TOWER 333

Technical Assignment 3

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Executive Summary:

The purpose of this report is to determine through analytical methods the response of the lateral force resisting system implemented for the design of the 260 foot tall office tower, Tower 333 in Bellevue, Washington under seismic and wind loads.

Existing Lateral System:

The existing lateral system is a dual-resisting system using a combination of special exterior moment frames and a special concrete shear wall centralized core. The concrete core is 40 feet by 32 feet with 5 foot openings for elevator access in the 32 foot length side. The moment frames consist of rolled W shapes with the columns ranging from W14x730 at the mezzanine level to W14x132 at the penthouse level. The moment frame beams range in size from W36x256 at floor 1 to W18x86 at the penthouse level.

Gravity System:

The existing gravity system is a 2-1/2" concrete slab on a 3" deep metal composite deck with an f'c of 4,000psi and WWF 6x6 W3.5xW3.5 reinforcing. Supporting the slab are W18x40 composite steel beams which span 42' N-S in a typical bay. The beams frame into composite steel girders on the interior which are typically W18x97 spanning E-W.

Conclusion:

In order to determine Tower 333's lateral resisting system response to seismic and wind loads a model of Tower 333's lateral system was created in ETABS. Only the core and perimeter moment frames were modeled and connected with a rigid diaphragm on each floor. Then the model was loaded with seismic and wind forces calculated using spreadsheets in accordance with ASCE-7 '05 and analyzed under the different load combinations required by ASCE-7. Using this ETABS model, in conjunction with hand calculated spot checks I was able to confirm that the assumptions made prior to the design of Tower 333 were correct. These assumptions include drift limitations of L/400 for wind and ASCE-7 '05 section 12.8.6 allowable drift for seismic. Based on the relative base shear distributions, it was determined that the moment frames resist 10% of the lateral load. However, these frames were initially designed for 25% of the seismic force in conjunction with the dual system requirements of ASCE-7 for the Seattle area. An examination of the drift results reveals that the dual system as originally designed is well balanced and subject to only minimal building torsions.

Existing Structural System:

Introduction:

Tower 333 is an 18 story office building located in Bellevue Washington. The total height of Tower 333 is 260 feet tall with 8 levels of below ground parking that extends 93 below grade. The building is scheduled to be completed in December of 2007. However, due to the recent tower-crane collapse on the construction site on November 16th this date could be postponed further, (see additional links on Author's CPEP website for more details.) The code used to design Tower 333 was the IBC 2003 with reference to ASCE-7 02' for load values. For this analysis, ASCE -7 05' was used as an update. When using ETABS for this report user defined loading for seismic and wind forces were calculated by spread sheet using ASCE-7 '05 and assigned to the model as a static representation of the dynamic loads.

Existing Gravity System:

The typical bay of the upper office floors of Tower 333 are supported by 42' long W18x40 composite beams with a camber of 1-1/2" and 30' long W18x97 composite girders with a camber of ¾". Both have a strength of 50ksi. These members in turn support a 2-1/2" concrete slab on a 3" deep composite metal deck with the strength of the concrete being 4,000psi. To control expansion and contraction of the concrete there is WWF 6x6 W3.5xW3.5 reinforcing in the slab. The floor to floor height is 13'-10" and the overall weight of this system is 58 psf with a framing depth of 24". The finished floor to finished ceiling height is 10' which allows 2-10" of plenum clearance space. This plenum space is utilized for the mechanical equipment which incorporates a variety of 12" and 14" deep ducts to transport air to strip diffusers along the perimeter of the building. Refer to Figure 1 for a framing plan of the existing system.

Existing Lateral Framing System:

The lateral system is a dual-resisting system utilizing a special concrete core and perimeter special moment frames. The concrete core consists of 2 foot thick walls, 40 feet in length along the North-South direction and 32 feet in length with 5 foot openings for elevator access in the East-West direction. See Figure 2 for layout of the core and frames.

The concrete shear walls have a bearing capacity of f’c = 9000 psi, with two curtains of #7 rebar at 12 inches on center and #5 hoops and ties at 6 inches on center. The core extends the full height of the building from sub parking level 8 to the roof level, a total of 338 feet. There are a total of four moment frames around the perimeter of Tower 333. One moment frame is on each North and South face, consisting of 3-30 foot bays with columns ranging from W14x730 at the mezzanine level to W14x132 at the penthouse level. The beams on the North and South frames range from W24x176 at floor 1 to W18x86 at the penthouse floor. The other two moment frames are on the East and West face, with one 26 foot bay and one 42 foot bay containing a range of columns from W14x550 at the mezzanine level to W14x132 at the penthouse level and beams ranging in size from W36x256 at floor 1 to W18x86 at the penthouse floor.

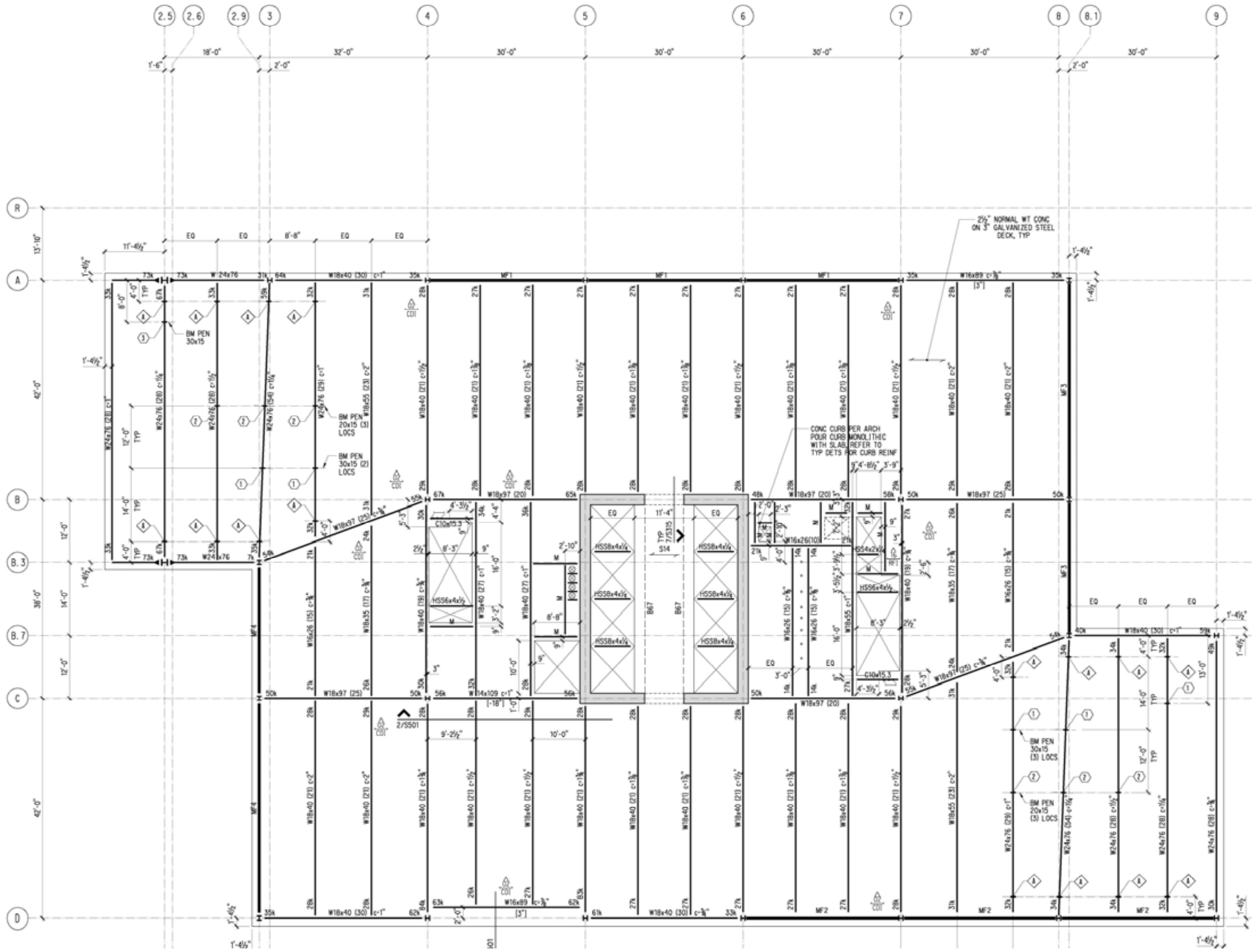

Figure 1:
Existing Structural Steel Floor Framing

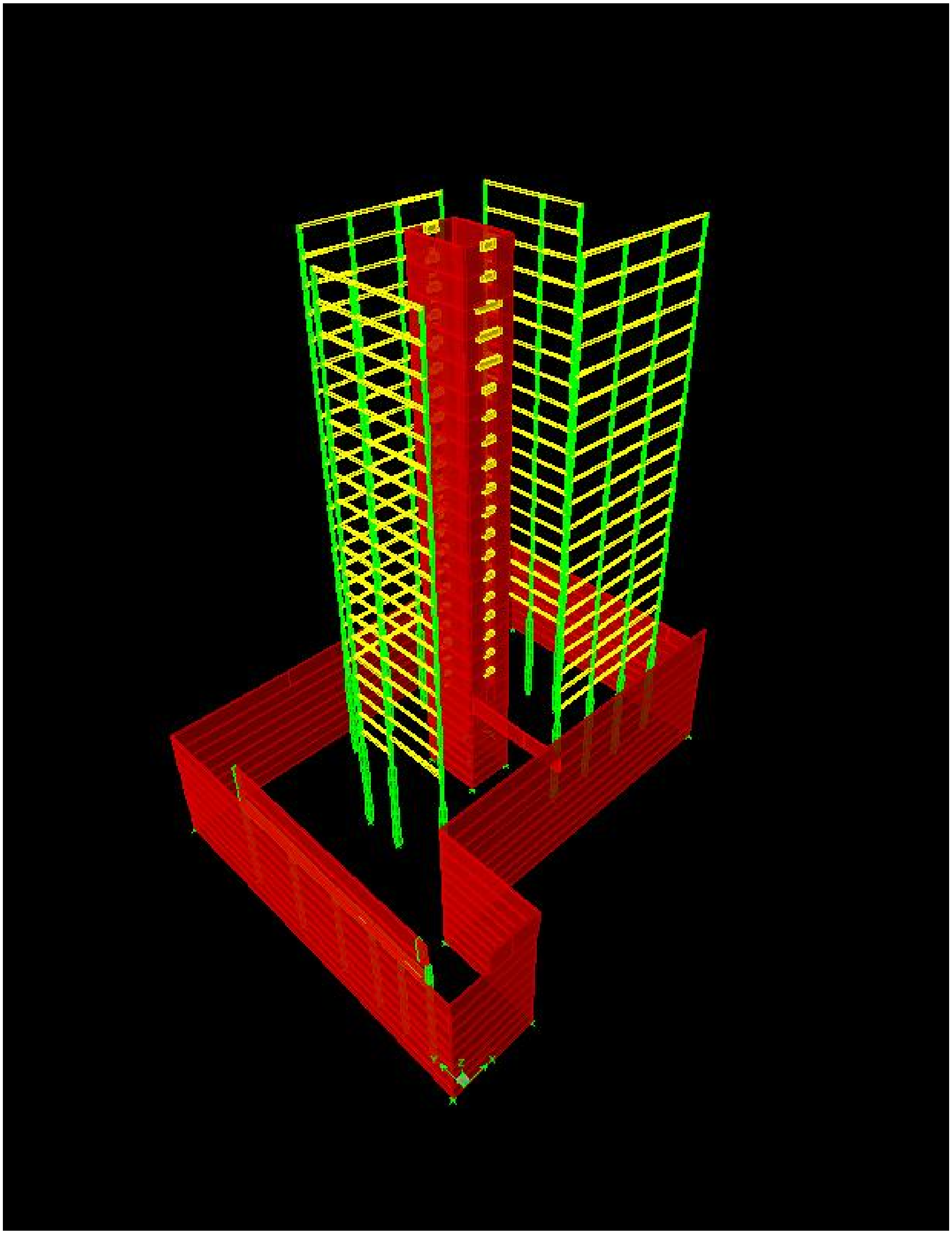

Figure 2
Existing dual core and moment frame lateral system.

Lateral Loads:

Wind Forces:

Although it has been determined that the wind forces are not the controlling lateral force case, the tables in Figure 3 show the wind forces implemented on each floor for the model of Tower 333 in ETABS. These forces were calculated through ASCE-7 '05 Chapter 6. Tower 333 is in an Exposure Category B, with an importance factor of 1.0 and with wind speed V=85mph. The results from ETABS for drift were a maximum displacement of 3.47 inches in the East-West direction and 4.33 inches in the North-South direction, both of which are well below the assumed drift tolerance of L/400 which equals 8 inches. A summary of the results follows:

D I S P L A C E M E N T S A N D D R I F T S AT P O I N T O B J E C T 88
(Wind Force in East-West Direction)

STORY	DISP-X	DISP-Y	DRIFT-X	DRIFT-Y
ROOF	3.473071	0.027104	0.001175	0.000008
STORY18	3.278020	0.025794	0.001190	0.000008

D I S P L A C E M E N T S A N D D R I F T S AT P O I N T O B J E C T 88
(Wind Force in North-South Direction)

STORY	DISP-X	DISP-Y	DRIFT-X	DRIFT-Y
ROOF	0.199125	4.329639	0.000020	0.001570
STORY18	0.195839	4.068970	0.000025	0.001580

			Wind from N-S					
Floor	Height (Ft.)	Trib. Height (Ft.)	Windward (PSF)	Leeward (PSF)	Total (PSF)	Story Force (Kip)	Total Shear (Kip)	Overturning Moment (Ft.-Kip)
1 (ground)	0	0	0	0	0	0	1365.32	195908.2
2	18.67	16.25	10.23	-10.06	20.29	70.56	1365.32	1317.3
3	32.5	13.83	11.71	-10.06	21.77	64.43	1294.76	2094.0
4	46.33	13.83	12.24	-10.06	22.3	66.00	1230.33	3057.8
5	60.167	13.83	12.66	-10.06	22.72	67.24	1164.33	4045.8
6	74	13.83	13.5	-10.06	23.56	69.73	1097.09	5159.9
7	87.83	13.83	13.82	-10.06	23.88	70.68	1027.36	6207.4
8	101.67	13.83	14.67	-10.06	24.73	73.19	956.68	7441.4
9	115.5	13.83	14.67	-10.06	24.73	73.19	883.49	8453.6
10	129.33	13.83	15.19	-10.06	25.25	74.73	810.30	9664.9
11	143.167	13.83	15.62	-10.06	25.68	76.00	735.57	10881.1
12	157	13.83	15.62	-10.06	25.68	76.00	659.57	11932.5
13	170.833	13.83	16.04	-10.06	26.1	77.25	583.56	13196.2
14	184.66	13.83	16.36	-10.06	26.42	78.19	506.32	14439.1
15	198.5	13.83	16.36	-10.06	26.42	78.19	428.13	15521.3
16	212.33	13.83	17.2	-10.06	27.26	80.68	349.93	17130.6
17	226.167	13.83	17.2	-10.06	27.26	80.68	269.25	18247.0
18	240	13.83	17.2	-10.06	27.26	80.68	188.57	19363.0
Pent	253.833	13.83	17.41	-10.06	27.47	81.30	107.89	20636.8
Roof	267.67	13.83	17.41	-10.06	27.47	26.59	26.59	7118.3

			Wind From E-W					
Floor	Height (Ft.)	Trib. Height (Ft.)	Windward (PSF)	Leeward (PSF)	Total (PSF)	Story Force (Kip)	Total Shear (Kip)	Overturning Moment (Ft.-Kip)
1 (ground)	0	0	0	0	0	0	807.11	115038.9
2	18.67	16.25	10.31	-10.22	20.53	42.04	807.11	784.8
3	32.5	13.83	11.8	-10.22	22.02	38.37	765.07	1247.1
4	46.33	13.83	12.34	-10.22	22.56	39.31	726.70	1821.4
5	60.167	13.83	12.77	-10.22	22.99	40.06	687.39	2410.4
6	74	13.83	13.62	-10.22	23.84	41.54	647.33	3074.2
7	87.83	13.83	13.94	-10.22	24.16	42.10	605.78	3697.7
8	101.67	13.83	14.8	-10.22	25.02	43.60	563.68	4432.7
9	115.5	13.83	14.8	-10.22	25.02	43.60	520.08	5035.7
10	129.33	13.83	15.33	-10.22	25.55	44.52	476.48	5758.1
11	143.167	13.83	15.76	-10.22	25.98	45.27	431.96	6481.5
12	157	13.83	15.76	-10.22	25.98	45.27	386.69	7107.7
13	170.833	13.83	16.19	-10.22	26.41	46.02	341.42	7862.0
14	184.66	13.83	16.51	-10.22	26.73	46.58	295.39	8601.3
15	198.5	13.83	16.51	-10.22	26.73	46.58	248.82	9246.0
16	212.33	13.83	17.36	-10.22	27.58	48.06	202.24	10204.7
17	226.167	13.83	17.36	-10.22	27.58	48.06	154.18	10869.7
18	240	13.83	17.36	-10.22	27.58	48.06	106.12	11534.5
Pent	253.833	13.83	17.58	-10.22	27.8	48.44	58.06	12296.6
Roof	267.67	13.83	17.58	-10.22	27.8	9.61	9.61	2572.8

Figure 3.

Lateral Forces Due to Wind

Seismic Loads:

The controlling forces in the lateral direction for Tower 333 were determined to be the seismic forces. These forces were obtained through ASCE-7 ’05 Chapter 12 and are displayed in Figure 4. Using the shear forces per floor (in kips) from Figure 4 and inputting that data into the ETABS model acting at the center of gravity of each floor, it was found that the maximum displacements were 12.92 inches in the East-West direction and 10.88 inches in the North-South direction. Using the amplification factor found in ASCE-7 ’05 equation 12.8-15 the seismic story drift at the roof level resulted in 51.68 inches in the East-West direction and 43.52 inches in the North-South direction. Both these drift values are well below the limit obtained from ASCE-7 ’05 table 12.12-1 which was determined to be 70.4 inches. A summary of this info follows:

D I S P L A C E M E N T S A N D D R I F T S AT P O I N T O B J E C T 88
(Seismic Force in East-West Direction)

STORY	DISP-X	DISP-Y	DRIFT-X	DRIFT-Y
ROOF	12.929284	-0.018166	0.004583	0.000017
STORY18	12.168436	-0.021037	0.004649	0.000013

D I S P L A C E M E N T S A N D D R I F T S AT P O I N T O B J E C T 88
(Seismic Force in North-South Direction)

STORY	DISP-X	DISP-Y	DRIFT-X	DRIFT-Y
ROOF	0.804788	10.883198	0.000098	0.004074
STORY18	0.788574	10.206968	0.000129	0.004108

When inspecting overturning moment the seismic forces produce a total moment of 460,413 ft-kips, taking the total weight of the structure to the seismic base which is 59,155 kips and multiplying by the moment arm from the center of gravity, (which is roughly centered inside the core,) to the edge of the core, 15 feet the resulting resistive moment is approximately 887,325 ft-kips. This value is almost twice that of the overturning moment which implies there are no uplift forces due to overturning moment.

Seismic Loading						
V= 2307						
K=1.4	Level	w_x	h_x	$w_x h_x^{1.4}$	C_{vx} (k)	Fx (k)
Roof	20	156	278.67	413286.2	0.007	16.68
Penthouse	19	2490	274.78	6468126.6	0.113	261.11
Office	18	2490	260.95	6016993.9	0.105	242.89
Office	17	2490	247.12	5575327.7	0.098	225.07
Office	16	2490	233.29	5143442.9	0.090	207.63
Office	15	2490	219.46	4721683.5	0.083	190.61
Office	14	2490	205.63	4310428.2	0.075	174.00
Office	13	2490	191.8	3910095.7	0.068	157.84
Office	12	2490	177.97	3521152.8	0.062	142.14
Office	11	2490	164.14	3144123.1	0.055	126.92
Office	10	2490	150.31	2779600.4	0.049	112.21
Office	9	2490	136.48	2428264.4	0.042	98.02
Office	8	2490	122.65	2090903.2	0.037	84.41
Office	7	2490	108.82	1768445.0	0.031	71.39
Office	6	2490	94.99	1462003.4	0.026	59.02
Office	5	2490	81.16	1172946.5	0.021	47.35
Office	4	2490	67.33	903007.6	0.016	36.45
Office	3	2490	53.5	654477.4	0.011	26.42
Office	2	2432	39.67	420543.2	0.007	16.98
Lobby	1	3442	21	244296.86	0.004	9.86
Mezzanine	M	2059	9	44626.812	0.001	1.80
Parking Level 1	P1	8736.5	0	0	0	0
Total		59155.5		57193775	1.001	2308.80
Total Base Shear			2308.80			
Total Overturning Moment			460413			

Moment From Each Floor (ft. Kips)
4649
71747
63383
55618
48438
41830
35780
30274
25297
20833
16866
13378
10352
7769
5606
3843
2454
1413
673
207
16
0
Total
460413

Figure 4.
Lateral Forces Due to Wind

Load Cases:

The following load cases as obtained from ASCE-7 ’05 chapter 2 were used in the analysis of Tower 333 in ETABS.

1) 1.4(D + F)
2) 1.2(D + F + T) +1.6(L + H) + 0.5(L_r or S or R)
3) 1.2D + 1.6(L_r or S or R) + (L or 0.8W)
4) 1.2D + 1.6W + L + 0.5(L_r or S or R)
5) 1.2D + 1.0E + L + 0.2S
6) 0.9D + 1.6W + 1.6H
7) 0.9D + 1.0E + 1.6H
8.) 1.0D + 1.0L + 1.0E

Load Distribution:

Through hand calculations following ASCE-7 ’05 Chapter 12 the story shears for the seismic forces were computed. These values were then inserted into ETABS at each floor’s center of gravity in the Tower 333 model. After analysis, the results for shear in each moment frame at the seismic base level were obtained and compared to the total shear at the seismic base level. The shear forces in both frames in the E-W direction were approximately 220 kips and both frames in the N-S direction were 230 kips. Compared to the total seismic base shear of 2308 kips, that results in 10% (+ - .5%) of the total base shear calculated from ASCE-7 ’05 to be taken by the perimeter moment frames. This 10% accumulation of base shear in the perimeter moment frames confirms the assumption made by the engineer of record that despite the frames being designed for at least 25% of the total base shear as required by code, in reality they are only taking roughly 10-11% of the total shear.

It is believed that the perimeter frames also play a significant role in minimizing torsion. This aspect of the structure will be analyzed in more detail as part of future investigations.

ETABS Analysis:

When using ETABS the model was simplified for Tower 333 down to the lateral system consisting of the perimeter moment frames and the shear wall core. To allow all the frames and core to act as one system the members were connected to a rigid diaphragm at each floor. This analysis technique permits a more direct analysis and interpretation of the results and easier application of the loads. The wind and seismic loads were then applied at each floor manually using the story forces calculated for the wind and seismic analysis (see Figures 3 and 4 for force results.) These forces were calculated in accordance with ASCE-7 ’05 chapters 6 and 12.

When viewing the animated results and story displacement values, it is clear that the wind and seismic forces develop little torsion. Acceptable maximum drift values that are below those mandated by ASCE-7 ’05, (see Figure 5) were also calculated using ETABS. The expected levels of shear in the frames and shear walls as assumed by the engineer of record were confirmed. This, in addition to the fact that the forces were user-defined from hand calculations rather than calculated by ETABS helps to confirm that the ETABS model has run properly and has developed justifiable results.

Conclusion:

By virtue of a thorough analysis utilizing the Tower 333 structure modeled in ETABS as well as hand calculations, the response characteristics of Tower 333's lateral force resisting system to seismic and wind loads was successfully determined. Modeling only the core and perimeter moment frames for ease of analysis and connecting them with a rigid diaphragm on each floor, it was possible to apply the lateral loads as calculated by ASCE-7 '05 to Tower 333 and run a analysis of the lateral systems.

I have concluded through the Tower 333 ETABS model as well as confirmation of spot checks that the assumptions the engineer of record made in designing Tower 333 were confirmed. These assumptions include drift limitations of L/400 for wind and ASCE-7 '05 section 12.8.6 allowable drift for seismic. Based on the relative base shear distributions, it was determined that the moment frames resist 10% of the lateral load. However, these frames were initially designed for 25% of the seismic force in conjunction with the dual system requirements of ASCE-7 for the Seattle area. An examination of the drift results reveals that the dual system as originally designed is well balanced and subject to only minimal building torsions. Based on this analysis, it is reasonable to conclude that the loads and force distributions used as part of this educational study are in agreement with the original values used by the designers.

Appendix:

Spot Checks & Tables

Building Information	
Exposure:	B
V (mph)	85
Importance	II
I	1
Kd	0.85
Kzt	1
h (ft)	260
Enclosure:	Enclosed
α	7
Zg (ft)	1200
Zmin (ft)	30
c	0.3
â	0.143
b hat	0.84
α bar	0.25
l(ft)	320
€ bar	0.33
b bar	0.45

Pressure Coefficients:	
Internal	
Gcpi	0.18
	-0.18
External	
Windward	
Cp	0.8
Leeward	
N-S---Cp	-0.5
E-W---Cp	-0.36
Period	
C_t	0.02
x	0.75
$h_{n\,(ft)}$	260
T_a	1.3
Nat. Freq: $n_{1\,(hz)}$	0.77

Flexible Building	
g_R	4.13
g_Q & g_v	3.40
R_n	0.049
R_h	0.097
n_1	0.77
η_h	9.80
V_z	94.0
ß	0.05
Wind from N-S	
η_B	8.06
η_L	15.9
R_B	0.12
R_L	0.06
Q	0.83
R	0.08
Gf	0.84
Wind from E-W	
η_B	4.75
η_L	27.00
R_B	0.19
R_L	0.04
Q	0.85
R	0.10
Gf	0.85

K_z & q_z

Z (ft)	Kz	qz
0-15	0.57	8.96
20	0.62	9.75
25	0.66	10.38
30	0.70	11.01
40	0.76	11.95
50	0.81	12.73
60	0.85	13.36
70	0.89	13.99
80	0.93	14.62
90	0.96	15.09
100	0.99	15.56
120	1.04	16.35
140	1.09	17.14
160	1.13	17.77
180	1.17	18.39
200	1.20	18.87
250	1.28	20.12
267	1.30	20.44

Pressure				
Wind From N-S				
Windward		Leeward		Total
h (ft)	P (psf)	h (ft)	P (psf)	
0-15	9.70	0-15	-10.06	19.76
20	10.23	20	-10.06	20.28
25	10.65	25	-10.06	20.71
30	11.07	30	-10.06	21.13
40	11.71	40	-10.06	21.76
50	12.24	50	-10.06	22.29
60	12.66	60	-10.06	22.71
70	13.08	70	-10.06	23.14
80	13.50	80	-10.06	23.56
90	13.82	90	-10.06	23.88
100	14.14	100	-10.06	24.19
120	14.67	120	-10.06	24.72
140	15.19	140	-10.06	25.25
160	15.62	160	-10.06	25.67
180	16.04	180	-10.06	26.10
200	16.36	200	-10.06	26.41
250	17.20	250	-10.06	27.26
267	17.41	267	-10.06	27.47
Wind From E-W				
Windward		Leeward		Total
h (ft)	P (psf)	h (ft)	P (psf)	
0-15	9.77	0-15	-10.22	19.99
20	10.31	20	-10.22	20.53
25	10.73	25	-10.22	20.95
30	11.16	30	-10.22	21.38
40	11.80	40	-10.22	22.02
50	12.34	50	-10.22	22.56
60	12.77	60	-10.22	22.98
70	13.19	70	-10.22	23.41
80	13.62	80	-10.22	23.84
90	13.94	90	-10.22	24.16
100	14.26	100	-10.22	24.48
120	14.80	120	-10.22	25.02
140	15.33	140	-10.22	25.55
160	15.76	160	-10.22	25.98
180	16.19	180	-10.22	26.41
200	16.51	200	-10.22	26.73
250	17.36	250	-10.22	27.58
267	17.58	267	-10.22	27.80

			Wind from N-S						
Floor	Height (Ft.)	Trib. Height (Ft.)	Windward (PSF)	Leeward (PSF)	Total (PSF)	Story Force (Kip)	Total Shear (Kip)	Overturning Moment (Ft.-Kip)
1 (ground)	0	0	0	0	0	0	1365.32	195908.2
2	18.67	16.25	10.23	-10.06	20.29	70.56	1365.32	1317.3
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11	143.167	13.83	15.62	-10.06	25.68	76.00	735.57	10881.1
12	157	13.83	15.62	-10.06	25.68	76.00	659.57	11932.5
13	170.833	13.83	16.04	-10.06	26.1	77.25	583.56	13196.2
14	184.66	13.83	16.36	-10.06	26.42	78.19	506.32	14439.1
15	198.5	13.83	16.36	-10.06	26.42	78.19	428.13	15521.3
16	212.33	13.83	17.2	-10.06	27.26	80.68	349.93	17130.6
17	226.167	13.83	17.2	-10.06	27.26	80.68	269.25	18247.0
18	240	13.83	17.2	-10.06	27.26	80.68	188.57	19363.0
Pent	253.833	13.83	17.41	-10.06	27.47	81.30	107.89	20636.8
Roof	267.67	13.83	17.41	-10.06	27.47	26.59	26.59	7118.3

			Wind From E-W					
Floor	Height (Ft.)	Trib. Height (Ft.)	Windward (PSF)	Leeward (PSF)	Total (PSF)	Story Force (Kip)	Total Shear (Kip)	Overturning Moment (Ft.-Kip)
1 (ground)	0	0	0	0	0	0	807.11	115038.9
2	18.67	16.25	10.31	-10.22	20.53	42.04	807.11	784.8
3	32.5	13.83	11.8	-10.22	22.02	38.37	765.07	1247.1
4	46.33	13.83	12.34	-10.22	22.56	39.31	726.70	1821.4
5	60.167	13.83	12.77	-10.22	22.99	40.06	687.39	2410.4
6	74	13.83	13.62	-10.22	23.84	41.54	647.33	3074.2
7	87.83	13.83	13.94	-10.22	24.16	42.10	605.78	3697.7
8	101.67	13.83	14.8	-10.22	25.02	43.60	563.68	4432.7
9	115.5	13.83	14.8	-10.22	25.02	43.60	520.08	5035.7
10	129.33	13.83	15.33	-10.22	25.55	44.52	476.48	5758.1
11	143.167	13.83	15.76	-10.22	25.98	45.27	431.96	6481.5
12	157	13.83	15.76	-10.22	25.98	45.27	386.69	7107.7
13	170.833	13.83	16.19	-10.22	26.41	46.02	341.42	7862.0
14	184.66	13.83	16.51	-10.22	26.73	46.58	295.39	8601.3
15	198.5	13.83	16.51	-10.22	26.73	46.58	248.82	9246.0
16	212.33	13.83	17.36	-10.22	27.58	48.06	202.24	10204.7
17	226.167	13.83	17.36	-10.22	27.58	48.06	154.18	10869.7
18	240	13.83	17.36	-10.22	27.58	48.06	106.12	11534.5
Pent	253.833	13.83	17.58	-10.22	27.8	48.44	58.06	12296.6
Roof	267.67	13.83	17.58	-10.22	27.8	9.61	9.61	2572.8

Seismic Loading						
V= 2307						
K=1.4	Level	w_x	h_x	$w_x h_x^{1.4}$	C_{vx} (k)	Fx (k)
Roof	20	156	278.67	413286.2	0.007	16.68
Penthouse	19	2490	274.78	6468126.6	0.113	261.11
Office	18	2490	260.95	6016993.9	0.105	242.89
Office	17	2490	247.12	5575327.7	0.098	225.07
Office	16	2490	233.29	5143442.9	0.090	207.63
Office	15	2490	219.46	4721683.5	0.083	190.61
Office	14	2490	205.63	4310428.2	0.075	174.00
Office	13	2490	191.8	3910095.7	0.068	157.84
Office	12	2490	177.97	3521152.8	0.062	142.14
Office	11	2490	164.14	3144123.1	0.055	126.92
Office	10	2490	150.31	2779600.4	0.049	112.21
Office	9	2490	136.48	2428264.4	0.042	98.02
Office	8	2490	122.65	2090903.2	0.037	84.41
Office	7	2490	108.82	1768445.0	0.031	71.39
Office	6	2490	94.99	1462003.4	0.026	59.02
Office	5	2490	81.16	1172946.5	0.021	47.35
Office	4	2490	67.33	903007.6	0.016	36.45
Office	3	2490	53.5	654477.4	0.011	26.42
Office	2	2432	39.67	420543.2	0.007	16.98
Lobby	1	3442	21	244296.86	0.004	9.86
Mezzanine	M	2059	9	44626.812	0.001	1.80
Parking Level 1	P1	8736.5	0	0	0	0
Total		59155.5		57193775	1.001	2308.80
Total Base Shear			2308.80			
Total Overturning Moment			460413			

Moment From Each Floor (ft. Kips)
4649
71747
63383
55618
48438
41830
35780
30274
25297
20833
16866
13378
10352
7769
5606
3843
2454
1413
673
207
16
0
Total
460413

DISPLACEMENTS AND DRIFTS AT POINT OBJECT 88
(Seismic Forces in E-W-Direction)

STORY	DISP-X	DISP-Y	DRIFT-X	DRIFT-Y
ROOF	12.929284	-0.018166	0.004583	0.000017
STORY18	12.168436	-0.021037	0.004649	0.000013
STORY17	11.396707	-0.023123	0.004798	0.000028
STORY16	10.600253	-0.027739	0.004908	0.000037
STORY15	9.785600	-0.033947	0.004908	0.000028
STORY14	8.970841	-0.038668	0.004796	0.000000
STORY13	8.174688	-0.038675	0.004762	0.000006
STORY12	7.384200	-0.037667	0.004711	0.000011
STORY11	6.602203	-0.035815	0.004639	0.000015
STORY10	5.832203	-0.033266	0.004533	0.000020
STORY9	5.079647	-0.030012	0.004405	0.000021
STORY8	4.348358	-0.026459	0.004241	0.000023
STORY7	3.644325	-0.022648	0.004046	0.000024
STORY6	2.972765	-0.018712	0.003810	0.000023
STORY5	2.340288	-0.014826	0.003528	0.000024
STORY4	1.754577	-0.010901	0.003188	0.000033
STORY3	1.225375	-0.005442	0.002982	0.000004
STORY2	0.730350	-0.004738	0.002411	0.000013
STORY1	0.330163	-0.002565	0.001676	0.000005
MEZZ.	0.051959	-0.003454	0.000101	0.000005
B1	0.037472	-0.002713	0.000068	0.000003
B2	0.030155	-0.002380	0.000061	0.000003
B3	0.022848	-0.002027	0.000067	0.000005
B4	0.015601	-0.001513	0.000054	0.000006
B5	0.009776	-0.000854	0.000040	0.000004
B6	0.005405	-0.000403	0.000029	0.000003
B7	0.002237	-0.000113	0.000021	0.000001

DISPLACEMENTS AND DRIFTS AT POINT OBJECT 88
(Seismic Force in N-S Direction)

STORY	DISP-X	DISP-Y	DRIFT-X	DRIFT-Y
ROOF	0.804788	10.883198	0.000098	0.004074
STORY18	0.788574	10.206968	0.000129	0.004108
STORY17	0.767125	9.525069	0.000245	0.004150
STORY16	0.726401	8.836228	0.000323	0.004171
STORY15	0.672728	8.143847	0.000314	0.004161
STORY14	0.620678	7.453071	0.000224	0.004117
STORY13	0.583480	6.769572	0.000224	0.004078
STORY12	0.546281	6.092628	0.000220	0.004016
STORY11	0.509722	5.425984	0.000200	0.003923
STORY10	0.476458	4.774738	0.000283	0.003823
STORY9	0.429528	4.140086	0.000282	0.003684
STORY8	0.382767	3.528504	0.000282	0.003521
STORY7	0.335965	2.943976	0.000283	0.003331
STORY6	0.288916	2.390990	0.000278	0.003109
STORY5	0.242704	1.874867	0.000257	0.002853
STORY4	0.200109	1.401287	0.000213	0.002543
STORY3	0.164732	0.979096	0.000482	0.002249
STORY2	0.084737	0.605699	0.000329	0.001853
STORY1	0.030178	0.298127	0.000193	0.001386
MEZZ.	-0.001783	0.068120	0.000007	0.000133
B1	-0.000817	0.048906	0.000004	0.000114
B2	-0.000393	0.036621	0.000002	0.000095
B3	-0.000151	0.025275	0.000001	0.000075
B4	-0.000080	0.017198	0.000001	0.000054
B5	-0.000022	0.011406	0.000000	0.000043
B6	0.000020	0.006717	0.000000	0.000034
B7	0.000030	0.003036	0.000000	0.000028

DISPLACEMENTS AND DRIFTS AT POINT OBJECT 88
(Wind Force in E-W Direction)

STORY	DISP-X	DISP-Y	DRIFT-X	DRIFT-Y
ROOF	3.473071	0.027104	0.001175	0.000008
STORY18	3.278020	0.025794	0.001190	0.000008
STORY17	3.080443	0.024499	0.001226	0.000012
STORY16	2.876885	0.022436	0.001255	0.000016
STORY15	2.668507	0.019808	0.001260	0.000015
STORY14	2.459410	0.017353	0.001237	0.000009
STORY13	2.254060	0.015904	0.001235	0.000008
STORY12	2.048999	0.014557	0.001231	0.000008
STORY11	1.844652	0.013275	0.001223	0.000008
STORY10	1.641572	0.012000	0.001205	0.000007
STORY9	1.441471	0.010864	0.001185	0.000007
STORY8	1.244788	0.009693	0.001155	0.000007
STORY7	1.052997	0.008518	0.001118	0.000007
STORY6	0.867440	0.007316	0.001069	0.000007
STORY5	0.689933	0.006072	0.001007	0.000007
STORY4	0.522713	0.004833	0.000927	0.000004
STORY3	0.368807	0.004110	0.000886	0.000012
STORY2	0.221718	0.002063	0.000729	0.000008
STORY1	0.100640	0.000715	0.000511	0.000010
MEZZ.	0.015852	-0.000968	0.000030	0.000001
B1	0.011550	-0.000758	0.000020	0.000001
B2	0.009345	-0.000662	0.000019	0.000001
B3	0.007124	-0.000562	0.000020	0.000001
B4	0.004938	-0.000417	0.000017	0.000002
B5	0.003155	-0.000232	0.000013	0.000001
B6	0.001784	-0.000106	0.000010	0.000001
B7	0.000758	-0.000027	0.000007	0.00000

DISPLACEMENTS AND DRIFTS AT POINT OBJECT 88
(Wind Force in N-S Direction)

STORY	DISP-X	DISP-Y	DRIFT-X	DRIFT-Y
ROOF	0.199125	4.329639	0.000020	0.001570
STORY18	0.195839	4.068970	0.000025	0.001580
STORY17	0.191647	3.806727	0.000045	0.001590
STORY16	0.184154	3.542729	0.000060	0.001598
STORY15	0.174181	3.277533	0.000060	0.001598
STORY14	0.164148	3.012213	0.000046	0.001591
STORY13	0.156460	2.748057	0.000047	0.001583
STORY12	0.148643	2.485281	0.000046	0.001567
STORY11	0.141058	2.225078	0.000038	0.001541
STORY10	0.134736	1.969189	0.000070	0.001514
STORY9	0.123145	1.717922	0.000070	0.001471
STORY8	0.111493	1.473734	0.000072	0.001419
STORY7	0.099588	1.238156	0.000074	0.001356
STORY6	0.087325	1.013073	0.000074	0.001279
STORY5	0.075027	0.800735	0.000068	0.001187
STORY4	0.063763	0.603705	0.000054	0.001071
STORY3	0.054844	0.425863	0.000165	0.000959
STORY2	0.027521	0.266663	0.000109	0.000803
STORY1	0.009422	0.133354	0.000062	0.000607
MEZZ	-0.000838	0.032558	0.000003	0.000061
B1	-0.000445	0.023739	0.000002	0.000053
B2	-0.000258	0.018017	0.000001	0.000045
B3	-0.000138	0.012668	0.000001	0.000036
B4	-0.000080	0.008796	0.000000	0.000027
B5	-0.000033	0.005919	0.000000	0.000022
B6	0.000000	0.003538	0.000000	0.000018
B7	0.000012	0.001612	0.000000	0.000015

SEISMIC STORY DRIFT

DEFLECTION AT LEVEL X

$\delta_x = \frac{C_d \delta_{xe}}{I}$ $I = 1.0$ (SECTION 11.5.1) $C_d = 4$ (TABLE 12.2-1)

@ ROOF:

SEISMIC IN X-DIRECTION: $\delta_{xe} = 12.92''$ — FROM ETABS MODEL

$\delta_x = \frac{4(12.92'')}{1.0} = 51.68''$

SEISMIC IN Y-DIRECTION $\delta_{xe} = 10.88''$ — FROM ETABS MODEL

$\delta_x = \frac{4(10.88'')}{1.0} = 43.52''$

STORY LIMIT DRIFT:

MAX $\Delta = .020(h_{sx})$ (TABLE 12.12-1)

$h_{sx} = (293.5')(12'') = 3{,}522''$

$\Delta_{max} = .02(3{,}522'') = 70.4''$

δ_x & δ_y @ ROOF SHALL NOT EXCEED Δ_{max}

$\delta_x = 51.68'' < \Delta_{max} = 70.4''$ ok

$\delta_y = 43.52'' < \Delta_{max} = 70.4''$ ok

WIND DRIFT

Δ_{max} ~ ASSUME $\frac{L}{400}$ $= \frac{(260ft)(12")}{400} \approx 7.8" \Rightarrow 8"$

WIND DRIFT AS COMPUTED FROM ETABS

WIND IN X-DIRECTION $\Delta_x = 3.47"$

WIND IN Y-DIRECTION $\Delta_y = 4.33"$

$\Delta_x = 3.47" < \Delta_{ALLOWABLE} = 8"$ ok

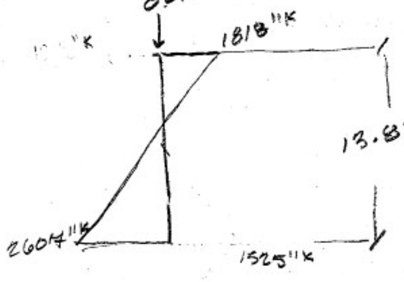
$\Delta_y = 4.33" < \Delta_{ALLOWABLE} = 8"$ ok

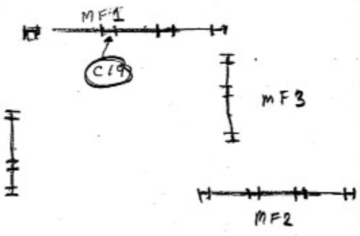
SPOT CHECK   Pg 3

FRAME MEMBER

$547^K = P$ $1724''K$ LOAD COMBO 8

<u>Col. #19</u> @ MF 1   LEVEL 7





$2607''^K / 12'' = 217.25$

$P_{eff} = P_u + m M_{ux} = 821.65^K + 1.71(217.25'^K)$

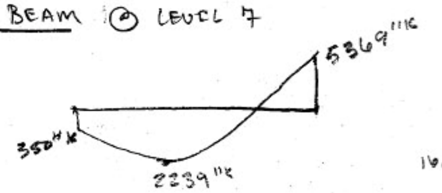
$m = \frac{24}{d} = \frac{24}{14} = 1.71$ $P_{eff} = 1193^K$

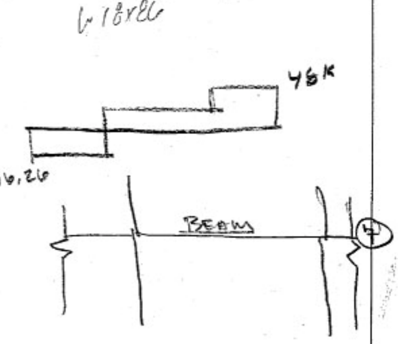
K_L 13.83' ⇒ 14' → TABLE 4-1 LRFD 13TH ED.

ASSUME TRIAL SIZE OF W14   W14X120

ENGINEER DESIGNED FOR W14x257 WHICH CONFIRMS FRAMES TAKE LESS THAN 25% OF DESIGNED LOADS.

FRAME BEAM @ LEVEL 7





MAX M = 5369"K ⇒ 447'K

MOMENTS OBTAINED FROM ETABS.

DESIGN BEAM FOR AT LEAST 447'K

⇓ FROM TABLE 3-2 LRFD 13TH ED.

LIGHTEST MEMBER TO CARRY MOMENT

W21x55

ENGINEER USES W18x86

CONCLUSION: ENGINEER PROBABLY USED HEAVIER MEMBER TO SAVE IN FRAMING DEPTH SO AS TO ALLOW GREATER FL. TO CEILING HEIGHT AS REQUIRED FOR GREEN BLD DESIGN FOR LARGER WINDOWS.

CORE WALL 1

SEISMIC BASE SHEAR
$V = 2308$ (FROM CALC TABLES)

SYM. WALL LAYOUT
DISTRB. IN N-S $= \frac{1}{2}$

BY INSPECTION THROUGH LOADS IN ETABS
MFRAMES TAKE ≈ 10% OF LOAD. ∴ DESIGN FOR
90% ON S.W.

$(2308)(.9) = 2077^k \Rightarrow$ EACH WALL TAKES 50%

$\Downarrow$

1038^K PER WALL.

$h = 24''$
$l_w = 40'$
$V = 1038^k$

DET. LONG & TRANSVERSE REINF.

/ SPOT CHECK EXISTING 2-CURTAIN REBAR DESIGN

$\rho_e, \rho_t \geq .0025$

$\therefore \frac{A_{sl}}{A_{cv}} \geq .0025$ $\quad A_{cv} = (24'')(12'') = 288\ in^2/ft$

$(288\ in^2/ft)(.0025)$

$= .72\ in^2/ft$ min.

ASSUME #5 IN 2-CURTAINS

$A_{sl} = \frac{.62\ in^2}{SPACE}$ $\quad \frac{.72\ in^2}{12''} = \frac{.62\ in^2}{S} \Rightarrow S = 10.33''\ max$

TRY #5's @ 10" SPACE BOTH DIRECTIONS.

S.W. 1 CONT...

NOMINAL SHEAR

$$V_n = A_{cv}(\alpha_c \sqrt{f'_c} + \rho_t f_y)$$

$$\frac{h_w}{l_w} = \frac{260'}{40'} = 6.5 > 2.0 \therefore \alpha_c = 2.0$$

$$A_{cv} = (24'')(40')(12'') = 11,520\,in^2$$

$$\rho_t = \frac{2(.31\,in^2)}{(24'')(12)} = .0022$$

$$V_u = (11,520\,in^2)\left[2.0\sqrt{9000\,psi} + .0022(60\,ksi)\right] = 3706^k$$

$$\phi V_n = .6(3706^k) = 2224 > 1038^k \therefore ok$$

$\frac{1200\,ft^2}{22,500\,ft^2}$ SHEAR WALL TRIB AREA

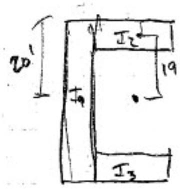
FL. PLATE $= .053 \times$ TOT DL.

$P_u = 2415^k$ $M_u = 327,639^{'k}$

FLOOR FORCE x HEIGHT

$$C_u = \frac{P_u}{2} + \frac{M_u}{d} = \frac{2415^k}{2} + \frac{327639^{'k}}{40'} = 9400^k \equiv P_u \text{ @ B.E.}$$

$$A_g = (2')(40') = 80\,ft^2$$



M_u ON S.W.

$I_1 = 10,667\,ft^4$

$I_2 = 6.67\,ft^4$

$\times\ Ad^2 = 48,133\,ft^4$

$$\frac{327,639^{'k}(.9)}{2} = 147,437^{'k}$$

$$I_g = 10,667 + 2(48133) = 106,943$$

SPOT CHECK

Pg 7

SW. 1 CONT.

$$f_c = \frac{P_u}{A_g} + \frac{M_u \cdot \frac{h_w}{2}}{I_g} = \frac{2415}{120 ft^2} + \frac{147,437\left(\frac{40'}{2}\right)}{166,943}$$

$= 27.57$ ksf

$= .20$ ksi

$.2f'_c = .2(9ksi) = 1.8ksi$

$f_c \le f'_c$ NO BOUNDARY NEEDED

$.2 ksi < 1.8 ksi$

CONCLUSION: RESULTS ATTAINED WERE ALIKE THAT OF ENG. OF RECORD THEREFORE SAFE TO CONCLUDE ASSUMPTIONS ARE CORRECT.

CAMPAD