Time History Analysis of Axial Forces (Pass Through Forces) at Joints in a Braced Frame

By

Vincent Paschini

B.Eng.

Polytechnique Montréal, 2011

Submitted to the Department of Civil and Environmental Engineering in Partial Fulfillment of the Requirements for the Degree of Master of Engineering in Civil and Environmental Engineering at the Massachusetts Institute of Technology

JUNE 2012

Author: ____

Department of Civil and Environmental Engineering

May 11th, 2012

Certified by: ____

Jerome J. Connor

Professor of Civil and Environmental Engineering

Thesis Supervisor

Accepted by: ____

Heidi M. Nepf

Chair, Departmental Committee of Graduate Students

Time History Analysis of Axial Forces (Pass Through Forces) at Joints in a Braced Frame

By

Vincent Paschini

Submitted to the Department of Civil and Environmental Engineering on May 11th, 2012 in Partial Fulfillment of the Requirements for the Degree of Master of Engineering in Civil and Environmental Engineering at the Massachusetts Institute of Technology

ABSTRACT

As buildings keep getting taller, traditional braced lateral systems take more loads. This generates a phenomenon at every joint of a frame called "Pass Through Force". Pass through forces come from the transfer of axial forces between two side by side members. Adding a bracing scheme to our frame will introduce even more pass through forces at the node since part the force in the bracing will be transferred in the horizontal member.

The main goal of this thesis is to find an appropriate way of computing pass through forces without being too conservative. If we take an accurate value of pass through force at a node, the steel connections will not be overdesigned, resulting in cost savings. In this thesis, we analyse multiple bracing configurations for a typical steel frame under different load combinations in order to find a procedure for computing pass through forces adequately. Each scenario will be analysed in detail, a time history analysis will be used to find precise values under earthquake loading. The results are compared with two traditional methods of finding pass through forces, and the best approach is identified.

Thesis Supervisor: Jerome J. Connor

Title: Professor of Civil and Environmental Engineering

Acknowledgements

First of all, I would like to thank my family, girlfriend and friends who greatly supported me during my whole journey here at MIT. This experience would have been even harder without their support. I wouldn't be able to do it without you. Thank you for believing in me and encouraging me. I really appreciate it.

To every professor from the Civil and Environmental Engineering department, but especially Prof. Jerome J. Connor and his teacher assistant Pierre Ghisbain who helped me understand every aspect of this thesis. I'm grateful for all the knowledge Prof. Jerome J. Connor provided me during the last nine months. Thank you, I will never forget everything I learned in the High Performance Structure program. Again, I really appreciate it.

To every student in the M.Eng. program and the other ones I met in the past year for being so kind and always there when I needed to take a time out. I now see you as friends instead of colleagues and hope to see you again in a near future. Thank you for those never-ending hours in the M.Eng. room and every special activity we did together. Once more, I really appreciate it.

To everybody else who crossed my path while I was here at MIT and didn't mention, thank you. To D.P.H.V. who gave me the idea for this thesis subject. I hope this thesis will help understanding every concept of pass through forces and even more. Thank you everybody for the support you gave me, I can't tell you how much I appreciate it.

- Vincent Paschini

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

LIST OF TABLES

CHAPTER 1: INTRODUCTION

Steel connection design is an art and can sometimes be costly. The less material you use, the better it is (as long as the connection capacity is greater than the demand). With buildings getting taller year after year, lateral systems need to be efficient in order to counter wind and earthquake loads. Depending on the lateral system of the building, the axial forces between two side by side members can be different. If we look at a conventional braced frame, the horizontal component of the force in the bracing adds an axial force at the joint.

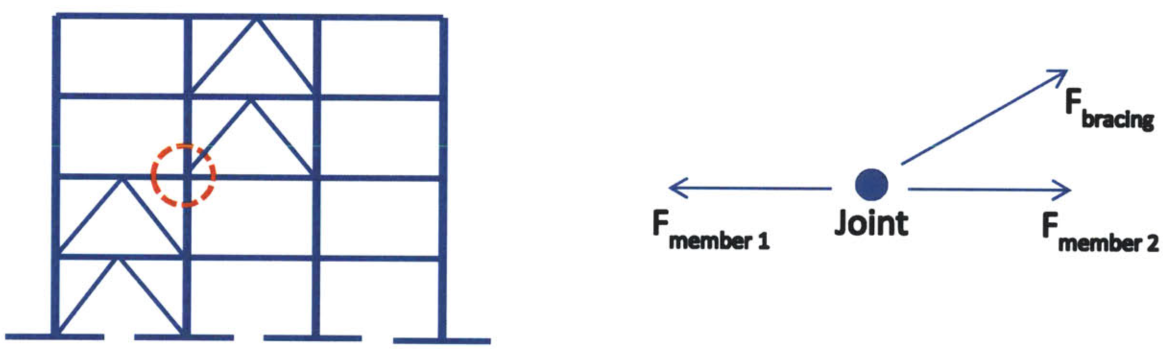

Figure 1 - Pass Through Force (PTF)

This additional force between two members is called "Pass Through Force" (PTF) and results in an extra check in the connection design. If the value of the PTF is not accurate (usually on the conservative side), the connection will be overdesigned and the cost will increase.

The purpose of this thesis is to find the absolute maximum value of the PTF at any joint and maybe find an algorithm on how to compute them. To begin with, a typical frame encounter on a past job will be replicated, and simplified (2D model). Loads and load combinations from the American Society of Civil Engineers (ASCE 7-10) and the International Building Code (IBC 2012) will be used throughout both static and dynamic analyses. Lateral wind loads will be analysed in both directions.

For multiple bracing configurations in our frame, the absolute maximum axial force in every member will be determined through several analyses (using SAP2000) for different load combinations. A time history analysis will be necessary for the dynamic part of this thesis in order to obtain accurate results under earthquake loads. Those analyses will give us force envelopes, which will be helpful to determine the appropriate PTF at a joint.

Once we obtain adequate results for our first braced frame, the bracing configuration will be modified in order to find (if possible) an algorithm on how to compute those forces. The last step of this thesis will be to compare those results with two traditional methods.

CHAPTER 2: FRAME & LOADS

2.1 FRAME

The first thing we needed to define was our frame dimensions & proprieties. The main frame used throughout this thesis is inspired from a previous frame encountered on a past job in Colonsay, Saskatchewan, Canada (I was working on this project last summer, 2011, designing steel connections for DPHV[1], a structural engineering firm located in Ste-Dorothée/Laval, Québec, Canada). This frame is part of a building used as a potash mining warehouse. To simplify our analysis, we will look at a 2D version of this frame and only part of it will be used.

The frame consists of three 25 feet wide bays with four 20 feet high storeys. According to the structural plans of this job, girders and columns are W16x40 and W18x119 steel sections respectively. Columns are fixed at the base and girders pinned at each joint. Frames in this building are spaced at 20 feet center to center of each other. A full sketch of the main frame used throughout this thesis and loads applied to it can be found in figure 3.

2.2 LOADS

We will assume that our building (and its frame) is located in the Boston area, Massachusetts, United States. The first step in the structural design of our building was determining the design loadings that would act on the structural members. Throughout this process, we used the LRFD (Load and Resistance Factor Design) method outlined in the ASCE 7-10 (American Society of Civil Engineers) Minimum Design Loads for

---

[1] http://www.dphv.ca/pages/dphv_profile.htm

Buildings and Other Structures, and the IBC 2012 (International Building Code). One categorization that had to be determined before we proceeded to individual loading types was the risk category, which we determined using Table 1-5.1 from ASCE 7-10. The risk category of a light warehouse is II (2). Every load will be applied as distributed (knowing our tributary length of 20 feet between each frame) on each floor/wall except for the earthquake loading, which will be taken as a dynamic load case.

2.2.1 Dead Load (D)

Dead loading applied to our frame consists of the self-weight of our members plus a 4 inches lightweight concrete (110 pounds per cubic foot) slab on top of them. Even if the slab thickness is usually smaller at the roof (or non-existent), we will also apply the full dead load at this location in order to obtain conservative values.

2.2.2 Live Loads (L & L_R)

Live loads in our building fell into two categories, interior live load and roof live load. The typical value of interior live load at each floor for a light warehouse is 125 psf. The roof live load will be taken as 20 psf. Both values for live loading were taken from Table 4-1 in ASCE 7-10. No live load reduction will be used, since we are not allowed to reduce interior live load greater than 100 psf and roof live load.

2.2.3 Snow Load (S)

Snow load for a flat roof top is defined in Chapter 7 of ASCE 7-10. The first thing we need to define is the *Terrain Category* as per section 26.7. For our type of building, the terrain category is B. Using the following equation (7.3-1 of ASCE 7-10):

$$S = P_f = 0.7 C_e C_t I_s P_g$$

where:

C_e = Exposure Factor (Table 7-2 of ASCE 7-10)
C_t = Thermal Factor (Table 7-3 of ASCE 7-10)
I_s = Importance Factor (Table 1.5-2 of ASCE 7-10)
P_g = Ground Snow Load (Figure 7-1 of ASCE 7-10)

we can determine our snow load. The exposure factor (C_e) for a terrain category B with a fully exposed roof is 0.9. The thermal factor (C_t) for a normal building and the importance factor (I_s) for risk category II are both 1.0. The ground snow load (P_g) in the Massachusetts area is 40 psf. Calculating the snow load we obtain P_f = 25.2 psf. To be conservative and because Massachusetts' winters are usually heavy in snow, we will use a snow load of 30 psf at the roof.

2.2.4 Wind Loads (W)

Again, wind loads fell into two categories, lateral (windward) wind pressure on walls of our building and roof (downward) wind pressure. We won't need to calculate our leeward wind pressure, because the opposite wall of our frame is connected to the rest of the building. Lateral wind load will be analysed in both directions. The first thing we needed to calculate was the velocity pressure coefficient (q_z) as per section 27.3.2 of ASCE 7-10:

$$q_z = 0.00256 \cdot K_z \cdot K_{zt} \cdot K_d \cdot v^2$$

where:

K_z = Velocity Pressure Exposure Coefficient (Table 27.3-1of ASCE 7-10)
K_{zt} = Topographic Factor (Table 26.8-1 of ASCE 7-10)
K_d = Wind Directional Factor (Table 26.6-1 of ASCE 7-10)
v = Wind Speed (Figure 26.5-1A of ASCE 7-10)

Wind speed (v) for risk category II buildings within the Massachusetts area is 140 miles per hour. The wind directional factor (K_d) equals 0.85 for a typical building and the topographic factor (K_{zt}) for an *Exposure Category* B (section 26.7 of ASCE 7-10) is 1.0. The velocity pressure exposure coefficient (K_z) depends on the height of our building, and values can be found in Table 27.3-1 of ASCE 7-10.

Once we know the velocity pressure coefficient (q_z), we can compute both lateral and roof wind loads with equation 27.4-1 of ASCE 7-10 for a rigid frame:

$$W = P_w = q_z G_e C_{pe} - q_h \left[G C_p \right]_i$$

where:

G_e = Gust Effect Factor (section 26.9 of ASCE 7-10)
C_{pe} = External Pressure Coefficient (Figure 27.4-1 of ASCE 7-10)
q_h = Velocity Pressure Coefficient at the Roof
$[GC_p]_i$ = Internal Pressure Coefficient (section 26.11 of ASCE 7-10)

The gust effect factor (G_e) is equal to 0.85, while the internal pressure coefficient ($[GC_p]_i$) is ±0.18 (note that -0.18 will control for the windward wind pressure). For the windward wind pressure, the external pressure coefficient (C_{pe}) is 0.8.

Exposure Coef.		**Velocity Pressure Coef.**		**Windward Wind Load**		
$K_{z0\text{-}15}$ =	0.57	$q_{z0\text{-}15}$ =	24.31	$P_{w0\text{-}15}$ =	23.67	psf
K_{z20} =	0.62	q_{z20} =	26.44	P_{w20} =	25.12	psf
K_{z25} =	0.66	q_{z25} =	28.14	P_{w25} =	26.28	psf
K_{z30} =	0.70	q_{z30} =	29.85	P_{w30} =	27.44	psf
K_{z40} =	0.76	q_{z40} =	32.41	P_{w40} =	29.18	psf
K_{z50} =	0.81	q_{z50} =	34.54	P_{w50} =	30.63	psf
K_{z60} =	0.85	q_{z60} =	36.25	P_{w60} =	31.79	psf
K_{z70} =	0.89	q_{z70} =	37.95	P_{w70} =	32.95	psf
K_h =	0.93	q_h =	39.66	P_{wh} =	34.11	psf

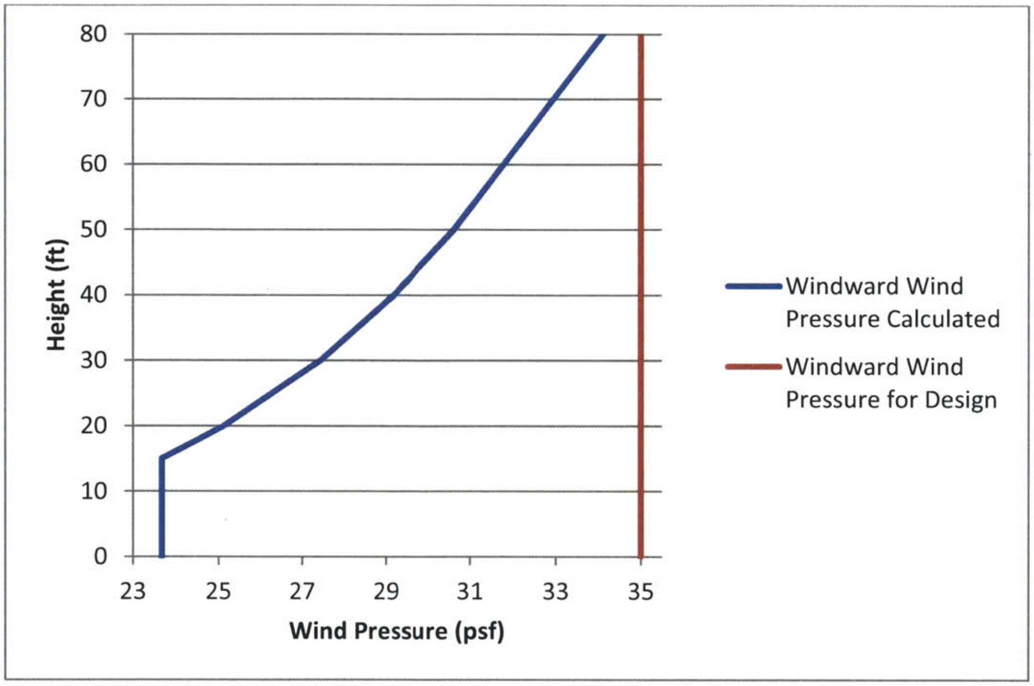

Figure 2 - Wind Pressure Diagram

To be conservative, we will use a value of 35 psf for the lateral windward wind load. At the roof, C_{pe} is equal to either -0.9 or -0.18. The roof wind pressure varies from 1.07 psf upward to 37.48 psf downward. Since the uplift is pretty small, we will neglect its effect and only apply a downward wind pressure at the roof. Again, to be conservative, we will use a roof wind load of 38 psf.

2.2.5 Earthquake Load (E)

For the earthquake loading, we will use a time history analysis. The result of this analysis will give us a force envelope for every member in our frame. In order to do this dynamic analysis, we need the acceleration data from an earthquake in the Massachusetts area. Using SAP2000 to do our analyses, the program's default database doesn't have any value for such a small earthquake. We will have to use a California earthquake and scale it down. To do so, we will start by doing a static analysis on our frame for both earthquakes (Massachusetts and California) and find the maximum displacement for each of them. The ratio between both displacements will give us the scale factor to use for our time history analysis. Even if this ratio doesn't fully characterize a Massachusetts earthquake, it is more than enough for the purpose of this thesis. The site classes in Massachusetts and California are both C (IBC 2012 – Table 1613.5.2), since soil conditions are average to poor.

The west coast earthquake used in our time history analysis is from Altadena - Eaton Canyon Park (Los Angeles County, California). This particular region in the south of California is known for their frequent earthquakes (magnitude 5.0 and up). A step by step procedure on how we scaled down our earthquake can be found in "Chapter 4: SAP2000 Model" of this thesis.

The next table summarizes all loads with their orientation in which they will be analysed plus their pounds per square foot value as well as their distributed load value.

Load	**Orientation**	**Value**	**Distributed Load**
D	↓	Self-weight + 37 psf	Self-weight + 0.74 kip/ft
L	↓	125 psf	2.5 kips/ft
L_r	↓	20 psf	0.4 kip/ft
S	↓	30 psf	0.6 kip/ft
W (roof)	↓	38 psf	0.76 kip/ft
W (windward)	↔	35 psf	0.7 kip/ft
E	↔	Dynamic Analysis	

Table 1 - Loads Summary

As mentioned earlier, LRFD load combinations will be used in all of our analyses. Every load case is presented below in Table 2. For cases 3c, 3d, 4a, 4b and 6a, lateral wind loading will be analysed in both directions. The same will be done in our time history analysis with the earthquake loading cases 5a, 5b, 7a and 7b in order to obtain a force envelope.

Case		Combination
1	a	1.4D
2	a	$1.2D + 1.6L + 0.5L_r$
	b	1.2D + 1.6L + 0.5S
3	a	$1.2D + 1.6L_r + L^*$
	b	1.2D + 1.6S + L*
	c	$1.2D + 1.6L_r + 0.5W$
	d	1.2D + 1.6S + 0.5W
4	a	$1.2D + 1.0W + L^* + 0.5L_r$
	b	1.2D + 1.0W + L* + 0.5S
5	a	1.2D + 1.0E + L* + 0.2S
	b	1.2D - 1.0E + L* + 0.2S
6	a	0.9D + 1.0W
7	a	0.9D + 1.0E
	b	0.9D - 1.0E

Table 2 - Load Combinations

Following ASCE 7-10, L* will be taken as L instead of 0.5L, since L is greater than 100 psf. The sketch below shows all dimensions of our typical frame with the location of every load. The next step involves on defining our bracing schemes.

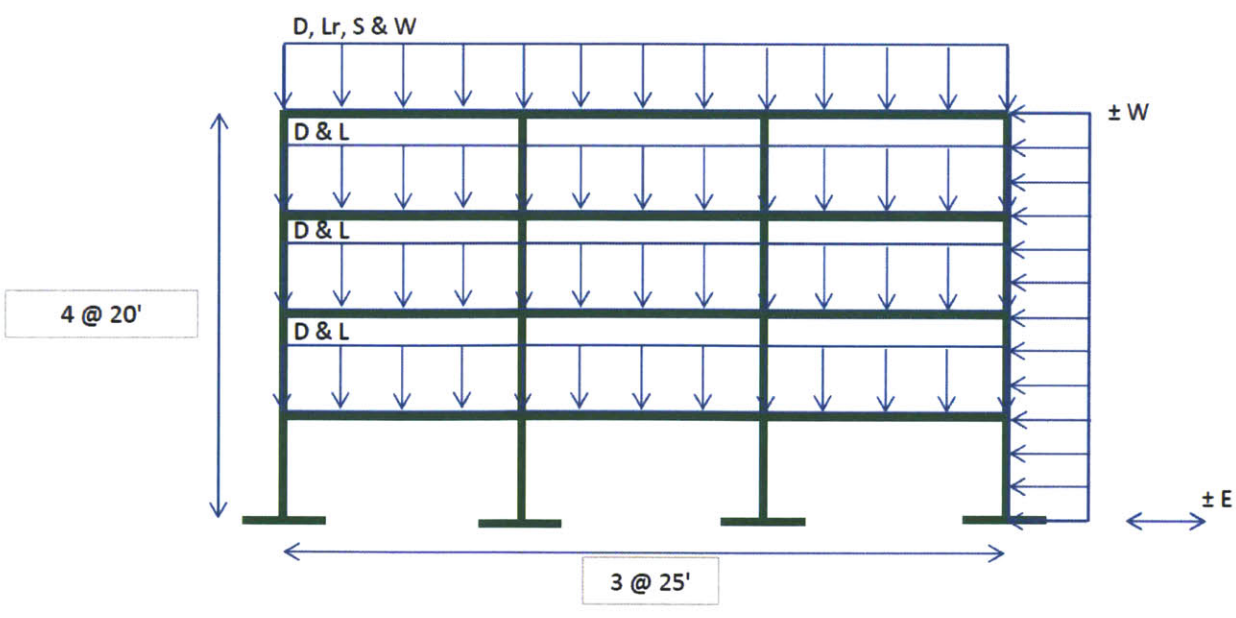

Figure 3 - Typical Frame Overview

CHAPTER 3: BRACING CONFIGURATIONS

To counter lateral loads, our typical frame needs a bracing system. We came up with nine different configurations of bracing. The first bracing configuration is copied from the original structural plan of the building and consists of multiple traditional x-bracings. The second, third and fourth configurations are also x-bracings but in a different pattern.

The fifth, sixth and seventh configurations are similar to previous patterns but with chevron bracings instead of x-bracings. The eighth configuration is quite simple and made of four single braces. Our last configuration is a mix between v-bracings and chevron bracings. All bracing configurations can be found below on figures 4 to12.

Those bracing configurations are really common lateral systems and mainly used in tall buildings. All brace members are going to be 2L6x6x3/8 (double angles back to back) as per structural plans. Now that we have our bracing configurations, we can model our braced frames in SAP2000.

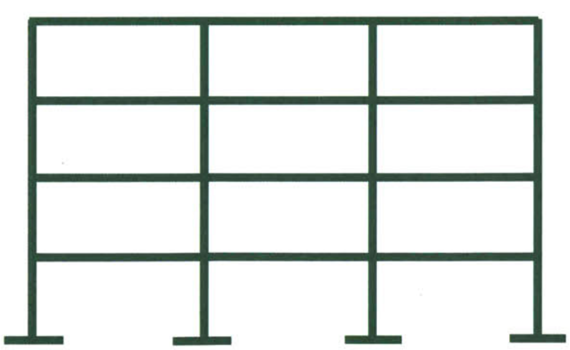

Figure 4 – Typical Frame

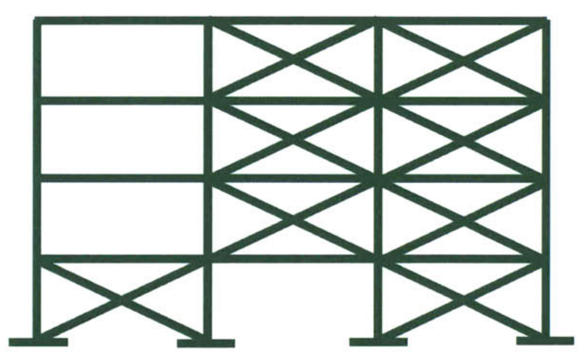

Figure 5 – Bracing Configuration 1

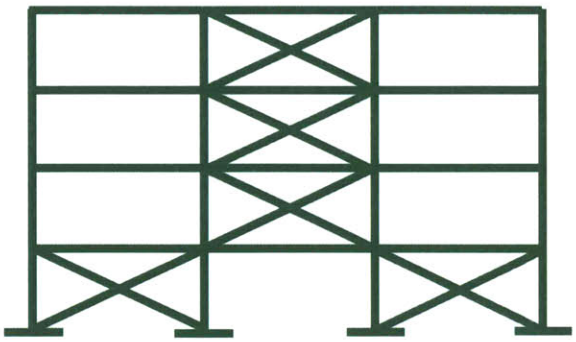

Figure 6 – Bracing Configuration 2

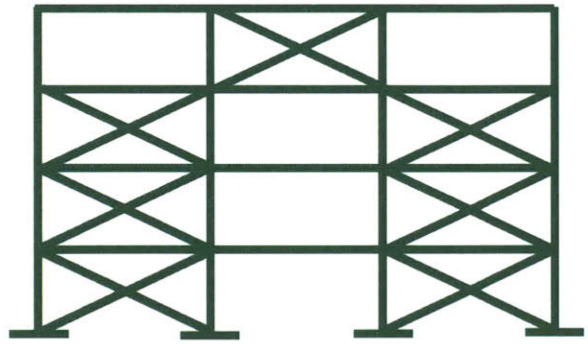

Figure 7 - Bracing Configuration 3

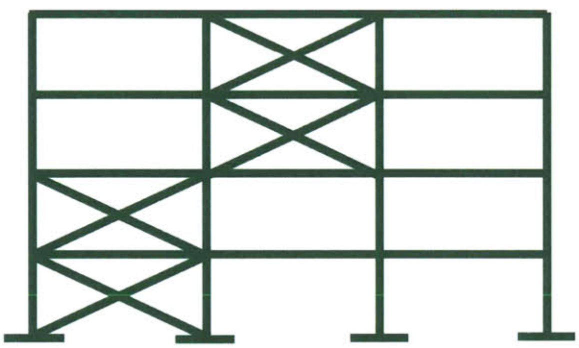

Figure 8 - Bracing Configuration 4

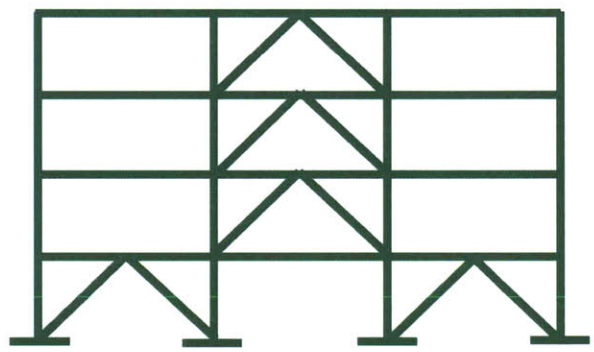

Figure 9 - Bracing Configuration 5

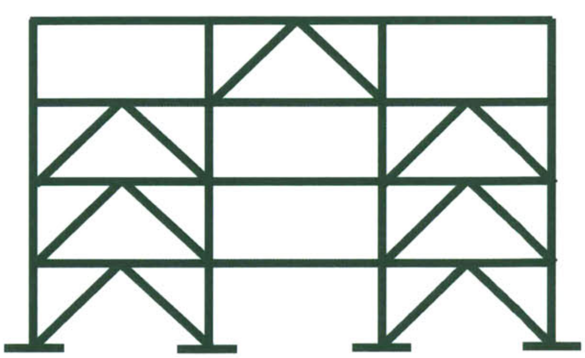

Figure 10 - Bracing Configuration 6

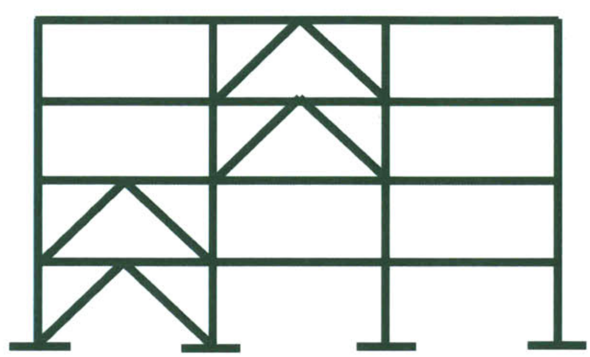

Figure 11 - Bracing Configuration 7

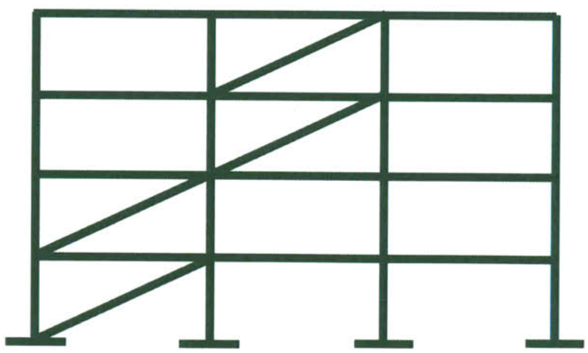

Figure 12 - Bracing Configuration 8

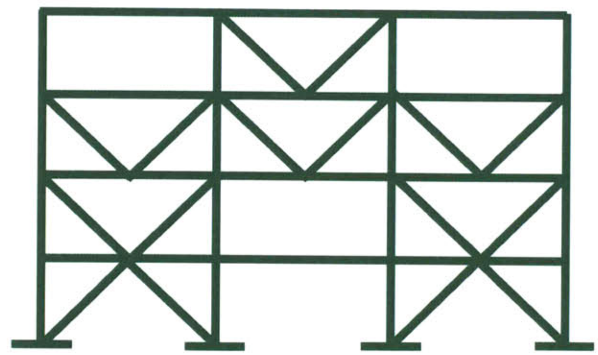

Figure 13 - Bracing Configuration 9

CHAPTER 4: SAP2000 MODEL

4.1 BUILDING THE MODEL

Our frame will be modeled in 2D (XZ plan). Column members are defined as W18x119 while girders are W16x40 sections. Numbering is an important issue here and need to be the same for all braced frames. The following figure shows the numbering of each horizontal member and nodes.

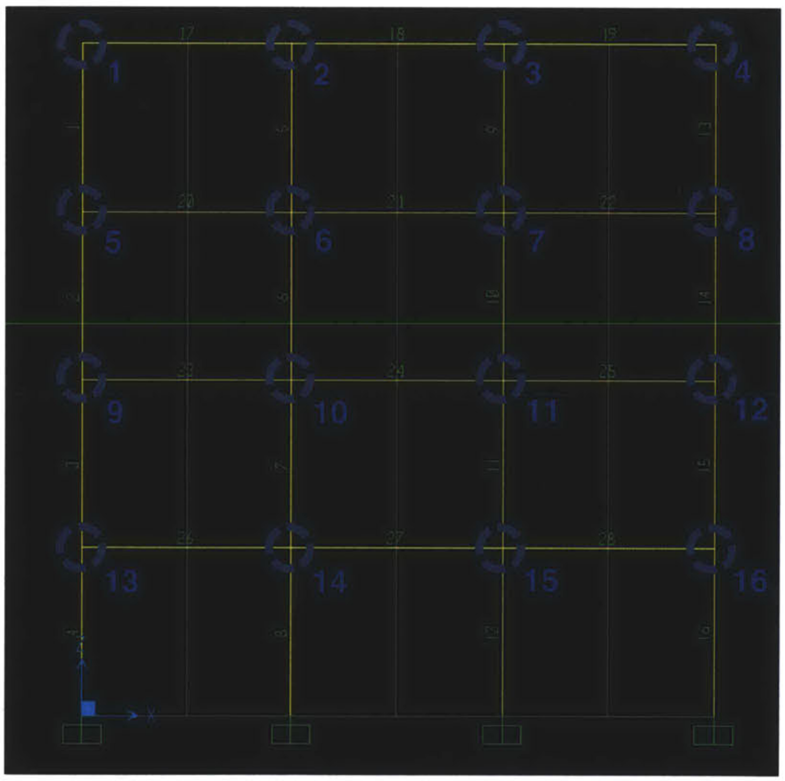

Figure 14 - Members & Nodes Numbering

Next, we restrain our columns by completely fixing them at their base (no rotation and translation allowed). We then define our load patterns (D, L, L_r, S, W and E) and apply them to the frame. The last step in building our model would be to input our load combinations defined earlier.

4.2 Massachusetts Earthquake Scaling

To scale down our California earthquake to a standard Massachusetts quake for our time history analysis, we will compare both frames under static earthquake loading and do a ratio of their maximum displacements. We start be defining two response spectrum functions (with the IBC 2006, SAP2000 integrated code) for both Altadena & Massachusetts areas. To do that, we need both respective zip codes and site classes in order to have adequate properties of our earthquakes. We will assume a 0.05 (5%) damping ratio in our typical frame.

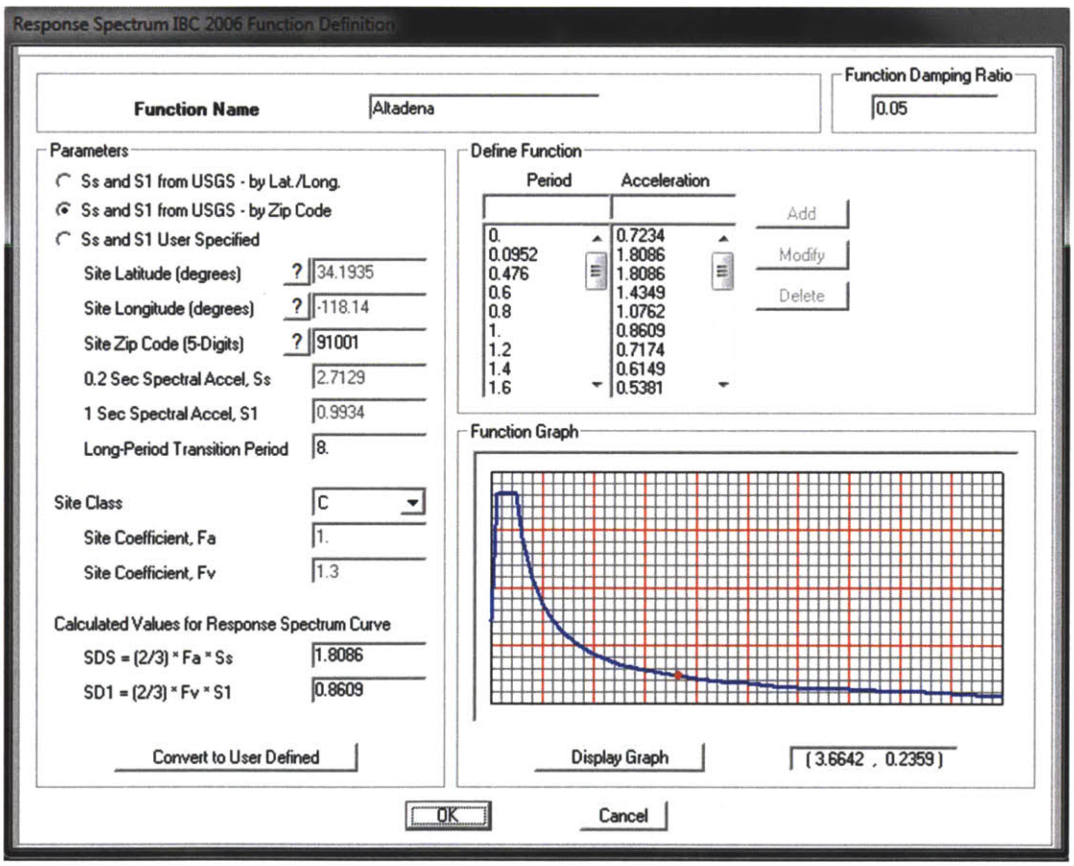

Figure 15 - Altadena Response Spectrum Proprieties

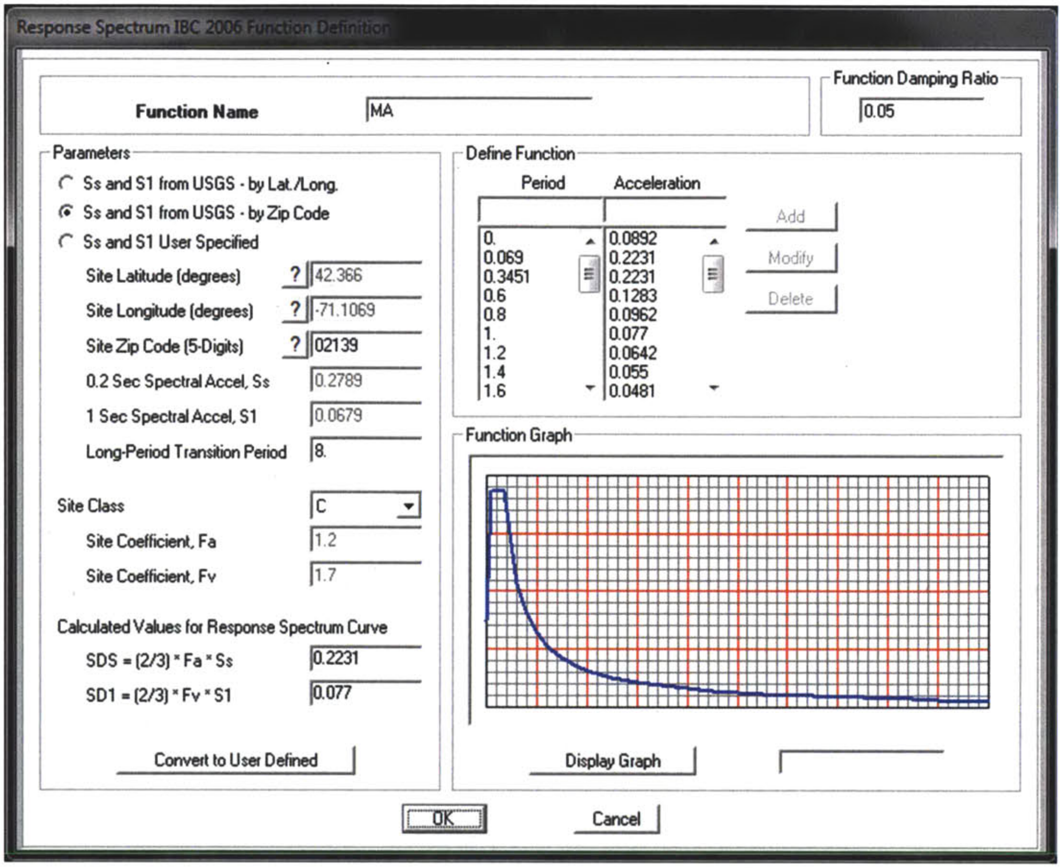

Figure 16 - Massachusetts Response Spectrum Proprieties

Once we have two appropriate response spectrum functions, we need to define them as a load case type to our earthquake load patterns (QUAKE 2 & 3 in the figure below). Note that the load pattern QUAKE will be used as a time history load case defined in the next section of this chapter.

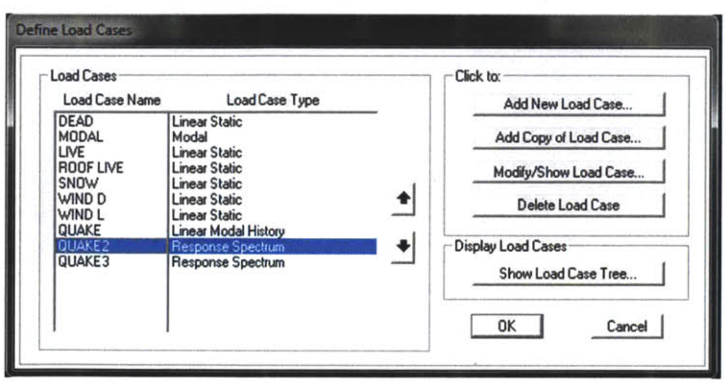

Figure 17 - Assign Load Case Type to the Earthquake Load

Running an analysis for both static earthquakes, we find the nodes with the maximum displacement and do a ratio between them. For the Altadena earthquake, the maximum displacement is 0.0011 foot while for the Massachusetts earthquake, it's 0.0001 foot. The ratio between both displacements equals:

$$Scale\ factor = \mu = \frac{u_{\max MA}}{u_{\max CA}} = \frac{0.0001}{0.0011} = 0.0909$$

In our time history analysis, we will scale down our California earthquake by this factor in order to have more realistic results. The next two figures (18 & 19) show the deformed shape of our frame under the static earthquake loading with their maximum displacement in the x-direction (circled in red).

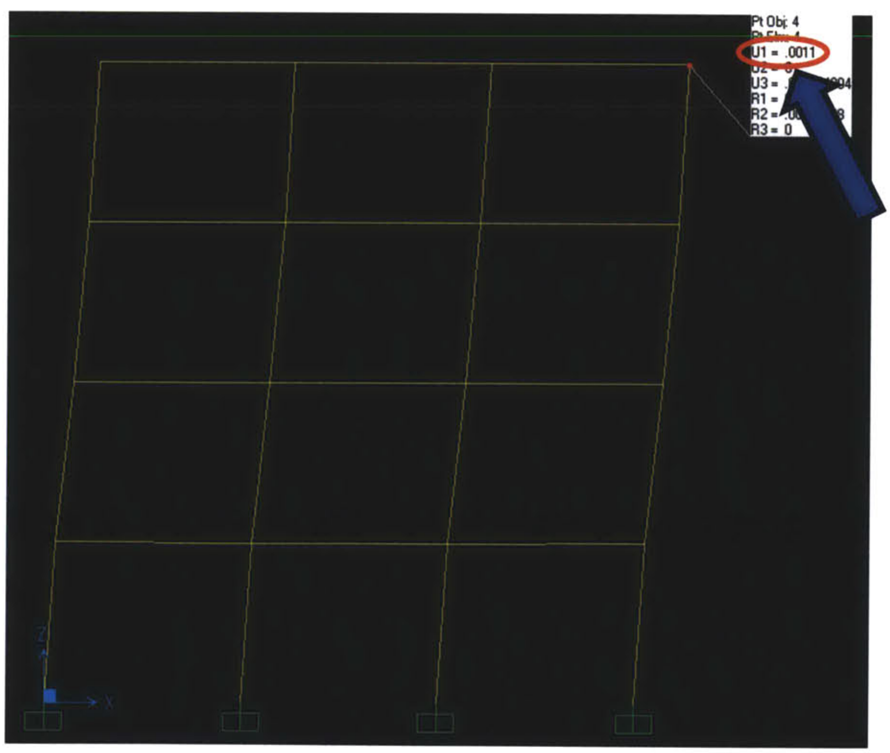

Figure 18 - Max. Displacement (Altadena Static Quake)

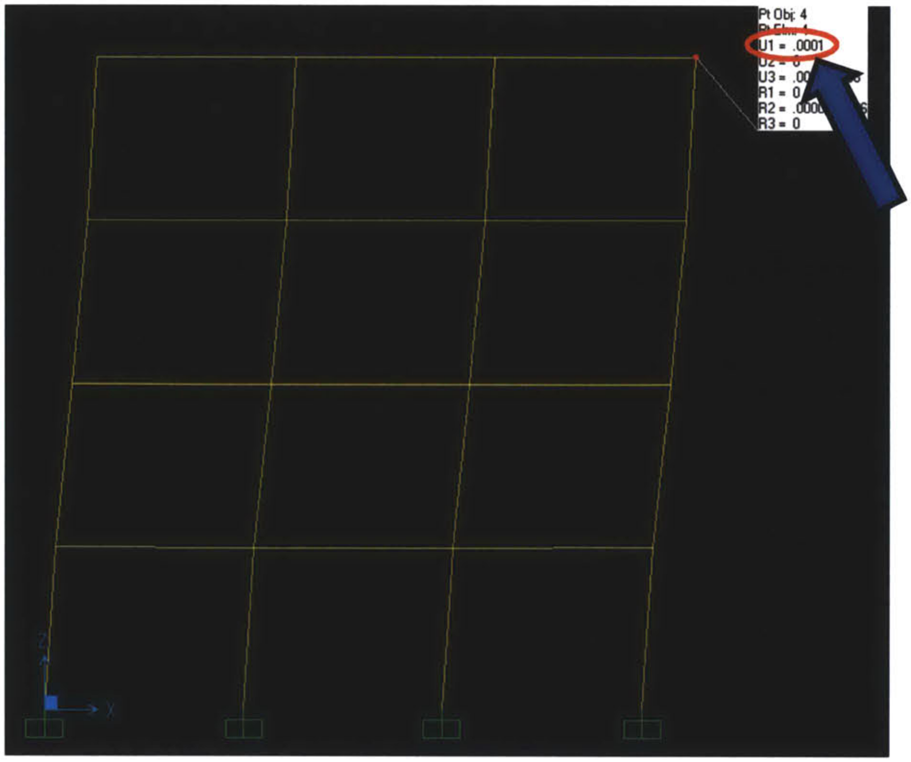

Figure 19 - Max. Displacement (Massachusetts Static Quake)

4.3 Time History Analysis Detail

To create a dynamic earthquake in SAP2000, we have to use a time history function. This function is defined from a .th (extension type) file built-in SAP2000's database. We have multiple choices of earthquake accelerograms to choose from and luckily for us, Altadena earthquake is one of them! Using those accelerogram values spaced equally at an interval of 0.02 second we can define our function (see figure 20).

Next, we need to modify our load case type QUAKE (Linear Modal History) with the appropriate scale factor. Note that accelerogram values are in cm/s^2, and all of our loads are in kips/ft. To have suitable results, we need to multiple our scale factor by 0.0328ft/cm. The final scale factor to be used is equal to 0.00298 (shown in figure 21).

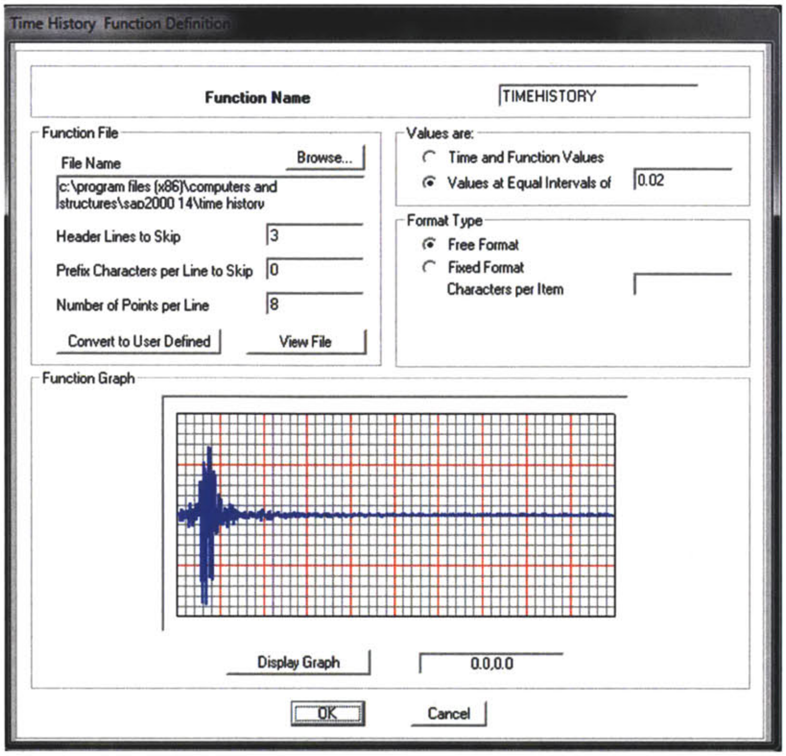

Figure 20 – Time History Function

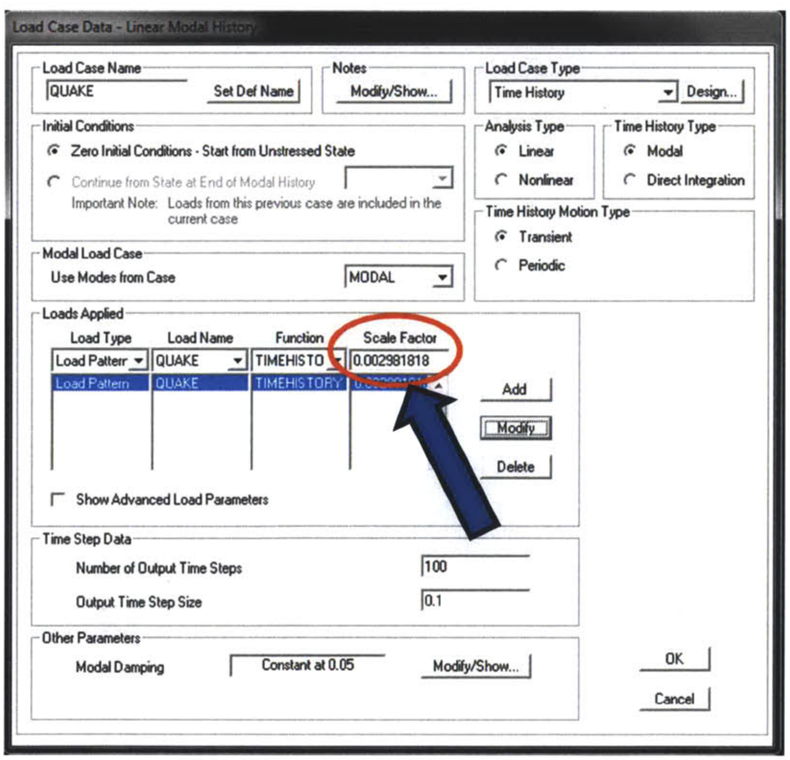

Figure 21 – Apply the Scale Factor to the Load Case

This time history analysis will give us a force envelope for each member, which represent the maximum and minimum axial forces in the member for the total duration of the earthquake. On the next figure, we can see the force envelopes for an earthquake created with a time history function (bracing configuration 4).

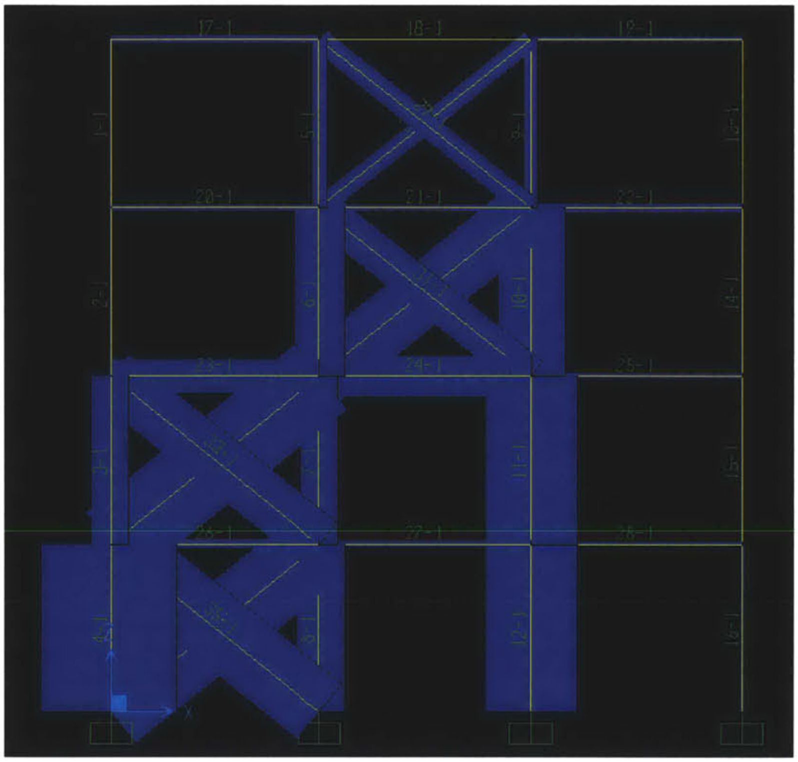

Figure 22 – Example of Force Envelopes Under a Dynamic Earthquake

The last step is to add every other bracing configuration (bracing members are 2L6x6x3/8) to the model and run multiple analyses to find the axial force in all horizontal members, for each load combination. Once we have those forces, we can now determine the pass through force at a joint. The next section of this thesis shows how we determined the absolute maximum PTF at all joints for our nine braced frames.

CHAPTER 5: RESULTS

First thing we needed to do was to export the values from SAP2000 to Excel. Once we exported all those values for every load combination, we could use a Pivot Chart in Excel to find the maximum and/or minimum axial forces in every member. The following chart (Table 3) is an example for the first bracing configuration. The members are numbered the same way mentioned earlier (see figure 14 and/or figure 23 at the end of this chapter).

Axial (+W)	Axial Load (kips)											
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB1a	-4.178	-2.637	-3.205	1.667	5.901	5.228	-0.606	9.925	5.649	5.658	0.699	10.493
COMB2a	-8.751	-8.967	-8.827	-4.241	7.924	6.273	-0.302	27.543	14.829	18.951	1.239	31.374
COMB2b	-9.018	-9.009	-8.936	-3.934	8.353	6.655	-0.352	27.835	14.992	19.048	1.265	31.569
COMB3a	-8.186	-6.667	-7.113	-0.535	9.055	7.572	-0.642	21.91	11.921	14.161	1.135	23.986
COMB3b	-9.039	-6.8	-7.465	0.447	10.425	8.797	-0.802	22.845	12.441	14.47	1.22	24.61
COMB3c	-9.207	-3.9	-4.329	-3.121	6.482	7.541	-7.756	8.498	6.457	4.744	1.778	10.471
COMB3d	-10.06	-4.033	-4.68	-2.14	7.853	8.766	-7.917	9.433	6.977	5.053	1.863	11.095
COMB4a	-14.851	-9.228	-8.385	-14.911	4.538	7.109	-14.252	16.864	12.355	12.288	3.038	23.586
COMB4b	-15.118	-9.27	-8.495	-14.605	4.966	7.492	-14.303	17.156	12.518	12.384	3.064	23.781
COMB6a	-10.525	-4.44	-3.816	-11.955	1.161	4.582	-14.221	2.621	4.781	2.19	2.468	7.204

Axial (-W)	Axial Load (kips)											
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB3c	-3.394	-1.472	-3.408	12.237	12.369	9.23	5.694	14.479	6.543	6.926	-0.04	11.495
COMB3d	-4.248	-1.605	-3.76	13.219	13.74	10.454	5.534	15.414	7.063	7.235	0.045	12.119
COMB4a	-3.226	-4.373	-6.544	15.805	16.312	10.485	12.648	28.826	12.527	16.652	-0.598	25.633
COMB4b	-3.493	-4.414	-6.654	16.112	16.74	10.868	12.598	29.118	12.69	16.749	-0.571	25.828
COMB6a	1.1	0.416	-1.975	18.761	12.935	7.958	12.679	14.583	4.953	6.554	-1.167	9.251

Earthquake	Axial Load (kips)											
Member #	17		18		19		20		21		22	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	-6.142	-7.5	-5.99	-6.941	-6.521	-6.562	-1.226	-3.103	7.371	6.244	5.622	5.534
COMB5b	-6.098	-7.456	-5.959	-6.91	-6.52	-6.562	-1.157	-3.034	7.413	6.286	5.629	5.541
COMB7a	-2.029	-3.387	-1.235	-2.186	-2.04	-2.081	1.976	0.099	4.336	3.209	3.401	3.313
COMB7b	-1.985	-3.343	-1.204	-2.156	-2.039	-2.081	2.045	0.167	4.378	3.251	3.408	3.32

Member #	23		24		25		26		27		28	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	0.093	-0.889	21.112	19.614	11.866	10.339	15.796	11.659	2.854	-0.735	23.14	22.795
COMB5b	0.127	-0.854	21.165	19.667	11.813	10.286	15.658	11.521	2.73	-0.859	23.149	22.803
COMB7a	0.084	-0.898	7.103	5.605	4.422	2.895	5.775	1.638	2.306	-1.283	6.914	6.569
COMB7b	0.119	-0.863	7.156	5.658	4.368	2.841	5.637	1.5	2.182	-1.407	6.922	6.577

Table 3 - Axial Forces in Members (Bracing Configuration 1)

This last table is divided into three parts; the first part is for static load combinations with the lateral wind load taken in the positive direction; the second part is for the wind load in the opposite orientation, while the last part is the axial force envelopes (max. and min.) for the dynamic load combinations (earthquake load). All other charts for every bracing configuration can be found in Appendix A.

Knowing the axial loads in every member for each load combination, we are now able to find the PTF at any node. First, we won't analyse the exterior nodes and concentrate our study on the interior ones only (node # 2, 3, 6, 7, 10, 11, 14 & 15). This is simply because there is no PTF at those joints. The PTF for every static load combination was calculate as follows:

$$PTF_{node} = abs(F_{AL} - F_{AR})$$

where:

PTF_{node} = Pass Through Force at the node
F_{AL} = Axial Load in the Member Left to the Node
F_{AR} = Axial Load in the Member Right to the Node

For example, the PTF at node 2 for the load combination 1a is the difference between the axial loads in members 17 & 18 of the same load combination. Note that we took the absolute value to be conservative and because the frame could be mirrored. For the dynamic load combinations, we took the maximum absolute value of the difference between the axial load envelopes of each member on each side of the node.

Table 4 shows the PTF at every node for all load combinations as well as the maximum calculated values for the first bracing configuration. Tables 5 through 12 summarize the maximum value of the PTFs for each bracing configuration. Detailed calculations of each case can be found in Appendix B.

Axial (+W)	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB1a	1.541	0.568	4.234	0.673	10.53	4.276	4.959	9.794
COMB2a	0.216	0.14	12.17	1.651	27.85	12.71	17.71	30.14
COMB2b	0.009	0.073	12.29	1.698	28.19	12.84	17.78	30.3
COMB3a	1.519	0.446	9.59	1.483	22.55	9.989	13.03	22.85
COMB3b	2.239	0.665	9.978	1.628	23.65	10.4	13.25	23.39
COMB3c	5.307	0.429	9.603	1.059	16.25	2.041	2.966	8.693
COMB3d	6.027	0.647	9.993	0.913	17.35	2.456	3.19	9.232
COMB4a	5.623	0.843	19.45	2.571	31.12	4.509	9.25	20.55
COMB4b	5.848	0.775	19.57	2.526	31.46	4.638	9.32	20.72
COMB6a	6.085	0.624	13.12	3.421	16.84	2.16	0.278	4.736

Axial (-W)	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB3c	1.922	1.936	0.132	3.139	8.785	7.936	6.966	11.54
COMB3d	2.643	2.155	0.521	3.286	9.88	8.351	7.19	12.07
COMB4a	1.147	2.171	0.507	5.827	16.18	16.3	17.25	26.23
COMB4b	0.921	2.24	0.628	5.872	16.52	16.43	17.32	26.4
COMB6a	0.684	2.391	5.826	4.977	1.904	9.63	7.721	10.42

Earthquake	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB5a	1.51	0.572	10.47	1.837	22	10.77	16.53	23.88
COMB5b	1.497	0.603	10.45	1.872	22.02	10.88	16.52	24.01
COMB7a	2.152	0.846	4.237	1.023	8.001	4.208	7.058	8.197
COMB7b	2.139	0.877	4.211	1.058	8.019	4.315	7.044	8.329

	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
MAX	6.085	2.391	19.57	5.872	31.46	16.43	17.78	30.3

Table 4 - PTFs (Bracing Configuration 1)

Table 4 is divided into three parts (exactly like the precedent table) plus a fourth part showing the maximum PTF at every node.

	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
MAX	8.086	5.293	22.08	14.99	36.25	32.19	21	21

Table 5 - PTFs (Bracing Configuration 2)

	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
MAX	13.85	10.41	13.05	13.05	20.2	20.79	39.17	39.17

Table 6 - PTFs (Bracing Configuration 3)

	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
MAX	8.056	4.89	22.89	19.27	11.18	19.16	35.46	1.384

Table 7 - PTFs (Bracing Configuration 4)

	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
MAX	10.82	10.92	26.2	25.89	27.86	27.85	20.25	20.25

Table 8 - PTFs (Bracing Configuration 5)

	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
MAX	8.051	8.199	25.54	24.79	29	27.88	30.43	25.02

Table 9 - PTFs (Bracing Configuration 6)

	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
MAX	12.21	12.41	18.97	20.21	35.06	20.82	36.12	2.591

Table 10 - PTFs (Bracing Configuration 7)

	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
MAX	5.331	6.206	14.76	20.49	13.05	3.202	46.54	2.652

Table 11 - PTFs (Bracing Configuration 8)

	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
MAX	13.25	13.25	8.165	7.711	45.79	45.79	10.11	10.11

Table 12 - PTFs (Bracing Configuration 9)

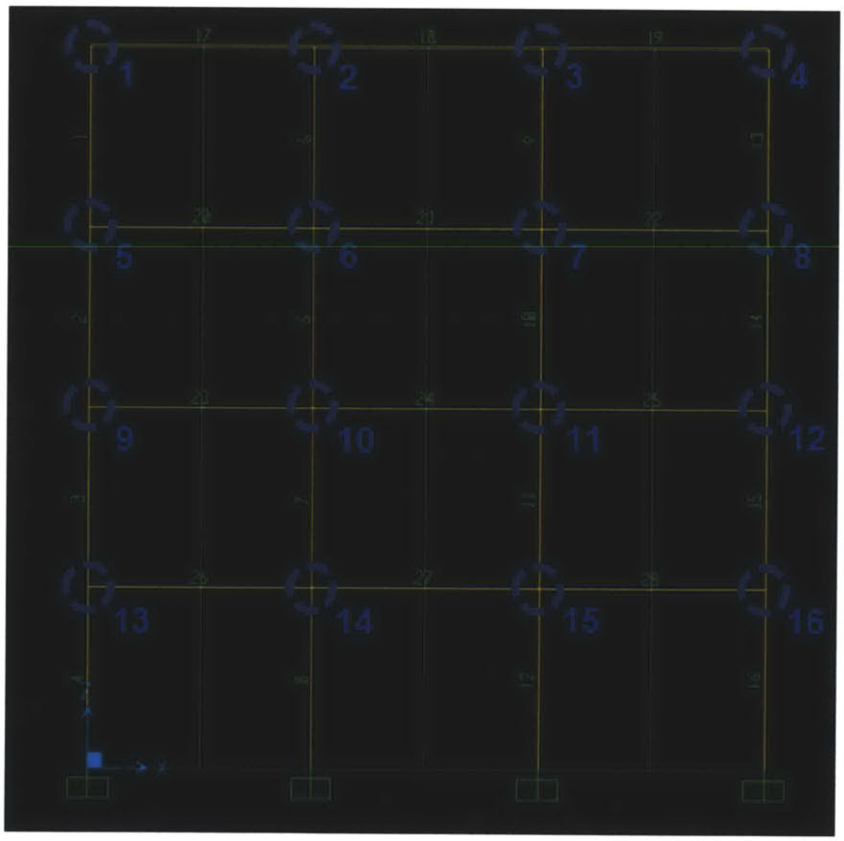

Figure 23 - Reminder of Members & Nodes Numbering

In the next chapter of this thesis, we will analyse each case as well as comparing our results with 2 different methods.

Chapter 6: Analysis & Comparison

6.1 Analysis

By looking at every PTF we calculated in the previous chapter, we can see that for every bracing configuration, PTFs at the top nodes (#2 & 3) are pretty small. This is mainly due to the load path taken by the load from the top to the bottom of the frame. A PTF will occur when the force in the bracing need to take a horizontal path instead of going directly to the ground. Since there is no bracing above the top nodes, no force is added to the members. Actually, PTFs at the top nodes are due to the fact that lateral forces go directly into the diagonal bracing (following the load path to the ground), which reduce the axial load in the members. Usually, PTFs less than 10 kips are not a big issue and barely affect the design of the steel connection.

6.1.1 Bracing Configuration 1

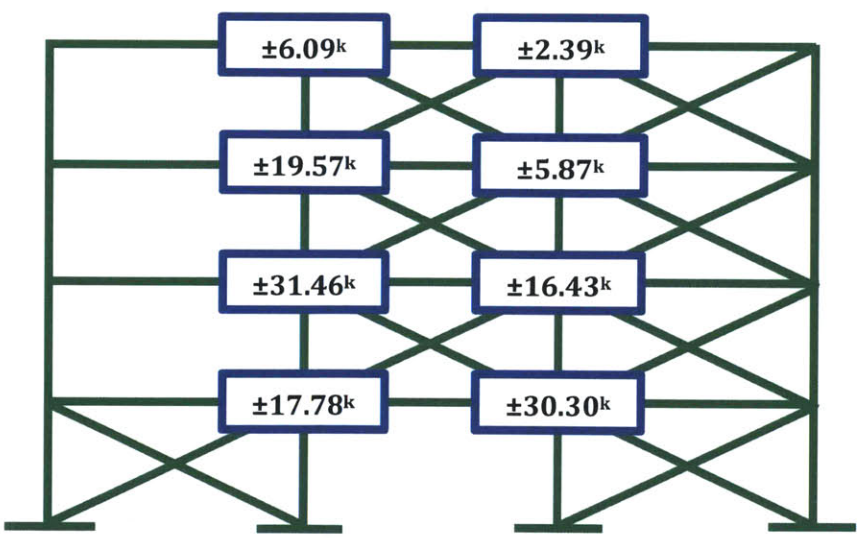

Figure 24 - PTFs Sketch (Bracing Configuration 1)

For the first bracing configuration, we can see that critical PTFs happen at nodes where bracings are non-symmetrical (nodes 6, 10 & 15). If bracings are symmetrical, the force follows the load path to the ground by transferring the majority of its force to the opposite bracing instead of going in the horizontal member. Maximum PTFs are located at nodes 10 (±31.46 kips) and 15 (±30.30 kips). Because bracings are not symmetrical at those locations, the forces will follow a different path to the ground, resulting in PTFs.

6.1.2 Bracing Configuration 2

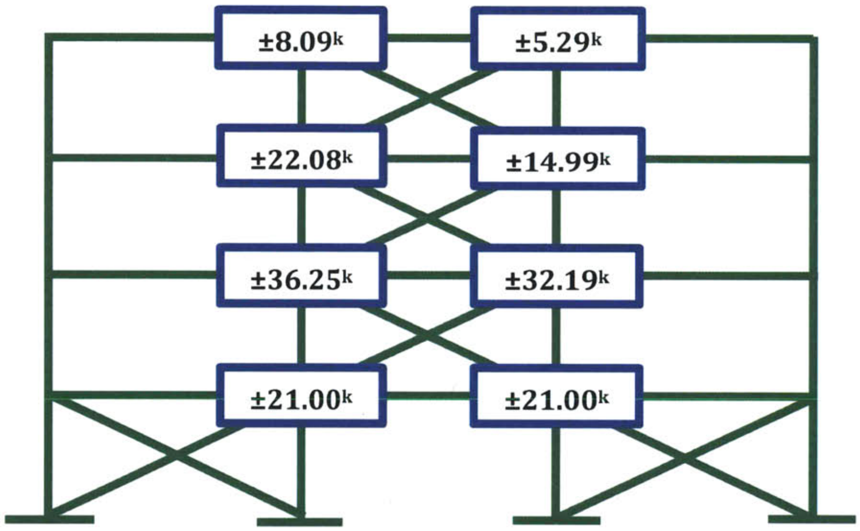

Figure 25 - PTFs Sketch (Bracing Configuration 2)

Again, for this bracing configuration, PTFs have a higher value at nodes where the bracing isn't symmetric. Critical values can be found at nodes 10 (±36.25 kips) and 11 (±32.19 kips). Forces follow the load path from the top of the building to the bottom (through bracings & columns) and when they arrive at those nodes, the unsymmetrical pattern of the bracing forces them to take a different path. Since the force has been built-up from the top (accumulation of lateral and gravity loads), the PTFs at those locations are the highest. We can also see that PTFs are smaller near the bottom, since forces go directly from one bracing to the other due to the symmetry in the brace configuration at those nodes.

6.1.3 BRACING CONFIGURATION 3

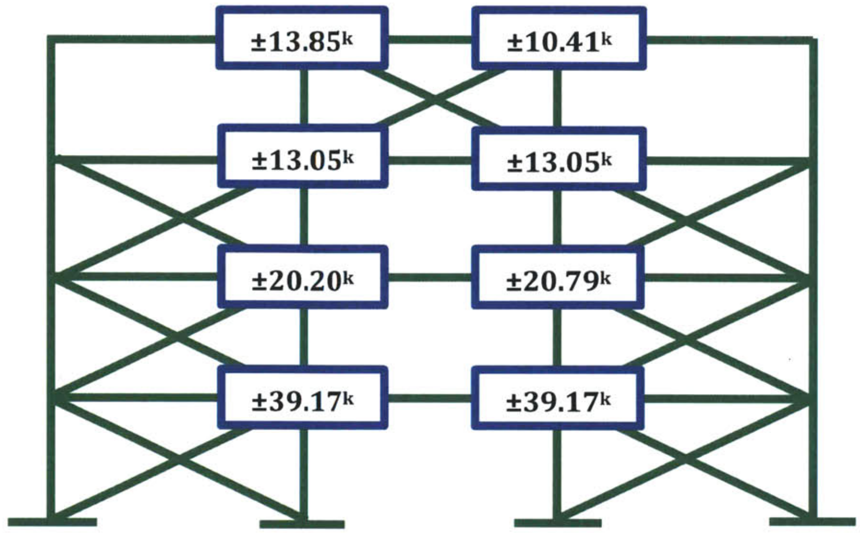

Figure 26 - PTFs Sketch (Bracing Configuration 3)

Like the previous bracing configuration, the highest values of PTFs are where the bracing scheme is non-symmetric. In this case, near the bottom of our frame we find the maximum values of PTFs.

6.1.4 BRACING CONFIGURATION 4

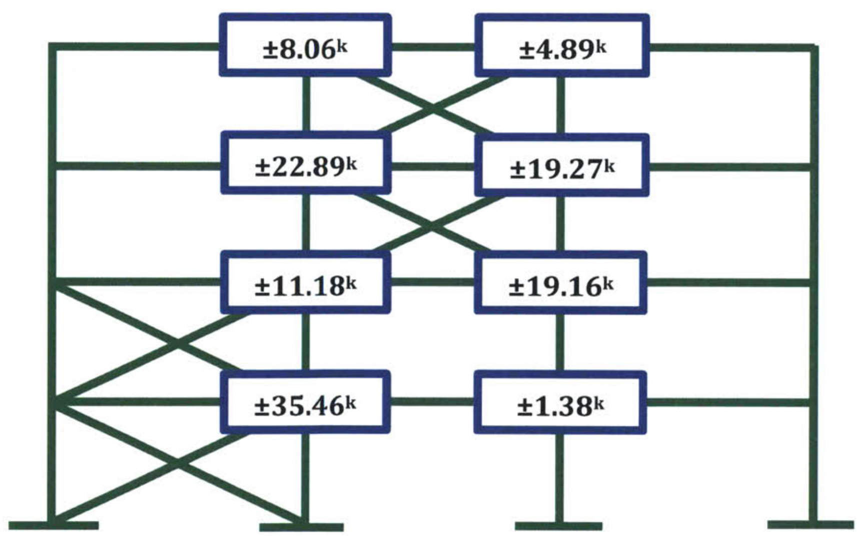

Figure 27 – PTFs Sketch (Bracing Configuration 4)

Here is a good example to prove our point that node where bracings are symmetric introduces less PTFs. Nodes 10 (±11.18 kips) and 15 (±1.38 kip) have a bracing scheme symmetric and missing respectively. Those two nodes have less PTFs than others (expect for the top nodes). Again, the maximum PTF is at the bottom, at node 14 (±35.46 kips). The next bracing configurations will be a little bit different by changing the x-bracing scheme to chevron braces.

6.1.5 Bracing Configuration 5

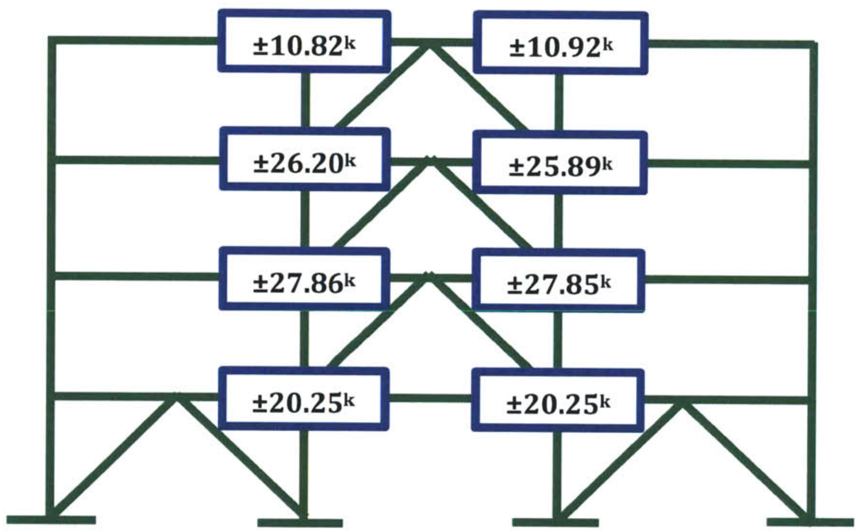

Figure 28 – PTFs Sketch (Bracing Configuration 5)

The next three bracing configurations are chevron braces which follow a quite different pattern if we compare with x-bracings. PTFs are generally smaller in a chevron brace configuration since loads tend to follow a direct path to the ground. In the case of a chevron, nodes don't have any symmetry relative to bracings. PTFs are mainly the result of the horizontal component of the force in the brace, and in the case of a symmetric frame (like we have here), PTFs will be similar at each storey. PTFs at the bottom are smaller since forces follow the shortest path to the ground. An interesting comparison can be done with the second bracing configuration, where PTFs were greater near the bottom and higher in general. Chevron brace schemes reduce PTFs at nodes since bracing take less axial loads (forces go mainly in columns).

6.1.6 Bracing Configuration 6

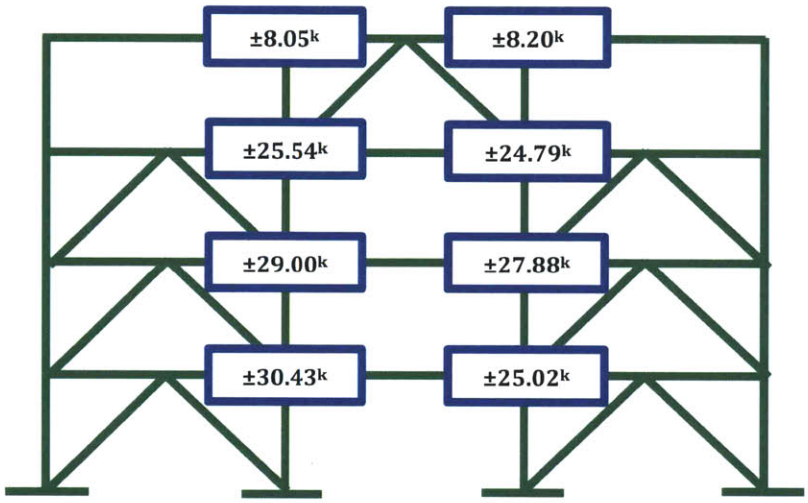

Figure 29 – PTFs Sketch (Bracing Configuration 6)

Here again, we notice the same pattern as the previous bracing configuration, where PTFs are similar at each floor and tend to be smaller at the bottom. Globally, PTFs are smaller if we compare with the third bracing configuration.

6.1.7 Bracing Configuration 7

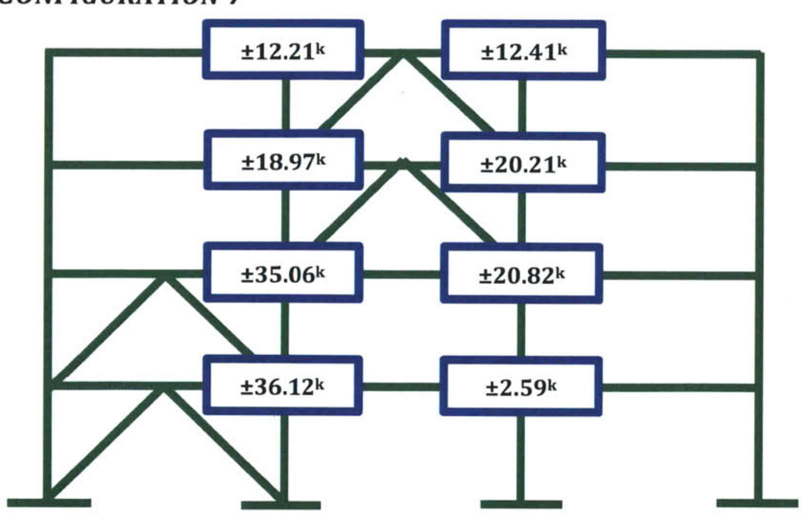

Figure 30 – PTFs Sketch (Bracing Configuration 7)

Due to the asymmetry of this bracing configuration, PTFs at each floor aren't the same. Again, where there is no bracing, the PTF is none. The main PTFs are located at the nodes where bracing frames in (nodes 10 & 14) and if we compare with the fourth bracing configuration, PTFs seem to be higher. This could be due to the load path forces are taking. Bracings on the left-side take much more loads. This bracing configuration demonstrates the load path being less distributed in the frame and columns and more concentrate toward braces. This results in more PTFs at the nodes.

6.1.8 Bracing Configuration 8

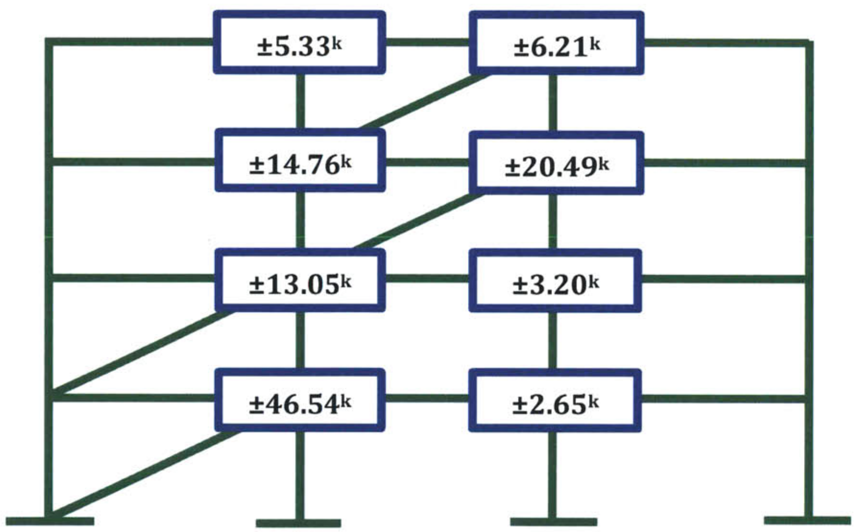

Figure 31 – PTFs Sketch (Bracing Configuration 8)

This bracing configuration is quite similar to the fourth configuration except there are two nodes without any bracing which outcomes small values of PTF. We can see that where bracings are symmetric (node 10), the PTF is small as well. The bracing which takes the most axial loads is the one at the bottom left, and as a result, creates a high value for the PTF in node 14 (±46.54 kips). Since there is less bracings in this configuration, diagonal members tend to take more loads.

6.1.9 Bracing Configuration 9

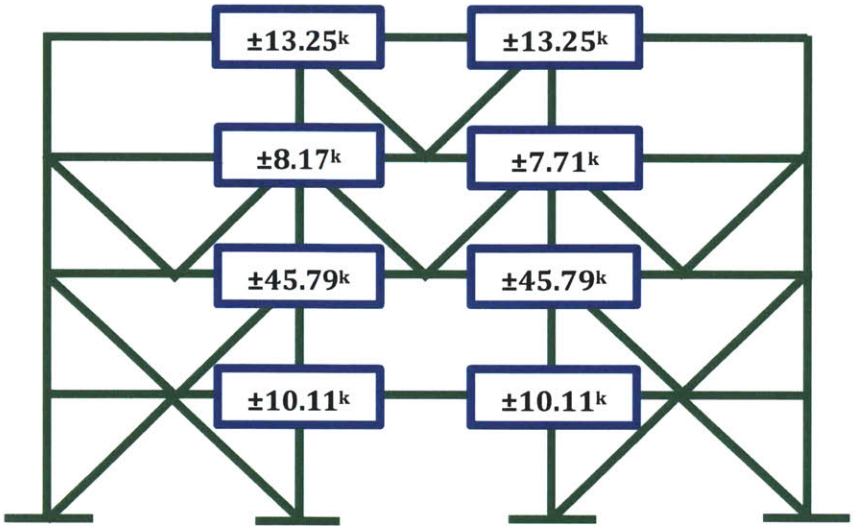

Figure 32 - PTFs Sketch (Bracing Configuration 9)

This last bracing configuration is kind of a mix of every other configuration. We have nodes with symmetry (6 & 7), as well as nodes with uneven symmetry (10 & 11) and nodes without brace (13 & 14). At nodes 6 & 7, the force doesn't have the chance to go from one horizontal member to the other, since it goes in the bracing instead. This results in small PTF at those locations. Because of the non-symmetry of nodes 10 & 11, huge PTFs are generated. Also axial load from center bracings of the third floor add more axial loads in the horizontal member below, which result in more PTFs at those nodes. As always, nodes 13 & 14, where no bracing is framing, have less PTF. As a reminder, because the horizontal component of the axial force in the brace is missing (absent brace) fewer axial loads are carried through the node.

6.2 Comparison

In this section, we will compare our results with two traditional ways of calculating PTFs. The first method consists of calculating the PTF with the maximum values of axial forces in the member (its design value). The second one is more conservative and take the PTF equals to the total axial loading in the bracing.

6.2.1 1ST METHOD

As mentioned earlier, this method consists of taking the design axial load in both girders on each side of the node and do the difference between those forces to get the actual PTF. Doing so, we will need to find the maximum design axial load in each member using the tables in Appendix A. Once we have those design values, we can compute the PTFs with the same formula used earlier (see chapter 5). The big difference of this method is that we calculate only one value of PTF at each node using the design axial force of the members instead of calculating PTFs for every load combination and take the maximum of them.

Using the first bracing configuration as an example, we first determine the maximum (tension) and minimum (compression) values of axial load in the members. The absolute maximum value from the table below is the design axial force (in kips) of the member.

Member #	17	18	19	20	21	22	23	24	25	26	27	28
MAX	1.1	0.416	-1.975	18.761	16.74	10.868	12.679	29.118	14.992	19.048	3.064	31.569
MIN	-15.118	-9.27	-8.936	-14.911	1.161	3.313	-14.303	2.621	2.841	1.5	-1.407	6.569
Abs Max	15.118	9.27	8.936	18.761	16.74	10.868	14.303	29.118	14.992	19.048	3.064	31.569

Table 13 - Design Axial Force of Members (Bracing Configuration 1)

We are then able to compute the PTF (in kips) at each node and compare those values with the results we found. The last row of Table 14 indicates if the PTF calculated with the 1st method is bigger than the one computed earlier. “NG” stands for “No Good”.

Node #	2	3	6	7	10	11	14	15
PTF	5.848	0.334	2.021	5.872	14.815	14.126	15.984	28.505
OK?	NG	NG	NG	NG	NG	NG	NG	NG

Table 14 – Comparison of PTFs using the 1st Method (Bracing Configuration 1)

Looking at the results in Appendix C for this 1st method for all bracing configurations, we find something interesting. The PTFs calculated with the design value of axial force in the members is ALWAYS smaller than what we've computed earlier. This means that if we design a connection using the 1st method, we will probably underestimate the value of PTF, which could result in a failure. It is safer to compute PTFs for every load combination and then take the maximum value.

6.2.2 2ND METHOD

For this second method, we will compare the design axial load in the diagonal members with our PTFs calculated in chapter 5. This method was used in real life for the first bracing configuration (Colonsay Project). We will only analyse the first bracing configuration for this method. First thing we need to do is number each brace.

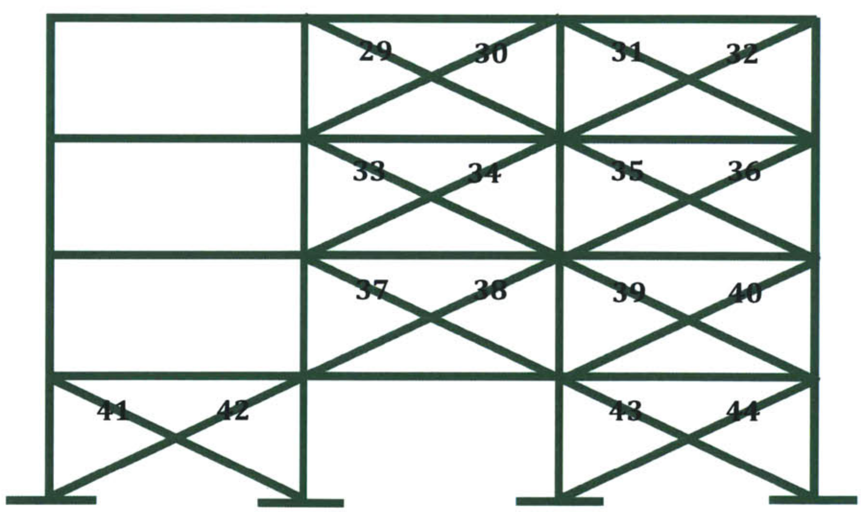

Figure 33 – Bracing Numbering (Bracing Configuration 1)

Using a similar approach with our SAP2000 results, we are able to find the design axial load in each diagonal member (in kips). Notice that the absolute maximum value of axial force in every brace is generated by compression (the absolute of the minimum value in Table 15 always governs). Detailed calculations for the axial force in bracings can be found in Appendix D.

Member #	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
MAX	1.574	-0.935	-0.099	1.869	10.377	0.192	2.001	5.119	7.648	2.983	4.523	5.559	11.219	2.624	2.593	8.61
MIN	-7.479	-8.662	-10.141	-4.005	-14.918	-16.317	-18.676	-7.697	-30.95	-43.435	-28.788	-10.75	-28.502	-66.785	-59.387	-20.283
Abs Max	7.479	8.662	10.141	4.005	14.918	16.317	18.676	7.697	30.95	43.435	28.788	10.745	28.502	66.785	59.387	20.283

Table 15 - Full Axial Force in Diagonal Members (Bracing Configuration 1)

Since PTFs are usually generated by the transfer of load from a bracing to another, we will do a force equilibrium at each node using the forces in the diagonal members (see Table 15). For example, the next figure illustrates the forces at node #15 (surrounded by bracings #37, 40 & 43):

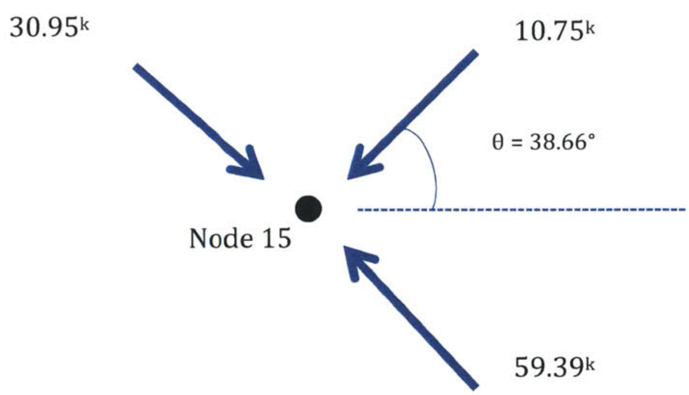

Figure 34 - Force Equilibrium at node 11 (Bracing Configuration 1)

A conservative way of doing this is to assume θ equals to zero. The PTF will be the sum of the full axial force in the bracing. Table 16 displays the value of PTF at each node using the 2nd comparative method.

	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
MAX	7.479	1.479	23.58	1.115	47.267	21.868	23.35	39.18
OK?	OK	NG	OK	NG	OK	OK	OK	OK

Table 16 - PTFs 2nd Method using θ = 0°

If we take the real value of θ (38.66°) and take the horizontal component of the bracing force instead of its full value, we obtain the PTFs in the table below (Table 17). In real life, they usually take θ equals to zero, but can we lower PTFs' values in order to save money in the connection design?

	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
MAX	5.84	1.155	18.413	0.871	36.909	17.076	18.233	30.6
OK?	NG	NG	NG	NG	OK	OK	OK	OK

Table 17 - PTFs 2nd Method using θ = 38.66°

Comparing results of the 2nd method with the values calculated in chapter 5 gives us interesting results. As a reminder, Table 18 shows the calculated PTFs (as per chapter 5) for the first bracing configuration. Starting with the case where θ is equals to zero, PTFs are relatively conservative except for node 3 & 7. Since those two nodes don't see a lot of PTFs (one node is at the top, the other is surrounded by symmetrical bracing) we can assume that it's a realistic and conservative way of computing PTFs.

	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
MAX	6.085	2.391	19.571	5.872	31.459	16.428	17.783	30.3

Table 18 – Reminder of PTFs Calculated for the First Bracing Configuration in Ch. 5

Taking the horizontal component of the bracing force instead of its full value

$$F_h = F \cdot \cos(\theta)$$

results in similar PTF at the node. We can see that PTFs at node 2, 3 & 7 are still smaller than the PTFs calculated in chapter 5. As mentioned earlier, top nodes and nodes with symmetrical bracing don't really cause a problem, since PTFs are generally small. For this case, we need to be careful because at node 6 (an asymmetrical node), the value of PTF is also smaller. Even if the difference is less than 10% (a little bit less than 6% to be accurate), it could be problematic. Using a conservative method by taking the angle equals to zero is probably the best way of obtaining adequate results if you decide to use the 2nd alternate method.

Following our analysis and comparison, the best way of obtaining the PTF at a node is to look at every load combination in detail. This means to find the maximum axial force in all members and compute the PTF at the joint for each load combination. Then take the maximum PTF of all load combinations to obtain the value to use in the steel connection design.

Using those steps to calculate the PTF will result in the cheapest and safest way of designing steel connections. The first method shouldn't be use at all while the second could be used but with caution and good judgement. If you don't know the PTF at a node and need to design a steel connection, the best alternative would be to use the second method with an angle equals to zero, since it is the most conservative and less time consuming.

6.3 Moving Forward

Now that we understand a little bit more where pass through forces come from, we could try to come up with a model for plan instead of elevation. PTFs can also be found in plan view as part of the lateral system. A similar model could be done to see if results concord. The next step would be to create a 3D model and find PTFs in all directions at a node. Sometime, connection designs can be tricky and the more accurate your design loads are, the more money you will save designing your connections. The next figure shows the complexity of some connections and how important it is to minimise the steel used in your connection. Overdesigned connections can increase the total cost of your building by a huge factor.

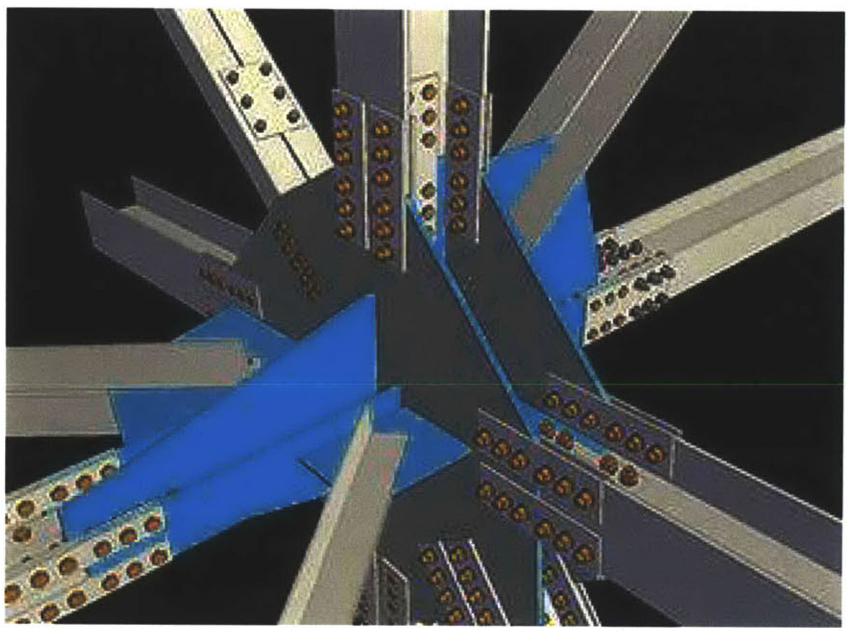

Figure 35 – Complex Steel Connection[2]

[2] Thanks to ADF Group Inc. (Fabricator of Complex Structural Steel and Heavy Built-Up Steel Components) for letting me use this picture in my thesis!

CHAPTER 7: CONCLUSION

Looking back at our results, we learned interesting facts about pass through forces. We first defined our static loads using the ASCE 7-10 as well as IBC 2012 codes and then scaled down a California earthquake to represent the magnitude of a Massachusetts quake so we could do a dynamic time history analysis. Using an existing braced frame and common bracing configurations, we have created multiple models in SAP2000 to analyse.

Exporting axial loads from SAP2000 to Excel and then using a Pivot Chart to find the maximum and minimum forces for each member of all load combinations of every bracing configuration was necessary to obtain accurate values of pass through forces. Then, knowing the axial force in each member on both sides of a node, we were able to calculate the pass through force at that node for each load combination. The maximum of those pass through forces was used to analyse each bracing scheme.

Comparing each bracing configuration's result, we learned that top nodes and nodes with symmetrical bracing carry fewer pass through force. This is due to the load path forces take from the top of the frame to the ground. If the force is able to transfer directly to the opposite bracing instead of going in the horizontal member, fewer pass through force will occur. Nodes without bracing have small value of pass through force, while nodes with asymmetric bracings are more subject to pass through force.

Next, we compared our results with two traditional methods of computing pass through forces. The first one consists of taking the design axial force of each member to calculate the pass through force at the joint. This method underestimates pass through forces and shouldn't be use. The second method is quite conservative and requires doing a force equilibrium at the node with the full or horizontal component of the force in the bracing. This second method needs to be used with caution in order to obtain accurate results.

The following step would be to expand our model to horizontal bracings on a plan view and see if we obtain concurring results. A 3D model could also be done to really understand in depth the pass through force phenomenon. Buildings getting taller every year, lateral systems take more axial loads which create larger values of pass through forces. Fully understand pass through forces will result in cost savings for steel connection design.

REFERENCES

BOOK

- *Minimum Design Loads for Buildings and Other Structures.* Reston, VA: American Society of Civil Engineers, 2010. Print.
- *2012 International Building Code.* Country Club Hills, IL: ICC, 2012. Print.
- *Steel Construction Manual Fourteenth Edition.* American Institute of Steel Construction, 2011. Print
- McCormac, Jack C. *Structural Steel Design Fifth Edition.* New York: Harper & Row, 1981. Print.
- Green, P.S., Sputo, T., and Veltri, P. (n.d.) *Connections Teaching Toolkit – A Teaching Guide for Structural Steel Connections.* American Institute of Steel Construction, Inc. Chicago, IL. Print
- Thornton, William A. *"Connections: Art, Science, and Information in the Quest for Economy and Safety."* Engineering Journal Vol. 32, No. 4 (1995). Print.

WEBSITE

- "Department of Civil and Environmental Engineering." *MIT EECS.* Web. 22 Mar. 2012. <http://www.eecs.mit.edu/ug/thesis-guide.html>.
- Earthquake Engineering Research Center, (EERC). (1997). W.G. Gooden Structural Engineering Slide Library. Godden J119. Web, 25 Mar 2012. <http://nisee.berkeley.edu/bertero/html/recent_developments_in_seismic_design_and_construction.html>.

- Sigi Engineering. *Connections and Bracing Configurations*. Web PDF. 25 Mar. 2012. < http://www.sigi.ca/engineering/civl331_2010/connections_bracing.pdf>.
- "Computers and Structures, Inc." *Computers and Structures, Inc.* Web. 25 Mar. 2012. <http://www.csiberkeley.com/>.
- "Altadena Earthquake Information." *Altadena Los Angeles County California Earthquake History and Probability Risk Grade*. Web. 26 Mar. 2012. <http://www.homefacts.com/earthquakes/California/Los-Angeles-County/Altadena.html>.
- Office of Construction & Facilities Management. *Seismic Design Requirements*. H-18-8. Department of Veterans Affairs. Web PDF. 28 Mar. 2012. <http://www.wbdg.org/ccb/VA/VASEISMC/seismic.pdf>.
- "Time History Analysis With Recorded Accelerograms." *Upload & Share PowerPoint Presentations and Documents*. Web. 2 Apr. 2012. <http://www.slideshare.net/alexpalm/time-history-analysis-with-recorded-accelerograms>.
- "DPHV's Firm Profile." *Accueil*. Web. 2 Feb. 2012. <http://dphv.ca/pages/dphv_profile.htm>.
- "ADF Group Inc." *Fabrication of Complex Structural Steel and Heavy Built-Up Steel Components*. Web. 28 Apr. 2012. <http://www.adfgroup.com/en/home.html>.

PROGRAM

- Computers & Structures, Inc. (CSI) - SAP2000 v14
- Microsoft Office - Excel 2010

APPENDIX A: AXIAL FORCES IN MEMBERS

Frame 0

Axial (+W)	Axial Load (kips)											
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB1a	-4.489	-7.628	-4.489	-4.392	-6.958	-4.392	10.808	-2.996	10.808	4.654	4.451	4.654
COMB2a	-9.826	-23.074	-9.826	-25.126	-30.839	-25.13	31.852	-13.64	31.852	15.082	14.556	15.082
COMB2b	-10.097	-23.314	-10.1	-24.929	-30.803	-24.93	32.181	-13.61	32.181	15.199	14.669	15.199
COMB3a	-8.977	-18.112	-8.977	-16.103	-21.325	-16.1	25.076	-9.311	25.076	11.527	11.11	11.527
COMB3b	-9.842	-18.882	-9.842	-15.475	-21.209	-15.48	26.129	-9.201	26.129	11.903	11.472	11.903
COMB3c	-9.566	-10.513	-6.623	-7.962	-7.727	-2.984	7.284	-2.796	11.63	2.77	2.786	3.174
COMB3d	-10.431	-11.283	-7.488	-7.333	-7.612	-2.355	8.337	-2.686	12.683	3.146	3.148	3.55
COMB4a	-15.762	-21.923	-9.875	-27.877	-25.472	-17.92	15.457	-10.36	24.148	7.067	7.108	7.876
COMB4b	-16.032	-22.163	-10.15	-27.681	-25.436	-17.73	15.786	-10.33	24.478	7.184	7.221	7.993
COMB6a	-10.861	-9.773	-4.974	-13.733	-8.461	-3.777	-1.223	-2.824	7.468	-0.951	-0.643	0.011

Axial (-W)	Axial Load (kips)											
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB3c	-3.646	-7.472	-6.59	4.441	-0.529	-0.537	17.957	3.572	13.611	7.606	7.15	7.202
COMB3d	-4.512	-8.242	-7.455	5.07	-0.414	0.092	19.009	3.682	14.664	7.982	7.511	7.578
COMB4a	-3.923	-15.842	-9.809	-3.072	-11.076	-13.03	36.801	2.375	28.11	16.74	15.835	15.931
COMB4b	-4.193	-16.082	-10.08	-2.875	-11.04	-12.83	37.13	2.41	28.439	16.857	15.948	16.048
COMB6a	0.978	-3.692	-4.908	11.073	5.935	1.117	20.121	9.912	11.43	13.444	8.084	7.913

Earthquake	Axial Load (kips)											
Member #	17		18		19		20		21		22	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	-6.882	-8.367	-16.86	-16.861	-6.774	-8.26	-17.029	-17.21	-19.13	-23.894	-17.038	-17.22
COMB5b	-6.774	-8.26	-16.86	-16.861	-6.882	-8.367	-17.038	-17.22	-19.13	-23.894	-17.029	-17.21
COMB7a	-2.197	-3.682	-4.904	-4.904	-2.09	-3.575	-2.727	-2.91	-2.092	-6.854	-2.737	-2.92
COMB7b	-2.09	-3.575	-4.904	-4.904	-2.197	-3.682	-2.737	-2.92	-2.092	-6.854	-2.727	-2.91
Member #	23		24		25		26		27		28	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	24.147	8.125	-6.825	-12.156	24.264	7.767	11.229	0.412	10.522	10.522	11.181	0.444
COMB5b	24.264	7.767	-6.825	-12.156	24.147	8.125	11.181	0.444	10.522	10.522	11.229	0.412
COMB7a	7.73	0.656	0.74	-4.592	7.847	0.299	3.305	0.041	2.862	2.862	3.257	0.073
COMB7b	7.847	0.299	0.74	-4.592	7.73	0.656	3.257	0.073	2.862	2.862	3.305	0.041

Bracing Configuration 1

Axial (+W)	Axial Load (kips)											
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB1a	-4.178	-2.637	-3.205	1.667	5.901	5.228	-0.606	9.925	5.649	5.658	0.699	10.493
COMB2a	-8.751	-8.967	-8.827	-4.241	7.924	6.273	-0.302	27.543	14.829	18.951	1.239	31.374
COMB2b	-9.018	-9.009	-8.936	-3.934	8.353	6.655	-0.352	27.835	14.992	19.048	1.265	31.569
COMB3a	-8.186	-6.667	-7.113	-0.535	9.055	7.572	-0.642	21.91	11.921	14.161	1.135	23.986
COMB3b	-9.039	-6.8	-7.465	0.447	10.425	8.797	-0.802	22.845	12.441	14.47	1.22	24.61
COMB3c	-9.207	-3.9	-4.329	-3.121	6.482	7.541	-7.756	8.498	6.457	4.744	1.778	10.471
COMB3d	-10.06	-4.033	-4.68	-2.14	7.853	8.766	-7.917	9.433	6.977	5.053	1.863	11.095
COMB4a	-14.851	-9.228	-8.385	-14.911	4.538	7.109	-14.252	16.864	12.355	12.288	3.038	23.586
COMB4b	-15.118	-9.27	-8.495	-14.605	4.966	7.492	-14.303	17.156	12.518	12.384	3.064	23.781
COMB6a	-10.525	-4.44	-3.816	-11.955	1.161	4.582	-14.221	2.621	4.781	2.19	2.468	7.204

Axial (-W)	Axial Load (kips)											
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB3c	-3.394	-1.472	-3.408	12.237	12.369	9.23	5.694	14.479	6.543	6.926	-0.04	11.495
COMB3d	-4.248	-1.605	-3.76	13.219	13.74	10.454	5.534	15.414	7.063	7.235	0.045	12.119
COMB4a	-3.226	-4.373	-6.544	15.805	16.312	10.485	12.648	28.826	12.527	16.652	-0.598	25.633
COMB4b	-3.493	-4.414	-6.654	16.112	16.74	10.868	12.598	29.118	12.69	16.749	-0.571	25.828
COMB6a	1.1	0.416	-1.975	18.761	12.935	7.958	12.679	14.583	4.953	6.554	-1.167	9.251

Earthquake	Axial Load (kips)											
Member #	17		18		19		20		21		22	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	-6.142	-7.5	-5.99	-6.941	-6.521	-6.562	-1.226	-3.103	7.371	6.244	5.622	5.534
COMB5b	-6.098	-7.456	-5.959	-6.91	-6.52	-6.562	-1.157	-3.034	7.413	6.286	5.629	5.541
COMB7a	-2.029	-3.387	-1.235	-2.186	-2.04	-2.081	1.976	0.099	4.336	3.209	3.401	3.313
COMB7b	-1.985	-3.343	-1.204	-2.156	-2.039	-2.081	2.045	0.167	4.378	3.251	3.408	3.32

Member #	23		24		25		26		27		28	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	0.093	-0.889	21.112	19.614	11.866	10.339	15.796	11.659	2.854	-0.735	23.14	22.795
COMB5b	0.127	-0.854	21.165	19.667	11.813	10.286	15.658	11.521	2.73	-0.859	23.149	22.803
COMB7a	0.084	-0.898	7.103	5.605	4.422	2.895	5.775	1.638	2.306	-1.283	6.914	6.569
COMB7b	0.119	-0.863	7.156	5.658	4.368	2.841	5.637	1.5	2.182	-1.407	6.922	6.577

Bracing Configuration 2

Axial (+W)	Axial Load (kips)											
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB1a	-4.118	-2.108	-4.118	1.662	6.481	1.662	-0.587	10.451	-0.587	5.679	-0.228	5.679
COMB2a	-8.535	-6.006	-8.535	-4.287	7.284	-4.287	-0.242	31.641	-0.242	18.99	-1.929	18.99
COMB2b	-8.8	-6.08	-8.8	-3.979	7.808	-3.979	-0.292	31.899	-0.292	19.082	-1.913	19.082
COMB3a	-8.022	-4.814	-8.022	-0.563	9.336	-0.563	-0.597	24.462	-0.597	14.166	-1.198	14.166
COMB3b	-8.87	-5.052	-8.87	0.42	11.013	0.42	-0.756	25.287	-0.756	14.459	-1.147	14.459
COMB3c	-9.051	-3.345	-6.37	-3.121	8.858	4.603	-7.706	9.841	-1.214	4.482	-1.088	2.961
COMB3d	-9.898	-3.583	-7.217	-2.137	10.535	5.586	-7.865	10.666	-1.373	4.775	-1.038	3.254
COMB4a	-14.507	-6.612	-9.146	-14.937	6.922	0.511	-14.145	21.794	-1.161	11.819	-3.254	8.778
COMB4b	-14.772	-6.686	-9.41	-14.63	7.447	0.818	-14.195	22.052	-1.211	11.911	-3.238	8.869
COMB6a	-10.298	-3.48	-4.936	-11.954	4.06	3.493	-14.145	5.184	-1.161	1.707	-2.134	-1.334

Axial (-W)	Axial Load (kips)											
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB3c	-3.413	-1.786	-6.094	12.237	12.948	4.513	5.683	13.334	-0.809	7.122	1.019	8.642
COMB3d	-4.261	-2.024	-6.942	13.22	14.626	5.496	5.524	14.159	-0.968	7.415	1.069	8.935
COMB4a	-3.233	-3.493	-8.595	15.778	15.104	0.33	12.633	28.781	-0.351	17.098	0.96	20.14
COMB4b	-3.498	-3.567	-8.86	16.085	15.628	0.637	12.583	29.038	-0.401	17.19	0.975	20.231
COMB6a	0.977	-0.361	-4.385	18.761	12.242	3.313	12.633	12.171	-0.351	6.986	2.08	10.028

Earthquake	Axial Load (kips)											
Member #	17		18		19		20		21		22	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	-5.881	-7.418	-4.428	-4.428	-5.872	-7.408	-0.985	-3.341	6.609	6.609	-0.98	-3.335
COMB5b	-5.872	-7.408	-4.428	-4.428	-5.881	-7.418	-0.98	-3.335	6.609	6.609	-0.985	-3.341
COMB7a	-1.884	-3.42	-1.355	-1.355	-1.875	-3.411	2.243	-0.112	4.166	4.166	2.249	-0.107
COMB7b	-1.875	-3.411	-1.355	-1.355	-1.884	-3.42	2.249	-0.107	4.166	4.166	2.243	-0.112

Member #	23		24		25		26		27		28	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	0.183	-0.885	23.122	23.122	0.21	-0.857	15.471	11.98	-1.28	-1.28	15.4	11.909
COMB5b	0.21	-0.857	23.122	23.122	0.183	-0.885	15.4	11.909	-1.28	-1.28	15.471	11.98
COMB7a	0.143	-0.925	6.718	6.718	0.17	-0.897	5.432	1.941	-0.147	-0.147	5.361	1.87
COMB7b	0.17	-0.897	6.718	6.718	0.143	-0.925	5.361	1.87	-0.147	-0.147	5.432	1.941

Bracing Configuration 3

Axial (+W)	Axial Load (kips)											
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB1a	-4.25	-0.198	-4.25	0.56	-2.749	0.56	6.976	1.079	6.976	11.821	-0.948	11.821
COMB2a	-8.728	-0.491	-8.728	-6.614	-19.599	-6.614	19.596	-0.516	19.596	36.657	-2.273	36.657
COMB2b	-8.998	-0.498	-8.998	-6.382	-19.43	-6.382	19.809	-0.387	19.809	36.904	-2.262	36.904
COMB3a	-8.212	-0.403	-8.212	-2.757	-12.261	-2.757	15.589	0.688	15.589	27.981	-1.668	27.981
COMB3b	-9.076	-0.423	-9.076	-2.013	-11.719	-2.013	16.273	1.101	16.273	28.771	-1.632	28.771
COMB3c	-9.486	-0.854	-6.271	-0.631	-3.464	0.94	5.67	-0.991	7.693	9.963	-2.62	12.328
COMB3d	-10.35	-0.874	-7.135	0.113	-2.922	1.684	6.353	-0.578	8.376	10.753	-2.584	13.118
COMB4a	-15.253	-1.665	-8.822	-8.978	-17.39	-5.835	11.298	-5.36	15.344	23.397	-5.477	28.127
COMB4b	-15.523	-1.671	-9.092	-8.745	-17.221	-5.602	11.511	-5.231	15.557	23.644	-5.465	28.373
COMB6a	-10.961	-1.416	-4.53	-4.838	-6.151	-1.695	1.132	-4.787	5.179	4.101	-4.369	8.83

Axial (-W)	Axial Load (kips)											
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB3c	-3.309	0.387	-6.525	6.334	2.207	4.762	10.645	5.47	8.622	15.337	1.225	12.972
COMB3d	-4.174	0.367	-7.389	7.078	2.749	5.506	11.328	5.882	9.305	16.127	1.261	13.762
COMB4a	-2.9	0.819	-9.331	4.953	-6.048	1.81	21.248	7.561	17.201	34.145	2.214	29.416
COMB4b	-3.17	0.812	-9.601	5.185	-5.879	2.042	21.461	7.69	17.415	34.392	2.225	29.663
COMB6a	1.392	1.067	-5.039	9.092	5.191	5.949	11.082	8.134	7.036	14.849	3.321	10.12

Earthquake	Axial Load (kips)											
Member #	17		18		19		20		21		22	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	-6.058	-7.711	-0.371	-0.371	-5.904	-7.557	-2.982	-4.772	-13.14	-13.142	-3.159	-4.949
COMB5b	-5.904	-7.557	-0.371	-0.371	-6.058	-7.711	-3.159	-4.949	-13.14	-13.142	-2.982	-4.772
COMB7a	-1.982	-3.636	-0.127	-0.127	-1.829	-3.482	1.343	-0.446	-1.767	-1.767	1.166	-0.623
COMB7b	-1.829	-3.482	-0.127	-0.127	-1.982	-3.636	1.166	-0.623	-1.767	-1.767	1.343	-0.446
Member #	23		24		25		26		27		28	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	14.755	14.135	0.018	0.018	14.822	14.203	26.886	26.47	-1.726	-1.726	26.926	26.509
COMB5b	14.822	14.203	0.018	0.018	14.755	14.135	26.926	26.509	-1.726	-1.726	26.886	26.47
COMB7a	4.76	4.141	0.694	0.694	4.828	4.208	7.788	7.371	-0.609	-0.609	7.828	7.411
COMB7b	4.828	4.208	0.694	0.694	4.76	4.141	7.828	7.411	-0.609	-0.609	7.788	7.371

Bracing Configuration 4

Axial (+W)	Axial Load (kips)										
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB1a	-4.071	-2.302	-4.112	1.346	7.542	1.633	3.378	3.896	-0.593	12.743	1.133	1.141
COMB2a	-8.423	-6.544	-8.55	-5.023	10.332	-4.291	11.019	11.644	-0.568	39.921	4.722	4.93
COMB2b	-8.687	-6.623	-8.815	-4.72	10.884	-3.984	11.093	11.727	-0.621	40.187	4.726	4.938
COMB3a	-7.934	-5.237	-8.03	-1.145	11.72	-0.576	8.352	8.954	-0.819	30.414	3.336	3.488
COMB3b	-8.78	-5.491	-8.878	-0.174	13.484	0.406	8.587	9.218	-0.988	31.263	3.348	3.513
COMB3c	-9.242	-3.545	-6.333	-3.038	9.295	4.713	4.741	8.261	-1.375	10.425	0.895	0.979
COMB3d	-10.088	-3.798	-7.181	-2.067	11.059	5.695	4.976	8.524	-1.545	11.275	0.907	1.004
COMB4a	-14.892	-7.021	-9.09	-14.744	7.902	0.769	10.777	17.38	-1.641	24.853	3.115	3.356
COMB4b	-15.156	-7.1	-9.355	-14.441	8.453	1.076	10.85	17.462	-1.694	25.119	3.119	3.364
COMB6a	-10.738	-3.611	-4.869	-11.399	3.455	3.746	4.92	11.293	-1.437	3.799	0.525	0.636

Axial (-W)	Axial Load (kips)										
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB3c	-3.13	-2.015	-6.121	11.532	14.877	4.35	2.551	0.098	-0.723	16.835	1.128	1.136
COMB3d	-3.976	-2.268	-6.969	12.502	16.64	5.332	2.786	0.362	-0.892	17.685	1.141	1.161
COMB4a	-2.668	-3.96	-8.665	14.395	19.066	0.043	6.398	1.055	-0.336	37.674	3.582	3.67
COMB4b	-2.933	-4.04	-8.93	14.698	19.617	0.35	6.471	1.138	-0.389	37.939	3.586	3.678
COMB6a	1.485	-0.551	-4.445	17.74	14.619	3.02	0.541	-5.032	-0.131	16.62	0.992	0.95

Earthquake	Axial Load (kips)											
Member #	17		18		19		20		21		22	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	-5.62	-7.519	-4.795	-4.861	-5.87	-7.401	-1.786	-3.599	9.621	8.111	-0.831	-3.588
COMB5b	-5.6	-7.499	-4.792	-4.857	-5.903	-7.434	-1.844	-3.657	9.597	8.088	-0.757	-3.514
COMB7a	-1.677	-3.577	-1.449	-1.514	-1.862	-3.392	1.801	-0.012	5.615	4.105	2.391	-0.365
COMB7b	-1.658	-3.557	-1.445	-1.51	-1.895	-3.425	1.743	-0.07	5.591	4.081	2.465	-0.291

Member #	23		24		25		26		27		28	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	12.652	3.133	14.192	2.582	-0.0071	-1.225	30.452	27.676	4.179	2.444	3.825	3.061
COMB5b	12.805	3.286	14.47	2.86	0.139	-1.079	30.391	27.615	4.186	2.45	3.834	3.071
COMB7a	6.854	-2.665	8.171	-3.439	0.155	-1.063	9.61	6.834	1.593	-0.143	1.111	0.347
COMB7b	7.008	-2.511	8.449	-3.161	0.301	-0.917	9.549	6.774	1.599	-0.136	1.12	0.357

Bracing Configuration 5

Axial (+W)	Axial Load (kips)										
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB1a	-4.21	-1.674	-4.21	1.398	4.896	1.398	1.016	3.448	1.016	1.69	3.383	1.69
COMB2a	-8.503	-3.672	-8.503	-5.834	4.513	-5.834	6.402	12.733	6.402	7.22	13.523	7.22
COMB2b	-8.779	-3.769	-8.779	-5.514	4.932	-5.514	6.352	12.757	6.352	7.231	13.526	7.231
COMB3a	-8.089	-3.336	-8.089	-1.55	6.549	-1.55	4.073	9.189	4.073	5.11	9.555	5.11
COMB3b	-8.973	-3.649	-8.973	-0.526	7.888	-0.526	3.914	9.264	3.914	5.143	9.565	5.143
COMB3c	-9.285	-2.634	-6.535	-3.147	9.699	4.464	-6.296	7.752	0.091	6.431	0.982	1.913
COMB3d	-10.169	-2.947	-7.419	-2.124	11.038	5.487	-6.455	7.828	-0.067	6.453	0.992	1.947
COMB4a	-14.694	-4.053	-9.194	-15.742	10.357	-0.52	-9.41	18.374	3.366	13.381	5.667	5.86
COMB4b	-14.97	-4.151	-9.47	-15.423	10.776	-0.2	-9.459	18.397	3.316	13.387	5.67	5.871
COMB6a	-10.526	-2.223	-5.026	-11.887	8.796	3.336	-13.047	11.506	-0.272	12.41	-1.7	1.883

Axial (-W)	Axial Load (kips)										
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB3c	-3.564	0.387	-6.314	12.069	17.151	4.457	7.027	14.685	0.64	8.722	4.88	10.398
COMB3d	-4.447	0.075	-7.197	13.092	18.49	5.481	6.869	14.761	0.481	8.755	4.889	10.419
COMB4a	-3.251	1.989	-8.751	14.69	25.262	-0.533	17.238	32.24	4.462	19.477	13.462	21.313
COMB4b	-3.528	1.891	-9.028	15.009	25.68	-0.214	17.188	32.263	4.413	19.487	13.465	21.319
COMB6a	0.917	3.819	-4.583	18.545	23.701	3.322	13.601	25.372	0.825	15.5	6.096	20.342

Earthquake	Axial Load (kips)											
Member #	17		18		19		20		21		22	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	-5.333	-7.579	-0.009	-5.647	-5.728	-7.974	-1.267	-4.557	12.238	-3.491	-1.869	-5.159
COMB5b	-5.728	-7.974	-0.009	-5.647	-5.333	-7.579	-1.869	-5.159	12.238	-3.491	-1.267	-4.557
COMB7a	-1.386	-3.632	1.743	-3.895	-1.78	-4.026	2.844	-0.445	11.012	-4.717	2.243	-1.047
COMB7b	-1.78	-4.026	1.743	-3.895	-1.386	-3.632	2.243	-1.047	11.012	-4.717	2.844	-0.445

Member #	23		24		25		26		27		28	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	5.268	3.669	19.84	-1.71	4.991	3.393	9.568	-10.71	9.539	9.539	13.083	-7.197
COMB5b	4.991	3.393	19.84	-1.71	5.268	3.669	13.083	-7.197	9.539	9.539	9.568	-10.71
COMB7a	1.591	-0.0076	12.992	-8.558	1.314	-0.284	8.603	-11.68	2.175	2.175	12.118	-8.162
COMB7b	1.314	-0.284	12.992	-8.558	1.591	-0.008	12.118	-8.162	2.175	2.175	8.603	-11.68

Bracing Configuration 6

Axial (+W)	Axial Load (kips)											
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB1a	-3.6	-2.695	-3.6	3.536	-2.649	3.536	7.061	1.913	7.061	7.39	2.776	7.39
COMB2a	-5.494	-7.764	-5.494	3.164	-19.552	3.164	27.378	2.699	27.378	28.247	10.165	28.247
COMB2b	-5.777	-7.875	-5.777	3.503	-19.382	3.503	27.443	2.846	27.443	28.319	10.232	28.319
COMB3a	-6.051	-6.291	-6.051	4.86	-12.196	4.86	19.716	3.062	19.716	20.402	7.587	20.402
COMB3b	-6.958	-6.646	-6.958	5.945	-11.653	5.945	19.925	3.535	19.925	20.633	7.799	20.633
COMB3c	-8.976	-3.362	-5.939	-0.998	-4.135	6.402	1.259	-0.1	9.218	6.387	0.852	10.956
COMB3d	-9.884	-3.718	-6.846	0.087	-3.591	7.486	1.14	0.373	9.426	6.5	1.064	11.188
COMB4a	-12.956	-6.485	-6.88	-9.028	-18.848	5.771	6.527	-2.957	24.925	17.098	3.393	28.402
COMB4b	-13.239	-6.596	-7.163	-8.689	-18.678	6.11	6.49	-2.81	24.991	17.133	3.459	28.474
COMB6a	-10.467	-2.416	-4.391	-6.048	-7.607	4.676	0.283	-4.14	10.035	7.292	-2.118	13.069

Axial (-W)	Axial Load (kips)											
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB3c	-2.979	-0.329	-6.016	13.975	3.06	6.575	16.27	6.393	7.534	18.072	5.258	10.444
COMB3d	-3.886	-0.684	-6.924	15.059	3.604	7.66	16.479	6.866	7.415	18.303	5.47	10.557
COMB4a	-0.96	-0.417	-7.036	20.917	-4.457	6.118	39.031	10.028	19.077	42.632	12.205	25.212
COMB4b	-1.244	-0.528	-7.319	21.256	-4.287	6.457	39.096	10.176	19.04	42.705	12.271	25.247
COMB6a	1.529	3.652	-4.547	19.822	6.784	8.596	24.141	8.845	12.833	27.299	6.694	15.406

Earthquake	Axial Load (kips)											
Member #	17		18		19		20		21		22	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	-3.683	-5.332	-3.827	-7.6	-3.821	-5.47	4.098	-14.73	-13.08	-13.08	3.935	-14.15
COMB5b	-3.821	-5.47	-3.827	-7.6	-3.683	-5.332	3.935	-14.15	-13.08	-13.08	4.098	-14.73
COMB7a	-1.421	-3.07	0.154	-3.619	-1.559	-3.208	3.274	-5.695	-1.703	-1.703	3.111	-5.115
COMB7b	-1.559	-3.208	0.154	-3.619	-1.421	-3.07	3.111	-5.115	-1.703	-1.703	3.274	-5.695

Member #	23		24		25		26		27		28	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	22.946	4.179	2.294	2.294	22.371	4.777	24.13	8.62	7.242	7.242	23.468	9.291
COMB5b	22.371	4.777	2.294	2.294	22.946	4.179	23.468	9.291	7.242	7.242	24.13	8.62
COMB7a	8.108	-2.095	1.23	1.23	7.533	-1.497	8.855	-1.158	1.784	1.784	8.193	-0.487
COMB7b	7.533	-1.497	1.23	1.23	8.108	-2.095	8.193	-0.487	1.784	1.784	8.855	-1.158

Bracing Configuration 7

Axial (+W)	Axial Load (kips)											
Member #	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
COMB1a	-4.412	-1.479	-4.296	2.772	3.721	1.808	1.405	3.039	-0.577	4.785	1.754	1.34
COMB2a	-9.398	-2.853	-8.883	0.243	-0.711	-4.109	7.962	11.082	-0.364	18.997	7.318	5.5
COMB2b	-9.674	-2.95	-9.16	0.565	-0.293	-3.787	7.919	11.098	-0.421	19.017	7.327	5.514
COMB3a	-8.716	-2.756	-8.357	2.704	2.901	-0.328	5.206	7.988	-0.707	13.517	5.182	3.938
COMB3b	-9.6	-3.066	-9.241	3.736	4.237	0.702	5.069	8.041	-0.89	13.582	5.209	3.981
COMB3c	-9.648	-2.513	-6.586	-1.508	9.093	4.929	9.251	7.127	-1.339	11.631	1	0.98
COMB3d	-10.533	-2.825	-7.471	-0.476	10.429	5.96	9.061	7.18	-1.521	11.716	1.028	1.023
COMB4a	-15.693	-3.662	-9.409	-10.613	7.531	0.891	21.481	16.748	-1.412	27.989	4.029	3.368
COMB4b	-15.969	-3.76	-9.685	-10.29	7.948	1.213	21.421	16.765	-1.469	28.016	4.038	3.382
COMB6a	-11.03	-2.106	-5.03	-10.115	8.858	3.799	18.713	10.786	-1.327	17.797	0.012	0.351

Axial (-W)	Axial Load (kips)											
Member #	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
COMB3c	-3.556	0.855	-6.418	12.841	15.598	4.74	8.194	-1.58	-0.817	18.767	2.18	1.593
COMB3d	-4.441	0.546	-7.303	13.874	16.916	5.771	8.056	-1.527	-1	18.833	2.208	1.637
COMB4a	-3.508	3.151	-9.074	18.086	20.637	0.514	19.925	-0.665	-0.369	42.495	6.389	4.595
COMB4b	-3.785	3.055	-9.35	18.408	21.049	0.836	19.882	-0.649	-0.426	42.516	6.398	4.608
COMB6a	1.155	4.532	-4.695	18.583	22.063	3.421	15.433	-6.627	-0.284	32.145	2.372	1.578

Earthquake	Axial Load (kips)											
Member #	**17**		**18**		**19**		**20**		**21**		**22**	
Envelope	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**
COMB5a	-5.648	-8.342	1.073	-5.39	-6.01	-8.305	2.497	0.084	8.293	-8.286	-0.537	-4.292
COMB5b	-6.213	-8.907	0.43	-5.581	-5.533	-7.827	1.969	-0.444	9.749	-7.167	0.286	-3.469
COMB7a	-1.207	-3.901	2.376	-3.911	-1.853	-4.148	3.252	0.84	10.047	-6.625	2.628	-1.127
COMB7b	-1.771	-4.465	1.909	-4.278	-1.375	-3.67	2.725	0.312	11.41	-5.412	3.451	-0.304

Member #	**23**		**24**		**25**		**26**		**27**		**28**	
Envelope	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**
COMB5a	17.8	-19.595	15.462	-3.867	0.325	-1.588	25.832	-0.737	5.809	4.092	4.143	3.435
COMB5b	25.885	-11.51	19.671	0.342	0.768	-1.145	27.23	0.987	6.183	4.465	4.3	3.592
COMB7a	14.985	-22.41	9.514	-9.816	0.364	-1.549	15.498	-10.91	1.799	0.082	1.137	0.429
COMB7b	23.07	-14.325	13.722	-5.607	0.807	-1.106	17.059	-9.347	2.173	0.455	1.294	0.586

Bracing Configuration 8

Axial (+W)	Axial Load (kips)											
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB1a	-4.115	-4.067	-4.139	1.572	1.618	1.614	-0.311	-0.551	-0.584	2.284	0.707	0.986
COMB2a	-8.577	-8.88	-8.539	-4.514	-3.925	-4.486	0.655	-1.006	-0.465	8.673	3.455	4.342
COMB2b	-8.839	-9.116	-8.808	-4.211	-3.645	-4.175	0.613	-1.051	-0.52	8.708	3.456	4.348
COMB3a	-8.034	-8.075	-8.053	-0.757	-0.488	-0.681	0.094	-1.036	-0.762	6.332	2.391	3.062
COMB3b	-8.873	-8.832	-8.914	0.211	0.41	0.316	-0.04	-1.18	-0.938	6.442	2.394	3.081
COMB3c	-9.24	-9.008	-6.445	-2.905	-5.614	4.827	-7.958	-2.241	-1.637	-19.097	0.44	0.774
COMB3d	-10.079	-9.765	-7.306	-1.937	-4.716	5.824	-8.091	-2.384	-1.813	-18.987	0.443	0.793
COMB4a	-14.948	-15.051	-9.22	-14.468	-19.316	0.849	-14.569	-3.803	-2.088	-36.37	2.044	2.815
COMB4b	-15.21	-15.287	-9.489	-14.166	-19.036	1.161	-14.611	-3.848	-2.143	-36.335	2.045	2.821
COMB6a	-10.713	-10.631	-5.011	-11.369	-16.553	3.938	-15.047	-3.318	-1.944	-41.082	0.111	0.414

Axial (-W)	Axial Load (kips)											
Member #	17	18	19	20	21	22	23	24	25	26	27	28
COMB3c	-3.165	-2.79	-6.139	11.774	14.111	4.294	6.572	0.382	-0.487	23.714	0.79	1.04
COMB3d	-4.005	-3.547	-7	12.743	15.009	5.291	6.438	0.239	-0.663	23.825	0.793	1.059
COMB4a	-2.799	-2.614	-8.609	14.891	20.135	-0.217	14.489	1.443	0.212	49.254	2.744	3.347
COMB4b	-3.061	-2.851	-8.878	15.194	20.416	0.095	14.448	1.398	0.157	49.288	2.745	3.353
COMB6a	1.436	1.806	-4.4	17.99	22.898	2.872	14.012	1.928	0.356	44.542	0.812	0.946

Earthquake	Axial Load (kips)											
Member #	17		18		19		20		21		22	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	-4.906	-7.951	-2.97	-9.665	-5.663	-7.982	-0.33	-3.723	11.039	-11.22	-0.344	-5.073
COMB5b	-5.389	-8.434	-4.026	-10.72	-5.327	-7.645	-0.939	-4.332	7.326	-14.933	0.472	-4.257
COMB7a	-0.881	-3.926	1.261	-5.434	-1.67	-3.988	3.012	-0.381	14.026	-8.233	2.994	-1.735
COMB7b	-1.364	-4.409	0.205	-6.49	-1.333	-3.652	2.402	-0.991	10.313	-11.946	3.81	-0.919

Member #	23		24		25		26		27		28	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	2.852	-1.453	0.685	-2.963	0.239	-1.513	32.279	-12.07	3.491	0.844	3.496	2.393
COMB5b	2.076	-2.23	1.356	-2.292	0.561	-1.191	24.374	-19.97	3.929	1.282	3.669	2.565
COMB7a	2.341	-1.964	1.134	-2.514	0.34	-1.412	27.594	-16.75	1.558	-1.089	1.1	-0.004
COMB7b	1.565	-2.741	1.806	-1.843	0.662	-1.09	19.689	-24.66	1.997	-0.65	1.272	0.169

Bracing Configuration 9

Axial (+W)	Axial Load (kips)											
Member #	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
COMB1a	-4.489	-7.628	-4.489	-4.392	-6.958	-4.392	10.808	-2.996	10.808	4.654	4.451	4.654
COMB2a	-9.826	-23.074	-9.826	-25.126	-30.839	-25.13	31.852	-13.64	31.852	15.082	14.556	15.082
COMB2b	-10.097	-23.314	-10.1	-24.929	-30.803	-24.93	32.181	-13.61	32.181	15.199	14.669	15.199
COMB3a	-8.977	-18.112	-8.977	-16.103	-21.325	-16.1	25.076	-9.311	25.076	11.527	11.11	11.527
COMB3b	-9.842	-18.882	-9.842	-15.475	-21.209	-15.48	26.129	-9.201	26.129	11.903	11.472	11.903
COMB3c	-9.566	-10.513	-6.623	-7.962	-7.727	-2.984	7.284	-2.796	11.63	2.77	2.786	3.174
COMB3d	-10.431	-11.283	-7.488	-7.333	-7.612	-2.355	8.337	-2.686	12.683	3.146	3.148	3.55
COMB4a	-15.762	-21.923	-9.875	-27.877	-25.472	-17.92	15.457	-10.36	24.148	7.067	7.108	7.876
COMB4b	-16.032	-22.163	-10.15	-27.681	-25.436	-17.73	15.786	-10.33	24.478	7.184	7.221	7.993
COMB6a	-10.861	-9.773	-4.974	-13.733	-8.461	-3.777	-1.223	-2.824	7.468	-0.951	-0.643	0.011

Axial (-W)	Axial Load (kips)											
Member #	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**
COMB3c	-3.646	-7.472	-6.59	4.441	-0.529	-0.537	17.957	3.572	13.611	7.606	7.15	7.202
COMB3d	-4.512	-8.242	-7.455	5.07	-0.414	0.092	19.009	3.682	14.664	7.982	7.511	7.578
COMB4a	-3.923	-15.842	-9.809	-3.072	-11.076	-13.03	36.801	2.375	28.11	16.74	15.835	15.931
COMB4b	-4.193	-16.082	-10.08	-2.875	-11.04	-12.83	37.13	2.41	28.439	16.857	15.948	16.048
COMB6a	0.978	-3.692	-4.908	11.073	5.935	1.117	20.121	9.912	11.43	13.444	8.084	7.913

Earthquake	Axial Load (kips)											
Member #	**17**		**18**		**19**		**20**		**21**		**22**	
Envelope	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**
COMB5a	-6.882	-8.367	-16.86	-16.861	-6.774	-8.26	-17.029	-17.21	-19.13	-23.894	-17.038	-17.22
COMB5b	-6.774	-8.26	-16.86	-16.861	-6.882	-8.367	-17.038	-17.22	-19.13	-23.894	-17.029	-17.21
COMB7a	-2.197	-3.682	-4.904	-4.904	-2.09	-3.575	-2.727	-2.91	-2.092	-6.854	-2.737	-2.92
COMB7b	-2.09	-3.575	-4.904	-4.904	-2.197	-3.682	-2.737	-2.92	-2.092	-6.854	-2.727	-2.91

Member #	**23**		**24**		**25**		**26**		**27**		**28**	
Envelope	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**
COMB5a	24.147	8.125	-6.825	-12.156	24.264	7.767	11.229	0.412	10.522	10.522	11.181	0.444
COMB5b	24.264	7.767	-6.825	-12.156	24.147	8.125	11.181	0.444	10.522	10.522	11.229	0.412
COMB7a	7.73	0.656	0.74	-4.592	7.847	0.299	3.305	0.041	2.862	2.862	3.257	0.073
COMB7b	7.847	0.299	0.74	-4.592	7.73	0.656	3.257	0.073	2.862	2.862	3.305	0.041

APPENDIX B: PTF AT NODES

Frame 0

Axial (+W)	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
COMB1a	0.111	0.111	0.212	0.212	0.172	0.172	0.065	0.065
COMB2a	0.247	0.247	0.359	0.359	0.112	0.112	0.125	0.125
COMB2b	0.227	0.227	0.324	0.324	0.129	0.129	0.13	0.13
COMB3a	0.017	0.017	0.023	0.023	0.216	0.216	0.122	0.122
COMB3b	0.046	0.046	0.134	0.134	0.272	0.272	0.135	0.135
COMB3c	1.507	0.999	1.663	2.608	2.348	1.77	1.236	1.299
COMB3d	1.569	0.937	1.552	2.719	2.404	1.714	1.223	1.313
COMB4a	2.467	2.545	4.263	4.28	4.313	3.923	2.537	2.533
COMB4b	2.487	2.525	4.228	4.314	4.33	3.906	2.533	2.537
COMB6a	2.642	2.369	3.996	4.546	4.285	3.951	2.598	2.472

Axial (-W)	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
COMB3c	0.915	1.591	2.734	1.537	1.693	2.425	1.437	1.099
COMB3d	0.852	1.653	2.844	1.427	1.638	2.481	1.451	1.084
COMB4a	2.376	2.636	4.53	4.012	3.77	4.467	2.809	2.262
COMB4b	2.356	2.656	4.565	3.978	3.752	4.484	2.813	2.258
COMB6a	2.201	2.811	4.797	3.746	3.797	4.439	2.748	2.323

Earthquake	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
COMB5a	0.807	0.776	0.189	0.188	0.271	0.278	0.749	0.779
COMB5b	0.776	0.807	0.188	0.189	0.278	0.271	0.779	0.749
COMB7a	0.728	0.759	0.167	0.168	0.258	0.265	0.691	0.722
COMB7b	0.759	0.728	0.168	0.167	0.265	0.258	0.722	0.691

	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
MAX	2.642	2.811	4.797	4.546	4.33	4.484	2.813	2.537

Bracing Configuration 1

Axial (+W)	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB1a	1.541	0.568	4.234	0.673	10.53	4.276	4.959	9.794
COMB2a	0.216	0.14	12.17	1.651	27.85	12.71	17.71	30.14
COMB2b	0.009	0.073	12.29	1.698	28.19	12.84	17.78	30.3
COMB3a	1.519	0.446	9.59	1.483	22.55	9.989	13.03	22.85
COMB3b	2.239	0.665	9.978	1.628	23.65	10.4	13.25	23.39
COMB3c	5.307	0.429	9.603	1.059	16.25	2.041	2.966	8.693
COMB3d	6.027	0.647	9.993	0.913	17.35	2.456	3.19	9.232
COMB4a	5.623	0.843	19.45	2.571	31.12	4.509	9.25	20.55
COMB4b	5.848	0.775	19.57	2.526	31.46	4.638	9.32	20.72
COMB6a	6.085	0.624	13.12	3.421	16.84	2.16	0.278	4.736

Axial (-W)	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB3c	1.922	1.936	0.132	3.139	8.785	7.936	6.966	11.54
COMB3d	2.643	2.155	0.521	3.286	9.88	8.351	7.19	12.07
COMB4a	1.147	2.171	0.507	5.827	16.18	16.3	17.25	26.23
COMB4b	0.921	2.24	0.628	5.872	16.52	16.43	17.32	26.4
COMB6a	0.684	2.391	5.826	4.977	1.904	9.63	7.721	10.42

Earthquake	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB5a	1.51	0.572	10.47	1.837	22	10.77	16.53	23.88
COMB5b	1.497	0.603	10.45	1.872	22.02	10.88	16.52	24.01
COMB7a	2.152	0.846	4.237	1.023	8.001	4.208	7.058	8.197
COMB7b	2.139	0.877	4.211	1.058	8.019	4.315	7.044	8.329

	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
MAX	6.085	2.391	19.57	5.872	31.46	16.43	17.78	30.3

Bracing Configuration 2

Axial (+W)	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
COMB1a	2.01	2.01	4.819	4.819	11.04	11.04	5.907	5.907
COMB2a	2.529	2.529	11.57	11.57	31.88	31.88	20.92	20.92
COMB2b	2.72	2.72	11.79	11.79	32.19	32.19	21	21
COMB3a	3.208	3.208	9.899	9.899	25.06	25.06	15.36	15.36
COMB3b	3.818	3.818	10.59	10.59	26.04	26.04	15.61	15.61
COMB3c	5.706	3.025	11.98	4.255	17.55	11.06	5.57	4.049
COMB3d	6.315	3.634	12.67	4.949	18.53	12.04	5.813	4.292
COMB4a	7.895	2.534	21.86	6.411	35.94	22.96	15.07	12.03
COMB4b	8.086	2.724	22.08	6.629	36.25	23.26	15.15	12.11
COMB6a	6.818	1.456	16.01	0.567	19.33	6.345	3.841	0.8

Axial (-W)	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
COMB3c	1.627	4.308	0.711	8.435	7.651	14.14	6.103	7.623
COMB3d	2.237	4.918	1.406	9.13	8.635	15.13	6.346	7.866
COMB4a	0.26	5.102	0.674	14.77	16.15	29.13	16.14	19.18
COMB4b	0.069	5.293	0.457	14.99	16.46	29.44	16.22	19.26
COMB6a	1.338	4.024	6.519	8.929	0.462	12.52	4.906	7.948

Earthquake	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
COMB5a	2.99	2.98	9.95	9.944	24.01	23.98	16.75	16.68
COMB5b	2.98	2.99	9.944	9.95	23.98	24.01	16.68	16.75
COMB7a	2.065	2.056	4.278	4.273	7.643	7.615	5.579	5.508
COMB7b	2.056	2.065	4.273	4.278	7.615	7.643	5.508	5.579

	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
MAX	8.086	5.293	22.08	14.99	36.25	32.19	21	21

Bracing Configuration 3

Axial (+W)	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB1a	4.052	4.052	3.309	3.309	5.897	5.897	12.77	12.77
COMB2a	8.237	8.237	12.99	12.99	20.11	20.11	38.93	38.93
COMB2b	8.5	8.5	13.05	13.05	20.2	20.2	39.17	39.17
COMB3a	7.809	7.809	9.504	9.504	14.9	14.9	29.65	29.65
COMB3b	8.653	8.653	9.706	9.706	15.17	15.17	30.4	30.4
COMB3c	8.632	5.417	2.833	4.404	6.661	8.684	12.58	14.95
COMB3d	9.476	6.261	3.035	4.606	6.931	8.954	13.34	15.7
COMB4a	13.59	7.157	8.412	11.56	16.66	20.7	28.87	33.6
COMB4b	13.85	7.421	8.476	11.62	16.74	20.79	29.11	33.84
COMB6a	9.545	3.114	1.313	4.456	5.919	9.966	8.47	13.2

Axial (-W)	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB3c	3.696	6.912	4.127	2.555	5.175	3.152	14.11	11.75
COMB3d	4.541	7.756	4.329	2.757	5.446	3.423	14.87	12.5
COMB4a	3.719	10.15	11	7.858	13.69	9.64	31.93	27.2
COMB4b	3.982	10.41	11.06	7.921	13.77	9.725	32.17	27.44
COMB6a	0.325	6.106	3.901	0.758	2.948	1.098	11.53	6.799

Earthquake	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB5a	7.34	7.186	10.16	9.983	14.74	14.8	28.61	28.65
COMB5b	7.186	7.34	9.983	10.16	14.8	14.74	28.65	28.61
COMB7a	3.509	3.355	3.11	2.933	4.066	4.134	8.397	8.437
COMB7b	3.355	3.509	2.933	3.11	4.134	4.066	8.437	8.397

	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
MAX	13.85	10.41	13.05	13.05	20.2	20.79	39.17	39.17

Bracing Configuration 4

Axial (+W)	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
COMB1a	1.769	1.81	6.196	5.909	0.518	4.489	11.61	0.008
COMB2a	1.879	2.006	15.36	14.62	0.625	12.21	35.2	0.208
COMB2b	2.064	2.192	15.6	14.87	0.634	12.35	35.46	0.212
COMB3a	2.697	2.793	12.87	12.3	0.602	9.773	27.08	0.152
COMB3b	3.289	3.387	13.66	13.08	0.631	10.21	27.92	0.165
COMB3c	5.697	2.788	12.33	4.582	3.52	9.636	9.53	0.084
COMB3d	6.29	3.383	13.13	5.364	3.548	10.07	10.37	0.097
COMB4a	7.871	2.069	22.65	7.133	6.603	19.02	21.74	0.241
COMB4b	8.056	2.255	22.89	7.377	6.612	19.16	22	0.245
COMB6a	7.127	1.258	14.85	0.291	6.373	12.73	3.274	0.111

Axial (-W)	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
COMB3c	1.115	4.106	3.345	10.53	2.453	0.821	15.71	0.008
COMB3d	1.708	4.701	4.138	11.31	2.424	1.254	16.54	0.02
COMB4a	1.292	4.705	4.671	19.02	5.343	1.391	34.09	0.088
COMB4b	1.107	4.89	4.919	19.27	5.333	1.527	34.35	0.092
COMB6a	2.036	3.894	3.121	11.6	5.573	4.901	15.63	0.042

Earthquake	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
COMB5a	2.724	2.606	13.22	13.21	11.06	15.42	28.01	1.381
COMB5b	2.707	2.642	13.25	13.11	11.18	15.55	27.94	1.384
COMB7a	2.128	1.943	5.627	5.98	10.84	9.234	9.753	1.254
COMB7b	2.112	1.98	5.661	5.882	10.96	9.366	9.685	1.256

	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
MAX	8.056	4.89	22.89	19.27	11.18	19.16	35.46	1.384

Bracing Configuration 5

Axial (+W)	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
COMB1a	2.536	2.536	3.498	3.498	2.432	2.432	1.693	1.693
COMB2a	4.831	4.831	10.35	10.35	6.331	6.331	6.303	6.303
COMB2b	5.01	5.01	10.45	10.45	6.405	6.405	6.295	6.295
COMB3a	4.753	4.753	8.099	8.099	5.116	5.116	4.445	4.445
COMB3b	5.324	5.324	8.414	8.414	5.35	5.35	4.422	4.422
COMB3c	6.651	3.901	12.85	5.235	14.05	7.661	5.449	0.931
COMB3d	7.222	4.472	13.16	5.551	14.28	7.895	5.461	0.955
COMB4a	10.64	5.141	26.1	10.88	27.78	15.01	7.714	0.193
COMB4b	10.82	5.319	26.2	10.98	27.86	15.08	7.717	0.201
COMB6a	8.303	2.803	20.68	5.46	24.55	11.78	14.11	3.583

Axial (-W)	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
COMB3c	3.951	6.701	5.082	12.69	7.658	14.05	3.842	5.518
COMB3d	4.522	7.272	5.398	13.01	7.892	14.28	3.866	5.53
COMB4a	5.24	10.74	10.57	25.8	15	27.78	6.015	7.851
COMB4b	5.419	10.92	10.67	25.89	15.08	27.85	6.022	7.854
COMB6a	2.902	8.402	5.156	20.38	11.77	24.55	9.404	14.25

Earthquake	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
COMB5a	7.57	7.965	16.8	17.4	16.17	16.45	20.25	16.74
COMB5b	7.965	7.57	17.4	16.8	16.45	16.17	16.74	20.25
COMB7a	5.375	5.769	11.46	12.06	13	13.28	13.85	10.34
COMB7b	5.769	5.375	12.06	11.46	13.28	13	10.34	13.85

	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
MAX	10.82	10.92	26.2	25.89	27.86	27.85	20.25	20.25

Bracing Configuration 6

Axial (+W)	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
COMB1a	0.905	0.905	6.185	6.185	5.148	5.148	4.614	4.614
COMB2a	2.27	2.27	22.72	22.72	24.68	24.68	18.08	18.08
COMB2b	2.098	2.098	22.89	22.89	24.6	24.6	18.09	18.09
COMB3a	0.24	0.24	17.06	17.06	16.65	16.65	12.82	12.82
COMB3b	0.312	0.312	17.6	17.6	16.39	16.39	12.83	12.83
COMB3c	5.614	2.577	3.137	10.54	1.359	9.318	5.535	10.1
COMB3d	6.166	3.128	3.678	11.08	0.767	9.053	5.436	10.12
COMB4a	6.471	0.395	9.82	24.62	9.484	27.88	13.71	25.01
COMB4b	6.643	0.567	9.989	24.79	9.3	27.8	13.67	25.02
COMB6a	8.051	1.975	1.559	12.28	4.423	14.18	9.41	15.19

Axial (-W)	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
COMB3c	2.65	5.687	10.92	3.515	9.877	1.141	12.81	5.186
COMB3d	3.202	6.24	11.46	4.056	9.613	0.549	12.83	5.087
COMB4a	0.543	6.619	25.37	10.58	29	9.049	30.43	13.01
COMB4b	0.716	6.791	25.54	10.74	28.92	8.864	30.43	12.98
COMB6a	2.123	8.199	13.04	1.812	15.3	3.988	20.61	8.712

Earthquake	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
COMB5a	3.917	3.779	17.18	17.02	20.65	20.08	16.89	16.23
COMB5b	3.779	3.917	17.02	17.18	20.08	20.65	16.23	16.89
COMB7a	3.224	3.362	4.977	4.814	6.878	6.303	7.071	6.409
COMB7b	3.362	3.224	4.814	4.977	6.303	6.878	6.409	7.071

	PTF (± kips)							
Node #	**2**	**3**	**6**	**7**	**10**	**11**	**14**	**15**
MAX	8.051	8.199	25.54	24.79	29	27.88	30.43	25.02

Bracing Configuration 7

Axial (+W)	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB1a	2.933	2.817	0.949	1.913	1.634	3.616	3.031	0.414
COMB2a	6.545	6.03	0.954	3.398	3.12	11.45	11.68	1.818
COMB2b	6.724	6.21	0.858	3.494	3.179	11.52	11.69	1.813
COMB3a	5.96	5.601	0.197	3.229	2.782	8.695	8.335	1.244
COMB3b	6.534	6.175	0.501	3.535	2.972	8.931	8.373	1.228
COMB3c	7.135	4.073	10.6	4.164	2.124	8.466	10.63	0.02
COMB3d	7.708	4.646	10.91	4.469	1.881	8.701	10.69	0.005
COMB4a	12.03	5.747	18.14	6.64	4.733	18.16	23.96	0.661
COMB4b	12.21	5.925	18.24	6.735	4.656	18.23	23.98	0.656
COMB6a	8.924	2.924	18.97	5.059	7.927	12.11	17.79	0.339

Axial (-W)	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB3c	4.411	7.273	2.757	10.86	9.774	0.763	16.59	0.587
COMB3d	4.987	7.849	3.042	11.15	9.583	0.527	16.63	0.571
COMB4a	6.659	12.23	2.551	20.12	20.59	0.296	36.11	1.794
COMB4b	6.84	12.41	2.641	20.21	20.53	0.223	36.12	1.79
COMB6a	3.377	9.227	3.48	18.64	22.06	6.343	29.77	0.794

Earthquake	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB5a	9.415	9.378	10.78	12.59	35.06	17.05	21.74	2.374
COMB5b	9.337	8.257	10.19	13.22	31.18	20.82	22.77	2.591
COMB7a	6.277	6.524	9.877	11.17	31.92	11.06	15.42	1.37
COMB7b	6.374	5.579	11.1	11.71	28.68	14.83	16.6	1.587

	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
MAX	12.21	12.41	18.97	20.21	35.06	20.82	36.12	2.591

Bracing Configuration 8

Axial (+W)	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB1a	0.048	0.072	0.046	0.004	0.24	0.033	1.577	0.279
COMB2a	0.303	0.341	0.589	0.561	1.661	0.541	5.218	0.887
COMB2b	0.277	0.308	0.566	0.53	1.664	0.531	5.252	0.892
COMB3a	0.041	0.022	0.269	0.193	1.13	0.274	3.941	0.671
COMB3b	0.041	0.082	0.199	0.094	1.14	0.242	4.048	0.687
COMB3c	0.232	2.563	2.709	10.44	5.717	0.604	19.54	0.334
COMB3d	0.314	2.459	2.779	10.54	5.707	0.571	19.43	0.35
COMB4a	0.103	5.831	4.848	20.17	10.77	1.715	38.41	0.771
COMB4b	0.077	5.798	4.87	20.2	10.76	1.705	38.38	0.776
COMB6a	0.082	5.62	5.184	20.49	11.73	1.374	41.19	0.303

Axial (-W)	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB3c	0.375	3.349	2.337	9.817	6.19	0.869	22.92	0.25
COMB3d	0.458	3.453	2.266	9.718	6.199	0.902	23.03	0.266
COMB4a	0.185	5.995	5.244	20.35	13.05	1.231	46.51	0.603
COMB4b	0.21	6.027	5.222	20.32	13.05	1.241	46.54	0.608
COMB6a	0.37	6.206	4.908	20.03	12.08	1.572	43.73	0.134

Earthquake	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB5a	4.981	5.012	14.76	16.11	5.815	3.202	31.44	2.652
COMB5b	5.331	5.393	13.99	15.41	4.368	2.853	23.9	2.387
COMB7a	5.187	5.249	14.41	15.76	4.855	2.854	28.68	2.189
COMB7b	5.126	5.157	14.35	15.76	4.547	2.896	26.66	1.922

	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
MAX	5.331	6.206	14.76	20.49	13.05	3.202	46.54	2.652

Bracing Configuration 9

Axial (+W)	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB1a	3.139	3.139	2.566	2.566	13.8	13.8	0.203	0.203
COMB2a	13.25	13.25	5.713	5.713	45.49	45.49	0.526	0.526
COMB2b	13.22	13.22	5.874	5.874	45.79	45.79	0.53	0.53
COMB3a	9.135	9.135	5.222	5.222	34.39	34.39	0.417	0.417
COMB3b	9.04	9.04	5.734	5.734	35.33	35.33	0.431	0.431
COMB3c	0.947	3.89	0.235	4.743	10.08	14.43	0.016	0.388
COMB3d	0.852	3.795	0.279	5.257	11.02	15.37	0.002	0.402
COMB4a	6.161	12.05	2.405	7.55	25.82	34.51	0.041	0.768
COMB4b	6.131	12.02	2.245	7.711	26.11	34.8	0.037	0.772
COMB6a	1.088	4.799	5.272	4.684	1.601	10.29	0.308	0.654

Axial (-W)	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB3c	3.826	0.882	4.97	0.008	14.39	10.04	0.456	0.052
COMB3d	3.73	0.787	5.484	0.506	15.33	10.98	0.471	0.067
COMB4a	11.92	6.033	8.004	1.951	34.43	25.74	0.905	0.096
COMB4b	11.89	6.002	8.165	1.791	34.72	26.03	0.909	0.1
COMB6a	4.67	1.216	5.138	4.818	10.21	1.518	5.36	0.171

Earthquake	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
COMB5a	9.979	10.09	6.865	6.856	36.3	36.42	10.11	10.08
COMB5b	10.09	9.979	6.856	6.865	36.42	36.3	10.08	10.11
COMB7a	2.707	2.814	4.127	4.117	12.32	12.44	2.821	2.789
COMB7b	2.814	2.707	4.117	4.127	12.44	12.32	2.789	2.821

	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
MAX	13.25	13.25	8.165	7.711	45.79	45.79	10.11	10.11

Appendix C: 1st Method Comparison

Frame 0

Member #	17	18	19	20	21	22	23	24	25	26	27	28
MAX	0.802	-1.399	-1.968	15.213	10.416	7.143	10.67	6.9	2.433	12.851	10.038	7.78
MIN	-14.65	-12.163	-9.638	-11.561	-7.298	-4.47	-11.789	-7.504	-3.553	-8.335	-5.737	-3.265
Abs MAX	14.65	12.163	9.638	15.213	10.416	7.143	11.789	7.504	3.553	12.851	10.038	7.78

Node #	2	3	6	7	10	11	14	15
PTF	2.487	2.525	4.797	3.273	4.285	3.951	2.813	2.258
OK?	NG	NG	NG	NG	NG	NG	NG	NG

Bracing Configuration 1

Member #	17	18	19	20	21	22	23	24	25	26	27	28
MAX	1.1	0.416	-1.975	18.761	16.74	10.868	12.679	29.118	14.992	19.048	3.064	31.569
MIN	-15.118	-9.27	-8.936	-14.911	1.161	3.313	-14.303	2.621	2.841	1.5	-1.407	6.569
Abs Max	15.118	9.27	8.936	18.761	16.74	10.868	14.303	29.118	14.992	19.048	3.064	31.569

Node #	2	3	6	7	10	11	14	15
PTF	5.848	0.334	2.021	5.872	14.815	14.126	15.984	28.505
OK?	NG	NG	NG	NG	NG	NG	NG	NG

Bracing Configuration 2

Member #	17	18	19	20	21	22	23	24	25	26	27	28
MAX	0.977	-0.361	-1.875	18.761	15.628	5.586	12.633	31.899	0.21	19.082	2.08	20.231
MIN	-14.772	-6.686	-9.41	-14.937	4.06	-4.287	-14.195	5.184	-1.373	1.707	-3.254	-1.334
Abs Max	14.772	6.686	9.41	18.761	15.628	5.586	14.195	31.899	1.373	19.082	3.254	20.231

Node #	2	3	6	7	10	11	14	15
PTF	8.086	2.724	3.133	10.042	17.704	30.526	15.828	16.977
OK?	NG	NG	NG	NG	NG	NG	NG	NG

Bracing Configuration 3

Member #	17	18	19	20	21	22	23	24	25	26	27	28
MAX	1.392	1.067	-1.829	9.092	5.191	5.949	21.461	8.134	19.809	36.904	3.321	36.904
MIN	-15.523	-1.671	-9.601	-8.978	-19.599	-6.614	1.132	-5.36	4.141	4.101	-5.477	7.371
Abs Max	15.523	1.671	9.601	9.092	19.599	6.614	21.461	8.134	19.809	36.904	5.477	36.904

Node #	2	3	6	7	10	11	14	15
PTF	13.852	7.93	10.507	12.985	13.327	11.675	31.427	31.427
OK?	NG	NG	NG	NG	NG	NG	NG	NG

Bracing Configuration 4

Member #	17	18	19	20	21	22	23	24	25	26	27	28
MAX	1.485	-0.551	-1.862	17.74	19.617	5.695	12.805	17.462	0.301	40.187	4.726	4.938
MIN	-15.156	-7.1	-9.355	-14.744	3.455	-4.291	-2.665	-5.032	-1.694	3.799	-0.143	0.347
Abs Max	15.156	7.1	9.355	17.74	19.617	5.695	12.805	17.462	1.694	40.187	4.726	4.938

Node #	2	3	6	7	10	11	14	15
PTF	8.056	2.255	1.877	13.922	4.657	15.768	35.461	0.212
OK?	NG	NG	NG	NG	NG	NG	NG	NG

Bracing Configuration 5

Member #	17	18	19	20	21	22	23	24	25	26	27	28
MAX	0.917	3.819	-1.386	18.545	25.68	5.487	17.238	32.263	6.402	19.487	13.526	21.319
MIN	-14.97	-5.647	-9.47	-15.742	-4.717	-5.834	-13.047	-8.558	-0.284	-11.677	-1.7	-11.68
Abs Max	14.97	5.647	9.47	18.545	25.68	5.834	17.238	32.263	6.402	19.487	13.526	21.319

Node #	2	3	6	7	10	11	14	15
PTF	9.323	3.823	7.135	19.846	15.025	25.861	5.961	7.793
OK?	NG	NG	NG	NG	NG	NG	NG	NG

Bracing Configuration 6

Member #	17	18	19	20	21	22	23	24	25	26	27	28
MAX	1.529	3.652	-1.421	21.256	6.784	8.596	39.096	10.176	27.443	42.705	12.271	28.474
MIN	-13.239	-7.875	-7.319	-14.727	-19.552	-14.73	-2.095	-4.14	-2.095	-1.158	-2.118	-1.158
Abs Max	13.239	7.875	7.319	21.256	19.552	14.727	39.096	10.176	27.443	42.705	12.271	28.474

Node #	2	3	6	7	10	11	14	15
PTF	5.364	0.556	1.704	4.825	28.92	17.267	30.434	16.203
OK?	NG	NG	NG	NG	NG	NG	NG	NG

Bracing Configuration 7

Member #	17	18	19	20	21	22	23	24	25	26	27	28
MAX	1.155	4.532	-1.375	18.583	22.063	5.96	25.885	19.671	0.807	42.516	7.327	5.514
MIN	-15.969	-5.581	-9.685	-10.613	-8.286	-4.292	-22.41	-9.816	-1.588	-10.908	0.012	0.351
Abs Max	15.969	5.581	9.685	18.583	22.063	5.96	25.885	19.671	1.588	42.516	7.327	5.514

Node #	2	3	6	7	10	11	14	15
PTF	10.388	4.104	3.48	16.103	6.214	18.083	35.189	1.813
OK?	NG	NG	NG	NG	NG	NG	NG	NG

Bracing Configuration 8

Member #	17	18	19	20	21	22	23	24	25	26	27	28
MAX	1.436	1.806	-1.333	17.99	22.898	5.824	14.489	1.928	0.662	49.288	3.929	4.348
MIN	-15.21	-15.287	-9.489	-14.468	-19.316	-5.073	-15.047	-3.848	-2.143	-41.082	-1.089	-0.004
Abs Max	15.21	15.287	9.489	17.99	22.898	5.824	15.047	3.848	2.143	49.288	3.929	4.348

Node #	2	3	6	7	10	11	14	15
PTF	0.077	5.798	4.908	17.074	11.199	1.705	45.359	0.419
OK?	NG	NG	NG	NG	NG	NG	NG	NG

Bracing Configuration 9

Member #	17	18	19	20	21	22	23	24	25	26	27	28
MAX	0.978	-3.692	-2.09	11.073	5.935	1.117	37.13	9.912	32.181	16.857	15.948	16.048
MIN	-16.032	-23.314	-10.15	-27.877	-30.839	-25.13	-1.223	-13.64	0.299	-0.951	-0.643	0.011
Abs Max	16.032	23.314	10.146	27.877	30.839	25.126	37.13	13.641	32.181	16.857	15.948	16.048

Node #	2	3	6	7	10	11	14	15
PTF	7.282	13.168	2.962	5.713	23.489	18.54	0.909	0.1
OK?	NG	NG	NG	NG	NG	NG	NG	NG

APPENDIX D: 2ND METHOD BRACING FORCE FINDING & PTFS

Axial (+W)	Axial Load (kips)															
Member #	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
COMB1a	-1.697	-3.388	-2.936	-0.857	-0.912	-5.189	-4.994	-0.377	-6.769	-12.06	-7.242	-1.422	-5.037	-19.136	-17.2	-3.614
COMB2a	-0.11	-7.631	-8.048	1.244	-5.895	-13.558	-13.2	-4.892	-21.787	-38.072	-22.544	-4.182	-16.891	-62.476	-55.443	-11.542
COMB2b	-0.374	-7.832	-8.188	1.044	-5.894	-13.795	-13.413	-4.839	-21.973	-38.369	-22.732	-4.253	-17.001	-62.869	-55.77	-11.6
COMB3a	-1.97	-6.897	-6.697	-0.528	-3.97	-11.361	-10.952	-2.907	-16.752	-29.199	-17.387	-3.436	-12.744	-47.222	-41.869	-8.672
COMB3b	-2.813	-7.542	-7.146	-1.168	-3.966	-12.118	-11.633	-2.737	-17.348	-30.148	-17.99	-3.663	-13.097	-48.479	-42.918	-8.856
COMB3c	-6.334	-5.42	-5.376	-2.183	-6.243	-4.882	-9.868	2.696	-14.411	-6.868	-13.433	1.564	-13.09	-11.454	-26.158	2.001
COMB3d	-7.176	-6.065	-5.825	-2.623	-6.239	-5.639	-10.549	2.865	-15.007	-7.817	-14.035	1.337	-13.443	-12.712	-27.207	1.817
COMB4a	-7.2	-8.46	-10.001	0.014	-14.918	-8.157	-18.463	2.222	-30.764	-17.158	-28.599	3.349	-28.392	-30.567	-59.06	2.514
COMB4b	-7.463	-8.662	-10.141	-0.186	-14.916	-8.394	-18.676	2.275	-30.95	-17.455	-28.788	3.278	-28.502	-30.96	-59.387	2.457
COMB6a	-7.479	-4.629	-5.809	-0.889	-11.528	-1.173	-11.659	5.119	-19.183	2.983	-16.696	5.559	-19.372	2.624	-29.691	8.61

Axial (-W)	Axial Load (kips)															
Member #	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
COMB3c	-1.947	-4.501	-2.521	-3.365	4.709	-8.843	-3.038	-2.263	-0.995	-19.858	-2.823	-5.448	2.205	-29.367	-10.016	-9.369
COMB3d	-2.789	-5.146	-2.97	-4.005	4.714	-9.601	-3.719	-2.094	-1.591	-20.807	-3.426	-5.675	1.852	-30.624	-11.065	-9.553
COMB4a	1.574	-6.623	-4.29	-2.35	6.987	-16.08	-4.804	-7.697	-3.933	-43.139	-7.381	-10.67	2.199	-66.392	-26.776	-20.226
COMB4b	1.311	-6.825	-4.431	-2.55	6.988	-16.317	-5.017	-7.644	-4.119	-43.435	-7.569	-10.75	2.089	-66.785	-27.104	-20.283
COMB6a	1.295	-2.792	-0.099	-3.253	10.377	-9.096	2.001	-4.8	7.648	-22.998	4.523	-8.465	11.219	-33.201	2.593	-14.13

Earthquake	Axial Load (kips)															
Member #	29		30		31		32		33		34		35		36	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	1.119	-3.607	-4.605	-8.182	-4.623	-8.569	1.869	-1.927	-0.336	-9.036	-6.602	-14.6	-6.784	-14.282	0.026	-7.352
COMB5b	1.236	-3.49	-4.683	-8.259	-4.532	-8.478	1.783	-2.013	-0.087	-8.788	-6.827	-14.83	-6.575	-14.072	-0.179	-7.556
COMB7a	0.63	-3.804	-0.935	-4.22	-0.544	-4.198	0.806	-2.698	3.056	-5.353	0.192	-7.514	-0.15	-7.356	2.965	-4.121
COMB7b	0.746	-3.688	-1.013	-4.297	-0.453	-4.107	0.72	-2.784	3.304	-5.104	-0.033	-7.739	0.059	-7.146	2.761	-4.325

Member #	37		38		39		40		41		42		43		44	
Envelope	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
COMB5a	-11.56	-21.47	-21.173	-34.89	-12.248	-22.021	0.443	-7.521	-9.009	-16.704	-38.375	-52.71	-34.083	-47.822	-3.773	-13.856
COMB5b	-11.27	-21.18	-21.595	-35.31	-11.963	-21.736	0.219	-7.745	-8.804	-16.499	-38.811	-53.15	-33.673	-47.412	-4.057	-14.14
COMB7a	-0.125	-9.742	-1.269	-14.69	-0.495	-9.977	2.596	-5.076	-0.077	-7.48	-5.498	-19.55	-4.976	-18.424	2.276	-7.514
COMB7b	0.163	-9.454	-1.692	-15.11	-0.21	-9.692	2.372	-5.3	0.127	-7.275	-5.934	-19.98	-4.566	-18.014	1.992	-7.799

Member #	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
MAX	1.574	-0.935	-0.099	1.869	10.377	0.192	2.001	5.119	7.648	2.983	4.523	5.559	11.219	2.624	2.593	8.61
MIN	-7.479	-8.662	-10.141	-4.005	-14.918	-16.317	-18.676	-7.697	-30.95	-43.435	-28.788	-10.75	-28.502	-66.785	-59.387	-20.283
Abs Max	7.479	8.662	10.141	4.005	14.918	16.317	18.676	7.697	30.95	43.435	28.788	10.745	28.502	66.785	59.387	20.283

PTFs using θ = 0°

	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
MAX	7.479	1.479	23.58	1.115	47.267	21.868	23.35	39.18
OK?	OK	NG	OK	NG	OK	OK	OK	OK

PTFs using θ = 38.66°

	PTF (± kips)							
Node #	2	3	6	7	10	11	14	15
MAX	5.84	1.155	18.413	0.871	36.909	17.076	18.233	30.6
OK?	NG	NG	NG	NG	OK	OK	OK	OK