35 WEST 21ST STREET NEW YORK, NY

TECHNICAL REPORT 3

DANIEL DONECKER
STRUCTURAL OPTION
FACULTY CONSULTAN: DR. THOMAS BOOTHBY
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Executive summary

35 West 21st Street is a cast in place concrete residential building with the first level consisting of two retail areas. The building is composed of two towers that are initially connected at the ground and second floor levels, but then set back to form two separate entities. The southern tower is 15 stories and has a roof height of 150 feet. The northern tower is 8 stories and has a roof height of 80 feet. The lateral system consists of reinforced concrete shear walls while the gravity system is two-way flat plate concrete reinforced with mild steel.

The purpose of this report is to study the lateral system of 35 West 21st Street in depth in order to gain a greater understanding of how the building behaves when loaded by seismic forces or wind pressures. The program ETABS was used extensively to study the lateral system of the building. Only the shear walls and floor diaphragms were modeled in order to force the entire lateral load into the main lateral force resisting system. After the ETABS model was complete, manual spot checks were executed to verify the answers given by the computer output.

This Report Concludes that the lateral force resisting system of 35 West 21st Street is adequate to carry the wind and seismic loads applied. The Shear walls actually seem to be over designed, however this could be due to the relatively short period of time that the structural engineer had to design the building.

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Introduction

35 West 21st Street is shaped by the surrounding buildings and its site. With adjacent 4-12 story buildings, the plan takes on a T-shape to maximize the footprint. The stem of the T-shape is an eight story residential tower facing the north, while the top of the T-shape is a fifteen story residential tower facing the south with retail space at grade. Over 162,000 sq. feet of residential and retail space are provided.

35 West 21st Street is located in the Flatiron District within the Ladies' Mile Historic District. The area is zoned as C6-4A which allows for commercial, light manufacturing, and residential construction. The predominant historical requirements of Ladies' Mile consist of street walls a minimum of 60 feet tall that are in character with the surrounding area. Therefore, the building is has a classic stone facade with infill glass windows.

The columns of superstructure are continuous from the foundation to the top of the building with no transfers throughout the building. The columns are arranged in a semi regular pattern where most bays are rectangular in plan. The arrangement of columns allows for open residential and retail floor plans while a two way flat plate concrete floor system allows for 8' high ceilings while maintaining a typical 9'-8" floor to floor height. The top residential units have large personal balconies which overlook the surrounding city and allow for a spacious outdoor room in crowded New York City.

Structural Systems Overview

Floor System

35 West 21st Street is a typical reinforced concrete residential structure. The floor system is a two way flat plate slab without drop panels or beams. Typical residential floors are 8 inches thick with typical reinforcement of #5 deformed bars at 12 inches on center bottom bars (each way) and #5 deformed bars at 12 inches on center Middle Strip top bars. Column Strip top bars vary according to span lengths which range from 13' to 18'. In areas of high shear, slab supports also have stud rails to help prevent punch through shear. Typical columns are gravity only, and run the entire height of the building without transfers. On the fifteenth floor, columns lining the exterior balconies are transferred to the 14" slab and then transferred to nearby columns that go down to the foundations. Typical columns are 16"x18" with 8-#7 longitudinal bars and #3 ties at 12 inches on center. Minimum concrete compressive strength is 5 ksi for slabs above ground, and 5.95 ksi for columns. The slab also provides a two hour fire rating.

Basement

The basement floor is a slab on grade reinforced with 6" WWF 6x6 – W2.0xW2.0. Typical slab on grade thickness is 6".

Roof system

The roof slab is 12 inches thick with typical reinforcing like that on all the residential floors. Cooling towers sit on dunnage that consists of 16"x16" concrete piers and galvanized W10x33 steel beams. The remaining mechanical equipment including elevator machines are housed in the bulkhead which consists of shear wall 16 and three transfer columns. Shear The concrete piers and columns are transferred through the 12" slab and into columns below that continue to the foundation.

Lateral System

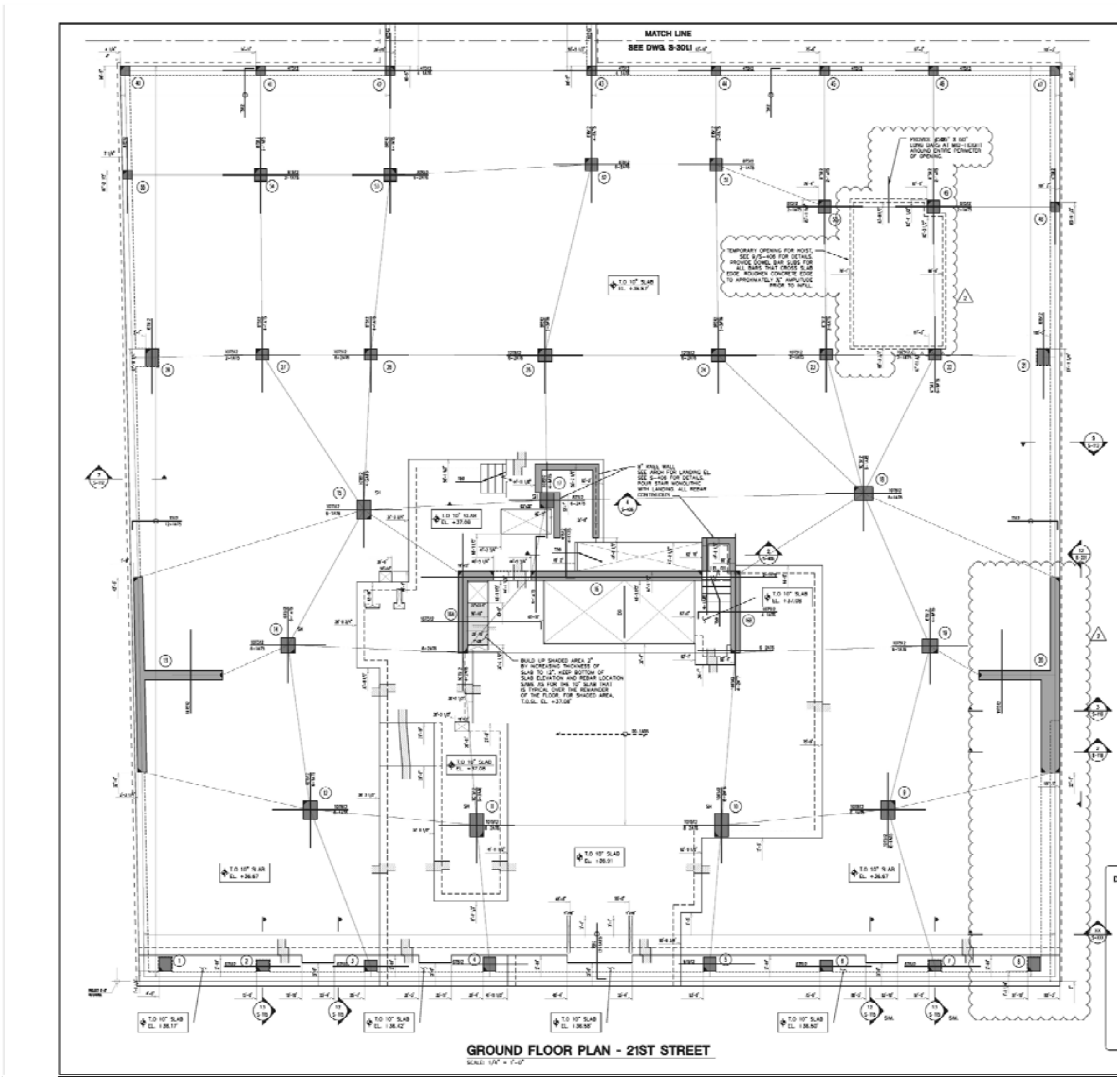
The lateral system of 35 West 21st Street is comprised of shear walls in both the North-South and East-West directions of the building. The two towers of the building are built integrally with each other through the two way slab on the basement, ground and second floor. However, at the second floor, the 15 story south tower steps back to allow for an outdoor courtyard, thus breaking the connection between the two towers. Because the connection of the two towers only exists on the first two floors, the towers' lateral systems were designed separately from each other. The assumption that the two buildings act separately and thus do not transfer any torsional moment between the two lateral systems will be investigated more closely in following technical reports. As for this technical report, it is assumed that the two buildings act separately. Typical shear walls are 1'-0" wide and longitudinal reinforcement ranges from #10 at 12" on center at the base of the shear walls to #4 at 12" on center at the top of the building. Horizontal shear reinforcement typically consists of #4 at 12" on center closed loop bars.

Foundation

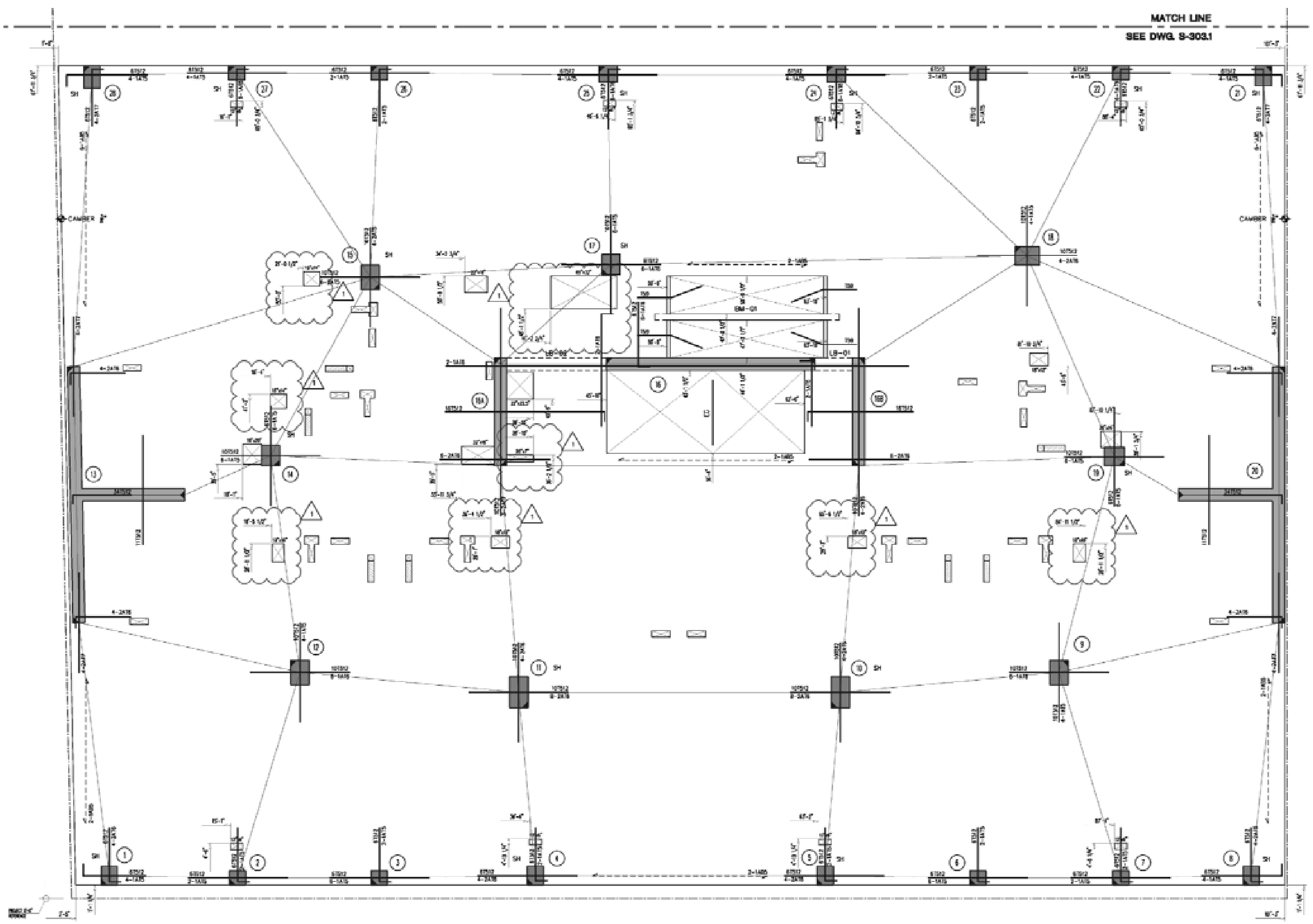
The foundation system consists of spread footings for typical concrete columns and large mat foundations for shear walls. On the east side of the building, 240 ton caissons spread loads from the footings to the bedrock below. The caissons are at a minimum drilled 9'-0" into bedrock and are typically 12 inches in diameter.

Existing Shear Wall Layout

The figure shown below shows the structural plan of the ground floor for the 15 story tower. At this floor and the second floor, the two towers that comprise the building are connected as shown at the top of the figure. The shear walls that make up the main lateral force resisting system are hatched gray.

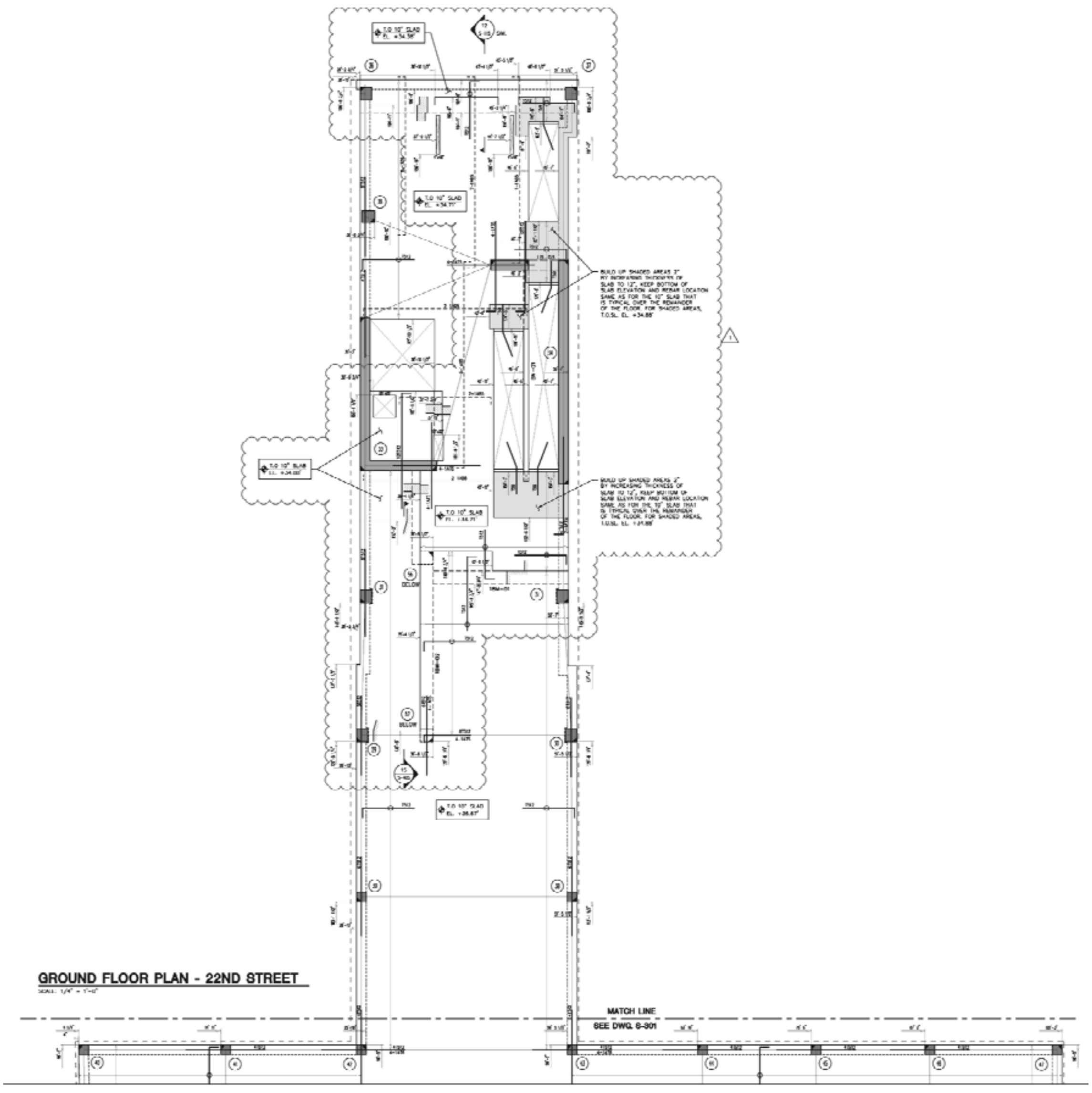


The figure shown below is the typical floor plan for the 15 story tower at levels 3-14. You can see that the back of the tower steps back from the 8 story building, allowing for two completely separate towers. In order to properly take this into account, the two towers were modeled separately since they are only connected at one story above grade. The shear walls are again hatched in gray.

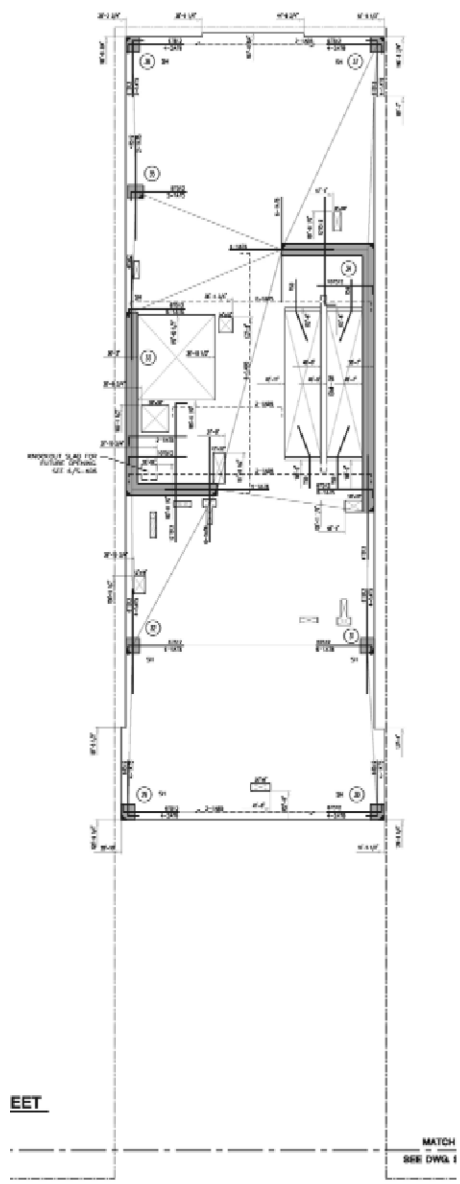


15 story tower

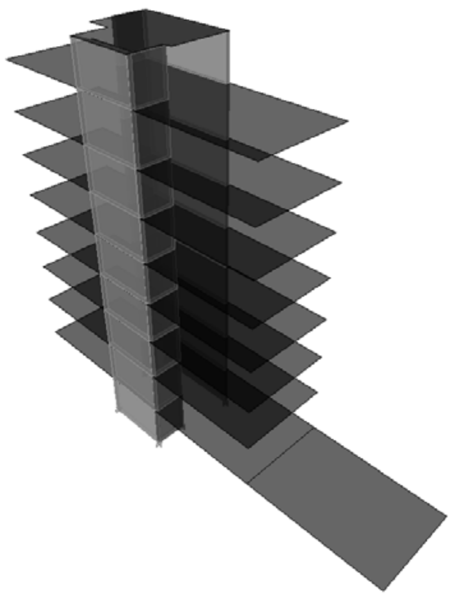
The figure below shows the ground floor plan of the 8 story tower, and its connection to the 15 story tower at the ground and second floor levels. The shear walls for this tower are set more towards the north of the building. This causes some large torsional shear on the lateral resisting system due to the distance between the center of rigidity and center of mass.

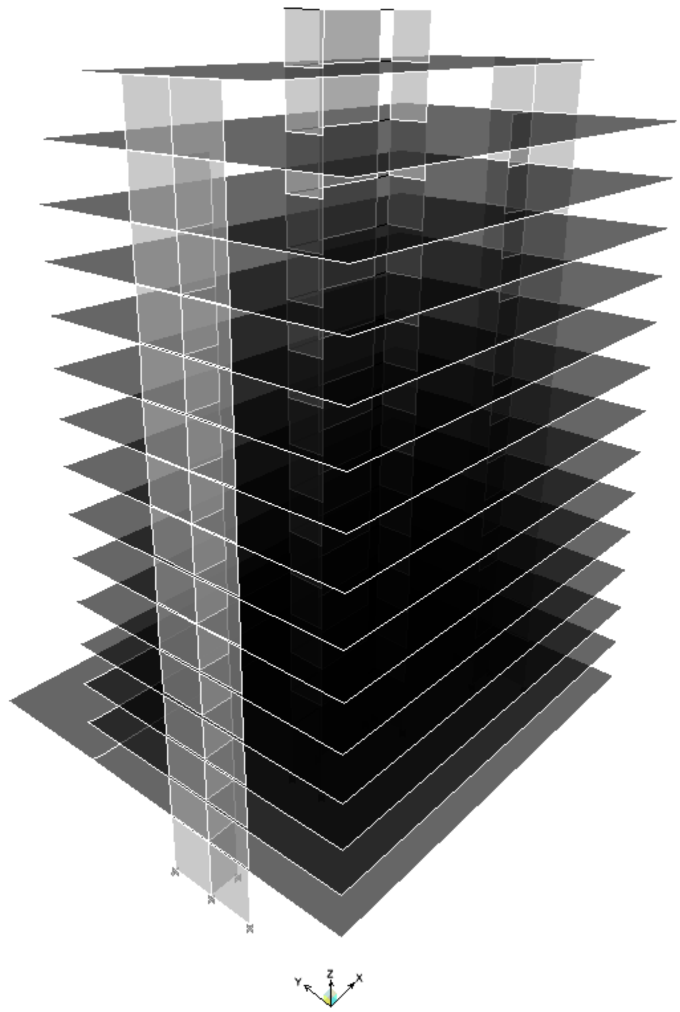


This figure is the existing floor plan of floors 3-roof for the 8 story tower. The structure steps back at the third story to form its own tower, just as the 15 story tower stepped back at the same level. Because of this step back, the center of rigidity and the center of mass are closer together making torsional affects much less significant.



The figures below show the two different ETABS models used to analyze the structure. You can clearly see that the two towers step back at the third level.





Load Combinations and Distribution of Lateral Loads

The following load combinations from ACI 318-05 were used for this analysis:
- 1.4D
- 1.2D + 1.6L
- 1.2D + 1.6W + 1.0L
- 1.2D + 1.0E + 1.0L
- 0.9D + 1.6W
- 0.9D + 1.0E

- See Appendix A for Load Calculations –

Distribution of lateral loads to shear walls is based on the assumption that the diaphragm is rigid. In order to determine how much load goes to each wall, the stiffness of the wall must be known. By placing a 10 kip load at the center of mass of each diaphragm in the ETABS model, and then determining the base shear for each of the shear walls; it is possible to find the percent fraction of the lateral load that is transferred to each of the walls. This fraction is a good estimate of each wall's stiffness. The lateral loads can then be distributed to each shear wall according to its relative stiffness or its stiffness compared to the stiffness of all walls that resist lateral forces in the plane of interest. However, another factor in determining lateral loads must not be over looked.

Torsion on a building due to lateral loads can have a significant effect on the amount of shear transferred to a lateral force resisting member. This torsion depends on the location of the resultant lateral load as compared to the location of the center of rigidity of the structure. The greater distance between these, the more torsion will have an effect on your resisting systems. Please see the Appendix for the approach used in this report to determine torsional loads.

An example of seismic and wind loads on the 15 story tower is shown below. Please see the appendix for all calculations regarding lateral load distribution.

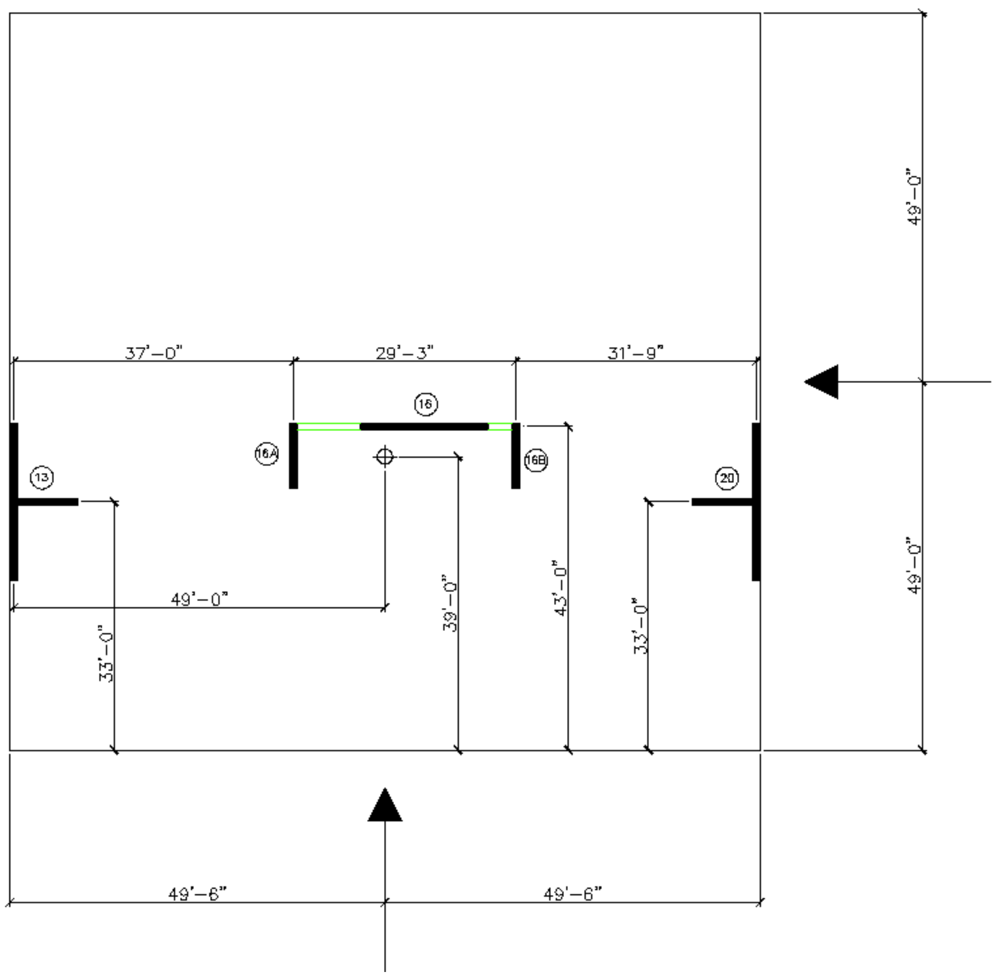
15 STORY TOWER SEISMIC FORCES												
story	story height	height (ft)	C_s	Building weight (kips)	Base Shear (kips)	k	w_x	$w_x h_x^k$	$\Sigma w_i h_i^k$	C_v	Story Force (kips)	Over-Turning Moment (ft-k)
bulkhead	9.00	160.40	0.0133	19604	262	0.43716	235.05	2162.77	127471	0.01697	4.44	711.91
roof	10.67	151.40	0.0133	19604	262	0.43716	1079.11	9681.49	127471	0.07595	19.87	3008.02
15	10.69	140.73	0.0133	19604	262	0.43716	1751.21	15217.4	127471	0.11938	31.23	4394.79
14	9.67	130.04	0.0133	19604	262	0.43716	1204.36	10110.5	127471	0.07932	20.75	2698.13
13	9.67	120.37	0.0133	19604	262	0.43716	1203.92	9770.76	127471	0.07665	20.05	2413.56
12	9.67	110.70	0.0133	19604	262	0.43716	1204.36	9423	127471	0.07392	19.34	2140.67
11	9.67	101.03	0.0133	19604	262	0.43716	1204.36	9053.51	127471	0.07102	18.58	1877.07
10	9.67	91.36	0.0133	19604	262	0.43716	1203.92	8660.31	127471	0.06794	17.77	1623.69
9	9.67	81.69	0.0133	19604	262	0.43716	1204.36	8249.91	127471	0.06472	16.93	1383.03
8	9.67	72.02	0.0133	19604	262	0.43716	1204.36	7807.26	127471	0.06125	16.02	1153.89
7	9.67	62.35	0.0133	19604	262	0.43716	1203.92	7326.97	127471	0.05748	15.04	937.50
6	9.67	52.68	0.0133	19604	262	0.43716	1204.36	6808.76	127471	0.05341	13.97	736.08
5	9.67	43.01	0.0133	19604	262	0.43716	1204.36	6230.05	127471	0.04887	12.79	549.89
4	9.67	33.34	0.0133	19604	262	0.43716	1203.92	5570.12	127471	0.0437	11.43	381.10
3	9.67	23.67	0.0133	19604	262	0.43716	1204.36	4795.79	127471	0.03762	9.84	232.95
2	14	14.00	0.0133	19604	262	0.43716	2088.2	6602.77	127471	0.0518	13.55	189.70
											Total =	24431.98

15 STORY TOWER N/S WIND FORCES									
story	story height	height (ft)	p_z (windward)	p_z (leeward)	Total Pressure (psf)	building length (ft)	Story Force (kips)	Diaphram Force (kips)	Over-Turning Moment (ft-k)
2	14.00	14.00	12.61	9.37	21.98	98	30.16		
								26.33	368.64
3	9.67	23.67	14.38	9.37	23.75	98	22.51		
								23.24	550.12
4	9.67	33.34	15.93	9.37	25.30	98	23.98		
								24.60	820.21
5	9.67	43.01	17.25	9.37	26.62	98	25.23		
								25.65	1103.14
6	9.67	52.68	18.14	9.37	27.51	98	26.07		
								26.49	1395.34
7	9.67	62.35	19.02	9.37	28.39	98	26.90		
								27.33	1703.76
8	9.67	72.02	19.91	9.37	29.28	98	27.75		
								28.16	2028.40
9	9.67	81.69	20.79	9.37	30.16	98	28.58		
								28.90	2360.75
10	9.67	91.36	21.46	9.37	30.83	98	29.22		
								29.42	2688.25
11	9.67	101.03	21.90	9.37	31.27	98	29.63		
								29.95	3025.45
12	9.67	110.70	22.56	9.37	31.93	98	30.26		
								30.47	3373.25
13	9.67	120.37	23.01	9.37	32.38	98	30.69		
								31.00	3731.22
14	9.67	130.04	23.67	9.37	33.04	98	31.31		
								33.16	4312.09
15	10.67	140.71	24.11	9.37	33.48	98	35.01		
								35.47	4991.55
roof	10.67	151.38	25.00	9.37	34.37	98	35.94		
								22.61	3422.64
bulk head	9	160.38	25.00	9.37	34.37	30	9.28		
								4.64	744.16
							Total =	427.42	36618.98

Shear Wall Analysis

A spot check of a shear wall 20 in the North/South direction was done to determine the adequacy of the design. Using ETABS it was found that the controlling case for combined flexure and compression, as well as overturning is 0.9D + 1.6L. This load combination also governed the shear reinforcement design. PCA Column was used to develop the interaction diagram for the wall which is reinforced with #9 longitudinal bars @ 6" o.c. (Each Face) and #4 transverse bars @ 12" o.c. A hand check of the shear reinforcement was also performed. It was found that the SW 20 is adequate to carry the imposed loads on it.

The overturning analysis revealed that the footing for SW 20 was subjected to tensile forces. However the engineer did design for those forces by anchoring the footing into bedrock with 240 Ton Caissons. Please see the appendix for the shear wall analysis calculations.



Drift Analysis

Drift analysis was carried out using ETABS. It was found that Wind controls the drift over seismic. The maximum drift in the 15 story tower is in the North/South direction. The total building drift is 2.88 inches. This coincides with an h/666 overall building sway. The maximum drift due to seismic loading is 2.12 inches which coincides with an h/900 overall building sway. Compared to the design standard limitation on building drift of h/400, the lateral force resisting system is stiffer than required. For seismic applications ASCE7-05 requires a maximum building drift of 0.02h = h/50 (Table 12.12-1). It is obvious that the lateral system meets this maximum sway.

15 Story Tower				
Wind Story Drift in N/S Direction				
Story	**Story Height (in)**	**Drift Ratio**	**Story Drift (in)**	**Building Drift (in)**
BULKHEAD	108	0.001921	0.207468	2.881508
ROOF	128	0.001945	0.24896	2.67404
STORY15	128	0.001946	0.249088	2.42508
STORY14	116	0.001941	0.225156	2.175992
STORY13	116	0.001927	0.223532	1.950836
STORY12	116	0.001901	0.220516	1.727304
STORY11	116	0.00186	0.21576	1.506788
STORY10	116	0.001802	0.209032	1.291028
STORY9	116	0.001724	0.199984	1.081996
STORY8	116	0.001621	0.188036	0.882012
STORY7	116	0.001493	0.173188	0.693976
STORY6	116	0.001336	0.154976	0.520788
STORY5	116	0.001147	0.133052	0.365812
STORY4	116	0.000924	0.107184	0.23276
STORY3	116	0.000664	0.077024	0.125576
STORY2	168	0.000289	0.048552	0.048552

Conclusion

The analysis of the lateral force resisting system reveals that the structure is adequate to carry the loads imposed on the structure through wind pressures and seismic forces. The building is sound in both serviceability and strength. The analysis also reveals that manual methods of calculating distribution of loads can match that of a computer within 10%. The only real difference in how the computer program calculates load distribution is that the computer uses shell elements which can take out of plane bending, while manual methods assume that out of plane bending is infinitely flexible.

Appendix A – Calculations

Load Distribution

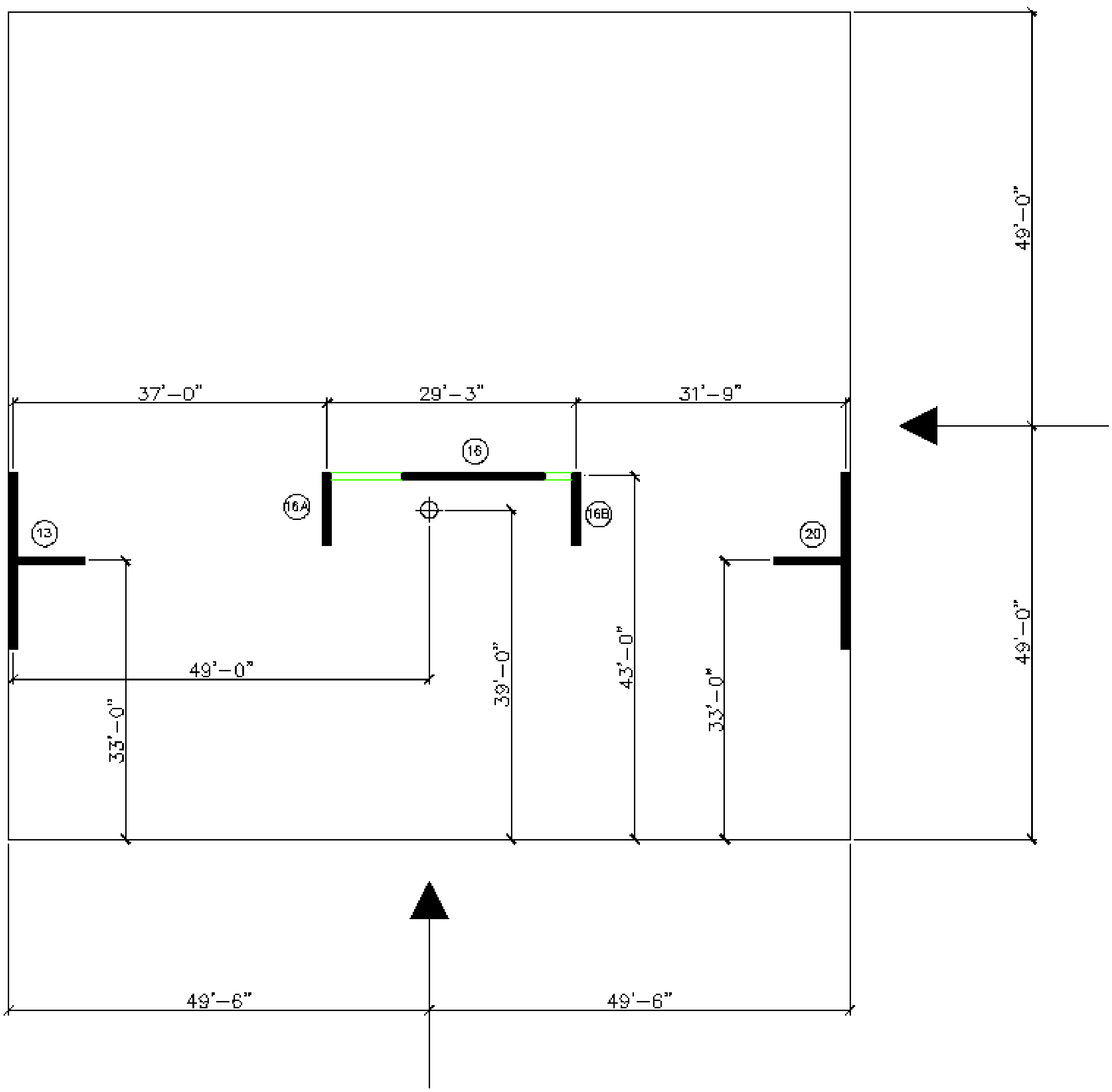
Shear Wall Stiffness's

Stiffness's were calculated by applying a 10 kip load at each story in ETABS and determining the percent fraction of total base shear that each wall took.

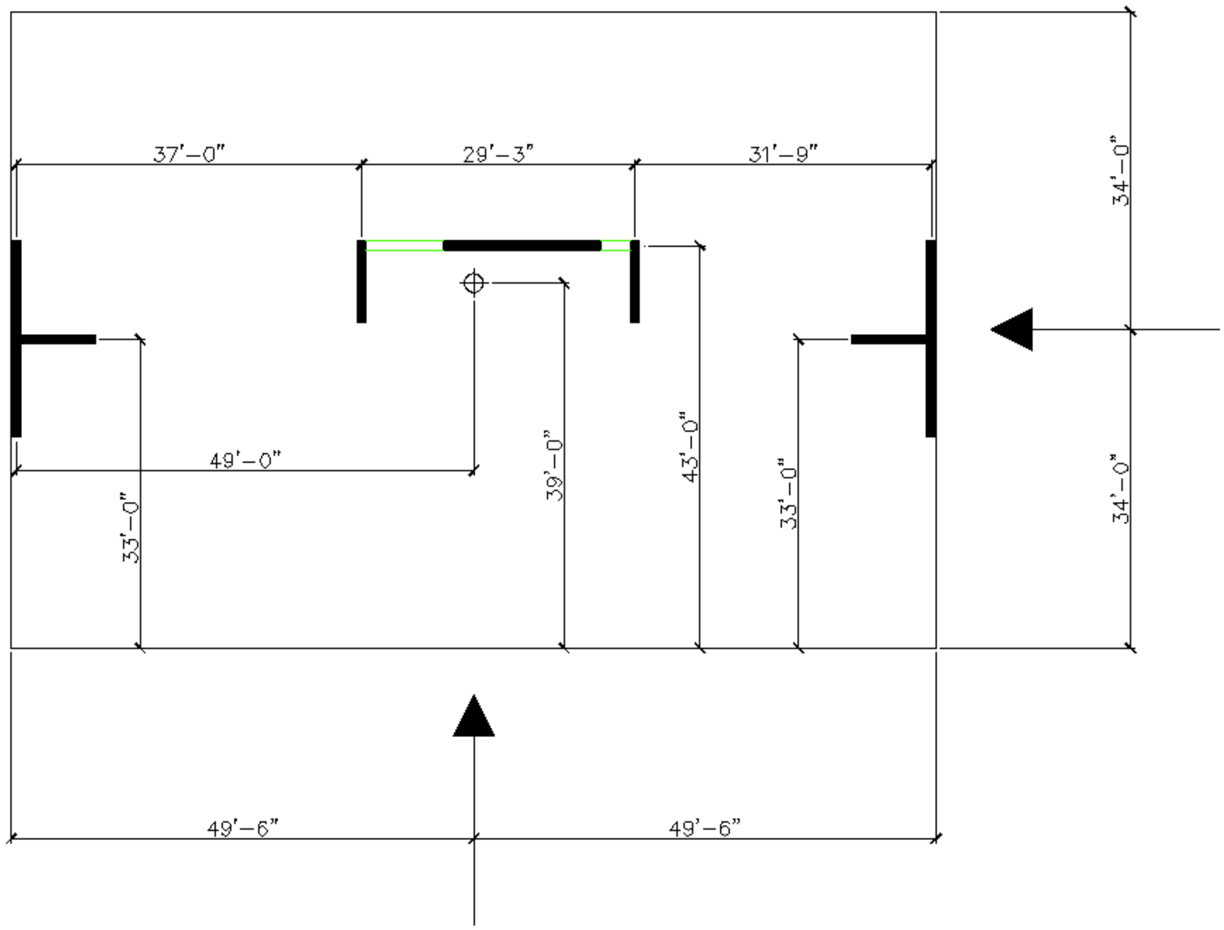
Shear Wall	wall base shear (kips)	Building base shear (kips)	k (stiffness)
16	93.204	160.000	0.583
13 short	25.961	160.000	0.162
20 short	34.322	160.000	0.215
16A	10.972	160.000	0.069
16B	10.972	160.000	0.069
13 long	68.16	160.000	0.426
20 long	68.16	160.000	0.426

Shear Wall	wall base shear (kips)	Building base shear (kips)	k (stiffness)
34 short	15.418	90	0.171
33 short	65.448	90	0.727
34 long	46.018	90	0.511
33long	43.091	90	0.479

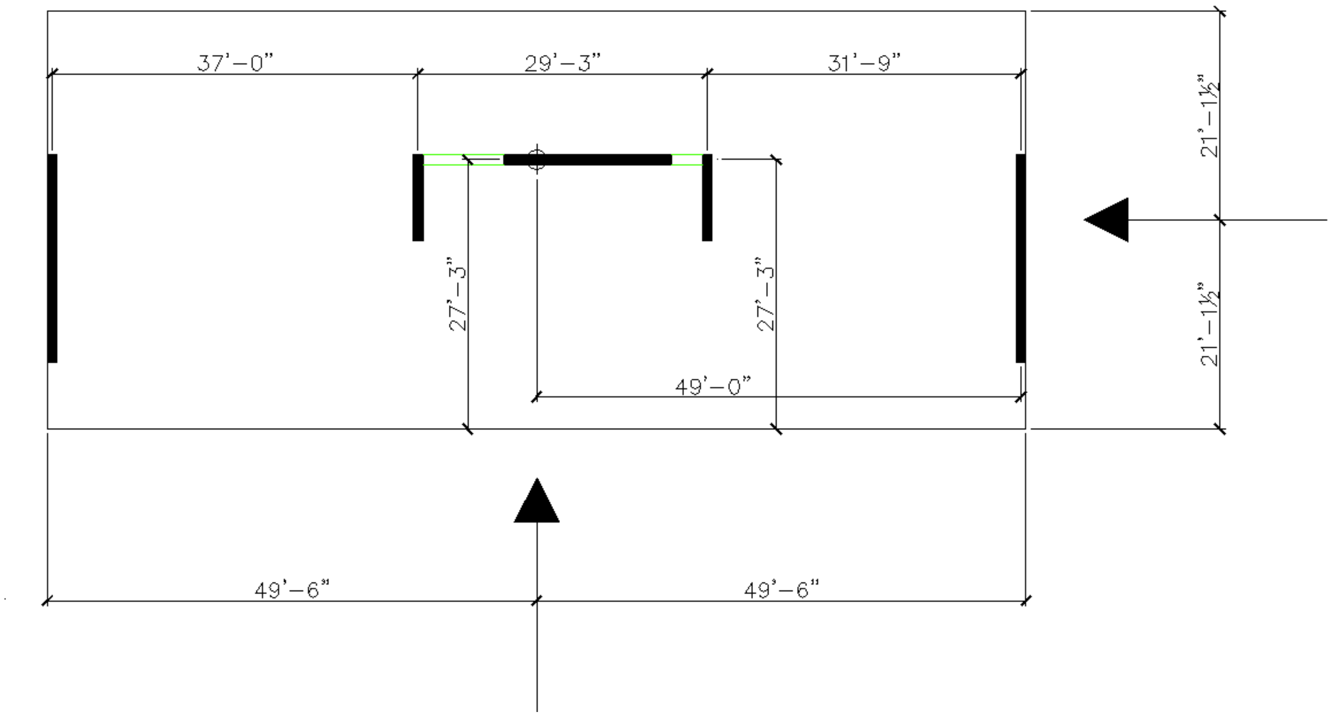
15 Story tower, Floor 2, Center of Rigidity



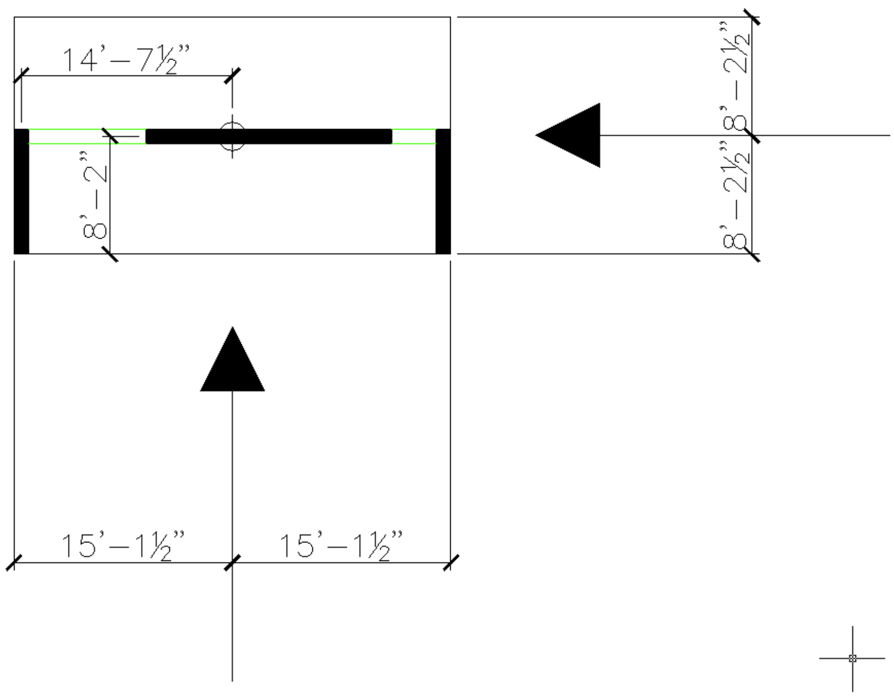
15 Story Tower, Floor 3-15, Center of Rigidity

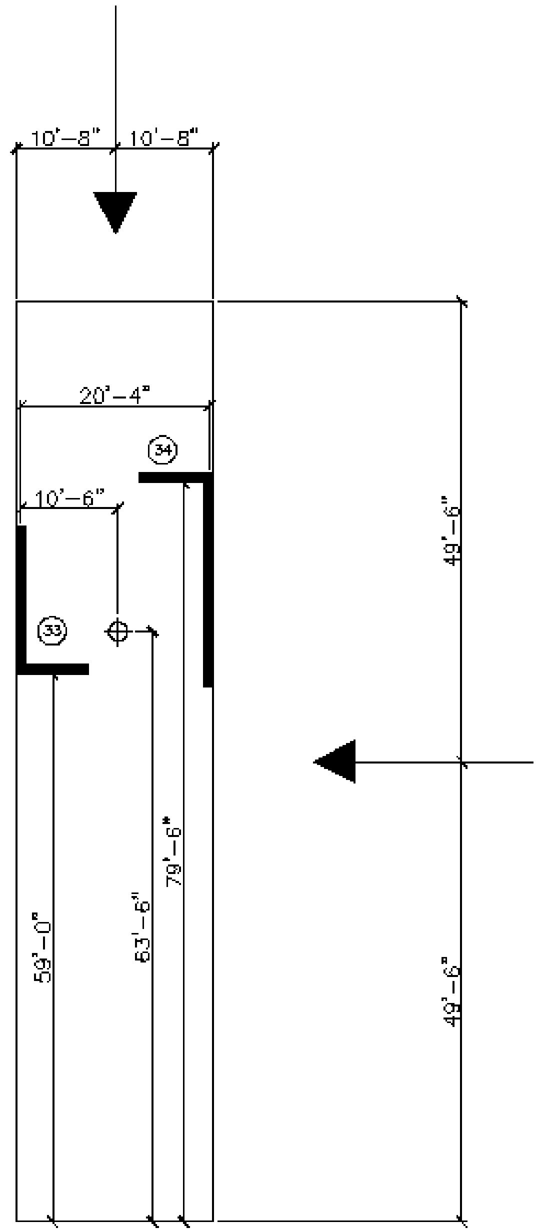


15 Story Tower, Roof, Center of Rigidity

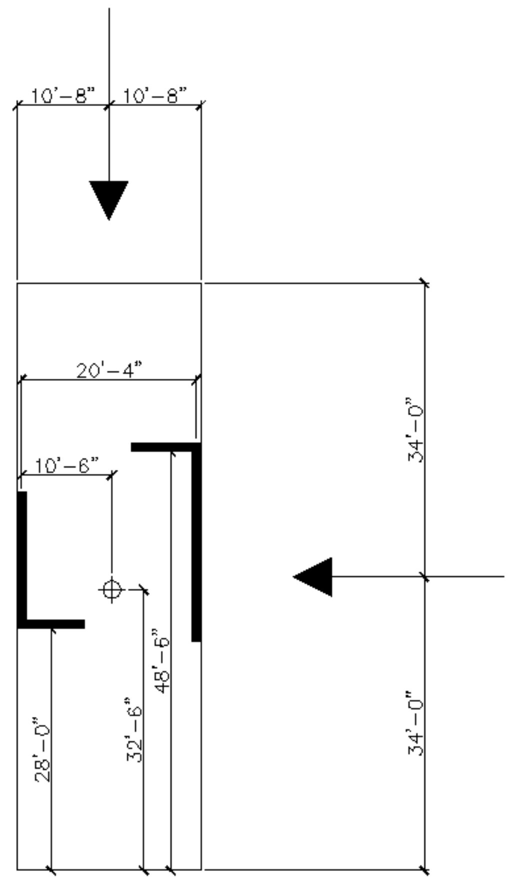


15 Story Tower, Bulkhead, Center of Rigidity



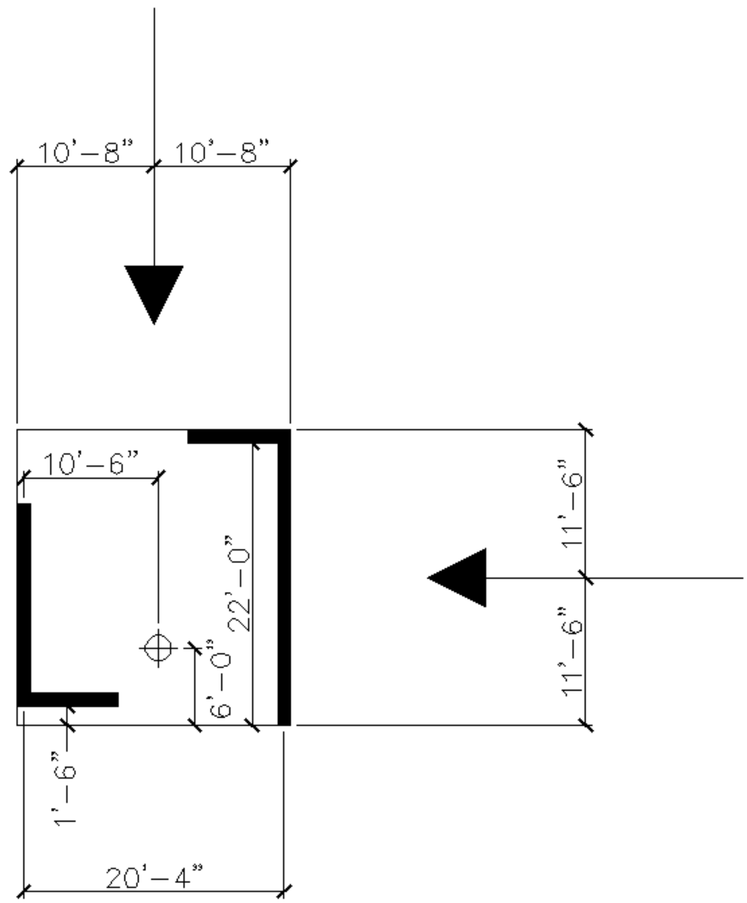


8 Story Tower, Floor 2, Center of Rigidity



8 Story Tower, Floor 3-Roof, Center of Rigidity

8 Story Tower, bulkhead, Center of Rigidity



DESIMONE

PROJECT: THESIS TECH 3 | PAGE: 1 | OF:
PROJECT NO.: | DATE: 11/20/08
ITEM: CENTER OF RIGIDITY | BY: DPD | CHK'D:

15 STORY TOWER:

Center of Rigidity for the second story plan

$K_{16} = 0.583$
$K_{13\,SHORT} = 0.162$
$K_{20\,SHORT} = 0.215$
$K_{16A} = 0.069$
$K_{16B} = 0.069$
$K_{13\,LONG} = 0.426$
$K_{20\,LONG} = 0.426$

$$CR_x = \frac{(37)(0.069) + (66.25)(0.069) + (98)(0.426)}{(0.069 + 0.426)(2)}$$

$CR_x = 49'-0"$

$$CR_y = \frac{(33)(0.162) + (33)(0.215) + (43)(0.583)}{0.162 + 0.215 + 0.583}$$

$CR_y = 39'-0"$

$CR_x = 49'-0"$
$CR_y = 39'-0"$

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PROJECT: THESIS TECH 3 PAGE: 2 OF:
PROJECT NO.:
DATE: 11/20/08
ITEM: CENTER OF RIGIDITY BY: DPD CHK'D:

8 STORY TOWER:

Center of Rigidity for the second story plan

$K_{34\,SHORT} = 0.171$
$K_{33\,SHORT} = 0.727$
$K_{34\,LONG} = 0.511$
$K_{33\,LONG} = 0.479$

$$CR_x = \frac{(20.33)(0.511)}{0.479 + 0.511}$$

$CR_x = 10'-6"$

$$CR_y = \frac{(59.5)(0.727) + (80)(0.171)}{0.727 + 0.171}$$

$CR_y = 63'-6"$

$CR_x = 10'-6"$
$CR_y = 63'-6"$

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PROJECT: THESIS TECH 3
PAGE: 1 OF
PROJECT NO.:
DATE:
ITEM: LAT. LOAD DIST.
BY: CHK'D:

15 STORY TOWER:

STORY 2: (EAST/WEST DIRECTION)

ECCENTRICITY = 49' − 39' = 10'

POLAR MOMENT OF INERTIA:

$$J = \sum k_i y_i^2 + \sum k_i x_i^2$$

		$k_i y_i^2 / k_i x_i^2$
$K_{16} = 0.583$	$y_{16} = 4'$	9.328
$K_{13\,SHORT} = 0.162$	$y_{13\,SHORT} = 6'$	5.832
$K_{20\,SHORT} = 0.215$	$y_{20\,SHORT} = 6'$	7.74
$K_{16A} = 0.069$	$x_{16A} = 12'$	9.936
$K_{16B} = 0.069$	$x_{16B} = 17.25'$	20.532
$K_{13\,LONG} = 0.426$	$x_{13\,LONG} = 49'$	1022.8
$K_{20\,LONG} = 0.426$	$x_{20\,LONG} = 49'$	1022.8

$J = 2099$ k-ft

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PROJECT: THESIS TECH 3
PAGE: 2 OF
PROJECT NO.:
DATE:
ITEM: LAT LOAD DIST.
BY:
CHK'D:

TORSIONAL SHEARS:

$$F = k_i x_i \frac{Ve}{J}$$

$F_{16} = (0.583)(4)\,V(10)/2099 = (0.0111)V$

$F_{13\,SHORT} = (0.162)(6)\,V(10)/2099 = (0.0046)V$

$F_{20\,SHORT} = (0.215)(6)\,V(10)/2099 = (0.0061)V$

$F_{16A} = (0.069)(12)\,V(10)/2099 = (0.0039)V$

$F_{16B} = (0.069)(17.25)\,V(10)/2099 = (0.0058)V$

$F_{13\,LONG} = (0.426)(49)\,V(10)/2099 = (0.0994)V$

$F_{20\,LONG} = (0.426)(49)\,V(10)/2099 = (0.0994)V$

DIRECT SHEAR:

$$F = \frac{k_i}{\Sigma k_i} V$$

$F_{16} = \frac{0.583}{0.583 + 0.162 + 0.215}(V) = (0.607)V$

$F_{13\,SHORT} = \frac{0.162}{0.583 + 0.162 + 0.215}(V) = (0.169)V$

$F_{20\,SHORT} = \frac{0.215}{0.583 + 0.162 + 0.215}(V) = (0.224)V$

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Table of Distribution Factors For Each Shea Wall

15 Story Tower - Story 2 - E/W Loading								
Orientation	Shear Wall	k (k/ft)	Eccentricity (ft)	x_i/y_i (ft)	Inertia (k-ft)	Torsional Shear Dist. Factor	Σk	Direct Shear Dist. Factor
E/W	16	0.583	10.000	4.000	9.320	0.01110	0.959	0.607
E/W	13 short	0.162	10.000	6.000	5.841	0.00464	0.959	0.169
E/W	20 short	0.215	10.000	6.000	7.722	0.00613	0.959	0.224
N/S	13 long	0.426	10.000	49.000	1022.826	0.09946		
N/S	20 long	0.426	10.000	49.000	1022.826	0.09946		
N/S	16 A	0.069	10.000	12.000	9.875	0.00392		
N/S	16 B	0.069	10.000	17.250	20.405	0.00564		

15 Story Tower - Story 2 - N/S Loading								
Orientation	Shear Wall	k (k/ft)	Eccentricity (ft)	x_i/y_i (ft)	Inertia (k-ft)	Torsional Shear Dist. Factor	Σk	Direct Shear Dist. Factor
E/W	16	0.583	0.000	4.000	9.320	0.00000		
E/W	13 short	0.162	0.000	6.000	5.841	0.00000		
E/W	20 short	0.215	0.000	6.000	7.722	0.00000		
N/S	13 long	0.426	0.000	49.000	1022.826	0.00000	0.989	0.431
N/S	20 long	0.426	0.000	49.000	1022.826	0.00000	0.989	0.431
N/S	16 A	0.069	0.000	12.000	9.875	0.00000	0.989	0.069
N/S	16 B	0.069	0.000	17.250	20.405	0.00000	0.989	0.069

15 Story Tower - Story 3 through 15 - E/W Loading								
Orientation	Shear Wall	k (k/ft)	Eccentricity (ft)	x_i/y_i (ft)	Inertia (k-ft)	Torsional Shear Dist. Factor	Σk	Direct Shear Dist. Factor
E/W	16	0.583	10.000	4.000	9.320	0.01110	0.959	0.607
E/W	13 short	0.162	10.000	6.000	5.841	0.00464	0.959	0.169
E/W	20 short	0.215	10.000	6.000	7.722	0.00613	0.959	0.224
N/S	13 long	0.426	10.000	49.000	1022.826	0.09946		
N/S	20 long	0.426	10.000	49.000	1022.826	0.09946		
N/S	16 A	0.069	10.000	12.000	9.875	0.00392		
N/S	16 B	0.069	10.000	17.250	20.405	0.00564		

15 Story Tower - Story 3 through 15 - N/S Loading								
Orientation	Shear Wall	k (k/ft)	Eccentricity (ft)	x_i/y_i (ft)	Inertia (k-ft)	Torsional Shear Dist. Factor	Σk	Direct Shear Dist. Factor
E/W	16	0.583	0.000	4.000	9.320	0.00000		
E/W	13 short	0.162	0.000	6.000	5.841	0.00000		
E/W	20 short	0.215	0.000	6.000	7.722	0.00000		
N/S	13 long	0.426	0.000	49.000	1022.826	0.00000	0.989	0.431
N/S	20 long	0.426	0.000	49.000	1022.826	0.00000	0.989	0.431
N/S	16 A	0.069	0.000	12.000	9.875	0.00000	0.989	0.069
N/S	16 B	0.069	0.000	17.250	20.405	0.00000	0.989	0.069

15 Story Tower - Story Roof - E/W Loading								
Orientation	Shear Wall	k (k/ft)	Eccentricity (ft)	x_i/y_i (ft)	Inertia (k-ft)	Torsional Shear Dist. Factor	Σk	Direct Shear Dist. Factor
E/W	16	0.583	6.125	0.000	0.000	0.00000	0.583	1.000
N/S	13 long	0.426	6.125	49.000	1022.826	0.06159		
N/S	20 long	0.426	6.125	49.000	1022.826	0.06159		
N/S	16 A	0.069	6.125	12.000	9.875	0.00243		
N/S	16 B	0.069	6.125	17.250	20.405	0.00349		

15 Story Tower - Story Roof - N/S Loading								
Orientation	Shear Wall	k (k/ft)	Eccentricity (ft)	x_i/y_i (ft)	Inertia (k-ft)	Torsional Shear Dist. Factor	Σk	Direct Shear Dist. Factor
E/W	16	0.583	0.000	0.000	0.000	0.00000		
N/S	13 long	0.426	0.000	49.000	1022.826	0.00000	0.989	0.431
N/S	20 long	0.426	0.000	49.000	1022.826	0.00000	0.989	0.431
N/S	16 A	0.069	0.000	12.000	9.875	0.00000	0.989	0.069
N/S	16 B	0.069	0.000	17.250	20.405	0.00000	0.989	0.069

15 Story Tower - Story bulkhead - N/S and E/W Loading								
Orientation	Shear Wall	k (k/ft)	Eccentricity (ft)	x_i/y_i (ft)	Inertia (k-ft)	Torsional Shear Dist. Factor	Σk	Direct Shear Dist. Factor
E/W	16	0.583	0.000	0.000	0.000	0.00000	0.583	1.000
N/S	16 A	0.069	0.000	12.000	9.875	0.00000	0.137	0.500
N/S	16 B	0.069	0.000	17.250	20.405	0.00000	0.137	0.500

8 Story Tower - Story 2 - E/W Loading								
Orientation	Shear Wall	k (k/ft)	Eccentricity (ft)	x_i/y_i (ft)	Inertia (k-ft)	Torsional Shear Dist. Factor	Σk	Direct Shear Dist. Factor
E/W	34 short	0.171	14.000	16.500	46.639	0.24656	0.899	0.191
E/W	33short	0.727	14.000	4.000	11.635	0.25373	0.899	0.809
N/S	34 long	0.511	14.000	9.833	49.438	0.43856		
N/S	33 long	0.479	14.000	10.500	52.786	0.43852		

8 Story Tower - Story 2 - N/S Loading								
Orientation	Shear Wall	k (k/ft)	Eccentricity (ft)	x_i/y_i (ft)	Inertia (k-ft)	Torsional Shear Dist. Factor	Σk	Direct Shear Dist. Factor
E/W	34 short	0.171	0.000	16.500	46.639	0.00000		
E/W	33short	0.727	0.000	4.000	11.635	0.00000		
N/S	34 long	0.511	0.000	9.833	49.438	0.00000	0.990	0.516
N/S	33 long	0.479	0.000	10.500	52.786	0.00000	0.990	0.484

8 Story Tower - Story 3 through roof - E/W Loading								
Orientation	Shear Wall	k (k/ft)	Eccentricity (ft)	x_i/y_i (ft)	Inertia (k-ft)	Torsional Shear Dist. Factor	Σk	Direct Shear Dist. Factor
E/W	34 short	0.171	1.500	16.500	46.639	0.02642	0.899	0.191
E/W	33short	0.727	1.500	4.000	11.635	0.02719	0.899	0.809
N/S	34 long	0.511	1.500	9.833	49.438	0.04699		
N/S	33 long	0.479	1.500	10.500	52.786	0.04698		

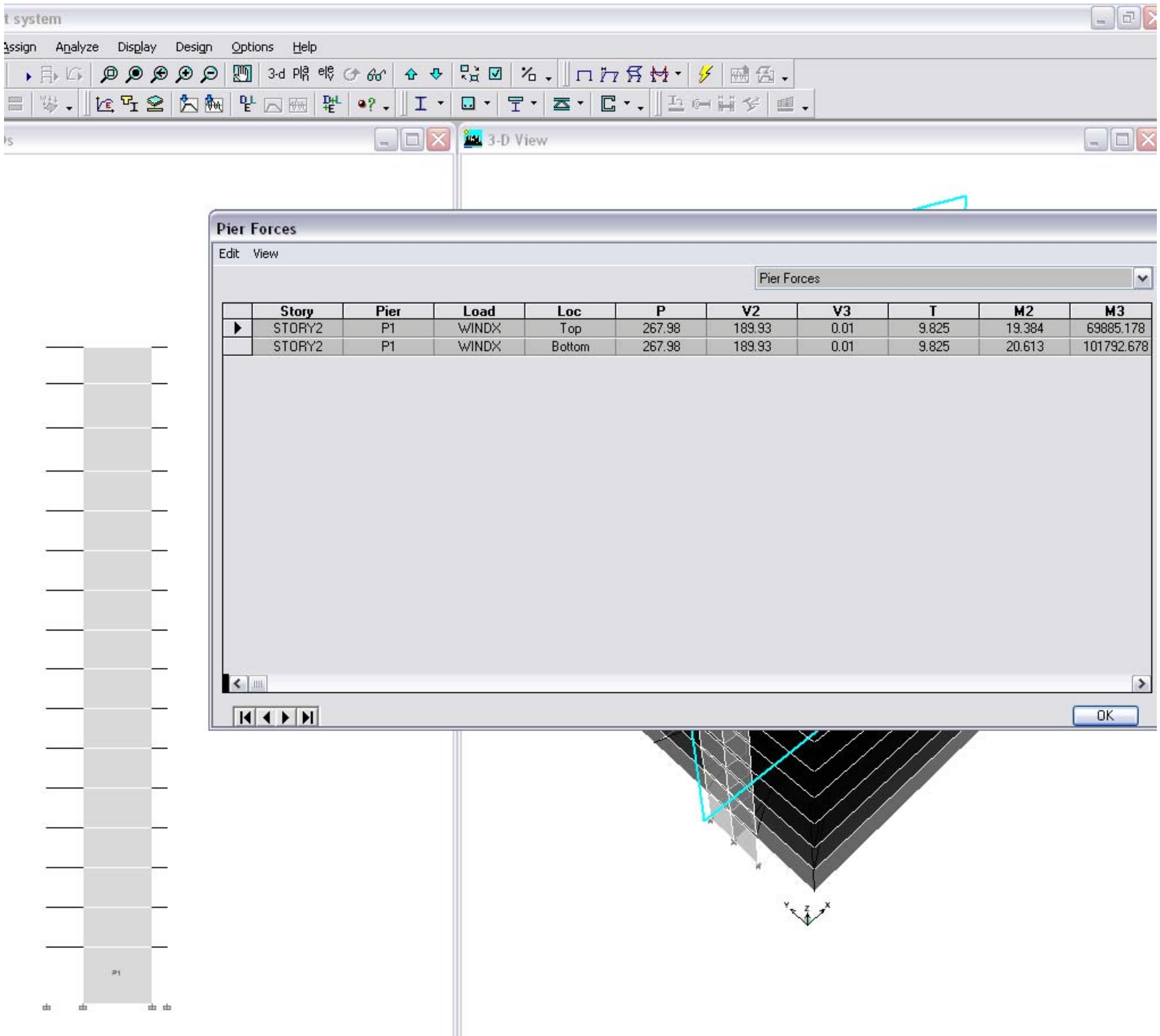
8 Story Tower - Story 3 through roof - N/S Loading								
Orientation	Shear Wall	k (k/ft)	Eccentricity (ft)	x_i/y_i (ft)	Inertia (k-ft)	Torsional Shear Dist. Factor	Σk	Direct Shear Dist. Factor
E/W	34 short	0.171	0.000	16.500	46.639	0.00000		
E/W	33short	0.727	0.000	4.000	11.635	0.00000		
N/S	34 long	0.511	0.000	9.833	49.438	0.00000	0.990	0.516
N/S	33 long	0.479	0.000	10.500	52.786	0.00000	0.990	0.484

8 Story Tower - bulkhead - E/W Loading								
Orientation	Shear Wall	k (k/ft)	Eccentricity (ft)	x_i/y_i (ft)	Inertia (k-ft)	Torsional Shear Dist. Factor	Σk	Direct Shear Dist. Factor
E/W	34 short	0.171	0.000	16.500	46.639	0.00000	0.899	0.191
E/W	33short	0.727	0.000	4.000	11.635	0.00000	0.899	0.809
N/S	34 long	0.511	0.000	10.500	56.372	0.00000		
N/S	33 long	0.479	0.000	10.500	52.786	0.00000		

8 Story Tower - bulkhead. - N/S Loading								
Orientation	Shear Wall	k (k/ft)	Eccentricity (ft)	x_i/y_i (ft)	Inertia (k-ft)	Torsional Shear Dist. Factor	Σk	Direct Shear Dist. Factor
E/W	34 short	0.171	4.167	16.500	46.639	0.07035		

Comparison of manually calculated base shear for SW 16 vs. Computer output

East/West Wind Loading on SW 16				
Story	Diaphram Force (kips)	Torsional Shear Dist. Factor	Direct Shear Dist. Factor	Force on SW 16 (kips)
2				
	25.74	0.01110	0.60700	15.91
3				
	18.14	-0.01110	0.60700	10.81
4				
	19.20	-0.01110	0.60700	11.44
5				
	20.02	-0.01110	0.60700	11.93
6				
	20.67	-0.01110	0.60700	12.32
7				
	21.33	-0.01110	0.60700	12.71
8				
	21.98	-0.01110	0.60700	13.10
9				
	22.55	-0.01110	0.60700	13.44
10				
	22.96	-0.01110	0.60700	13.68
11				
	23.37	-0.01110	0.60700	13.93
12				
	23.78	-0.01110	0.60700	14.17
13				
	24.19	-0.00311	0.60700	14.61
14				
	25.88	-0.01110	0.60700	15.42
15				
	22.32	-0.01110	0.60700	13.30
roof				
	11.53	0.00000	1.00000	11.53
bulk head				
	2.87	0.00000	1.00000	2.87
		Total Base Shear (kips) =		201.16



Manually calculated base shear = 201.16 kips

ETABS calculated base shear = 189.93 kips

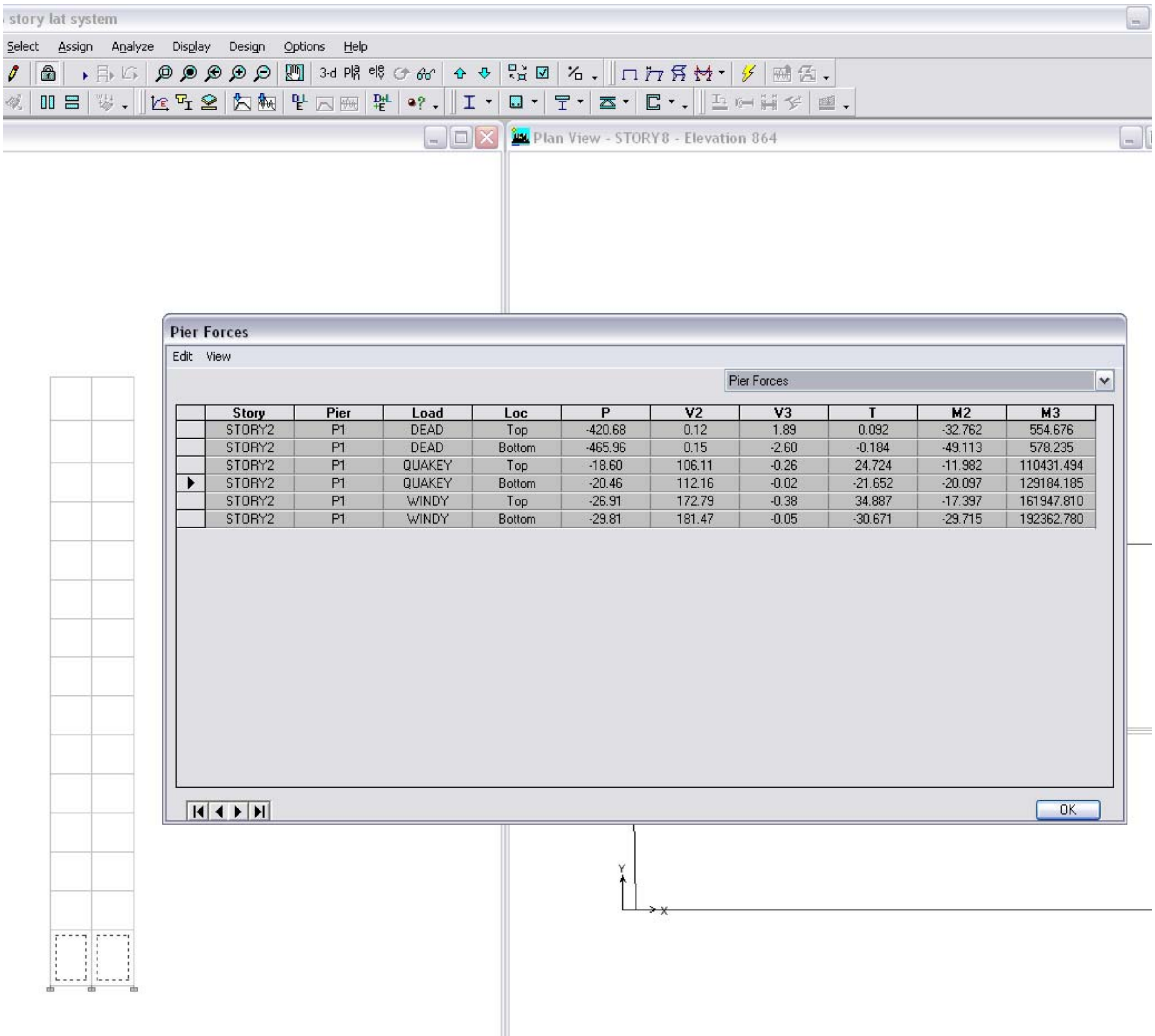
Error = 5.9%

Manual calculation matches computer output fairly closely.

Appendix B – Calculations

Shear Wall Calculations

Loads on SW20 (N/S Direction)



Story	Pier	Load	Loc	P	V2	V3	T	M2	M3
STORY2	P1	DEAD	Top	-420.68	0.12	1.89	0.092	-32.762	554.676
STORY2	P1	DEAD	Bottom	-465.96	0.15	-2.60	-0.184	-49.113	578.235
STORY2	P1	QUAKEY	Top	-18.60	106.11	-0.26	24.724	-11.982	110431.494
STORY2	P1	QUAKEY	Bottom	-20.46	112.16	-0.02	-21.652	-20.097	129184.185
STORY2	P1	WINDY	Top	-26.91	172.79	-0.38	34.887	-17.397	161947.810
STORY2	P1	WINDY	Bottom	-29.81	181.47	-0.05	-30.671	-29.715	192362.780

DL = 466 kip

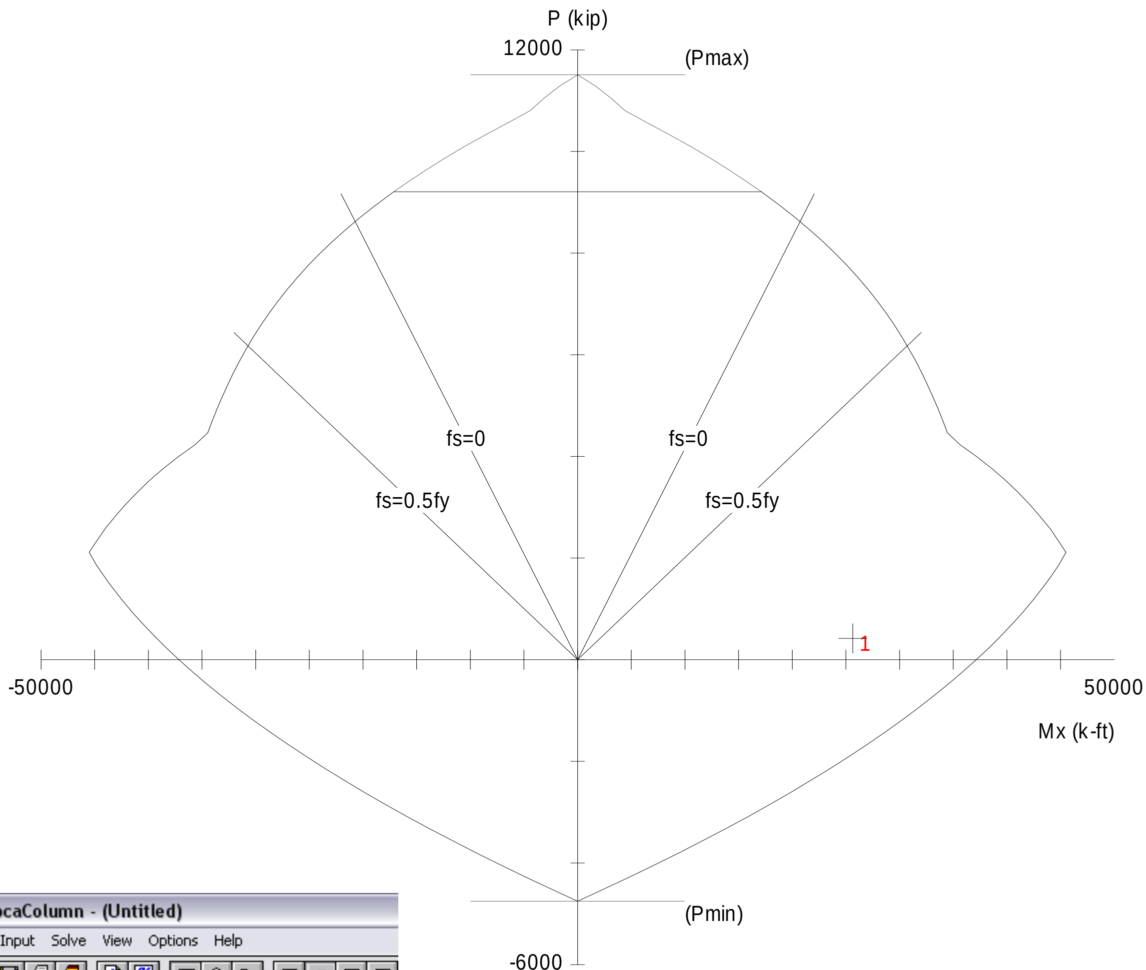
E = 129184 in-k = 10765 ft-k

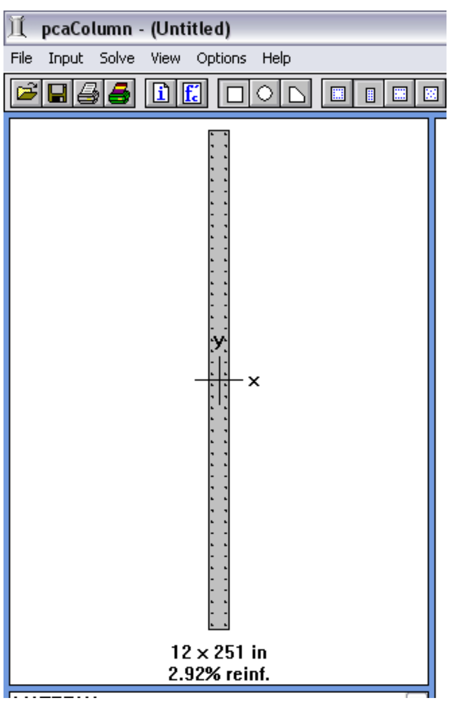
W = 192363 in-k = 16030 ft-k

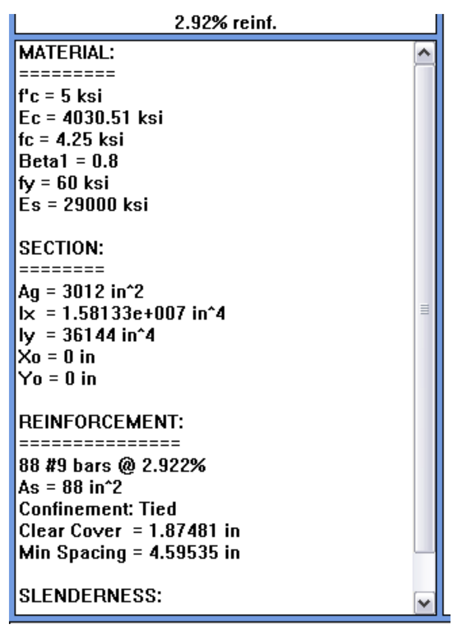
For Over Turning Governing Combination is 0.9D + 1.6W = 419 k D + 25648 ft-k W

For shear Wind governs: Vu = 1.6(182) = 291 kips

Combined Axial and Bending Check






2.92% reinf.

MATERIAL:
=========
f'c = 5 ksi
Ec = 4030.51 ksi
fc = 4.25 ksi
Beta1 = 0.8
fy = 60 ksi
Es = 29000 ksi

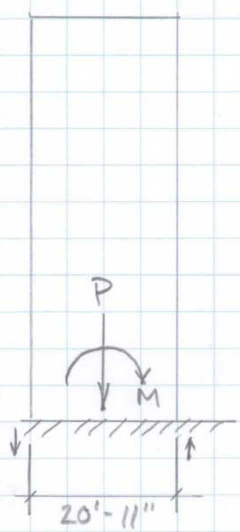
SECTION:
========
Ag = 3012 in^2
Ix = 1.58133e+007 in^4
Iy = 36144 in^4
Xo = 0 in
Yo = 0 in

REINFORCEMENT:
==============
88 #9 bars @ 2.922%
As = 88 in^2
Confinement: Tied
Clear Cover = 1.87481 in
Min Spacing = 4.59535 in

SLENDERNESS:

DESIMONE

PROJECT: THESIS TECH 3 | PAGE ____ OF ____
PROJECT NO. ____ | DATE ____
ITEM: OVERTURNING | BY ____ CHK'D ____



$P = 466^k$ (DEAD LOAD)

$M = 16030$ ft-k (WIND)

LC: $0.9D + 1.6W$

$= (0.9)(466) + (1.6)(16030)$

$\Rightarrow P' = 419^k$

$M' = 25648$ ft-k

$M_{RESISTING} = (419^k)\left(\frac{20'-11''}{2}\right) = 4382$ ft-k

$M_{RESISTING} < M_{OVERTURNING}$

$4382 < 25648$

∴ FTG IS SUBJECTED TO UPLIFT *

* HOWEVER, FTG IS ANCHORED BY 240 TON CAISSONS, WHICH PREVENT OVERTURNING

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DESIMONE

PROJECT THESIS TECH 3 PAGE ____ OF ____
PROJECT NO. ____ DATE ____
ITEM SW 20 SHEAR CHECK BY ____ CHK'D ____

$V_{n,MAX} = 10\sqrt{f'_c}\,hd = 10\sqrt{5000}(12)(0.8)(251)$ ACI 11.10.3

$V_{n,MAX} = 1704^k$

$V_{c,MAX} = 2\sqrt{f'_c}\,hd = \frac{1}{5}V_{n,MAX} = 341^k$ ACI 11.10.5

$V_u = (1.6)(182) = 291^k$

$V_u > 0.5\phi V_c$

$\phi V_n \geq V_u = \phi V_s + \phi V_c \Rightarrow V_s \geq \frac{V_u - \phi V_c}{\phi}$

$V_s \geq \frac{291 - (0.75)(341)}{0.75} = 48^k$

$V_s = \frac{A_v f_y d}{s} \Rightarrow \frac{A_v}{s} = \frac{V_s}{f_y d}$ ACI 11.10.9.1

$\frac{A_v}{s} = \frac{48^k}{(60\,ksi)(0.8)(251)} = 0.004\ in^2/in$

EXISTING SPACING = 12 in

$\Rightarrow A_v \geq 12(0.004) = 0.048\ in^2$

$A_{v\ PROVIDED} = 2\text{-}\#4 = 0.40\ in^2 > A_{v,MIN}$

* ∴ SW IS ADEQUATE

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Appendix C – Calculations

Story Drift and Over Turning Moment

15 Story Tower				
Wind Story Drift in E/W Direction				
Story	Story Height (in)	Drift Ratio	Story Drift (in)	Building Drift (in)
BULKHEAD	108	0.001029	0.111132	2.214648
ROOF	128	0.001142	0.146176	2.103516
STORY15	128	0.001344	0.172032	1.95734
STORY14	116	0.001368	0.158688	1.785308
STORY13	116	0.001392	0.161472	1.62662
STORY12	116	0.001413	0.163908	1.465148
STORY11	116	0.001425	0.1653	1.30124
STORY10	116	0.001424	0.165184	1.13594
STORY9	116	0.001407	0.163212	0.970756
STORY8	116	0.001368	0.158688	0.807544
STORY7	116	0.001303	0.151148	0.648856
STORY6	116	0.001208	0.140128	0.497708
STORY5	116	0.001075	0.1247	0.35758
STORY4	116	0.0009	0.1044	0.23288
STORY3	116	0.000676	0.078416	0.12848
STORY2	168	0.000298	0.050064	0.050064

15 Story Tower				
Earth Quake Story Drift in E/W Direction				
Story	Story Height (in)	Drift Ratio	Story Drift (in)	Building Drift (in)
BULKHEAD	108	0.001035	0.11178	2.124112
ROOF	128	0.001148	0.146944	2.012332
STORY15	128	0.001342	0.171776	1.865388
STORY14	116	0.001359	0.157644	1.693612
STORY13	116	0.001374	0.159384	1.535968
STORY12	116	0.001384	0.160544	1.376584
STORY11	116	0.001384	0.160544	1.21604
STORY10	116	0.00137	0.15892	1.055496
STORY9	116	0.00134	0.15544	0.896576
STORY8	116	0.001289	0.149524	0.741136
STORY7	116	0.001216	0.141056	0.591612
STORY6	116	0.001114	0.129224	0.450556
STORY5	116	0.000981	0.113796	0.321332
STORY4	116	0.000812	0.094192	0.207536
STORY3	116	0.000602	0.069832	0.113344
STORY2	168	0.000259	0.043512	0.043512

15 Story Tower				
Wind Story Drift in N/S Direction				
Story	Story Height (in)	Drift Ratio	Story Drift (in)	Building Drift (in)
BULKHEAD	108	0.001921	0.207468	2.881508
ROOF	128	0.001945	0.24896	2.67404
STORY15	128	0.001946	0.249088	2.42508
STORY14	116	0.001941	0.225156	2.175992
STORY13	116	0.001927	0.223532	1.950836
STORY12	116	0.001901	0.220516	1.727304
STORY11	116	0.00186	0.21576	1.506788
STORY10	116	0.001802	0.209032	1.291028
STORY9	116	0.001724	0.199984	1.081996
STORY8	116	0.001621	0.188036	0.882012
STORY7	116	0.001493	0.173188	0.693976
STORY6	116	0.001336	0.154976	0.520788
STORY5	116	0.001147	0.133052	0.365812
STORY4	116	0.000924	0.107184	0.23276
STORY3	116	0.000664	0.077024	0.125576
STORY2	168	0.000289	0.048552	0.048552

15 Story Tower				
Earth Quake Story Drift in N/S Direction				
Story	Story Height (in)	Drift Ratio	Story Drift (in)	Building Drift (in)
BULKHEAD	108	0.001356	0.146448	1.992284
ROOF	128	0.001364	0.174592	1.845836
STORY15	128	0.001364	0.174592	1.671244
STORY14	116	0.001358	0.157528	1.496652
STORY13	116	0.001346	0.156136	1.339124
STORY12	116	0.001324	0.153584	1.182988
STORY11	116	0.001292	0.149872	1.029404
STORY10	116	0.001247	0.144652	0.879532
STORY9	116	0.001187	0.137692	0.73488
STORY8	116	0.001112	0.128992	0.597188
STORY7	116	0.001019	0.118204	0.468196
STORY6	116	0.000907	0.105212	0.349992
STORY5	116	0.000774	0.089784	0.24478
STORY4	116	0.000619	0.071804	0.154996
STORY3	116	0.000442	0.051272	0.083192
STORY2	168	0.00019	0.03192	0.03192

8 Story Tower				
Wind Story Drift in E/W Direction				
Story	Story Height (in)	Drift Ratio	Story Drift (in)	Building Drift (in)
BULKHEAD	108	0.001805	0.19494	1.520844
ROOF	128	0.001818	0.232704	1.325904
STORY8	116	0.001801	0.208916	1.0932
STORY7	116	0.001753	0.203348	0.884284
STORY6	116	0.001655	0.19198	0.680936
STORY5	116	0.001488	0.172608	0.488956
STORY4	116	0.001236	0.143376	0.316348
STORY3	116	0.000893	0.103588	0.172972
STORY2	168	0.000413	0.069384	0.069384

8 Story Tower				
Earth Quake Story Drift in E/W Direction				
Story	Story Height (in)	Drift Ratio	Story Drift (in)	Building Drift (in)
BULKHEAD	108	0.001308	0.141264	0.96886
ROOF	128	0.001318	0.168704	0.800156
STORY8	116	0.001294	0.150104	0.650052
STORY7	116	0.001244	0.144304	0.505748
STORY6	116	0.001157	0.134212	0.371536
STORY5	116	0.001024	0.118784	0.252752
STORY4	116	0.000837	0.097092	0.15566
STORY3	116	0.000583	0.067628	0.088032
STORY2	168	0.000262	0.044016	0.044016

8 Story Tower				
Wind Story Drift in N/S Direction				
Story	Story Height (in)	Drift Ratio	Story Drift (in)	Building Drift (in)
BULKHEAD	108	0.00009	0.00972	0.076684
ROOF	128	0.000091	0.011648	0.066964
STORY8	116	0.00009	0.01044	0.055316
STORY7	116	0.000088	0.010208	0.044876
STORY6	116	0.000083	0.009628	0.034668
STORY5	116	0.000075	0.0087	0.02504
STORY4	116	0.000063	0.007308	0.01634
STORY3	116	0.000046	0.005336	0.009032
STORY2	168	0.000022	0.003696	0.003696

8 Story Tower				
Earth Quake Story Drift in N/S Direction				
Story	Story Height (in)	Drift Ratio	Story Drift (in)	Building Drift (in)
BULKHEAD	108	0.000195	0.02106	0.163172
ROOF	128	0.000197	0.025216	0.142112
STORY8	116	0.000195	0.02262	0.116896
STORY7	116	0.000189	0.021924	0.094276
STORY6	116	0.000177	0.020532	0.072352
STORY5	116	0.000158	0.018328	0.05182
STORY4	116	0.000131	0.015196	0.033492
STORY3	116	0.000094	0.010904	0.018296
STORY2	168	0.000044	0.007392	0.007392

8 STORY TOWER SEISMIC FORCES												
story	story height	height (ft)	C_s	Building weight (kips)	Base Shear (kips)	k	w_x	$w_x h_x^k$	$\Sigma w_i h_i^k$	C_v	Story Force (kips)	Over-Turning Moment (ft-k)
bulkhead	9.00	92.71	0.0200	3689	74	0.291056	205.25	759.303	10844.216	0.070	5.18	479.93
roof	10.67	83.71	0.0200	3689	74	0.291056	419.962	1506.435	10844.216	0.139	10.27	859.73
8	10.69	73.04	0.0200	3689	74	0.291056	404.169	1391.088	10844.216	0.128	9.48	692.71
7	9.67	62.35	0.0200	3689	74	0.291056	404.683	1333.758	10844.216	0.123	9.09	566.96
6	9.67	52.68	0.0200	3689	74	0.291056	403.398	1263.315	10844.216	0.116	8.61	453.73
5	9.67	43.01	0.0200	3689	74	0.291056	404.169	1190.068	10844.216	0.110	8.11	348.96
4	9.67	33.34	0.0200	3689	74	0.291056	404.169	1100.134	10844.216	0.101	7.50	250.06
3	9.67	23.67	0.0200	3689	74	0.291056	403.912	986.909	10844.216	0.091	6.73	159.26
2	14.00	14.00	0.0200	3689	74	0.291056	639.1565	1313.205	10844.216	0.121	8.95	125.34
											Total =	3936.68

15 STORY TOWER SEISMIC FORCES												
story	story height	height (ft)	C_s	Building weight (kips)	Base Shear (kips)	k	w_x	$w_x h_x^k$	$\Sigma w_i h_i^k$	C_v	Story Force (kips)	Over-Turning Moment (ft-k)
bulkhead	9.00	160.40	0.0133	19604	262	0.43716	235.05	2162.77	127471	0.01697	4.44	711.91
roof	10.67	151.40	0.0133	19604	262	0.43716	1079.11	9681.49	127471	0.07595	19.87	3008.02
15	10.69	140.73	0.0133	19604	262	0.43716	1751.21	15217.4	127471	0.11938	31.23	4394.79
14	9.67	130.04	0.0133	19604	262	0.43716	1204.36	10110.5	127471	0.07932	20.75	2698.13
13	9.67	120.37	0.0133	19604	262	0.43716	1203.92	9770.76	127471	0.07665	20.05	2413.56
12	9.67	110.70	0.0133	19604	262	0.43716	1204.36	9423	127471	0.07392	19.34	2140.67
11	9.67	101.03	0.0133	19604	262	0.43716	1204.36	9053.51	127471	0.07102	18.58	1877.07
10	9.67	91.36	0.0133	19604	262	0.43716	1203.92	8660.31	127471	0.06794	17.77	1623.69
9	9.67	81.69	0.0133	19604	262	0.43716	1204.36	8249.91	127471	0.06472	16.93	1383.03
8	9.67	72.02	0.0133	19604	262	0.43716	1204.36	7807.26	127471	0.06125	16.02	1153.89
7	9.67	62.35	0.0133	19604	262	0.43716	1203.92	7326.97	127471	0.05748	15.04	937.50
6	9.67	52.68	0.0133	19604	262	0.43716	1204.36	6808.76	127471	0.05341	13.97	736.08
5	9.67	43.01	0.0133	19604	262	0.43716	1204.36	6230.05	127471	0.04887	12.79	549.89
4	9.67	33.34	0.0133	19604	262	0.43716	1203.92	5570.12	127471	0.0437	11.43	381.10
3	9.67	23.67	0.0133	19604	262	0.43716	1204.36	4795.79	127471	0.03762	9.84	232.95
2	14	14.00	0.0133	19604	262	0.43716	2088.2	6602.77	127471	0.0518	13.55	189.70
											Total =	24431.98

15 STORY TOWER N/S WIND FORCES									
story	story height	height (ft)	p_z (windward)	p_z (leeward)	Total Pressure (psf)	building length (ft)	Story Force (kips)	Diaphram Force (kips)	Over-Turning Moment (ft-k)
2	14.00	14.00	12.61	9.37	21.98	98	30.16		
								26.33	368.64
3	9.67	23.67	14.38	9.37	23.75	98	22.51		
								23.24	550.12
4	9.67	33.34	15.93	9.37	25.30	98	23.98		
								24.60	820.21
5	9.67	43.01	17.25	9.37	26.62	98	25.23		
								25.65	1103.14
6	9.67	52.68	18.14	9.37	27.51	98	26.07		
								26.49	1395.34
7	9.67	62.35	19.02	9.37	28.39	98	26.90		
								27.33	1703.76
8	9.67	72.02	19.91	9.37	29.28	98	27.75		
								28.16	2028.40
9	9.67	81.69	20.79	9.37	30.16	98	28.58		
								28.90	2360.75
10	9.67	91.36	21.46	9.37	30.83	98	29.22		
								29.42	2688.25
11	9.67	101.03	21.90	9.37	31.27	98	29.63		
								29.95	3025.45
12	9.67	110.70	22.56	9.37	31.93	98	30.26		
								30.47	3373.25
13	9.67	120.37	23.01	9.37	32.38	98	30.69		
								31.00	3731.22
14	9.67	130.04	23.67	9.37	33.04	98	31.31		
								33.16	4312.09
15	10.67	140.71	24.11	9.37	33.48	98	35.01		
								35.47	4991.55
roof	10.67	151.38	25.00	9.37	34.37	98	35.94		
								22.61	3422.64
bulk head	9	160.38	25.00	9.37	34.37	30	9.28		
								4.64	744.16
							Total =	427.42	36618.98

15 STORY TOWER E/W WIND FORCES									
story	story height	height (ft)	p_z (windward)	p_z (leeward)	Total Pressure (psf)	building length (ft)	Story Force (kips)	Diaphram Force (kips)	Over-Turning Moment (ft-k)
2	14.00	14.00	14.18	10.54	24.72	98	33.92		
								25.74	360.35
3	9.67	23.67	16.17	10.54	26.71	68	17.56		
								18.14	429.28
4	9.67	33.34	17.91	10.54	28.45	68	18.71		
								19.20	640.10
5	9.67	43.01	19.40	10.54	29.94	68	19.69		
								20.02	860.94
6	9.67	52.68	20.40	10.54	30.94	68	20.34		
								20.67	1088.98
7	9.67	62.35	21.39	10.54	31.93	68	21.00		
								21.33	1329.67
8	9.67	72.02	22.39	10.54	32.93	68	21.65		
								21.98	1583.01
9	9.67	81.69	23.38	10.54	33.92	68	22.31		
								22.55	1842.33
10	9.67	91.36	24.13	10.54	34.67	68	22.80		
								22.96	2097.78
11	9.67	101.03	24.63	10.54	35.17	68	23.13		
								23.37	2361.13
12	9.67	110.70	25.37	10.54	35.91	68	23.62		
								23.78	2632.40
13	9.67	120.37	25.87	10.54	36.41	68	23.94		
								24.19	2911.57
14	9.67	130.04	26.62	10.54	37.16	68	24.43		
								25.88	3365.15
15	10.67	140.71	27.12	10.54	37.66	68	27.32		
								22.32	3140.84
roof	10.67	151.38	28.11	10.54	38.65	42	17.32		
								11.53	1745.47
bulk head	9	160.38	28.11	10.54	38.65	16.5	5.74		
								2.87	460.27
							Total =	326.52	26849.27

8 STORY TOWER N/S WIND FORCES									
story	story height	height (ft)	p_z (windward)	p_z (leeward)	Total Pressure (psf)	building length (ft)	Story Force (kips)	Diaphram Force (kips)	Over-Turning Moment (ft-k)
2	14.00	14.00	10.29	7.65	17.94	22	5.53		
								4.83	67.55
3	9.67	23.67	11.74	7.65	19.39	22	4.13		
								4.26	100.81
4	9.67	33.34	13.00	7.65	20.65	22	4.39		
								4.51	150.30
5	9.67	43.01	14.08	7.65	21.73	22	4.62		
								4.70	202.12
6	9.67	52.68	14.80	7.65	22.45	22	4.78		
								4.85	255.69
7	9.67	62.35	15.53	7.65	23.18	22	4.93		
								5.01	312.24
8	9.67	72.02	16.25	7.65	23.90	22	5.08		
								5.16	371.70
roof	9.67	81.69	16.97	7.65	24.62	22	5.24		
								2.62	213.93
bulkhead	9	90.69	16.97	7.65	24.62	22	4.87		
								2.44	221.05
							Total =	35.93	1674.35

8 STORY TOWER E/W WIND FORCES									
story	story height	height (ft)	p_z (windward)	p_z (leeward)	Total Pressure (psf)	building length (ft)	Story Force (kips)	Diaphram Force (kips)	Over-Turning Moment (ft-k)
2	14.00	14.00	12.07	7.65	19.72	99	27.33		
								20.71	289.92
3	9.67	23.67	13.77	7.65	21.42	68	14.08		
								14.57	344.91
4	9.67	33.34	15.25	7.65	22.90	68	15.06		
								15.48	515.96
5	9.67	43.01	16.52	7.65	24.17	68	15.89		
								16.17	695.59
6	9.67	52.68	17.37	7.65	25.02	68	16.45		
								16.73	881.42
7	9.67	62.35	18.22	7.65	25.87	68	17.01		
								17.29	1078.07
8	9.67	72.02	19.07	7.65	26.72	68	17.57		
								17.85	1285.28
Roof	9.67	81.69	19.91	7.65	27.56	68	18.12		
								9.06	740.21
Bulkhead	9	90.69	19.91	7.65	27.56	23	5.70		
								2.85	258.69
							Total =	127.86	6090.04