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110 Third Avenue
110 Third Avenue
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11/21/05

Structural Technical Report 3

Lateral System Analysis and Confirmation Design

1.1 Executive Summary

This report includes a design study of the lateral system in 110 Third Avenue. In the first technical report, wind and seismic loads were calculated and subsequently, in this report, they will be applied to the building to determine if the lateral resisting system is adequate. In essence, this report is an extension of Technical Report 1 and will examine the details of the lateral resisting system. Each load case and each direction for wind and seismic loading are summarized and analyzed for their affect on the structure. Worst case scenarios are evaluated to determine whether the building can handle the given loading, and serviceability issues are also examined.

A computer model was generated in ETABS to assist in the evaluation of lateral loading on 110 Third Avenue. Upon first glance, 110 Third Avenue appeared to resist lateral loads solely through the use of shear walls. The ETABS model, after producing abnormally large drifts (although strangely still within seismic code limitations), presented serious serviceability issues. Further examination of the lateral system showed that designers must have used a combination system that utilized the slab and columns in a moment frame.

The report shows that the lateral system was competently designed, although using ETABS did not necessarily demonstrate exact loading and resisting conditions. The difference in results using computer models is clearly explained from the different approach a combination system takes. The use of the combined frame and shear wall reduces lateral movement for a given size and reinforcing of shear walls.

1.2 Scope

The scope of this structural technical report includes a design study of the lateral system in 110 Third Avenue. In the first technical report, wind and seismic loads were calculated and subsequently, in this report, they will be applied to the building to determine if the lateral resisting system is adequate. In essence, this report is an extension of Technical Report 1 and will examine the details of the lateral resisting system.

1.3 Introduction

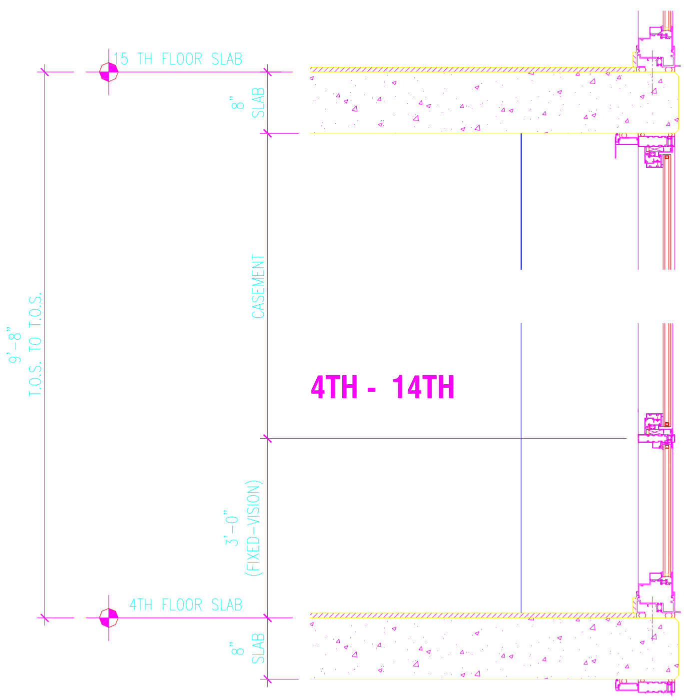
110 Third Avenue is a residential mid-rise tower that sits in the heart of Manhattan between Gramercy and East Village. Standing at 210' to the bulkhead slab, it offers 21 stories of mid-sized apartments totaling approximately 107,000 square feet of inhabitable space. The structural system of 110 Third Avenue is predominantly cast-in-place concrete. Most floors have 8" CIP slab, but beginning with floor 15 the slab increases to as much as 24" to support cantilevered portions of the building and mechanical equipment on the roof. All slabs and columns have $f'_c = 5000$ psi. Loads are carried from the two-way slab system to concrete columns ranging from 12x12 to 40x12. The columns are continuous throughout the height of the building except for a few columns that terminate at floor 16 due to a setback in the building perimeter, and a few columns that originate on the drawings at floor 11 due to the reduction of the elevator core to column-sized portions. Footings range from 4'6" square up to 15' x 9'6". The only beams present in the structure are in the basement level and are grade beams extending from perimeter East-face and West-Face footings to the outside wall. Shear walls extend throughout the height of the building and are located mostly on the North and South sides of the building. The roof is a flat slab system that is drained by roof drains nested under pavers. Supporting columns are recessed from the façade on average 10", and therefore allow the designer to use non-bearing prefabricated panels.

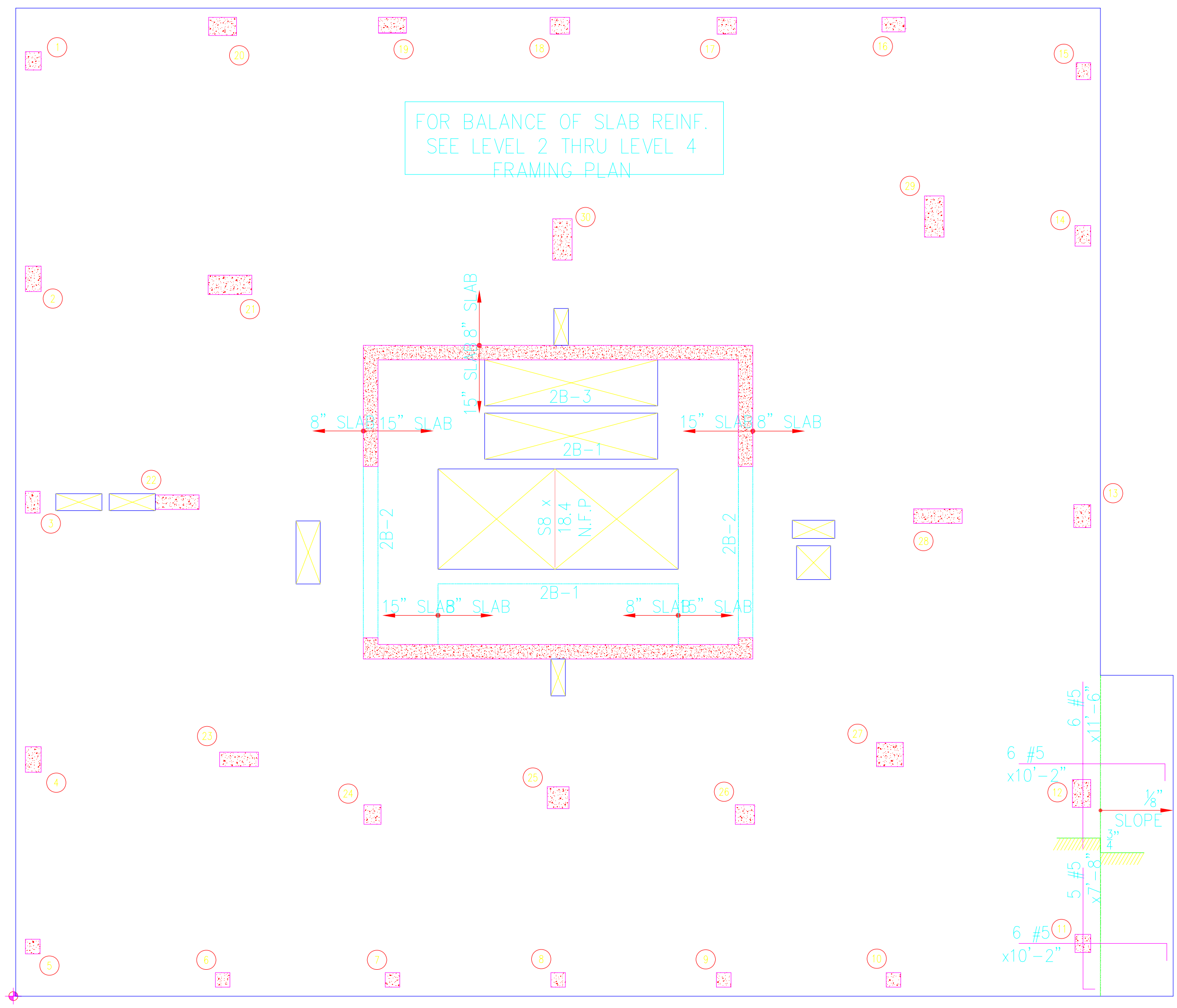
Loading conditions on the vast majority of the building are relatively light due to their use as residential space. A table below provides a complete description of loads according to drawing S.001 provided by Axis Design Group. When factored according to ASCE-07, loading throughout the apartments is only 94 psf. Low loading consequently makes the existing system, the 8" flat plate system, a very good choice in order to maximize space. Most other systems aren't competitive simply because they cannot maintain a depth of only 8".

Floor	Partition	Ceiling & Mech.	Floor Finish	Live	Total Imposed
Lobby	-	5	40	100	145
Apartment	12	-	5	40	65
Roof	-	5	25	30	60
Retail	-	5	15	100	120
Storage	-	5	-	100	105
Stairs	-	-	-	100	100
Private Roof Terrace	-	-	65	60	200
Public Roof Terrace	-	-	65	100	200
Mechanical	-	25	40	150	215
Gym	-	5	15	100	215
Courtyard	-	-	65	60	215

1.4 Existing Structural Floor System

110 Third Avenue is completely a flat plate system with columns roughly sorted into a 7x5 element bay. The building extends 68' in the North-South direction (5 columns) and 75' in the East-West direction (7 columns). A flat plate system supports the loads placed on the building and directly transfers the loading to the columns. No drop panels assist in the distribution of weight or add to the building's resistance to punching shear. A central shear wall system centered around the elevator core provides lateral stability and resistance to wind and seismic loading.





Typical Floor Plan for Floors 5 through 10, other floors are very similar

Design weight of floor framing is 8" thick concrete flat plate slab at 100 PSF (S-001) A typical flat plate slab system serves the entirety of 110 Third Avenue. Slab size increases around the elevator core to 15", and increases to 24" near the elevator core on the roof level to support mechanical equipment. Slabs are continued, in portions of each floor, past the perimeter to form balconies. The balconies have a ¾" step down from the 8" slab that makes up the entire interior space, and are therefore 7 ¼ in. thick. The flat plate slab is a great approach to a mid-rise residential tower because it saves on formwork and labor costs. All slabs are 5000 psi concrete.

2.1 Loads and Load Cases

D = dead load;
D_i = weight of ice;
E = earthquake load;
F = load due to fluids with well-defined pressures and maximum heights;
F_a = flood load;
H = load due to lateral earth pressure, ground water pressure, or pressure of bulk materials;
L = live load;
L_r = roof live load;
R = rain load;
S = snow load;
T = self-straining force;
W = wind load;

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. $0.9D + 1.0E + 1.6H$

Exceptions:
1. The load factor on L in combinations (3),

Max wind loading: 1.6W
Max Seismic loading: 1.0E

As detailed above, ASCE7-02 gives seven loading combinations that could be applied to 110 Third Avenue. Evaluation of considered lateral loadings (W and E) shows that W and E are never combined in any ratios. Therefore, the ETABS model presented later in this report considers the maximum factored wind load of 1.6W and the maximum seismic load of 1.0E separately. Taking these loads separately accurately reflects the provisions laid out by ASCE7-02. Note that several wind loading patterns must also be considered as per ASCE7-02 figure 6-9. In this report, case 1 and case 3 are the only cases considered since cases 2 and 4 almost never control.

	Fy (N-S)			Fx (E-W)		
Level	Seismic	Wind	Controlling	Fx (E-W)	Fx (E-W)	Controlling
21(roof)	13.1	22.4	WIND	13.1	13.8	WIND
20	26.4	41.7	WIND	26.4	25.8	SEISMIC
19	24.7	38.7	WIND	24.7	23.9	SEISMIC
18	23.0	38.3	WIND	23.0	23.7	WIND
17	21.4	38.0	WIND	21.4	23.4	WIND
16	19.8	37.6	WIND	19.8	23.2	WIND
15	18.2	37.2	WIND	18.2	22.9	WIND
14	16.6	36.8	WIND	16.6	22.7	WIND
13	15.1	36.3	WIND	15.1	22.4	WIND
12	13.6	35.9	WIND	13.6	22.1	WIND
11	12.1	35.4	WIND	12.1	21.8	WIND
10	10.7	34.8	WIND	10.7	21.5	WIND
9	9.3	34.3	WIND	9.3	21.1	WIND
8	8.0	33.7	WIND	8.0	20.7	WIND
7	6.7	33.0	WIND	6.7	20.3	WIND
6	5.5	32.3	WIND	5.5	19.9	WIND
5	4.3	31.4	WIND	4.3	19.3	WIND
4	3.3	30.5	WIND	3.3	18.7	WIND
3	2.2	29.9	WIND	2.2	18.4	WIND
2	1.3	28.9	WIND	1.3	17.7	WIND
1	0.5	30.3	WIND	0.5	18.6	WIND

The above table shows that wind is generally the controlling load for 110 Third Avenue with the rare exception of the 19th and 20th floors in the E-W direction. Each loading utilizes its respective load factor of 1.0E or 1.6W.

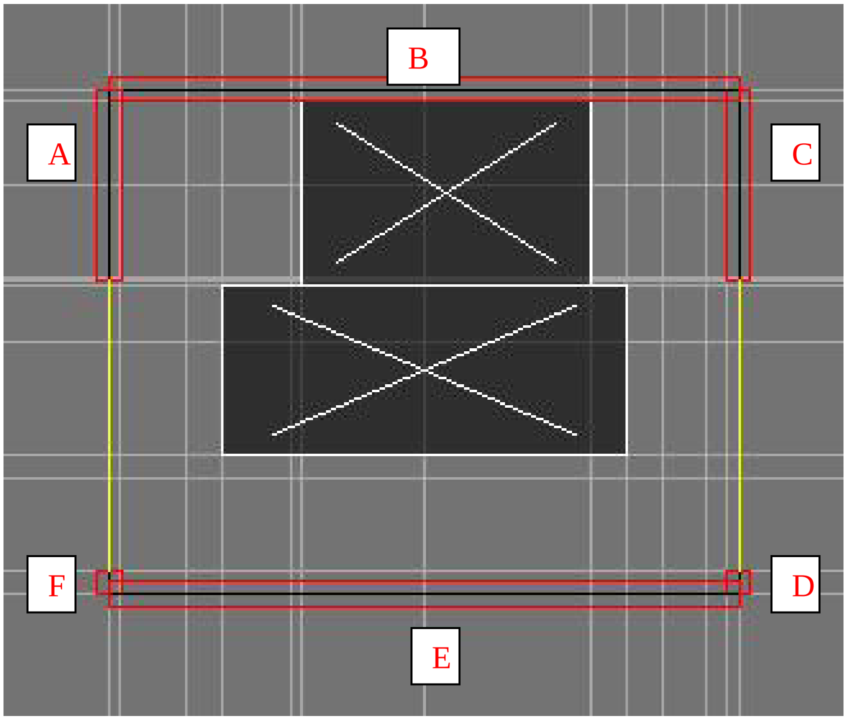
3.1 Distribution

3.1.1 Distribution by rigidity in Excel

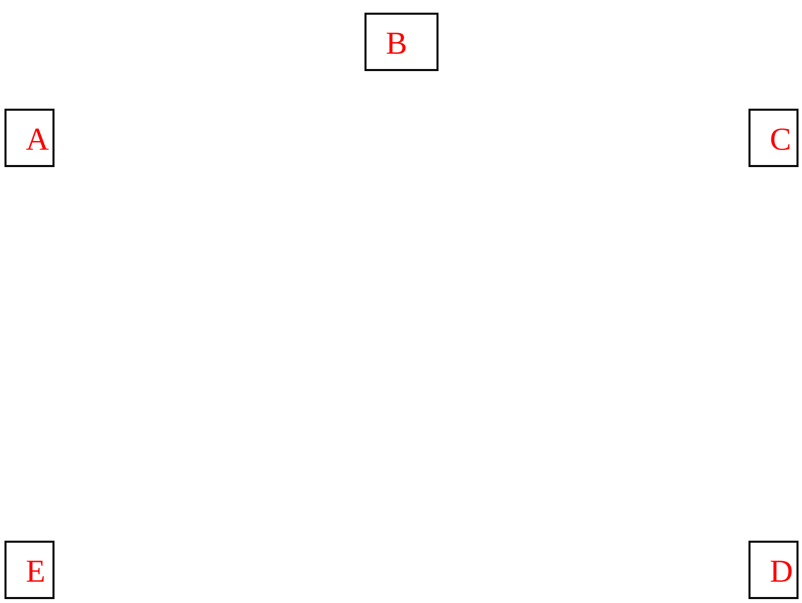
Lateral forces were distributed based on rigidity. A complete Excel file giving the forces on each wall for each story for each wind load case is included in this report. See below for an outlined procedure used in determining forces.

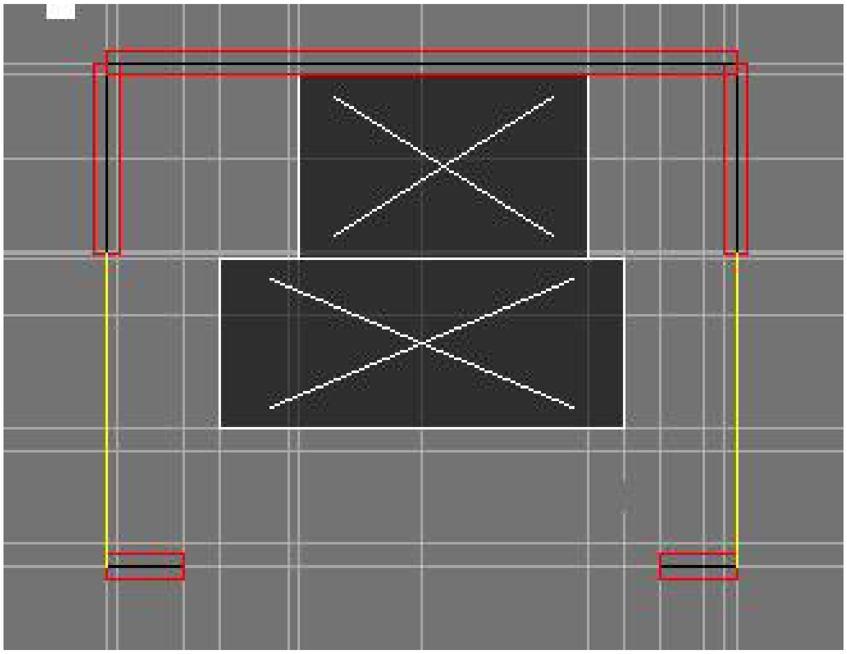
- Step 1: Determine Center of Mass (assumed to be in the center due to symmetrical placement of walls
- Step 2: Find h/L and classify as short, intermediate, or tall walls
- Step 3: Find K
- Step 4: Determine Center of Rigidity
- Step 5: Determine Eccentricities
- Step 6: Determine Torsional Moment
- Step 7: Develop Coordinate system with center of rigidity at center
- Step 8: Determine Polar Moment of Inertia

- Step 9: Find Direct forces
- Step 10: Find Torsional Shears
- Step 11: Combine Direct and Torsional Shears, but do not deduct torsional shears if negative



Shear Walls- Floors 1 to 10





Shear Walls- Floors 11 to 21

Lateral Distribution for 110 Third Avenue

Assumptions:
- Normalized height is 9.67 ft. and exclude abnormal floor heights such as floor 1
- Floor 1 shear walls have the same dimensions as floors 2 through 10

B=	26.75
L=	21.58

Floors 1 to 10		
Wall	Height	Length
A	9.67	8.33
B	9.67	24.75
C	9.67	8.33
D	9.67	1.50
E	9.67	24.75
F	9.67	1.50

Floors 11 to 21		
Wall	Height	Length
A	9.67	8.33
B	9.67	24.75
C	9.67	8.33
D	9.67	3.67
E	9.67	3.67

Step 2: h/l

Floors 1 to 10		
Wall	h/l	Class
A	1.16	Intermediate
B	0.39	Intermediate
C	1.16	Intermediate
D	6.45	TALL
E	0.39	Intermediate
F	6.45	TALL

Floors 11 to 21		
Wall	h/l	Class
A	1.16	Intermediate
B	0.39	Intermediate
C	1.16	Intermediate
D	2.63	Intermediate
E	2.63	Intermediate

Step 3: K

Floors 1 to 10	
Wall	K
A	0.105432
B	0.754868
C	0.105432
D	0.000933
E	0.754868
F	0.000933

Floors 11 to 21	
Wall	K
A	0.105432
B	0.754868
C	0.105432
D	0.012423
E	0.012423

Step 4: Determine Center of Rigidity

Floors 1 to 10	
Xcr	13.38
Ycr	10.79

Floors 11 to 21	
Xcr	13.38
Ycr	20.90

Step 5: Determine Eccentricities
Neglect accidental torsion for wind (ASCE7-02 sec. 6.5.12.3)
Neglect accidental torsion for Seismic: 5%*B added

Floors 1 to 10

ex	0.00
ey	0.00

Floors 11 to 21

ex	0.00
ey	10.11

Step 6: Determine Torsional Moment

	N-S	E-W
Floor	M_t (ft.-k)	M_t (ft.-k)
21.00	226.54	0.00
20.00	648.13	0.00
19.00	1039.06	0.00
18.00	1426.42	0.00
17.00	1810.05	0.00
16.00	2189.80	0.00
15.00	2565.50	0.00
14.00	2936.95	0.00
13.00	3303.94	0.00
12.00	3666.22	0.00
11.00	4023.50	0.00
10.00	0.00	0.00
9.00	0.00	0.00
8.00	0.00	0.00
7.00	0.00	0.00
6.00	0.00	0.00
5.00	0.00	0.00
4.00	0.00	0.00
3.00	0.00	0.00
2.00	0.00	0.00
1.00	0.00	0.00

GOVERNING VALUES
FLOOR SHEAR

(Kips)

Floor	N-S (Y)	E-W (X)
21.00	22.4	13.8
20.00	64.1	39.6
19.00	102.8	63.5
18.00	141.2	87.1
17.00	179.1	110.6
16.00	216.7	133.8
15.00	253.9	156.7
14.00	290.6	179.4
13.00	327.0	201.8
12.00	362.8	223.9
11.00	398.2	245.7
10.00	433.0	267.1
9.00	467.3	288.2
8.00	500.9	309.0
7.00	533.9	329.3
6.00	566.2	349.1
5.00	597.6	368.5
4.00	628.1	387.2
3.00	658.0	405.6
2.00	686.9	423.3
1.00	717.2	441.9

Step 7: Develop Coordinate System w/CR at center

Floors 1 to 10	
d_a	-13.38
d_b	10.79
d_c	13.38
d_d	13.38
d_e	-10.79
d_f	-13.38

Floors 11 to 21	
d_a	-13.38
d_b	10.79
d_c	13.38
d_d	-10.79
d_e	-10.79

Step 8: Determine Polar Moment of Inertia

Floors 1 to 10	
d^2*k	18.86
	87.88
	18.87
	0.17
	87.88
	0.17
J=SUM	213.84

Floors 11 to 21	
d^2*k	18.87
	87.88
	18.87
	1.45
	1.45
J=SUM	128.53

Step 9: Find Direct Shear
*Table gives direct shear value in kips

walls in same dir.	A,C	B,D,E	21.00
	A,C,D,F	B,E	1.00

N-S (Y)						
Wall						
Floor	A	B	C	D	E	F
21	11.21	21.70	11.21	0.36	0.36	0.00
20	32.07	62.09	32.07	1.02	1.02	0.00
19	51.41	99.55	51.41	1.64	1.64	0.00
18	70.58	136.66	70.58	2.25	2.25	0.00
17	89.56	173.41	89.56	2.85	2.85	0.00
16	108.35	209.79	108.35	3.45	3.45	0.00
15	126.94	245.79	126.94	4.04	4.04	0.00
14	145.32	281.38	145.32	4.63	4.63	0.00
13	163.48	316.53	163.48	5.21	5.21	0.00
12	181.40	351.24	181.40	5.78	5.78	0.00
11	199.08	385.47	199.08	6.34	6.34	0.00
10	214.60	216.49	214.60	1.90	216.49	1.90
9	231.58	233.63	231.58	2.05	233.63	2.05
8	248.26	250.46	248.26	2.20	250.46	2.20
7	264.61	266.95	264.61	2.34	266.95	2.34
6	280.60	283.08	280.60	2.48	283.08	2.48
5	296.18	298.80	296.18	2.62	298.80	2.62
4	311.29	314.05	311.29	2.76	314.05	2.76
3	326.11	328.99	326.11	2.89	328.99	2.89
2	340.44	343.45	340.44	3.01	343.45	3.01
1	355.45	358.60	355.45	3.15	358.60	3.15

E-W(X)						
Wall						
Floor	A	B	C	D	E	F
21	6.92	13.40	6.92	0.22	0.22	0.00
20	19.80	38.34	19.80	0.63	0.63	0.00
19	31.74	61.46	31.74	1.01	1.01	0.00
18	43.57	84.37	43.57	1.39	1.39	0.00
17	55.29	107.05	55.29	1.76	1.76	0.00
16	66.88	129.50	66.88	2.13	2.13	0.00
15	78.35	151.71	78.35	2.50	2.50	0.00
14	89.69	173.66	89.69	2.86	2.86	0.00
13	100.89	195.34	100.89	3.21	3.21	0.00
12	111.94	216.74	111.94	3.57	3.57	0.00
11	122.83	237.84	122.83	3.91	3.91	0.00
10	132.39	133.57	132.39	1.17	133.57	1.17
9	142.86	144.12	142.86	1.26	144.12	1.26
8	153.13	154.48	153.13	1.36	154.48	1.36
7	163.20	164.64	163.20	1.44	164.64	1.44
6	173.03	174.56	173.03	1.53	174.56	1.53
5	182.62	184.23	182.62	1.62	184.23	1.62
4	191.91	193.60	191.91	1.70	193.60	1.70
3	201.00	202.78	201.00	1.78	202.78	1.78
2	209.79	211.65	209.79	1.86	211.65	1.86
1	218.99	220.93	218.99	1.94	220.93	1.94

Step 10: Torsional Shear

N-S (Y)						
Wall						
Floor	A	B	C	D	E	F
21	-2.49	14.36	2.49	-0.24	-0.24	0.00
20	-7.11	41.07	7.11	-0.68	-0.68	0.00
19	-11.40	65.85	11.40	-1.08	-1.08	0.00
18	-15.66	90.39	15.66	-1.49	-1.49	0.00
17	-19.87	114.71	19.87	-1.89	-1.89	0.00
16	-24.03	138.77	24.03	-2.28	-2.28	0.00
15	-28.16	162.58	28.16	-2.68	-2.68	0.00
14	-32.24	186.12	32.24	-3.06	-3.06	0.00
13	-36.26	209.38	36.26	-3.45	-3.45	0.00
12	-40.24	232.34	40.24	-3.82	-3.82	0.00
11	-44.16	254.98	44.16	-4.20	-4.20	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00

E-W(X)						
Wall						
Floor	A	B	C	D	E	F
21	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00

Step 11: Sum forces, direct and torsional

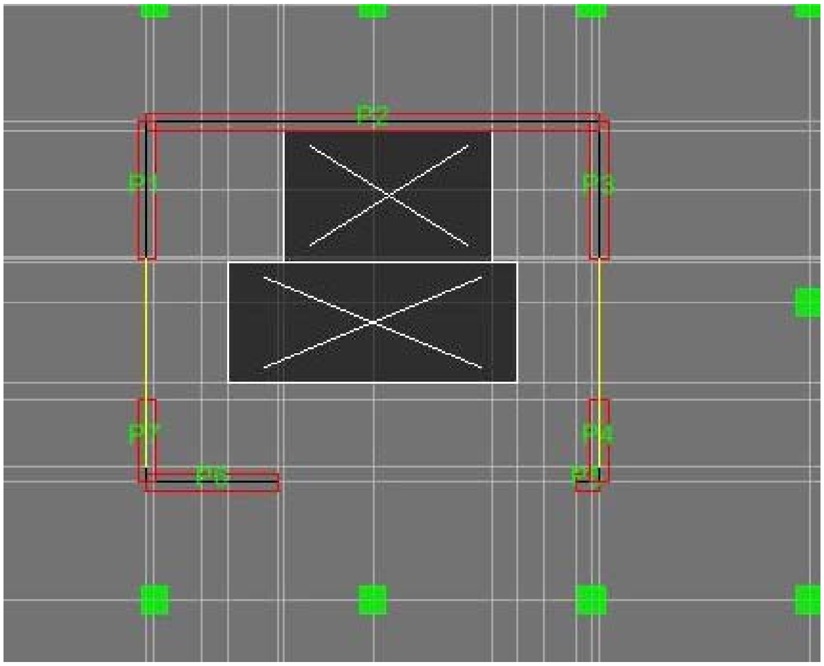
N-S				
Floor	Wall	F_{direct}	$F_{torsional}$	F_{total}
21	A	11.21	-2.49	11.21
	B	21.70	14.36	36.06
	C	11.21	2.49	13.70
	D	0.36	-0.24	0.36
	E	0.36	-0.24	0.36
20	A	32.07	-7.11	32.07
	B	41.07	41.07	82.15
	C	32.07	7.11	39.18
	D	1.02	-0.68	1.02
	E	1.02	-0.68	1.02
19	A	51.41	-11.40	51.41
	B	99.55	65.85	165.39
	C	51.41	11.40	62.82
	D	-1.08	-1.08	-1.08
	E	1.64	-1.08	1.64
18	A	70.58	-15.66	70.58
	B	136.66	90.39	227.05
	C	70.58	15.66	86.23
	D	2.25	-1.49	2.25
	E	2.25	-1.49	2.25
17	A	89.56	-19.87	89.56
	B	173.41	114.71	288.12
	C	89.56	19.87	109.43
	D	2.85	-1.89	2.85
	E	2.85	-1.89	2.85
16	A	108.35	-24.03	108.35
	B	209.79	138.77	348.57
	C	108.35	24.03	132.38
	D	3.45	-2.28	3.45
	E	3.45	-2.28	3.45
15	A	126.94	-28.16	126.94
	B	245.79	162.58	408.37
	C	126.94	28.16	155.10
	D	4.04	-2.68	4.04
	E	4.04	-2.68	4.04
14	A	145.32	-32.24	145.32
	B	281.38	186.12	467.50
	C	145.32	32.24	177.55
	D	4.63	-3.06	4.63
	E	4.63	-3.06	4.63
13	A	163.48	-36.26	163.48
	B	316.53	209.38	525.91
	C	163.48	36.26	199.74
	D	5.21	-3.45	5.21
	E	5.21	-3.45	5.21
12	A	181.40	-40.24	181.40
	B	351.24	232.34	583.58
	C	181.40	40.24	221.64
	D	5.78	-3.82	5.78
	E	5.78	-3.82	5.78
11	A	199.08	-44.16	199.08
	B	385.47	254.98	640.45
	C	199.08	44.16	243.24
	D	6.34	-4.20	6.34
	E	6.34	-4.20	6.34

E-W				
Floor	Wall	F_{direct}	$F_{torsional}$	F_{total}
21	A	6.92	0.00	6.92
	B	13.40	0.00	13.40
	C	6.92	0.00	6.92
	D	0.22	0.00	0.22
	E	0.22	0.00	0.22
20	A	19.80	0.00	19.80
	B	38.34	0.00	38.34
	C	19.80	0.00	19.80
	D	0.63	0.00	0.63
	E	0.63	0.00	0.63
19	A	31.74	0.00	31.74
	B	61.46	0.00	61.46
	C	31.74	0.00	31.74
	D	1.01	0.00	1.01
	E	1.01	0.00	1.01
18	A	43.57	0.00	43.57
	B	84.37	0.00	84.37
	C	43.57	0.00	43.57
	D	1.39	0.00	1.39
	E	1.39	0.00	1.39
17	A	55.29	0.00	55.29
	B	107.05	0.00	107.05
	C	55.29	0.00	55.29
	D	1.76	0.00	1.76
	E	1.76	0.00	1.76
16	A	66.88	0.00	66.88
	B	129.50	0.00	129.50
	C	66.88	0.00	66.88
	D	2.13	0.00	2.13
	E	2.13	0.00	2.13
15	A	78.35	0.00	78.35
	B	151.71	0.00	151.71
	C	78.35	0.00	78.35
	D	2.50	0.00	2.50
	E	2.50	0.00	2.50
14	A	89.69	0.00	89.69
	B	173.66	0.00	173.66
	C	89.69	0.00	89.69
	D	2.86	0.00	2.86
	E	2.86	0.00	2.86
13	A	100.89	0.00	100.89
	B	195.34	0.00	195.34
	C	100.89	0.00	100.89
	D	3.21	0.00	3.21
	E	3.21	0.00	3.21
12	A	111.94	0.00	111.94
	B	216.74	0.00	216.74
	C	111.94	0.00	111.94
	D	3.57	0.00	3.57
	E	3.57	0.00	3.57
11	A	122.83	0.00	122.83
	B	237.84	0.00	237.84
	C	122.83	0.00	122.83
	D	3.91	0.00	3.91
	E	3.91	0.00	3.91

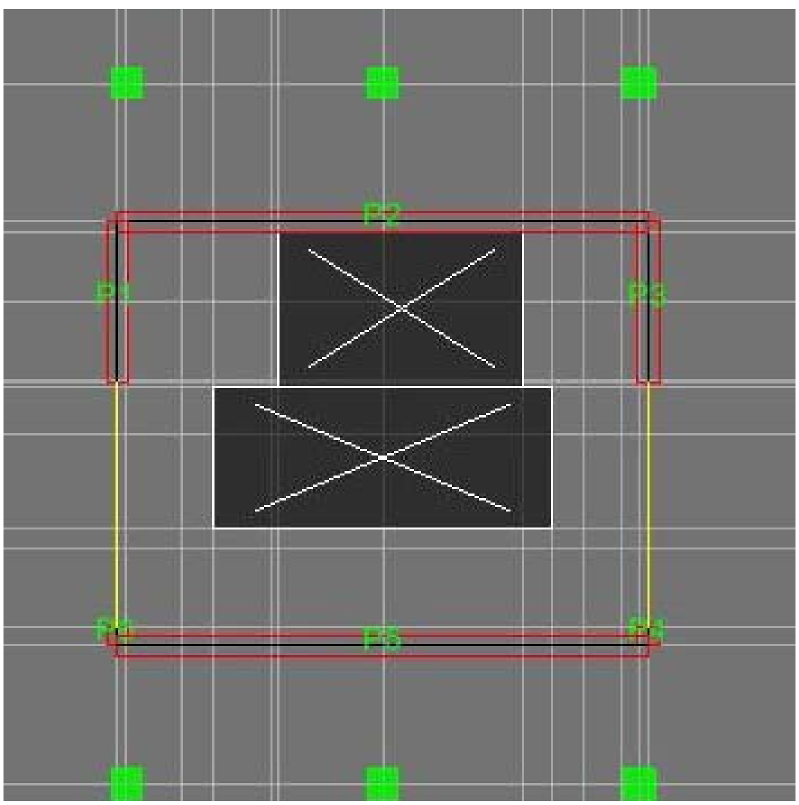
10	A	214.60	0.00	214.60
	B	216.49	0.00	216.49
	C	214.60	0.00	214.60
	D	1.90	0.00	1.90
	E	216.49	0.00	216.49
	F	1.90	0.00	1.90
9	A	231.58	0.00	231.58
	B	233.63	0.00	233.63
	C	231.58	0.00	231.58
	D	2.05	0.00	2.05
	E	233.63	0.00	233.63
	F	2.05	0.00	2.05
8	A	248.26	0.00	248.26
	B	250.46	0.00	250.46
	C	248.26	0.00	248.26
	D	2.20	0.00	2.20
	E	250.46	0.00	250.46
	F	2.20	0.00	2.20
7	A	264.61	0.00	264.61
	B	266.95	0.00	266.95
	C	264.61	0.00	264.61
	D	2.34	0.00	2.34
	E	266.95	0.00	266.95
	F	2.34	0.00	2.34
6	A	280.60	0.00	280.60
	B	283.08	0.00	283.08
	C	280.60	0.00	280.60
	D	2.48	0.00	2.48
	E	283.08	0.00	283.08
	F	2.48	0.00	2.48
5	A	296.18	0.00	296.18
	B	298.80	0.00	298.80
	C	296.18	0.00	296.18
	D	2.62	0.00	2.62
	E	298.80	0.00	298.80
	F	2.62	0.00	2.62
4	A	311.29	0.00	311.29
	B	314.05	0.00	314.05
	C	311.29	0.00	311.29
	D	2.76	0.00	2.76
	E	314.05	0.00	314.05
	F	2.76	0.00	2.76
3	A	326.11	0.00	326.11
	B	328.99	0.00	328.99
	C	326.11	0.00	326.11
	D	2.89	0.00	2.89
	E	328.99	0.00	328.99
	F	2.89	0.00	2.89
2	A	340.44	0.00	340.44
	B	343.45	0.00	343.45
	C	340.44	0.00	340.44
	D	3.01	0.00	3.01
	E	343.45	0.00	343.45
	F	3.01	0.00	3.01
1	A	355.45	0.00	355.45
	B	358.60	0.00	358.60
	C	355.45	0.00	355.45
	D	3.15	0.00	3.15
	E	358.60	0.00	358.60
	F	3.15	0.00	3.15

10	A	132.39	0.00	132.39
	B	133.57	0.00	133.57
	C	132.39	0.00	132.39
	D	1.17	0.00	1.17
	E	133.57	0.00	133.57
	F	1.17	0.00	1.17
9	A	142.86	0.00	142.86
	B	144.12	0.00	144.12
	C	142.86	0.00	142.86
	D	1.26	0.00	1.26
	E	144.12	0.00	144.12
	F	1.26	0.00	1.26
8	A	153.13	0.00	153.13
	B	154.48	0.00	154.48
	C	153.13	0.00	153.13
	D	1.36	0.00	1.36
	E	154.48	0.00	154.48
	F	1.36	0.00	1.36
7	A	163.20	0.00	163.20
	B	164.64	0.00	164.64
	C	163.20	0.00	163.20
	D	1.44	0.00	1.44
	E	164.64	0.00	164.64
	F	1.44	0.00	1.44
6	A	173.03	0.00	173.03
	B	174.56	0.00	174.56
	C	173.03	0.00	173.03
	D	1.53	0.00	1.53
	E	174.56	0.00	174.56
	F	1.53	0.00	1.53
5	A	182.62	0.00	182.62
	B	184.23	0.00	184.23
	C	182.62	0.00	182.62
	D	1.62	0.00	1.62
	E	184.23	0.00	184.23
	F	1.62	0.00	1.62
4	A	191.91	0.00	191.91
	B	193.60	0.00	193.60
	C	191.91	0.00	191.91
	D	1.70	0.00	1.70
	E	193.60	0.00	193.60
	F	1.70	0.00	1.70
3	A	201.00	0.00	201.00
	B	202.78	0.00	202.78
	C	201.00	0.00	201.00
	D	1.78	0.00	1.78
	E	202.78	0.00	202.78
	F	1.78	0.00	1.78
2	A	209.79	0.00	209.79
	B	211.65	0.00	211.65
	C	209.79	0.00	209.79
	D	1.86	0.00	1.86
	E	211.65	0.00	211.65
	F	1.86	0.00	1.86
1	A	218.99	0.00	218.99
	B	220.93	0.00	220.93
	C	218.99	0.00	218.99
	D	1.94	0.00	1.94
	E	220.93	0.00	220.93
	F	1.94	0.00	1.94

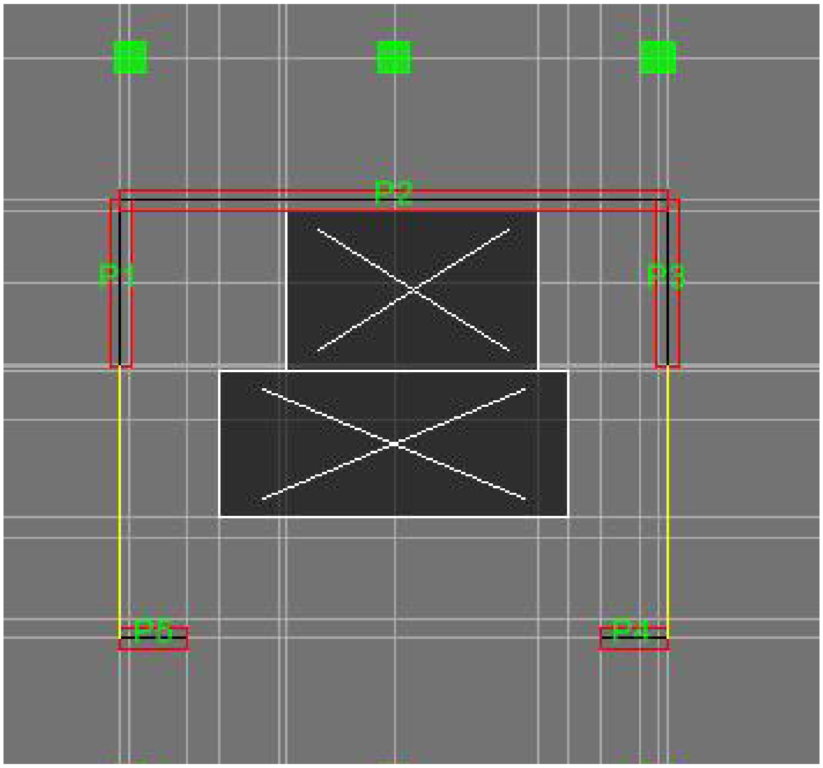
3.1.2 Distribution using ETABS



Pier labels- Floor 1



Pier labels- Floors 2 through 10



Pier labels- Floors 11 through 21

Included below is an example of the pier forces found in ETABS. All loads are displayed for floor 18.

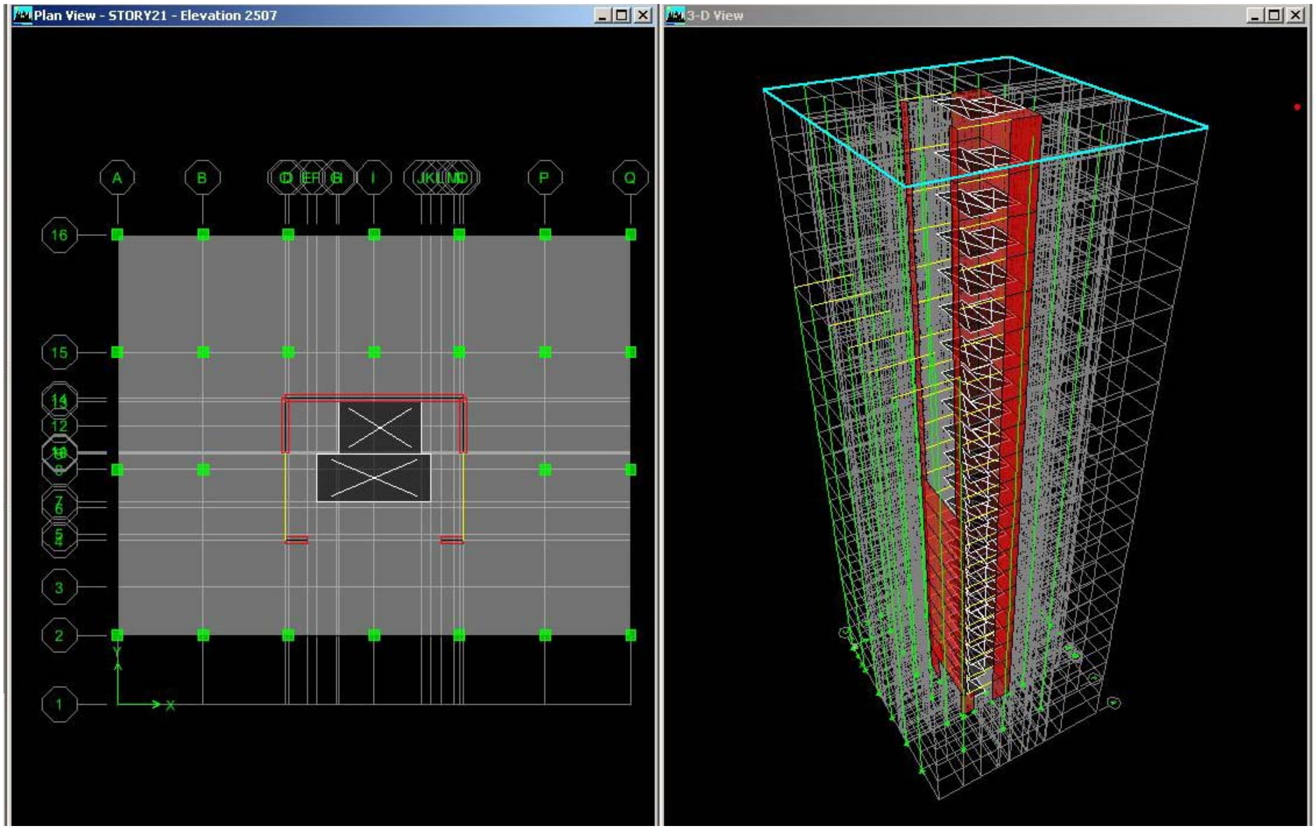
Story	Pier	Load	Loc	P	V2	V3	T	M2	M3
STORY18	P2	NYCY	Top	214.56	0.02	0.63	0.355	-245.791	121.243
STORY18	P2	NYCY	Bottom	214.56	0.02	0.63	0.355	-173.207	123.512
STORY18	P2	WINDY	Top	204.59	0.02	1.24	0.452	-391.08	154.676
STORY18	P2	WINDY	Bottom	167.26	0.02	1.24	0.452	-247.803	157.571
STORY18	P2	CASE3	Top	161.02	48.18	0.47	689.477	-184.349	-2505.599
STORY18	P2	CASE3	Bottom	161.02	48.18	0.47	689.477	-130.079	3083.026
STORY18	P2	SEISMICY	Top	126.83	0.02	1.66	0.365	-364.414	124.972
STORY18	P2	SEISMICY	Top	126.83	0.02	1.66	0.365	-364.414	124.972
STORY18	P4	CASE3AS(	Top	117.66	5.57	24.18	750.809	-1513.107	-543.535
STORY18	P5	SEISMICY	Top	107.35	-3.07	18.56	-395.039	-1152.761	207.775
STORY18	P5	SEISMICY	Top	107.35	-3.07	18.56	-395.039	-1152.761	207.775
STORY18	P4	SEISMICY	Top	106.68	3.02	18.45	392.89	-1146.429	-200.346
STORY18	P4	SEISMICY	Top	106.68	3.02	18.45	392.89	-1146.429	-200.346
STORY18	P4	CASE3AS(	Bottom	106.64	5.57	24.18	750.809	1292.329	102.126
STORY18	P5	WINDY	Top	105.51	-3.02	18.39	-392.871	-1149.019	206.033
STORY18	P4	WINDY	Top	104.67	2.96	18.27	390.211	-1141.182	-196.838
STORY18	P5	SEISMICY	Bottom	102.76	-3.07	18.56	-395.039	999.633	-148.415
STORY18	P5	SEISMICY	Bottom	102.76	-3.07	18.56	-395.039	999.633	-148.415
STORY18	P4	SEISMICY	Bottom	102.09	3.02	18.45	392.89	994.304	149.988
STORY18	P4	SEISMICY	Bottom	102.09	3.02	18.45	392.89	994.304	149.988
STORY18	P5	WINDY	Bottom	100.92	-3.02	18.39	-392.871	984.69	-144.785
STORY18	P4	WINDY	Bottom	100.08	2.96	18.27	390.211	978.094	146.732
STORY18	P2	SEISMICY	Bottom	89.49	0.02	1.66	0.365	-172.405	127.312
STORY18	P2	SEISMICY	Bottom	89.49	0.02	1.66	0.365	-172.405	127.312
STORY18	P5	NYCY	Top	81.13	-2.08	12.1	-258.776	-755.884	140.9
STORY18	P5	NYCY	Bottom	81.13	-2.08	12.1	-258.776	647.697	-100.948
STORY18	P2	CASE3AS(	Top	80.83	127.38	1.77	1896.878	-468.469	-7932.202
STORY18	P4	NYCY	Top	80.48	2.04	12	256.691	-749.741	-133.692
STORY18	P4	NYCY	Bottom	80.48	2.04	12	256.691	642.527	102.474
STORY18	P5	CASE3AS(	Top	77.49	-0.92	17.68	-142.1	-1101.994	-102.085
STORY18	P1	WINDX	Top	69.1	3.91	0.26	472.214	-7.733	1505.33
STORY18	P4	CASE3	Top	67.6	2.35	10.17	302.753	-636.21	-212.733
STORY18	P4	CASE3	Bottom	67.6	2.35	10.17	302.753	543.955	60.077
STORY18	P5	CASE3AS(	Bottom	66.47	-0.92	17.68	-142.1	949.037	-208.332
STORY18	P1	SEISMIC	Top	58.38	3.65	0.21	423.468	-10.99	846.351
STORY18	P1	SEISMICX	Top	58.38	3.65	0.21	423.468	-10.99	846.351
STORY18	P1	WINDX	Bottom	57.74	3.91	0.26	472.214	22.269	1959.168
STORY18	P1	NYCX	Top	54.18	0.56	0.15	274.177	-4.759	761.947
STORY18	P1	NYCX	Bottom	54.18	0.56	0.15	274.177	12.139	826.522
STORY18	P5	CASE3	Top	53.64	-0.74	7.91	-83.968	-493.349	-6.705
STORY18	P5	CASE3	Bottom	53.64	-0.74	7.91	-83.968	423.983	-92.575
STORY18	P1	SEISMIC	Bottom	47.02	3.65	0.21	423.468	13.356	1269.429
STORY18	P1	SEISMICX	Bottom	47.02	3.65	0.21	423.468	13.356	1269.429
STORY18	P4	NYCX	Top	9.66	1.1	1.56	146.979	-98.539	-149.952
STORY18	P4	NYCX	Bottom	9.66	1.1	1.56	146.979	82.746	-22.371
STORY18	P2	NYCX	Top	0.14	64.22	0	918.948	-0.007	-3462.042
STORY18	P2	NYCX	Bottom	0.14	64.22	0	918.948	-0.233	3987.19
STORY18	P4	WINDX	Top	-6.63	1.68	1.88	235.463	-119.74	-256.108
STORY18	P2	CASE3AS(	Bottom	-8.77	127.38	1.77	1896.878	-263.629	6843.557
STORY18	P5	NYCX	Top	-9.61	1.1	-1.56	146.819	98.085	-149.839
STORY18	P5	NYCX	Bottom	-9.61	1.1	-1.56	146.819	-82.386	-22.486
STORY18	P4	SEISMIC	Top	-10.46	1.27	1.24	201.241	-77.069	-154.261

4.1 Analysis

A computer model using ETABS was generated to assist in the lateral analysis of 110 Third Avenue. The shear walls act as vertical cantilever beams which transfer lateral forces from the superstructure to the foundation. In 110 Third Avenue, the shear walls are coupled together with link beams, as reflected in the ETABS model. In the included ETABS analysis, each floor is assumed to act as a rigid diaphragm for loads in the plane of the floor. Thus, the shear walls alone are assumed to resist all lateral forces. The model is a simplified version of the building structure, because initial inspection shows that the shear walls provide the sole lateral resisting forces. Normalized bays with even column spacing are used in the model, even though the actual building has varying sizes of bays and columns. Both hand-calculated loads and those generated by ETabs were used in the analysis. Using this simplified model made its construction in ETABS more efficient, and should not have posed any problem to analyzing the structure. Upon closer inspection after completing the ETABS analysis, large story drifts made it clear that there had to be another resisting system. The structural engineer assigned to the project was contacted, and he confirmed that 110 Third Avenue uses a combined system of shear walls and a slab-column moment frame. It is clear to see that a large portion of the lateral resisting capabilities of 110 Third Avenue come from a reliance on this combined system. Drifts as much as L/75.28 occur without the use of this combined system. Please note that this combined system was not evaluated due to time constraints but will be evaluated in the future. From a practical standpoint, the structure should not drift more than H/400 to prevent serviceability issues from arising. Although the structure manages to meet code requirements for seismic drift, it does not reach L/360. This, of course, is due to a lack of using the walls and columns in a combined frame-shear wall system.

The slab-column moment frame, when used in combination with shear walls, produces a much greater effect in reducing story drifts. Each system alone cannot compare to the benefits of the combined system. Research included in Appendix B of this report shows the benefits of the combined system.

Below are some graphics of the computer model generated using ETABS. They are provided simply as reference to demonstrate the setup of the model.



ASCE7-02 does not provide a detailed description of story drift limits due to wind (sec. B.1.2) but does give drift limits cause by seismic forces (sec. 9.5.2.8). The following table compares allowable drifts to actual drifts due to seismic forces.

Allowable Story Drifts based on ASCE7-02 sec. 9.5.2.8

Use Group	II	
Allowable Drift:	$.015h_{sx}$	L/67

Floor	Height (in.)	Allowable Drift (in)	Seismic X	Drift (in.)	OK?	Seismic Y	Drift (in.)	OK?
21	144.00	2.16	0.003475	0.5004	OK	0.006419	0.924336	OK
20	116.00	1.74	0.003545	0.41122	OK	0.006523	0.756668	OK
19	116.00	1.74	0.003639	0.422124	OK	0.006672	0.773952	OK
18	116.00	1.74	0.003733	0.433028	OK	0.006861	0.795876	OK
17	116.00	1.74	0.003797	0.440452	OK	0.007055	0.81838	OK
16	120.00	1.80	0.004573	0.54876	OK	0.00739	0.8868	OK
15	132.00	1.98	0.004581	0.604692	OK	0.007727	1.019964	OK
14	116.00	1.74	0.004396	0.509936	OK	0.007879	0.913964	OK
13	116.00	1.74	0.003957	0.459012	OK	0.00789	0.91524	OK
12	116.00	1.74	0.003275	0.3799	OK	0.007741	0.897956	OK
11	116.00	1.74	0.00216	0.25056	OK	0.00742	0.86072	OK
10	116.00	1.74	0.001047	0.121452	OK	0.006977	0.809332	OK
9	116.00	1.74	0.000986	0.114376	OK	0.006586	0.763976	OK
8	116.00	1.74	0.000892	0.103472	OK	0.006146	0.712936	OK
7	116.00	1.74	0.000827	0.095932	OK	0.005682	0.659112	OK
6	116.00	1.74	0.000759	0.088044	OK	0.005155	0.59798	OK
5	116.00	1.74	0.000675	0.0783	OK	0.004559	0.528844	OK
4	116.00	1.74	0.000571	0.066236	OK	0.003865	0.44834	OK
3	120.00	1.80	0.000448	0.05376	OK	0.003048	0.36576	OK
2	120.00	1.80	0.000299	0.03588	OK	0.002027	0.24324	OK
1	144.00	2.16	0.000166	0.023904	OK	0.000804	0.115776	OK

The criterion of drift must be less than or equal to H/400 was used to evaluate drifts caused by wind in the N-S and E-W directions. The following table evaluates ASCE7-02 loading and NYC building code loading in terms of drift.

Wind Drift Check

Drift based on good judgement, not code		
Allowable Drift:	$.0028h_{sx}$	L/360

ASCE7-02 Loadings

			WINDX			WINDY		
Floor	Height (in.)	Allowable Drift (in)	Wind X	Drift (in.)	OK?	Wind Y	Drift (in.)	OK?
21	144.00	0.40	0.003883	0.559152	NOT OK	0.006402	0.921888	NOT OK
20	116.00	0.32	0.003982	0.461912	NOT OK	0.006514	0.755624	NOT OK
19	116.00	0.32	0.004126	0.478616	NOT OK	0.006681	0.774996	NOT OK
18	116.00	0.32	0.004289	0.497524	NOT OK	0.0069	0.8004	NOT OK
17	116.00	0.32	0.004437	0.514692	NOT OK	0.007137	0.827892	NOT OK
16	120.00	0.34	0.005468	0.65616	NOT OK	0.007531	0.90372	NOT OK
15	132.00	0.37	0.005618	0.741576	NOT OK	0.007941	1.048212	NOT OK
14	116.00	0.32	0.005539	0.642524	NOT OK	0.008175	0.9483	NOT OK
13	116.00	0.32	0.005148	0.597168	NOT OK	0.008276	0.960016	NOT OK
12	116.00	0.32	0.004432	0.514112	NOT OK	0.00822	0.95352	NOT OK
11	116.00	0.32	0.003129	0.362964	NOT OK	0.007987	0.926492	NOT OK
10	116.00	0.32	0.001766	0.204856	OK	0.007627	0.884732	NOT OK
9	116.00	0.32	0.001588	0.184208	OK	0.007319	0.849004	NOT OK
8	116.00	0.32	0.00154	0.17864	OK	0.006953	0.806548	NOT OK
7	116.00	0.32	0.001462	0.169592	OK	0.006548	0.759568	NOT OK
6	116.00	0.32	0.001354	0.157064	OK	0.006055	0.70238	NOT OK
5	116.00	0.32	0.001216	0.141056	OK	0.00546	0.63336	NOT OK
4	116.00	0.32	0.00104	0.12064	OK	0.004719	0.547404	NOT OK
3	120.00	0.34	0.000826	0.09912	OK	0.003795	0.4554	NOT OK
2	120.00	0.34	0.000566	0.06792	OK	0.002572	0.30864	OK
1	144.00	0.40	0.00026	0.03744	OK	0.001039	0.149616	OK

NYC Building Code Loadings

			NYCX			NYCY		
Floor	Height	Allowable Drift (in)	Wind X	Drift (in.)	OK?	Wind Y	Drift (in.)	OK?
21	144.00	0.40	0.002243	0.322992	OK	0.004119	0.593136	NOT OK
20	116.00	0.32	0.002299	0.266684	OK	0.004191	0.486156	NOT OK
19	116.00	0.32	0.00238	0.27608	OK	0.004299	0.498684	NOT OK
18	116.00	0.32	0.002469	0.286404	OK	0.00444	0.51504	NOT OK
17	116.00	0.32	0.002546	0.295336	OK	0.004597	0.533252	NOT OK
16	120.00	0.34	0.003119	0.37428	NOT OK	0.004848	0.58176	NOT OK
15	132.00	0.37	0.003185	0.42042	NOT OK	0.005101	0.673332	NOT OK
14	116.00	0.32	0.003123	0.362268	NOT OK	0.005245	0.60842	NOT OK
13	116.00	0.32	0.002886	0.334776	NOT OK	0.005302	0.615032	NOT OK
12	116.00	0.32	0.002468	0.286288	OK	0.005259	0.610044	NOT OK
11	116.00	0.32	0.00172	0.19952	OK	0.005101	0.591716	NOT OK
10	116.00	0.32	0.000942	0.109272	OK	0.00486	0.56376	NOT OK
9	116.00	0.32	0.000841	0.097556	OK	0.004654	0.539864	NOT OK
8	116.00	0.32	0.000814	0.094424	OK	0.004413	0.511908	NOT OK
7	116.00	0.32	0.000771	0.089436	OK	0.004151	0.481516	NOT OK
6	116.00	0.32	0.000712	0.082592	OK	0.003836	0.444976	NOT OK
5	116.00	0.32	0.000636	0.073776	OK	0.003459	0.401244	NOT OK
4	116.00	0.32	0.000541	0.062756	OK	0.002994	0.347304	NOT OK
3	120.00	0.34	0.000425	0.051	OK	0.002415	0.2898	OK
2	120.00	0.34	0.000289	0.03468	OK	0.001649	0.19788	OK
1	144.00	0.40	0.000151	0.021744	OK	0.000689	0.099216	OK

Note that neither loading case gave all drifts less than H/400. However, if the NYC building loads are used, the loading that designers probably used, 110 Third Avenue can meet L/360 with some adjustment. With the integration of the frame system in addition to the shear walls, drifts would be reduced drastically and easily pass the H/400 test.

The following graphic illustrates the max drifts associated with each load case.

	Load					
	Wind				Seismic	
	Wind X	Wind Y	NYC X	NYC Y	Seismic X	Seismic Y
Floor	Drift (in.)	Drift (in.)	Drift (in.)	Drift (in.)	Drift (in.)	Drift (in.)
21	0.559152	0.921888	0.322992	0.593136	0.5004	0.924336
20	0.461912	0.755624	0.266684	0.486156	0.41122	0.7566679
19	0.478616	0.774996	0.27608	0.498684	0.422124	0.7739519
18	0.497524	0.8004	0.286404	0.51504	0.433028	0.7958759
17	0.514692	0.827892	0.295336	0.533252	0.440452	0.8183799
16	0.65616	0.90372	0.37428	0.58176	0.54876	0.8868
15	0.741576	1.048212	0.42042	0.673332	0.604692	1.019964
14	0.642524	0.9483	0.362268	0.60842	0.509936	0.9139639
13	0.597168	0.960016	0.334776	0.615032	0.459012	0.9152399
12	0.514112	0.95352	0.286288	0.610044	0.3799	0.8979559
11	0.362964	0.926492	0.19952	0.591716	0.25056	0.8607199
10	0.204856	0.884732	0.109272	0.56376	0.121452	0.8093319
9	0.184208	0.849004	0.097556	0.539864	0.114376	0.7639759
8	0.17864	0.806548	0.094424	0.511908	0.103472	0.712936
7	0.169592	0.759568	0.089436	0.481516	0.095932	0.659112
6	0.157064	0.70238	0.082592	0.444976	0.088044	0.59798
5	0.141056	0.63336	0.073776	0.401244	0.0783	0.528844
4	0.12064	0.547404	0.062756	0.347304	0.066236	0.44834
3	0.09912	0.4554	0.051	0.2898	0.05376	0.36576
2	0.06792	0.30864	0.03468	0.19788	0.03588	0.24324
1	0.03744	0.149616	0.021744	0.099216	0.023904	0.115776
Total Drift	7.386936	15.91771	4.142284	10.18404	5.74144	14.809151

*Assume story drifts can be added due to the rigid diaphragm

4.2 Overturning

The foundation system in 110 Third Avenue resists overturning. The overturning moment in the N-S direction is 81347 ft-kips, and in the E-W direction it is 50168 ft-kips.

Floor	FLOOR SHEAR (Kips) N-S	FLOOR SHEAR (Kips) E-W	Floor Height	M (N-S)	M (E-W)
21	22.4	13.8	12.000	269.0205	166.1308
20	64.1	39.6	9.667	619.9979	382.8349
19	102.8	63.5	9.667	993.966	613.7061
18	141.2	87.1	9.667	1364.509	842.4283
17	179.1	110.6	9.667	1731.491	1068.916

16	216.7	133.8	10.000	2166.995	1337.663
15	253.9	156.7	11.000	2792.659	1723.738
14	290.6	179.4	9.667	2809.485	1733.976
13	327.0	201.8	9.667	3160.544	1950.471
12	362.8	223.9	9.667	3507.095	2164.139
11	398.2	245.7	9.667	3848.871	2374.809
10	433.0	267.1	9.667	4185.557	2582.286
9	467.3	288.2	9.667	4516.789	2786.341
8	500.9	309.0	9.667	4842.131	2986.699
7	533.9	329.3	9.667	5161.051	3183.028
6	566.2	349.1	9.667	5472.889	3374.912
5	597.6	368.5	9.667	5776.789	3561.816
4	628.1	387.2	9.667	6071.6	3743.016
3	658.0	405.6	10.000	6579.887	4055.667
2	686.9	423.3	10.000	6868.965	4233.003
1	717.2	441.9	12.000	8606.287	5302.359

Overturning Moment	N-S	81346.5789	ft-kips
	E-W	50167.9383	ft-kips

As per the seismic analysis performed in Technical Report 1, the weight of the building is as follows:

Level	w_x
21(roof)	178.74
20	382.98
19	382.98
18	382.98
17	382.98
16	382.98
15	382.98
14	382.98
13	382.98
12	382.98
11	382.98
10	382.98
9	382.98
8	382.98
7	382.98
6	382.98
5	382.98
4	382.98
3	382.98
2	382.98
1	382.98
Total	7838.34

Assume a worst case scenario with a support at each end of the building. Weight of the building is 7,838.34 k as above. Therefore, each end of the building has support 7,838.34/2 = 3919.17 k to resist uplift.

N-S Direction: Axial load = M/ L = 81347 ft-kip/68 ft. = 1196 k
E-W Direction: Axial load = M/ L = 50168 ft-kip/75 ft. = 669 k

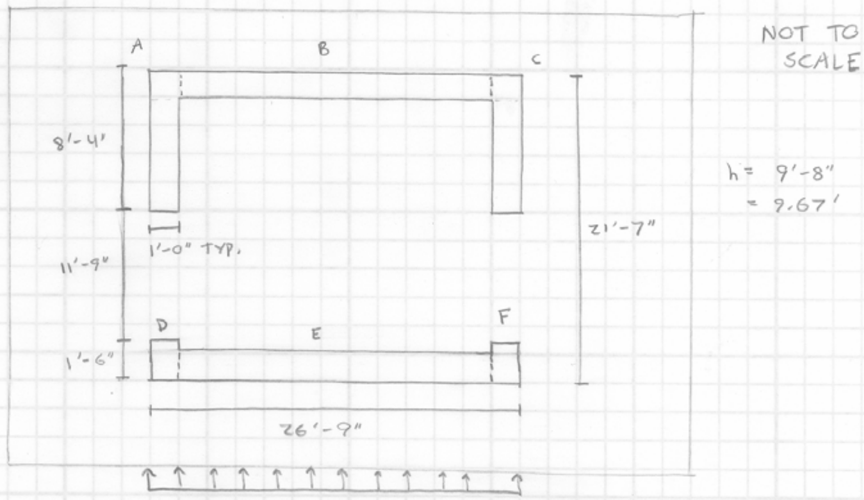
The allowable uplift force of 3919.17 is greater than both applied moments (1196 k and 669 k), so the weight of the building is great enough to resist the downward forces from the overturning moment.

5.1 Spot Check

Distribution of Lateral Loads by Rigidity – N-S Direction

Assume that distribution by rigidity will apply to 110 Third Avenue for simplicity. 110 Third Avenue does not comply with the stipulation of being less than seven stories, but has a rigid diaphragm and uniform lateral resisting behavior.

- Analyze shear wall plan for level 19, N-S direction:



Step 1: Determine center of mass

@ center of shear wall system

Step 2:

$\left(h/L\right)_A = \left(\frac{9.67'}{8.33'}\right) = 1.16$ Intermediate wall $\left(K = \frac{Et}{4(h/L)^3 + 2.78}\right.$

$\left(h/L\right)_B = \left(\frac{9.67'}{24.75'}\right) = .391$ " "

$\left(h/L\right)_C = \left(\frac{9.67}{8.33}\right) = 1.16$ " "

$\left(h/L\right)_D = \left(\frac{9.67}{1.5}\right) = 6.45$ Tall wall $\left(k = \frac{3EI}{h^3}\right)$

$\left(h/L\right)_E = \left(\frac{9.67}{24.75}\right) = .391$ Intermediate wall

$\left(h/L\right)_F = \left(\frac{9.67}{1.5}\right) = 6.45$ Tall wall

$$K_A = \frac{Et}{4\left(h/L\right)^3 + 2.78\left(h/L\right)} = \frac{1}{4\left(1.16\right)^3 + 2.78\left(1.16\right)} = .10561$$

$$K_B = \frac{1}{4(.391)^3 + 2.78(.391)} = .754$$

$$K_C = .10561$$

$$K_D = \frac{3EI}{h^3} = \frac{3\left(bh_s^3/12\right)}{h^3} = \frac{3\left((1')(1.5')^3/12\right)}{(9.67)^3} = 9.33 \times 10^{-4}$$

$$K_E = .754$$

$$K_F = 9.33 \times 10^{-4}$$

Step 3: Determine Center of Rigidity

$x_A = x_D = 0$ $y_B = 21'$

$x_C = x_F = 26'$ $y_E = 0'$

$$x_{CR} = \frac{\Sigma K_i x_i}{\Sigma K_i} = \frac{(K_C \cdot x_C) + (K_F \cdot x_F)}{\Sigma K_i} = \frac{(.10561 \cdot 26') + (9.33\times10^{-4} \cdot 26')}{(.10561)2 + (9.33\times10^{-4})2}$$

$$= \frac{2.77}{.213} = 13'$$

$y_{CR} = 10.5'$ by inspection

Step 4: Determine Eccentricities

$e_x = 0$

$e_y = 0$

} No accidental Torsion

Step 5: Determine Torsional Moment

$M_t = P_y \cdot e_x + P_x \cdot e_y = 0$ No torsional moment

Step 6: Develop coordinate system w/origin at CR
Not necessary

Step 7: Determine polar moment of inertia

$$J = \Sigma(k_i d_i^2) = 0$$

Step 8: Determine direct shear in each frame/wall in x-direction

Assume: Analyze for Floor 19

Floor Shear, N-S = 102.8 kips = P

No lateral force in x-direction

Step 9: direct shear in y-dir.

$$F_{A_{DIRECT}} = F_{C_{DIRECT}} = \frac{K_A}{\Sigma k_i} P_x = \frac{.10561}{(.10561)2 + 9.33\times10^{-4}(2)}(102.8\ k) = 50.95\ k$$

$$F_{D_{DIRECT}} = F_{F_{DIRECT}} = \frac{9.33\times10^{-4}}{(.10561)2 + 9.33\times10^{-4}(2)}(102.8) = .45\ k$$

Step 10: Torsional Shear

No torsional Shear

Final Total Shears in each wall:

F_A : 50.95 k

F_B : 0

F_C : 50.95 k

F_D : .45 k

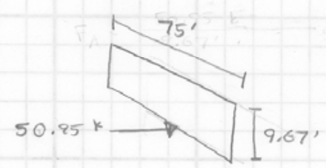
F_E : 0

F_F : .45 k

Lateral Check

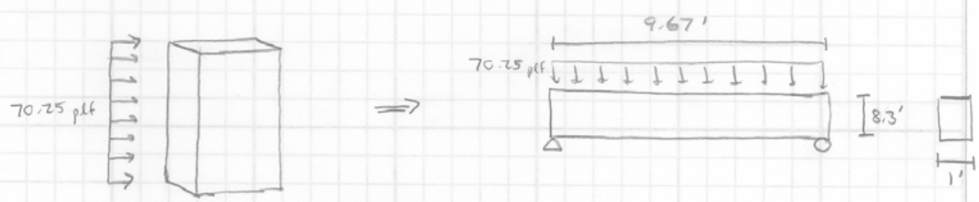
- Check wall A (see Lateral distribution for wall label) at floor 19 for N-S wind loading

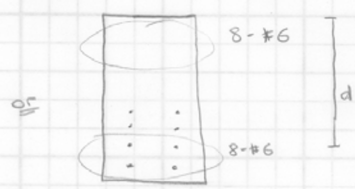
$F_A = 50.95\ k$



$$W = \frac{50.95\ k}{9.67' \cdot 75'} = 70.25\ plf$$

Wall A





$A_s = 8(.44) = 3.52\ in^2$

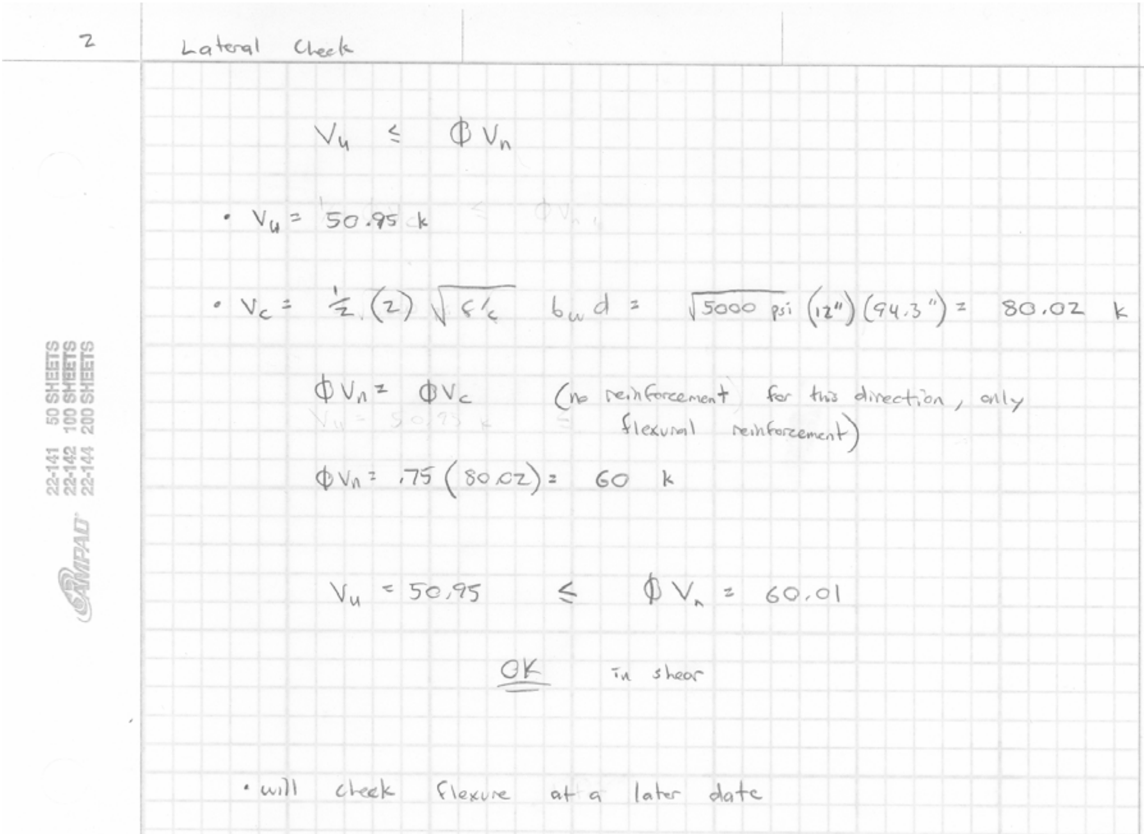
$\phi = 3/4 = .75$

$$a = \frac{A_s f_y}{.85 f'_c b} = \frac{(3.52)(60)}{.85(5)(12)} = 4.14''$$

$$d = (8.33')(12\ in/ft) - \underset{cover}{1.5} - \underset{stirrup}{.5} - \underset{\phi}{.75} - 1.5 - .75 - \frac{1.5}{2} = 94.3$$

$$\phi M_n = .9\left[A_s f_y \left(d - \frac{a}{2}\right)\right] = .9\left[3.52\ in^2 (60)\left(94.3 - \frac{4.14}{2}\right)\right]$$

$\phi M_n = 17{,}520.8$



2 Lateral Check

$V_u \le \phi V_n$

• $V_u = 50.95$ k

• $V_c = \frac{1}{2}(2)\sqrt{f'_c}\; b_w d = \sqrt{5000 \text{ psi}}\,(12'')(94.3'') = 80.02$ k

$\phi V_n = \phi V_c$ (no reinforcement for this direction, only flexural reinforcement)

$\phi V_n = .75\,(80.02) = 60$ k

$V_u = 50.95 \le \phi V_n = 60.01$

OK in shear

• will check flexure at a later date

6.1 Conclusions

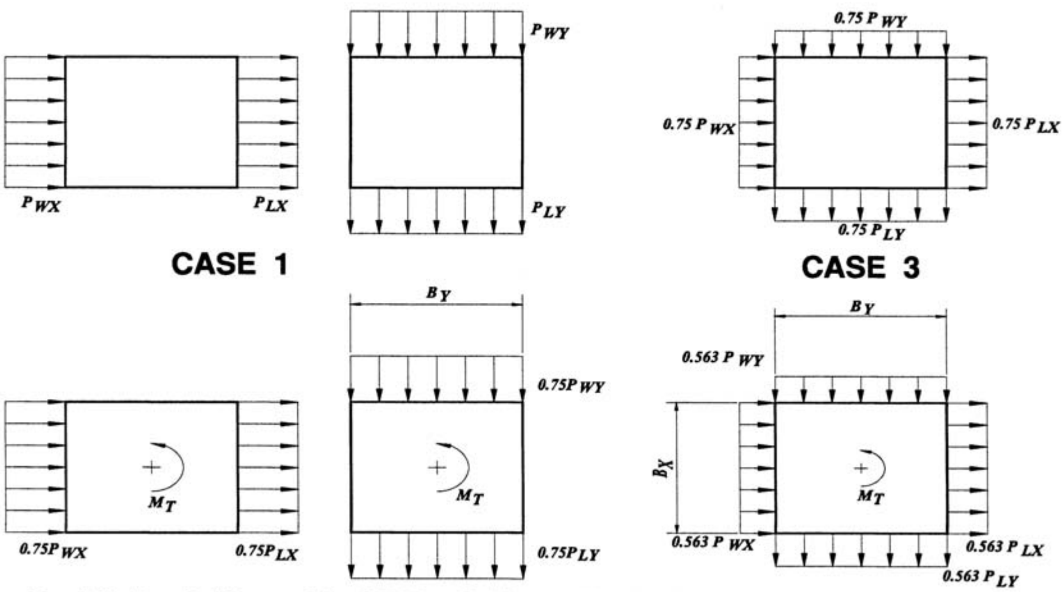
Several discrepancies within this report must be explained. First, the application wind and seismic loadings to the ETABS model produced large drifts that seemed unrealistic for a residential structure. After further investigation, insight into the design was provided by Axis Design Group engineer Nathan Shuman who noted they used a combined lateral-resisting system. Both shear walls and the use of slabs and columns as a moment frame acted together to drastically reduce the drift with minimal force in the slab. The columns have no additional size or reinforcement and the slab simply includes a few additional top bars at the columns for the wind moment. Due to time constraints, a completely new model could not be created in time for this report. In future analysis, this combination system will be examined and checked to see if drift criteria are met.

Second, distribution using Excel produced different loadings than ETABS used. For example, in floor 18 in pier 1/pier A, shear was 214.56 k in ETABS and 70.58 k in Excel. An answer for this discrepancy can possibly be found in the use of factored loads in ETABS vs. non-factored loads in Excel. Factored loads were used in Etabs to check drifts and should be removed. According to the designer, however, the analyst should expect high loads that would cause 110 Third Avenue to fail with regard to serviceability and drift. Therefore, even if the factored loads were removed from ETABS, the Excel distribution would produce forces too low.

In either case, the drift can be further analyzed in the future using revised load cases (without factors) and the combined system previously specified. If these two adjustments are made to the computer model, it should produce perfectly reasonable drifts. Finally, the Excel file, although seemingly off in its forces, also uses reasonable values for base shear and weight of the building (242.8 k base shear and 7838.8 k weight). The wind forces applied to both the ETABS and Excel model are identical except for the 1.6 factor, indicating they should be off by a multiplier of 1.6, not 3.

Appendix A
ASCE7-02
References

Main Wind Force Resisting System– Method 2		All Heights
Figure 6-9	Design Wind Load Cases	



$M_T = 0.75\ (P_{WX}+P_{LX})B_X e_X$ $\quad e_X = \pm\ 0.15\ B_X$

$M_T = 0.75\ (P_{WY}+P_{LY})B_Y e_Y$ $\quad e_Y = \pm\ 0.15\ B_Y$

$M_T = 0.563\ (P_{WX}+P_{LX})B_X e_X + 0.563\ (P_{WY}+P_{LY})B_Y e_Y$ $\quad e_X = \pm\ 0.15\ B_X \quad e_Y = \pm\ 0.15\ B_Y$

CASE 2 **CASE 4**

Case 1. Full design wind pressure acting on the projected area perpendicular to each principal axis of the structure, considered separately along each principal axis.

Case 2. Three quarters of the design wind pressure acting on the projected area perpendicular to each principal axis of the structure in conjunction with a torsional moment as shown, considered separately for each principal axis.

Case 3. Wind loading as defined in Case 1, but considered to act simultaneously at 75% of the specified value.

Case 4. Wind loading as defined in Case 2, but considered to act simultaneously at 75% of the specified value.

Notes:

1. Design wind pressures for windward and leeward faces shall be determined in accordance with the provisions of 6.5.12.2.1 and 6.5.12.2.3 as applicable for building of all heights.
2. Diagrams show plan views of building.
3. Notation:
   - P_{WX}, P_{WY}: Windward face design pressure acting in the x, y principal axis, respectively.
   - P_{LX}, P_{LY}: Leeward face design pressure acting in the x, y principal axis, respectively.
   - $e\ (e_X, e_Y)$: Eccentricity for the x, y principal axis of the structure, respectively.
   - M_T: Torsional moment per unit height acting about a vertical axis of the building.

6.5.12.3 Design Wind Load Cases. The main wind force-resisting system of buildings of all heights, whose wind loads have been determined under the provisions of Sections 6.5.12.2.1 and 6.5.12.2.3, shall be designed for the wind load cases as defined in Figure 6-9. The eccentricity e for rigid structures shall be measured from the geometric center of the building face and shall be considered for each principal axis (e_X, e_Y). The eccentricity e for flexible structures shall be determined from the following equation and shall be considered for each principal axis (e_X, e_Y):

$$e = e_Q + 1.7 I_Z (g_Q Q e_Q)^2 + (g_R R e_R)^2$$

$$1.7 I_Z (g_Q Q)^2 + (g_R R)^2 \quad \textbf{(Eq. 6-21)}$$

where

e_Q = eccentricity e as determined for rigid structures in Figure 6-9

e_R = distance between the elastic shear center and center of mass of each floor

I_Z, g_Q, Q, g_R, R shall be as defined in Section 6.5.8

The sign of the eccentricity e shall be plus or minus, whichever causes the more severe load effect.

Exception: One-story buildings with h less than or equal to 30 ft, buildings two stories or less framed with light-framed construction and buildings two stories or less designed with flexible diaphragms need only be designed for Load Case 1 and Load Case 3 in Figure 6-9.

TABLE 9.5.2.8
ALLOWABLE STORY DRIFT, Δ_a[a]

Structure	Seismic Use Group		
	I	II	III
Structures, other than masonry shear wall or masonry wall frame structures, four stories or less with interior walls, partitions, ceilings and exterior wall systems that have been designed to accommodate the story drifts.	$0.025h_{sx}$[b]	$0.020h_{sx}$	$0.015h_{sx}$
Masonry cantilever shear wall structures[c]	$0.010h_{sx}$	$0.010h_{sx}$	$0.010h_{sx}$
Other masonry shear wall structures	$0.007h_{sx}$	$0.007h_{sx}$	$0.007h_{sx}$
Masonry wall frame structures	$0.013h_{sx}$	$0.013h_{sx}$	$0.010h_{sx}$
All other structures	$0.020h_{sx}$	$0.015h_{sx}$	$0.010h_{sx}$

[a] h_{sx} is the story height below Level x.
[b] There shall be no drift limit for single-story structures with interior walls, partitions, ceilings, and exterior wall systems that have been designed to accommodate the story drifts. The structure separation requirement of Section 9.5.2.8 is not waived.
[c] Structures in which the basic structural system consists of masonry shear walls designed as vertical elements cantilevered from their base or foundation support which are so constructed that moment transfer between shear walls (coupling) is negligible.

SECTION B.1
DEFLECTION, VIBRATION, AND DRIFT

B.1.1 Vertical Deflections. Deformations of floor and roof members and systems due to service loads shall not impair the serviceability of the structure.

B.1.2 Drift of Walls and Frames. Lateral deflection or drift of structures and deformation of horizontal diaphragms and bracing systems due to wind effects shall not impair the serviceability of the structure.

B.1.3 Vibrations. Floor systems supporting large open areas free of partitions or other sources of damping, where vibration due to pedestrian traffic might be objectionable, shall be designed with due regard for such vibration.

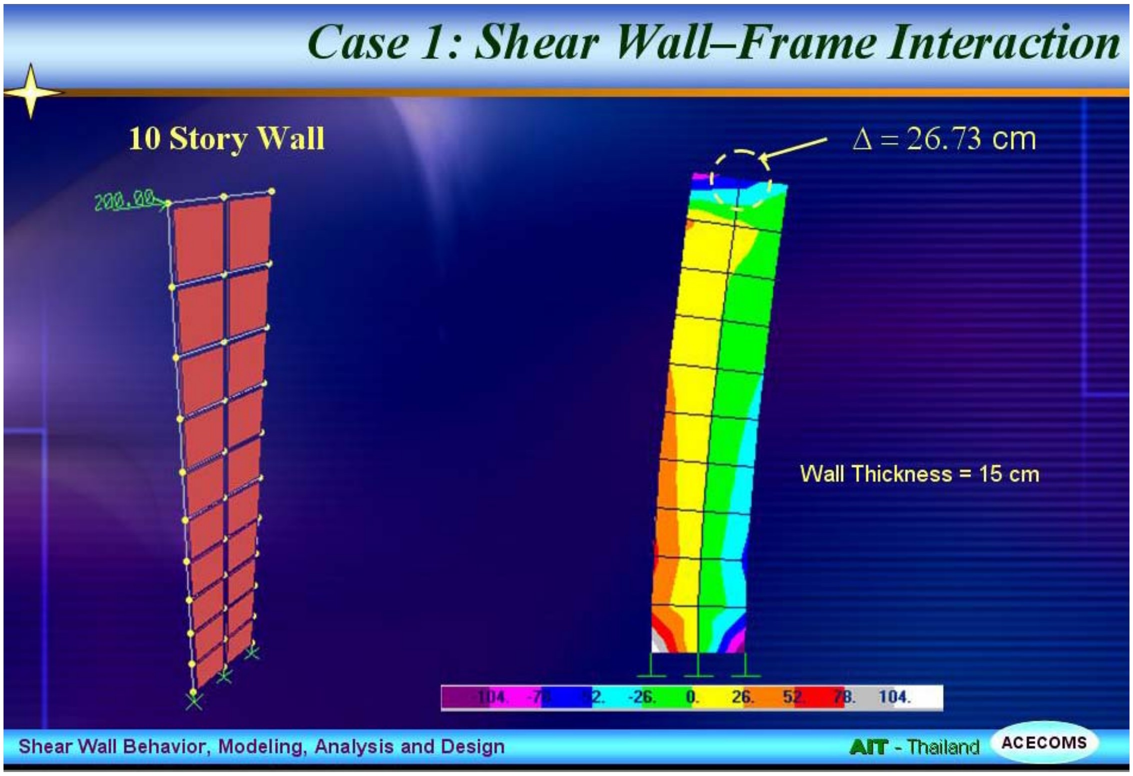
Mechanical equipment that can produce objectionable vibrations in any portion of an inhabited structure shall be isolated to minimize the transmission of such vibrations to the structure.

Building structural systems shall be designed so that wind-induced vibrations do not cause occupant discomfort or damage to the building, its appurtenances, or its contents.

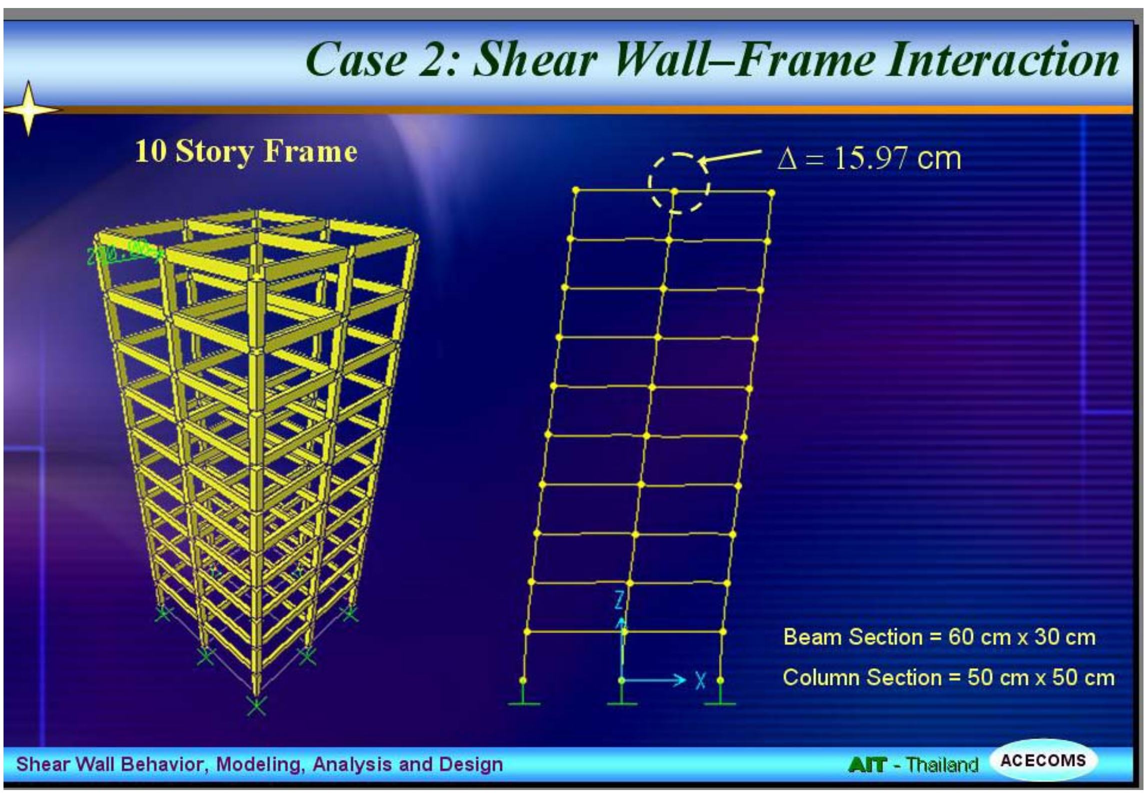
Appendix B
Shear Wall-Frame System Research

The following Power Point slides show research regarding the advantages of using a combined shear wall/ slab moment frame system to reduce overall drifts.

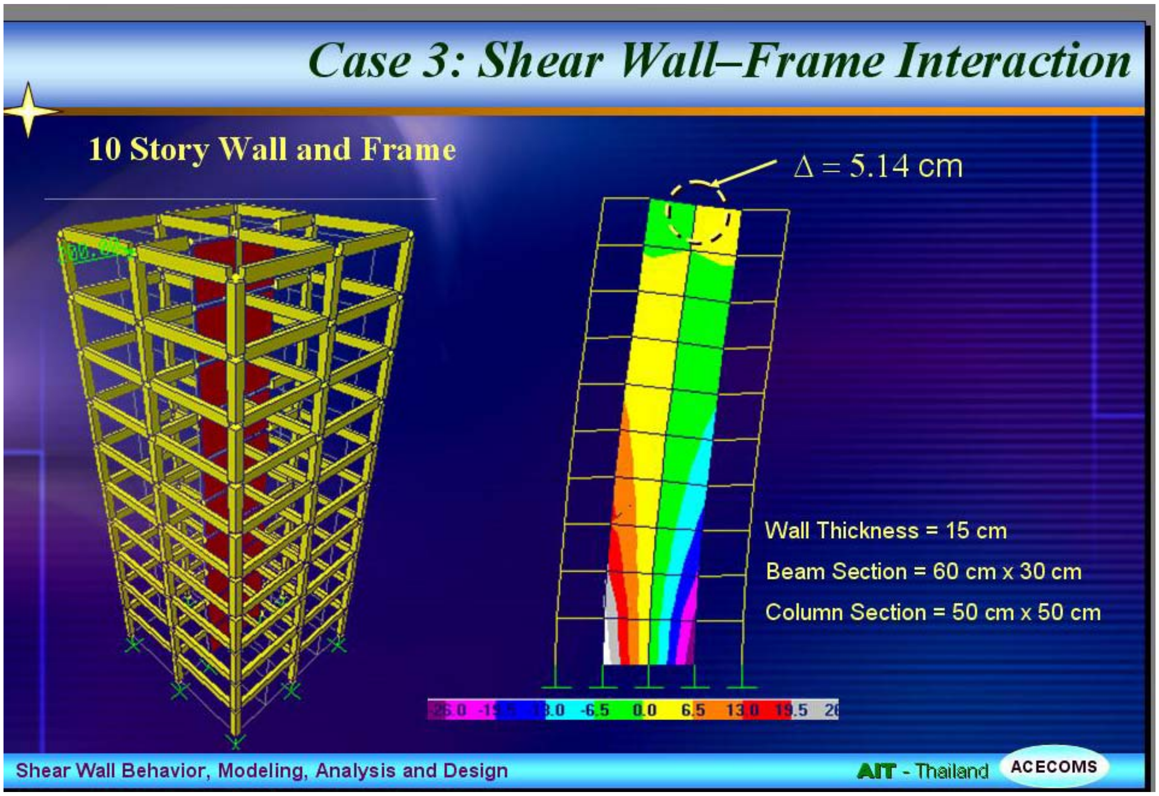
Anwar, Naveed. Behavior, Modeling and Design of Shear Wall-Frame Systems. Asian Center for Engineering Computations and Software, ACECOMS, AIT. Available, http://www.comp-engineering.com/technical_papers.htm. November 20, 2005.

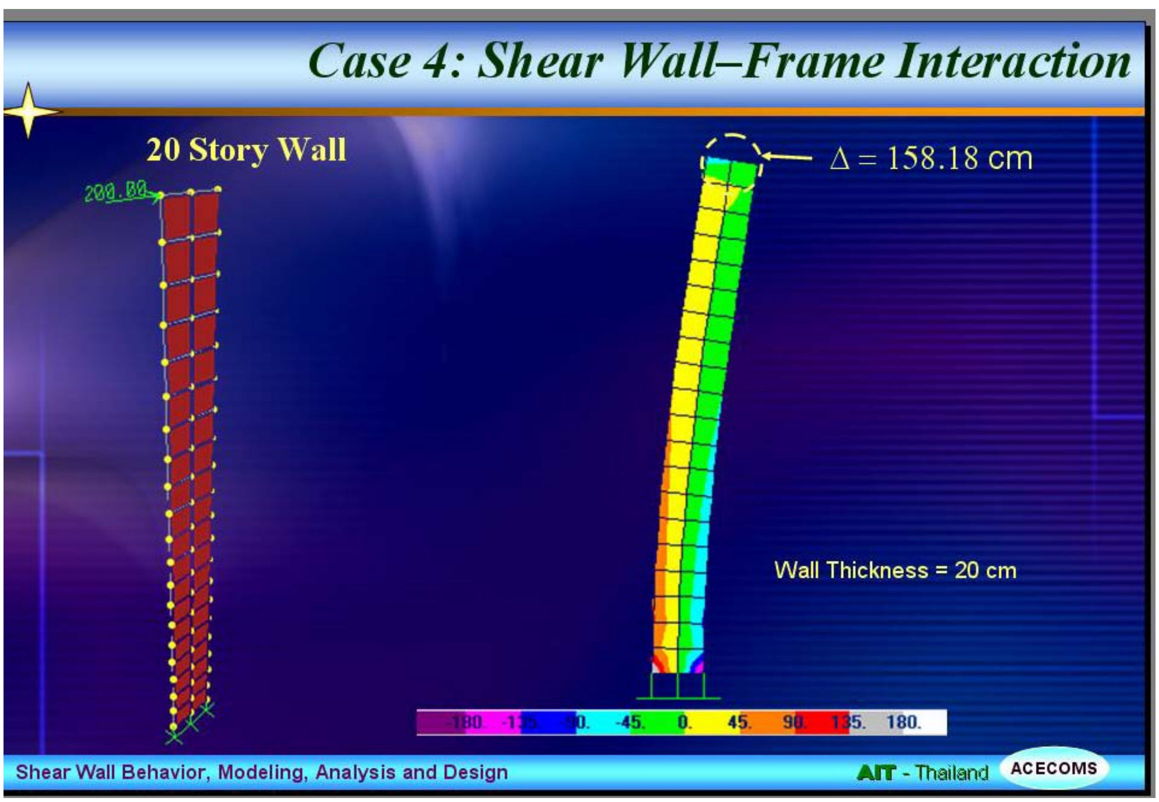


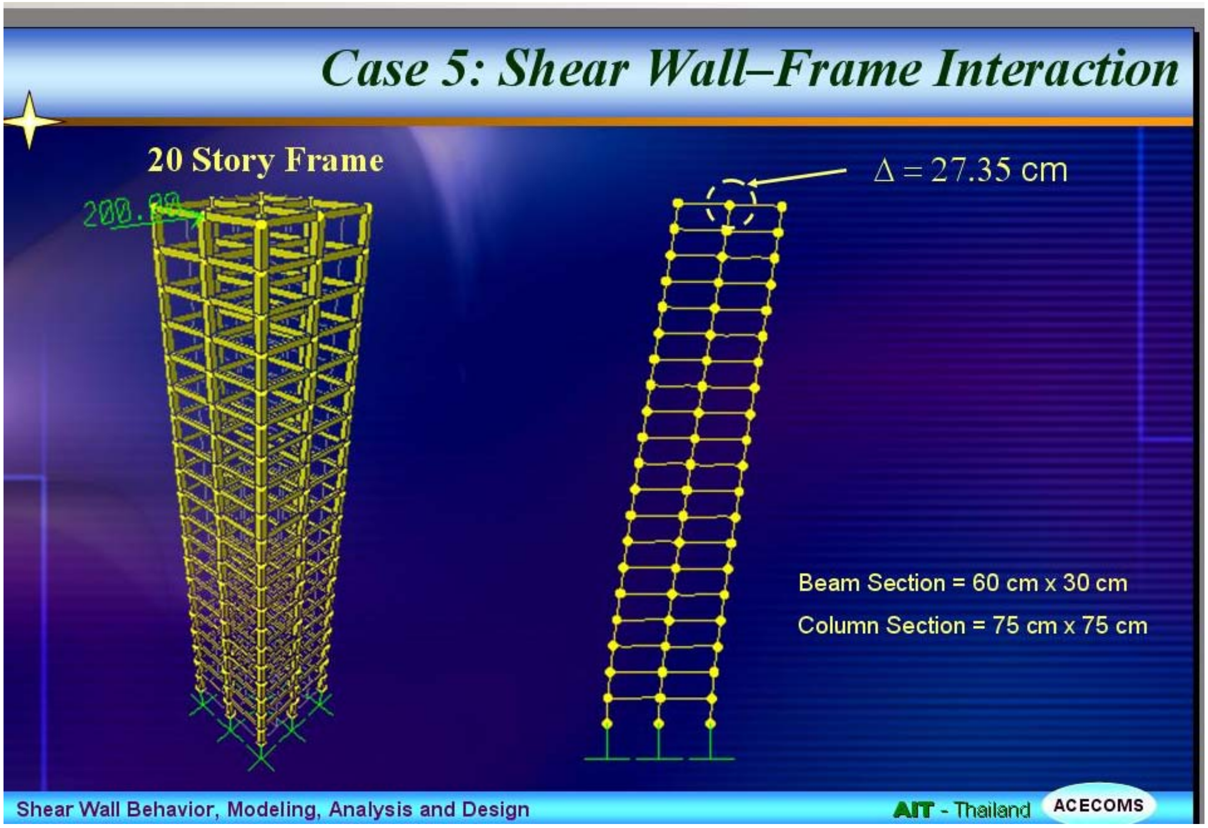
Case 1: Shear Wall–Frame Interaction
10 Story Wall
200.00
Δ = 26.73 cm
Wall Thickness = 15 cm
-104. -78. -52. -26. 0. 26. 52. 78. 104.
Shear Wall Behavior, Modeling, Analysis and Design
AIT - Thailand
ACECOMS

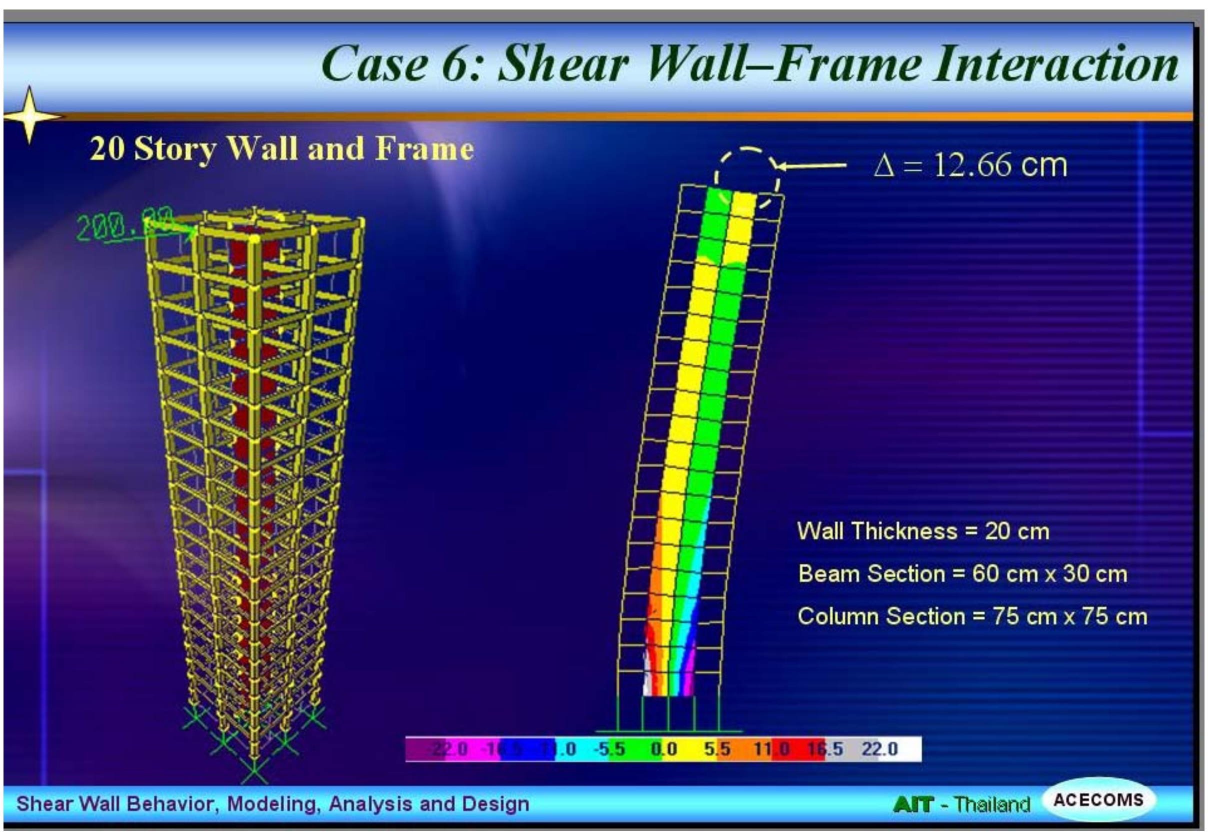


Case 2: Shear Wall–Frame Interaction
10 Story Frame
Δ = 15.97 cm
Z
X
Beam Section = 60 cm x 30 cm
Column Section = 50 cm x 50 cm
Shear Wall Behavior, Modeling, Analysis and Design
AIT - Thailand
ACECOMS


Case 3: Shear Wall–Frame Interaction
10 Story Wall and Frame
Δ = 5.14 cm
Wall Thickness = 15 cm
Beam Section = 60 cm x 30 cm
Column Section = 50 cm x 50 cm
Shear Wall Behavior, Modeling, Analysis and Design
AIT - Thailand
ACECOMS


Case 4: Shear Wall–Frame Interaction
20 Story Wall
Δ = 158.18 cm
Wall Thickness = 20 cm
Shear Wall Behavior, Modeling, Analysis and Design
AIT - Thailand
ACECOMS


Case 5: Shear Wall–Frame Interaction
20 Story Frame
200.00
Δ = 27.35 cm
Beam Section = 60 cm x 30 cm
Column Section = 75 cm x 75 cm
Shear Wall Behavior, Modeling, Analysis and Design
AIT - Thailand
ACECOMS


Case 6: Shear Wall–Frame Interaction
20 Story Wall and Frame
200.00
Δ = 12.66 cm
Wall Thickness = 20 cm
Beam Section = 60 cm x 30 cm
Column Section = 75 cm x 75 cm
-5.5
0.0
5.5
22.0
Shear Wall Behavior, Modeling, Analysis and Design
AIT - Thailand
ACECOMS