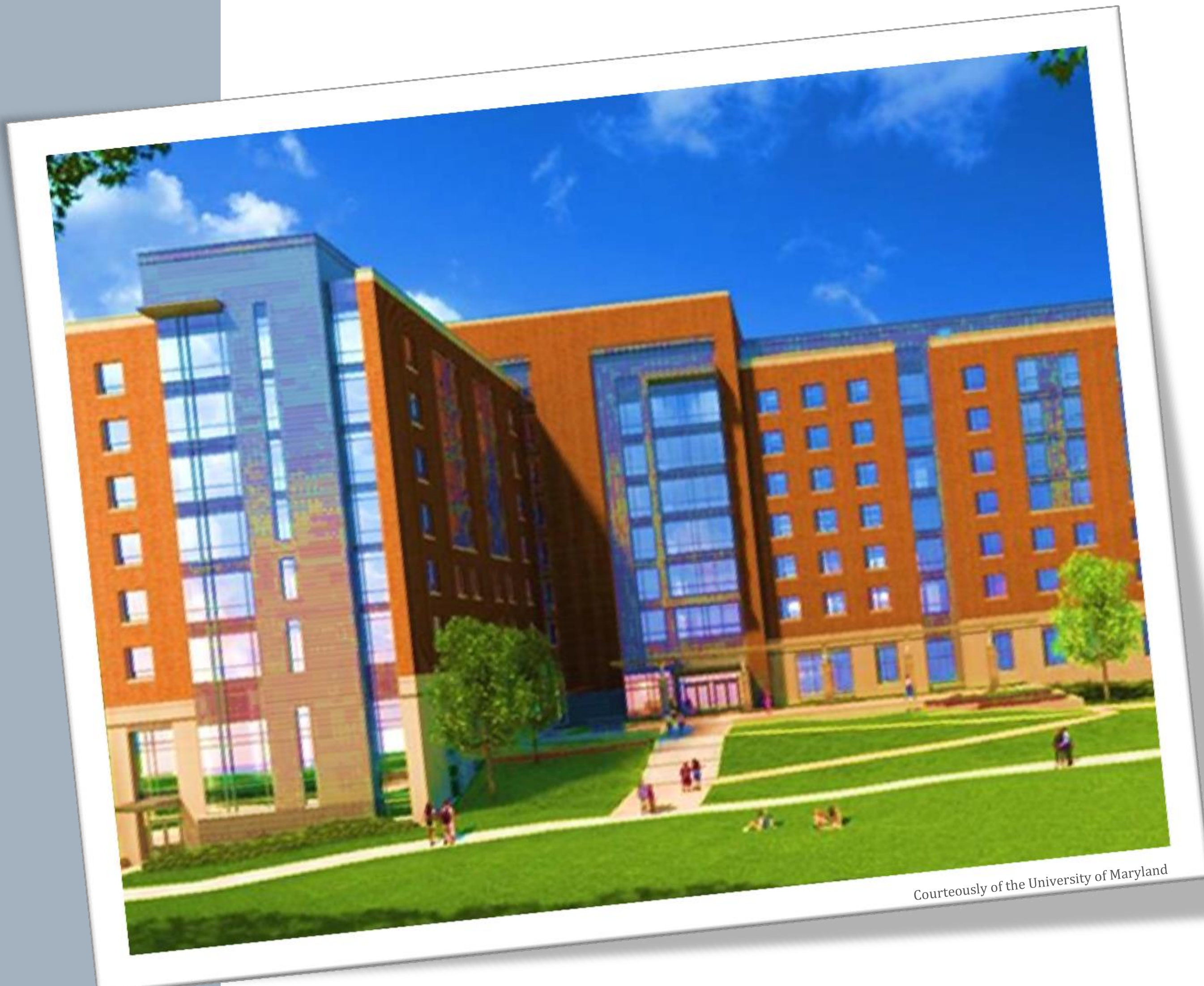
Lateral System Analysis Study



Prince Frederick Hall

The University of Maryland

College Park, MD

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AE Senior Thesis- Structural

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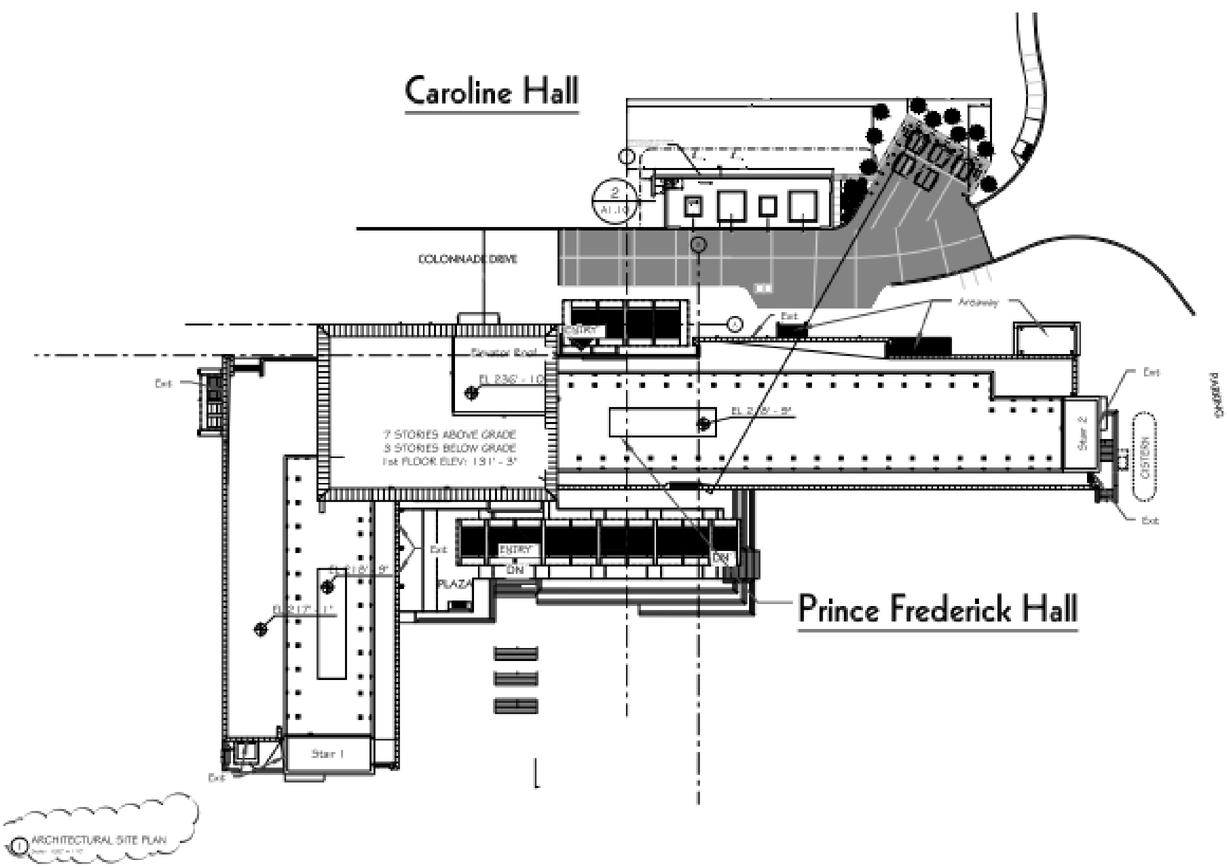
Table of Contents

Executive Summary

The purpose of this technical report is to establish an understanding of Prince Frederick Hall's structural and existing features. Prince Frederick Hall is nestled at the heart of The University of Maryland's campus and is a multi-use dormitory building consisting of living and office spaces. This document provides an overview of all the structural components designed by Cagley & Associates Inc. including general floor framing, structural slabs, shear wall, and the foundation system. Integration of all structural components is explained and elaborated upon. The pictures and images (unless otherwise noted) are the property of The University of Maryland and WDG Architecture PLLC and are being used solely for educational purposes.

Site Plan and Location of Building



LIST OF DOCUMENTS USED

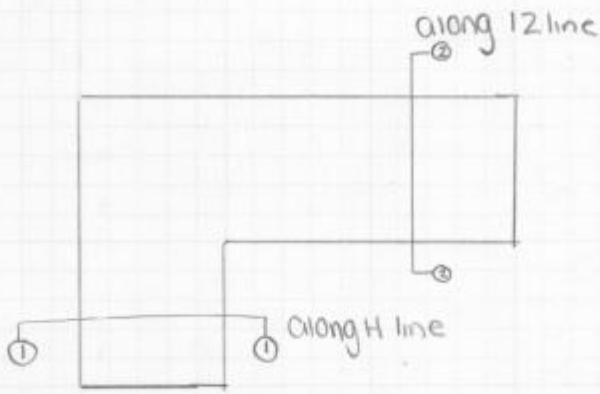
Documents and Programs Used for Analysis and Design

- ASCE 7-08
- ACI 318-08
- AISC 14th Edition
- ETABS 2013
- Reinforced Concrete Mechanics and Design 6th edition, Wright

GRAVITY LOAD calculations

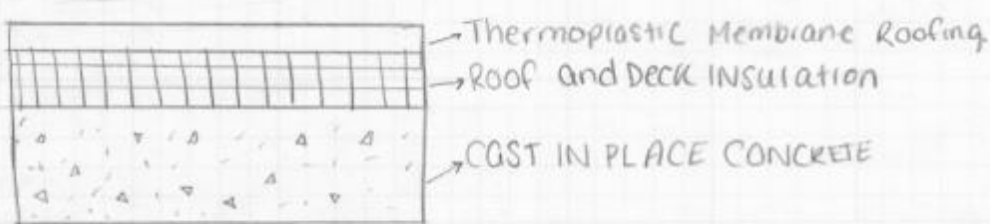
Roof Design (LOADS)

see page B of APPENDIX for detailed roof plan
C for section cuts
D for roof materials



ROOF Plan OUTLINE

TYPICAL CUT 1.



deadload of roofing (AISC 4th edition pg 17-26

material	weight psf
plastic Membrane	1
deck insulation	2
Mechanical	8 (MEP from ceiling below)

≈ 10 psf

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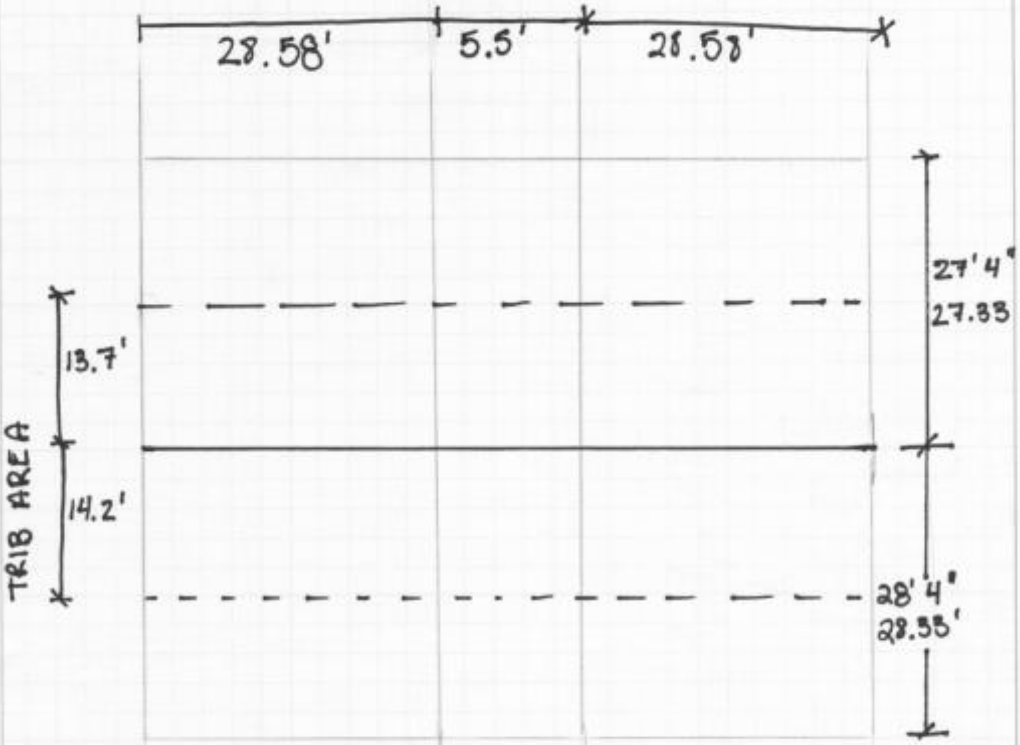
dead load roof = 10 psf [STRUCTURAL NOTES S.1.00]

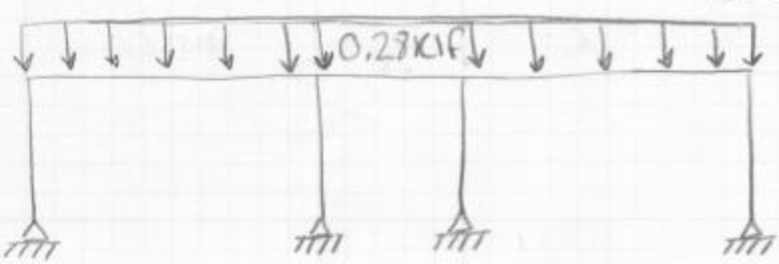
plan view



in feet

$(13.7 + 14.2)(10\,psf) = 279\ \frac{ft\,lb}{ft^2} = 279\,plf$

$= 0.28\,klf$



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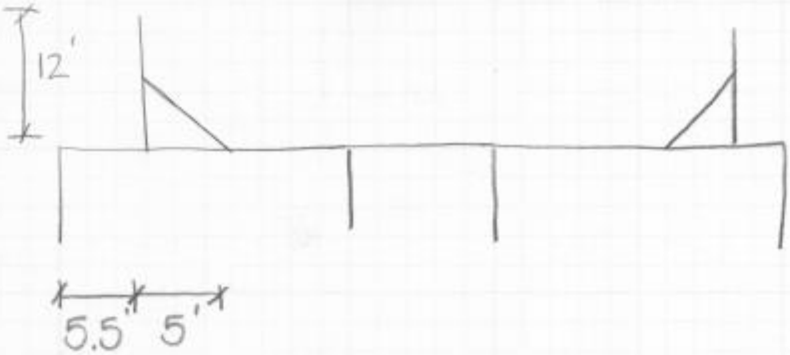
Roof Screen Dead Load Approximation:

see appendix E for roof screen details

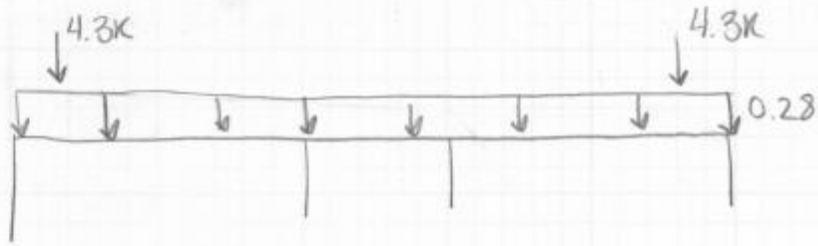


metal decking is about 3psf

$(3psf)(12ft) = 36plf = 0.36klf$

each support is about 6' apart.

$(0.36)(1\ \ ) = 4.3K$



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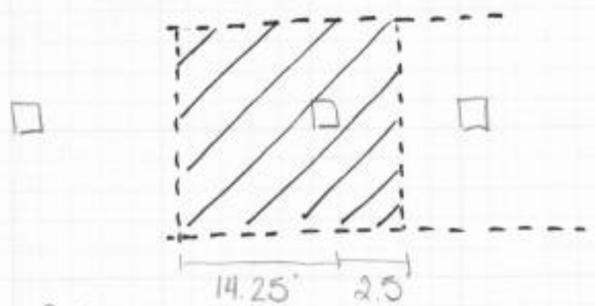
<u>live load Design</u>:

live load on roof (ASCE 7-05 § 4.9.1)

max loads

$$L_r = L_o(R_1)(R_2) \quad \text{where} \quad 12 \le L_r \le 20$$

L_o - table 4-1 L_o = 20psf (flat roof)



either of these

A_T → max trib area for a column on line H

$A_T = (27.9)(17) = 474.3 ft^2$

see Appendix E for R1 equation

$R_1 = 1.2 - 0.001 A_T$

$R_1 = 1.2 - 0.001(474.3)$

$R_1 = 0.73$

F is # of inches of rise per foot.

8" min slab deck to 14" max slab deck at a typ span goes for 14.35'

$$\frac{\text{rise}}{\text{span}} = \frac{0.5'}{14.35'} \times 32 = 1.1$$

$R_2 = 1.0$ $\qquad F \le 4.0$ due to minimal slope

$L_r = 20(0.73)(1.0)$

$L_r = 14.6$ psf

L_r + 10psf for workers = 24.6psf

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GRAVITY LOADS

CHRISTOPHER CIOFFI | gravity loads | 9/27

IN STRUCTURAL NOTES S1.00 Roof live load
-30psf min (ponding or snow load is used when greater than 30psf)

-design with 30psf

$$\underbrace{(13.7 + 14.2)}_{\text{feet}}(30\,\text{psf}) = 837\,\text{psf}$$

$$\boxed{= 0.837\,\text{klf}}$$

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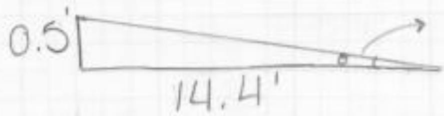
Christopher Cioffi	Gravity Loads	Structural thesis	9/27

Roof Snow loads:



$\tan\theta = \frac{0.5}{14.4}$

$\theta < 5° \rightarrow$ flat roof snow load.

→ Found that roof is flat from S1.00 of structural notes

See appendix F.

snow load P_f (calculated in psf).

$$P_f = 0.7\, C_e C_t I P_g \qquad \text{(eq 7-1)}$$

see appendix F for the following equations/ ASCE 7 tables.

P_g - ground snow load (table 7-1 ASCE 7) = 30

$P_g > 20\ \text{lb/ft}^2 \longrightarrow P_f = 20I$

C_e - exposure factor (table 7-2 ASCE7) = 1.0

C_t - thermal factor (table 7-3 ASCE7).

$C_t = 1.0$

I - importance factor (table 7-4 ASCE7) = 1.0

Balanced load assumption

$P_f = 0.7\, C_e C_t I P_g$

$P_f = 0.7(1.0)(1.0)(1.0)(30)$

$\boxed{P_f = 21\ \text{lbs/ft}^2}$

min value

$P_f = 20(I)$

$= 20(1.0)$

$= 20\ \text{lbs/ft}^2$

snow load sect 1 = (13.7 + 14.2)(21) = 0.59 klf

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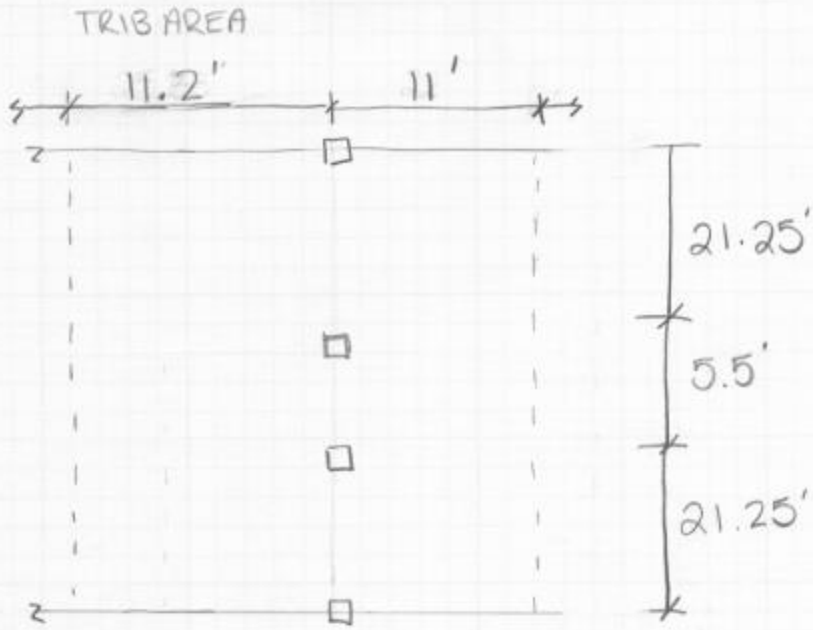
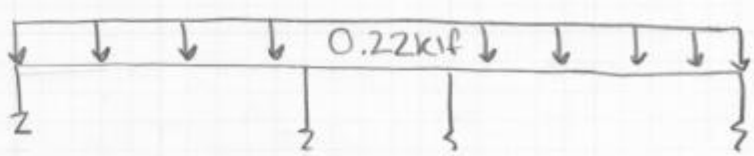
Section 2



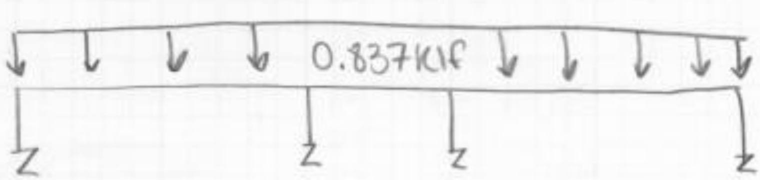
dead load roof

(11.2 + 11)(10psf) = 222 plf
= 0.22 klf

ft



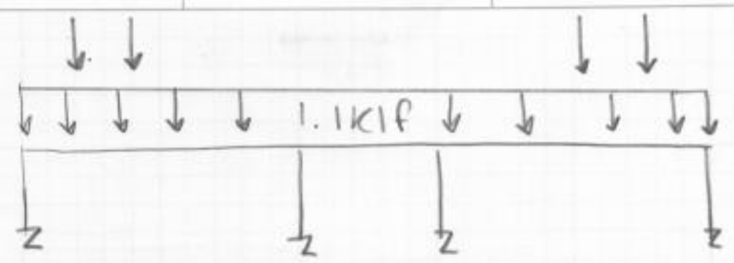
live load roof = 0.837 klf



live load will be the same as the other section
The greater area will control.

GRAVITY LOADS

CHRISTOPHER CIOFFI | Gravity Loads | Structural thesis | 9/27



$T_L = 0.22\,klf + 0.837\,klf = 1.1\,klf$

<u>Snow load on roof:</u>

$(11.2 + 11)(21\,psf) = 466.2\,plf$

$(11.2 + 11)$ feet

$= 0.47\,klf$

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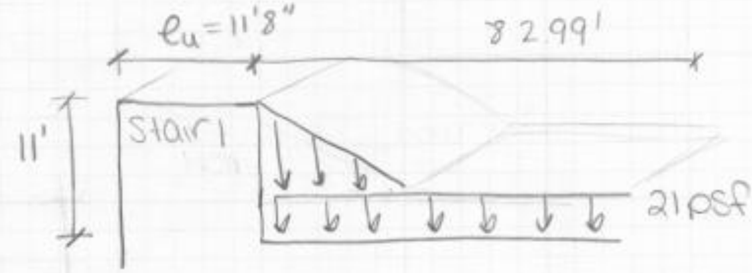
Snow Drift on Roof:



82.99 ≥ 15'
drift required

$C_e = 1.0$ table 7-2
$C_t = 1.0$ table 7-3
$C_s = 1.0$
$I_s = 1.0$ table 7-4

flat roof snow load $P_f = 21$ psf
snow density γ =

$\gamma = 0.13P_g + 14 \leq$ ground snow load

$P_f = 0.7\, C_e C_t I_s P_g$

$21 = 0.7(P_g)$

$\boxed{P_g = 30}$

$\gamma = 0.13(30) + 14 = 17.9$

$P_s = C_s P_f$
$1.0(21)$
$= 21$ psf

$h_b = P_s/\gamma = 21/17.9 = 1.17'$

$\frac{h_c}{h_b} \geq 0.2 \quad \frac{11'}{1.17} > 0.2$ yes

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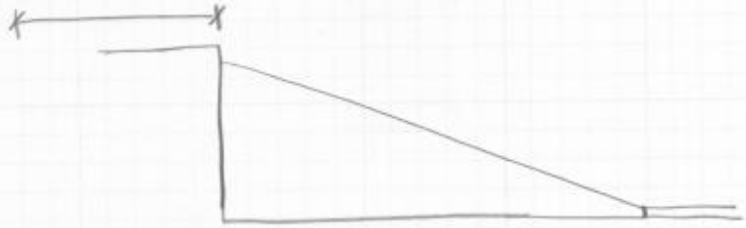
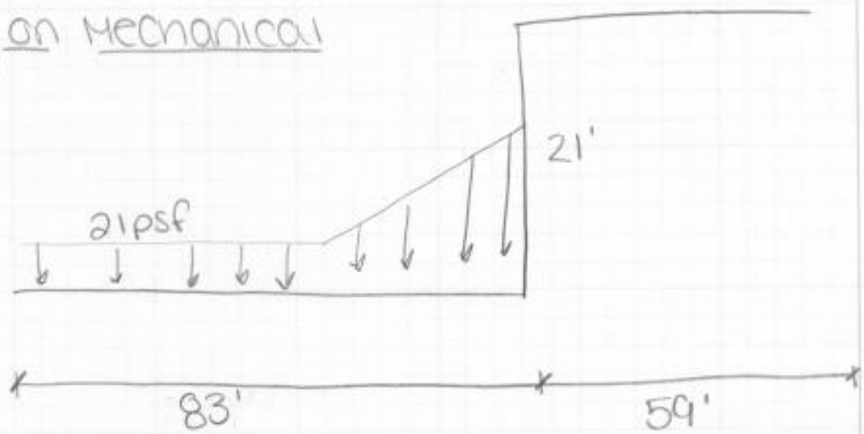
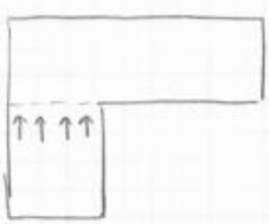


lu < 25 feet.

Ignore the drift.

Drift on Mechanical area:





$\gamma = 0.13 P_g + 14$

$\gamma = 0.13(30) + 14$

$= 17.9$

$P_f = 0.7 C_e C_T I_s P_g$

$21 = 0.7 P_g$

$P_g = 30$

$h_b = C_s P_f$

$= 1.0(21)$

$= 21 psf$

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$h_b = P_s / \gamma = 21 / 17.9 = 1.17'$

$h_r = h_c + h_b$

$\frac{h_c}{h_b} \geq 0.2 \qquad \frac{20}{1.17}$ yes

windward:

$l_u > 25$ ✓

$h_d = 0.75\left(0.43\, l_u^{1/3} (P_g + 10)^{(1/4)} - 1.5\right)$

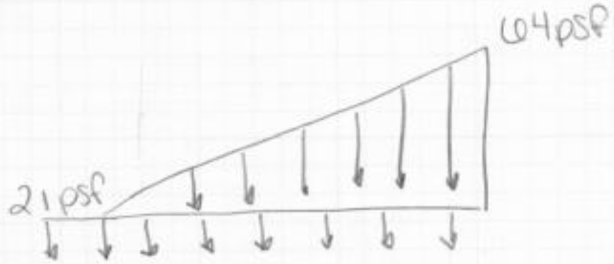
$h_d = 2.4\text{ft}$

$W = 4(2.4\text{ ft}) = 9.6$ feet

$P_d = h_d \gamma = 2.4(17.9) = 43$ psf

$P_d + P_f = 43 + 21 = 64$ psf

gradient $= \frac{P_d}{W} = \frac{43}{9.6} = 4.5$



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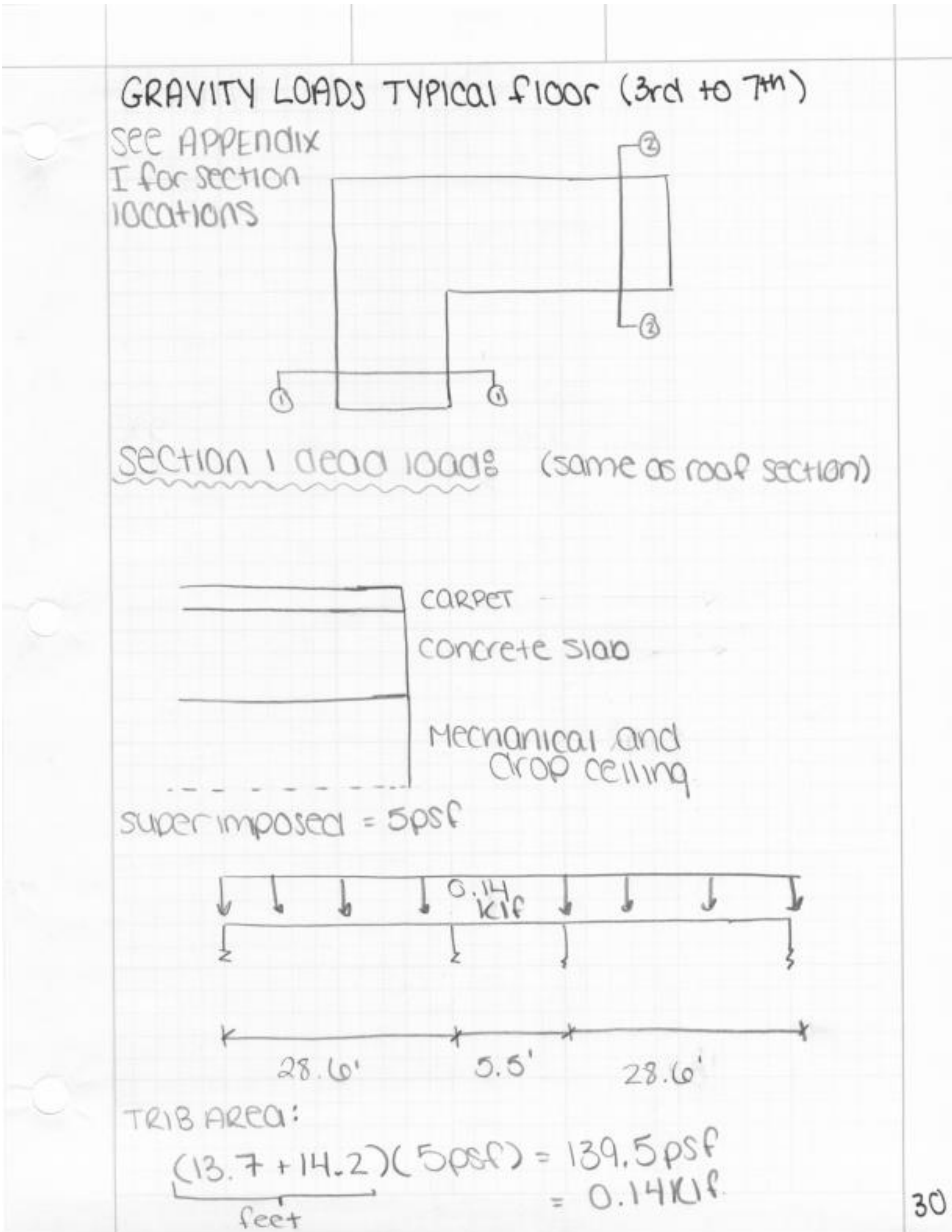


GRAVITY LOADS Typical floor (3rd to 7th)

See Appendix I for section locations

Section 1 dead loads (same as roof section)

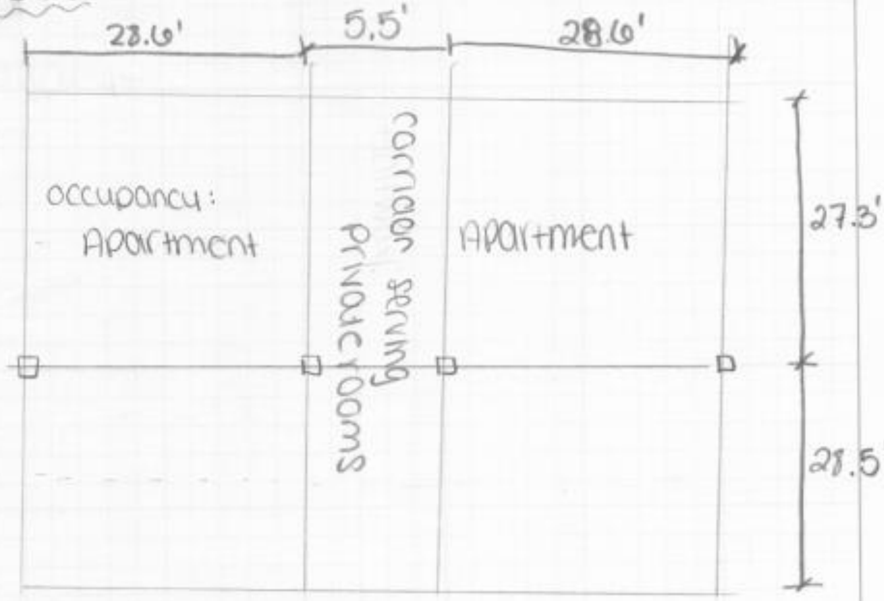
superimposed = 5psf

TRIB AREA:

(13.7 + 14.2)(5psf) = 139.5 psf
feet
= 0.14klf

30

live load:



(ASCE7 Occupancy live loads)

Apartments = 40 + 10psf (partitions)

corridors serving private rooms = 40 psf

(13.7 + 14.2) (50psf) = 1395 plf = 1.395klf
feet

(13.7 + 14.2) (40) = 1116 plf = 1.116klf
feet

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live load reductions:

$K_{LL}A_T > 400 ft^2$

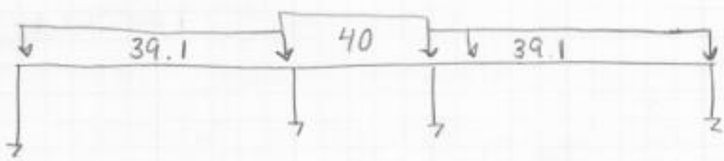
$A_T = (27.3/2 + 28.5/2)(28.6) = 798 sf$

K_{LL} – two way slab = 1.0

Live load can be reduced for Apartment load.

$$L = L_o\left(0.25 + \frac{15}{\sqrt{K_{LL}A_T}}\right)$$

$$= 50\left(0.25 + \frac{15}{\sqrt{1.0(798)}}\right) = 39.1 psf$$



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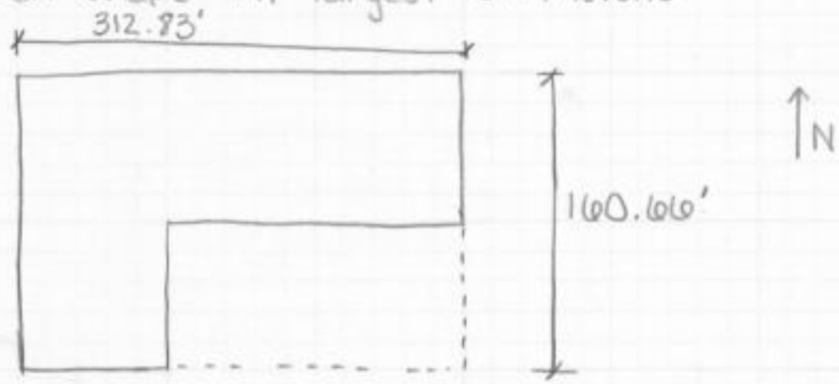
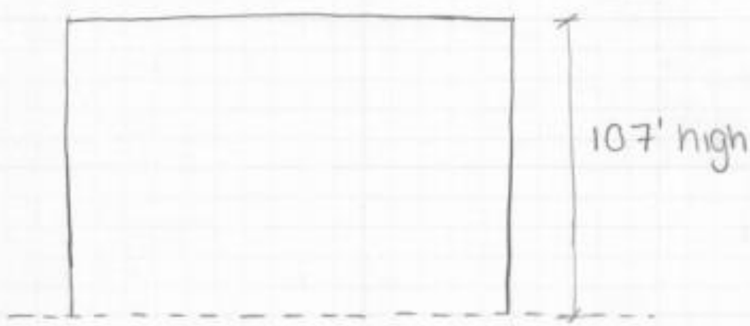
Wind Load Calculations:

Calculations based off of the building in a box shape w/ largest diminsions



plan

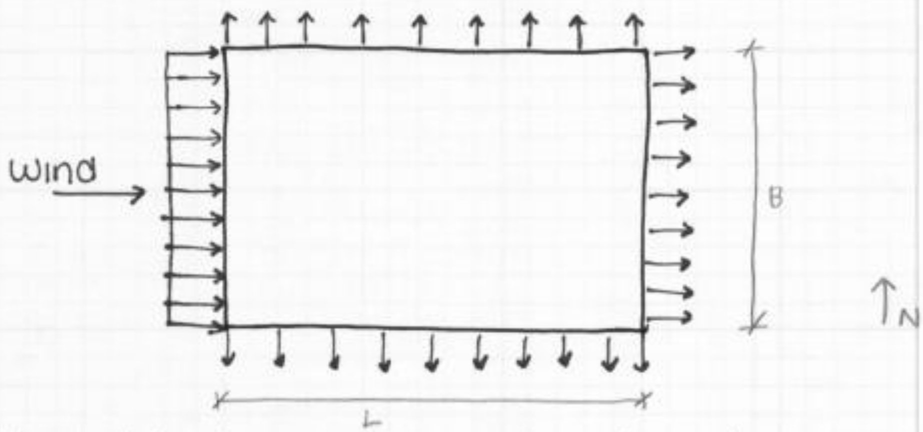


elevation

Use MWFRS - Main Wind-Force Resisting System
wind speed (figure 6-1 ASCE 7-05) = 90mph (see Appendix J)
Building Classification = III
"Building and other structure that represent a substantial hazard to human life in the event of failure.
- college building/living space

Wind Load Calculations

Exposure category: B (section 6.5.6)
wind analysis one...



Building Width (Normal to wind) = 160.66'
Building Length (parallel to wind) = 312.83'
Roof Type - essentially a flat roof.
Topographic factor: (6.5.7)
① satisfied
② satisfied
③ not at crest of an escarpement
$K_{zt} = 1.0$
Direct Factor Kd (table 6-4) Kd = 0.85
Enclosed - yes according to figure 6-5
Hurricane region - yes
roof angle - 0°
mean roof height = 107 ft
windward wall Cp = 0.8 (figure 6-6)
leeward side Cp = 4/13 = 312.83/160
= -0.5 use w/ign.
side walls Cp = -0.7

WIND LOAD CALCULATIONS

Wind Load Calculations

$K_z = 2.01(15/z_g)^{(2/\alpha)}$ if $z < 15'$

$K_z = 2.01(z/z_g)^{(2/\alpha)}$ if $z > 15'$

$z_g = 1200$ table 6.2

$\alpha = 7.0$

K_z for $z = 0 = 13$ $= 2.01(15/1200)^{(2/7)} = 0.574$

K_z for $z = 32 = 2.01(32/1200)^{(2/7)} = 0.714$

Calculations for rest of heights show on excel sheet attached at end of section.

$Q_z = 0.00256 K_z K_{zt} K_d V^2 I$ Eq 6-15

K_z = calculated above

$K_{zt} = 1.0$ topo factor

K_d = wind directionality $= 0.85$

$V = 90$

$I = 1.15$

Gust factor (E-W)

$I_{\bar{z}} = C(33/\bar{z})^{(1/6)} =$

$\bar{z} = 0.6h = 0.6(107) = 64.2$

$L_{\bar{z}} = \ell\left(\frac{\bar{z}}{33}\right)^{\bar{\varepsilon}} = 320\left(\frac{64.2}{33}\right)^{1/3} = 399.5$

$Q = \sqrt{\frac{1}{1 + 0.63\left(\frac{B+h}{L_{\bar{z}}}\right)^{0.63}}}$

Wind Load Calculations

$$Q = \sqrt{1/\left(1 + 0.63\left(\frac{160.7+107}{399.5}\right)^{0.63}\right)} =$$

$Q = 0.750$

$$G = 0.925\left[\frac{1 + 1.7\, g_Q I_z Q}{1 + 1.7\, g_v I_z}\right]$$

$$= 0.925\left(\frac{1 + 1.7(3.4)(0.27)(.75)}{1 + 1.7(3.4)(0.27)}\right)$$

$= 0.784$

P (windward) = $Q_z G C_p - q_i G C_{pi}$ eq 6.5 (12.2.1)

$q_i G C_{pi}$ → 0: internal pressure is in equilibrium

$C_p = 0.8$

P at $z = 0$ = (11.6)(0.784)(.8)
= 7.306

P(leeward) = $Q_{z_{roof}} G C_p$
= (20.42)(0.784)(0.8)
= 12.81

roofing pressures:

$\frac{h}{L} = \frac{107}{312.83} = 0.34$ normal to ridge $\theta < 10$

WIND LOAD CALCULATIONS

Wind Load Calculations

zone 1	0 to h/2	C_p = -0.9	0 - 53 ft
zone 2	h/2 to h	-0.9	53 - 107 ft
zone 3	h to 2h	-0.5	107 - 214 ft
zone 4	>2h	-0.3	214 - end

$P_{zone\,1} = q C_p G$

$= 20.42(-0.9)(0.784)$

$= -14.41$

$P_{zone\,2} = 20.42(-0.9)(0.784)$

$= -14.41$

$P_{zone\,3} = 20.42(-0.5)(0.784)$

$= 8.0$

$P_{zone\,4} = 20.42(-0.3)(0.784)$

$= 4.80$

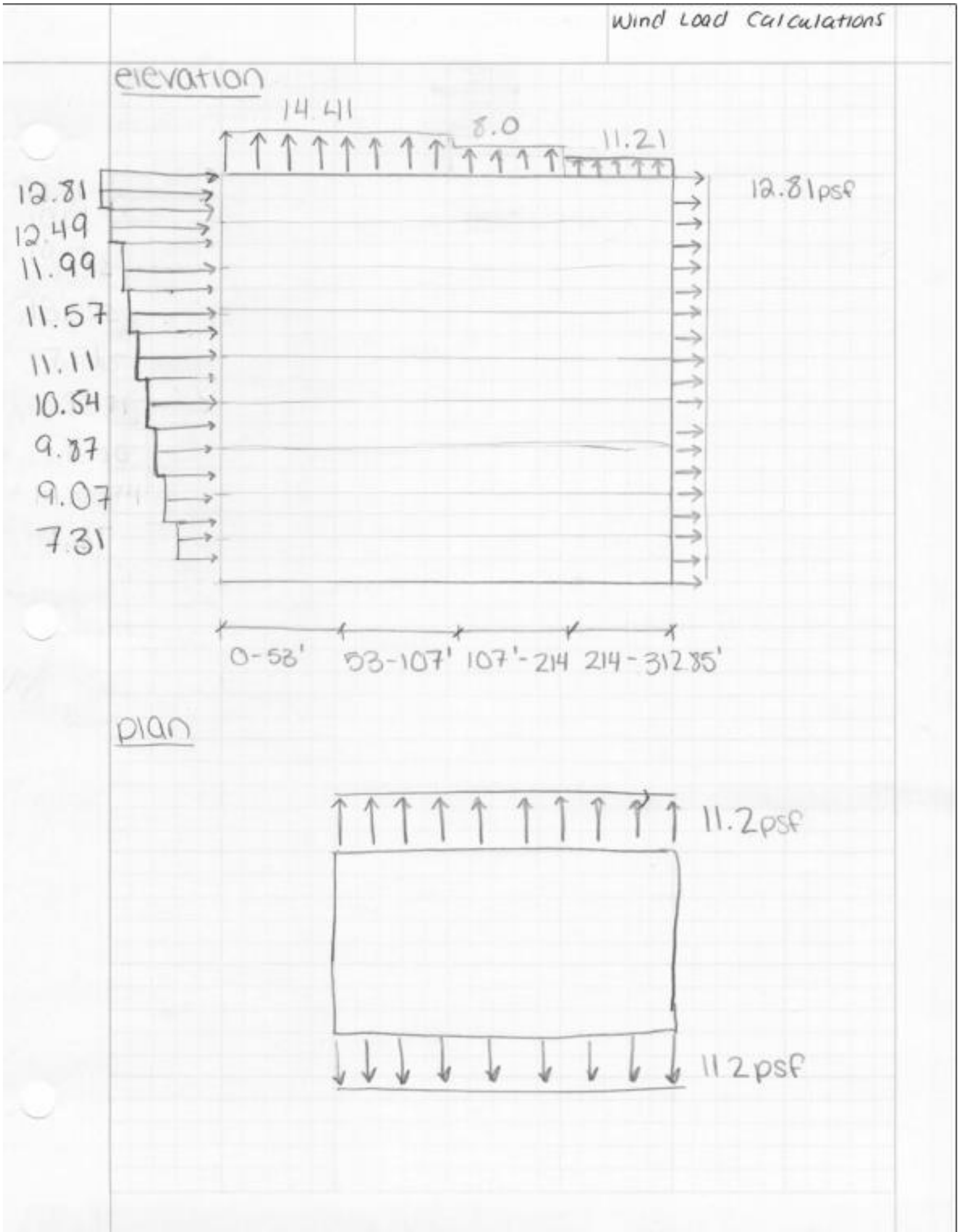
side walls:

$P = q_h G C_p =$

$20.42(0.784)(0.7)$ → sidewall

$P = 11.21$

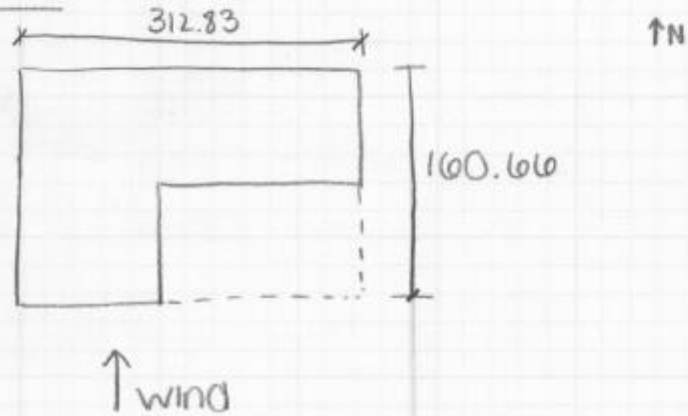
WIND LOAD CALCULATIONS



WIND LOAD CALCULATIONS

Wind Load Calculations

Wind loads N-S



Building width - 312.83'

Building length - 160.66'

$K_z = 2.01\left(\frac{15}{z_g}\right)^{(2/\alpha)}$ for $z < 15'$

$K_z = 2.01(z/z_g)^{(2/\alpha)}$ for $z > 15'$

$Q_z = 0.00256 K_z K_{zt} K_d V^2 I$ ($V \rightarrow 90$; $K_d \rightarrow 0.85$; $I \rightarrow$ table 6.1)

Gust factor:

$$Q = \sqrt{1/1 + 0.63\left(\frac{B+h}{L_z}\right)^{0.63}}$$

$$= \sqrt{1/1 + 0.63\left(\frac{312.83 + 107}{399.5}\right)^{0.63}} = 0.702$$

$$L_z = \ell\left(\frac{\bar{z}}{33}\right)^{\epsilon} = 320\left(\frac{64.2}{33}\right)^{1/3} = 399.5$$

$$I_z = c\left(\frac{33}{\bar{z}}\right)^{1/6} = 0.3(33/64.2)^{1/6} = 0.27$$

$$G = 0.925\left[\frac{1 + 1.7(3.4)(0.27)(0.702)}{1 + 1.7(3.4)(0.27)}\right]$$

$G = (0.925)((1 + 1.0955)/(1 + 1.5606))$
$= 0.757$

$P(\text{windward}) = Q_z G C_p$

$P_{(z=0)} = (11.6)(0.757)(0.8) = 7.025$

$P(\text{leeward}) = Q_{z_{roof}}(G)(C_p)$
$= (20.4)(0.757)(0.8) =$

roofing pressures:

$\frac{h}{L} = \frac{107}{160.66} = 0.6$ normal to ridge $< 10°$

figure 6-6
ASCE7-05

		C_p
zone 1	0 to h/2	-1.3
zone 2	h/2 to h	-0.7

$P_{zone1} = q C_p G = 20.42(-1.3)(0.757) =$
$= -20.1$

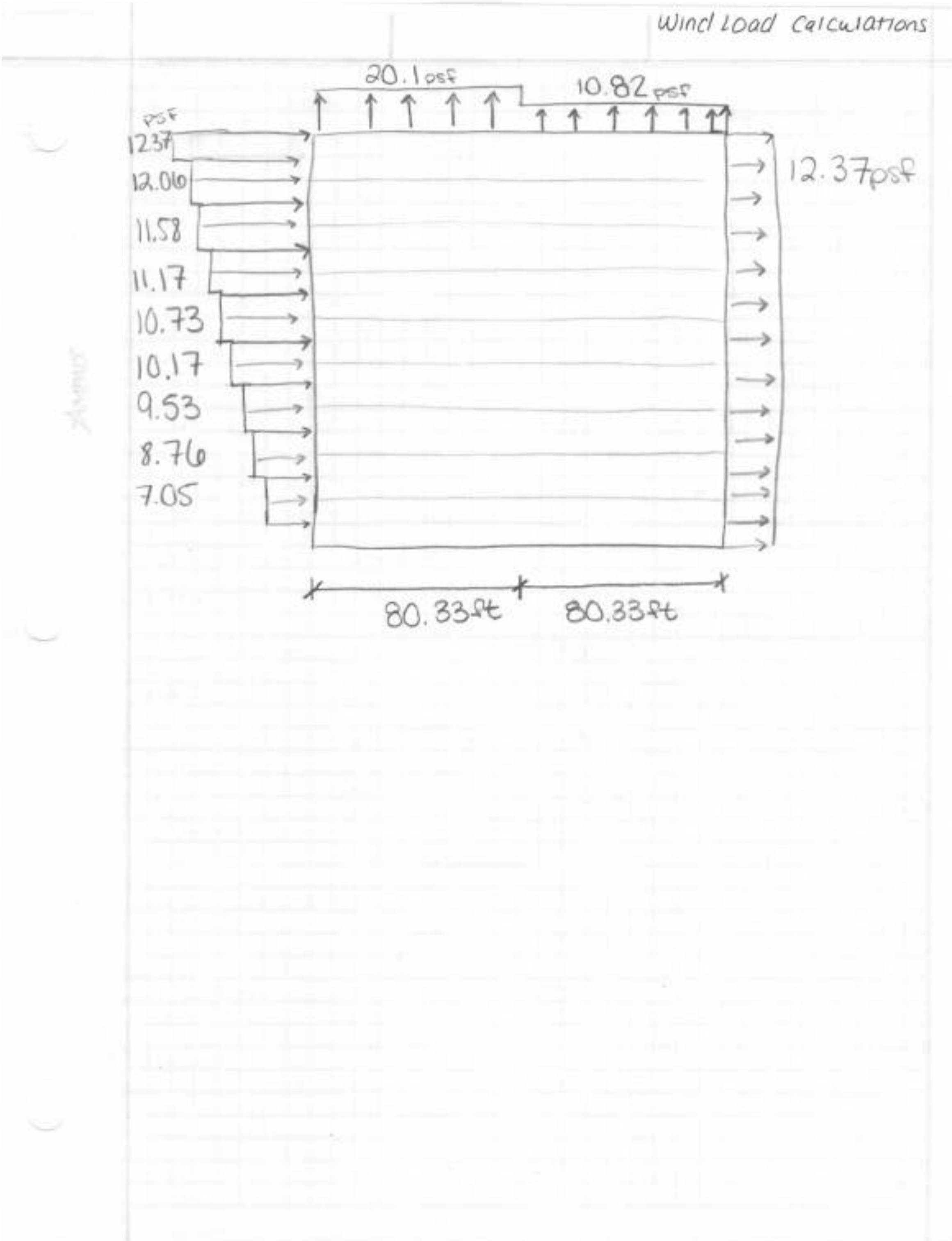
$P_{zone2} = q C_p G = 20.42(-0.7)(0.757) =$
$= -10.82$

side walls:

$P = Q_h G C_p = 20.42(0.757)(0.7)$
$= 10.82$

plan view:

WIND LOAD CALCULATIONS



SEISMIC CALCULATIONS

Seismic design

Seismic design:

variable	value
S_S	0.155
S_1	0.051
Site class	D
S_{DS}	0.165
S_{D1}	0.081
F_a	1.6
F_v	2.4

S_{DS}, S_{D1}: from docs S1.00, verified w/ code ASCE 7-05 Ch 11.

F_a: table 11.4.1

F_v: table 11.4.2

$S_{MS} = F_a S_S = (1.6)(0.155) = 0.248$

$S_{M1} = F_v S_1 = (2.4)(0.051) = 0.1224$

ASCE 7-05 11.4.4

$S_{DS} = (2/3)(S_{MS}) = (2/3)(0.248) = 0.165 \rightarrow$ matches STR docs ✓

$S_{D1} = 2/3\, S_{M1} = (2/3)(0.1224) = 0.081 \rightarrow$ matches ✓

$S_a = \frac{S_{D1}}{T}$

ASCE 7-05 -12.8-2

$T = C_t h_n^x$

C_t (all other STR systems) = 0.02

$x = 0.75$

$T_a = (0.02)(107)^{0.75}$

$T_a = 0.67$

$T = C_u T_a$

$1.7(0.67) = 1.139$

$S_a = 0.081 / 0.67 = 0.121$

T_L = ASCE 7-05 figure 22-15 = 8

$C_s = S_{D1} / T(R/I) = 0.081 / (1.139)(\frac{3}{1}) = 0.026$

3.417

C_s matches DOCS. ✓

Seismic design

Shear at base of Building:

$V = C_s W$

$V = 0.026(29694) = 772.04$ kips

from docs → 782k — ✓✓ very close.

vertical distribution:

$F_x = C_{vx} V$

$$C_{vx} = \frac{W_x h_x^k}{\sum w h_i^k}$$

period	k
0.5	1
1.139	1.3
2.5	2

interpolation

roof:

$$C_{vx} = \frac{(2648.76)(107)^{1.3}}{\sum W_x h_x^{1.3}}$$

→ see excel charts for shear distribution

SEISMIC CALCULATIONS

Building Weight

	Slab Area (sft)	Slab Thickness (ft)	Slab Total Weight	Super Imposed Dead Loads	Live loads Avg on Floor(psf)	Live Load Weight (Kips)
Roof	22073	0.666666667	2207.3	220.73	10	220.73
7th Floor	22073	0.666666667	2207.3	110.365	50	1103.65
6th Floor	22073	0.666666667	2207.3	110.365	50	1103.65
5th Floor	22073	0.666666667	2207.3	110.365	50	1103.65
4th Floor	22073	0.666666667	2207.3	110.365	50	1103.65
3rd Floor	22073	0.666666667	2207.3	110.365	50	1103.65
2nd Floor	22073	0.666666667	2207.3	110.365	50	1103.65
1st Floor	22073	0.666666667	2207.3	110.365	60	1324.38
Ground Floor						
Upper Scub						
Lower Scub						
		Total:	17658.4	993.285		8167.01

Building Weight

Column Size	Quantity	Area (sft)	Height(ft)	Total Weight of Column(kips)
30"x18"	40	3.75	107	2407.5
18"x42"	2	5.25	107	168.525
18"x69"	1	8.625	107	138.43125
30"x24"	2	5	107	160.5
			Total:	2874.95625

Total Building Weight (kips)	29693.65125

Weight at Each Floor						
	Height From Ground (ft)	Slabs (kips)	Dead Loads (kips)	Live Loads(kips)	Columns Per Floor (kips)	
Roof (top)	107	2207.3	220.73	220.73	0	2648.76
7th Floor	73	4414.6	331.095	1324.38	359.3	6429.375
6th Floor	63	6621.9	441.46	2428.03	718.6	10209.99
5th Floor	53	8829.2	551.825	3531.68	1077.9	13990.605
4th Floor	43	11036.5	662.19	4635.33	15449.9	31783.92
3rd Floor	31	13243.8	772.555	5738.98	1796.5	21551.835
2nd Floor	19	15451.1	882.92	6842.63	2155.8	25332.45
1st Floor	1	17658.4	993.285	7946.28	2874	29693.65125
Ground Floor						
Upper Scub						
Lower Scub						

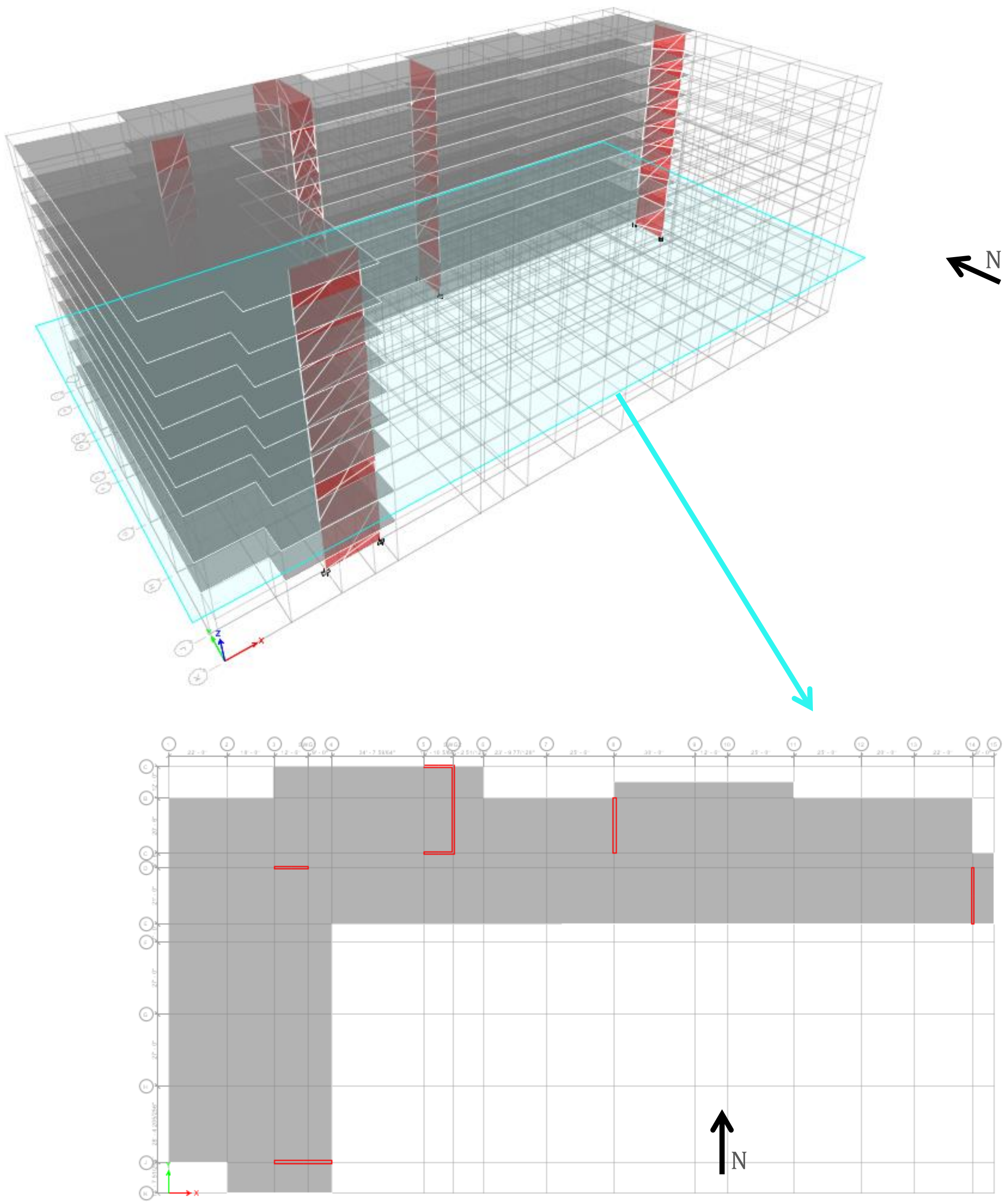
Seismic Calculations							
	Height from Ground (ft)	Weight at Each Floor(kips)	K	Wxhx^k	Cvx	Shear at Base	Fx
Roof (top)	107	2648.76	1.3	1151440.551	0.077744351	772.04	60.022
7th Floor	73	6429.375	1.3	1700154.837	0.114793104	772.04	88.625
6th Floor	63	10209.99	1.3	2229297.51	0.150520397	772.04	116.21
5th Floor	53	13990.605	1.3	2440029.774	0.164748872	772.04	127.19
4th Floor	43	31783.92	1.3	4223927.46	0.285196227	772.04	220.18
3rd Floor	31	21551.835	1.3	1871778.504	0.126380998	772.04	97.571
2nd Floor	19	25332.45	1.3	1164278.494	0.078611159	772.04	60.691
1st Floor	1	29693.65125	1.3	29693.65125	0.002004892	772.04	1.5479

Wind and Seismic Overview

Wind Verses Seismic Forces at Story Levels/ Overturning Moments			
	N-S Wind Fy (kips)	E-W Wind Fx (kips)	Fx/Fy Seismic Design (Kips)
Roof	23.57	49.06	60.02
7th Floor	48.88	89.10	88.62
6Th Floor	42.37	64.07	116.21
5Th Floor	41.57	62.70	127.19
4th Floor	40.87	61.24	220.18
3rd Floor	39.87	59.36	97.57
2nd Floor	53.40	101.65	60.69
1st Floor	23.21	71.66	1.55
Ground Floor	51.50	95.30	0
Lower Scub	0	0	0
Overturning Moment (Ft-Kip)	24409	42316	4016

ETABS Model

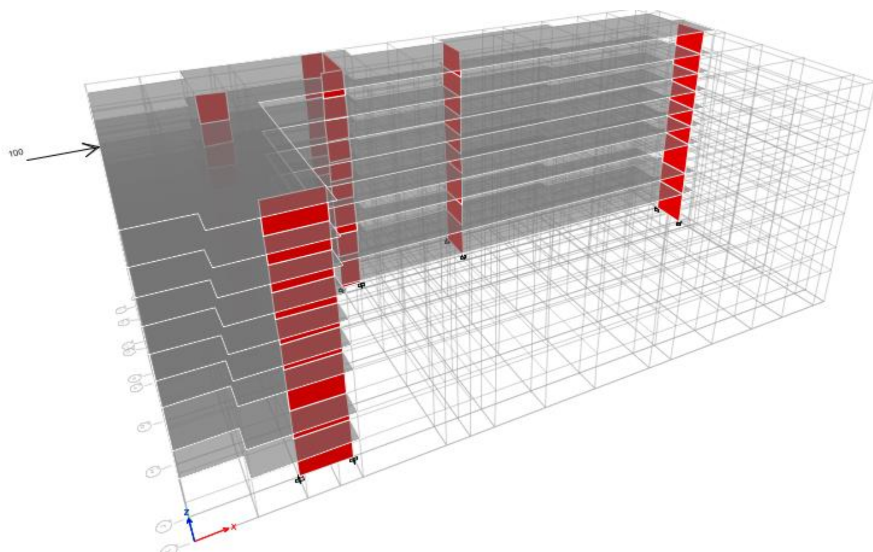
An ETABS model was created for the buildings structural lateral system. The model includes the 7 shear wall concrete lateral system. Both the wind and seismic loads that were found in the previous technical reports were input at the center of rigidity, all results are compared to hand calculations.

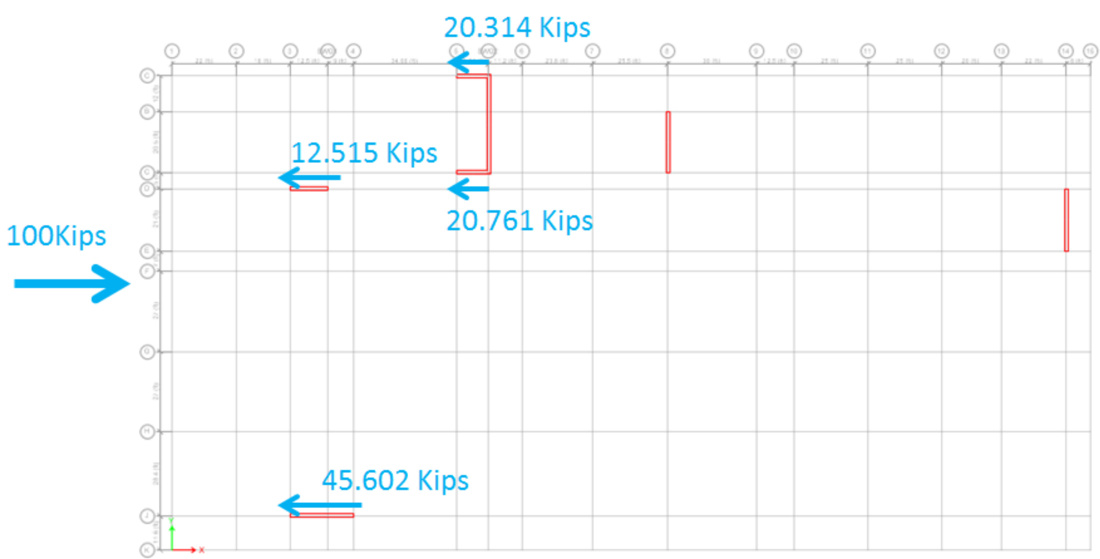


Typical Floor Layout (Shear Walls are indicated in red)

ETABS Model Check:

To ensure proper modeling, a dummy load of 100 kips was placed at roof level in both X and Y directions. The dummy load was applied at the center of pressure.



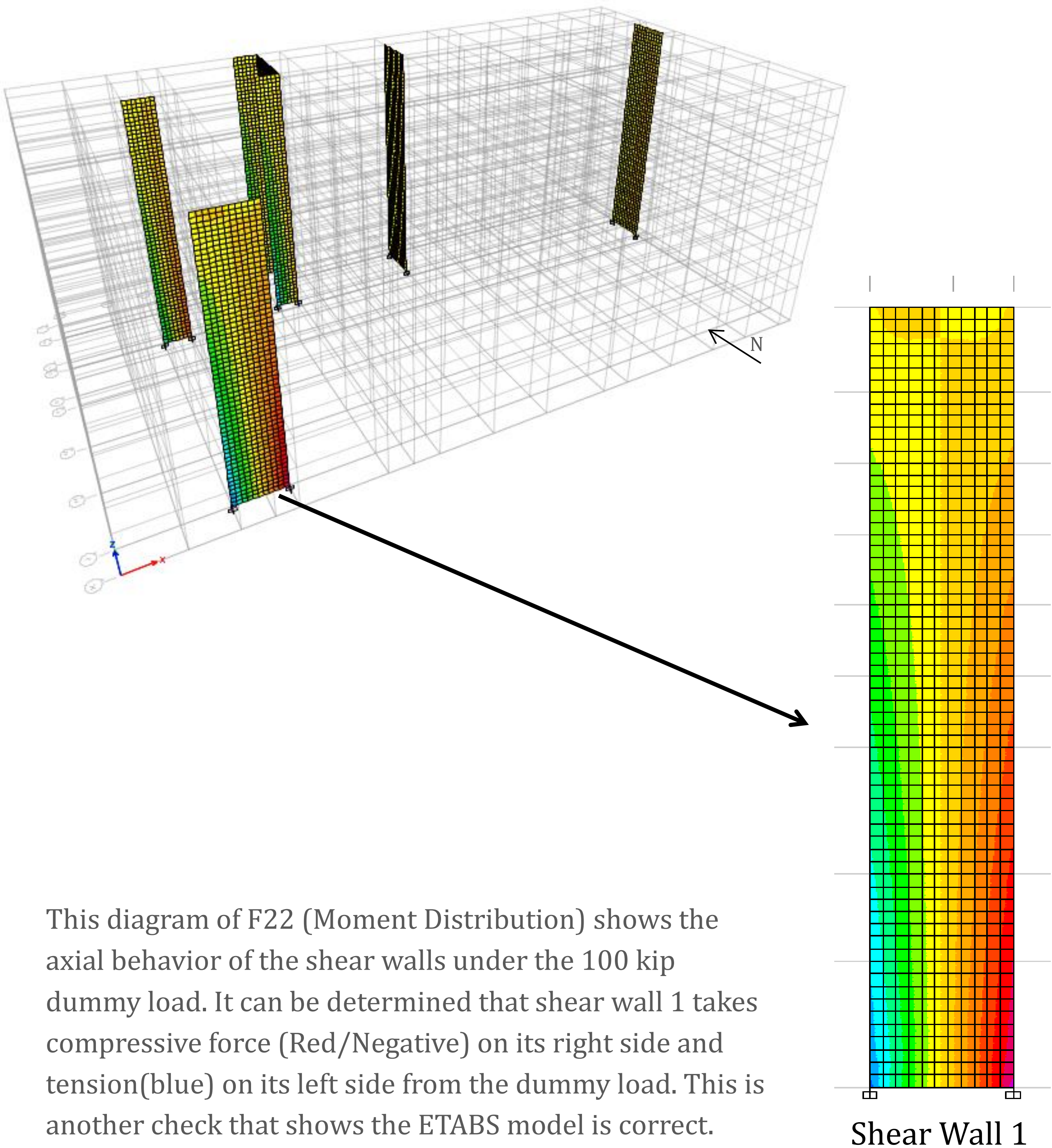


$\sum F=0$

$100 = 12.515 + 20.314 + 20.761 + 45.602$

$100=99.14$ Good

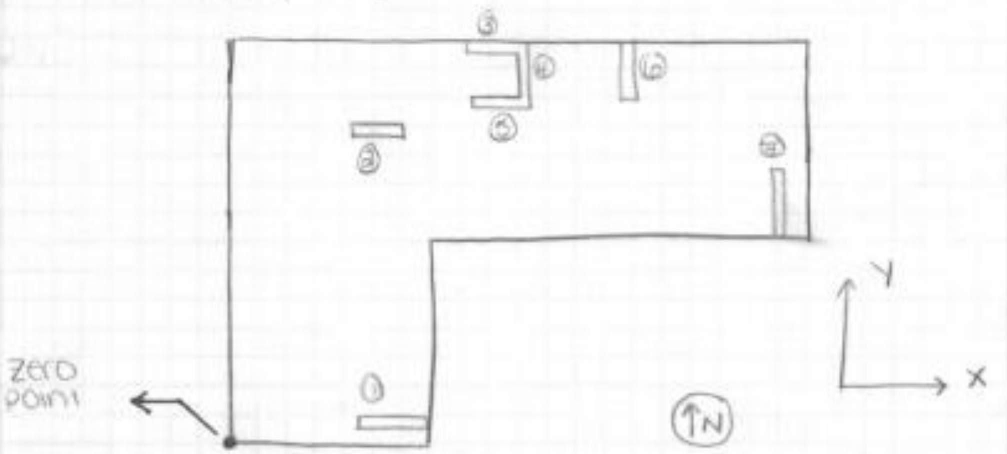
ETABS MODEL CHECK



This diagram of F22 (Moment Distribution) shows the axial behavior of the shear walls under the 100 kip dummy load. It can be determined that shear wall 1 takes compressive force (Red/Negative) on its right side and tension(blue) on its left side from the dummy load. This is another check that shows the ETABS model is correct.

Center of Rigidity

Center of Rigidity:



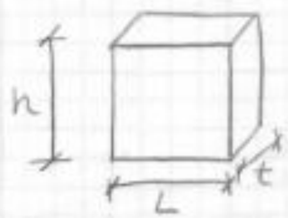
Fixed - Fixed:

$$R = \frac{1}{\left(\frac{h^3}{EL^3} + \frac{1.2h}{G(L)}\right)}$$

$E = 57000\sqrt{f'c}$

$= 57000\sqrt{4000}$ psi

$= 3.60 \times 10^6$ psi



h: height at each story

L: Length of wall

t: thickness = 12"

$G = 0.4E$

$G = 0.4(3.60\times10^6) = 1.44\times10^6$

Distance from zero point

Element	X (Feet)	Y(Feet)
Shear Wall #1	52	12
Shear Wall #2	42	127
Shear Wall #3	108	160
Shear Wall #4	112	150
Shear Wall #5	108	135
Shear Wall #6	177	144
Shear Wall #7	312	117

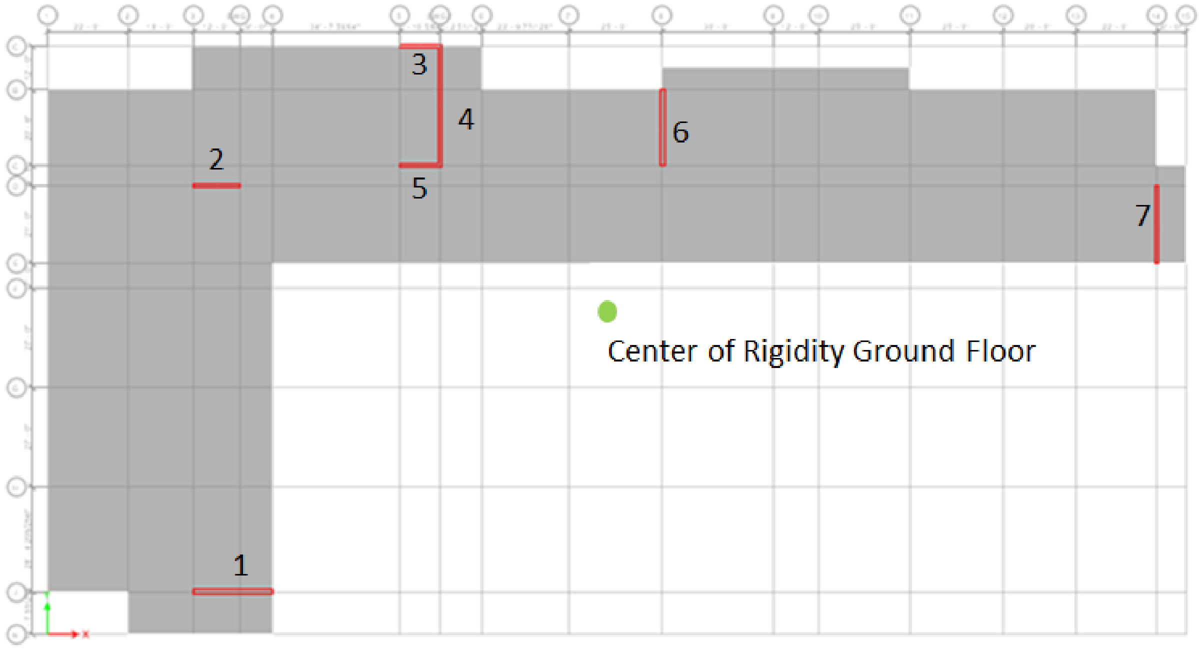
*distances are measured to the center of Element from zero point.

Shear Wall Relative Rigidity

Shear Wall:	1	2	3	4	5	6	7
Ground	18.63	12.62	4.73	34.05	4.73	12.62	12.62
First	17.96	13.37	6.43	29.08	6.43	13.37	13.37
Second	18.63	12.62	4.73	34.05	4.73	12.62	12.62
Third	17.61	13.50	7.14	27.61	7.14	13.50	13.50
Fourth	17.61	13.50	7.14	27.61	7.14	13.50	13.50
Fifth	17.61	13.50	7.14	27.61	7.14	13.50	13.50
Sixth	17.61	13.50	7.14	27.61	7.14	13.50	13.50
Seventh	17.61	13.50	7.14	27.61	7.14	13.50	13.50
Roof	17.91	13.39	6.53	28.85	6.53	13.39	13.39

The relative rigidity of shear wall number 4 is much larger in comparison to all the other shear walls. This is because shear wall 4 is much larger in depth than the other walls, having more area to resist forces.

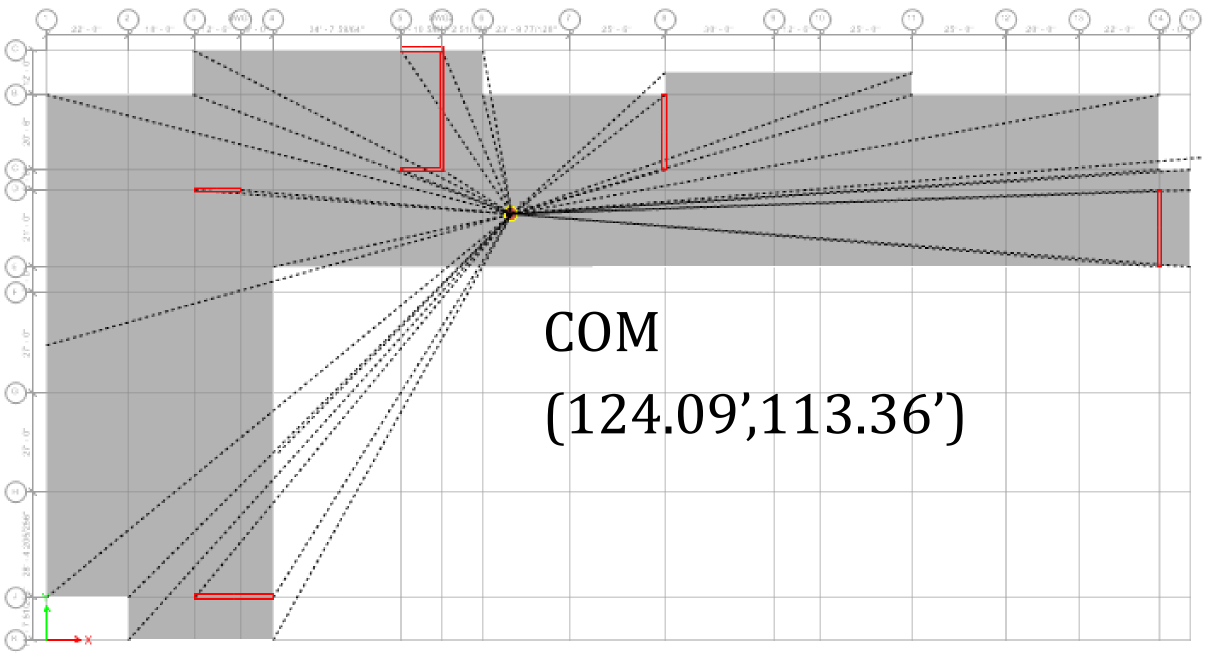
Center of Rigidity/ Center of Mass



Center of Rigidity: Hand Calculations vs. ETABS				
	Hand Calculations		ETABS Calculation	
	X	Y	X	Y
Ground Floor	168.39'	79.14'	162.20'	80.94'
First Floor	175.48'	86.22'	148.42'	75.47'
Second Floor	168.39'	79.14'	138.65'	73.65'
Third to Seventh Floor	177.51'	110.95'	115.40'	73.01'
Roof	175.80'	86.61'	131.56'	73.03'

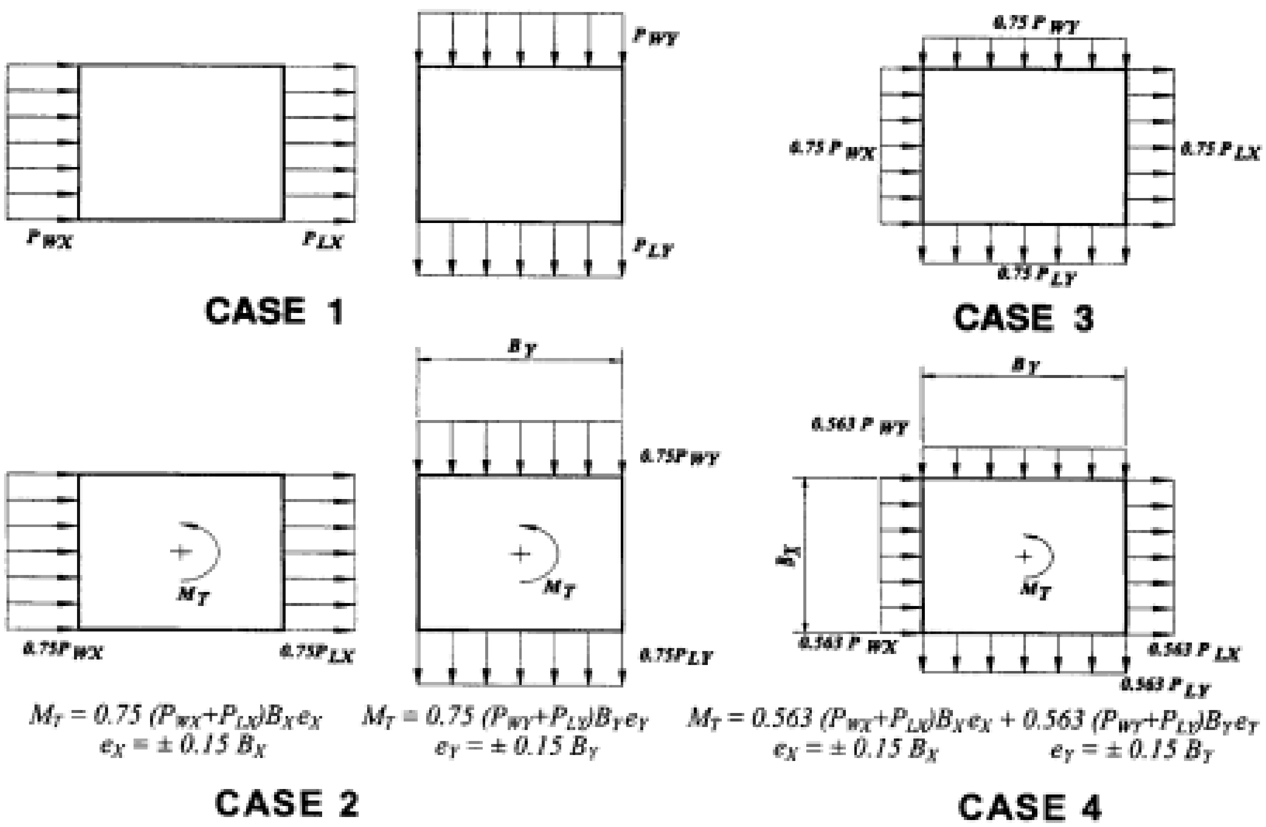
Center of Mass:

See Appendix for COM hand calculations



Wind Load Combinations:

Wind Load combinations are derived from the Main Wind Force Resisting System (MWFRS) Method two in ASCE 7-05. Figure 6-9 from ASCE 7-05 explains the different wind loading cases on buildings of all heights. These four directional load cases were used to consider the potential effects of the basic wind loads. For case one and three, the wind forces are applied at the center of pressure without any eccentricity, Case two and four loads are applied at positive and negative eccentricity from the center of pressure.



ASCE 7-05 Figure 6-9

Wind Load Combinations

ASCE 7-05 Wind Load Case 1						
Level	F_x(K)	F_y(K)	e_y(ft)	e_x(ft)	M_x(ft-k)	M_y(ft-k)
Roof	24.59	46.47	0	0	0	0
7Th Floor	45.88	45.89	0	0	0	0
6Th Floor	42.34	42.33	0	0	0	0
5th Floor	41.62	41.61	0	0	0	0
4th Floor	40.83	40.83	0	0	0	0
3rd Floor	39.86	39.85	0	0	0	0
2nd Floor	53.84	53.82	0	0	0	0
1st Floor	56.01	56	0	0	0	0
Ground	20.92	20.92	0	0	0	0

ASCE 7-05 Wind Load Case 2						
Level	F_x(K)	F_y(K)	e_y(ft)	e_x(ft)	M_x(ft-k)	M_y(ft-k)
Roof	18.44	40.29	47	24	53107.2	444529.6
7Th Floor	34.42	74.15	47	24	99129.6	818115.5
6Th Floor	31.75	67.07	47	24	91440	740000.1
5th Floor	31.21	64.7	47	24	89884.8	713851.3
4th Floor	30.63	62.15	47	24	88214.4	685716.5
3rd Floor	29.9	58.91	47	24	86112	649968.8
2nd Floor	40.83	76.75	47	24	117590.4	846801.9
1st Floor	42.01	76.09	47	24	120988.8	839520
Ground	15.93	24.88	47	24	45878.4	274507.3

ASCE 7-05 Wind Load Case 3						
Level	F_x(K)	F_y(K)	e_y(ft)	e_x(ft)	M_x(ft-k)	M_y(ft-k)
Roof	18.44	34.85	0	0	0	0
7Th Floor	34.42	64.98	0	0	0	0
6Th Floor	31.93	59.99	0	0	0	0
5th Floor	31.21	58.96	0	0	0	0
4th Floor	30.36	57.86	0	0	0	0
3rd Floor	29.9	56.45	0	0	0	0
2nd Floor	40.37	76.27	0	0	0	0
1st Floor	42.01	79.36	0	0	0	0
Ground	15.69	29.64	0	0	0	0

ASCE 7-05 Wind Load Case 4							
Level	F_x(K)	F_y(K)	e_y(ft)	e_x(ft)	M_x(ft-k)	M_y(ft-k)	Mtotal(ft-k)
Roof	13.016	4.949	24	46.95	55048	20930.59	75978.584
7Th Floor	23.975	9.108	24	46.95	101396.4	38520.06	139916.476
6Th Floor	21.665	8.239	24	46.95	91626.83	34844.84	126471.671
5th Floor	20.906	7.947	24	46.95	88416.83	33609.9	122026.723
4th Floor	20.075	7.634	24	46.95	84902.31	32286.14	117188.455
3rd Floor	19.045	7.236	24	46.95	80546.18	30602.9	111149.077
2nd Floor	24.796	9.427	24	46.95	104868.6	39869.2	144737.828
1st Floor	24.576	9.346	24	46.95	103938.2	39526.63	143464.822
Ground	8.047	3.056	24	46.95	34032.82	12924.61	46957.4294

Seismic Loading:

Design seismic loads were calculated in technical report number 2 and were applied to the ETABS model. Since the center of mass and center of rigidity are not aligned, there is an inherent torsional moment caused by the seismic forces. A torsional amplification factor was taken into account; this factor was calculated after testing a dummy amplification factor of 1.0. With the calculated drift from the dummy factor, a new amplification factor was applied to the ETABS model. The torsional amplification factor is in accordance to ASCE 7-05 figure 12.8-1. Since the amplification factor was smaller than the dummy 1.0 factor, the actual factor remained 1.0.

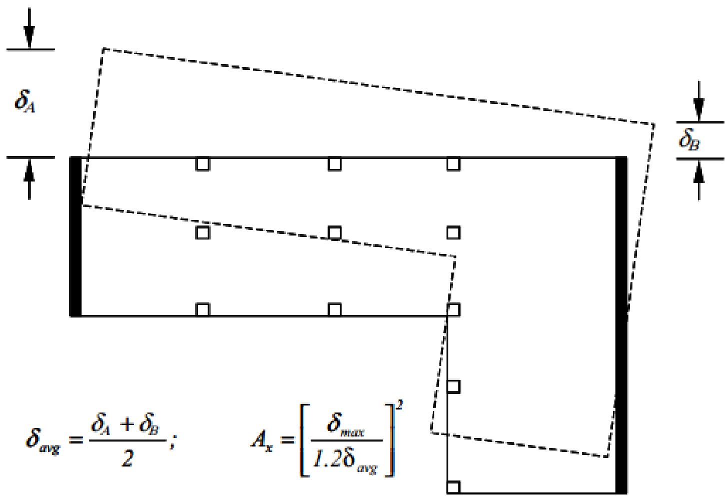


FIGURE 12.8-1 TORSIONAL AMPLIFICATION FACTOR, A_x

ASCE 7-05

Amplification Factors				
Level	Max Deflection X	Avg Deflection X	Ax	Ax
Roof	3.842793	3.534884	0.820693807	1
7Th Floor	3.29542	3.033173	0.819718414	1
6Th Floor	2.835284	2.611468	0.81858018	1
5th Floor	2.378003	2.192322	0.81705938	1
4th Floor	1.928897	1.780507	0.815019899	1
3rd Floor	1.493781	1.381211	0.81225298	1
2nd Floor	1.08755	1.007675	0.808900316	1
1st Floor	0.48066	0.447618	0.800752655	1
Ground	0.18816	0.176147	0.792394796	1

Seismic Load Combinations

N-S Seismic Forces					
Level	Story Force (K)	Story Shear (k)	5% L (ft)	A_x	Moment (ft-k)
Roof	60.02	60.02	8	1	480.16
7Th Floor	88.62	148.64	8	1	1189.12
6Th Floor	116.21	264.85	8	1	2118.8
5th Floor	127.19	392.04	8	1	3136.32
4th Floor	220.18	612.22	8	1	4897.76
3rd Floor	97.57	709.79	8	1	5678.32
2nd Floor	60.69	770.48	8	1	6163.84
1st Floor	1.55	772.03	8	1	6176.24
Ground	0	772.03	8	1	6176.24

Horizontal Structural Irregularities:

Torsional Irregularities were analyzed based off of ASCE 7-05 table 12-3-1. There were no significant cases of torsional irregularities. No factors were applied to the torsion.

TABLE 12.3-1 HORIZONTAL STRUCTURAL IRREGULARITIES

	Irregularity Type and Description	Reference Section	Seismic Design Category Application
1a.	**Torsional Irregularity** is defined to exist where the maximum story drift, computed including accidental torsion, at one end of the structure transverse to an axis is more than 1.2 times the average of the story drifts at the two ends of the structure. Torsional irregularity requirements in the reference sections apply only to structures in which the diaphragms are rigid or semirigid.	12.3.3.4 12.8.4.3 12.7.3 12.12.1 Table 12.6-1 Section 16.2.2	D, E, and F C, D, E, and F B, C, D, E, and F C, D, E, and F D, E, and F B, C, D, E, and F
1b.	**Extreme Torsional Irregularity** is defined to exist where the maximum story drift, computed including accidental torsion, at one end of the structure transverse to an axis is more than 1.4 times the average of the story drifts at the two ends of the structure. Extreme torsional irregularity requirements in the reference sections apply only to structures in which the diaphragms are rigid or semirigid.	12.3.3.1 12.3.3.4 12.7.3 12.8.4.3 12.12.1 Table 12.6-1 Section 16.2.2	E and F D B, C, and D C and D C and D D B, C, and D
2.	**Reentrant Corner Irregularity** is defined to exist where both plan projections of the structure beyond a reentrant corner are greater than 15% of the plan dimension of the structure in the given direction.	12.3.3.4 Table 12.6-1	D, E, and F D, E, and F
3.	**Diaphragm Discontinuity Irregularity** is defined to exist where there are diaphragms with abrupt discontinuities or variations in stiffness, including those having cutout or open areas greater than 50% of the gross enclosed diaphragm area, or changes in effective diaphragm stiffness of more than 50% from one story to the next.	12.3.3.4 Table 12.6-1	D, E, and F D, E, and F
4.	**Out-of-Plane Offsets Irregularity** is defined to exist where there are discontinuities in a lateral force-resistance path, such as out-of-plane offsets of the vertical elements.	12.3.3.4 12.3.3.3 12.7.3 Table 12.6-1 16.2.2	D, E, and F B, C, D, E, and F B, C, D, E, and F D, E, and F B, C, D, E, and F
5.	**Nonparallel Systems-Irregularity** is defined to exist where the vertical lateral force-resisting elements are not parallel to or symmetric about the major orthogonal axes of the seismic force–resisting system.	12.5.3 12.7.3 Table 12.6-1 Section 16.2.2	C, D, E, and F B, C, D, E, and F D, E, and F B, C, D, E, and F

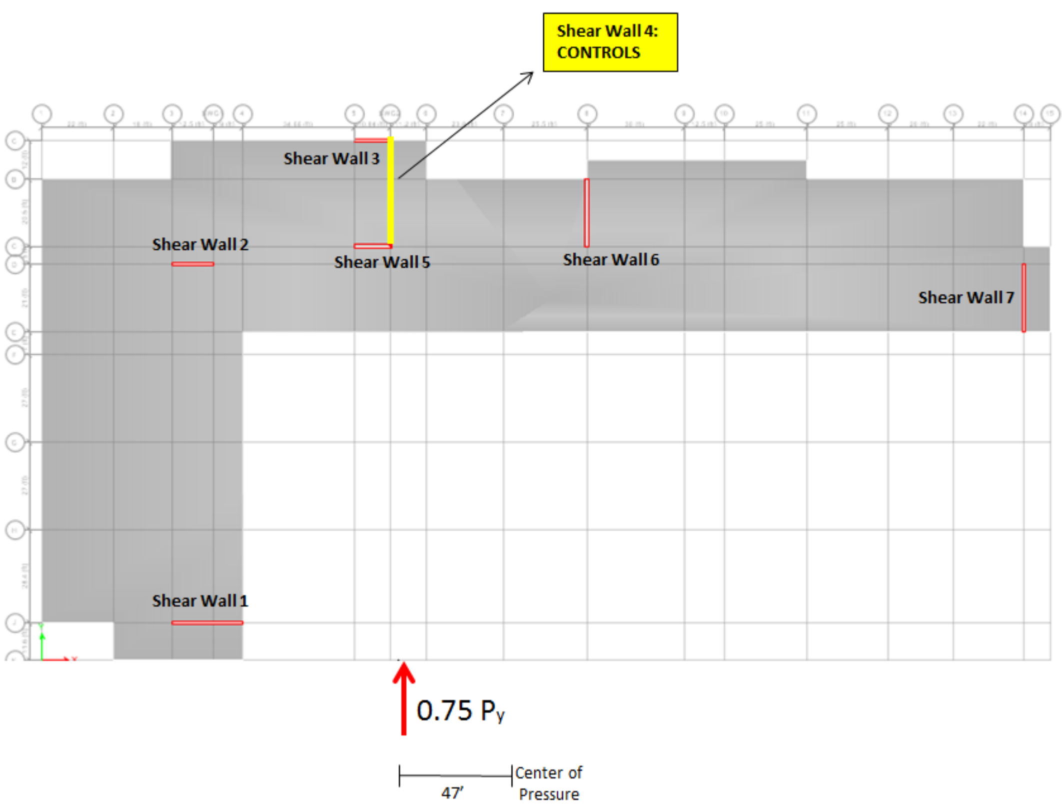
ASCE 7-05

Controlling Load Case:

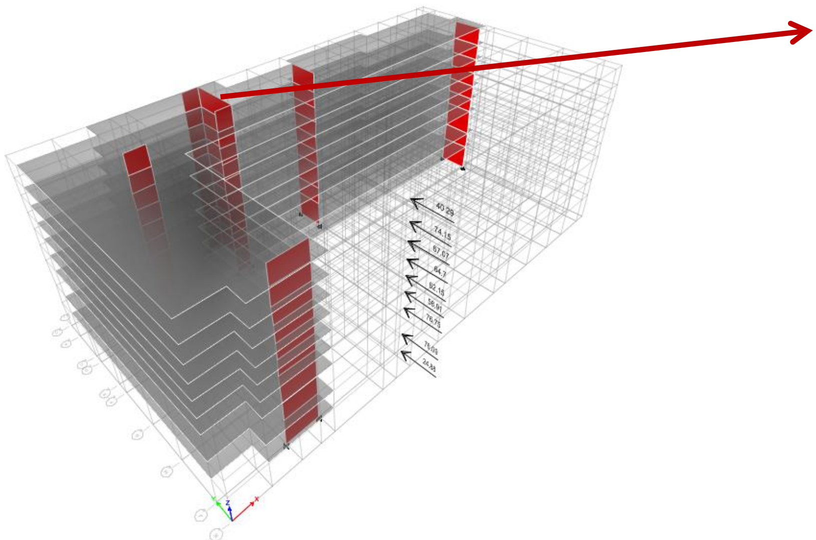
After testing thirteen different load cases on the ETABS model, Case 2: Y Negative Eccentricity is the controlling load case producing a shear about 430 kips at the bottom of shear wall 4.

Load Cases Tested
Case 1: X-Direction
Case 1: Y-Direction
Case 2: X Positive Eccentricity
Case 2: X Negative Eccentricity
Case 2: Y Positive Eccentricity
Case 2: Y Negative Eccentricity
Case 3: X and Y (75%) Reduction
Case 4: X+ and Y+
Case 4: X- and Y-
Case 4: X+ and Y-
Case 4: X- and Y+
Seismic X plus Moment
Seismic Y plus Moment

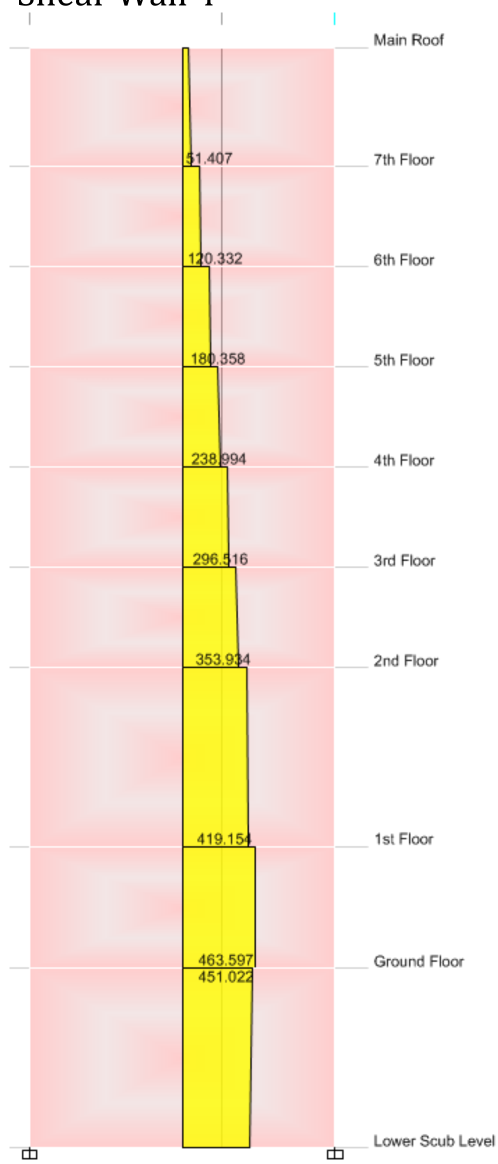
Member	Controlling Load Case	Maximum Shear (kips)
Shear Wall 1	Seismic X plus Moment	352.138
Shear Wall 2	Seismic X plus Moment	112.459
Shear Wall 3	Seismic X plus Moment	140.236
Shear Wall 4	Case 2: Y Negative Eccentricity	430.065
Shear Wall 5	Case 4: X+ and Y-	412.784
Shear Wall 6	Seismic Y Plus Moment	136.955
Shear Wall 7	Seismic Y plus Moment	216.267



Case 2: Y Negative Eccentricity controlling is logical because wind applied in the Y direction along the largest part of the building creates the highest story loads. The negative eccentricity places the forces 47 feet from the center of pressure which creates positive and negative moments about the center of rigidity. Being the most rigid shear wall, shear wall 4 takes the most loads when it is applied close to it.



Shear Wall 4

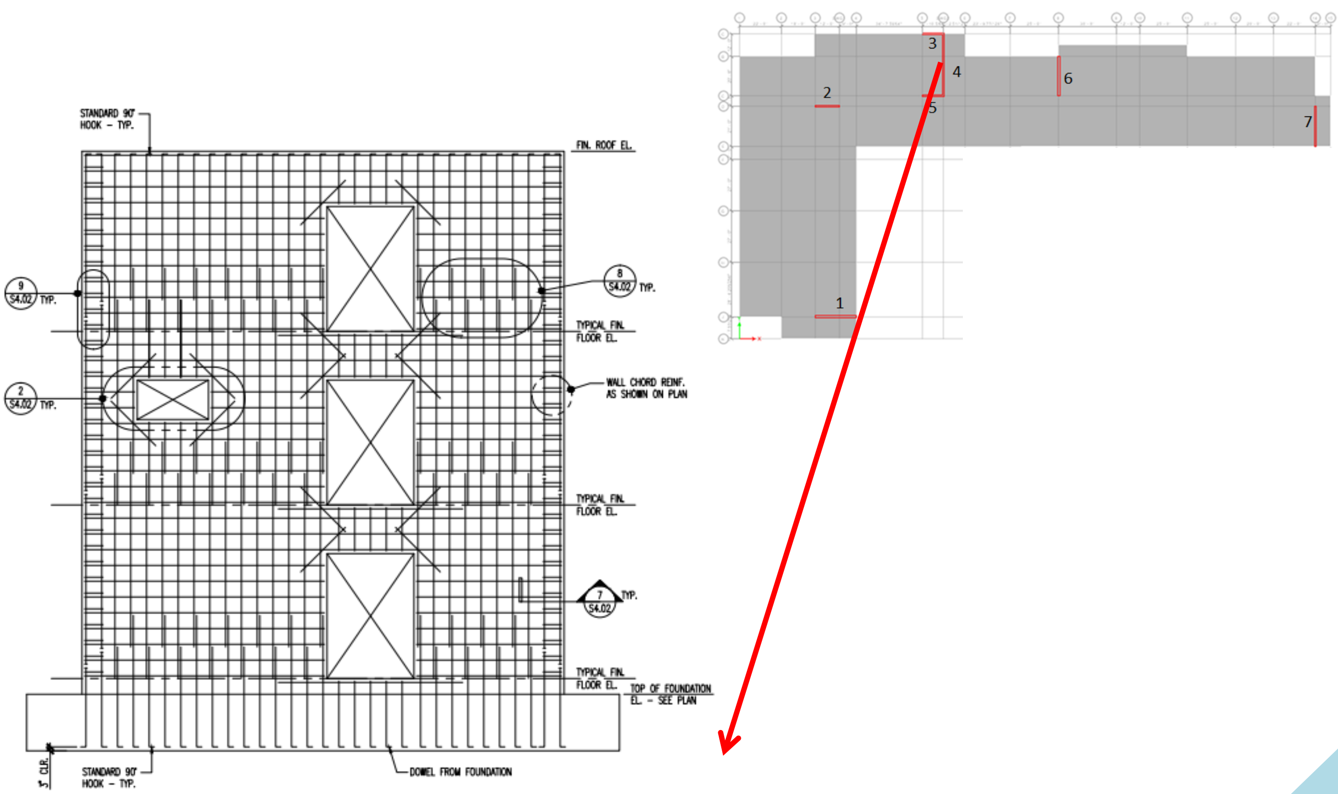


This diagram shows the shear distribution while under the maximum load case for shear wall 4. The drop of shear within the scub level is due to the transfer of some of the shear to the adjacent shear wall 3. This is very minimal shear transfer.

Member Strength Spot Check

Checking Shear Wall #4(Structural Wall Subjected to Lateral Wind Loads):

1. $1.4(D + F)$
2. $1.2(D + F + T) + 1.6(L + H) + 0.5(L_r \text{ or } S \text{ or } R)$
3. $1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (L \text{ or } 0.8W)$
4. $1.2D + 1.6W + L + 0.5(L_r \text{ or } S \text{ or } R)$
5. $1.2D + 1.0E + L + 0.2S$
6. $0.9D + 1.6W + 1.6H$
7. $0.9D + 1.0E + 1.6H$



Structural Diagram for TYP Shear Wall S4.02.1

Member Strength Spot Check

Shear Wall #4 Checks:

① initial check of wall reinforcement.

$$\rho_t = \frac{A_{v\,HORZ}}{hs^2}$$

$$\rho_t = \frac{2(0.44)}{12 \times 16} = 0.00458 \checkmark \text{ good}$$

max center to center spacing

$$\frac{l_w}{5} = \frac{30}{5} = 6'' \checkmark$$

$$\rho_l = \frac{A_{v\,vert}}{hs_1} = \frac{2(0.44)}{10 \times 18} = 0.00488 \checkmark \text{ good}$$

Check moment strength:

$$N_u = 760(0.9) = 684 \text{ kips}$$

$$\beta_1 = 0.85 \qquad f'c = 5000\text{psi} \qquad f_y = 60\text{ksi}$$

$$\omega = \rho_l \frac{f_y}{f'c} = 0.00488\left[\frac{60}{5}\right] = 0.058$$

$$\alpha = \frac{N_u}{h\,l_w f'c} = \frac{684}{12(30)(12)(5)} = 0.032$$

$$c = \left(\frac{\alpha + \omega}{0.85\beta_1 + 2\omega}\right) l_w$$

$$= \left(\frac{0.032 + 0.058}{0.85(0.85) + 2(0.058)}\right) 360 = 38.6\text{in}$$

$$A_{ST} = 2A_b\left(\frac{l_w}{s_1}\right) = 2(0.44)\left(\frac{360}{18}\right) = 17.6\text{in}^2$$

$$T = A_{ST} f_y \left(\frac{\ell_w - c}{\ell_w} \right)$$

$$= 17.6(60)\left(\frac{360 - 38.6}{360} \right) = 942.7 \text{ Kips}$$

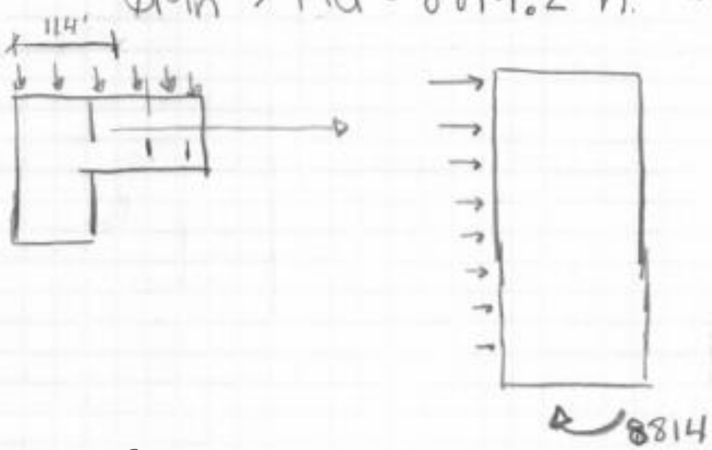
$$M_n = T\left(\frac{\ell_w}{2} \right) + N_u \left(\frac{\ell_w - c}{2} \right)$$

$$= 942.7\left(\frac{360}{2} \right) + 684\left(\frac{360 - 38.6}{2} \right)$$

$$= 23{,}300 \text{ kip foot}$$

ϕM_n [Strength reduction factor] $= 0.9 M_n = 20{,}970$ ft·k

$\phi M_n > M_u = 8814.2$ 'k. ✓good



Calculation for N_u

	Slab Thickness (ft)	Trib Area (sft)	Dead Floors (pcf)	Live Floors (psf)	Total Dead(kips)	Total Live		
Roof	0.667	165	150	30	16.50825	4.95		
7th Floor	0.667	165	150	50	16.50825	8.25		
6th Floor	0.667	165	150	50	16.50825	8.25		
5th Floor	0.667	165	150	50	16.50825	8.25		
4th Floor	0.667	165	150	50	16.50825	8.25		
3rd Floor	0.667	165	150	50	16.50825	8.25		
2nd Floor	0.667	165	150	50	16.50825	8.25		
1st Floor	0.667	165	150	100	16.50825	16.5		
Ground	0.667	165	150	100	16.50825	16.5		
Scub	0.667	165	150	150	16.50825	24.75		Total Weight (kips)
				Total Weight :	165.0825	112.2	481.5	758.7825

Shear wall Weight				
Height	Length	Width	pcf	Total
107	30	1	150	481.5

Calculation for Shear Wall #4 Base Moment M_u

	Trib Height	Trib Width	Trib Area	Wind load (psf)	Py (kip)	Height from Ground (ft)	
Roof	6.3	114	718.2	12.37	8.884134	115.02	
7th Floor	16.97	114	1934.58	12.06	23.3310348	102.35	
6th Floor	10.67	114	1216.38	11.58	14.0856804	91.687	
5th Floor	10.67	114	1216.38	11.17	13.5869646	81.01	
4th Floor	10.67	114	1216.38	10.73	13.0517574	70.34	
3rd Floor	10.67	114	1216.38	10.17	12.3705846	59.67	
2nd Floor	14.8	114	1687.2	9.53	16.079016	49	
1st Floor	16	114	1824	8.76	15.97824	30	
Ground	6.5	114	741	7.05	5.22405	17	
Scub	0	114	0	0	0	0	
						Moment (ft-k):	8814.17952

Check shear strength:

$$V_u = (1.6)(196.15) = 313.84\text{k}$$

$$\frac{h_w}{l_w} = \frac{107}{30} = 3.5 \quad \text{Slender wall}$$

$\lambda = 1.0$ NW concrete.

$$d = 0.8 l_w = 0.8(30) = 24' = 288''$$

$$V_c = 3.3\lambda\sqrt{f'c}\,hd + \frac{N_u d}{4 l_w}$$

$$= 3.3(1.0)(\sqrt{5000})(12)(288) + \frac{684(12)}{4(360)}$$

$$= 806 \text{ kips}$$

Member Strength Spot Check

$$M_{u\,\text{critical section}} = M_{u\,base} - V_{u\,base}\left(\frac{\ell_w}{2}\right)$$

$$= 8814 - 313.84\left(\frac{30}{2}\right)$$

$$= 4106.4 \text{ k-ft}$$

$$\frac{M_u}{V_u} = \frac{4106.4}{313.84} = 13.08 \text{ feet}$$

$$V_c = \left[0.6\lambda\sqrt{f'c} + \frac{\left(\ell_w\left(1.25\lambda\left(\sqrt{f'c}\right) + 0.2\frac{N_u}{\ell_w h}\right)\right)}{\frac{M_u}{V_u} - \frac{\ell_w}{2}}\right] hd$$

$$= \left[(12)(288)\right] \times \left[0.6\sqrt{5000} + \frac{\left(360(1.25\sqrt{5000}) + 0.2\left(\frac{694}{360(12)}\right)\right)}{157 - \frac{360}{2}}\right]$$

$$V_c = 463 \text{ kips} > 430 \text{ kips} \quad \text{max case*}$$

good ✓

Shear wall #4 passed both the moment and critical shear tests. It is designed with adequate strength to withstand the maximum load case.

Story Drift Checks

Story Displacement:

The maximum allowable story displacement according to ASCE7-05 is based off of the equation H/400.(128.02*12/400= 3.841”). The maximum allowable story drift ratio is 0.2.

Loading Case	Max Roof Story Displacement (Inches)	Max Displacement ASCE 7-05 (Inches)	Pass/Fail
Case 1: X-Direction	1.138	3.841	Pass
Case 1: Y-Direction	0.557	3.841	Pass
Case 2: X Positive Eccentricity	1.138	3.841	Pass
Case 2: X Negative Eccentricity	1.059	3.841	Pass
Case 2: Y Positive Eccentricity	1.597	3.841	Pass
Case 2: Y Negative Eccentricity	0.579	3.841	Pass
Case 3: X and Y (75%) Reduction	1.116	3.841	Pass
Case 4: X+ and Y+	0.689	3.841	Pass
Case 4: X- and Y-	0.691	3.841	Pass
Case 4: X+ and Y-	0.789	3.841	Pass
Case 4: X- and Y+	0.762	3.841	Pass
Seismic X plus Moment	3.80	3.841	Pass
Seismic Y plus Moment	1.62	3.841	Pass

Loading Case	Drift Ratio (Roof)		Maximum Drift Ratio (ASCE7-05)	Pass/Fail
	X	Y		
Case 1: X-Direction	0.001	0.000	0.02	Pass
Case 1: Y-Direction	0.000	0.005	0.02	Pass
Case 2: X Positive Eccentricity	0.001	0.0002	0.02	Pass
Case 2: X Negative Eccentricity	0.0009	0.001	0.02	Pass
Case 2: Y Positive Eccentricity	0.0006	0.002	0.02	Pass
Case 2: Y Negative Eccentricity	0.0002	0.001	0.02	Pass
Case 3: X and Y (75%) Reduction	0.001	0.006	0.02	Pass
Case 4: X+ and Y+	0.006	0.0005	0.02	Pass
Case 4: X- and Y-	0.0085	0.007	0.02	Pass
Case 4: X+ and Y-	0.007	0.002	0.02	Pass
Case 4: X- and Y+	0.007	0.002	0.02	Pass

Maximum Overturning Moment and Resisting Moment:

Maximum moments for each case were evaluated at the base of the structure. To get the resisting moment, the weight of the building at the center of mass was multiplied by its shortest moment arm to the exterior of the foundation. Then it was divided by a safety factor of 1.5. The new calculated factor of safety is about 7.9.

Load Case	Maximum Overturning Moment (Ft-K)		Absulute Value
	X	Y	
Case 1: X-Direction	0	-25433.8	25433.8
Case 1: Y-Direction	27991.6	0	27991.6
Case 2: X Positive Eccentricity	0	-19103.7	19103.7
Case 2: X Negative Eccentricity	0	-19103.6	19103.6
Case 2: Y Positive Eccentricity	39056.9	0	39056.9
Case 2: Y Negative Eccentricity	39056.9	0	39056.9
Case 3: X and Y (75%) Reduction	36032.3	-19070	36032.3
Case 4: X+ and Y+	4797.5	-12620.6	12620.6
Case 4: X- and Y-	4797.5	-12620.6	12620.6
Case 4: X+ and Y-	4797.5	-12620.6	12620.6
Case 4: X- and Y+	4797.5	-12620.6	12620.6
Seismic X plus Moment	0	-62805.4	62805.4
Seismic Y plus Moment	62805.4	0	62805.4

Weight of Building (kips)	Moment arm (ft)	F.O.S.	Resisting Moment
39056.9	18.94	1.5	493158.4573

Max Overturn Moment	Resisting Moment	F.O.S	
62805.4	493158.4573	7.852166491	

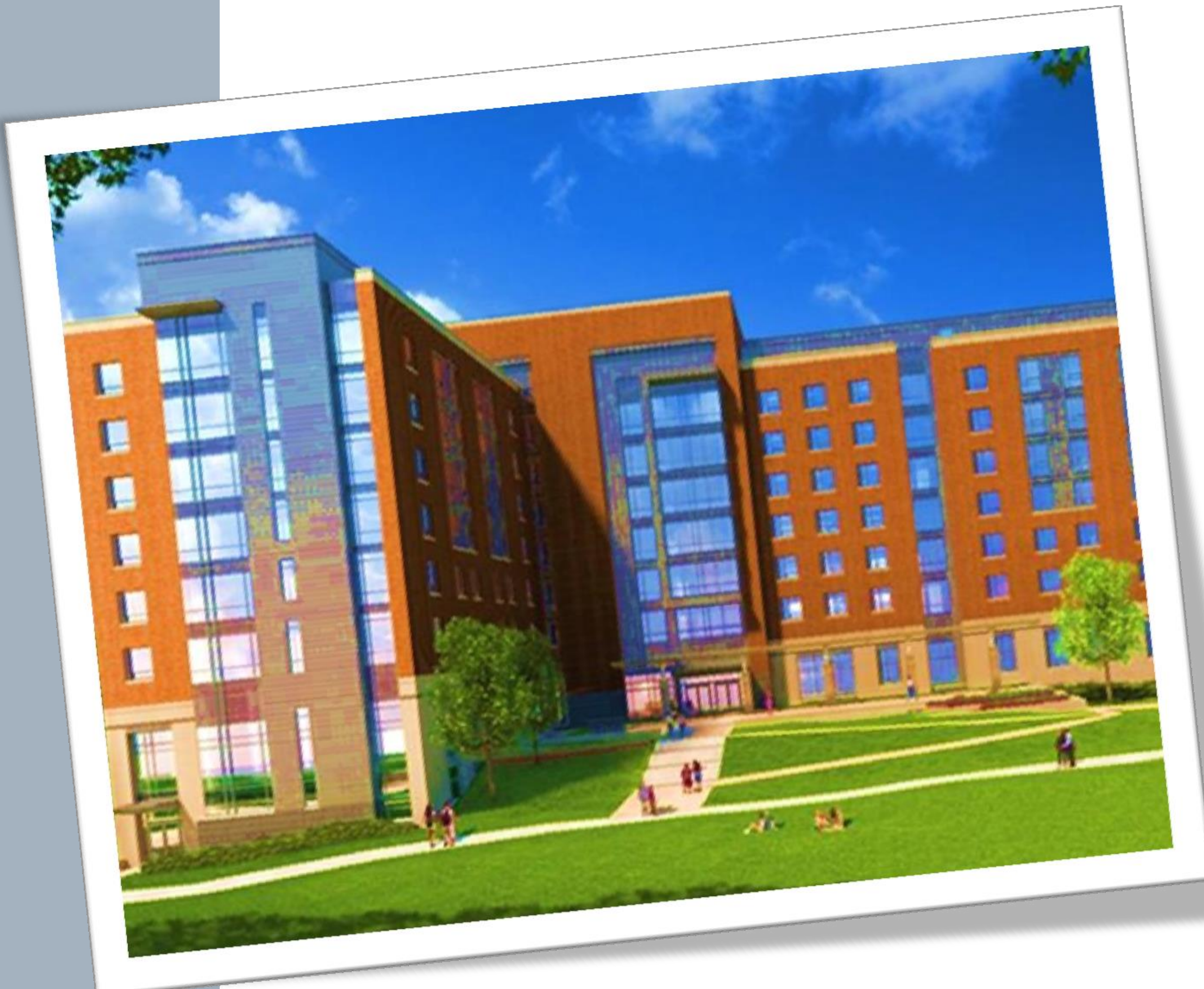
Foundations Impact:

The foundation was checked for overturning moment and found that the resisting moment was about 493158 Ft-Kips. The resisting moment is much larger than the overturning moment therefore the foundation is found to be sufficient to resist the maximum load case. More in depth analysis of the foundations would need to be checked for settlement and uplift.

Conclusion:

This report included the analysis of Prince Frederick Hall's lateral force resisting system under wind and seismic conditions. Using ASCE7-05, wind and seismic loads were calculated based on location and specific site information. Those loads from tech 2 were used on the ETABS model specifically created for this technical report. These loads were calculated from the code used to design the building. The building passed checks for deflections, shear and overturning moment. This was done by looking specifically at the worst case loading scenario and the controlling shear wall. Shear wall number 4 spot checks show that all the shear walls were designed to withstand the maximum forces on the building,

APPENDIX TECH REPORT 4



Prince Frederick Hall

The University of Maryland

College Park, MD

Christopher Cioffi

AE Senior Thesis- Structural

Advisor: Heather Sustersic

Center of Rigidity/ Center of Mass

Realitive Rigidity										
Shear Wall 1										
(Level Below)	Height(Ft)	Height (In)	Thickness(In)	Length(Ft)	E	R	Total Rigidity/Floor	Relative Rigidity		
Ground	19	228	12	20	3600000	1354720	7270888.56	18.63211549		
First	13	156	12	20	3600000	1735253	9662768.298	17.95813897		
Second	19	228	12	20	3600000	1354720	7270888.56	18.63211549		
Third	10.67	128.04	12	20	3600000	1844408	10472385.05	17.61210866		
Fourth	10.67	128.04	12	20	3600000	1844408	10472385.05	17.61210866		
Fifth	10.67	128.04	12	20	3600000	1844408	10472385.05	17.61210866		
Sixth	10.67	128.04	12	20	3600000	1844408	10472385.05	17.61210866		
Seventh	10.67	128.04	12	20	3600000	1844408	10472385.05	17.61210866		
Roof	12.67	152.04	12	20	3600000	1752475	9785446.71	17.90899276		

Shear Wall 2										
Ground	19	228	12	16	3600000	917300.2	7270888.56	12.61606677		
First	13	156	12	16	3600000	1292000	9662768.298	13.37091308		
Second	19	228	12	16	3600000	917300.2	7270888.56	12.61606677		
Third	10.67	128.04	12	16	3600000	1413664	10472385.05	13.49896808		
Fourth	10.67	128.04	12	16	3600000	1413664	10472385.05	13.49896808		
Fifth	10.67	128.04	12	16	3600000	1413664	10472385.05	13.49896808		
Sixth	10.67	128.04	12	16	3600000	1413664	10472385.05	13.49896808		
Seventh	10.67	128.04	12	16	3600000	1413664	10472385.05	13.49896808		
Roof	12.67	152.04	12	16	3600000	1310732	9785446.71	13.39470291		

Shear Wall 3										
Ground	19	228	12	10	3600000	344201.2	7270888.56	4.733962894		
First	13	156	12	10	3600000	621010.9	9662768.298	6.426842169		
Second	19	228	12	10	3600000	344201.2	7270888.56	4.733962894		
Third	10.67	128.04	12	10	3600000	747699.6	10472385.05	7.139726153		
Fourth	10.67	128.04	12	10	3600000	747699.6	10472385.05	7.139726153		
Fifth	10.67	128.04	12	10	3600000	747699.6	10472385.05	7.139726153		
Sixth	10.67	128.04	12	10	3600000	747699.6	10472385.05	7.139726153		
Seventh	10.67	128.04	12	10	3600000	747699.6	10472385.05	7.139726153		
Roof	12.67	152.04	12	10	3600000	638988.8	9785446.71	6.529991573		
Shear Wall 4										
Ground	19	228	12	30	3600000	2475865	7270888.56	34.05175841		
First	13	156	12	30	3600000	2809492	9662768.298	29.07543745		
Second	19	228	12	30	3600000	2475865	7270888.56	34.05175841		
Third	10.67	128.04	12	30	3600000	2891586	10472385.05	27.61153479		
Fourth	10.67	128.04	12	30	3600000	2891586	10472385.05	27.61153479		
Fifth	10.67	128.04	12	30	3600000	2891586	10472385.05	27.61153479		
Sixth	10.67	128.04	12	30	3600000	2891586	10472385.05	27.61153479		
Seventh	10.67	128.04	12	30	3600000	2891586	10472385.05	27.61153479		
Roof	12.67	152.04	12	30	3600000	2822800	9785446.71	28.84691536		
Shear Wall 5										
Ground	19	228	12	10	3600000	344201.2	7270888.56	4.733962894		
First	13	156	12	10	3600000	621010.9	9662768.298	6.426842169		
Second	19	228	12	10	3600000	344201.2	7270888.56	4.733962894		
Third	10.67	128.04	12	10	3600000	747699.6	10472385.05	7.139726153		
Fourth	10.67	128.04	12	10	3600000	747699.6	10472385.05	7.139726153		
Fifth	10.67	128.04	12	10	3600000	747699.6	10472385.05	7.139726153		
Sixth	10.67	128.04	12	10	3600000	747699.6	10472385.05	7.139726153		
Seventh	10.67	128.04	12	10	3600000	747699.6	10472385.05	7.139726153		
Roof	12.67	152.04	12	10	3600000	638988.8	9785446.71	6.529991573		

Center of Rigidity/ Center of Mass

Shear Wall 6										
Ground	19	228	12	16	3600000	917300.2	7270888.56	12.61606677		
First	13	156	12	16	3600000	1292000	9662768.298	13.37091308		
Second	19	228	12	16	3600000	917300.2	7270888.56	12.61606677		
Third	10.67	128.04	12	16	3600000	1413664	10472385.05	13.49896808		
Fourth	10.67	128.04	12	16	3600000	1413664	10472385.05	13.49896808		
Fifth	10.67	128.04	12	16	3600000	1413664	10472385.05	13.49896808		
Sixth	10.67	128.04	12	16	3600000	1413664	10472385.05	13.49896808		
Seventh	10.67	128.04	12	16	3600000	1413664	10472385.05	13.49896808		
Roof	12.67	152.04	12	16	3600000	1310732	9785446.71	13.39470291		

Shear Wall 7										
Ground	19	228	12	16	3600000	917300.2	7270888.56	12.61606677		
First	13	156	12	16	3600000	1292000	9662768.298	13.37091308		
Second	19	228	12	16	3600000	917300.2	7270888.56	12.61606677		
Third	10.67	128.04	12	16	3600000	1413664	10472385.05	13.49896808		
Fourth	10.67	128.04	12	16	3600000	1413664	10472385.05	13.49896808		
Fifth	10.67	128.04	12	16	3600000	1413664	10472385.05	13.49896808		
Sixth	10.67	128.04	12	16	3600000	1413664	10472385.05	13.49896808		
Seventh	10.67	128.04	12	16	3600000	1413664	10472385.05	13.49896808		
Roof	12.67	152.04	12	16	3600000	1310732	9785446.71	13.39470291		

Center of Rigidity

Ground Floor

	Distance From Zero Reference		Relative Rigidity						
Element	X (Ft)	Y (Ft)	Rx	Ry	RxY	RyX			
Shear Wall 1	52	12	18.63211549	0	223.5853859	0			
Shear Wall 2	42	127	12.61606677	0	1602.24048	0			
Shear Wall 3	108	160	4.733962894	0	757.434063	0			
Shear Wall 4	112	150	0	34.05175841	0	3813.796942			
Shear Wall 5	108	135	4.733962894	0	639.0849906	0			
Shear Wall 6	177	144	0	12.61606677	0	2233.043818			
Shear Wall 7	312	117	0	12.61606677	0	3936.212832			
								X bar r	Y bar r
Totals			40.71610805	59.28389195	3222.344919	9983.053593		168.394	79.14177

First Floor

	Distance From Zero Reference		Relative Rigidity						
Element	X (Ft)	Y (Ft)	Rx	Ry	RxY	RyX			
Shear Wall 1	52	12	17.95813897	0	215.4976676	0			
Shear Wall 2	42	127	13.37091308	0	1698.105961	0			
Shear Wall 3	108	160	6.426842169	0	1028.294747	0			
Shear Wall 4	112	150	0	29.07543745	0	3256.448994			
Shear Wall 5	108	135	6.426842169	0	867.6236928	0			
Shear Wall 6	177	144	0	13.37091308	0	2366.651615			
Shear Wall 7	312	117	0	13.37091308	0	4171.724882			
								X bar r	Y bar r
Totals			44.18273639	55.81726361	3809.522069	9794.825491		175.4802	86.22196

Second Floor

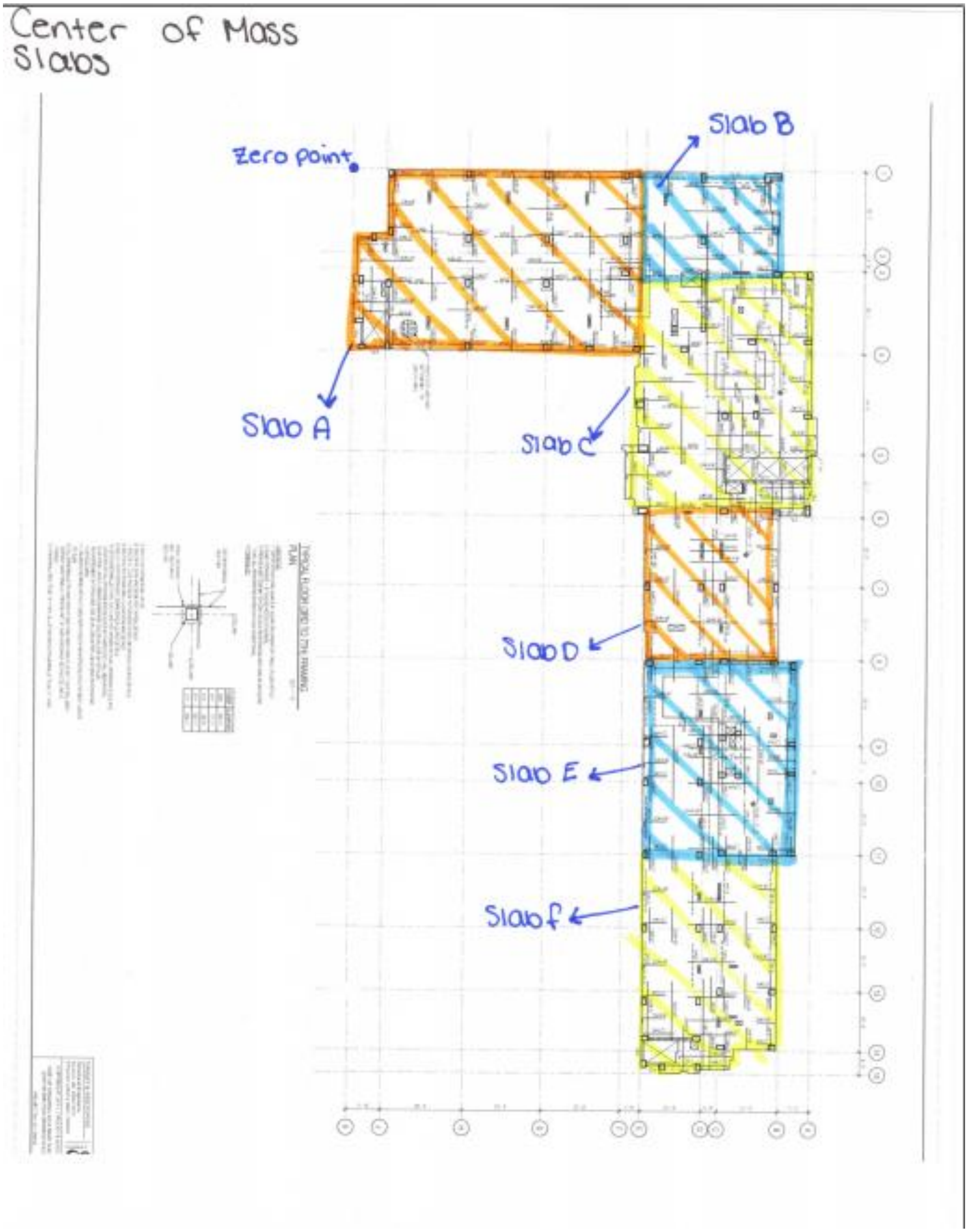
	Distance From Zero Reference		Relative Rigidity						
Element	X (Ft)	Y (Ft)	Rx	Ry	RxY	RyX			
Shear Wall 1	52	12	18.63211549	0	223.5853859	0			
Shear Wall 2	42	127	12.61606677	0	1602.24048	0			
Shear Wall 3	108	160	4.733962894	0	757.434063	0			
Shear Wall 4	112	150	0	34.05175841	0	3813.796942			
Shear Wall 5	108	135	4.733962894	0	639.0849906	0			
Shear Wall 6	177	144	0	12.61606677	0	2233.043818			
Shear Wall 7	312	117	0	12.61606677	0	3936.212832			
								X bar r	Y bar r
Totals			40.71610805	59.28389195	3222.344919	9983.053593		168.394	79.14177

Center of Rigidity/ Center of Mass

Third To Seventh Floor (Heights are consistant)									
	Distance From Zero Reference		Relative Rigidity						
Element	X (Ft)	Y (Ft)	Rx	Ry	RxY	RyX			
Shear Wall 1	52	12	17.61210866	0	211.3453039	0			
Shear Wall 2	42	127	13.49896808	0	1714.368946	0			
Shear Wall 3	108	160	27.61153479	0	4417.845566	0			
Shear Wall 4	112	150	0	27.61153479	0	3092.491896			
Shear Wall 5	108	135	7.139726153	0	963.8630306	0			
Shear Wall 6	177	144	0	13.49896808	0	2389.317351			
Shear Wall 7	312	117	0	13.49896808	0	4211.678042			
								X bar r	Y bar r
Totals			65.86233768	54.60947095	7307.422847	9693.487289		177.5056	110.9499

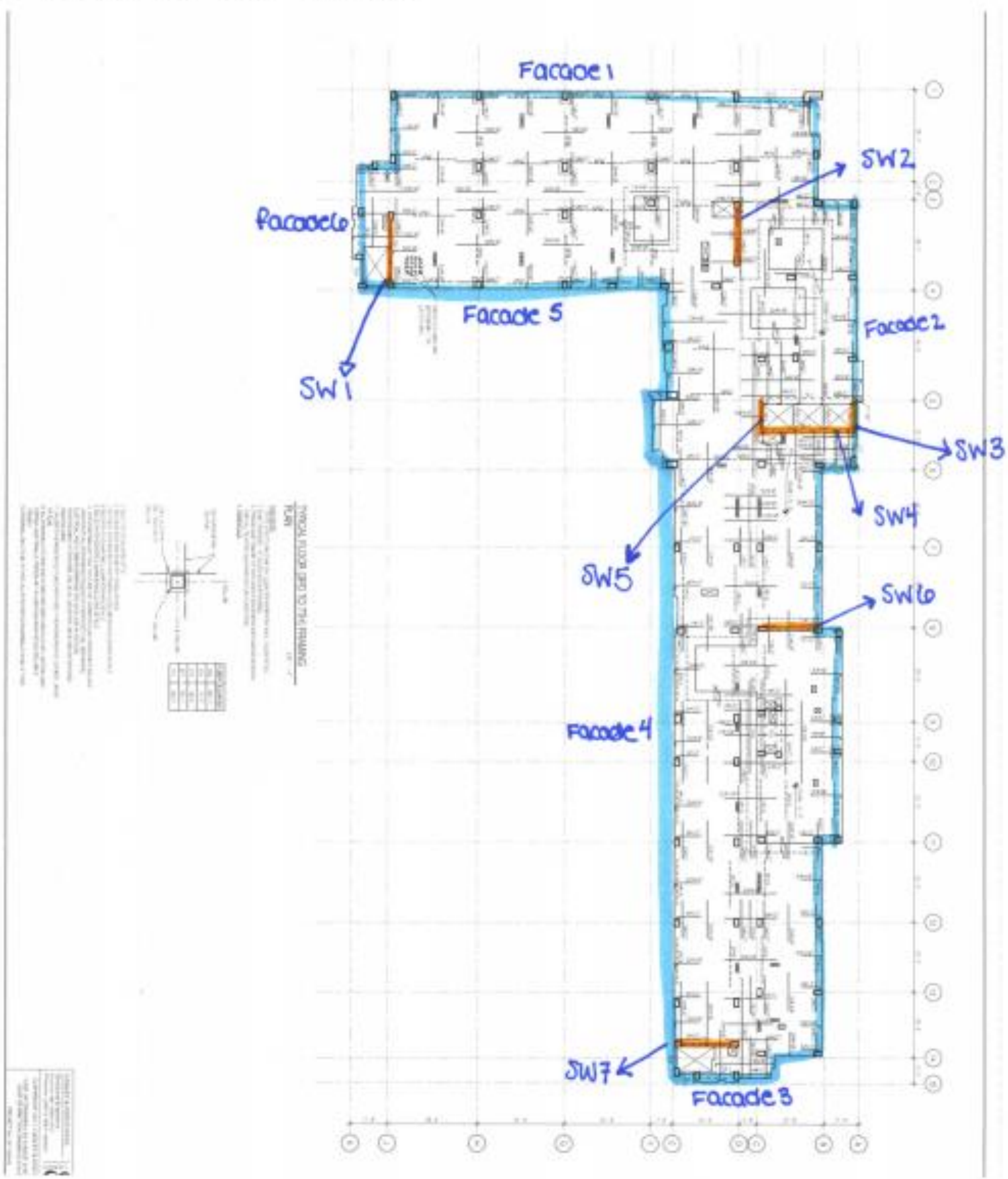
Roof									
	Distance From Zero Reference		Relative Rigidity						
Element	X (Ft)	Y (Ft)	Rx	Ry	RxY	RyX			
Shear Wall 1	52	12	17.90899276	0	214.9079131	0			
Shear Wall 2	42	127	13.39470291	0	1701.12727	0			
Shear Wall 3	108	160	6.529991573	0	1044.798652	0			
Shear Wall 4	112	150	0	28.84691536	0	3230.85452			
Shear Wall 5	108	135	6.529991573	0	881.5488624	0			
Shear Wall 6	177	144	0	13.39470291	0	2370.862416			
Shear Wall 7	312	117	0	13.39470291	0	4179.147309			
								X bar r	Y bar r
Totals			44.36367882	55.63632118	3842.382697	9780.864244		175.8	86.611

Center of Rigidity/ Center of Mass



Center of Rigidity/ Center of Mass

CENTER OF MASS
-SHEAR Walls and Facade



Center of Rigidity/ Center of Mass

Center of Mass For Typical Floors 3-7

Façades

Element (CMU)	Wall Length (Ft)	Wall Height(Ft)	Thickness (Ft)	Unit Weight(Lbs/cFt)	Weight (k)	Distance From Zero Reference X (ft)	Y (ft)	Wx	Wy
Façade 1	160	10.67	1	86	146.8192	0	80	0	11745.54
Façade 2	312	10.67	1	86	286.29744	156	160	44662.4	45807.59
Façade 4	249	10.67	1	86	228.48738	187.5	112	42841.38	25590.59
Façade 5	112	10.67	1	86	102.77344	63	56	6474.727	5755.313
Element(Glass)	Wall Length (Ft)	Wall Height(Ft)		Unit Weight(Lbs/sft)	Weight (k)	X (ft)	Y (ft)	Wx	Wy
Façade 3	48	10.67		9	4.60944	312	136	1438.145	626.8838
Façade 6	63	10.67		9	6.04989	31.5	0	190.5715	0
				Total:	775.03679		Total:	95607.23	89525.91

Slab

Element	Floor Area Length (Ft)	Floor Area Width(Ft)	Thickness (Ft)	Unit Weight(Lbs/cFt)	Weight (k)	Distance From Zero Reference X (ft)	Y (ft)	Wx	Wy
A	100	65	0.667	150	650.325	32.5	50	21135.56	32516.25
B	35	65	0.667	150	227.61375	17.5	126.5	3983.241	28793.14
C	87	65	0.667	150	565.78275	62.71	132.5	35480.24	74966.21
D	50	65	0.667	150	325.1625	142.3	132.5	46270.62	43084.03
E	70	65	0.667	150	455.2275	201.1	132.5	91546.25	60317.64
F	80	65	0.667	150	520.26	273	132.5	142031	68934.45
				Total:	2744.3715		Total:	340446.9	308611.7

Shear Walls

Element	Length (Ft)	Width(Ft)	Height	Unit Weight(Lbs/cFt)	Weight (k)	Distance From Zero Reference X (ft)	Y (ft)	Wx	Wy
Shear Wall 1	20	1	10.67	150	32.01	52	12	1664.52	384.12
Shear Wall 2	16	1	10.67	150	25.608	42	127	1075.536	3252.216
Shear Wall 3	10	1	10.67	150	16.005	108	160	1728.54	2560.8
Shear Wall 4	30	1	10.67	150	48.015	112	150	5377.68	7202.25
Shear Wall 5	10	1	10.67	150	16.005	108	135	1728.54	2160.675
Shear Wall 6	16	1	10.67	150	25.608	177	144	4532.616	3687.552
Shear Wall 7	16	1	10.67	150	25.608	312	117	7989.696	2996.136
				Total:	188.859		Total:	24097.13	22243.75

Center of Mass

∑W	∑Wx	Wy	X bar	Y bar
3708.267	460151.2	420381.4	124.0879	113.3633

ETABS OUTPUT CONTROLLING LOAD: CASE 2 Y-

Story	Shear Wall	P (kip)	V2 (kip)	V3 (kip)	T (kip-ft)	M2 (kip-ft)	M3 (kip-ft)
Main Roof	Shear Wall 1	0	1.379	-0.036	-2.9048	-0.4566	17.4679
Main Roof	Shear Wall 2	0	-0.34	-0.022	-1.691	-0.2844	-4.3081
Main Roof	Shear Wall 5	13.087	7.561	-3.651	-19.8652	-5.7658	22.2499
Main Roof	Shear Wall 3	-13.997	-8.492	-3.606	-19.6206	-5.7027	-30.0889
Main Roof	Shear Wall 4	0.91	51.407	0.098	-11.8264	0.2599	130.7305
Main Roof	Shear Wall 6	0	-3.163	0.007	-2.7701	0.0834	-40.074
Main Roof	Shear Wall 7	0	-0.639	0.003	-2.8374	0.0438	-8.0978
7th Floor	Shear Wall 1	0	-0.475	-0.001	-2.9388	-0.4724	12.4016
7th Floor	Shear Wall 2	0	-0.052	-0.001	-1.7088	-0.2933	-4.8673
7th Floor	Shear Wall 5	37.564	13.654	-2.956	-17.3211	-4.512	31.3991
7th Floor	Shear Wall 3	-37.608	-12.969	-2.883	-16.9354	-4.4034	-38.1538
7th Floor	Shear Wall 4	0.044	120.332	0.155	-15.5749	0.3843	568.3989
7th Floor	Shear Wall 6	0	0.328	0.002	-2.8021	0.101	-36.5724
7th Floor	Shear Wall 7	0	-0.38	0.001	-2.8705	0.0574	-12.1504
6th Floor	Shear Wall 1	0	-3.923	0.044	-2.9758	-0.0049	-29.4534
6th Floor	Shear Wall 2	0	0.595	0.028	-1.7272	0.0002	1.4864
6th Floor	Shear Wall 5	76.342	21.338	-2.773	-16.1707	-4.1477	43.2521
6th Floor	Shear Wall 3	-72.522	-17.908	-2.688	-15.7139	-4.0098	-35.7944
6th Floor	Shear Wall 4	-3.82	180.358	0.117	-21.1952	0.1988	1236.301
6th Floor	Shear Wall 6	0	6.813	-0.01	-2.8368	-0.0039	36.1199
6th Floor	Shear Wall 7	0	-0.271	-0.005	-2.9063	-0.0012	-15.0445
5th Floor	Shear Wall 1	0	-6.915	0.065	-2.9764	0.6888	-103.2398
5th Floor	Shear Wall 2	0	1.12	0.036	-1.7263	0.3801	13.4403
5th Floor	Shear Wall 5	129.315	29.138	-2.594	-15.3391	-3.6823	59.1081
5th Floor	Shear Wall 3	-118.659	-23.28	-2.486	-14.7472	-3.4998	-27.4754
5th Floor	Shear Wall 4	-10.656	238.994	0.089	-28.5393	-0.124	2120.6684
5th Floor	Shear Wall 6	0	12.475	-0.016	-2.8371	-0.1792	169.2237
5th Floor	Shear Wall 7	0	-0.28	-0.01	-2.9067	-0.1089	-18.0294
4th Floor	Shear Wall 1	0	-9.119	0.107	-2.9269	1.8289	-200.5446
4th Floor	Shear Wall 2	0	1.427	0.069	-1.6959	1.1215	28.6714
4th Floor	Shear Wall 5	195.995	36.602	-2.393	-14.4543	-3.0025	77.0254
4th Floor	Shear Wall 3	-176.039	-28.866	-2.227	-13.5356	-2.7266	-14.5029
4th Floor	Shear Wall 4	-19.956	296.516	0.08	-38.6967	-0.5131	3217.7673
4th Floor	Shear Wall 6	0	16.605	-0.023	-2.7894	-0.4273	346.3974
4th Floor	Shear Wall 7	0	-0.317	-0.013	-2.8581	-0.2468	-21.4138
3rd Floor	Shear Wall 1	0	-10.423	0.061	-2.8217	2.4759	-311.7548
3rd Floor	Shear Wall 2	0	1.527	0.024	-1.6313	1.3753	44.9603
3rd Floor	Shear Wall 5	275.044	43.903	-2.92	-16.8503	-3.6977	100.6625
3rd Floor	Shear Wall 3	-243.733	-34.761	-2.605	-15.1241	-3.1882	-5.1595
3rd Floor	Shear Wall 4	-31.311	353.934	0.277	-51.97	-0.5854	4551.8723
3rd Floor	Shear Wall 6	0	19.397	-0.018	-2.6889	-0.6216	553.3656
3rd Floor	Shear Wall 7	0	-0.622	-0.012	-2.7553	-0.3777	-28.0476
2nd Floor	Shear Wall 1	0	-14.784	0.133	-2.5199	4.9953	-592.6566
2nd Floor	Shear Wall 2	0	2.08	0.094	-1.4573	3.1698	84.4814
2nd Floor	Shear Wall 5	446.694	53.496	-1.906	-11.7302	-1.518	143.1209
2nd Floor	Shear Wall 3	-386.22	-40.16	-1.324	-8.4879	-0.5484	34.6352
2nd Floor	Shear Wall 4	-60.474	419.154	0.68	-69.5152	-0.732	7344.9088
2nd Floor	Shear Wall 6	0	28.581	-0.031	-2.4009	-1.2037	1096.4124
2nd Floor	Shear Wall 7	0	-0.713	-0.018	-2.4604	-0.7134	-41.5933
1st Floor	Shear Wall 1	0	-26.943	-0.063	-2.0435	4.1804	-942.9198
1st Floor	Shear Wall 2	0	4.685	-0.087	-1.1866	2.0397	145.3844
1st Floor	Shear Wall 5	583.147	61.737	1.355	5.2336	4.2443	173.8307
1st Floor	Shear Wall 3	-489.837	-38.537	2.039	8.9319	5.409	114.1697
1st Floor	Shear Wall 4	-93.31	463.597	0.977	-65.8729	-1.4287	9502.925
1st Floor	Shear Wall 6	0	53.458	-0.014	-1.9489	-1.39	1791.3705
1st Floor	Shear Wall 7	0	-0.19	-0.02	-1.9962	-0.9772	-44.0606
Ground Floor	Shear Wall 1	0	-45.8	1.147	-1.4174	25.9752	-1813.1271
Ground Floor	Shear Wall 2	0	9.44	0.712	-0.7403	15.5751	324.745
Ground Floor	Shear Wall 5	771.893	56.104	10.069	44.3261	28.1393	153.0156
Ground Floor	Shear Wall 3	-617.688	-22.052	10.645	46.7825	29.2525	477.3994
Ground Floor	Shear Wall 4	-154.205	430.065	-1.944	-127.738	-12.8878	12875.2904
Ground Floor	Shear Wall 6	0	87.829	-0.236	-1.334	-5.8816	3460.1141
Ground Floor	Shear Wall 7	0	4.523	-0.128	-1.3754	-3.408	41.8803