Structural Technical Report 3
(Lateral System Analysis and Confirmation Design)

Advisor: Boothby
11-21-2005

Executive Summary

The Christina Landing Apartment Tower is a 22 story apartment building located just outside center city Wilmington, DE. The tower provides 250,000 square feet of floor space. The structure is a predominately cast-in-place concrete building. Its floors are supported by a two way flat slab system. The typical floor system also incorporates small areas of reinforced concrete and post-tensioned beams to aid the lateral force resisting system. The floors are supported by square and round concrete columns. Lateral forces induced on the building are resisted by a box of four shear walls. All columns and shear walls rest on a foundation system of H-piles and pile caps. Typical floor loads are 130psf dead load and 40psf live load.

For this report I looked at the lateral resisting system in detail. The system uses both a box of four shear walls, as well as concrete moment frames. By choosing the controlling load case of wind from technical assignment 1 and using those story pressures I found the rigidities of the lateral resisting elements. I found that the shear walls were much more rigid than the moment frames, however, the moment frames resist more load as the story heights increase. Through a series of excel spreadsheets I was able to find the shear forces at each floor in all of my lateral resisting elements. The base shear for the walls was as large as 750k while for the frames was as small as 7k. The shear forces in the frames actually increase as the stories go up which seems unusual. What actually happens is that as you come down the building the shear is transferred out of the frames and into the walls through the rigid floor diaphragms, because the walls are able to carry a much larger shear load on the lower floors. Once all the forces for all the lateral resisting elements were calculated I analyzed them for story drift using both STAAD.Pro and RAM Advanse. I found the drifts to be approximately 8" for both the wall and frame. These deflections were greater than the maximum drifts of L/400 or 6.9". For my report I also checked one of the shear walls for strength requirements and found it to be inadequate in reinforcement. However, because of the complexities of the wall I will need to look at it in greater detail to actually confirm whether or not it is sufficient.

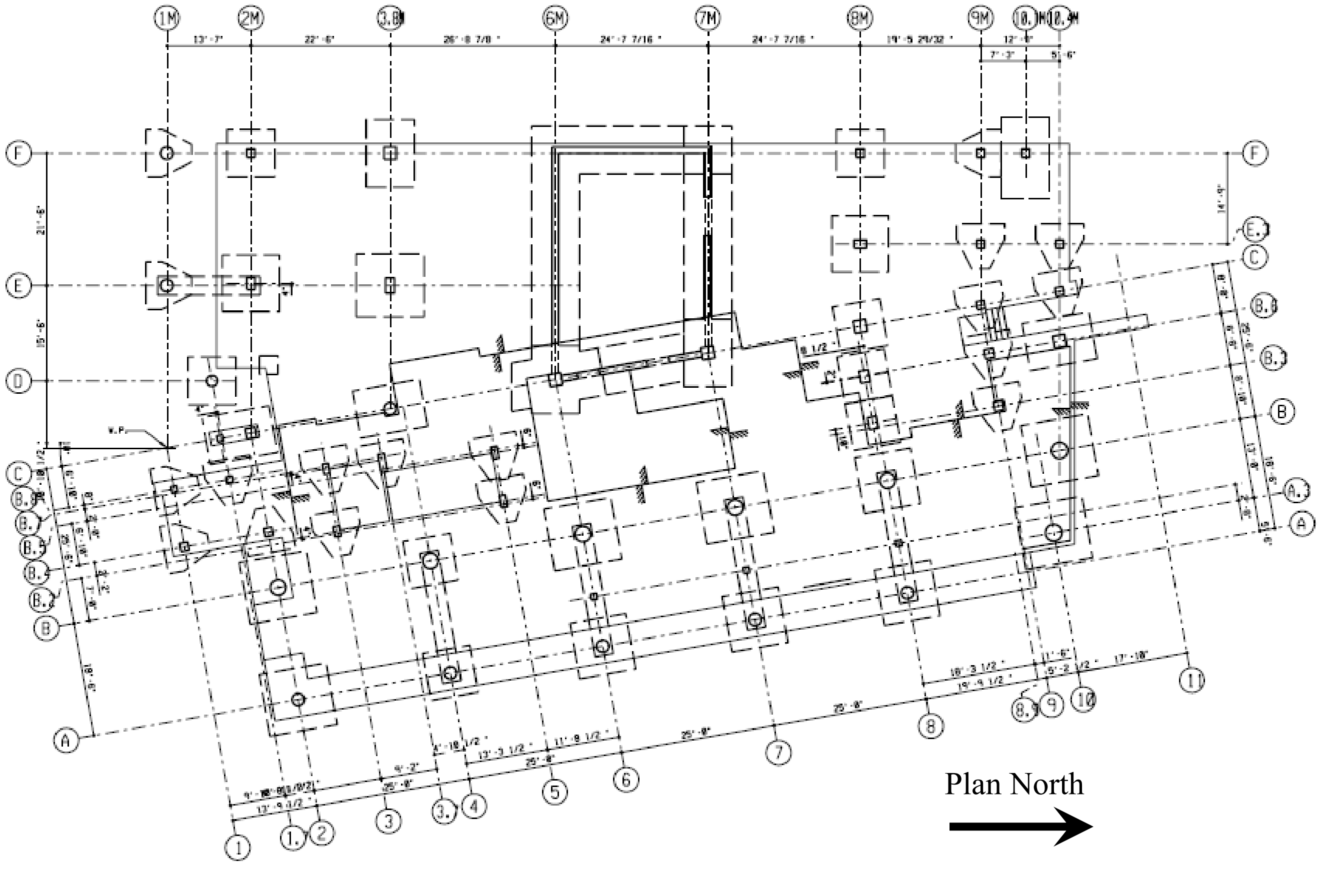
Building Introduction

The Christina Landing Apartment Tower is a 22 story apartment building located just outside center city Wilmington, DE. The tower provides 250,000 square feet of floor space and its footprint covers approximately 12,000 square feet. The typical floor to floor height (floors 3-20) is 10 feet, while the common spaces on the first and second floors and the penthouses on the 21st and 22nd floor have 12 foot floor heights. The total building height is 230'. The structure is a predominately cast-in-place concrete building. Its floors are supported by a two way flat slab system. Spans between columns are on average approximately 20 to 25 feet. Other than the bays that contain slab openings, the typical panel ratios range from 1:1 to 1:1.5 (see page 5 for framing plan). The typical floor system also incorporates small areas of reinforced concrete beams and post-tensioned beams in the plan-northeast and southeast corners to aid the lateral force resisting system. The floors are supported by square and round concrete columns. Column sizes for typical bays are 2' square or 2' round columns. For columns that surround slab openings and support smaller spans, sizes range down to 12"*12". Column sizes seldom vary from floor to floor although reinforcement frequently changes (see page 29 for column schedule). Lateral forces induced on the building are resisted by a box of four shear walls located in the center of the west wall. Because of the large torsional force created by this eccentricity of the center of rigidity the regions of post-tensioned framing are used to provide extra stiffness. All columns and shear walls rest on a foundation system of H-piles and pile caps. Concrete strengths differ throughout the structure, ranging from 4000 psi to 8000 psi (see page 4 for concrete strength schedule.)

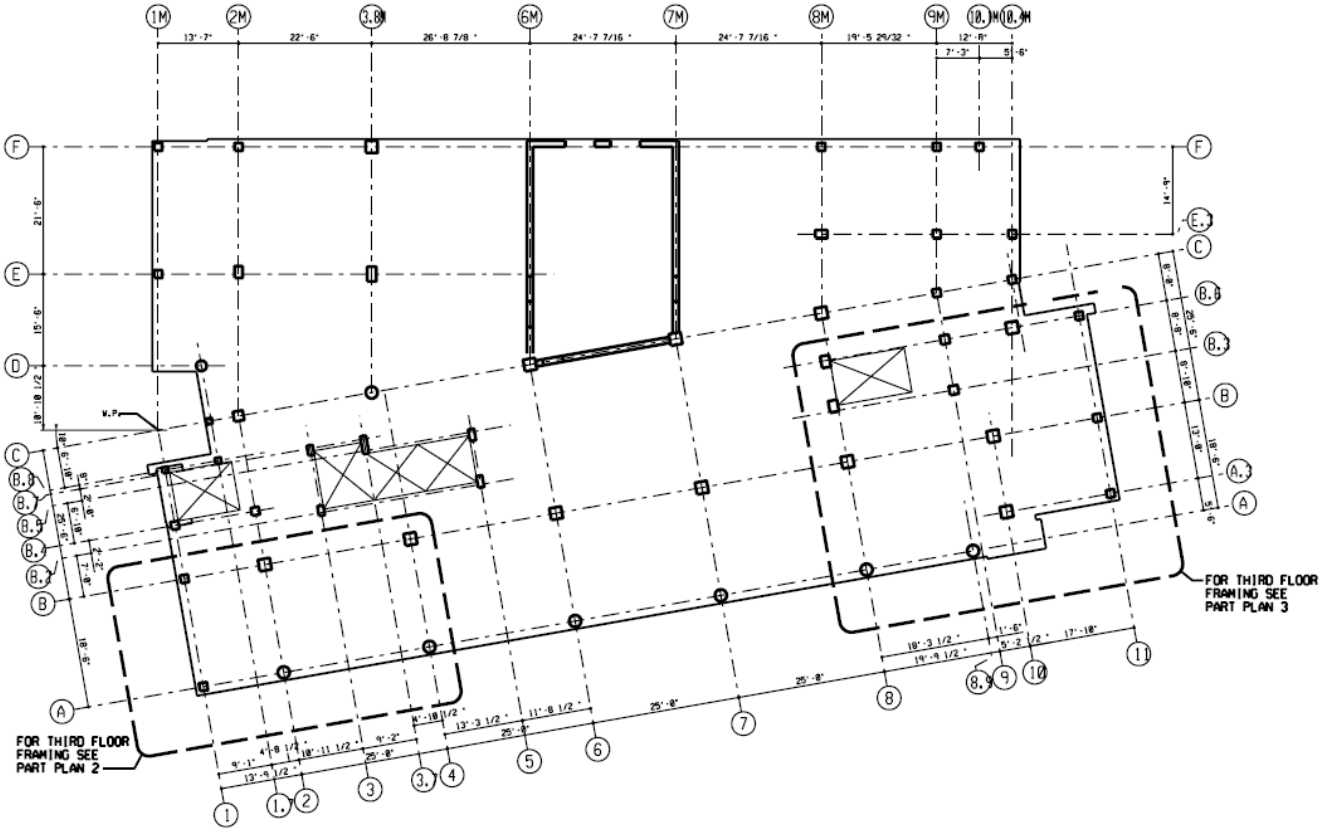
This report will cover, in order, the following areas.
Loads and Load Cases
Distribution of Loads
Analysis
Member Checks
Conclusions

Concrete Strength Schedule	
Element	28 Day Cylinder Strength (psi)
Pile Caps	4,000
Slabs 5th Floor and Above	4,500
Slabs Below 5th Floor	5,600
Columns 5th Floor and Above	5,000
Columns Below 5th Floor	8,000
Exterior Slabs and Paving	5,000
Shear Walls	5,000
Topping Fills	4,000

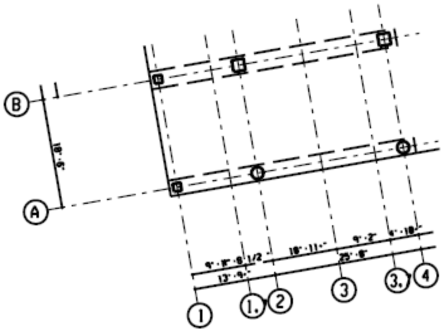
1st Floor Framing Plan



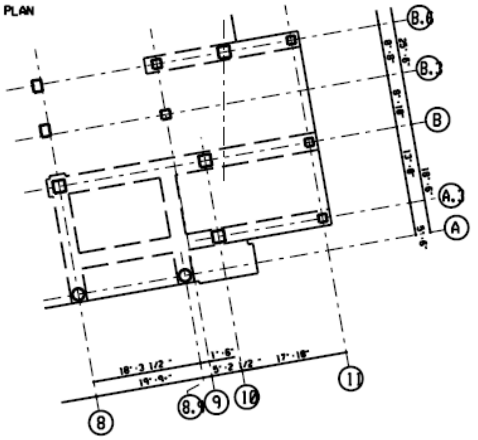
Typical Framing Plan



1 TYPICAL FLOOR (3RD - 20TH) FRAMING PLAN



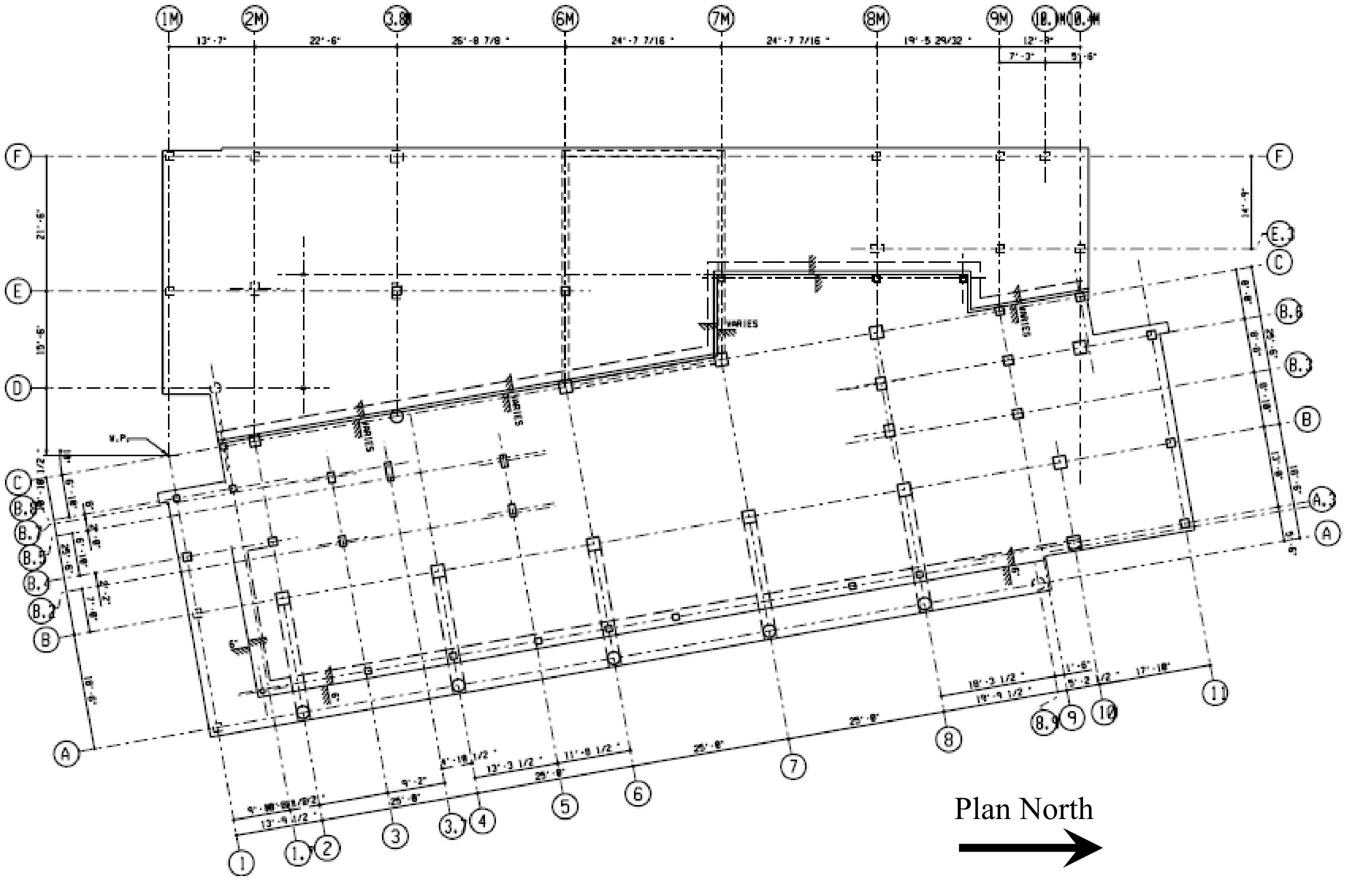
2 PART PLAN - THIRD FLOOR FRAMING PLAN



3 PART PLAN - THIRD FLOOR FRAMING PLAN

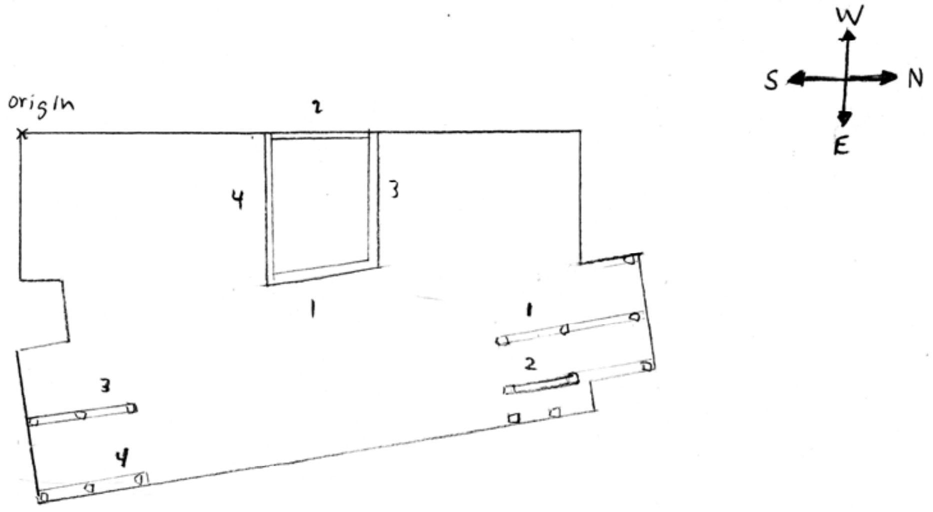
Plan North →

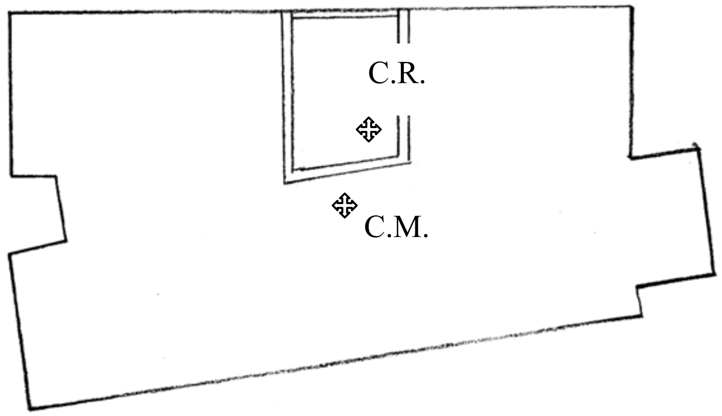
21st Floor Framing Plan



Introduction of Lateral System

The lateral system of this building consists of both shear walls and concrete moment frames. There are four shear walls in the tower arranged in a box at the center of the west wall. The walls are connected at the corners and act in unison to allow for shear flow. For ease of analysis I assumed that all four walls are perpendicular to each other by conservatively adjusting their lengths. All of the walls are 12” thick with #4 bars at 12” on center each way in each face. Two of the walls are 32’ and two of the walls are 24’. The building has 7 concrete moment frames. For my analysis I included the 4 frames that have the most significant affect on curbing the large torsional force produced by a north-south wind. The frames are located in the north-east and south-east corners of the tower. Although the bay sizes vary, each of the 4 frames include 3 columns: 2-24” square, and 1-16” square. The columns are connected by 36”x60” post-tensioned beams.





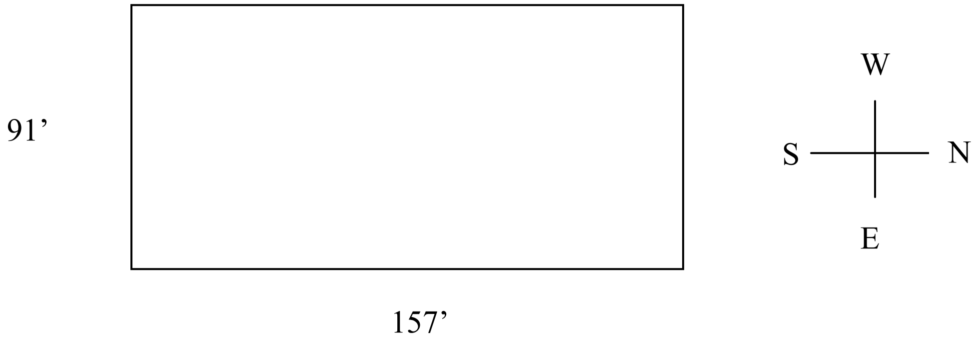
Loads and Load Cases

The loads used for this design are as follows:
Self Weight Slab = 100psf
Partitions = 20psf
Miscellaneous Dead Load = 10psf
Live Load = 40psf

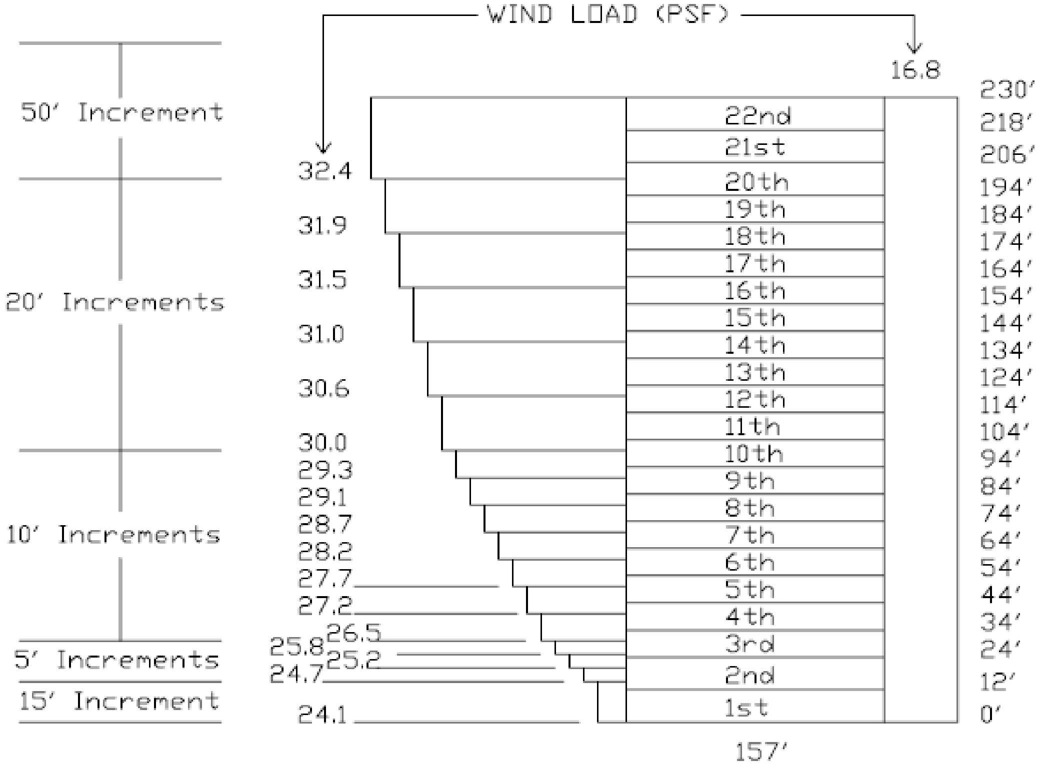
For gravity loads the load case used was 1.2D+1.6L
For wind loads the load case used was 1.2D+1.6W+L

Lateral Loads

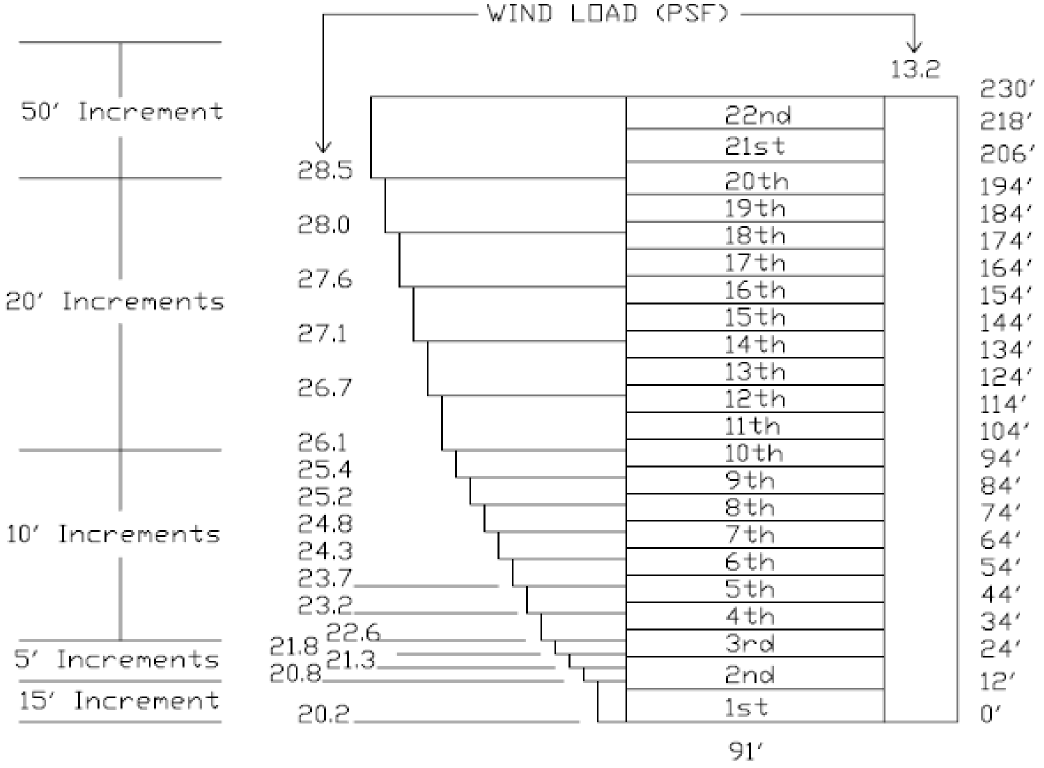
From Technical Report 1 I found wind to be the controlling lateral load. The images on the following page are wind loading diagrams for the apartment tower. For the calculations I estimated the building to be a 91'x157' rectangle. These dimensions are conservative and provide the loading for the worst case scenario pressures on the structure. In order to calculate the building pressures I used method 2 for high rise buildings from ASCE7. It was also determined that the tower was not able to be classified as a rigid structure and therefore a gust factor needed to be found. Other relevant information used in the wind loading calculations includes an importance factor of 1 and a wind exposure of class "C". The total base shear on the building due to the North-South wind load is 968 k and the total resisting moment at the base of the structure is 114,795 ft-k. The total base shear on the building due to the East-West wind load is 1400 k and the total resisting moment at the base of the structure is 166,980 ft-k. All of the information presented here is generated from calculations and spreadsheets found on page 17-23 in the appendix.



N-S WIND LOAD



E-W WIND LOAD



Distribution of Loads

In order to distribute the loads I found the proportion of rigidity carried by each frame and wall at each level. In order to find the rigidity of the moment frames I entered each of the frames in STAAD.Pro. One at a time I placed a one kip load at each of the story heights and found the horizontal deflection at that point. Taking the inverse of the deflections at each floor I found the stiffness at each floor. In order to find the rigidities of the shear walls I investigate several different options. The three ideas I had to find the rigidities were: first, to analyze the walls separately using the equation R=Et/(4(h/L)^3+3(h/L)); second, to analyze the walls separately using a unit load at a distance to find the relative stiffnesses of the walls compared to each other; third, to analyze the walls was one unit again using a unit load at a distance to find the relative stiffnesses. I knew I wanted the walls to work as a single box however could only find ways to relate their stiffnesses to each other and not to the moment frames as well. As it turned out analyzing the walls the first method mention gave similar proportions to that of the preferred third method. This was quite convenient because I was able to use the first method which was easily related to the moment frames in the structure (see page 36 in appendix for comparison). I used Microsoft excel and the equation R=Et/(4(h/L)^3+3(h/L)) adjusting the height of the wall to find the rigidity at the story heights. Comparing each rigidity to the total of all the walls acting in its direction I found the proportion of stiffness for each wall in each direction at each floor. I found that the moment frames and the shear walls resist a significantly different proportion of the load at different elevations. For example the shear walls tend to resist a huge proportion of the load at the lower levels while at greater heights the moment frames begin to contribute a larger percentage to the resisting system. Because of this relationship the center of rigidity changes for every floor, while the center of mass remains the same. This in turn varies the torsional moment on each floor. The next step I took was to apply the torsional moment to each wall and frame at each floor to find the torsional shear in each brace. In order to do this I needed to create 22 small tables, one for each floor. After finding the torsional shears I added them to the direct shears where the forces would be additive due to the eccentricity. Where the forces acted in opposite directions I used only the direct shear. For my case the controlling forces for the walls and frames were always in the direction of the direct shear because it is larger then the purely torsional shear in the perpendicular direction of the load.

Distribution of story shears for all four shear walls and moment frames are given on the following pages. To save space I left off floor numbers. The first number is the story shear at the 2^{nd} floor which is the first slab above grade. The last two numbers in each list are the 22^{nd} floor and the roof. All results are calculated from pages 24-31 in the appendix.

Walls 1-4

Wall 1		
Direct Shear	Torsional	Total
460.93	292.23	753.15
440.85	266.16	707.02
418.41	235.98	654.39
395.48	207.32	602.79
372.41	182.40	554.81
348.65	159.03	507.68
324.84	137.87	462.71
300.97	118.54	419.51
277.19	101.00	378.20
253.88	85.50	339.38
230.85	71.80	302.65
208.27	59.53	267.80
186.17	48.91	235.08
164.88	39.88	204.75
144.08	31.96	176.04
124.03	25.17	149.20
104.70	19.54	124.24
85.94	14.67	100.61
67.93	10.67	78.61
48.77	6.91	55.68
28.62	3.70	32.33
9.32	1.11	10.42

Wall 2		
Direct Shear	Torsional	Total
460.93	neg value	460.93
440.85	neg value	440.85
418.41	neg value	418.41
395.48	neg value	395.48
372.41	neg value	372.41
348.65	neg value	348.65
324.84	neg value	324.84
300.97	neg value	300.97
277.19	neg value	277.19
253.88	neg value	253.88
230.85	neg value	230.85
208.27	neg value	208.27
186.17	neg value	186.17
164.88	neg value	164.88
144.08	neg value	144.08
124.03	neg value	124.03
104.70	neg value	104.70
85.94	neg value	85.94
67.93	neg value	67.93
48.77	neg value	48.77
28.62	neg value	28.62
9.32	neg value	9.32

Wall 3		
Direct Shear	Torsional	Total
700.19	neg value	700.19
684.48	neg value	684.48
652.92	neg value	652.92
623.04	neg value	623.04
595.01	neg value	595.01
566.47	neg value	566.47
537.51	neg value	537.51
508.16	neg value	508.16
478.40	neg value	478.40
448.32	neg value	448.32
418.04	neg value	418.04
387.28	neg value	387.28
356.48	neg value	356.48
325.22	neg value	325.22
293.91	neg value	293.91
262.33	neg value	262.33
230.71	neg value	230.71
198.74	neg value	198.74
166.73	neg value	166.73
134.44	neg value	134.44
98.89	neg value	98.89
59.27	neg value	59.27

Wall 4		
Direct Shear	Torsional	Total
700.19	19.41	719.59
684.48	20.65	705.13
652.92	20.28	673.19
623.04	19.25	642.29
595.01	17.95	612.96
566.47	16.47	582.94
537.51	14.96	552.48
508.16	13.46	521.62
478.40	12.01	490.41
448.32	10.65	458.98
418.04	9.38	427.42
387.28	8.19	395.47
356.48	7.09	363.57
325.22	6.09	331.31
293.91	5.17	299.07
262.33	4.32	266.64
230.71	3.55	234.26
198.74	2.84	201.58
166.73	2.19	168.92
134.44	1.53	135.97
98.89	0.88	99.77
59.27	0.28	59.55

Frames 1-4

Frame 1		
Direct Shear	Torsional	Total
5.96	7.49699341	13.46
4.75	5.68749848	10.44
5.21	5.8273098	11.04
7.02	7.29807655	14.32
8.44	8.20229754	16.65
10.22	9.24301908	19.46
11.84	9.96750409	21.81
13.43	10.4893489	23.92
14.90	10.7709389	25.67
16.05	10.724233	26.78
16.99	10.483774	27.48
17.68	10.0246433	27.71
18.07	9.41737883	27.49
18.03	8.65094481	26.68
17.65	7.76563457	25.42
16.83	6.77334052	23.60
15.58	5.76850155	21.35
14.06	4.75940093	18.82
12.05	3.75564684	15.81
9.48	2.6647107	12.14
6.03	1.54618744	7.57
2.09	0.4925529	2.59

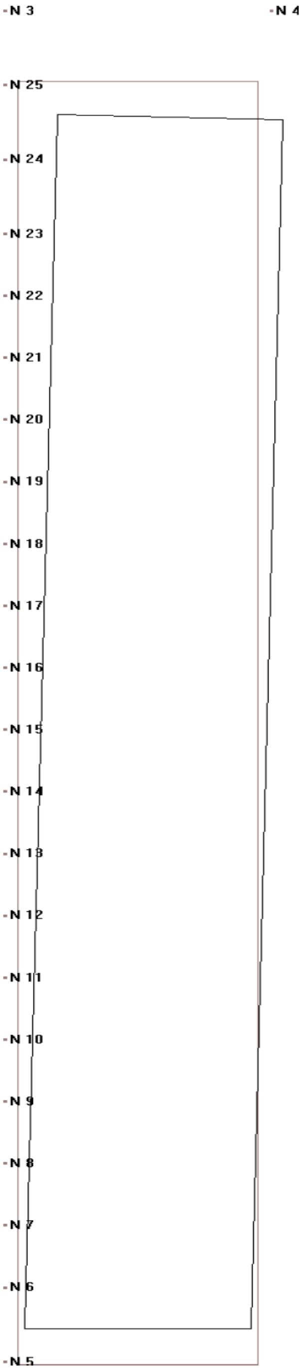
Frame 2		
Direct Shear	Torsional	Total
5.96	10.7337377	16.70
4.75	8.14301328	12.89
5.21	8.343186587	13.55
7.02	10.44894069	17.47
8.44	11.74354912	20.19
10.22	13.23359072	23.45
11.84	14.27086414	26.11
13.43	15.01800971	28.44
14.90	15.42117305	30.32
16.05	15.35430247	31.41
16.99	15.01002783	32.00
17.68	14.35267252	32.03
18.07	13.48322836	31.56
18.03	12.38589491	30.42
17.65	11.11836172	28.77
16.83	9.697655649	26.53
15.58	8.258988524	23.84
14.06	6.814219841	20.87
12.05	5.377105985	17.43
9.48	3.815170182	13.29
6.03	2.213736835	8.24
2.09	0.705207188	2.80

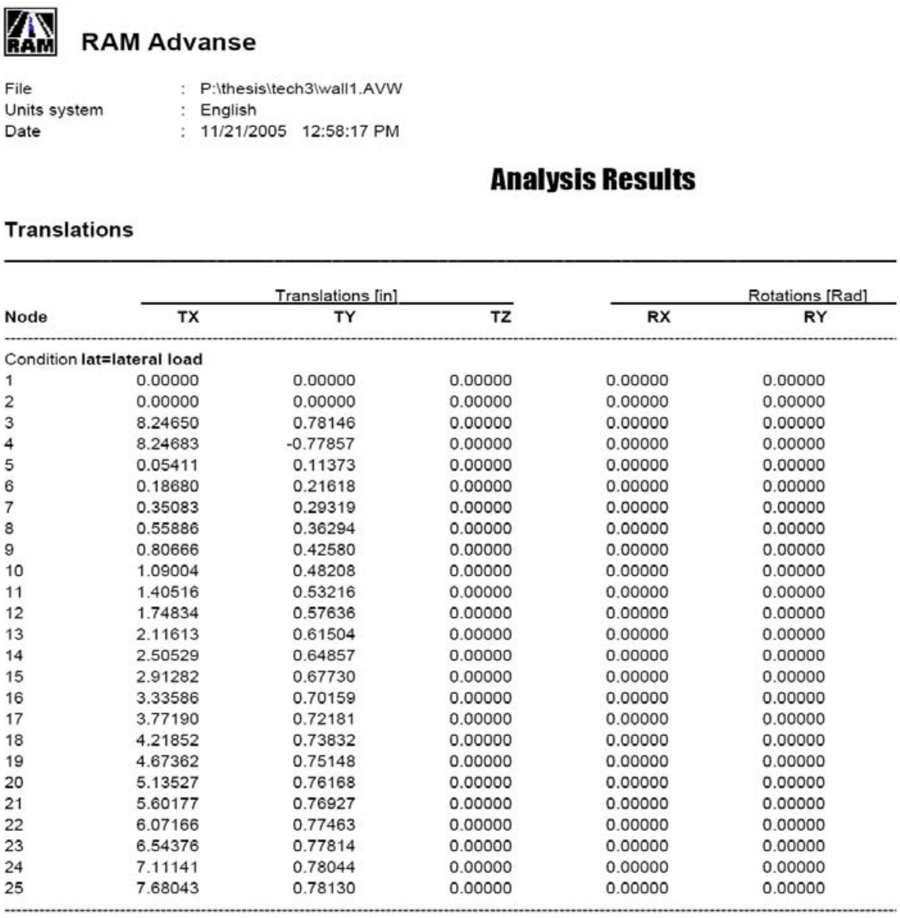
Frame 3		
Direct Shear	Torsional	Total
6.15	13.0086987	19.16
5.04	10.1549817	15.20
5.96	11.2112732	17.17
7.43	12.9824763	20.41
9.12	14.8898478	24.01
10.91	16.5937018	27.50
12.66	17.9253121	30.59
14.30	18.7780502	33.07
15.76	19.1457105	34.90
16.96	19.0524287	36.02
17.81	18.4742091	36.29
18.44	17.5813151	36.03
18.63	16.3247681	34.96
18.41	14.8503062	33.26
17.88	13.222984	31.10
17.03	11.5214715	28.55
15.67	9.75066656	25.42
13.99	7.96274251	21.95
11.89	6.22879469	18.12
9.28	4.38809275	13.67
5.82	2.51268623	8.34
2.02	0.7974758	2.81

Frame 4		
Direct Shear	Torsional	Total
6.15	17.73225044	23.89
5.04	13.84232832	18.89
5.96	15.28216678	21.24
7.43	17.6965064	25.12
9.12	20.29645816	29.41
10.91	22.6189938	33.53
12.66	24.43412135	37.10
14.30	25.59649476	39.89
15.76	26.09765513	41.85
16.96	25.97050203	42.93
17.81	25.18232684	42.99
18.44	23.96521651	42.41
18.63	22.25240835	40.88
18.41	20.24255879	38.65
17.88	18.02434416	35.90
17.03	15.7050004	32.73
15.67	13.29120344	28.96
13.99	10.85407136	24.84
11.89	8.490514671	20.38
9.28	5.981440662	15.26
5.82	3.425060598	9.25
2.02	1.087044979	3.10

Analysis

From the distributions given on the previous page I calculated story forces. First I used the story forces in shear wall 4 to find the total building drift at the roof level. To find this value I imputed all the story forces at each level into RAM Advanse and analyzed the total wall deflection. The following diagrams are my output files from the analysis. The right hand picture shows the deflected shape of the wall and the nodes. The table shows the deflection at each node. The total drift was 8.24”. The maximum allowable story drift L/400=6.9”. This drift exceeds the allowable limit however it is within a reasonable margin. I will look further into this issue in my following reports.





RAM Advanse

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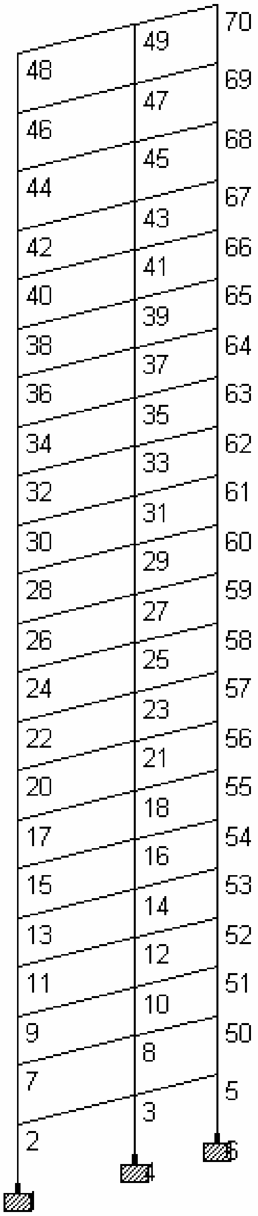
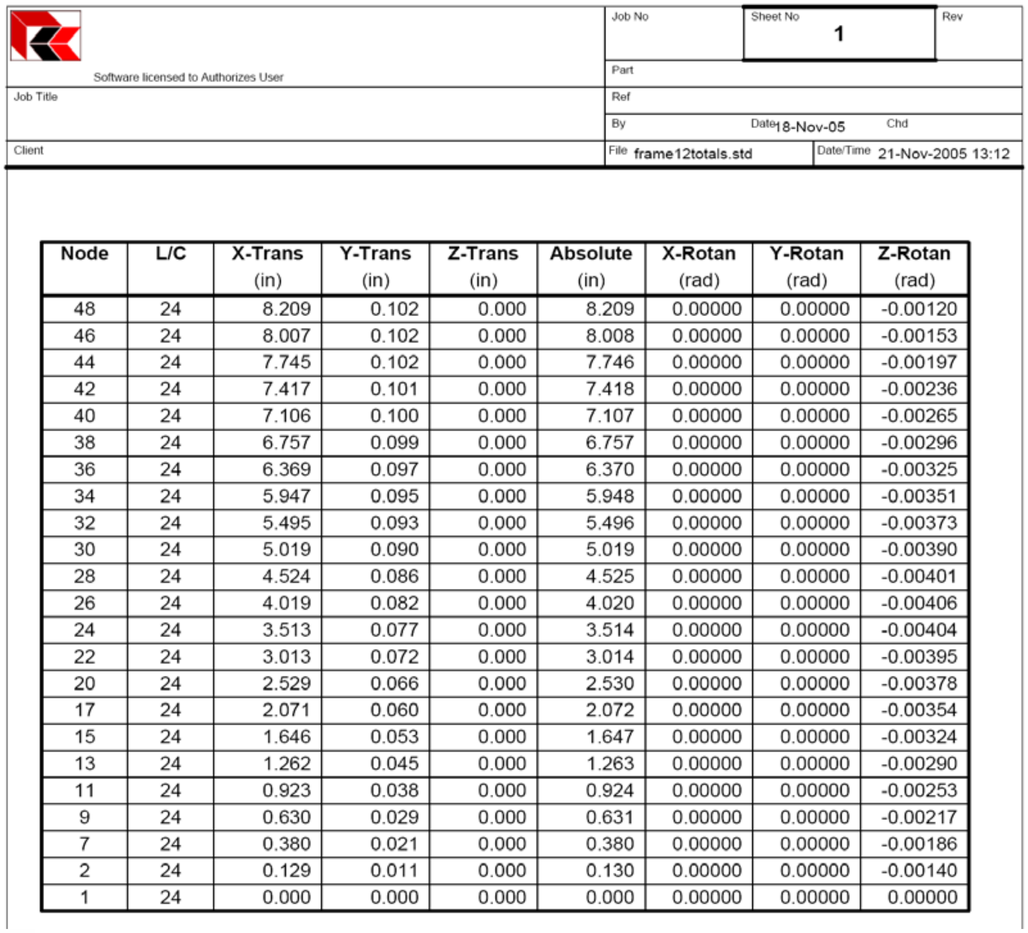
Analysis Results

Translations

	Translations [in]			Rotations [Rad]	
Node	**TX**	**TY**	**TZ**	**RX**	**RY**
Condition **lat=lateral load**					
1	0.00000	0.00000	0.00000	0.00000	0.00000
2	0.00000	0.00000	0.00000	0.00000	0.00000
3	8.24650	0.78146	0.00000	0.00000	0.00000
4	8.24683	-0.77857	0.00000	0.00000	0.00000
5	0.05411	0.11373	0.00000	0.00000	0.00000
6	0.18680	0.21618	0.00000	0.00000	0.00000
7	0.35083	0.29319	0.00000	0.00000	0.00000
8	0.55886	0.36294	0.00000	0.00000	0.00000
9	0.80666	0.42580	0.00000	0.00000	0.00000
10	1.09004	0.48208	0.00000	0.00000	0.00000
11	1.40516	0.53216	0.00000	0.00000	0.00000
12	1.74834	0.57636	0.00000	0.00000	0.00000
13	2.11613	0.61504	0.00000	0.00000	0.00000
14	2.50529	0.64857	0.00000	0.00000	0.00000
15	2.91282	0.67730	0.00000	0.00000	0.00000
16	3.33586	0.70159	0.00000	0.00000	0.00000
17	3.77190	0.72181	0.00000	0.00000	0.00000
18	4.21852	0.73832	0.00000	0.00000	0.00000
19	4.67362	0.75148	0.00000	0.00000	0.00000
20	5.13527	0.76168	0.00000	0.00000	0.00000
21	5.60177	0.76927	0.00000	0.00000	0.00000
22	6.07166	0.77463	0.00000	0.00000	0.00000
23	6.54376	0.77814	0.00000	0.00000	0.00000
24	7.11141	0.78044	0.00000	0.00000	0.00000
25	7.68043	0.78130	0.00000	0.00000	0.00000

After finding the maximum drift due to the story forces in shear wall 4 I went on to check the deflection in moment frame 4. Once again I found the story forces at each level from my story shears. For this analysis I used STAAD.Pro, after imputing the forces and running the program I found the total story drift to be 8.21”. The maximum story drift equals 6.9”. The drift found exceeds the story drift however is not far from the allowable limit. I will look at this issue more in upcoming reports.





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Job No

Sheet No 1

Rev

Part

Job Title

Ref

By

Date 18-Nov-05

Chd

Client

File frame12totals.std

Date/Time 21-Nov-2005 13:12

Node	L/C	X-Trans (in)	Y-Trans (in)	Z-Trans (in)	Absolute (in)	X-Rotan (rad)	Y-Rotan (rad)	Z-Rotan (rad)
48	24	8.209	0.102	0.000	8.209	0.00000	0.00000	-0.00120
46	24	8.007	0.102	0.000	8.008	0.00000	0.00000	-0.00153
44	24	7.745	0.102	0.000	7.746	0.00000	0.00000	-0.00197
42	24	7.417	0.101	0.000	7.418	0.00000	0.00000	-0.00236
40	24	7.106	0.100	0.000	7.107	0.00000	0.00000	-0.00265
38	24	6.757	0.099	0.000	6.757	0.00000	0.00000	-0.00296
36	24	6.369	0.097	0.000	6.370	0.00000	0.00000	-0.00325
34	24	5.947	0.095	0.000	5.948	0.00000	0.00000	-0.00351
32	24	5.495	0.093	0.000	5.496	0.00000	0.00000	-0.00373
30	24	5.019	0.090	0.000	5.019	0.00000	0.00000	-0.00390
28	24	4.524	0.086	0.000	4.525	0.00000	0.00000	-0.00401
26	24	4.019	0.082	0.000	4.020	0.00000	0.00000	-0.00406
24	24	3.513	0.077	0.000	3.514	0.00000	0.00000	-0.00404
22	24	3.013	0.072	0.000	3.014	0.00000	0.00000	-0.00395
20	24	2.529	0.066	0.000	2.530	0.00000	0.00000	-0.00378
17	24	2.071	0.060	0.000	2.072	0.00000	0.00000	-0.00354
15	24	1.646	0.053	0.000	1.647	0.00000	0.00000	-0.00324
13	24	1.262	0.045	0.000	1.263	0.00000	0.00000	-0.00290
11	24	0.923	0.038	0.000	0.924	0.00000	0.00000	-0.00253
9	24	0.630	0.029	0.000	0.631	0.00000	0.00000	-0.00217
7	24	0.380	0.021	0.000	0.380	0.00000	0.00000	-0.00186
2	24	0.129	0.011	0.000	0.130	0.00000	0.00000	-0.00140
1	24	0.000	0.000	0.000	0.000	0.00000	0.00000	0.00000

Member Check

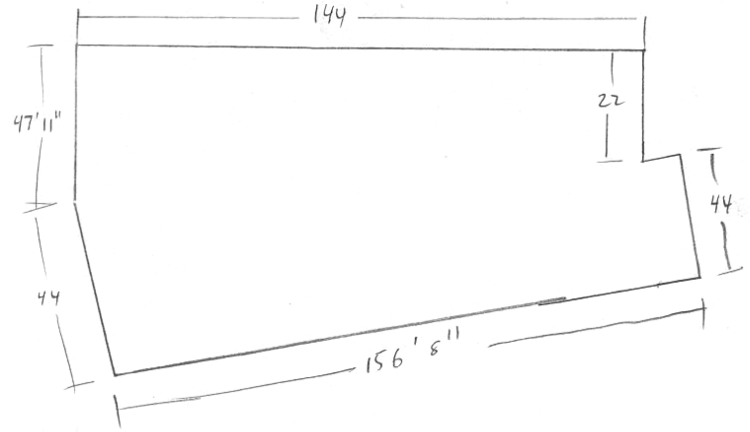
For my member check I used shear wall 1. I chose this wall because it had the highest base shear and was one of the two shorter walls. Because of these it would therefore require the most reinforcement. The first thing I checked was the horizontal reinforcement needed in the wall. I found that the provided typical reinforcement of #4 bars at 12” on center each way in each face was not sufficient shear reinforcing. However, all of the shear walls in the building have extra reinforcing around the openings for doors and windows. I assume that this extra area of steel will help the strength of the wall but that the opening will weaken it. This will be an area of extra attention in following reports. Next I checked the vertical reinforcement in the wall using ρ_h, the ratio of horizontal shear reinforcement area to gross concrete area of the vertical section. I found #4 bars at 12” on center each way in each face was sufficient. For my next check I found that the flexural reinforcing provided wasn’t suitable for the moment. However, once again the wall has extra vertical reinforcing around opening and at the corners of the wall which would probably aid in flexural strength. Finally I checked the overturning moment in the wall and found the resisting moment to be sufficient to resist it. See appendix pages 32-34 for additional assumptions and calculations.

Conclusion

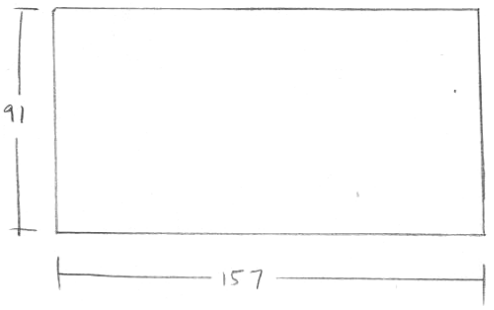
For this technical report I found that the controlling force on the building was due to wind loading. By finding the relative rigidities of my various lateral force resisting elements per floor I was able to find both direct, and torsional shears on each element at each floor and in each direction of wind loading. I accomplished this by using a combination of computer programs and predominantly Excel spreadsheets. By sorting out all the controlling cases I was able to find both the story shears and story forces at each level. From these values I used both STAAD.Pro and RAM advanse to find the total building drift due to all the applied story forces. I found both to be approximately 8" while the limiting deflection for a building of my height is 6.9". From my results I was also able to check one of the shear walls for strength requirements. I found the wall to be insufficient in several areas, however I did not account for the fact that the walls had both penetrations, and extra reinforcement surrounding the openings on all sides. For my upcoming reports I will explore all these discrepancies further. I feel that although my numbers did not all meet required values that I was within the realm of reason and am confident I will be able to confirm the design with further investigation.

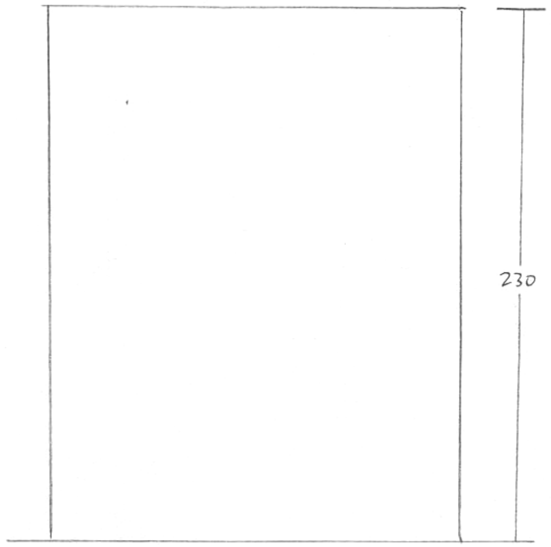
Appendix

Wind Load Analysis



assume





floors	1+2	12'0"
floors	3-19	10'6"
floors	20-21	12'0"
floor	22	12'0"
total		230'0"

BASIC WIND SPEED: 75 mph (1609.3) use 90 mph

IMPORTANCE FACTOR $I = 1.05$ (1609.5)

WIND EXPOSURE "C" OPEN TERRAIN

① find V 6.5.4
find Kd

② find I 6.5.5

③ find K_z, K_h 6.5.6

④ find K_{zt} 6.5.7

⑤ find G or Gf 6.5.8

⑥ enclosure classification 6.5.9

⑦ internal pressure coeff. GC_{pi} 6.5.11.1

⑧ external pressure coeff 6.5.11.2,3
C_p or GC_{pf} C_f

⑨ velocity pressure q_z or q_h 6.5.10

⑩ design wind load p or F 6.5.12

① $V = 90$ mph
$K_d = .85$

② Building category II
$I = 1.0$

③ K_z, $K_h = 1.50$

④ $K_{zt} = 1.0$ flat ground

⑤ $C_t = .016$ $x = .9$

$T = .016 (230)^{.9} = 2.14$

$n_1 = \frac{1}{2.14} = .467$ FLEXIBLE

Gust factor calcs.

$$G = .925\left(\frac{1+1.7 I_{\bar{z}}\sqrt{g_Q^2 Q^2 + g_R^2 R^2}}{1+1.7 g_v I_{\bar{z}}}\right)$$

$$g_v = g_Q = 3.4$$

$$g_R = \sqrt{2\ln[(3600)\underset{\overset{\uparrow}{n_1}}{(.467)}]} + \frac{.577}{\sqrt{2\ln[3600\underset{\overset{\uparrow}{n_1}}{(.467)}]}} = 4.00$$

$$R = \sqrt{\frac{1}{\beta} R_n R_h R_B (.53 + .47 R_L)}$$

$$z_{min} = 15 \text{ ft}$$

$$c = .20$$

$$\bar{z} = .6(230) = 138 \text{ ft}$$

$$\ell = 500 \text{ ft}$$

$$\bar{\epsilon} = 1/5.0$$

$$L_{\bar{z}} = 500\left(\frac{138}{33}\right)^{1/5} = 665.6$$

$$\bar{b} = .65$$

$$\bar{\alpha} = 1/6.5$$

$$\bar{V}_{\bar{z}} = \bar{b}\left(\frac{\bar{z}}{33}\right)^{\bar{\alpha}} V\left(\frac{88}{60}\right) = .65\left(\frac{138}{33}\right)^{1/6.5} 90\left(\frac{88}{60}\right) = 106.9$$

$$N_1 = \frac{n_1 L_{\bar{z}}}{V_{\bar{z}}} = \frac{.467(665.6)}{106.9} = 2.91$$

$$R_n = \frac{7.47 N_1}{(1+10.3 N_1)^{5/3}} = \frac{7.47(2.91)}{[1+10.3(2.91)]^{5/3}} = .0712$$

$$\eta_h = 4.6 n_1\left(h/\bar{V}_{\bar{z}}\right) = 4.6(.467)\left(\frac{230}{106.9}\right) = 4.62$$

$$\eta_B = 4.6\left(\frac{n_1}{\bar{V}_{\bar{z}}}\right) = 4.6\left(\frac{.467}{106.9}\right) = .020$$

$$\eta_L = 15.4 n_1\left(\frac{L}{\bar{V}_{\bar{z}}}\right) = 15.4(.467)\left(\frac{157}{106.9}\right) = 10.56$$

$$R_\ell = \frac{1}{n} - \frac{1}{2n^2}\left(1-e^{-2n}\right)$$

$$R_h = \frac{1}{4.62} - \frac{1}{2(4.62)^2}\left(1-e^{-2(4.62)}\right) = .193$$

$$R_B = \frac{1}{.02} - \frac{1}{2(.02)^2}\left(1-e^{-2(.02)}\right) = .987$$

$$R_L = \frac{1}{10.56} - \frac{1}{2(10.56)^2}\left(1-e^{-2(10.56)}\right) = .090$$

$$R = \sqrt{\frac{1}{\beta} R_n R_h R_B(.53 + .47 R_L)} = \sqrt{\left(\frac{1}{.05}\right) .0712 (.193)(.987)\left[.53 + .47(.09)\right]}$$

$R = .394$

$$I_{\bar{z}} = c\left(33/\bar{z}\right)^{1/6} = .2\left(\frac{33}{138}\right)^{1/6} = .158$$

$$Q = \sqrt{\frac{1}{1 + .63\left(\frac{B+h}{L_{\bar{z}}}\right)^{.63}}} = \sqrt{\frac{1}{1 + .63\left(\frac{91+230}{665.6}\right)^{.63}}} = .846$$

$$G_f = .925\left[\frac{1 + 1.7(.158)\sqrt{3.4^2(.846)^2 + (4)^2(.394)^2}}{1 + 1.7(3.4)(.158)}\right] = .909$$

Velocity Pressure

$$q_z = .00256\, K_z K_{zt} K_d V^2 I$$

see spreadsheet

$$p = \overset{q_z}{q}\, G_f C_p - \overset{q_h}{q_i}(G C_{pi})$$

$G C_{pi} = .18$

$C_p = .8$ for windward

$-.35$ for leeward E-W

$-.5$ for leeward N-S

Gust Factor N-S

$$n_L = 15.4(.467)\left(\frac{91}{106.9}\right) = 6.12$$

$$R_L = \frac{1}{6.12} - \frac{1}{2(6.12)^2}\left[1 - e^{-2(6.12)}\right] = .15$$

$$R = \sqrt{\frac{1}{.05}(.0712)(.193)(.987)\left[.53 + .47(.15)\right]} = .404$$

$$Q = \sqrt{\frac{1}{1 + .63\left(\frac{157+230}{665.6}\right)^{.63}}} = .831$$

$$G_f = .925\left[\frac{1 + 1.7(.158)\sqrt{3.4^2(.831)^2 + (4)^2(.404)^2}}{1 + 1.7(3.4)(.158)}\right] = .906$$

WIND CALCULATIONS (see calcs. for additional info.)

Kzt=	1
Kd=	0.85
V=	90
I=	1
Gf (E-W)=	0.909
Gcpi=	0.18
Cp windward=	0.8
Cp leeward=	-0.35
Cp leeward=	-0.5
Gf (N-S)=	0.906

E-W

Height	Kz	qz		p(windward)	p(leeward)	pressure (psf)
0-15	0.85	14.982		20.161	-13.188	33.348
20	0.9	15.863		20.801	-13.188	33.989
25	0.94	16.568		21.314	-13.188	34.502
30	0.98	17.273		21.827	-13.188	35.015
40	1.04	18.331		22.596	-13.188	35.784
50	1.09	19.212		23.237	-13.188	36.425
60	1.13	19.917		23.749	-13.188	36.937
70	1.17	20.622		24.262	-13.188	37.450
80	1.21	21.327		24.775	-13.188	37.963
90	1.24	21.856		25.159	-13.188	38.347
100	1.26	22.208		25.416	-13.188	38.603
120	1.31	23.090		26.056	-13.188	39.244
140	1.36	23.971		26.697	-13.188	39.885
160	1.39	24.500		27.082	-13.188	40.270
180	1.43	25.205		27.595	-13.188	40.782
200	1.46	25.733		27.979	-13.188	41.167
250	1.53	26.967		28.876	-13.188	42.064
230	1.502	26.474		28.517	-13.188	41.705

story	elev.	trib. H below	trib. H above	trib. range	V(lb)	V(k)	M(ft*k)
ground	0		6	0-6	31414.158	31.414	0.000
1	12	6	6	6-18	63130.164	63.130	757.562
2	24	6	5	18-29	59745.807	59.746	1433.899
3	34	5	5	29-39	56059.602	56.060	1906.026
4	44	5	5	39-49	57085.886	57.086	2511.779
5	54	5	5	49-59	57910.938	57.911	3127.191
6	64	5	5	59-69	58715.867	58.716	3757.815
7	74	5	5	69-79	59520.796	59.521	4404.539
8	84	5	5	79-89	60144.616	60.145	5052.148
9	94	5	5	89-99	60567.203	60.567	5693.317
10	104	5	5	99-109	61512.994	61.513	6397.351
11	114	5	5	109-119	61613.610	61.614	7023.952
12	124	5	5	119-129	62519.155	62.519	7752.375
13	134	5	5	129-139	62619.771	62.620	8391.049
14	144	5	5	139-149	63163.098	63.163	9095.486
15	154	5	5	149-159	63223.468	63.223	9736.414
16	164	5	5	159-169	63947.904	63.948	10487.456
17	174	5	5	169-179	64028.397	64.028	11140.941
18	184	5	5	179-189	64571.723	64.572	11881.197
19	194	5	6	189-200	71095.302	71.095	13792.489
20	206	6	6	200-212	79248.862	79.249	16325.266
21	218	6	6	212-224	79248.862	79.249	17276.252
22	230	6	0	224-230	39286.361	39.286	9035.863
						1400.375	166980.368

Base Shear= 1400.375
Base Resisting Moment= 166980.4

N-S

Height	Kz	qz		p(windward)	p(leeward)	pressure (psf)
0-15	0.85	14.982		24.096	-16.758	40.853
20	0.9	15.863		24.734	-16.758	41.492
25	0.94	16.568		25.245	-16.758	42.003
30	0.98	17.273		25.756	-16.758	42.514
40	1.04	18.331		26.523	-16.758	43.281
50	1.09	19.212		27.162	-16.758	43.919
60	1.13	19.917		27.673	-16.758	44.430
70	1.17	20.622		28.184	-16.758	44.941
80	1.21	21.327		28.695	-16.758	45.452
90	1.24	21.856		29.078	-16.758	45.836
100	1.26	22.208		29.333	-16.758	46.091
120	1.31	23.090		29.972	-16.758	46.730
140	1.36	23.971		30.611	-16.758	47.369
160	1.39	24.500		30.994	-16.758	47.752
180	1.43	25.205		31.505	-16.758	48.263
200	1.46	25.733		31.888	-16.758	48.646
250	1.53	26.967		32.783	-16.758	49.540
230	1.502	26.474		32.425	-16.758	49.183

story	elev.	trib. H below	trib. H above	trib. range	V(lb)	V(k)	M(ft*k)
ground	0		6	0-6	22305.971	22.306	0.000
1	12	6	6	6-18	44786.321	44.786	537.436
2	24	6	5	18-29	42138.185	42.138	1011.316
3	34	5	5	29-39	39315.670	39.316	1336.733
4	44	5	5	39-49	39908.559	39.909	1755.977
5	54	5	5	49-59	40385.196	40.385	2180.801
6	64	5	5	59-69	40850.207	40.850	2614.413
7	74	5	5	69-79	41315.218	41.315	3057.326
8	84	5	5	79-89	41675.602	41.676	3500.751
9	94	5	5	89-99	41919.733	41.920	3940.455
10	104	5	5	99-109	42466.121	42.466	4416.477
11	114	5	5	109-119	42524.248	42.524	4847.764
12	124	5	5	119-129	43047.385	43.047	5337.876
13	134	5	5	129-139	43105.512	43.106	5776.139
14	144	5	5	139-149	43419.394	43.419	6252.393
15	154	5	5	149-159	43454.270	43.454	6691.958
16	164	5	5	159-169	43872.780	43.873	7195.136
17	174	5	5	169-179	43919.281	43.919	7641.955
18	184	5	5	179-189	44233.164	44.233	8138.902
19	194	5	6	189-200	48694.844	48.695	9446.800
20	206	6	6	200-212	54098.172	54.098	11144.223
21	218	6	6	212-224	54098.172	54.098	11793.401
22	230	6	0	224-230	26853.781	26.854	6176.370
						968.388	114794.600

Base Shear= 968.3878
Base Resisting Moment= 114794.6

Proportion of Rigidity per Floor for Shear Walls

Shear Walls	Direction	E (ksi)	floor	t (in)	h (ft)	L (ft)	Rigidity	Proportion of Rigidity	Percent Rigidity
Wall 1/Wall 2	N-S	4287.00	ground	12.00	0	24.58	#DIV/0!	#DIV/0!	
	N-S	4287.00	2	12.00	12	24.58	26659.73	0.49	48.72
	N-S	4287.00	3	12.00	24	24.58	7735.04	0.49	48.91
	N-S	4287.00	4	12.00	34	24.58	3492.15	0.49	48.70
	N-S	4287.00	5	12.00	44	24.58	1817.53	0.48	48.24
	N-S	4287.00	6	12.00	54	24.58	1050.19	0.48	47.75
	N-S	4287.00	7	12.00	64	24.58	656.26	0.47	47.14
	N-S	4287.00	8	12.00	74	24.58	435.48	0.46	46.49
	N-S	4287.00	9	12.00	84	24.58	302.91	0.46	45.78
	N-S	4287.00	10	12.00	94	24.58	218.82	0.45	45.02
	N-S	4287.00	11	12.00	104	24.58	163.03	0.44	44.25
	N-S	4287.00	12	12.00	114	24.58	124.62	0.43	43.45
	N-S	4287.00	13	12.00	124	24.58	97.35	0.43	42.61
	N-S	4287.00	14	12.00	134	24.58	77.46	0.42	41.77
	N-S	4287.00	15	12.00	144	24.58	62.62	0.41	40.95
	N-S	4287.00	16	12.00	154	24.58	51.33	0.40	40.11
	N-S	4287.00	17	12.00	164	24.58	42.60	0.39	39.28
	N-S	4287.00	18	12.00	174	24.58	35.74	0.39	38.51
	N-S	4287.00	19	12.00	184	24.58	30.27	0.38	37.70
	N-S	4287.00	20	12.00	194	24.58	25.86	0.37	36.97
	N-S	4287.00	21	12.00	206	24.58	21.63	0.36	36.11
	N-S	4287.00	22	12.00	218	24.58	18.27	0.35	35.36
	N-S	4287.00	roof	12.00	230	24.58	15.57	0.35	34.70
Wall 3/Wall 4	E-W	4287.00	ground	12.00	0	32.42	#DIV/0!	#DIV/0!	
	E-W	4287.00	2	12.00	12	32.42	39167.14	0.5	50.00
	E-W	4287.00	3	12.00	24	32.42	13381.74	0.5	50.00
	E-W	4287.00	4	12.00	34	32.42	6627.89	0.5	50.00
	E-W	4287.00	5	12.00	44	32.42	3655.10	0.5	50.00
	E-W	4287.00	6	12.00	54	32.42	2190.28	0.5	50.00
	E-W	4287.00	7	12.00	64	32.42	1401.56	0.5	50.00
	E-W	4287.00	8	12.00	74	32.42	945.12	0.5	50.00
	E-W	4287.00	9	12.00	84	32.42	664.90	0.5	50.00
	E-W	4287.00	10	12.00	94	32.42	484.27	0.5	50.00
	E-W	4287.00	11	12.00	104	32.42	363.02	0.5	50.00
	E-W	4287.00	12	12.00	114	32.42	278.80	0.5	50.00
	E-W	4287.00	13	12.00	124	32.42	218.58	0.5	50.00
	E-W	4287.00	14	12.00	134	32.42	174.43	0.5	50.00
	E-W	4287.00	15	12.00	144	32.42	141.35	0.5	50.00
	E-W	4287.00	16	12.00	154	32.42	116.10	0.5	50.00
	E-W	4287.00	17	12.00	164	32.42	96.49	0.5	50.00
	E-W	4287.00	18	12.00	174	32.42	81.05	0.5	50.00
	E-W	4287.00	19	12.00	184	32.42	68.73	0.5	50.00
	E-W	4287.00	20	12.00	194	32.42	58.77	0.5	50.00
	E-W	4287.00	21	12.00	206	32.42	49.20	0.5	50.00
	E-W	4287.00	22	12.00	218	32.42	41.60	0.5	50.00
	E-W	4287.00	roof	12.00	230	32.42	35.48	0.5	50.00

Proportion of Rigidity per Floor for Moment Frames

Moment Frames			floor		height	Deflection	Rigidity		
Frame 1/2		N-S	ground		0	0.00000	#DIV/0!	#DIV/0!	
		N-S	2		12	0.0029	344.83	0.006302	0.63
		N-S	3		24	0.012	83.33	0.00527	0.53
		N-S	4		34	0.023	43.48	0.006063	0.61
		N-S	5		44	0.031	32.26	0.008561	0.86
		N-S	6		54	0.042	23.81	0.010825	1.08
		N-S	7		64	0.052	19.23	0.013815	1.38
		N-S	8		74	0.063	15.87	0.016946	1.69
		N-S	9		84	0.074	13.51	0.020424	2.04
		N-S	10		94	0.085	11.76	0.024205	2.42
		N-S	11		104	0.097	10.31	0.027979	2.80
		N-S	12		114	0.109	9.17	0.031986	3.20
		N-S	13		124	0.121	8.26	0.036175	3.62
		N-S	14		134	0.133	7.52	0.040543	4.05
		N-S	15		144	0.146	6.85	0.044788	4.48
		N-S	16		154	0.159	6.29	0.04914	4.91
		N-S	17		164	0.173	5.78	0.053297	5.33
		N-S	18		174	0.188	5.32	0.057316	5.73
		N-S	19		184	0.202	4.95	0.06166	6.17
		N-S	20		194	0.218	4.59	0.065587	6.56
		N-S	21		206	0.238	4.20	0.070161	7.02
		N-S	22		218	0.26	3.85	0.074445	7.44
		N-S	roof		230	0.286	3.50	0.077928	7.79
Frame 3/4		N-S	ground		0	0.00000	#DIV/0!	#DIV/0!	
		N-S	2		12	0.00281	355.87	0.006503	0.65
		N-S	3		24	0.0113	88.50	0.005596	0.56
		N-S	4		34	0.0201	49.75	0.006938	0.69
		N-S	5		44	0.0293	34.13	0.009058	0.91
		N-S	6		54	0.0389	25.71	0.011688	1.17
		N-S	7		64	0.0487	20.53	0.014751	1.48
		N-S	8		74	0.0589	16.98	0.018126	1.81
		N-S	9		84	0.0695	14.39	0.021747	2.17
		N-S	10		94	0.0804	12.44	0.02559	2.56
		N-S	11		104	0.0918	10.89	0.029564	2.96
		N-S	12		114	0.104	9.62	0.033524	3.35
		N-S	13		124	0.116	8.62	0.037734	3.77
		N-S	14		134	0.129	7.75	0.0418	4.18
		N-S	15		144	0.143	6.99	0.045728	4.57
		N-S	16		154	0.157	6.37	0.049766	4.98
		N-S	17		164	0.171	5.85	0.05392	5.39
		N-S	18		174	0.187	5.35	0.057623	5.76
		N-S	19		184	0.203	4.93	0.061356	6.14
		N-S	20		194	0.221	4.52	0.064697	6.47
		N-S	21		206	0.243	4.12	0.068717	6.87
		N-S	22		218	0.269	3.72	0.071954	7.20
		N-S	roof		230	0.297	3.37	0.075042	7.50

Center of Rigidity and Center of Mass per Floor

Center of Rigidity					Center of Mass				Difference		
Floor	Distance from West Face		Distance from South		Distance From West Face		Distance from South Face		E-W		N-S
ground											
2	17.452457		75.15		40.3		73.9		22.84754		1.25
3	17.2663312		75.15						23.03367		
4	17.4869697		75.15						22.81303		
5	17.9283802		75.15						22.37162		
6	18.4136458		75.15						21.88635		
7	19.0050986		75.15						21.2949		
8	19.6447797		75.15						20.65522		
9	20.3398169		75.15						19.96018		
10	21.0841364		75.15						19.21586		
11	21.8437546		75.15						18.45625		
12	22.6190645		75.15						17.68094		
13	23.4379946		75.15						16.86201		
14	24.2530072		75.15						16.04699		
15	25.0422851		75.15						15.25771		
16	25.8527104		75.15						14.44729		
17	26.6624975		75.15						13.6375		
18	27.4077762		75.15						12.89222		
19	28.1809931		75.15						12.11901		
20	28.8758374		75.15						11.42416		
21	29.7007007		75.15						10.5993		
22	30.4096797		75.15						9.89032		
roof	31.0409457		75.15						9.259054		

Torsional Forces in Both Directions per Floor

Story Shear			Torsional Force N-S wind	Torsional Force E-W wind
ground	22.31	968.39	0	
2.00	44.79	946.08	21615.64	1182.60227
3.00	42.14	901.30	20760.14	1126.61937
4.00	39.32	859.16	19599.98	1073.94664
5.00	39.91	819.84	18341.19	1024.80205
6.00	40.39	779.93	17069.89	974.916352
7.00	40.85	739.55	15748.6	924.434857
8.00	41.32	698.70	14431.75	873.372098
9.00	41.68	657.38	13121.47	821.728075
10.00	41.92	615.71	11831.34	769.633572
11.00	42.47	573.79	10589.96	717.233906
12.00	42.52	531.32	9394.252	664.151254
13.00	43.05	488.80	8242.094	610.995945
14.00	43.11	445.75	7152.937	557.186713
15.00	43.42	402.64	6143.425	503.304823
16.00	43.45	359.22	5189.82	449.03058
17.00	43.87	315.77	4306.317	394.712743
18.00	43.92	271.90	3505.362	339.871767
19.00	44.23	227.98	2762.869	284.972665
20.00	48.69	183.74	2099.132	229.68121
21.00	54.10	135.05	1431.437	168.812655
22.00	54.10	80.95	800.6407	101.189941
roof	26.85	26.85	248.6406	33.5672263
base shear	968.39			

Direct Story Shear on Each Floor in Each Direction

N-S									
		Story Shear		Wall 1	Wall 2	Frame 1	Frame 2	Frame 3	Frame 4
ground	22.31	968.39		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
2.00	44.79	946.08		460.93	460.93	5.96	5.96	6.15	6.15
3.00	42.14	901.30		440.85	440.85	4.75	4.75	5.04	5.04
4.00	39.32	859.16		418.41	418.41	5.21	5.21	5.96	5.96
5.00	39.91	819.84		395.48	395.48	7.02	7.02	7.43	7.43
6.00	40.39	779.93		372.41	372.41	8.44	8.44	9.12	9.12
7.00	40.85	739.55		348.65	348.65	10.22	10.22	10.91	10.91
8.00	41.32	698.70		324.84	324.84	11.84	11.84	12.66	12.66
9.00	41.68	657.38		300.97	300.97	13.43	13.43	14.30	14.30
10.00	41.92	615.71		277.19	277.19	14.90	14.90	15.76	15.76
11.00	42.47	573.79		253.88	253.88	16.05	16.05	16.96	16.96
12.00	42.52	531.32		230.85	230.85	16.99	16.99	17.81	17.81
13.00	43.05	488.80		208.27	208.27	17.68	17.68	18.44	18.44
14.00	43.11	445.75		186.17	186.17	18.07	18.07	18.63	18.63
15.00	43.42	402.64		164.88	164.88	18.03	18.03	18.41	18.41
16.00	43.45	359.22		144.08	144.08	17.65	17.65	17.88	17.88
17.00	43.87	315.77		124.03	124.03	16.83	16.83	17.03	17.03
18.00	43.92	271.90		104.70	104.70	15.58	15.58	15.67	15.67
19.00	44.23	227.98		85.94	85.94	14.06	14.06	13.99	13.99
20.00	48.69	183.74		67.93	67.93	12.05	12.05	11.89	11.89
21.00	54.10	135.05		48.77	48.77	9.48	9.48	9.28	9.28
22.00	54.10	80.95		28.62	28.62	6.03	6.03	5.82	5.82
roof	26.85	26.85		9.32	9.32	2.09	2.09	2.02	2.02
base shear	968.39								

E-W					
				Wall 3	Wall 4
ground	31.41	1400.37		700.19	700.19
2.00	63.13	1368.96		684.48	684.48
3.00	59.75	1305.83		652.92	652.92
4.00	56.06	1246.08		623.04	623.04
5.00	57.09	1190.02		595.01	595.01
6.00	57.91	1132.94		566.47	566.47
7.00	58.72	1075.03		537.51	537.51
8.00	59.52	1016.31		508.16	508.16
9.00	60.14	956.79		478.40	478.40
10.00	60.57	896.65		448.32	448.32
11.00	61.51	836.08		418.04	418.04
12.00	61.61	774.57		387.28	387.28
13.00	62.52	712.95		356.48	356.48
14.00	62.62	650.43		325.22	325.22
15.00	63.16	587.81		293.91	293.91
16.00	63.22	524.65		262.33	262.33
17.00	63.95	461.43		230.71	230.71
18.00	64.03	397.48		198.74	198.74
19.00	64.57	333.45		166.73	166.73
20.00	71.10	268.88		134.44	134.44
21.00	79.25	197.78		98.89	98.89
22.00	79.25	118.54		59.27	59.27
roof	39.29	39.29		19.64	19.64
base shear	1400.37				

Torsional Shears per Wall/Frame per Floor

Torsion	Floor 2				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	26659.73	14.94754	5956558	0.01351929	292.228117
Wall 2 (N-S)	26659.73	17.45246	8120241	0.01578485	341.1997973
Wall 3 (E-W)	39167.14	12.35	5973870	0.01641032	19.40688107
Wall 4 (E-W)	39167.14	12.35	5973870	0.01641032	19.40688107
Frame 1 (N-S)	344.83	29.64754	303095.5	0.00034683	7.496993406
Frame 2 (N-S)	344.83	42.44754	621308.2	0.00049657	10.7337377
Frame 3 (N-S)	355.87	49.84754	884262.5	0.00060182	13.00869873
Frame 4 (N-S)	355.87	67.94754	1643014	0.00082034	17.73225044
			29476219		

Torsion	Floor 3				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	7735.04	14.94754	1728233	0.01282082	266.162123
Wall 2 (N-S)	7735.04	17.45246	2356003	0.01496934	310.7656557
Wall 3 (E-W)	13381.74	12.35	2041016	0.0183258	20.64620603
Wall 4 (E-W)	13381.74	12.35	2041016	0.0183258	20.64620603
Frame 1 (N-S)	83.33	29.64754	73248.07	0.00027396	5.687498482
Frame 2 (N-S)	83.33	42.44754	150149.5	0.00039224	8.14301328
Frame 3 (N-S)	88.50	49.84754	219891.8	0.00048916	10.1549817
Frame 4 (N-S)	88.50	67.94754	408572.4	0.00066677	13.84232832
			9018130		

Torsion	Floor 4				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	3492.15	14.94754	780248	0.01203967	235.9772366
Wall 2 (N-S)	3492.15	17.45246	1063668	0.01405728	275.5223765
Wall 3 (E-W)	6627.89	12.35	1010902	0.01887965	20.27573334
Wall 4 (E-W)	6627.89	12.35	1010902	0.01887965	20.27573334
Frame 1 (N-S)	43.48	29.64754	38216.38	0.00029731	5.827309796
Frame 2 (N-S)	43.48	42.44754	78338.87	0.00042567	8.343186587
Frame 3 (N-S)	49.75	49.84754	123620.8	0.000572	11.21127317
Frame 4 (N-S)	49.75	67.94754	229695	0.0007797	15.28216678
			4335592		

Torsion	Floor 5				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	1817.53	14.94754	406089.1	0.01130331	207.3160321
Wall 2 (N-S)	1817.53	17.45246	553598.4	0.01319752	242.0581183
Wall 3 (E-W)	3655.10	12.35	557484.7	0.01878106	19.24686459
Wall 4 (E-W)	3655.10	12.35	557484.7	0.01878106	19.24686459
Frame 1 (N-S)	32.26	29.64754	28354.09	0.00039791	7.298076553
Frame 2 (N-S)	32.26	42.44754	58122.38	0.0005697	10.44894069
Frame 3 (N-S)	34.13	49.84754	84804.69	0.00070783	12.98247626
Frame 4 (N-S)	34.13	67.94754	157572.3	0.00096485	17.6965064
			2403510		

Torsion	Floor 6				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	1050.19	14.94754	234643.7	0.01068573	182.4043254
Wall 2 (N-S)	1050.19	17.45246	319876.5	0.01247645	212.9716999
Wall 3 (E-W)	2190.28	12.35	334066.9	0.01841331	17.95143695
Wall 4 (E-W)	2190.28	12.35	334066.9	0.01841331	17.95143695
Frame 1 (N-S)	23.81	29.64754	20928.02	0.00048051	8.202297538
Frame 2 (N-S)	23.81	42.44754	42899.85	0.00068797	11.74354912
Frame 3 (N-S)	25.71	49.84754	63876.03	0.00087229	14.88984776
Frame 4 (N-S)	25.71	67.94754	118685.6	0.00118902	20.29645816
			1469044		

Torsion	Floor 7				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	656.26	14.94754	146627.8	0.01009794	159.028479
Wall 2 (N-S)	656.26	17.45246	199889.4	0.01179016	185.6785218
Wall 3 (E-W)	1401.56	12.35	213769.8	0.01781828	16.47184246
Wall 4 (E-W)	1401.56	12.35	213769.8	0.01781828	16.47184246
Frame 1 (N-S)	19.23	29.64754	16903.4	0.00058691	9.243019081
Frame 2 (N-S)	19.23	42.44754	34649.88	0.0008403	13.23359072
Frame 3 (N-S)	20.53	49.84754	51022.13	0.00105366	16.59370179
Frame 4 (N-S)	20.53	67.94754	94802.23	0.00143625	22.6189938
			971434.3		

Torsion	Floor 8				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	435.48	14.94754	97298.16	0.00955331	137.871053
Wall 2 (N-S)	435.48	17.45246	132641.1	0.01115426	160.9755277
Wall 3 (E-W)	945.12	12.35	144152.1	0.01713062	14.961408
Wall 4 (E-W)	945.12	12.35	144152.1	0.01713062	14.961408
Frame 1 (N-S)	15.87	29.64754	13952.01	0.00069066	9.967504086
Frame 2 (N-S)	15.87	42.44754	28599.9	0.00098885	14.27086414
Frame 3 (N-S)	16.98	49.84754	42186.38	0.00124207	17.9253121
Frame 4 (N-S)	16.98	67.94754	78384.87	0.00169308	24.43412135
			681366.6		

Torsion	Floor 9				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	302.91	14.94754	67680	0.0090344	118.544684
Wall 2 (N-S)	302.91	17.45246	92264.34	0.01054839	138.4104396
Wall 3 (E-W)	664.90	12.35	101412	0.01638443	13.46354629
Wall 4 (E-W)	664.90	12.35	101412	0.01638443	13.46354629
Frame 1 (N-S)	13.51	29.64754	11878.06	0.0007994	10.48934891
Frame 2 (N-S)	13.51	42.44754	24348.57	0.00114454	15.01800971
Frame 3 (N-S)	14.39	49.84754	35752.19	0.00143109	18.7780502
Frame 4 (N-S)	14.39	67.94754	66429.76	0.00195073	25.59649476
			501176.9		

Torsion	Floor 10				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	218.82	14.94754	48890.87	0.00853705	101.0047318
Wall 2 (N-S)	218.82	17.45246	66650.17	0.00996769	117.9311367
Wall 3 (E-W)	484.27	12.35	73862.52	0.01561015	12.01409465
Wall 4 (E-W)	484.27	12.35	73862.52	0.01561015	12.01409465
Frame 1 (N-S)	11.76	29.64754	10340.9	0.00091037	10.77093888
Frame 2 (N-S)	11.76	42.44754	21197.58	0.00130342	15.42117305
Frame 3 (N-S)	12.44	49.84754	30905.19	0.00161822	19.14571048
Frame 4 (N-S)	12.44	67.94754	57423.74	0.00220581	26.09765513
			383133.5		

Torsion	Floor 11				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	163.03	14.94754	36425.7	0.00807408	85.50419119
Wall 2 (N-S)	163.03	17.45246	49657.11	0.00942714	99.83301059
Wall 3 (E-W)	363.02	12.35	55369.11	0.01485442	10.65409339
Wall 4 (E-W)	363.02	12.35	55369.11	0.01485442	10.65409339
Frame 1 (N-S)	10.31	29.64754	9061.617	0.00101268	10.72423303
Frame 2 (N-S)	10.31	42.44754	18575.19	0.00144989	15.35430247
Frame 3 (N-S)	10.89	49.84754	27067.29	0.0017991	19.05242868
Frame 4 (N-S)	10.89	67.94754	50292.69	0.00245237	25.97050203
			301817.8		

Torsion	Floor 12				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	124.62	14.94754	27844.11	0.00764288	71.79910646
Wall 2 (N-S)	124.62	17.45246	37958.32	0.00892367	83.83122342
Wall 3 (E-W)	278.80	12.35	42523.52	0.01412718	9.382584771
Wall 4 (E-W)	278.80	12.35	42523.52	0.01412718	9.382584771
Frame 1 (N-S)	9.17	29.64754	8064.007	0.00111598	10.48377395
Frame 2 (N-S)	9.17	42.44754	16530.22	0.00159779	15.01002783
Frame 3 (N-S)	9.62	49.84754	23892.09	0.00196654	18.47420915
Frame 4 (N-S)	9.62	67.94754	44392.97	0.00268061	25.18232684
			243728.8		

Torsion	Floor 13				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	97.35	14.94754	21749.75	0.00722292	59.53195011
Wall 2 (N-S)	97.35	17.45246	29650.22	0.00843333	69.50833313
Wall 3 (E-W)	218.58	12.35	33337.99	0.01339987	8.187265143
Wall 4 (E-W)	218.58	12.35	33337.99	0.01339987	8.187265143
Frame 1 (N-S)	8.26	29.64754	7264.271	0.00121627	10.02464325
Frame 2 (N-S)	8.26	42.44754	14890.86	0.00174139	14.35267252
Frame 3 (N-S)	8.62	49.84754	21420.5	0.00213311	17.58131505
Frame 4 (N-S)	8.62	67.94754	39800.59	0.00290766	23.96521651
			201452.2		

Torsion	Floor 14				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	77.46	14.94754	17305.95	0.00683808	48.91236285
Wall 2 (N-S)	77.46	17.45246	23592.23	0.00798401	57.10911209
Wall 3 (E-W)	174.43	12.35	26603.78	0.01272287	7.089012438
Wall 4 (E-W)	174.43	12.35	26603.78	0.01272287	7.089012438
Frame 1 (N-S)	7.52	29.64754	6608.848	0.00131658	9.417378826
Frame 2 (N-S)	7.52	42.44754	13547.32	0.00188499	13.48322836
Frame 3 (N-S)	7.75	49.84754	19261.84	0.00228225	16.32476809
Frame 4 (N-S)	7.75	67.94754	35789.68	0.00311095	22.25240835
			169313.4		

Torsion	Floor 15				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	62.62	14.94754	13991.31	0.00649091	39.87642272
Wall 2 (N-S)	62.62	17.45246	19073.56	0.00757866	46.55892625
Wall 3 (E-W)	141.35	12.35	21558.84	0.0121053	6.092655238
Wall 4 (E-W)	141.35	12.35	21558.84	0.0121053	6.092655238
Frame 1 (N-S)	6.85	29.64754	6020.389	0.00140816	8.650944811
Frame 2 (N-S)	6.85	42.44754	12341.05	0.00201612	12.38589491
Frame 3 (N-S)	6.99	49.84754	17376.07	0.00241727	14.85030621
Frame 4 (N-S)	6.99	67.94754	32285.79	0.003295	20.24255879
			144205.9		

Torsion	Floor 16				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	51.33	14.94754	11469.71	0.00615766	31.95715163
Wall 2 (N-S)	51.33	17.45246	15636.01	0.00718956	37.31254121
Wall 3 (E-W)	116.10	12.35	17707.34	0.01150587	5.166488754
Wall 4 (E-W)	116.10	12.35	17707.34	0.01150587	5.166488754
Frame 1 (N-S)	6.29	29.64754	5528.156	0.00149632	7.765634569
Frame 2 (N-S)	6.29	42.44754	11332.04	0.00214234	11.11836172
Frame 3 (N-S)	6.37	49.84754	15826.61	0.00254787	13.22298395
Frame 4 (N-S)	6.37	67.94754	29406.81	0.00347302	18.02434416
			124614		

Torsion	Floor 17				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	42.60	14.94754	9518.032	0.00584429	25.16735864
Wall 2 (N-S)	42.60	17.45246	12975.4	0.00682368	29.38491256
Wall 3 (E-W)	96.49	12.35	14717.66	0.0109377	4.317250444
Wall 4 (E-W)	96.49	12.35	14717.66	0.0109377	4.317250444
Frame 1 (N-S)	5.78	29.64754	5080.791	0.00157288	6.773340517
Frame 2 (N-S)	5.78	42.44754	10414.99	0.00225196	9.697655649
Frame 3 (N-S)	5.85	49.84754	14530.86	0.00267548	11.52147154
Frame 4 (N-S)	5.85	67.94754	26999.23	0.00364697	15.7050004
			108954.6		

Torsion	Floor 18				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	35.74	14.94754	7984.27	0.00557397	19.53878514
Wall 2 (N-S)	35.74	17.45246	10884.51	0.00650806	22.81310093
Wall 3 (E-W)	81.05	12.35	12362.46	0.01044569	3.550196439
Wall 4 (E-W)	81.05	12.35	12362.46	0.01044569	3.550196439
Frame 1 (N-S)	5.32	29.64754	4675.409	0.00164562	5.768501546
Frame 2 (N-S)	5.32	42.44754	9584.01	0.0023561	8.258988524
Frame 3 (N-S)	5.35	49.84754	13287.58	0.00278164	9.750666556
Frame 4 (N-S)	5.35	67.94754	24689.14	0.00379168	13.29120344
			95829.84		

Torsion	Floor 19				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	30.27	14.94754	6762.502	0.00530997	14.67075702
Wall 2 (N-S)	30.27	17.45246	9218.938	0.00619982	17.12928712
Wall 3 (E-W)	68.73	12.35	10482.53	0.00996217	2.838944778
Wall 4 (E-W)	68.73	12.35	10482.53	0.00996217	2.838944778
Frame 1 (N-S)	4.95	29.64754	4351.37	0.00172263	4.759400933
Frame 2 (N-S)	4.95	42.44754	8919.772	0.00246636	6.814219841
Frame 3 (N-S)	4.93	49.84754	12240.28	0.00288206	7.962742505
Frame 4 (N-S)	4.93	67.94754	22743.2	0.00392855	10.85407136
			85201.11		

Torsion	Floor 20				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	25.86	14.94754	5777.398	0.00508482	10.67370037
Wall 2 (N-S)	25.86	17.45246	7876.002	0.00593693	12.46240245
Wall 3 (E-W)	58.77	12.35	8964.12	0.0095489	2.193203302
Wall 4 (E-W)	58.77	12.35	8964.12	0.0095489	2.193203302
Frame 1 (N-S)	4.59	29.64754	4032.004	0.00178914	3.755646844
Frame 2 (N-S)	4.59	42.44754	8265.11	0.00256158	5.377105985
Frame 3 (N-S)	4.52	49.84754	11243.34	0.00296732	6.228794692
Frame 4 (N-S)	4.52	67.94754	20890.81	0.00404477	8.490514671
			76012.9		

Torsion	Floor 21				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	21.63	14.94754	4831.932	0.00483078	6.914953667
Wall 2 (N-S)	21.63	17.45246	6587.101	0.00564032	8.073763789
Wall 3 (E-W)	49.20	12.35	7504.469	0.0090807	1.532936577
Wall 4 (E-W)	49.20	12.35	7504.469	0.0090807	1.532936577
Frame 1 (N-S)	4.20	29.64754	3693.18	0.00186156	2.6647107
Frame 2 (N-S)	4.20	42.44754	7570.563	0.00266527	3.815170182
Frame 3 (N-S)	4.12	49.84754	10225.42	0.00306552	4.388092747
Frame 4 (N-S)	4.12	67.94754	18999.46	0.00417863	5.981440662
			66916.59		

Torsion	Floor 22				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	18.27	14.94754	4081.733	0.0046247	3.702725992
Wall 2 (N-S)	18.27	17.45246	5564.397	0.00539971	4.323229985
Wall 3 (E-W)	41.60	12.35	6344.549	0.00870047	0.88040045
Wall 4 (E-W)	41.60	12.35	6344.549	0.00870047	0.88040045
Frame 1 (N-S)	3.85	29.64754	3380.68	0.00193119	1.546187444
Frame 2 (N-S)	3.85	42.44754	6929.977	0.00276496	2.213736835
Frame 3 (N-S)	3.72	49.84754	9237.091	0.00313834	2.512686226
Frame 4 (N-S)	3.72	67.94754	17163.08	0.0042779	3.425060598
			59046.06		

Torsion	Floor roof				
Wall	R	x	Rx^2	Rx/Rx^2	Torsional Shear
Wall 1 (N-S)	15.57	14.94754	3478.946	0.00444771	1.105880328
Wall 2 (N-S)	15.57	17.45246	4742.652	0.00519305	1.291204103
Wall 3 (E-W)	35.48	12.35	5411.371	0.00837334	0.28106966
Wall 4 (E-W)	35.48	12.35	5411.371	0.00837334	0.28106966
Frame 1 (N-S)	3.50	29.64754	3073.345	0.00198098	0.492552901
Frame 2 (N-S)	3.50	42.44754	6299.979	0.00283625	0.705207188
Frame 3 (N-S)	3.37	49.84754	8366.254	0.00320734	0.797475802
Frame 4 (N-S)	3.37	67.94754	15545.01	0.00437195	1.087044979
			52328.93		

Shear Wall 1 Spot Check

WALL 1 CHECK

BASE SHEAR = 753.2 k

$V_u = 1.6(753.2) = 1205.1$ k

$\phi V_c = .75(2)\sqrt{f'_c}\, h d = .75(2)\sqrt{5000}\,(12)(.8)(24.583)(12) = 300.4$ k

$\phi V_c < V_u$ provide reinf

$\phi V_n = 10\sqrt{f'_c}\, h d = 10\sqrt{5000}\,(12)(.8)(24.583)(12) = 2003$ k > 1205.1 k

$\therefore$ section adequate

$\phi V_s = V_u - \phi V_c = 1205.1 - 300.4 = 904.7$ $V_s = 1206$

$V_s = \dfrac{A_v f_y d}{s} = \dfrac{.4(60)(.8)(24.583)(12)}{12''} = 472.0$ k

#4 @ 12" o.c. E.W. E.F. not good enough

there are other bars in the wall which will help this

without the others the required reinforcent is $A_s =$ 1" per foot or #7s @ 12" E.W. E.F.

$\rho_h = \dfrac{A_{vh}}{s h} = \dfrac{1}{12(12)} = .0069$

$\rho_v = .0025 + .5\left(2.5 - \dfrac{230}{24.583}\right)(.0069 - .0025) =$

$\dfrac{h_w}{L_w} = \dfrac{230}{24.583} = 9.36 \geq 2.5$

$A_v = .0025(12)(12) = .36'' \geq .4''$ #4 bars @ 12" o.c. ok

FLEXURAL DESIGN

wall D.L. = $.150(1)(24.583)(230) = 848$ k

floor load DL $= 792(21)\left[150\left(\frac{8}{12}\right) + 25\right] = 2079$ K

$LL = 40\left[.25 + \frac{15}{\sqrt{2(16632)}}\right] = 13.3$ use 16 psf

$LL = 792(21)(16) = 226$ k

$P_u = 1.2(848 + 2079) + 226 = 3738$ k

$M_u = 74288(1.6) = 118861$ ft·k

$A_{st} = .4(24.583) = 10.2$ in^2

$$w = \frac{10.2}{24.583(12)(12)}\left(\frac{60}{5}\right) = .035$$

$$\alpha = \frac{3738}{24.583(12)(12)(5)} = .211$$

$$\frac{c}{l_w} = \frac{.035 + .211}{2(.035) + .85(.8)} = .33$$

$$\phi M_n = .9\left[.5(10.2)(60)(24.583)(12)\left(1 + \frac{3738}{10.2(60)}\right)(1 - .33)\right] = 386894$$

$\phi M_n = 32241$ ft·k $<$ 118861 ft·k

no good but wall has extra vertical bars
near edges and around openings which
will add this moment capacity

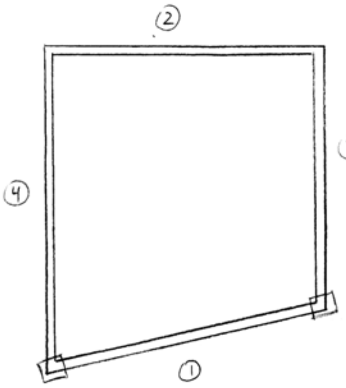
Overturning of Wall 1

$M_{ov} = 74288$ ft·k

$M_r = 6550\left(\frac{24.583}{2}\right) = 80509$ ft·k

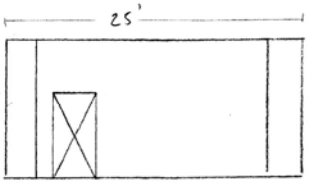
No overturning

Shear Wall Geometry and Reinforcing



WALL REINF
#4 @ 12" E.W. E.F.
2 #9 @ each side of opening
and @ corners
above openings 3 #9, 8, 7, or 6
depending on floor (horz)
above openings #4 @ 2", 3", 4", 6", 10", 12"
depending on floor (vert)

①



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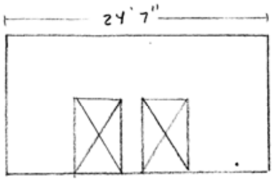

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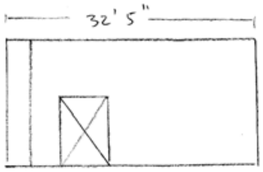

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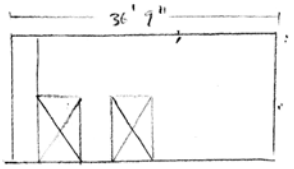
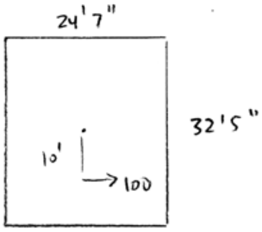


3 Methods of Finding Rigidity in Shear Walls Compared



4 seperate walls

Torque long wall $R_x^2 = \frac{32.417}{24.583}\left(\frac{24.583}{2}\right)^2 = 199.2$

Torque short wall $R_x^2 \left(\frac{32.417}{2}\right)^2 = 262.7$

$\Sigma R_x^2 = 199.2(2) + 262.7(2) = 923.8$

$T = 1000$ ft·k

long wall $\dfrac{1000\left(\frac{32.417}{24.583}\right)\left(\frac{24.583}{2}\right)}{923.8} = 17.55$

short wall $\dfrac{1000\left(\frac{32.417}{2}\right)}{923.8} = 17.55$

walls joined

shear flow $\dfrac{1000}{2(32.417)(24.583)} = .627$ k/ft

long wall $.627(32.417) = 20.3$

short wall $.627(24.583) = 15.4$

3 METHODS

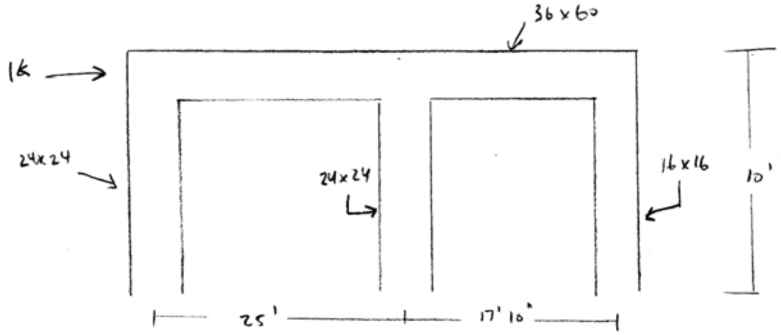
4 walls seperate w/ rigidity ratio long: short 1.43:1

4 walls seperate theoretical ratio long: short 1:1

walls joined theoretical ratio long: short 1.32:1

Moment Frame 1 and Sample Calculations

FRAME 1



used 1 k point load

$\Delta = .00088$ in

$R = 1136$ k/in

SHEAR WALLS

$$R = \frac{Et}{4\left(\frac{h}{L}\right)^3 + 3\left(\frac{h}{L}\right)}$$

assume conservatively

wall 1 = wall 2 = 24'7"

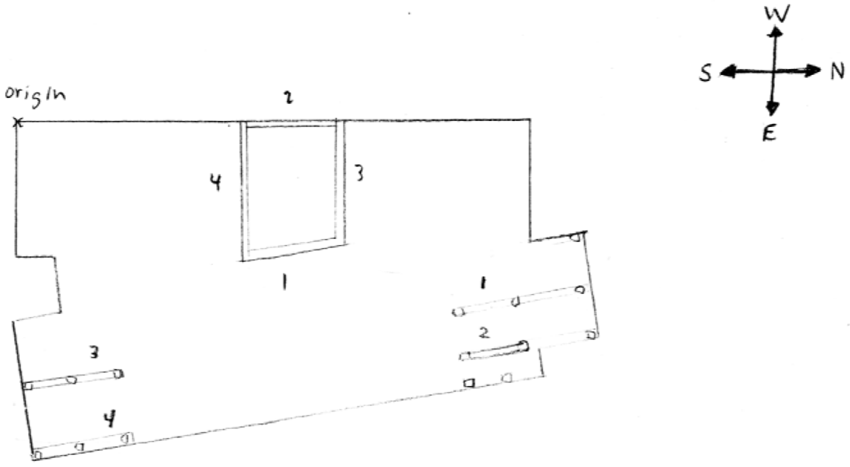
wall 3 = wall 4 = 32'5"

$E_c = 33(150)^{1.5}\sqrt{5000} \approx 4287$ ksi

$$R_{1,2} = \frac{4287\,(12)}{4\left(\frac{10(12)}{295}\right)^3 + 3\left(\frac{10\,(12)}{295}\right)} = 34536 \text{ k/in}$$

$$R_{34} = \frac{4287\,(12)}{4\left(\frac{10(12)}{389}\right)^3 + 3\left(\frac{10(12)}{389}\right)} = 49329 \text{ k/in}$$

Center of Rigidity Sample Caclulation



CENTER OF RIGIDITY

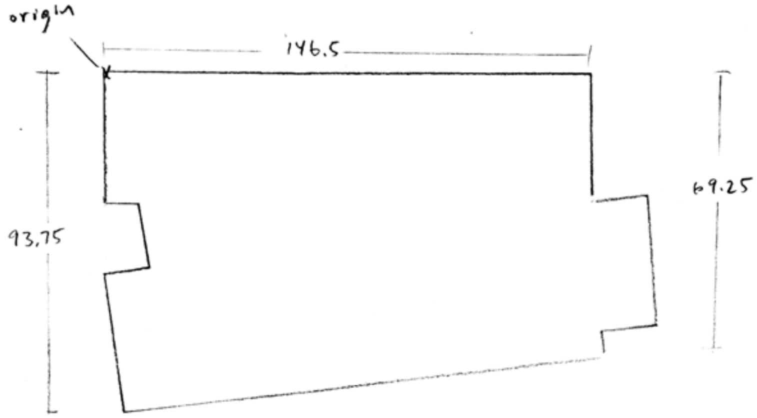
$$C.R._x = \frac{49329(62.83) + 49329(87.5) + 826(113.5) + 826(134.5)}{100310}$$

$$= 76'0''$$

$$C.R._y = \frac{34536(32.417) + 806.45(29.83) + 1136(47.083) + 1136(59.917) + 1136(67.25) + 1136(85.417)}{74422}$$

$$= 19.33'$$

Center of Mass Sample Caclulation



$$C.M._x = \frac{146.5(59.25)(73.25) + 24.5(146.5)(.5)(48.83) + 35(15)(154) - 8.5(15)(4)}{146.5(59.25) + 24.5(146.5)(.5) + 35(15) - 8.5(15)}$$

$$= 73.9'$$

$$C.M_y = \frac{80.5}{2} = 40.3'$$

$$\left.\begin{array}{l} CM_x = 73.9 \\ CR_x = 76 \end{array}\right\rangle \; 2.1 \text{ ft}$$

$$\left.\begin{array}{l} CM_y : 40.3 \\ CR_y : 19.33 \end{array}\right\rangle \; 21 \text{ ft}$$