Appendix B – Lateral Loads

B.1 Wind Loads

Locality Input			
Basic Wind Speed	V =	85	mph
Wind Directionality Factor	K_d =	0.85	
Exposure	(B, C, or D)	C	
Enclosure	(E, PE, O)	E	
Building Category		II	
Importance Factor	I =	1	
Mean Roof Height	h =	95.54	feet
Parapet Height		4	feet
L (plan north-south)		194.33	feet
L (plan east-west)		219.83	feet
Rigid Structure?	Y/N	Y	
Roof Angle	θ =	0	
Topographic Factor	Kzt =	1	

Table 6-2			
Exposure		C	
α		9.5	
z_g		900	feet
a^		0.11	
b^		1	
$\bar{\alpha}$		0.15	
b		0.65	
c		0.2	
l		500	
ϵ		0.2	
z_{min}		15	feet

Gust Effect Factor		
z		57.32
L_z		558
Q (plan north-south)		0.83
Q (plan east-west)		0.91
I_z		0.18
g_Q		3.4
g_v		3.4
G (plan north-south)		0.85
G (plan east-west)		0.88

Internal Pressure Coefficients	
+ GCpi	- GCpi
0.18	-0.18

Figure 52 – Wind Input

Wall Pressure Coefficients					
Surface	L/B	Cp		Actual L/B	Cp
Windward Wall	All Values	0.8			0.80
Leeward Wall	0-1	-0.5	North-South	0.88	-0.50
	2	-0.3			
	>=4	-0.2			
	0-1	-0.5	East-West	1.13	-0.47
	2	-0.3			
	>=4	-0.2			
Side Wall	All Values	-0.7			-0.70

Roof Pressure Coefficients							
Wind Direction	h/L	Horizontal Distance from Windward Edge	Cp	Actual h/L	Actual Horizontal Distance (feet)	Interpolate Between Cp	
North to South	<= 0.5	0 to h/2	- 0.9, - 0.18	0.49	<= 48	-0.90	-0.18
		h/2 to h	- 0.9, - 0.18		48 96	-0.90	-0.18
		h to 2h	- 0.5, - 0.18		96 191	-0.50	-0.18
		> 2h	- 0.3, - 0.18		> 191	-0.30	-0.18
	>= 1.0	0 to h/2	- 1.3, - 0.18		<= 48	-1.30	-0.18
		> h/2	- 0.7, - 0.18		> 48	-0.70	-0.18
East to West	<= 0.5	0 to h/2	- 0.9, - 0.18	0.43	<= 48	-0.90	-0.18
		h/2 to h	- 0.9, - 0.18		48 96	-0.90	-0.18
		h to 2h	- 0.5, - 0.18		96 191	-0.50	-0.18
		> 2h	- 0.3, - 0.18		> 191	-0.30	-0.18
	>= 1.0	0 to h/2	- 1.3, - 0.18		<= 48	-1.30	-0.18
		> h/2	- 0.7, - 0.18		> 48	-0.70	-0.18

Figure 53 – Wind Pressure Coefficients

Table 6-3					
Height Above Ground Level, z	Exposure C Case 1 & 2	K_z	K_h	q_h	q_z
0-15	0.85	0.85	1.25	19.71	13.35
20	0.90	0.90	1.25	19.71	14.18
25	0.94	0.95	1.25	19.71	14.86
30	0.98	0.98	1.25	19.71	15.44
40	1.04	1.04	1.25	19.71	16.41
50	1.09	1.09	1.25	19.71	17.20
60	1.13	1.14	1.25	19.71	17.87
70	1.17	1.17	1.25	19.71	18.46
80	1.21	1.21	1.25	19.71	18.98
90	1.24	1.24	1.25	19.71	19.46
100	1.26	1.27	1.25	19.71	19.90
120	1.31	1.32	1.25	19.71	20.68
140	1.36	1.36	1.25	19.71	21.36
160	1.39	1.40	1.25	19.71	21.97

Figure 54 – Wind q Factor Calculation

MWFRS Design Pressures						
Walls						
	Wind Direction	**Pressures (lb/ft²)**				
Leeward	North/South		P =	-8.34	±	3.55
	East/West		P =	-8.26	±	3.55
Side			P =	-12.20	±	3.55
	Wind Direction	**Height (feet)**	**Pressures (lb/ft²)**			
Windward	North-South	0-15	P =	9.03	±	3.55
		20	P =	9.60	±	3.55
		25	P =	10.06	±	3.55
		30	P =	10.45	±	3.55
		40	P =	11.10	±	3.55
		50	P =	11.64	±	3.55
		60	P =	12.09	±	3.55
		70	P =	12.49	±	3.55
		80	P =	12.85	±	3.55
		90	P =	13.17	±	3.55
		100	P =	13.47	±	3.55
		120	P =	13.99	±	3.55
		140	P =	14.45	±	3.55
		160	P =	14.87	±	3.55
	East-West	0-15	P =	9.44	±	3.55
		20	P =	10.03	±	3.55
		25	P =	10.52	±	3.55
		30	P =	10.93	±	3.55
		40	P =	11.61	±	3.55
		50	P =	12.17	±	3.55
		60	P =	12.64	±	3.55
		70	P =	13.06	±	3.55
		80	P =	13.43	±	3.55
		90	P =	13.77	±	3.55
		100	P =	14.08	±	3.55
		120	P =	14.63	±	3.55
		140	P =	15.11	±	3.55
		160	P =	15.54	±	3.55

Figure 55 – MWFRS Design Pressures

MWFRS Design Pressures										
Roof										
	Wind Direction	Distance From Windward Wall (feet)	Pressures (lb/ft^2)							
Windward	North-South	0 to 34	P =	-15.00	±	3.55	or	-0.64	±	3.55
		34 to 68	P =	-15.00	±	3.55	or	-0.64	±	3.55
		68 to 137	P =	-8.34	±	3.55	or	-0.64	±	3.55
		over 137	P =	-5.00	±	3.55	or	-0.64	±	3.55
	East-West	0 to 34	P =	-15.69	±	3.55	or	-0.64	±	3.55
		34 to 68	P =	-15.69	±	3.55	or	-0.64	±	3.55
		68 to 137	P =	-8.72	±	3.55	or	-0.64	±	3.55
		over 137	P =	-5.23	±	3.55	or	-0.64	±	3.55

Parapet							
	GC_{pn}	K_p	q_p	Pressures (lb/ft2)			
Windward	1.5	1.26	19.88	P =	29.82	±	3.55
Leeward	-1	1.26	19.88	P =	-19.88	±	3.55

Windscreen							
height =	12	feet					
	GC_{pn}	K_w	q_w	Pressures (lb/ft2)			
Windward	1.5	1.29	20.20	P =	30.31	±	3.55
Leeward	-1	1.29	20.20	P =	-20.20	±	3.55

Figure 56 – MWFRS Design Pressures

Total Wind Forces and Overturning Moments - East-West Wind

Height Above Grade (ft)		Wind Pressure (Windward)	Wind Pressure (Leeward)	Total Wind Pressure	Level	T.O.S. Height	Total Area per Level and Pressure (in^2)	(ft^2)	Force	Total Level Force F (k)	Overturning Moment M (k-ft)
0	6.77	9.44	-8.91	18.35	1	0	0	0	0.00	0.00	0.0
6.77	15	9.44	-8.91	18.35	2	162.5	224188	1556.9	28.57	48.90	662.1
15	20	10.52	-8.91	19.43			139920	971.67	18.88		
20	20.38	10.93	-8.91	19.84			10494	72.875	1.45		
20.38	25	10.93	-8.91	19.84	3	326.5	129426	898.79	17.83	53.88	1466.1
25	30	11.61	-8.91	20.52			139920	971.67	19.94		
30	34.04	11.61	-8.91	20.52			113102	785.43	16.12		
34.04	40	11.61	-8.91	20.52	4	490.5	166738	1157.9	23.76	55.33	2261.79
40	47.71	12.17	-8.91	21.08			215710	1498	31.57		
47.71	50	12.17	-8.91	21.08	5	654.5	64130	445.35	9.39	57.14	3116.78
50	60	12.64	-8.91	21.55			279840	1943.3	41.89		
60	61.38	13.06	-8.91	21.97			38478	267.21	5.87		
61.38	70	13.06	-8.91	21.97	6	818.5	241362	1676.1	36.83	58.72	4005.06
70	75.04	13.43	-8.91	22.34			141086	979.76	21.89		
75.04	80	13.43	-8.91	22.34	7	982.5	138754	963.57	21.53	61.93	5070.78
80	89.17	13.77	-8.91	22.68			256520	1781.4	40.40		
89.17	90	13.77	-8.91	22.68	Roof	1146.5	23320	161.94	3.67	32.53	3107.67
90	96.46	14.08	-8.91	22.99			180730	1255.1	28.85		
96.46	100	14.08	-8.91	22.99	Roof - Stair	1146.5	6120	42.5	0.98	58.39	3187.72
100	109.5	14.63	-8.91	23.54			12750	88.542	2.08		
96.46	108.5	30.31	-20.20	50.51	Windscreen		43350	301.04	15.21		
96.46	108.5	30.31	-20.20	50.51			2550	17.708	0.89		
96.46	100.5	29.82	-19.88	49.70	Parapet		113664	789.33	39.23		
									Totals	426.83	22878.0

Figure 57 – Wind Forces and Overturning Moments - E-W Wind

Total Wind Forces and Overturning Moments - North-South Wind

Height Above Grade				Wind Pressure (Windward)	Wind Pressure (Leeward)	Total Wind Pressure	Level	T.O.S. Height	Total Area per Level and Pressure		Force	Total Level Force F (k)	Overturning Moment M (k-ft)
Min	ft	Max	ft						in^2	ft^2			
0	0	81.3	6.77	9.03	-8.34	17.37	1	0	0	0	0.00	0.00	0.0
81.3	6.77	163	13.5	9.03	-8.34	17.37	2	162.5	214337	1488	25.86	52.66	713.1
163	13.5	180	15	9.03	-8.34	17.37			46165	320.6	5.57		
180	15	240	20	9.60	-8.34	17.94			158280	1099	19.71		
240	20	245	20.4	10.06	-8.34	18.40			11871	82.44	1.52		
245	20.4	300	25	10.06	-8.34	18.40	3	326.5	146409	1017	18.70	56.03	1524.5
300	25	327	27.2	10.45	-8.34	18.79			69907	485.5	9.12		
327	27.2	360	30	10.45	-8.34	18.79			83756	581.6	10.93		
360	30	409	34	11.10	-8.34	19.44			127943	888.5	17.28		
409	34	480	40	11.10	-8.34	19.44	4	490.5	188617	1310	25.47	59.32	2424.70
480	40	491	40.9	11.64	-8.34	19.98			27699	192.4	3.84		
491	40.9	573	47.7	11.64	-8.34	19.98			216316	1502	30.01		
573	47.7	600	50	11.64	-8.34	19.98	5	654.5	72545	503.8	10.06	61.28	3342.25
600	50	655	54.5	12.09	-8.34	20.43			143771	998.4	20.40		
655	54.5	720	60	12.09	-8.34	20.43			172789	1200	24.52		
720	60	737	61.4	12.49	-8.34	20.83			43527	302.3	6.30		
737	61.4	819	68.2	12.49	-8.34	20.83	6	818.5	216316	1502	31.29	60.91	4154.24
819	68.2	840	70	12.49	-8.34	20.83			48473	336.6	7.01		
840	70	901	75	12.85	-8.34	21.19			153597	1067	22.60		
901	75	960	80	12.85	-8.34	21.19	7	982.5	156961	1090	23.09	66.44	5439.84
960	80	983	81.9	13.17	-8.34	21.51			59355	412.2	8.87		
983	81.9	1065	88.7	13.17	-8.34	21.51			230825	1603	34.48		
1065	88.7	1080	90	13.17	-8.34	21.51	Roof	1147	26380	183.2	3.94	34.90	3334.33
1080	90	1147	95.5	13.47	-8.34	21.81	Roof		204445	1420	30.96		
1147	95.5	1303	109	13.47	-8.34	21.81	Roof - Stair	1147	4392	30.5	0.67	87.39	4771.06
1147	95.5	1291	108	30.31	-20.20	50.51	Windscreen		120960	840	42.43		
1147	95.5	1195	99.6	29.82	-19.88	49.70	Parapet		128352	891.3	44.30		
											Totals	478.92	25704.0

Figure 58 – Wind Forces and Overturning Moments – N-S Wind

Wind Story Drift									
Story	Item	Load	Point		Story Height	Story Drift		Allowable Drift	Conclusion
			X	Y	Z	X	Y		
			in	in	in	in	in	in	
ROOF	Max Drift X	DSTLD1	780	-142	1146.5	6.3E-05		0.41	OK
ROOF	Max Drift Y	DSTLD1	2638.5	1464	1146.5		5.2E-05	0.41	OK
7TH	Max Drift X	DSTLD1	780	-142	982.5	6.2E-05		0.41	OK
7TH	Max Drift Y	DSTLD1	2638.5	1464	982.5		5.7E-05	0.41	OK
6TH	Max Drift X	DSTLD1	780	-142	818.5	0.00005		0.41	OK
6TH	Max Drift Y	DSTLD1	2638.5	1464	818.5		4.9E-05	0.41	OK
5TH	Max Drift X	DSTLD1	780	-142	654.5	3.7E-05		0.41	OK
5TH	Max Drift Y	DSTLD1	2638.5	1464	654.5		3.5E-05	0.41	OK
4TH	Max Drift X	DSTLD1	780	-142	490.5	2.7E-05		0.41	OK
4TH	Max Drift Y	DSTLD1	2638.5	1464	490.5		0.00003	0.41	OK
3RD	Max Drift X	DSTLD1	780	-142	326.5	1.5E-05		0.41	OK
3RD	Max Drift Y	DSTLD1	2638.5	1464	326.5		0.00002	0.41	OK
2ND	Max Drift X	DSTLD1	1260	384	162.5	5E-06		0.40625	OK
2ND	Max Drift Y	DSTLD1	2638.5	1464	162.5		1.5E-05	0.40625	OK
ROOF	Max Drift X	DSTLD2	780	-142	1146.5	9.7E-05		0.41	OK
ROOF	Max Drift Y	DSTLD2	2638.5	1464	1146.5		0.00008	0.41	OK
7TH	Max Drift X	DSTLD2	780	-142	982.5	9.6E-05		0.41	OK
7TH	Max Drift Y	DSTLD2	2638.5	1464	982.5		8.9E-05	0.41	OK
6TH	Max Drift X	DSTLD2	780	-142	818.5	7.7E-05		0.41	OK
6TH	Max Drift Y	DSTLD2	2638.5	1464	818.5		7.6E-05	0.41	OK
5TH	Max Drift X	DSTLD2	780	-142	654.5	5.7E-05		0.41	OK
5TH	Max Drift Y	DSTLD2	2638.5	1464	654.5		5.5E-05	0.41	OK
4TH	Max Drift X	DSTLD2	780	-142	490.5	4.2E-05		0.41	OK
4TH	Max Drift Y	DSTLD2	2638.5	1464	490.5		4.8E-05	0.41	OK
3RD	Max Drift X	DSTLD2	780	-142	326.5	2.4E-05		0.41	OK
3RD	Max Drift Y	DSTLD2	2638.5	1464	326.5		3.1E-05	0.41	OK
2ND	Max Drift X	DSTLD2	1260	384	162.5	7E-06		0.40625	OK
2ND	Max Drift Y	DSTLD2	2638.5	1464	162.5		2.4E-05	0.40625	OK

Figure 59 – Wind Story Drift

The spreadsheet above represents only a portion of the actual drift checks performed for American Eagle Outfitters: Quantum III. Over 20 load cases were taken into account resulting in a spreadsheet over 300 cells long. See book for full checks.

B.2 Seismic Loads

BUILDING IRREGULARITIES - HORIZ. PG 1 SMPJ

① TORSIONAL IRREGULARITIES

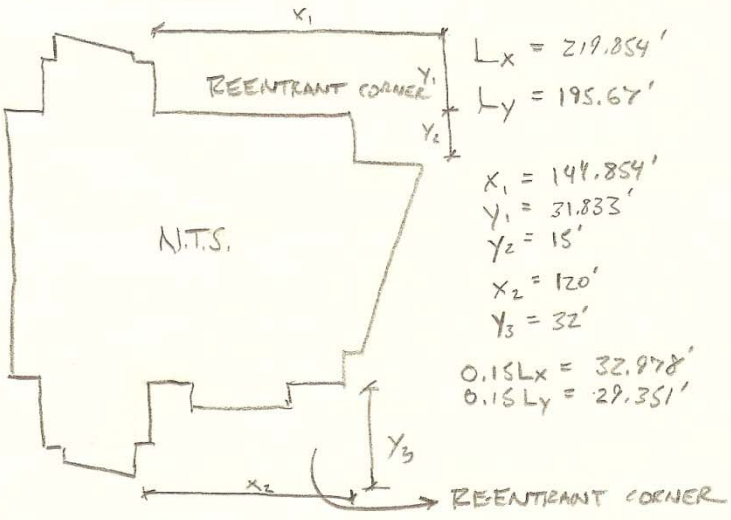
- LOAD CASE WITH MAX ROTATION: QUAKEXY1
  RZ = -0.00045 RAD
- BUILDING CORNER DISPLACEMENTS:
  ELEVATIONS:
  - NORTH: LEFT = 3.625344" RIGHT = 2.436467" (Y)
  - EAST: TOP = 2.570868" BOTTOM = 2.570868" (X)
  - SOUTH: LEFT = 3.625344" RIGHT = 2.436467 (Y)
  - WEST: SAME AS EAST
- EAST TORSIONAL IRREGULARITY:

$$\frac{\Delta_1 + \Delta_2}{2} = \frac{3.625344 + 2.436467}{2} = 3.03091"$$

$$\frac{3.625344}{3.03091} = 1.1961 < 1.2 \quad \text{OK} \checkmark \quad \text{BUT CLOSE}$$

∴ NO TORSIONAL IRREGULARITY

② RE-ENTRANT CORNER IRREGULARITIES



$L_x = 219.854'$
$L_y = 195.67'$

$X_1 = 149.854'$
$Y_1 = 31.833'$
$Y_2 = 15'$
$X_2 = 120'$
$Y_3 = 32'$

$0.15L_x = 32.978'$
$0.15L_y = 29.351'$

BUILDING IRREGULARITIES PG 2 SMPJ

② CONTINUED

∴ RE-ENTRANT CORNERS ARE PRESENT

↳ SEIS. DESIGN FORCES INCREASED BY 25% FOR CONNECTIONS OF DIAPHRAGMS TO VERTICAL ELEMENTS AND TO COLLECTORS & CONNECTIONS OF COLLECTORS TO VERTICAL ELEMENTS

③ DIAPHRAGM DISCONTINUITY

∴ DOES NOT EXIST BY INSPECTION

④ & ⑤ OUT OF PLANE OFFSETS & NONPARALLEL SYSTEMS

∴ IRREGULARITIES DO NOT EXIST BY INSPECTION

BUILDING IRREGULARITIES - VERT. PG 1 SMPJ

① STIFFNESS SOFT STORY

STIFFNESS INCREASES SIGNIFICANTLY AS YOU PROGRESS DOWN THE BUILDING

∴ NO IRREGULARITY BY INSPECTION

②-⑤ IRREGULARITIES DO NOT EXIST BY INSPECTION

SEISMIC CALCULATIONS

SMPS PG 1

- OCCUPANCY CAT. : CATEGORY II — PEOPLE ARE NOT CONGREGATED
- SPECTRAL RESPONSE ACCELERATION:

$S_S = 1.522$
$S_1 = 0.6$ (USGS 12TH ST. OAKLAND, CA 94607)

- SITE CLASS: ASSUME D (DATA UNKNOWN)
- SITE CLASS FACTORS: $F_a = 1.0$, $F_v = 1.5$

$S_{MS} = F_a S_S = 1.0(1.522) = 1.522$
$S_{M1} = F_v S_1 = 1.5(0.6) = 0.9$

$S_{DS} = \frac{2}{3} S_{MS} = 1.015$
$S_{D1} = \frac{2}{3} S_{M1} = 0.6$

- IMPORTANCE FACTOR: $I = 1.0$
- SEISMIC DESIGN CATEGORY:

$S_1 > 0.75$ ∴ CATEGORY E (ASCE 7-05 11.6)

- BUILDING FRAME SYSTEM: SPECIAL STEEL CONC FRAMES

$R = 6$
$\Omega_0 = 2$
$C_d = 5$

FOR CATEGORY E: $h < 160'$
ACTUAL HT = 96.458' < 160' OK

- FIND T

$C_t = 0.02$, $x = 0.75$ } ALL OTHER STR. SYSTEMS

$T_a = 0.02(96.458 + 13.25)^{0.75} = 0.678$

SEISMIC CALCULATIONS

SMTPJ PG 2

$S_{D1} = 0.6 \quad \therefore C_u = 1.4$

$T \leq C_u T_a = 1.4(0.678) = \boxed{0.949 \text{ sec CONTROLS}}$

$T_{ETABS} = 1.1371 \text{ sec} \quad (3\text{-}27\text{-}08)$

- FIND C_S

$$C_{S,ACT} = \frac{S_{DS}}{R/I} = \frac{1.015}{6/1} = 0.169$$

$$C_S \leq \frac{S_{D1}}{T(R/I)} = \frac{0.6}{0.949(6/1)} = 0.1054 \qquad T = 0.949 << T_L = 8$$

$T_L = 8$ FIG 22-16 (OAKLAND, CA)

$C_S > 0.01$

$$C_S > \frac{0.5S_1}{R/I} = \frac{0.5(0.6)}{6/1.0} = 0.05$$

$\therefore$ MAX | 0.01, 0.05, 0.169 BUT MIN | 0.1054 ← CONTROLS, 0.169

$\therefore C_S = 0.1054$

• SEISMIC: PERMITTED ANALYTICAL PROCEDURES PG 1 SMTJ

SEISMIC DESIGN CATEGORY E

STRUCTURE HAS HORIZONTAL IRREGULARITY (2) REENTRANT CORNER

⇒ IRREGULARITIES PERMITTED:

HORIZ: 2, 3, 4, & 5 OK ✓

VERT: 4, 5a, & 5b OK ✓

⇒ $T < 3.5T_S$

$T_S = S_{D1}/S_{DS} = \frac{0.6}{1.015} = 0.591$ s

$3.5T_S = 2.069$ s

$T_{ETABS} = 1.2249$ s $< 3.5T_S$ OK ✓

$T_{CONTROLLING} = 0.949$s $< 3.5T_S$ OK ✓

∴ EQUIVALENT LATERAL FORCE ANALYSIS PERMITTED

• RHO (ρ) FACTOR CHECK

↳ BRACED FRAMES

↳ NO TORSIONAL IRREGULARITIES PRESENT

↳ REMOVAL OF SINGLE BRACE OR CONNECTION DOES NOT RESULT IN 33% REDUCTION OF STRENGTH

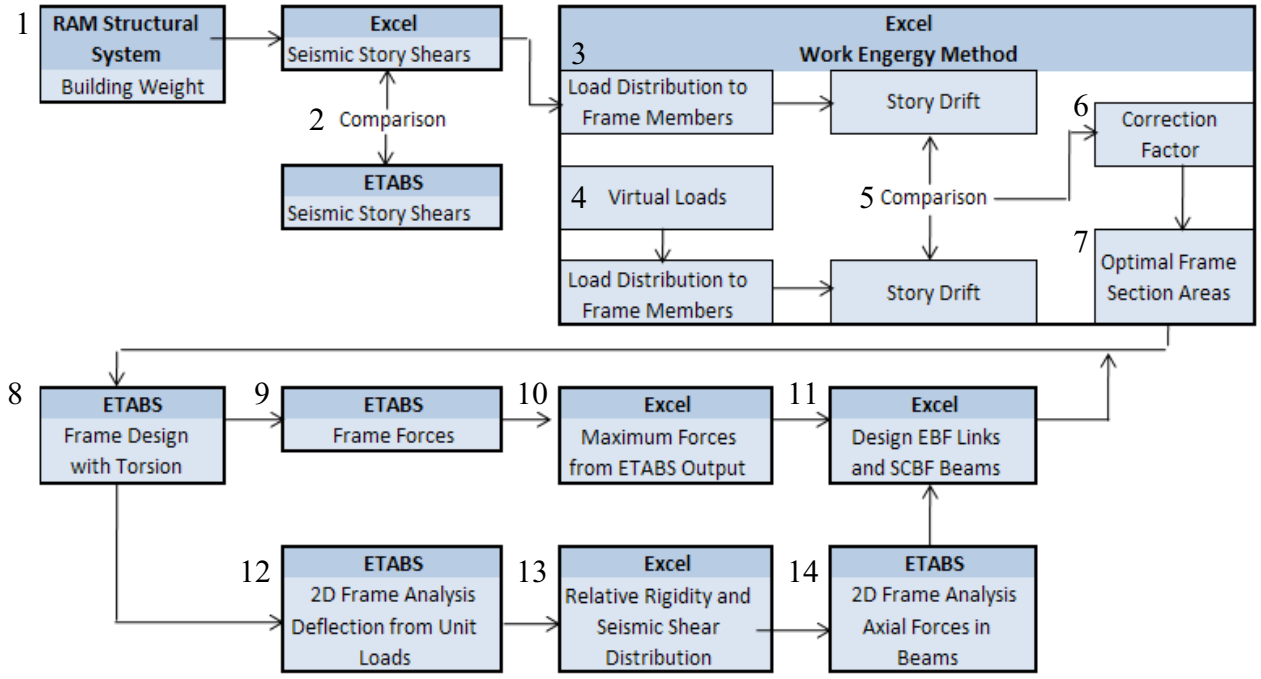


Figure 60 – Seismic Design Methodology

Building Weights Per Floor			RamSTEEL		7-Apr-08			
Total Level Weight k	Story Weight k		Area	Location X	Location Y			
1420.2	1381.5	42.904	229954	106.84	92.3	11.04	9.84	None
	38.7	1.201	7960	45	75.75	---	---	None
3139.5	3128	97.144	559007	94.57	88.33	10.95	9.87	None
	11.5	0.358	26	212.2	134.46	---	---	None
3136	3124.5	97.033	558801	94.54	88.35	10.95	9.87	None
	11.5	0.358	26	212.19	134.46	---	---	None
3140.5	3129	97.175	559521	94.54	88.33	10.95	9.87	None
	11.5	0.358	26	212.19	134.46	---	---	None
3143	3131.5	97.25	560020	94.54	88.36	10.95	9.87	None
	11.5	0.358	26	212.19	134.46	---	---	None
3147.9	3136.4	97.403	560907	94.55	88.36	10.95	9.87	None
	11.5	0.358	26	212.19	134.46	---	---	None
3154.8	3143.3	97.617	562234	94.54	88.33	10.95	9.87	None
	11.5	0.358	26	212.19	134.46	---	---	None

Figure 61 – RAM Building Weights (1)

Building Masses							
		Weight	Mass	Floor Area	Mass / Area		
		k	$(k\ s^2)/in$	ETABS in^2			
Roof		1420.2	3.6793	4142910	8.8809E-07	8.8809E-07	1.2788E-04
	7	3139.5	8.1334	4142910	1.9632E-06	1.9632E-06	2.8270E-04
	6	3136	8.1244	4142910	1.9610E-06	1.9610E-06	2.8238E-04
	5	3140.5	8.1360	4142910	1.9638E-06	1.9638E-06	2.8279E-04
	4	3143	8.1425	4142910	1.9654E-06	1.9654E-06	2.8302E-04
	3	3147.9	8.1552	4142910	1.9685E-06	1.9685E-06	2.8346E-04
	2	3154.8	8.1731	4142910	1.9728E-06	1.9728E-06	2.8408E-04

Figure 62 – Building Masses (1)

Seismic Base Shear										
Level	h_x (in)	h_x (ft)	h_x^k	W	$W * h_x^k$	C_{vx}	F	V	M	$\sum M$
Roof	1146.50	95.54	265.917	1420	377655.3	0.146	311.34	311.34	29745.96	29745.96
7	982.50	81.88	220.117	3140	691057.6	0.267	569.71	881.05	46645.01	93290.02
6	818.50	68.21	176.009	3136	551963	0.213	455.04	1336.09	31037.52	124327.5
5	654.50	54.54	133.852	3141	420361.3	0.162	346.55	1682.64	18901.26	143228.8
4	490.50	40.88	94.022	3143	295511.5	0.114	243.62	1926.26	9957.992	153186.8
3	326.50	27.21	57.121	3148	179809.8	0.069	148.24	2074.49	4033.249	157220
2	162.50	13.54	24.307	3155	76683.93	0.030	63.22	2137.71	856.0834	158076.1
1	0.00	0.00	0.000	0	0	0.000	0.00	2137.71	0	158076.1
			Totals	20281.9	2593043	1	2137.71		141177.1	

		Cs	W (kips)		Total Force	
$V = C_s * W =$		0.1054	20281.9	=	2137.71226	k

T	k
0.50	1
0.95	1.2245
2.50	2

	Lower Bound	Exact	Upper Bound	Use
Cs =	0.05	0.169	0.1054	0.1054

Figure 63 – Seismic Base Shear (2)

Seismic Base Shear Comparison			
Level	Hand Calculated k	ETABS k	Percent Difference
Roof	311.34	327.1	4.82
7	881.05	917.92	4.02
6	1336.09	1391.37	3.97
5	1682.64	1755.67	4.16
4	1926.26	2013.2	4.32
3	2074.49	2170.67	4.43
2	2137.71	2238.14	4.49

Figure 64 – Seismic Base Shear Comparison (2)

Y Direction				
Frame	Load	Deflection	Stiffness	Relative Stiffness
	k	in	k/in	%
NT-B	10	0.120841	82.75337	0.12015
NT-C	10	0.051038	195.9324	0.284476
NT-D	10	0.120841	82.75337	0.12015
VT-A	10	0.059777	167.2884	0.242888
VT-C	10	0.062492	160.0205	0.232335
		Total	688.7481	

X Direction				
Frame	Load	Deflection	Stiffness	Relative Stiffness
	k	in	k/in	%
VT-B	10	0.055156	181.3039	0.319817
VT-D	10	0.051868	192.7971	0.340091
VT-E	10	0.051868	192.7971	0.340091
		Total	566.8981	

Figure 65 – Preliminary Frame Relative Rigidities (3)

These deflections were determined through iterations in ETABS. Using the following spreadsheet to determine optimal areas, then inputting to ETABS, the author found actual deflections. Then optimal areas were found again based on more accurate seismic shears.

Braced Frame:	D & E	Relative Stiffness =	0.3400913	Cd =	5

Story Shears - X Direction

Level	Height ft	Floor Height ft	Total Force k	Force per Level k	Story Force k	Story Shear k
Roof	96.46	14.58333	311.34	311.34	105.88	105.88
7	81.88	13.6667	881.05	569.710035	193.75	299.64
6	68.21	13.6667	1336.09	455.040022	154.76	454.39
5	54.54	13.6667	1682.64	346.547148	117.86	572.25
4	40.88	13.6667	1926.26	243.620603	82.85	655.10
3	27.21	13.6667	2074.49	148.235783	50.41	705.52
2	13.54	13.5417	2137.71	63.2184642	21.50	727.02

Member Loads

Level	Height ft	Floor Height ft	Story Force k	Story Shear k	Story Moment ft-k	Axial Forces					
						Actual			Virtual		
						Column k	Girder k	Brace k	Column k	Girder k	Brace k
Roof	96.46	14.58	105.88	105.88	1544.14282	0	52.94204	73.84	0	0	0.697355
7	81.88	13.67	193.75	299.64	4095.05559	51.471427	149.8187	202.68	0.486111	0.5	0.676411
6	68.21	13.67	154.76	454.39	6210.04757	187.97328	227.1963	307.36	0.941668	0.5	0.676411
5	54.54	13.67	117.86	572.25	7820.77278	394.97487	286.1251	387.08	1.397224	0.5	0.676411
4	40.88	13.67	82.85	655.10	8953.10311	655.66729	327.5518	443.12	1.852781	0.5	0.676411
3	27.21	13.67	50.41	705.52	9642.09194	954.10406	352.7586	477.22	2.308338	0.5	0.676411
2	13.54	13.54	21.50	727.02	9845.04948	1275.5071	363.5086	489.73	2.763894	0.5	0.673612

Bay Length, L =	30 ft
Virtual Load	1.00 k

Member Areas and Strains

Level	Height ft	Floor Height ft	Areas			Strain		
			Column	Girder	Brace	Column	Girder	Brace
Roof	96.46	14.58	0.00	0.00	7.18	0.0000	0.0000	0.0891
7	81.88	13.67	5.00	8.66	11.71	0.0582	0.1074	0.1453
6	68.21	13.67	13.30	10.66	14.42	0.0799	0.1323	0.1790
5	54.54	13.67	23.49	11.96	16.18	0.0951	0.1485	0.2009
4	40.88	13.67	34.85	12.80	17.31	0.1064	0.1589	0.2149
3	27.21	13.67	46.93	13.28	17.97	0.1150	0.1649	0.2230
2	13.54	13.54	59.37	13.48	18.16	0.1204	0.1674	0.2255

Elastic Modulus	Columns	29000 ksi
	Braces	ksi

Rho's and Deflections										
Level	Height ft	Floor Height ft	Rho					Deflection		
			Column	Sum Column	Girder	Brace	Sum	Floor in	Total in	Amplified in
Roof	96.46	14.58	0.0000	0.0026	0.000000	0.000710	0.003265	0.5714	4.4520	22.26
7	81.88	13.67	0.0003	0.0026	0.000655	0.001199	0.004409	0.7231	3.8807	19.40
6	68.21	13.67	0.0004	0.0022	0.000807	0.001476	0.004515	0.7405	3.1575	15.79
5	54.54	13.67	0.0005	0.0018	0.000905	0.001657	0.004350	0.7135	2.4170	12.09
4	40.88	13.67	0.0006	0.0013	0.000969	0.001773	0.004001	0.6562	1.7036	8.52
3	27.21	13.67	0.0006	0.0007	0.001005	0.001840	0.003514	0.5763	1.0474	5.24
2	13.54	13.54	0.0007	0.0000	0.001030	0.001869	0.002899	0.4711	0.4711	2.36

Optimum Areas									
Level	Height ft	Floor Height ft	Area			Correction Factor	Optimal Areas		
			Column	Girder	Brace		Column	Girder	Brace
Roof	96.46	14.58	0.00	0.00	7.18	0.96	0.00	0.00	6.90
7	81.88	13.67	5.00	8.66	11.71	0.96	4.81	8.32	11.26
6	68.21	13.67	13.30	10.66	14.42	0.96	12.79	10.25	13.86
5	54.54	13.67	23.49	11.96	16.18	0.96	22.59	11.50	15.56
4	40.88	13.67	34.85	12.80	17.31	0.96	33.51	12.31	16.65
3	27.21	13.67	46.93	13.28	17.97	0.96	45.13	12.77	17.28
2	13.54	13.54	59.37	13.48	18.16	0.96	57.09	12.96	17.46

Target Building Deflection	0.0200
Calculated Building Deflection	0.0192
Correction Factor	0.96

0.020hsx =	23.15

Figure 66 – Frame Preliminary Sizing
(3-7)

Insert ETABS Point Deflections For EBF Below This								
Story	Point	Load	UX	UY	UZ	RX	RY	RZ
STORY7	11	LATERAL	0.1602	0	0.0207	0	0.00012	0
STORY6	11	LATERAL	0.1351	0	0.0198	0	0.00013	0
STORY5	11	LATERAL	0.1109	0	0.0183	0	0.00013	0
STORY4	11	LATERAL	0.0851	0	0.0152	0	0.00013	0
STORY3	11	LATERAL	0.0606	0	0.0127	0	0.00013	0
STORY2	11	LATERAL	0.0361	0	0.0088	0	0.00013	0
STORY1	11	LATERAL	0.0132	0	0.005	0	0.00011	0

Insert ETABS Point Deflections For SCBF Below This								
Story	Point	Load	UX	UY	UZ	RX	RY	RZ
STORY7	3	LATERAL	0.3083	0	0.0251	0	0.00028	0
STORY6	3	LATERAL	0.2549	0	0.025	0	0.0003	0
STORY5	3	LATERAL	0.2031	0	0.024	0	0.0003	0
STORY4	3	LATERAL	0.1521	0	0.0211	0	0.00028	0
STORY3	3	LATERAL	0.1033	0	0.0179	0	0.00026	0
STORY2	3	LATERAL	0.0596	0	0.0127	0	0.00022	0
STORY1	3	LATERAL	0.0234	0	0.0074	0	0.00018	0

Figure 67 – Actual Frame Deflection Data from ETABS (13)

Deflections shown in Figure 67 are based on actual model data from ETABS. First, optimal areas of members were determined; then inputting similar wide flange shapes into ETABS found actual deflections. In turn, these deflections produced more accurate relative rigidities, and therefore more accurate optimal areas.

Frame Relative Rigidities													
Level	Load			Deflection			Rigidity			Total	Relative Rigidity (Percent)		
	VT-A	NT-B	NT-D	VT-A	NT-B	NT-D	VT-A	NT-B	NT-D		VT-A	NT-B	NT-D
Roof	10	10	10	0.1602	0.3083	0.3083	62.42	32.44	32.44	127.29	0.4904	0.2548	0.2548
7	10	10	10	0.1351	0.2549	0.2549	74.02	39.23	39.23	152.48	0.4854	0.2573	0.2573
6	10	10	10	0.1109	0.2031	0.2031	90.17	49.24	49.24	188.64	0.4780	0.2610	0.2610
5	10	10	10	0.0851	0.1521	0.1521	117.51	65.75	65.75	249.00	0.4719	0.2640	0.2640
4	10	10	10	0.0606	0.1033	0.1033	165.02	96.81	96.81	358.63	0.4601	0.2699	0.2699
3	10	10	10	0.0361	0.0596	0.0596	277.01	167.79	167.79	612.58	0.4522	0.2739	0.2739
2	10	10	10	0.0132	0.0234	0.0234	757.58	427.35	427.35	1612.28	0.4699	0.2651	0.2651
						Total	1543.72	878.59	878.59				

Distribution of Seismic Shears				
Level	Seismic Force	Force VT-A	NT-B	NT-D
Roof	311.34	**152.67**	**79.33**	**79.33**
7	569.71	**276.56**	**146.58**	**146.58**
6	455.04	**217.51**	**118.77**	**118.77**
5	346.55	**163.54**	**91.50**	**91.50**
4	243.62	**112.10**	**65.76**	**65.76**
3	148.24	**67.03**	**40.60**	**40.60**
2	63.22	**29.71**	**16.76**	**16.76**

Figure 68 – Frame Actual Relative Rigidities (13)

SCBF Beams - Elevation 5

MAX SHEAR	12.56
ROW	

MAX MOMENT	1513.958
ROW	5409

Insert ETABS Force Data Below This Row

Story	Beam	Load	Loc	P	V2	V3	T	M2	M3	Absolute Value of Shear	Absolute Value of Moment		
ROOF	B3	QUAKEX	7.15	0	0.54	0	-0.01	0	93.541	0.54	93.541	...	...
ROOF	B3	QUAKEX	28.756	0	0.54	0	-0.01	0	81.849	0.54	81.849	...	...
ROOF	B3	QUAKEX	50.363	0	0.54	0	-0.01	0	70.156	0.54	70.156	...	...
ROOF	B3	QUAKEX	71.969	0	0.54	0	-0.01	0	58.463	0.54	58.463	...	...
ROOF	B3	QUAKEX	93.575	0	0.54	0	-0.01	0	46.771	0.54	46.771	...	...
ROOF	B3	QUAKEX	115.181	0	0.54	0	-0.01	0	35.078	0.54	35.078	...	...
ROOF	B3	QUAKEX	136.788	0	0.54	0	-0.01	0	23.385	0.54	23.385	...	...
ROOF	B3	QUAKEX	158.394	0	0.54	0	-0.01	0	11.693	0.54	11.693	...	...
ROOF	B3	QUAKEX	180	0	0.54	0	-0.01	0	0	0.54	0	...	...
ROOF	B3	QUAKEX	180	0	0.54	0	0.011	0	0	0.54	0	...	...
ROOF	B3	QUAKEX	201.606	0	0.54	0	0.011	0	-11.693	0.54	11.693	...	...
ROOF	B3	QUAKEX	223.212	0	0.54	0	0.011	0	-23.385	0.54	23.385	...	...
ROOF	B3	QUAKEX	244.819	0	0.54	0	0.011	0	-35.078	0.54	35.078	...	...
ROOF	B3	QUAKEX	266.425	0	0.54	0	0.011	0	-46.771	0.54	46.771	...	...
ROOF	B3	QUAKEX	288.031	0	0.54	0	0.011	0	-58.463	0.54	58.463	...	...
ROOF	B3	QUAKEX	309.637	0	0.54	0	0.011	0	-70.156	0.54	70.156	...	...
ROOF	B3	QUAKEX	331.244	0	0.54	0	0.011	0	-81.849	0.54	81.849	...	...

Figure 69 – Max Shear and Moment

The above spreadsheet takes thousands of rows of data output from ETABS and finds the maximum shear and moment. The two columns of triple dots on the right are conditionally formatted to find where the shear and moment are maximum. This spreadsheet exists for each inverted V-truss and the eccentric braced frame.

Frame Sections			Forces			Factors	
Beam	W36X361		Pu =	522.47	k	Øb =	0.9
Brace	W18X119		Py =	5300	k	Øv =	0.9
Column	W14X370					Øc =	0.9
Story h	164	in	Vu =	12.56	k		
Bay w	30	ft					
Brace L	243.5077	in	Δx =		in		
lu, x	30	ft					
lu, y	15	ft	Mu =	1514	ft-k		
Fy, brace	50	ksi					
Fu, brace	65	ksi					
Fy, beam	50	ksi					
Fu, beam	65	ksi					
E	29000	ksi					

Figure 70 – SCBF Design Spreadsheet - Input

Beam Properties		Brace Properties	
bf =	16.7 in	bf =	11.3 in
tf =	2.01 in	tf =	1.06 in
tw =	1.12 in	tw =	0.655 in
d =	38 in	d =	19 in
Ag =	106 in2	Ag =	35.1 in2
Z =	1550 in3	Z =	262 in3
rx =	15.6 in		
ry =	3.85 in	ry =	2.69 in
I =	25700 in4		

Flange Width Comparison: Beam vs. Brace			bf, beam > bf, brace YES
bf, beam	=	16.7	
bf. brace	=	11.3	**Beam Flange Adequate**

Element Slenderness - Beam			
	λ_f =	4.15422886	$\lambda_f < \lambda_{ps}$ YES
	λ_p =	9.15161188	**Flanges are Compact**
	λ_w =	33.9285714	
	λ_p =	90.5527912	$\lambda_w < \lambda_{ps}$ YES
			Web is Compact

Brace Axial Force	
Ry =	1.1
Pt =	**1930.5**
KL/r =	90.52331
Fe =	34.92826
Fcr =	27.46372
Pc =	**289.1929**

Unbalanced Vertical Beam Load	
Pty =	1300.17244
Pcy =	194.768556
Qb =	1105.40388

Additional Beam Axial Force	
Ptx =	1427.0185
Pcx =	213.77037
Pu =	820.39445

Unbraced Length Check		Lb < Lp YES
Lp =	9.29 ft	
dc =	17.9	
Lb =	8.544167	**Controlling Limit State is Yielding**

Flexural Strength		Mu < ØbMn YES
Mn =	77500 ft-k	
ØbMn =	69750 ft-k	
Mu =	1514 ft-k	**Beam is Adequate in Flexure**

Compression Strength		Pu < ØcPn YES
KLx/rx	23.07692 **Controls**	
Klxy/ry	46.75325	
ØcFcr =	38.5 ksi	
ØcPn =	4081 k	**Beam is Adequate in Compression**

Combined Loading			Pr/Pc < 0.2 NO	
Pe1 =	56757.84			
Cm =	1	Combined Ratio		Limit
B2 =	1	0.348814655	<=	1
Pr =	1342.864			
B1 =	1.024233			
Mrx =	1550.689			
Pr/Pc =	0.329053	Beam is Adequate in Combined Loading		

Shear Strength			Vu < ØVn YES
h/tw =	33.92857		
2.24*(E*Fy)^0.5 =		53.9463437	
Aw =	38.0576		
Vn =	1141.728		
Vu =	1117.964	Beam is Adequate in Shear	

Beam is Adequate

Figure 71 – SCBF Inverted V Beam Design

Link Element			Forces			Factors	
Beam	W24X279		Pu =	530.63	k	Øb =	0.9
Brace	W18X143		Py =	4100	k	Øv =	0.9
e	48	in					
Story h	162.5	in	Vu =	579.04	k		
Bay w	30	ft					
			Δx =	0.1412	in		
Fy, beam	50	ksi					
Fu, beam	65	ksi					
E	29000	ksi					

Beam Properties	
bf =	13.3
tf =	2.09
tw =	1.16
h =	26.7
Ag =	82
Z =	835

Flange Width Comparison: Beam vs. Brace			bf, beam > bf, brace YES
bf, beam	=	13.3	
bf. brace	=	11.2	Beam Flange Adequate

Figure 72 – EBF Beam Input and Design

Link Element Slenderness			
	λ_f =	3.181818	$\lambda_f < \lambda_{ps}$ YES
	λ_{ps} =	7.224957	Flanges Meet Local Buckling Criteria
	λ_w =	23.01724	
	C_a =	0.143802	Ca > 0.125 YES
	λ_{ps} =	58.96869	$\lambda_w < \lambda_{ps}$ YES
			Web Meets Local Buckling Criteria

Link Shear Strength				
	0.15Py =	615 k	Pu > 0.15Py NO	
	Aw =	26.1232 in2	Beam Axial Force Can Be Neglected in Shear Strength Determination	
	Vp =	783.696 k		
	Vpa =	777.1048 k	If Beam Axial Force Must Be Included:	If Beam Axial Not Included:
	Mp =	41750 ft-k		
	Mpa =	42889.03 ft-k	Vu < Va YES	Vu < Vp YES
	Va =	699.3943 k	Beam Link is Adequate in Shear	Beam Link OK

Allowable Link Length				
	ρ' =	0.916396		
	$\frac{Vp * e}{Mp}$ =		0.901016	Link Behavior Dominated by Shear Behavior
	ρ' * (Aw/Ag) =		0.291941	e < emax YES
	emax =	85.23713		Link Length is OK

Allowable Link Rotation				
	1.6 * (Mp/Vp) =		85.23713	
	2.6 * (Mp/Vp) =		138.5103	
	Θa =	0.08		γp < Θa YES
	Θp =	0.000869		
	γp =	0.006517		Link Rotation OK

Beam Link is Adequate

Figure 73 – EBF Link Design

Cd =	5

I =	1

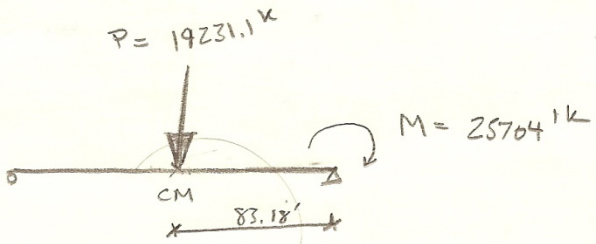
Siesmic Story Drift

Story	Load	Total Drift		Center of Mass		Story Height		Amplified Story Drift		Allowable Drift	Conclusion	
		UX	UY	X	Y	Z		X	Y		X	Y
ROOF	QUAKEX	1.8976	0.4132	1156.966	1064.648	1146.5		1.6055	0.4325	3.28	OK	OK
7TH	QUAKEX	1.5765	0.3267	1157.97	1065.287	982.5		1.7365	0.4505	3.28	OK	OK
6TH	QUAKEX	1.2292	0.2366	1158.218	1065.555	818.5		1.6	0.378	3.28	OK	OK
5TH	QUAKEX	0.9092	0.161	1157.048	1065.698	654.5		1.492	0.317	3.28	OK	OK
4TH	QUAKEX	0.6108	0.0976	1156.388	1066.125	490.5		1.2865	0.2525	3.28	OK	OK
3RD	QUAKEX	0.3535	0.0471	1156.881	1066.551	326.5		1.0615	0.16	3.28	OK	OK
2ND	QUAKEX	0.1412	0.0151	1157.853	1067.224	162.5		0.706	0.0755	3.25	OK	OK
ROOF	QUAKEXY1	1.8938	0.4415	1156.966	1064.648	1146.5		1.5965	0.4825	3.28	OK	OK
7TH	QUAKEXY1	1.5745	0.345	1157.97	1065.287	982.5		1.7255	0.499	3.28	OK	OK
6TH	QUAKEXY1	1.2294	0.2452	1158.218	1065.555	818.5		1.596	0.4035	3.28	OK	OK
5TH	QUAKEXY1	0.9102	0.1645	1157.048	1065.698	654.5		1.488	0.337	3.28	OK	OK
4TH	QUAKEXY1	0.6126	0.0971	1156.388	1066.125	490.5		1.287	0.2615	3.28	OK	OK
3RD	QUAKEXY1	0.3552	0.0448	1156.881	1066.551	326.5		1.064	0.159	3.28	OK	OK
2ND	QUAKEXY1	0.1424	0.013	1157.853	1067.224	162.5		0.712	0.065	3.25	OK	OK
ROOF	QUAKEXY2	1.9015	0.3849	1156.966	1064.648	1146.5		1.6145	0.383	3.28	OK	OK
7TH	QUAKEXY2	1.5786	0.3083	1157.97	1065.287	982.5		1.748	0.402	3.28	OK	OK
6TH	QUAKEXY2	1.229	0.2279	1158.218	1065.555	818.5		1.6045	0.352	3.28	OK	OK
5TH	QUAKEXY2	0.9081	0.1575	1157.048	1065.698	654.5		1.4955	0.2975	3.28	OK	OK
4TH	QUAKEXY2	0.609	0.098	1156.388	1066.125	490.5		1.2865	0.243	3.28	OK	OK
3RD	QUAKEXY2	0.3517	0.0494	1156.881	1066.551	326.5		1.0585	0.161	3.28	OK	OK
2ND	QUAKEXY2	0.14	0.0172	1157.853	1067.224	162.5		0.7	0.086	3.25	OK	OK
ROOF	QUAKEY	0.4358	3.0722	1156.966	1064.648	1146.5		0.522	2.804	3.28	OK	OK
7TH	QUAKEY	0.3314	2.5114	1157.97	1065.287	982.5		0.5035	2.856	3.28	OK	OK
6TH	QUAKEY	0.2307	1.9402	1158.218	1065.555	818.5		0.413	2.6615	3.28	OK	OK
5TH	QUAKEY	0.1481	1.4079	1157.048	1065.698	654.5		0.3345	2.323	3.28	OK	OK
4TH	QUAKEY	0.0812	0.9433	1156.388	1066.125	490.5		0.2365	2.0395	3.28	OK	OK
3RD	QUAKEY	0.0339	0.5354	1156.881	1066.551	326.5		0.1365	1.6245	3.28	OK	OK
2ND	QUAKEY	0.0066	0.2105	1157.853	1067.224	162.5		0.033	1.0525	3.25	OK	OK
ROOF	QUAKEYX1	0.4401	3.0405	1156.966	1064.648	1146.5		0.532	2.7485	3.28	OK	OK
7TH	QUAKEYX1	0.3337	2.4908	1157.97	1065.287	982.5		0.516	2.8015	3.28	OK	OK
6TH	QUAKEYX1	0.2305	1.9305	1158.218	1065.555	818.5		0.418	2.633	3.28	OK	OK
5TH	QUAKEYX1	0.1469	1.4039	1157.048	1065.698	654.5		0.3385	2.3005	3.28	OK	OK
4TH	QUAKEYX1	0.0792	0.9438	1156.388	1066.125	490.5		0.2365	2.029	3.28	OK	OK
3RD	QUAKEYX1	0.0319	0.538	1156.881	1066.551	326.5		0.1335	1.6255	3.28	OK	OK
2ND	QUAKEYX1	0.0052	0.2129	1157.853	1067.224	162.5		0.026	1.0645	3.25	OK	OK
ROOF	QUAKEYX2	0.4314	3.104	1156.966	1064.648	1146.5		0.5115	2.86	3.28	OK	OK
7TH	QUAKEYX2	0.3291	2.532	1157.97	1065.287	982.5		0.491	2.91	3.28	OK	OK
6TH	QUAKEYX2	0.2309	1.95	1158.218	1065.555	818.5		0.408	2.691	3.28	OK	OK
5TH	QUAKEYX2	0.1493	1.4118	1157.048	1065.698	654.5		0.3305	2.345	3.28	OK	OK
4TH	QUAKEYX2	0.0832	0.9428	1156.388	1066.125	490.5		0.237	2.05	3.28	OK	OK
3RD	QUAKEYX2	0.0358	0.5328	1156.881	1066.551	326.5		0.1395	1.6235	3.28	OK	OK
2ND	QUAKEYX2	0.0079	0.2081	1157.853	1067.224	162.5		0.0395	1.0405	3.25	OK	OK

Figure 74 – Seismic Drift

OVERTURNING PG 1 SMPJ

WIND



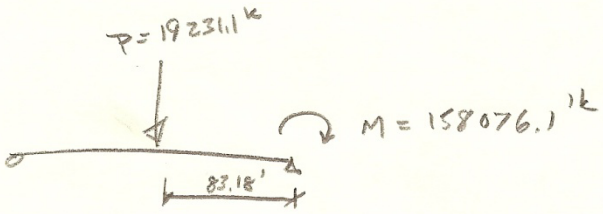
Pd = 19231.1 k 83.18' = 1.6E6

M = 25704 'k

FACTOR OF SAFETY = $\frac{1.6E6}{25704}$ = 62.2 >> 3

OKAY ✓

SEISMIC



FACTOR OF SAFETY = $\frac{19231.1^{k} \cdot 83.18'}{158076.1\ 'k}$

= 10.12 Ok ✓

Figure 75 – Wind and Seismic Overturning Moments