246 West 17th Street

New York, NY

3rd Technical Report

Lateral System Analysis

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Executive Summary

Intent

The purpose of this study was to fully analyze the lateral load system of 246 West 17th Street. This system is comprised of four primary shear walls and two secondary shear walls. The primary shear walls are each 10” thick: two run north-south along the east and west exterior walls of the structure, and two run east-west toward the center of the building, encasing the vertical circulation core. The two 8” thick secondary shear wall returns also surround the core. Each shear wall is constructed of 5950psi strength concrete,

Content

Included within this report are the results of the lateral analysis of the structure, which considered both seismic and wind loading per the ASCE7-05 standard. The relative stiffnesses of the members were evaluated and compared to evaluate the load path through the structure. Also, the deflection of the members were calculated and compared to allowable drift amounts per the NYC Building Code and ASCE7-05. Torsion within the structure was also considered as was overturning. The mass masonry wall – which makes up the exterior wall for the first three stories – and its effect on the lateral resistance of the structure was not considered for this report. Lastly, design checks were performed on each of the primary shear walls to check the adequacy of the original design.

Results

It was concluded that the shear walls are accurate for strength, and that drift controls the design of these elements. It was also found that torsion might be an issue in the design of this structure, but these effects will be looked at in further detail at a later date.

Please Note
To clearly distinguish between the various structures present in 246 West 17th Street, the terms *existing*, *historic*, and *original* shall refer to the 1925 structure. The terms *current*, *as-designed*, and *new* shall refer to the 2008 renovation design.

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Introduction

The original structure of 236 West 17th Street in New York, NY was a three-story brick garage built in 1925. The current design includes an architectural renovation of the existing building along with the addition of seven stories atop the garage structure to transform this garage into a 34-unit, high-end condominium building.

Scope

This report features a full analysis of the lateral load resisting system of 246 West 17th Street. The relative stiffness of the shear walls were calculated on a floor-to-floor basis, as with the torsional shear component of each shear wall. Overall building drift and story drift were found using an ETABS model of 246 West 17th Street. All calculated values and program analysis results were compared to required values per ASCE7-05 to check whether they were adequate. Furthermore, the controlling load in the east-west and north-south direction was then used to check the adequacy of the current shear wall designs. These calculations can all be found within the various appendices.

Design Parameters

Although the original building of 246 West 17th Street was designed per the New York City Building Code, this analysis was structured around the requirements of ASCE 7-05. Wind and seismic loading requirements, analysis methods, and required values were all determined from the ASCE7-05 standard.

Overview of Existing Structure

Architecture

As with the original building, the cellar of 246 West 17th Street contains garage parking with added mechanical and storage spaces. The 1st floor has been altered to include three condominium units and two recreational spaces. The 2nd and 3rd floors of the original garage building each accommodate five condo units. The 4th floor – the start of the new construction – steps back from the brick structure below, providing residents in each of the three units on this floor with a personal terrace space. The 5th, 6th, and 7th floors have identical floor plans: each holds four units, and each unit features a balcony. The 8th floor again steps back, providing terrace spaces for each of the two condo units. The 9th and 10th floors feature two condo units as well, each with personal balconies. The floor-to-floor heights range between 10’-7 ½” on a majority of the middle floors to 16’-6” on the first floor.

Building Envelope

The addition features a mix of glass and aluminum curtain walls, metal paneling, and dark brick veneers, adding a modern look to the upper two-thirds of the structure. The structural backing to the paneling and veneer systems typically consists of cold-formed metal framing filled with batting insulation, although areas around the seismic joint are backed by a concrete wall, and the parapets are backed by 6" CMU to account for the higher seismic and wind loading on these areas, respectively.

The original mass masonry wall of the base garage building spans from the cellar level to the third floor. This wall has been opened up through the use of large glass and aluminum punched windows to allow for more light and air into the condominiums.

The addition adds a modern look to the upper two-thirds of the structure, while the brick and original ornamentation of the lower half holds fast to the charm and historical context of the surrounding area. The addition also brings 246 West 17th Street up to the heights of the adjacent buildings, which sit tightly on either side of the site.

Foundation

The soils under the existing slab of 246 West 17th Street are considered to be stable and have high bearing pressures when classified according to the NYCBC. The geotechnical investigation provided by Pillory Associates found there to be a layer of fill soil directly below the existing slab, followed by Glacial Alluvium and Mica Schist Bedrock below this. The bearing pressure of the Glacial Alluvium is rather high at 3.5 tons/sf (7000 psf), and Pillory states in their report that any new slab may hence be designed as slab-on-grade; the geotechnical engineers specifically recommend the use of either a footing foundation or a mat slab to replace the existing slab on grade. Ultimately, after the original slab was removed, both systems were utilized on site: Spread footings measuring 3'-10" thick were placed on a 2" rat slab on gravel on the southern half of the cellar, while a 3'-10" thick mat slab was placed on the same 2" rat slab on gravel on the northern half of the cellar.

Fortunately, no underpinning was required for the project because the cellar walls and perimeter foundations were kept intact.

Floor Systems

There are two distinct floor types within 246 West 17th Street: those with steel framing (existing) and those without (new construction).

The existing floor systems (floors 1, 2, and 3) consist of a steel frame with an 8" concrete slab on deck. The frame is comprised of steel w-shape beams (sizes unknown) at 5'-6" O/C framing into 24" to 26" deep steel girders at 20'-8" O/C. The typical bay size is 20'-8" by 35'-8", with the girders spanning the entire 35'-8" length. The original girders frame into steel columns on the interior and into mass brick piers on the perimeter edge. Both of these vertical elements have been reinforced in the new design.

The top existing floor system (floor 3) has been structurally reinforced through the addition of new steel long-span beams and diagonal angle bracing beneath the slab level. The redundancy of these new beams will help the original long-span girder beams act as transfer beams to carry the weight of the seven new stories above.

The addition stories (floors 7 through 10) are constructed of 8” two-way, concrete, flat-plate moment frames. Circular concrete columns between 14”, 16” or 18” in diameter are placed throughout the interior on a relatively irregular pattern due to the various condominium layouts. Rectangular concrete columns flank the perimeter, and range in size between 10”x18” and 24”x24”.

Roof System

Multiple set-backs in 246 West 17th Street provide a variety of private terraces for the condominium owners. Façade set-backs occur at the 2nd, 4th, and 8th floors, in addition to a large decrease in the floor plan area at the roof level, as the building narrows around the stair and machine room bulkhead area. This decrease in area provides penthouse tenants with a private roof terrace. Each of these terraces is finished with concrete pavers and wrapped by 3’-8” tall glass railings or a 5’ tall parapet.

The typical roof system of 246 West 17th Street – which includes these terrace areas – features a single-ply EPDM roofing membrane topped with 4” of extruded polystyrene insulation, filter fabric, and 2’x2’ pavers on adjustable pedestals to ensure that the interior finish level matches that of the outside terrace. This system rests on a low-slope topping slab, which is supported by the structural slab below.

Lateral System

The lateral load resisting system consists of concrete shear walls. Although the building is constructed as a concrete flat plate system with concrete columns, the shear walls were designed to take the entire lateral load. There are four primary shear walls and two secondary shear wall returns. The primary shear walls (shown in pink in Figure 1 on the next page) are 10” thick and constructed of 5950psi concrete. Two of these primary shear walls run north-south along the east and west exterior walls, while the other two run east-west at the interior of the structure, encompassing the vertical transportation core. Two secondary shear wall returns (shown in blue in Figure 1 on the next page) help to add further rigidity to the core of 246 West 17th Street. These secondary shear walls are each 8” thick and are also constructed of 5950psi concrete. The secondary shear walls and the associated primary shear wall run the entire height of the building, from the cellar to the top of the bulkhead. The remaining three shear walls run from the cellar to the roof. The orientation and heights of the shear walls can be seen as related to the building as a whole in Figure 2 on the next page.

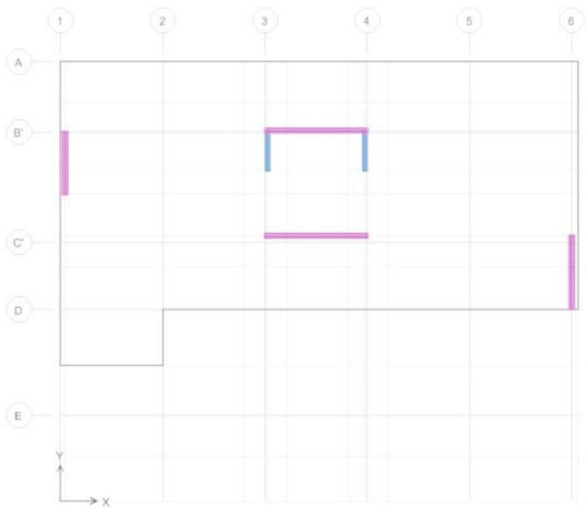


Figure 1: Shear Wall Layout on Typical Story

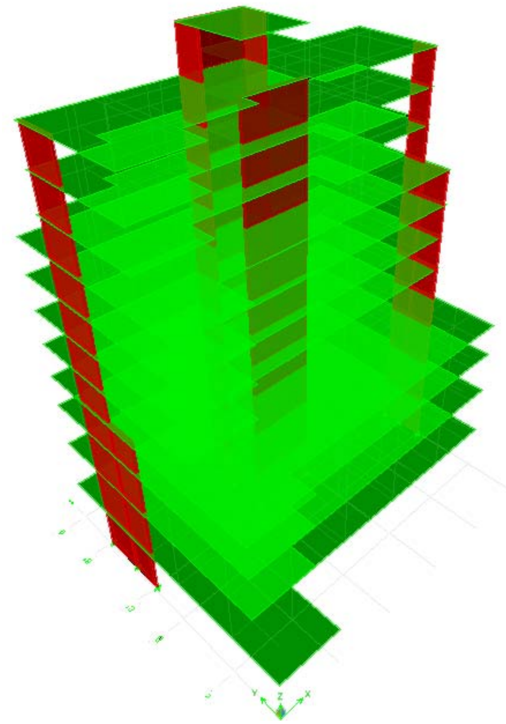


Figure 2: Perspective View of Shear Walls within Structure

Discussion of Lateral Force Resisting Systems

System Discussion

The lateral forces are resisted through a set of six shear walls. The four primary shear walls are 10" thick and constructed of 5950psi concrete; two of these run north-south along a portion of the east and west exterior walls, and two of these run east-west as a means to stabilize the vertical circulation core containing the stairs and elevators. The two secondary shear walls are 8" thick and also constructed of 5950psi concrete. They project orthogonally from one of the east-west primary shear walls to further encase the circulation core. While these do offer some lateral resistance, they were not relied on fully for their support. For this conservative reason, during the design checks these secondary elements were not considered.

Lateral Load Cases

ASCE7-05 was recently adopted by the NYC Building Code, therefore the following highlighted load cases from ASCE7-05 were used in this lateral analysis:

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

By inspection and by knowing that wind loading controlled over seismic in Technical Report 1, is clear that the combination containing 1.6xWind will control. Gravity loading is not taken into account in this analysis, so it is unnecessary to test the other combinations which also contain 1.6W.

In terms of loading cases, ASCE7-05 defines the following possibilities in Figure 3 below, which is pulled directly from the standard:

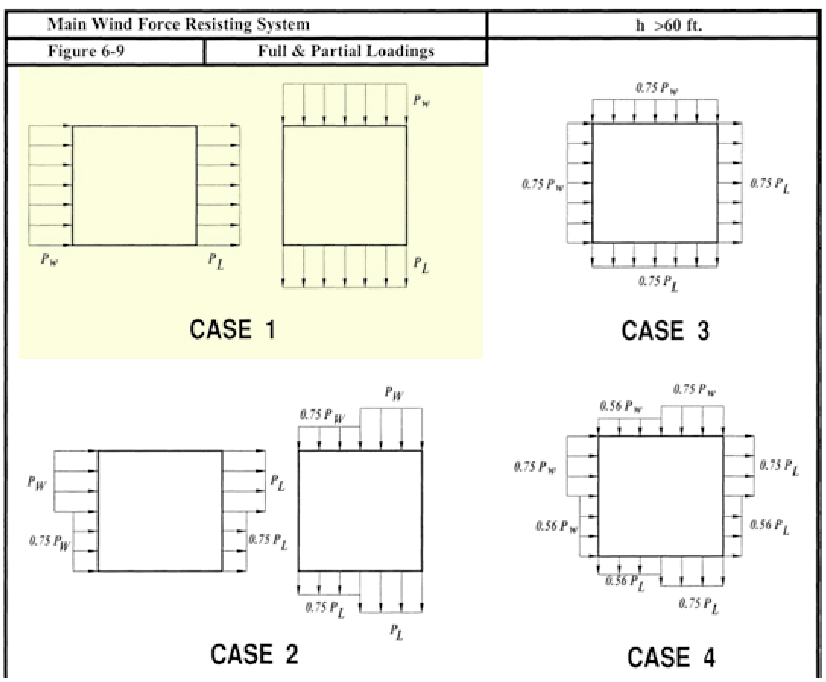


Figure 3: Lateral Load Cases from Fig. 6-9 ASCE7-05

Here, case one was selected for this analysis to look at whether torsional effects might be problematic. Because the results do seem to be indicative of having torsion, other load cases should be looked at in detail in the future, potentially as a thesis proposal topic. These effects are discussed in a later section of this report.

Lateral Force Distribution

The lateral forces acting in any direction upon 246 West 17th Street are transferred from the shear walls to the concrete flat plate floor system through rigid reinforced concrete connections. At the third level, some of this load is transferred to the exterior mass masonry walls; however, the primary connection between the 3rd floor slab and the mass masonry wall is at the masonry piers, which were not deemed to be a lateral load resisting element. For this reason, the mass masonry wall was not considered for lateral load resistance in this analysis as a conservative measure, because in actuality it would absorb some of the lateral loading at the lower stories.

Because all of the lateral force resisting members are shear walls, and because the floor diaphragms were assumed to be rigid, the lateral loads in 246 West 17th Street are distributed by shear wall stiffness. Seeing as force follows stiffness, the stiffer shear walls were found to absorb more of the load. To determine the stiffnesses of the lateral system components, the following equation relating the force applied and the induced deflection was used:

$$Ki = Pi / \Delta i$$

Where: Ki = Stiffness of lateral element i
Pi = Applied load
ΔI = Deflection of lateral element i

This was followed by the calculation of the relative stiffnesses:

$$Ri = Ki / \sum K$$

Where: Ri = Relative stiffness of lateral element i
Ki = Stiffness of lateral element i
∑K = Sum of all stiffnesses on that story

In the north-south direction, the shear wall along gridline 1 was found to be the stiffest shear wall on each floor, meaning this one would take the largest load per floor. This makes sense, because this is a primary shear wall, which also happens to be the longest overall when total length (per floor) is summed cumulatively throughout the building.

In the east-west direction, the shear walls were found to have essentially the same stiffness, and therefore take the same load. Again, this makes sense because these shear walls are both primary shear walls, and they are roughly the same length (8” difference).

Drift

An ETABS model was used to determine the overall drift of 246 West 17th Street under various load cases. As expected, north-south wind loading controlled the drift values in the north-south direction, and east-west wind loading controlled the drift values in the east-west direction. The total drift at the roof level in the east-west direction was 1.16”, which is less that the 2” maximum permitted by the new NYC Building Code. However, in the north-south direction, the total drift at the roof level was 2.90”, which is greater than the allowable limit. However, this is much smaller than the 8” seismic joint that is positioned in this direction between 246 West 17th Street and the adjacent building, which is approximately the same height, and might therefore have a similar deflection. With these assumptions, the seismic joint would have enough room to accommodate the sway of this structure and the adjacent in the case that they both sway to these extremes at the same instant. But because this value is still larger than the 2” allowable, building drift will have to be looked at again more closely.

Per ASCE12.12.1, the story drift limits for Occupancy Category I structures classified as “All other structures” has a limit of 0.020h, as noted below in the following excerpts from ASCE7-05:

12.12 DRIFT AND DEFORMATION

12.12.1 Story Drift Limit. The design story drift (Δ) as determined in Sections 12.8.6, 12.9.2, or 16.1, shall not exceed the allowable story drift (Δ_a) as obtained from Table 12.12-1 for any story. For structures with significant torsional deflections, the maximum drift shall include torsional effects. For structures assigned to Seismic Design Category C, D, E, or F having horizontal irregularity Types 1a or 1b of Table 12.3-1, the design story drift, Δ, shall be computed as the largest difference of the deflections along any of the edges of the structure at the top and bottom of the story under consideration.

TABLE 12.12-1 ALLOWABLE STORY DRIFT, $\Delta_a{}^{a,b}$

Structure	Occupancy Category		
	I or II	III	IV
Structures, other than masonry shear wall structures, 4 stories or less with interior walls, partitions, ceilings and exterior wall systems that have been designed to accommodate the story drifts.	$0.025h_{sx}{}^{c}$	$0.020h_{sx}$	$0.015h_{sx}$
Masonry cantilever shear wall structures [d]	$0.010h_{sx}$	$0.010h_{sx}$	$0.010h_{sx}$
Other masonry shear wall structures	$0.007h_{sx}$	$0.007h_{sx}$	$0.007h_{sx}$
All other structures	$0.020h_{sx}$	$0.015h_{sx}$	$0.010h_{sx}$

[a] h_{sx} is the story height below Level x.
[b] For seismic force–resisting systems comprised solely of moment frames in Seismic Design Categories D, E, and F, the allowable story drift shall comply with the requirements of Section 12.12.1.1.
[c] 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 12.12.3 is not waived.
[d] 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.

Figures 4 and 5: Story Drift Limitations per ASCE7-05, According to this limit, and as shown in the drift table in Appendix B, many of the story drifts in the north-south direction exceed the allowable amount. The greatest percent difference is 54% as seen on the roof level in this direction. This could be due to the fact that deflection through hand calculations was calculated by story, using the story height as “h” in the following equation:

$$\Delta cant = \Delta F + \Delta S$$

$$= P.h^3/(3E.I) + (1.2)P.h/(Er.A)$$

Where:
ΔF = Deflection due to flexure
ΔS = Deflection due to shear
P = Applied load
h = Height (here, floor-to-floor story height was used)
E = Modulus of elasticity of concrete
Er = Modulus of rigidity = 0.4E
A = Area

Due to the linear relationship between shear deflections, it is acceptable to use floor-to-floor heights for each story, and sum these to reach the total deflection at the top of the building. However, for flexural deflection, the height is cubed; therefore, this will result in a much greater flexural deflection per story when calculated floor-by-floor, rather than if the deflection were calculated from the ground. In the latter case, the story deflection would be found by subtracting one story from the one above it, instead of calculating it individually using the story height. I am certain that this is where the difference is accounted for.

Another source for the difference is that the wind loads should be applied to the center of pressure, but in this ETABS model, they were applied to the center of mass.

Story drift and overall building drift is something that will be looked at more closely in the future, potentially as a thesis proposal topic.

Torsion

The torsional shear was found through a long process involving story deflection, element stiffness, relative stiffness, center of rigidity, and ultimately torsional shear. The increase in shear to be carried by the shear walls due to torsion over the direct shear due to direct loading was seen to be quite an increase in places, which is indicative of torsion-related problems. The torsion effects of 246 West 17^{th} Street were calculated by hand. These detailed calculations and the results of each shear wall per floor can be found in Appendix C.

Overturning

Overturning and uplift should not be an issue for 246 West 17th Street. The weight of the building is more than enough to counter any uplift generated by the maximum overturning moments found in Technical Report 1, from wind loading.

In addition, the soils are rather stable under the structure, and the foundations consist of a heavy, 3'-10" thick mat slab paired with spread footings. This foundation type typically does not have overturning problems in a relatively short building due to the mass of the system.

Below is a summary of the overturning calculations, which can also be found in Appendix D.

Overturning Calculations						
North-South Direction						
Mo =	29,924	ft-k				
L =	92	ft				
Mo / L =	**325.26**	**k**				
W =	18800	k				
W/2 =	**9400**	**k**				
		9400	**>**	325.261	therefore	**OK!**
East-West						
Mo =	26,144	ft-k				
L =	106	ft				
Mo / L =	**246.64**	**k**				
W =	18800	k				
W/2 =	**9400**	**k**				
		9400	**>**	246.642	therefore	**OK!**

Mo/L < 1/2 (Wt)

Strength Design Checks

PCA column was used to evaluate the shear walls under factored axial load and factored moment as found in Technical Report 1, and as determined through ASCE7-05.
The reinforcing was placed within the shear wall as designed, and the concrete strength was assigned to be 5950psi, also per original design. The shear walls were found to be far overdesigned in combined loading, which makes sense seeing as drift was found to be the controlling factor. The PCA column results may be found in Appendix E.

Conclusion

Based on analysis results for the lateral system, the shear walls were deemed to be more than accurate in combined bending and axial loading. The full story shear was applied to each, without considering the decreased value due to relative stiffness, which was a conservative measure that still proved to be adequate.

This means that the drift is what controls the design of the shear walls, as the case in the north-south load direction where an upwards of 50% increase was seen over the allowable. This could be due to the method of calculation, or to the fact that the wind load was applied at the center of mass of the building, instead of the center of pressure.

In addition, it was determined that torsional shear might be an issue within 246 West 17th Street. The torsional shear value will add a significant amount over the direct shear value for many of the shear walls, so this is an issue that will have to be studied in detail in the future. This is a topic that will be considered as a thesis proposal topic, in which case the mass masonry wall will also be looked at in more detail.

Appendix A

Calculations Leading up to Relative Stiffness and Center of Rigidity

Deflection per Story: North-South Wind Loading

Deflection by Story												
North-South Shear Walls												
SW Along 1	1	2	3	4	5	6	7	8	9	10	R	
P = applied force =	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	lbs
H = total height =	178.44	376.44	551.64	679.8	807.84	935.76	1063.8	1191.84	1319.76	1447.8	1575.72	inches
h = story height =	178.44	198	175.2	128.16	128.04	127.92	128.04	128.04	127.92	128.04	127.92	inches
Er = modulus of rigidity = 0.4E =	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706.34	psi
E = modulus of elasticity = 57000 sq.rt.(f'c) =	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	psi
f'c =	5950	5950	5950	5950	5950	5950	5950	5950	5950	5950	5950	psi
A = area =	2660	2660	2660	2660	1480	1480	1480	1480	1480	1480	1480	inches^2
I = moment of inertia = t(L^3)/12	15684247	15684247	15684247	15684247	2701493.3	2701493.3	2701493.3	2701493.3	2701493.3	2701493.3	2701493.33	inches^4
t = wall thickness =	10	10	10	10	10	10	10	10	10	10	10	inches
L = wall length =	266	266	266	266	148	148	148	148	148	148	148	inches
ΔF =	2.746E-05	3.752E-05	2.599E-05	1.018E-05	5.891E-05	5.874E-05	5.891E-05	5.891E-05	5.874E-05	5.891E-05	5.8743E-05	inches
ΔS =	4.577E-05	5.079E-05	4.494E-05	3.287E-05	5.903E-05	5.897E-05	5.903E-05	5.903E-05	5.897E-05	5.903E-05	5.8975E-05	inches
Δcant =	7.324E-05	8.831E-05	7.094E-05	4.305E-05	0.0001179	0.0001177	0.0001179	0.0001179	0.0001177	0.0001179	0.00011772	inches
SW Along 6	1	2	3	4	5	6	7	8	9	10	R	
P = applied force =	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	lbs
H = total height =	178.44	376.44	551.64	679.8	807.84	935.76	1063.8	1191.84	1319.76	1447.8	1575.72	inches
h = story height =	178.44	198	175.2	128.16	128.04	127.92	128.04	128.04	127.92	128.04	127.92	inches
Er = modulus of rigidity = 0.4E =	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706.34	psi
E = modulus of elasticity = 57000 sq.rt.(f'c) =	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	psi
f'c =	5950	5950	5950	5950	5950	5950	5950	5950	5950	5950	5950	psi
A = area =	1780	1780	1780	1780	1780	1780	1780	1780	760	760	760	inches^2
I = moment of inertia = t(L^3)/12	4699793.3	4699793.3	4699793.3	4699793.3	4699793.3	4699793.3	4699793.3	4699793.3	365813.33	365813.33	365813.333	inches^4
t = wall thickness =	10	10	10	10	10	10	10	10	10	10	10	inches
L = wall length =	178	178	178	178	178	178	178	178	76	76	76	inches
ΔF =	9.165E-05	0.0001252	8.675E-05	3.396E-05	3.386E-05	3.377E-05	3.386E-05	3.386E-05	0.0004338	0.000435	0.00043381	inches
ΔS =	6.84E-05	7.59E-05	6.716E-05	4.913E-05	4.908E-05	4.904E-05	4.908E-05	4.908E-05	0.0001148	0.000115	0.00011485	inches
Δcant =	0.0001601	0.0002011	0.0001539	8.308E-05	8.294E-05	8.28E-05	8.294E-05	8.294E-05	0.0005487	0.00055	0.00054866	inches
SW Along 3.1	1	2	3	4	5	6	7	8	9	10	R	
P = applied force =	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	lbs
H = total height =	178.44	376.44	551.64	679.8	807.84	935.76	1063.8	1191.84	1319.76	1447.8	1575.72	inches
h = story height =	178.44	198	175.2	128.16	128.04	127.92	128.04	128.04	127.92	128.04	127.92	inches
Er = modulus of rigidity = 0.4E =	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706.34	psi
E = modulus of elasticity = 57000 sq.rt.(f'c) =	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	psi
f'c =	5950	5950	5950	5950	5950	5950	5950	5950	5950	5950	5950	psi
A = area =	768	768	768	768	768	768	768	768	768	768	768	inches^2
I = moment of inertia = t(L^3)/12	589824	589824	589824	589824	589824	589824	589824	589824	589824	589824	589824	inches^4
t = wall thickness =	8	8	8	8	8	8	8	8	8	8	8	inches
L = wall length =	96	96	96	96	96	96	96	96	96	96	96	inches
ΔF =	0.0007303	0.0009977	0.0006912	0.0002706	0.0002698	0.0002691	0.0002698	0.0002698	0.0002691	0.0002698	0.00026905	inches
ΔS =	0.0001585	0.0001759	0.0001557	0.0001139	0.0001138	0.0001136	0.0001138	0.0001138	0.0001136	0.0001138	0.00011365	inches
Δcant =	0.0008888	0.0011737	0.0008469	0.0003844	0.0003836	0.0003827	0.0003836	0.0003836	0.0003827	0.0003836	0.0003827	inches
SW Along 4.1	1	2	3	4	5	6	7	8	9	10	R	
P = applied force =	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	lbs
H = total height =	178.44	376.44	551.64	679.8	807.84	935.76	1063.8	1191.84	1319.76	1447.8	1575.72	inches
h = story height =	178.44	198	175.2	128.16	128.04	127.92	128.04	128.04	127.92	128.04	127.92	inches
Er = modulus of rigidity = 0.4E =	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706.34	psi
E = modulus of elasticity = 57000 sq.rt.(f'c) =	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	psi
f'c =	5950	5950	5950	5950	5950	5950	5950	5950	5950	5950	5950	psi
A = area =	768	768	768	768	768	768	768	768	768	768	768	inches^2
I = moment of inertia = t(L^3)/12	589824	589824	589824	589824	589824	589824	589824	589824	589824	589824	589824	inches^4
t = wall thickness =	8	8	8	8	8	8	8	8	8	8	8	inches
L = wall length =	96	96	96	96	96	96	96	96	96	96	96	inches
ΔF =	0.0007303	0.0009977	0.0006912	0.0002706	0.0002698	0.0002691	0.0002698	0.0002698	0.0002691	0.0002698	0.00026905	inches
ΔS =	0.0001585	0.0001759	0.0001557	0.0001139	0.0001138	0.0001136	0.0001138	0.0001138	0.0001136	0.0001138	0.00011365	inches
Δcant =	0.0008888	0.0011737	0.0008469	0.0003844	0.0003836	0.0003827	0.0003836	0.0003836	0.0003827	0.0003836	0.0003827	inches

Δcant = ΔF + ΔS = P.h^3/(3E.I) + (1.2)P.h/(Er.A)

Calculations Leading up to Relative Stiffness and Center of Rigidity

Deflection per Story: East-West Wind Loading

Deflection by Story												
East-West Shear Walls												
SW Along B1	1	2	3	4	5	6	7	8	9	10	R	
P = applied force =	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	lbs
H = total height =	178.44	376.44	551.64	679.8	807.84	935.76	1063.8	1191.84	1319.76	1447.8	1575.72	inches
h = story height =	178.44	198	175.2	128.16	128.04	127.92	128.04	128.04	127.92	128.04	127.92	inches
Er = modulus of rigidity = 0.4E =	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706.34	psi
E = modulus of elasticity = 57000 sq.rt.(f'c) =	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	psi
f'c =	5950	5950	5950	5950	5950	5950	5950	5950	5950	5950	5950	psi
A = area =	2360	2360	2360	2360	2360	2360	2360	2360	2360	2360	2360	inches^2
I = moment of inertia = t(L^3)/12	10953547	10953547	10953547	10953547	10953547	10953547	10953547	10953547	10953547	10953547	10953546.7	inches^4
t = wall thickness =	10	10	10	10	10	10	10	10	10	10	10	inches
L = wall length =	236	236	236	236	236	236	236	236	236	236	236	inches
ΔF =	3.932E-05	5.373E-05	3.722E-05	1.457E-05	1.453E-05	1.449E-05	1.453E-05	1.453E-05	1.449E-05	1.453E-05	1.4488E-05	inches
ΔS =	5.159E-05	5.725E-05	5.065E-05	3.705E-05	3.702E-05	3.698E-05	3.702E-05	3.702E-05	3.698E-05	3.702E-05	3.6984E-05	inches
Δcant =	9.092E-05	0.000111	8.787E-05	5.162E-05	5.155E-05	5.147E-05	5.155E-05	5.155E-05	5.147E-05	5.155E-05	5.1472E-05	inches
SW Along C1	1	2	3	4	5	6	7	8	9	10	R	
P = applied force =	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	lbs
H = total height =	178.44	376.44	551.64	679.8	807.84	935.76	1063.8	1191.84	1319.76	1447.8	1575.72	inches
h = story height =	178.44	198	175.2	128.16	128.04	127.92	128.04	128.04	127.92	128.04	127.92	inches
Er = modulus of rigidity = 0.4E =	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706	1758706.34	psi
E = modulus of elasticity = 57000 sq.rt.(f'c) =	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	4396766	psi
f'c =	5950	5950	5950	5950	5950	5950	5950	5950	5950	5950	5950	psi
A = area =	2480	2480	2480	2480	2480	2480	2480	2480	2480	2480	2480	inches^2
I = moment of inertia = t(L^3)/12	12710827	12710827	12710827	12710827	12710827	12710827	12710827	12710827	12710827	12710827	12710826.7	inches^4
t = wall thickness =	10	10	10	10	10	10	10	10	10	10	10	inches
L = wall length =	248	248	248	248	248	248	248	248	248	248	248	inches
ΔF =	3.389E-05	4.63E-05	3.208E-05	1.256E-05	1.252E-05	1.248E-05	1.252E-05	1.252E-05	1.248E-05	1.252E-05	1.2485E-05	inches
ΔS =	4.909E-05	5.448E-05	4.82E-05	3.526E-05	3.523E-05	3.519E-05	3.523E-05	3.523E-05	3.519E-05	3.523E-05	3.5194E-05	inches
Δcant =	8.298E-05	0.0001008	8.028E-05	4.782E-05	4.775E-05	4.768E-05	4.775E-05	4.775E-05	4.768E-05	4.775E-05	4.7679E-05	inches

Δcant = ΔF + ΔS = P.h^3/(3E.I) + (1.2)P.h/(Er.A)

Calculations Leading up to Relative Stiffness and Center of Rigidity

Calculation of Deflection of Lateral Force Resisting Elements per Story

Deflection of Lateral Force Resisting Elements [inches]			
North-South Direction		East-West Direction	
Roof		Roof	
Shear Wall Along 1	0.00012	Shear Wall Along C1	0.00005
Shear Wall Along 6	0.00055	Shear Wall Along B1	0.00005
Shear Wall Along 3.1	0.00038		
Shear Wall Along 4.1	0.00038		
Roof Sum	0.00143	Roof Sum	0.00010
Floor 10		Floor 10	
Shear Wall Along 1	0.00012	Shear Wall Along C1	0.00005
Shear Wall Along 6	0.00055	Shear Wall Along B1	0.00005
Shear Wall Along 3.1	0.00038		
Shear Wall Along 4.1	0.00038		
Floor 10 Sum	0.00144	Floor 10 Sum	0.00010
Floor 9		Floor 9	
Shear Wall Along 1	0.00012	Shear Wall Along C1	0.00005
Shear Wall Along 6	0.00055	Shear Wall Along B1	0.00005
Shear Wall Along 3.1	0.00038		
Shear Wall Along 4.1	0.00038		
Floor 9 Sum	0.00143	Floor 9 Sum	0.00010
Floor 8		Floor 8	
Shear Wall Along 1	0.00012	Shear Wall Along C1	0.00005
Shear Wall Along 6	0.00008	Shear Wall Along B1	0.00005
Shear Wall Along 3.1	0.00038		
Shear Wall Along 4.1	0.00038		
Floor 8 Sum	0.00097	Floor 8 Sum	0.00010
Floor 7		Floor 7	
Shear Wall Along 1	0.00012	Shear Wall Along C1	0.00005
Shear Wall Along 6	0.00008	Shear Wall Along B1	0.00005
Shear Wall Along 3.1	0.00038		
Shear Wall Along 4.1	0.00038		
Floor 7 Sum	0.00097	Floor 7 Sum	0.00010
Floor 6		Floor 6	
Shear Wall Along 1	0.00012	Shear Wall Along C1	0.00005
Shear Wall Along 6	0.00008	Shear Wall Along B1	0.00005
Shear Wall Along 3.1	0.00038		
Shear Wall Along 4.1	0.00038		
Floor 6 Sum	0.00097	Floor 6 Sum	0.00010
Floor 5		Floor 5	
Shear Wall Along 1	0.00012	Shear Wall Along C1	0.00005
Shear Wall Along 6	0.00008	Shear Wall Along B1	0.00005
Shear Wall Along 3.1	0.00038		
Shear Wall Along 4.1	0.00038		
Floor 5 Sum	0.00097	Sum (8-R)	0.00010
Floor 4		Floor 4	
Shear Wall Along 1	0.00004	Shear Wall Along C1	0.00005
Shear Wall Along 6	0.00008	Shear Wall Along B1	0.00005
Shear Wall Along 3.1	0.00038		
Shear Wall Along 4.1	0.00038		
Floor 4 Sum	0.00089	Floor 4 Sum	0.00010
Floor 3		Floor 3	
Shear Wall Along 1	0.00007	Shear Wall Along C1	0.00009
Shear Wall Along 6	0.00015	Shear Wall Along B1	0.00008
Shear Wall Along 3.1	0.00085		
Shear Wall Along 4.1	0.00085		
Floor 3 Sum	0.00192	Floor 3 Sum	0.00017
Floor 2		Floor 2	
Shear Wall Along 1	0.00009	Shear Wall Along C1	0.00011
Shear Wall Along 6	0.00020	Shear Wall Along B1	0.00010
Shear Wall Along 3.1	0.00117		
Shear Wall Along 4.1	0.00117		
Floor 2 Sum	0.00264	Floor 2 Sum	0.00021
Floor 1		Floor 1	
Shear Wall Along 1	0.00007	Shear Wall Along C1	0.00009
Shear Wall Along 6	0.00016	Shear Wall Along B1	0.00008
Shear Wall Along 3.1	0.00089		
Shear Wall Along 4.1	0.00089		
Floor 1 Sum	0.00201	Floor 1 Sum	0.00017

Calculations Leading up to Relative Stiffness and Center of Rigidity

Stiffness of Lateral Force Resisting Elements

R = P/Δ

Stiffness of Lateral Force Resisting Elements			
North-South Direction		East-West Direction	
Roof		Roof	
Shear Wall Along 1	8494903	Shear Wall Along C1	19428054
Shear Wall Along 6	1822633	Shear Wall Along B1	20973398
Shear Wall Along 3.1	2612998		
Shear Wall Along 4.1	2612998		
Roof Sum	15543531	Roof Sum	40401452
Floor 10		Floor 10	
Shear Wall Along 1	8478999	Shear Wall Along C1	19399596
Shear Wall Along 6	1818226	Shear Wall Along B1	20943448
Shear Wall Along 3.1	2607109		
Shear Wall Along 4.1	2607109		
Floor 10 Sum	15511442	Floor 10 Sum	40343044
Floor 9		Floor 9	
Shear Wall Along 1	8494903	Shear Wall Along C1	19428054
Shear Wall Along 6	1822633	Shear Wall Along B1	20973398
Shear Wall Along 3.1	2612998		
Shear Wall Along 4.1	2612998		
Floor 9 Sum	15543531	Floor 9 Sum	40401452
Floor 8		Floor 8	
Shear Wall Along 1	8478999	Shear Wall Along C1	19399596
Shear Wall Along 6	12056571	Shear Wall Along B1	20943448
Shear Wall Along 3.1	2607109		
Shear Wall Along 4.1	2607109		
Floor 8 Sum	25749788	Floor 8 Sum	40343044
Floor 7		Floor 7	
Shear Wall Along 1	8478999	Shear Wall Along C1	19399596
Shear Wall Along 6	12056571	Shear Wall Along B1	20943448
Shear Wall Along 3.1	2607109		
Shear Wall Along 4.1	2607109		
Floor 7 Sum	25749788	Floor 7 Sum	40343044
Floor 6		Floor 6	
Shear Wall Along 1	8494903	Shear Wall Along C1	19428054
Shear Wall Along 6	12077119	Shear Wall Along B1	20973398
Shear Wall Along 3.1	2612998		
Shear Wall Along 4.1	2612998		
Floor 6 Sum	25798017	Floor 6 Sum	40401452

Floor 5		Floor 5	
Shear Wall Along 1	8478999	Shear Wall Along C1	19399596
Shear Wall Along 6	12056571	Shear Wall Along B1	20943448
Shear Wall Along 3.1	2607109		
Shear Wall Along 4.1	2607109		
Floor 5 Sum	25749788	Floor 5 Sum	40343044
Floor 4		Floor 4	
Shear Wall Along 1	23229028	Shear Wall Along C1	19371193
Shear Wall Along 6	12036068	Shear Wall Along B1	20913554
Shear Wall Along 3.1	2601236		
Shear Wall Along 4.1	2601236		
Floor 4 Sum	40467568	Floor 4 Sum	40284747
Floor 3		Floor 3	
Shear Wall Along 1	14097331	Shear Wall Along C1	11379803
Shear Wall Along 6	6497365	Shear Wall Along B1	12456694
Shear Wall Along 3.1	1180793		
Shear Wall Along 4.1	1180793		
Floor 3 Sum	22956282	Floor 3 Sum	23836497
Floor 2		Floor 2	
Shear Wall Along 1	11323687	Shear Wall Along C1	9011308
Shear Wall Along 6	4972275	Shear Wall Along B1	9923189
Shear Wall Along 3.1	852040		
Shear Wall Along 4.1	852040		
Floor 2 Sum	18000043	Floor 2 Sum	18934498
Floor 1		Floor 1	
Shear Wall Along 1	13654578	Shear Wall Along C1	10999263
Shear Wall Along 6	6247934	Shear Wall Along B1	12050779
Shear Wall Along 3.1	1125075		
Shear Wall Along 4.1	1125075		
Floor 1 Sum	22152661	Floor 1 Sum	23050043

Calculations Leading up to Relative Stiffness and Center of Rigidity

Relative Stiffness of Lateral Force Resisting Elements

Relative Stiffness of Lateral Force Resisting Elements			
North-South Direction		East-West Direction	
Roof		Roof	
Shear Wall Along 1	0.55	Shear Wall Along C1	0.5
Shear Wall Along 6	0.12	Shear Wall Along B1	0.5
Shear Wall Along 3.1	0.17		
Shear Wall Along 4.1	0.17		
Roof Sum	1.00	Roof Sum	1.0
Floor 10		Floor 10	
Shear Wall Along 1	0.55	Shear Wall Along C1	0.5
Shear Wall Along 6	0.12	Shear Wall Along B1	0.5
Shear Wall Along 3.1	0.17		
Shear Wall Along 4.1	0.17		
Floor 10 Sum	1.00	Floor 10 Sum	1.0
Floor 9		Floor 9	
Shear Wall Along 1	0.55	Shear Wall Along C1	0.5
Shear Wall Along 6	0.12	Shear Wall Along B1	0.5
Shear Wall Along 3.1	0.17		
Shear Wall Along 4.1	0.17		
Floor 9 Sum	1.00	Floor 9 Sum	1.0
Floor 8		Floor 8	
Shear Wall Along 1	0.33	Shear Wall Along C1	0.5
Shear Wall Along 6	0.47	Shear Wall Along B1	0.5
Shear Wall Along 3.1	0.10		
Shear Wall Along 4.1	0.10		
Floor 8 Sum	1.00	Floor 8 Sum	1.0
Floor 7		Floor 7	
Shear Wall Along 1	0.33	Shear Wall Along C1	0.5
Shear Wall Along 6	0.47	Shear Wall Along B1	0.5
Shear Wall Along 3.1	0.10		
Shear Wall Along 4.1	0.10		
Floor 7 Sum	1.00	Floor 7 Sum	1.0
Floor 6		Floor 6	
Shear Wall Along 1	0.33	Shear Wall Along C1	0.5
Shear Wall Along 6	0.47	Shear Wall Along B1	0.5
Shear Wall Along 3.1	0.10		
Shear Wall Along 4.1	0.10		
Floor 6 Sum	1.00	Floor 6 Sum	1.0
Floor 5		Floor 5	
Shear Wall Along 1	0.33	Shear Wall Along C1	0.5
Shear Wall Along 6	0.47	Shear Wall Along B1	0.5
Shear Wall Along 3.1	0.10		
Shear Wall Along 4.1	0.10		
Floor 5 Sum	1.00	Floor 5 Sum	1.0
Floor 4		Floor 4	
Shear Wall Along 1	0.57	Shear Wall Along C1	0.5
Shear Wall Along 6	0.30	Shear Wall Along B1	0.5
Shear Wall Along 3.1	0.06		
Shear Wall Along 4.1	0.06		
Floor 4 Sum	1.00	Floor 4 Sum	1.0
Floor 3		Floor 3	
Shear Wall Along 1	0.61	Shear Wall Along C1	0.5
Shear Wall Along 6	0.28	Shear Wall Along B1	0.5
Shear Wall Along 3.1	0.05		
Shear Wall Along 4.1	0.05		
Floor 3 Sum	1.00	Floor 3 Sum	1.0
Floor 2		Floor 2	
Shear Wall Along 1	0.63	Shear Wall Along C1	0.5
Shear Wall Along 6	0.28	Shear Wall Along B1	0.5
Shear Wall Along 3.1	0.05		
Shear Wall Along 4.1	0.05		
Floor 2 Sum	1.00	Floor 2 Sum	1.0
Floor 1		Floor 1	
Shear Wall Along 1	0.62	Shear Wall Along C1	0.5
Shear Wall Along 6	0.28	Shear Wall Along B1	0.5
Shear Wall Along 3.1	0.05		
Shear Wall Along 4.1	0.05		
Floor 1 Sum	1.00	Floor 1 Sum	1.0

RS = R / Sum(R)

Calculations Leading up to Relative Stiffness and Center of Rigidity

Center of Rigidity of Floor Areas

Center of Rigidity					
North-South Direction			East-West Direction		
Roof	X-Ordinate	Relative Stiffness	**Roof**	Y-Ordinate	Relative Stiffness
Shear Wall Along 1	11	0.55	Shear Wall Along C1	642	0.5
Shear Wall Along 6	502	0.12	Shear Wall Along B1	897	0.5
Shear Wall Along 3.1	738	0.17			
Shear Wall Along 4.1	1240	0.17			
XCM	397		YCM	740	
10	X-Ordinate	Relative Stiffness	**10**	Y-Ordinate	Relative Stiffness
Shear Wall Along 1	11	0.55	Shear Wall Along C1	642	0.5
Shear Wall Along 6	502	0.12	Shear Wall Along B1	897	0.5
Shear Wall Along 3.1	738	0.17			
Shear Wall Along 4.1	1240	0.17			
XCM	397		YCM	740	
9	X-Ordinate	Relative Stiffness	**9**	Y-Ordinate	Relative Stiffness
Shear Wall Along 1	11	0.55	Shear Wall Along C1	642	0.5
Shear Wall Along 6	502	0.12	Shear Wall Along B1	897	0.5
Shear Wall Along 3.1	738	0.17			
Shear Wall Along 4.1	1240	0.17			
XCM	397		YCM	740	
8	X-Ordinate	Relative Stiffness	**8**	Y-Ordinate	Relative Stiffness
Shear Wall Along 1	11	0.33	Shear Wall Along C1	642	0.5
Shear Wall Along 6	502	0.47	Shear Wall Along B1	897	0.5
Shear Wall Along 3.1	738	0.10			
Shear Wall Along 4.1	1240	0.10			
XCM	439		YCM	740	
7	X-Ordinate	Relative Stiffness	**7**	Y-Ordinate	Relative Stiffness
Shear Wall Along 1	11	0.33	Shear Wall Along C1	642	0.5
Shear Wall Along 6	502	0.47	Shear Wall Along B1	897	0.5
Shear Wall Along 3.1	738	0.10			
Shear Wall Along 4.1	1240	0.10			
XCM	439		YCM	740	
6	X-Ordinate	Relative Stiffness	**6**	Y-Ordinate	Relative Stiffness
Shear Wall Along 1	11	0.33	Shear Wall Along C1	642	0.5
Shear Wall Along 6	502	0.47	Shear Wall Along B1	897	0.5
Shear Wall Along 3.1	738	0.10			
Shear Wall Along 4.1	1240	0.10			
XCM	439		YCM	740	

(Continued on Next Page)

Calculations Leading up to Relative Stiffness and Center of Rigidity

(Continued from Previous Page)

Center of Rigidity of Floor Areas

5	X-Ordinate	Relative Stiffness	**5**	Y-Ordinate	Relative Stiffness
Shear Wall Along 1	11	0.33	Shear Wall Along C1	642	0.5
Shear Wall Along 6	502	0.47	Shear Wall Along B1	897	0.5
Shear Wall Along 3.1	738	0.10			
Shear Wall Along 4.1	1240	0.10			
XCM	439		YCM	740	
4	X-Ordinate	Relative Stiffness	**4**	Y-Ordinate	Relative Stiffness
Shear Wall Along 1	11	0.57	Shear Wall Along C1	642	0.5
Shear Wall Along 6	502	0.30	Shear Wall Along B1	897	0.5
Shear Wall Along 3.1	738	0.06			
Shear Wall Along 4.1	1240	0.06			
XCM	283		YCM	740	
3	X-Ordinate	Relative Stiffness	**3**	Y-Ordinate	Relative Stiffness
Shear Wall Along 1	11	0.61	Shear Wall Along C1	642	0.5
Shear Wall Along 6	502	0.28	Shear Wall Along B1	897	0.5
Shear Wall Along 3.1	738	0.05			
Shear Wall Along 4.1	1240	0.05			
XCM	251		YCM	735	
2	X-Ordinate	Relative Stiffness	**2**	Y-Ordinate	Relative Stiffness
Shear Wall Along 1	11	0.63	Shear Wall Along C1	642	0.5
Shear Wall Along 6	502	0.28	Shear Wall Along B1	897	0.5
Shear Wall Along 3.1	738	0.05			
Shear Wall Along 4.1	1240	0.05			
XCM	239		YCM	732	
1	X-Ordinate	Relative Stiffness	**1**	Y-Ordinate	Relative Stiffness
Shear Wall Along 1	11	0.62	Shear Wall Along C1	642	0.5
Shear Wall Along 6	502	0.28	Shear Wall Along B1	897	0.5
Shear Wall Along 3.1	738	0.05			
Shear Wall Along 4.1	1240	0.05			
XCM	249		YCM	734	

Appendix B

Drift

ETABS Values with Comparisons

Diaphragm CM Displacements													
Story	Load	UX	TOTAL UX	Story UX	NG	OK	0.002h	UY	MAX UY		NG	OK	h/400
ROOF	WINDEW	**1.16**	**1.16**	0.11		<	0.21	0.45	**2.90**	0.35	>		0.21
ROOF	WINDNS	0.15					inches	**2.90**					inches
ROOF	EQEW	0.46						0.05					
ROOF	EQNS	0.08						1.21					
STORY10	WINDEW	**1.06**	**1.06**	0.13		<	0.21	0.41	**2.55**	0.35	>		0.21
STORY10	WINDNS	0.15						**2.55**					
STORY10	EQEW	0.41						0.04					
STORY10	EQNS	0.08						1.07					
STORY9	WINDEW	**0.93**	**0.93**	0.14		<	0.21	0.36	**2.20**	0.36	>		0.21
STORY9	WINDNS	0.13						**2.20**					
STORY9	EQEW	0.36						0.04					
STORY9	EQNS	0.07						0.92					
STORY8	WINDEW	**0.78**	**0.78**	0.12		<	0.21	0.29	**1.84**	0.32	>		0.21
STORY8	WINDNS	0.11						**1.84**					
STORY8	EQEW	0.31						0.03					
STORY8	EQNS	0.05						0.77					
STORY7	WINDEW	**0.66**	**0.66**	0.12		<	0.21	0.26	**1.52**	0.30	>		0.21
STORY7	WINDNS	0.09						**1.52**					
STORY7	EQEW	0.27						0.03					
STORY7	EQNS	0.05						0.64					
STORY6	WINDEW	**0.54**	**0.54**	0.11		<	0.21	0.22	**1.22**	0.28	>		0.21
STORY6	WINDNS	0.08						**1.22**					
STORY6	EQEW	0.22						0.02					
STORY6	EQNS	0.04						0.52					
STORY5	WINDEW	**0.43**	**0.43**	0.04		<	0.21	0.19	**0.94**	0.24	>		0.21
STORY5	WINDNS	0.07						**0.94**					
STORY5	EQEW	0.17						0.02					
STORY5	EQNS	0.03						0.40					
STORY4	WINDEW	**0.39**	**0.39**	0.12		<	0.21	0.15	**0.69**	0.21		.=	0.21
STORY4	WINDNS	0.12						**0.69**					
STORY4	EQEW	0.14						0.02					
STORY4	EQNS	0.06						0.30					
STORY3	WINDEW	**0.28**	**0.28**	0.13		<	0.29	0.11	**0.48**	0.24		<	0.29
STORY3	WINDNS	0.08						**0.48**					
STORY3	EQEW	0.10						0.01					
STORY3	EQNS	0.04						0.21					
STORY2	WINDEW	**0.14**	**0.14**	0.10		<	0.33	0.05	**0.25**	0.18		<	0.33
STORY2	WINDNS	0.04						**0.25**					
STORY2	EQEW	0.05						0.01					
STORY2	EQNS	0.02						0.10					
STORY1	WINDEW	**0.04**	**0.04**	0.04		<	0.30	0.01	**0.06**	0.06		<	0.30
STORY1	WINDNS	0.01						**0.06**					
STORY1	EQEW	0.01						0.00					
STORY1	EQNS	0.01						0.03					

h = story height

Appendix C

Calculations of Torsional Shear in Individual Shear Walls

North-South Shear Walls

North-South Shear Walls												
Story Information					Shear Wall Information							
STORY	Vtot (N-S)	XCR	XCM	e (X)	**GRID**	xi	di (X)	Ri	[Ri(di^2)] (X)	J (X)	**Vi (X)**	Vi/Vtot
Roof	75.5	397.39	623.02	225.62	**1**	11	-386.39	0.55	81596.37	186191.1	**-19.32**	-0.26
					3.1	502	104.61	0.17	1839.49		**1.61**	0.02
					4.1	738	340.61	0.17	19502.60		**5.24**	0.07
					6	1240	842.61	0.12	83252.63		**9.04**	0.12
STORY	Vtot (N-S)	XCR	XCM	e (X)	**GRID**	xi	di (X)	Ri	[Ri(di^2)] (X)	J (X)	**Vi (X)**	Vi/Vtot
10	107.8	397.39	623.02	225.62	**1**	11	-386.39	0.55	81596.37	186191.1	**-27.59**	-0.26
					3.1	502	104.61	0.17	1839.49		**2.30**	0.02
					4.1	738	340.61	0.17	19502.60		**7.48**	0.07
					6	1240	842.61	0.12	83252.63		**12.91**	0.12
STORY	Vtot (N-S)	XCR	XCM	e (X)	**GRID**	xi	di (X)	Ri	[Ri(di^2)] (X)	J (X)	**Vi (X)**	Vi/Vtot
9	137.8	397.39	623.02	225.62	**1**	11	-386.39	0.55	81596.37	186191.1	**-35.25**	-0.26
					3.1	502	104.61	0.17	1839.49		**2.94**	0.02
					4.1	738	340.61	0.17	19502.60		**9.56**	0.07
					6	1240	842.61	0.12	83252.63		**16.50**	0.12
STORY	Vtot (N-S)	XCR	XCM	e (X)	**GRID**	xi	di (X)	Ri	[Ri(di^2)] (X)	J (X)	**Vi (X)**	Vi/Vtot
8	167.1	397.39	623.02	225.62	**1**	11	-386.39	0.33	49162.40	137916	**-34.77**	-0.21
					3.1	502	104.61	0.47	5123.40		**13.39**	0.08
					4.1	738	340.61	0.10	11745.96		**9.43**	0.06
					6	1240	842.61	0.10	71884.28		**23.32**	0.14
STORY	Vtot (N-S)	XCR	XCM	e (X)	**GRID**	xi	di (X)	Ri	[Ri(di^2)] (X)	J (X)	**Vi (X)**	Vi/Vtot
7	195.6	397.39	623.02	225.62	**1**	11	-386.39	0.33	49162.40	137916	**-40.72**	-0.21
					3.1	502	104.61	0.47	5123.40		**15.67**	0.08
					4.1	738	340.61	0.10	11745.96		**11.04**	0.06
					6	1240	842.61	0.10	71884.28		**27.30**	0.14
STORY	Vtot (N-S)	XCR	XCM	e (X)	**GRID**	xi	di (X)	Ri	[Ri(di^2)] (X)	J (X)	**Vi (X)**	Vi/Vtot
6	223.4	397.39	623.02	225.62	**1**	11	-386.39	0.33	49162.53	137947.5	**-46.48**	-0.21
					3.1	502	104.61	0.47	5122.54		**17.89**	0.08
					4.1	738	340.61	0.10	11750.48		**12.60**	0.06
					6	1240	842.61	0.10	71911.97		**31.18**	0.14
STORY	Vtot (N-S)	XCR	XCM	e (X)	**GRID**	xi	di (X)	Ri	[Ri(di^2)] (X)	J (X)	**Vi (X)**	Vi/Vtot
5	250.2	397.39	623.02	225.62	**1**	11	-386.39	0.33	49162.40	137916	**-52.08**	-0.21
					3.1	502	104.61	0.47	5123.40		**20.05**	0.08
					4.1	738	340.61	0.10	11745.96		**14.12**	0.06
					6	1240	842.61	0.10	71884.28		**34.92**	0.14
STORY	Vtot (N-S)	XCR	XCM	e (X)	**GRID**	xi	di (X)	Ri	[Ri(di^2)] (X)	J (X)	**Vi (X)**	Vi/Vtot
4	275.9	397.39	623.02	225.62	**1**	11	-386.39	0.57	85701.03	142050.2	**-97.21**	-0.35
					3.1	502	104.61	0.30	3254.51		**13.64**	0.05
					4.1	738	340.61	0.06	7457.20		**9.60**	0.03
					6	1240	842.61	0.06	45637.43		**23.74**	0.09
STORY	Vtot (N-S)	XCR	XCM	e (X)	**GRID**	xi	di (X)	Ri	[Ri(di^2)] (X)	J (X)	**Vi (X)**	Vi/Vtot
3	304.8	397.39	623.02	225.62	**1**	11	-386.39	0.61	91684.83	137268.3	**-118.89**	-0.39
					3.1	502	104.61	0.28	3097.02		**14.83**	0.05
					4.1	738	340.61	0.05	5967.26		**8.78**	0.03
					6	1240	842.61	0.05	36519.15		**21.72**	0.07
STORY	Vtot (N-S)	XCR	XCM	e (X)	**GRID**	xi	di (X)	Ri	[Ri(di^2)] (X)	J (X)	**Vi (X)**	Vi/Vtot
2	337.8	397.39	623.02	225.62	**1**	11	-386.39	0.63	93923.96	136045.5	**-136.18**	-0.40
					3.1	502	104.61	0.28	3022.66		**16.19**	0.05
					4.1	738	340.61	0.05	5491.48		**9.03**	0.03
					6	1240	842.61	0.05	33607.42		**22.34**	0.07
STORY	Vtot (N-S)	XCR	XCM	e (X)	**GRID**	xi	di (X)	Ri	[Ri(di^2)] (X)	J (X)	**Vi (X)**	Vi/Vtot
1	354.6	397.39	623.02	225.62	**1**	11	-386.39	0.62	92026.84	137063.1	**-139.00**	-0.39
					3.1	502	104.61	0.28	3086.16		**17.22**	0.05
					4.1	738	340.61	0.05	5891.94		**10.10**	0.03
					6	1240	842.61	0.05	36058.19		**24.98**	0.07

Calculations of Torsional Shear in Individual Shear Walls

North-South Shear Walls

East-West Shear Walls												
					Shear Wall Information							
	Vtot (E-W)	YCR	YCM	e (Y)	**Grid**	yi	di (Y)	Ri	[Ri(di^2)] (Y)	J (Y)	**Vi (Y)**	Vi/Vtot
Roof	65.9	740.07	750.20	10.13	**B1**	897	156.93	0.50	12314.01	17122.56	**3.06**	0.05
					C1	642	-98.07	0.50	4808.55		**-1.91**	-0.03
STORY	Vtot (E-W)	YCR	YCM	e (Y)	**Grid**	yi	di (Y)	Ri	[Ri(di^2)] (Y)	J (Y)	**Vi (Y)**	Vi/Vtot
10	94.1	740.07	750.20	10.13	**B1**	897	156.93	0.50	12314.01	17122.56	**4.37**	0.05
					C1	642	-98.07	0.50	4808.55		**-2.73**	-0.03
STORY	Vtot (E-W)	YCR	YCM	e (Y)	**Grid**	yi	di (Y)	Ri	[Ri(di^2)] (Y)	J (Y)	**Vi (Y)**	Vi/Vtot
9	120.3	740.07	750.20	10.13	**B1**	897	156.93	0.50	12314.01	17122.56	**5.58**	0.05
					C1	642	-98.07	0.50	4808.55		**-3.49**	-0.03
STORY	Vtot (E-W)	YCR	YCM	e (Y)	**Grid**	yi	di (Y)	Ri	[Ri(di^2)] (Y)	J (Y)	**Vi (Y)**	Vi/Vtot
8	145.9	740.07	750.20	10.13	**B1**	897	156.93	0.50	12314.01	17122.56	**6.77**	0.05
					C1	642	-98.07	0.50	4808.55		**-4.23**	-0.03
STORY	Vtot (E-W)	YCR	YCM	e (Y)	**Grid**	yi	di (Y)	Ri	[Ri(di^2)] (Y)	J (Y)	**Vi (Y)**	Vi/Vtot
7	170.9	740.07	750.20	10.13	**B1**	897	156.93	0.50	12314.01	17122.56	**7.93**	0.05
					C1	642	-98.07	0.50	4808.55		**-4.96**	-0.03
STORY	Vtot (E-W)	YCR	YCM	e (Y)	**Grid**	yi	di (Y)	Ri	[Ri(di^2)] (Y)	J (Y)	**Vi (Y)**	Vi/Vtot
6	195.2	740.07	750.20	10.13	**B1**	897	156.93	0.50	12314.01	17122.56	**9.06**	0.05
					C1	642	-98.07	0.50	4808.55		**-5.66**	-0.03
STORY	Vtot (E-W)	YCR	YCM	e (Y)	**Grid**	yi	di (Y)	Ri	[Ri(di^2)] (Y)	J (Y)	**Vi (Y)**	Vi/Vtot
5	218.6	740.07	750.20	10.13	**B1**	897	156.93	0.50	12314.01	17122.56	**10.15**	0.05
					C1	642	-98.07	0.50	4808.55		**-6.34**	-0.03
STORY	Vtot (E-W)	YCR	YCM	e (Y)	**Grid**	yi	di (Y)	Ri	[Ri(di^2)] (Y)	J (Y)	**Vi (Y)**	Vi/Vtot
4	241.1	740.07	750.20	10.13	**B1**	897	156.93	0.50	12314.01	17122.56	**11.19**	0.05
					C1	642	-98.07	0.50	4808.55		**-6.99**	-0.03
STORY	Vtot (E-W)	YCR	YCM	e (Y)	**Grid**	yi	di (Y)	Ri	[Ri(di^2)] (Y)	J (Y)	**Vi (Y)**	Vi/Vtot
3	266.4	740.07	750.20	10.13	**B1**	897	156.93	0.50	12314.01	17122.56	**12.37**	0.05
					C1	642	-98.07	0.50	4808.55		**-7.73**	-0.03
STORY	Vtot (E-W)	YCR	YCM	e (Y)	**Grid**	yi	di (Y)	Ri	[Ri(di^2)] (Y)	J (Y)	**Vi (Y)**	Vi/Vtot
2	295.2	740.07	750.20	10.13	**B1**	897	156.93	0.50	12314.01	17122.56	**13.70**	0.05
					C1	642	-98.07	0.50	4808.55		**-8.56**	-0.03
STORY	Vtot (E-W)	YCR	YCM	e (Y)	**Grid**	yi	di (Y)	Ri	[Ri(di^2)] (Y)	J (Y)	**Vi (Y)**	Vi/Vtot
1	309.9	740.07	750.20	10.13	**B1**	897	156.93	0.50	12314.01	17122.56	**14.38**	0.05
					C1	642	-98.07	0.50	4808.55		**-8.99**	-0.03

Appendix D

Overturning Calculations

Using Wind Overturning Moments found in Technical Report 1

Overturning Calculations						
North-South Direction						
Mo =	29,924	ft-k				
L =	92	ft				
Mo / L =	**325.26**	**k**				
W =	18800	k				
W/2 =	**9400**	**k**				
		9400	**>**	325.261	therefore	**OK!**
East-West						
Mo =	26,144	ft-k				
L =	106	ft				
Mo / L =	**246.64**	**k**				
W =	18800	k				
W/2 =	**9400**	**k**				
		9400	**>**	246.642	therefore	**OK!**

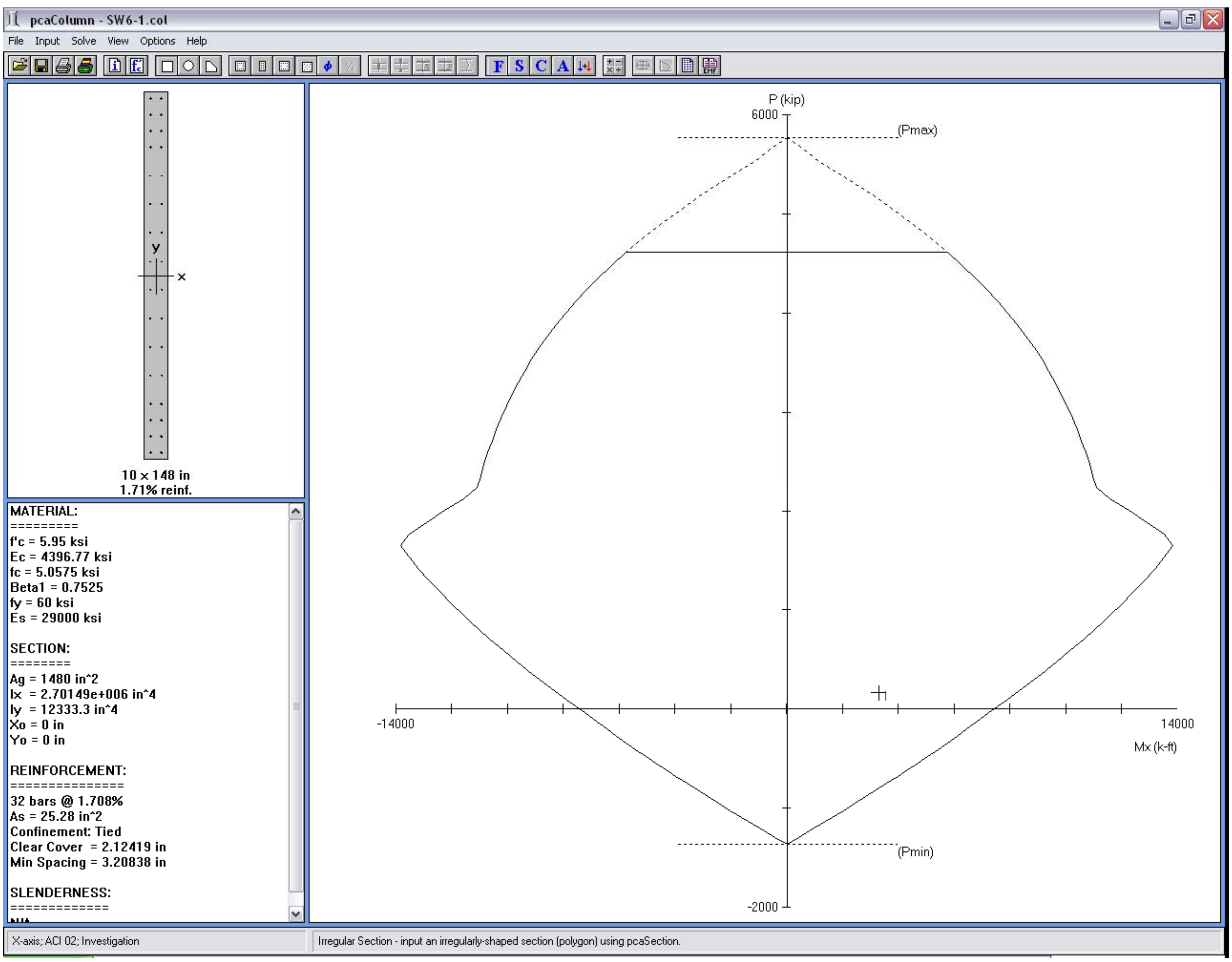
Mo/L < 1/2 (Wt)

Appendix E

Strength Design Checks

Shear Wall Along Gridline 1

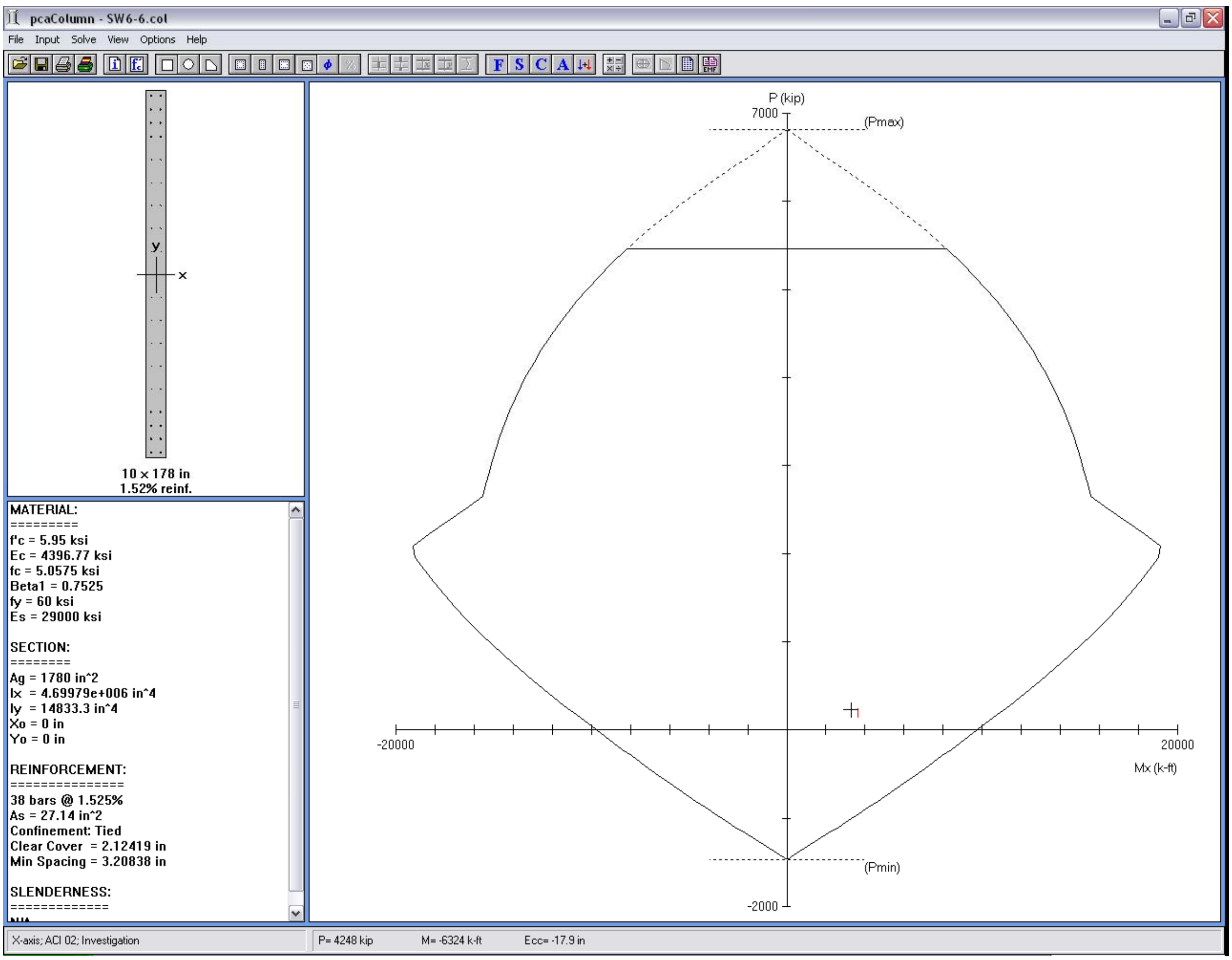
Shear Wall 1 Loads			
Based on the Following Information			
189 sf	Tributary Area	*Dim1*	*Dim2*
		18	10.5
200 psf	Unfactored Floor Loading	*DL*	*LL*
		160	40
256 psf	Factored Floor Loading		
48.384 kips	Axial Load		
4 stories	Number of Stories Above		
169.344 kips	Total Factored Axial Load at Floor 6		
2053 ft-k	Unfactored Wind Load (N-S Direction)		
3284.8 ft-k	Factored Wind Load		



Strength Design Checks

Shear Wall Along Gridline 6

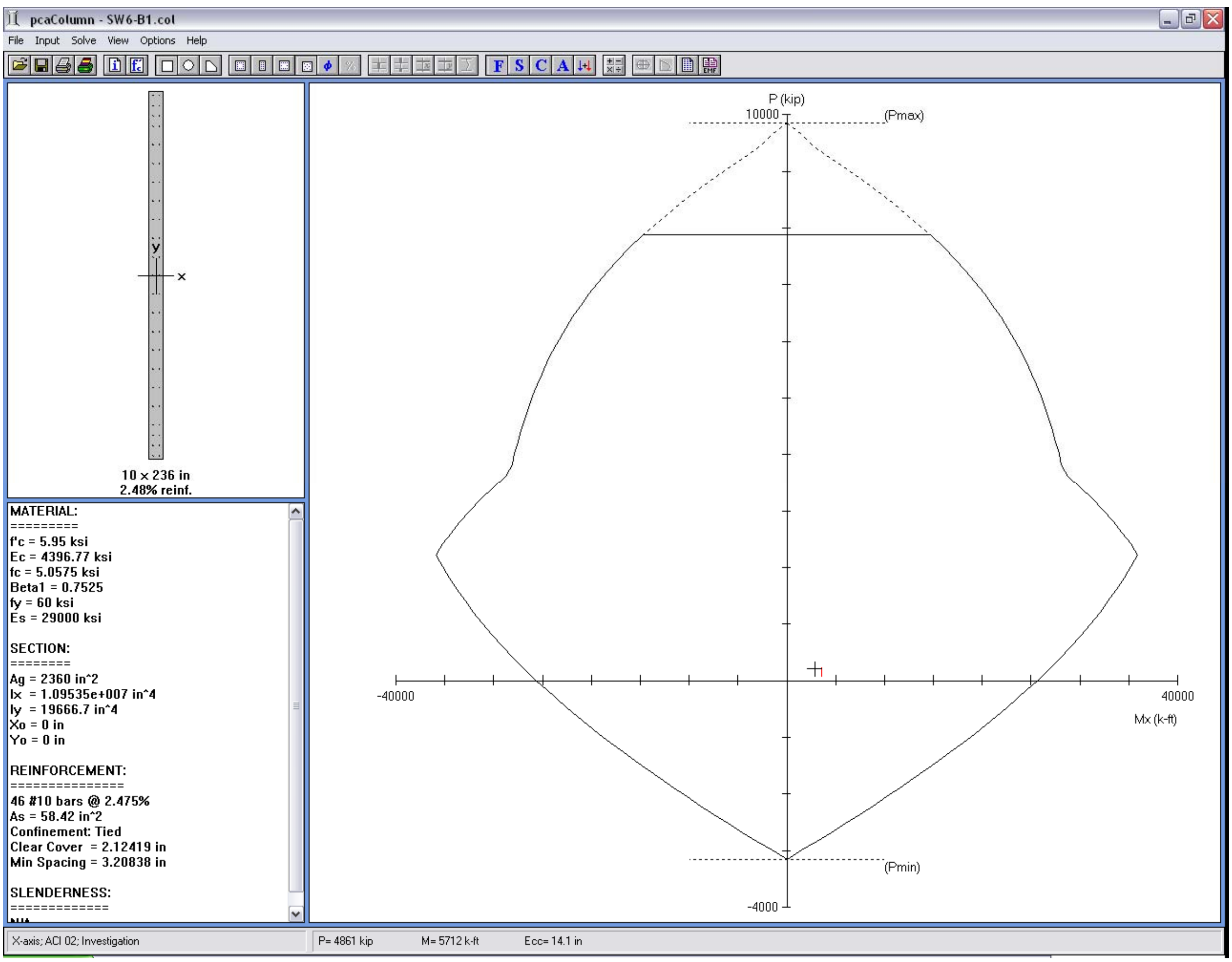
Shear Wall 6 Loads			
Based on the Following Information			
257.25 sf	Tributary Area	*Dim1*	*Dim2*
		24.5	10.5
200 psf	Unfactored Floor Loading	*DL*	*LL*
		160	40
256 psf	Factored Floor Loading		
65.856 kips	Axial Load		
4 stories	Number of Stories Above		
230.496 kips	Total Factored Axial Load at Floor 6		
2053 ft-k	Unfactored Wind Load (N-S Direction)		
3284.8 ft-k	Factored Wind Load		



Strength Design Checks

Shear Wall Along Gridline B1

Shear Wall B1 Loads			
Based on the Following Information			
236.25 sf	Tributary Area	*Dim1*	*Dim2*
		7.5	31.5
200 psf	Unfactored Floor Loading	*DL*	*LL*
		160	40
256 psf	Factored Floor Loading		
60.48 kips	Axial Load		
4 stories	Number of Stories Above		
211.68 kips	Total Factored Axial Load at Floor 6		
1796 ft-k	Unfactored Wind Load (E-W Direction)		
2873.6 ft-k	Factored Wind Load		



Strength Design Checks

Shear Wall Along Gridline C1

Shear Wall C1 Loads			
Based on the Following Information			
567 sf	Tributary Area	*Dim1*	*Dim2*
		13.5	42
200 psf	Unfactored Floor Loading	*DL*	*LL*
		160	40
256 psf	Factored Floor Loading		
145.152 kips	Axial Load		
4 stories	Number of Stories Above		
508.032 kips	Total Factored Axial Load at Floor 6		
1796 ft-k	Unfactored Wind Load (E-W Direction)		
2873.6 ft-k	Factored Wind Load