weight (Section 12.7-2)

Area A & B

Level	Story Height (ft)	Area (ft²)	Perimeter (ft)	Total Dead Load (PSF)	Exterior Wall Load (PSF)	Story Weight W (kips)
Ground	25.5	32300	921.25	73	15	2710.28
1st	14.67	32300	921.25	73	15	2560.62
2nd	14.67	32300	921.25	73	15	2560.62
3rd	14.67	32300	921.25	73	15	2560.62
4th	14.67	32300	921.25	73	15	2560.62
5th	14.67	32300	921.25	73	15	2560.62
Penthouse	19.83	32300	921.25	103	15	3600.93
Roof		32300	921.25	154	0	4974.20
					Total	24088.51

Area C

Level	Story Height (ft)	Area (ft²)	Perimeter (ft)	Total Dead Load (PSF)	Exterior Wall Load (PSF)	Story Weight W (kips)
Ground	25.5	14511	535.33	73	45	1673.59
1st	14.67	14511	535.33	73	45	1412.70
Roof		14511	535.33	36.5	45	529.65
					Total	3615.95

Total Seismic Weight (kips)	27704.46

Seismic Base Shear:

$V = C_s W$ (Section 12.8)

$= 0.053(27{,}704.46)$

$= 1468.34$ kips

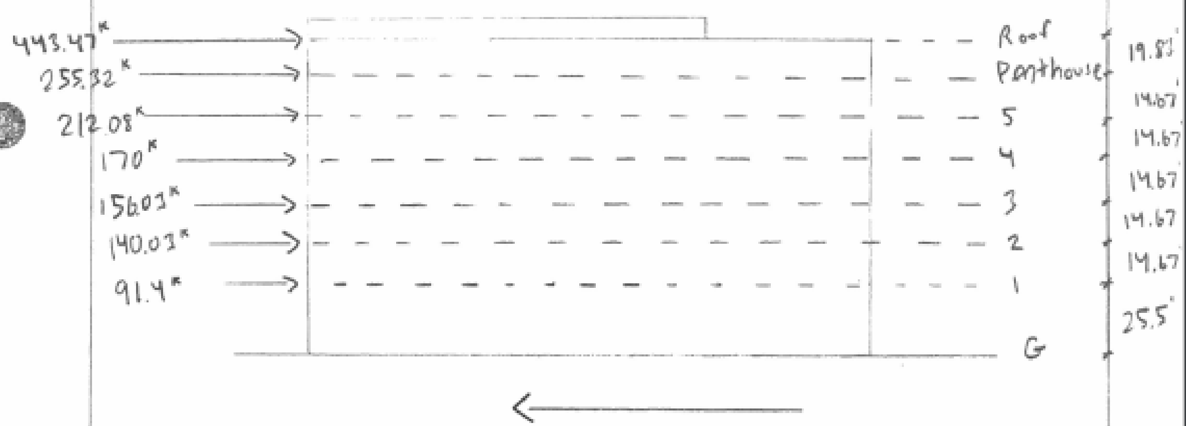
Vertical Distribution of Forces: (Section 12.8.3)

$$C_{vx} = \frac{w_x h_x^{\,k}}{\sum_{i=1}^{n} w_i h_i^{\,k}}$$

$T_a = 0.81 \rightarrow k = 1.155$ interpolating b/w 1 and 2

Brendan Barrett | Seismic Loads

Level	h_x	W_x	h_x^k	$W_x h_x^k$	C_{vx}	F_x	V_x
Ground	25.5	4383.87	42.13	184676.57	0.06	91.40	1468.34
1st	40.17	3973.32	71.20	282917.88	0.10	140.03	1376.93
2nd	54.84	3090.27	102.01	315249.45	0.11	156.03	1236.91
3rd	69.51	2560.62	134.14	343486.70	0.12	170.00	1080.88
4th	84.18	2560.62	167.35	428510.65	0.14	212.08	910.88
5th	98.85	2560.62	201.46	515873.68	0.17	255.32	698.79
Penthouse	118.68	3600.93	248.83	896025.21	0.30	443.47	443.47
Roof		4974.20	0.00	0.00	0.00	0.00	0.00
Total		27704.46		2966740.15	1.00	1468.34	

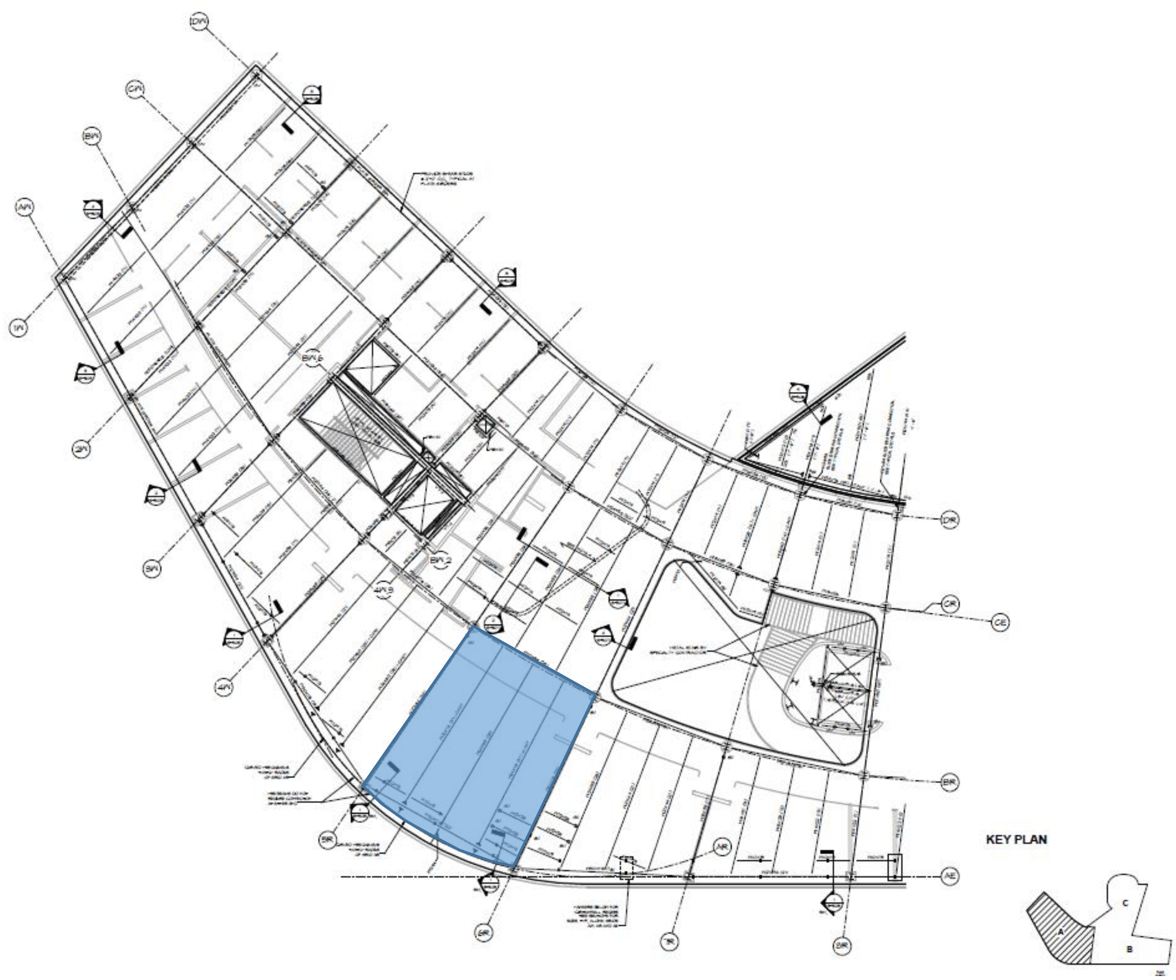


V = 1468.34 kips

* Seismic Base Shear is the same in both directions

Appendix A

The highlighted bay was used for determination of gravity loads at a typical floor and the roof. This bay was used because it has the largest spans throughout the building, which results in a higher dead load and is thus more conservative.



Appendix B

This diagram shows the orientation of the direction that the wind load was applied. Due to the irregular shape of the building, the buildings largest dimensions were used to yield a more conservative analysis.